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INTERNATIONAL SOIL SCIENCE SYMPOSIUM on

SOIL SCIENCE & PLANT NUTRITION

(9th International Scientific Meeting)

8 – 9 December 2023

Samsun, Türkiye

Editors

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Dr.Coşkun GÜLSER
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Preface I

Dear Colleagues,

On behalf of the Federation of Eurasian Soil Societies (FESSS), it is with immense pleasure that we extend a warm welcome to you at the "Soil Science and Plant Nutrition" (EURASIAN SOIL Symposium 2023). Your presence at this esteemed event is truly gratifying, and we trust that the discussions on soil science within this forum will hold significant importance.

Representing our country at this symposium is a great honor for us, and we are eager to contribute to the wealth of knowledge that will be shared during this gathering. The symposium, themed "Soil Science and Plant Nutrition," will delve into applied research and innovative approaches, aiming to integrate scientific insights into the physical, chemical, and biological properties of soil, plant nutrition, and fertility mechanisms across various ecosystems.

Covering a spectrum of scales, from the molecular to the field level, the symposium promises to foster diversity in experiences, opinions, and scientific knowledge. It serves as an excellent platform for learning, discussing the latest advancements in soil science, and establishing meaningful contacts and collaborations with fellow participants. Emphasizing a multidisciplinary approach to soil science, the symposium places particular importance on key research, the latest technological developments, and fundamental concepts related to soil.

We are grateful for the opportunity to host such distinguished individuals, and we look forward to the rich interactions that will take place during the scientific sessions. The symposium not only aims to showcase recent achievements in soil science but also provides numerous opportunities for fruitful interactions among scientists from both public and private sectors.

Once again, thank you for joining us at this significant event. We anticipate a symposium filled with enlightening discussions and meaningful exchanges that will contribute to the advancement of soil science and plant nutrition.

Best regards,

Prof.Dr.Garib Mamadov
President, FESSS

Preface II

Dear Distinguished Colleagues and Esteemed Guests,

Good morning, and it is truly an honor to stand before you as the secretary general of the Federation of Eurasian Soil Science Societies (FESSS) for the opening of the 9th Annual International Symposium on "Soil Science and Plant Nutrition." I extend my warmest greetings to all of you, and I am delighted to welcome each one of you to this significant gathering.

Firstly, I would like to express my sincere gratitude to our co-organizer, the Erasmus Mundus Joint Master Degree in Soil Science Programme (emiSS), and its dedicated Coordinator, Dr. Coskun Gulser, for their invaluable collaboration and presence here today. This marks a special occasion as it is the second symposium co-organized with emiSS, highlighting the growing partnership between our organizations. FESSS continues to be an associate partner in the emiSS Project, fostering a stronger bond within the realm of soil science.

I extend a warm welcome once again to our esteemed colleagues from the University of Agriculture in Krakow, Poland, Agricultural University Plovdiv in Bulgaria, and participants from various countries who have joined us for this symposium. This annual event serves as a platform to facilitate international collaboration and exchange of knowledge, and I believe it has played a pivotal role in fostering connections and advancing our collective understanding.

The theme of this year's symposium is "Soil Science and Plant Nutrition," a subject of paramount importance in addressing the intricate relationships between soil, plants, and the environment across diverse ecosystems. Our goal is ambitious - to integrate scientific backgrounds, applied research, and innovative approaches. Discussions will span physical, chemical, and biological soil properties, mechanisms of plant nutrition and fertility, all studied at different scales, from the molecular to the field level.

This symposium provides a unique opportunity to delve into recent advances in soil science, offering a multidisciplinary approach with a focus on basic research and the latest technological developments in soil science and plant nutrition. The sessions will underscore fundamental soil concepts, and I am confident that the interactions among scientists from various public and private institutions will be both enriching and enlightening.

The Federation of Eurasian Soil Science Societies, with its distinctive organization comprising eight member countries, stands poised to contribute significantly to the critical areas of Soil Science and Plant Nutrition. Since its establishment in 2012, FESSS has grown to include Romania, Kyrgyzstan, Bosnia & Herzegovina, and Serbia Soil Science Societies, all united by the common goal of sharing knowledge and bridging the gap between soil science, policy-making, and public awareness at both national and international levels.

I extend my heartfelt appreciation to the program steering committee for curating an outstanding lineup of speakers, and my gratitude goes to each speaker and moderator for their invaluable contributions. Lastly, I thank all the participants for your unwavering support, and I eagerly anticipate your active engagement in the discussions that lie ahead.

Wishing you all a most enjoyable and productive symposium.

Thank you.

Prof.Dr.Rıdvan Kızılkaya
Chair, Organization Committee

Dear participants,

It is my great pleasure to joint the International Soil Symposium on "Soil Science & Plant Nutrition" as a part of organizing committee. This symposium has been organized by the Federation of Eurasian Soil Science Societies (FESSS) collaborating with ERASMUS MUNDUS Joint Master Degree in Soil Science (emiSS) programme. I would like to express my grateful thanks to FESSS and Prof. Dr. Ridvan Kizilkaya, who is the Chairman of the Symposium, giving us chance to represent emiSS programme in this International Symposium. The emiSS programme has been founded with the support of the Erasmus+ Programme of the European Union and organized by a consortium of the four Universities: Ondokuz Mayıs University (OMU-Türkiye), University of Agriculture in Krakow (UAK-Poland), Agricultural University Plovdiv (AU-Bulgaria) and Jordan University of Science and Technology (JUST-Jordan) in 2019. The aim of emiSS programme is to raise and meet the need for qualified and skilled soil scientists at the master level through a higher educational programme under the training in soil science, soil management, soil fertility, soil ecosystem with intercultural competence and language skills. So far, there are 74 international emiSS programme students from the different geographical parts of the World, So far 34 of them graduated from the emiSS programme. Some of emiSS students will be among us and make an oral presentation during the Symposium. I think that the mission of the symposium will be successful with sharing novel access that fulfill the needs of applications in soil science and plant nutrition field, and identifying new directions for future researches and developments in soil science area. At the same time, this symposium will give researchers and participants a unique opportunity to share their perspectives with others interested in the various aspects of soil science. I hope this symposium also will be helpful to increase young soil scientists' knowledge and their presentation skills front of the audience. Once more I would like to thank the organizing committee and all participants to their helps and sharing their scientific knowledge in this symposium.

Prof.Dr.Coşkun Gülser
emiSS Coordinator

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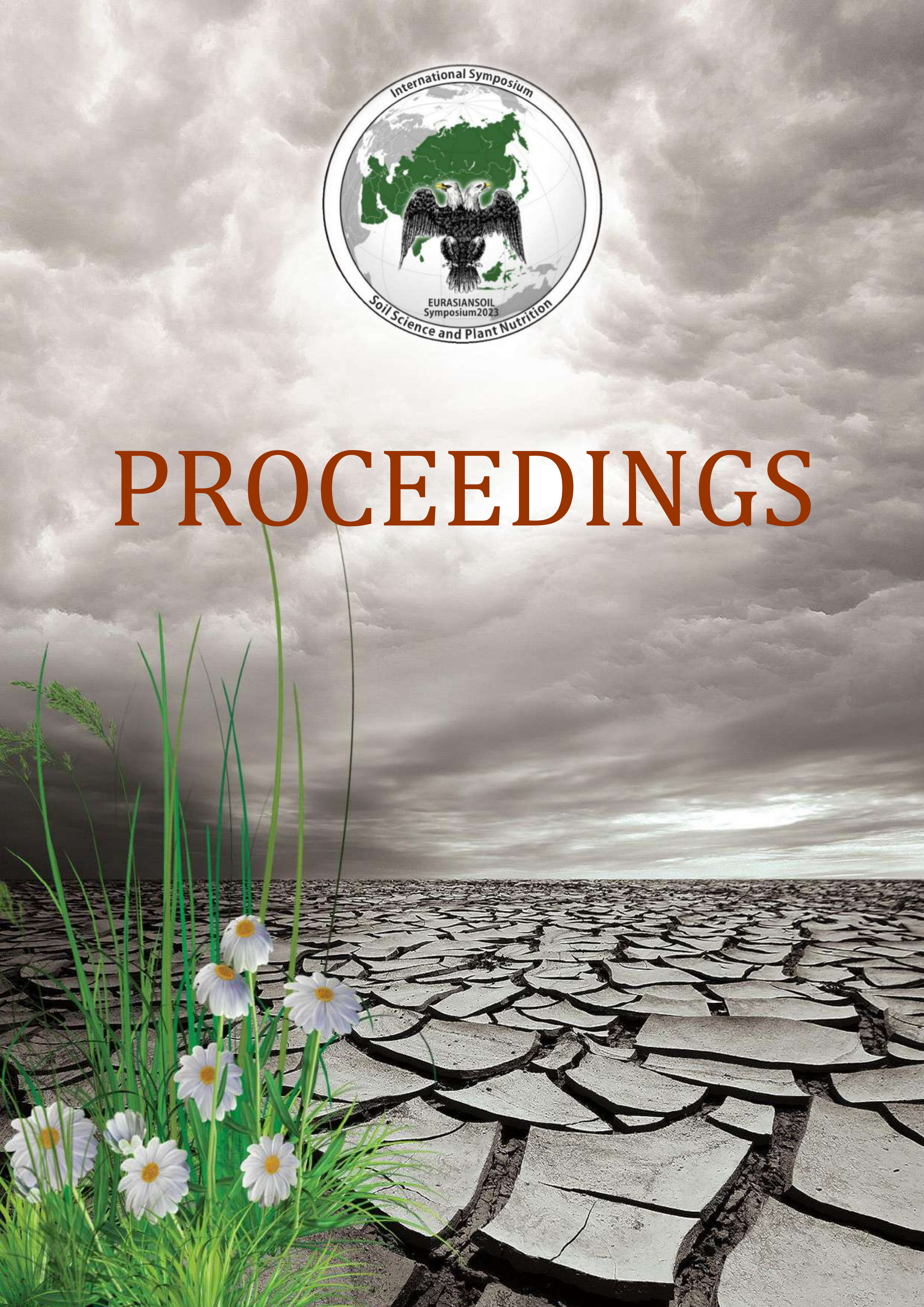

Results from the previously neglected element silicon

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Abstract
The study is in the field of Regenerative Agriculture. The main task was the optimization of crop nutrition, especially silicon fertilization. The neglected element silicon (Si) turns out to be extremely necessary and useful for the development of crops, protects them from diseases and climate changes, suppresses toxic elements, and thus increase plant biomass accumulation, and yield. Field trials were conducted on two soils with contrasting soil properties with the application of mineral fertilizers - N, P, K, and Si. Each year, large amounts of silicon are irreversibly leached from the soil. A comparison of the amount of soil silicon determined at sowing and harvesting shows a depletion of this nutrient. Yield models were derived and optimum silicon levels were determined. It is recommended for soil and crop scientists to conduct extensive studies on the influence of silicon on different crops.

Keywords: Field experiment, Models, Silicon, Uptake, Yield

Introduction

The European Parliament's report on "Precision Agriculture and the future of farming in Europe" defines Precision agriculture as: "a modern farming management concept using digital techniques to monitor and optimize agricultural production processes". The key point here is optimization. This leads to optimized fertilizer usage, saving costs, and reducing the environmental impact (EPRS, 2016). Regenerative Agriculture means a perspective steeped in the use of plant, soil, ecological, and system sciences to support the production of food, feed, and fiber sustainably (Giller et al., 2021). An effective tool for analyzing problems in Regenerative Agriculture is Mathematical Agronomy a theory of mathematical models of agronomic objects, processes, and phenomena (Sadovski, 2020).

Decreased soil fertility and abiotic-biotic stress factors on the plant cause crop losses. As a result of these negative effects, silicon (Si) applications have become an important tool for sustainable agriculture (Savant et al., 1999; Zargar et al., 2019; Atanassova et al., 2022; Hou et al., 2023). The application of silicon shows the potential to increase the availability of nutrients in the rhizosphere and their uptake by plants (Pavlovic et al., 2021). Silicon plays an important role in combating various abiotic stress factors such as high temperature, radiation, salinity, metal toxicity, nutrient imbalance, and biotic stresses such as bacterial diseases, fungi, and other pests, and thus increase plant biomass accumulation and yield (Aydin et al., 2022; Zichuan et al., 2018). Every year, 20 to 700 kg of Si/ha are irreversibly removed from the soil (Bocharnikova & Matichenkov, 2012). Silicon diminution in the soil can occur in intensive cultivation practices and continuous monoculture of high-yielding cultivars. (Korndörfer & Lepsch, 2001). The use of the previously neglected element of silicon can contribute to increasing the quantity and quality of yields, as well as to the sustainability of crops.

Silicon-based fertilization application in agriculture is therefore efficient and should be largely disseminated, emphasizing to farmers and other stakeholders its multiple benefits. Given our current challenges with climate change, natural resource exhaustion, and land degradation, silicon fertilization can provide an efficient answer to capacitate plants with resilient ways to face adversities (Barao, 2022).

Material and Methods

In the experimental fields of the Institute of Soil Science, Agrotechnologies and Plant Protection "N. Poushkarov" in Bozhurishte, Sofia district and in Tsalapitsa, Plovdiv district, field experiments were conducted with the application of mineral fertilizers - N (ammonium nitrate), P (superphosphate), K (potassium sulfate), and Si (diatomic soil which represents 89-95% silica in amorphous form). Only 1/3 of the norm of N was imported before wheat sowing and the other quantity of the N norm was spread during early spring time. The experiments include 9 variants of fertilization with the size of the experimental parcels - 25 m2. The design of treatments is presented in Table 1.

Table 1. Experimental design - the active substance in kg/ha

	Factors			
No	N	P	K	Si
1	100	80	60	14
2	200	80	60	28
3	100	160	60	28
4	200	160	60	14
5	100	80	120	14
6	200	80	120	28
7	100	160	120	28
8	200	160	120	14
9	0	0	0	0

The test crops were Maize, Sunflower, and Wheat. The trials are conducted on two soils with contrasting soil properties. The soil in Bozhurishte is defined as Pelic Vertisol (FAO, 2015). The soil in Tsalapitsa is defined as Eutric Fluvisol. Soil agrochemical characteristics determined before starting the experiments are presented in Tables 2 and 3.

Table 2. Agrochemical characteristic of Pellic Vertisol, Bozhurishte

Sample layer	pH		$\sum$ N-NH_4+NO_3	Total N	P_2O_5	K_2O	Humus
	H_2O	KCl	mg.kg^{-1}	%	mg.100g^{-1}		%
0-30 cm	6,2	5,4	12,67	0,139	0,20	30,11	3,02
30-60cm	6,5	5,6	8,64	0,113	0,34	21,8	3,09

Table 3. Agrochemical characteristic of Eutric Fluvisol, Tsalapitsa

Sample layer	pH		$\sum$ N-NH_4+NO_3	Total N	P_2O_5	K_2O	Humus
	H_2O	KCl	mg.kg^{-1}	%	mg.100g^{-1}		%
0-30 cm	7,4	6,8	11,52	0,056	8,09	14,35	1,16
30-60cm	7,3	6,4	16,70	0,061	5,91	15,35	1,20

The plant height and the yield of fresh and dried biomass from the aboveground part of the crops at harvest were studied. Analysis of soluble and exchangeable forms of silicon was by acetic acid and calcium chloride (Snyder, 2001; Heckman & Wolf, 2009). The one-way-ANOVA method was used for statistical analysis and the least significant differences between the variants (LSD) were determined at $p \leq 0.05$ (95%). Optimization was performed by step-wise regression analysis.

Results And Discussion

Many of the known models of yield have the argument X on their right-hand side representing the introduced quantity of mineral fertilizer, without taking into account the quantity of nutrients already available in the soil (Sadovski, 2021).

This quantity of a given nutrient X is a sum of the initial level of the nutrient X0 which is readily available to plants (the so-called soil equivalent) and the quantity introduced with fertilizers F

$$X = X0 + F \quad (1)$$

The main equation represents yield as an intrinsically non-linear function of macro element fertilization and has the expression

$$Y = f(X) = a(X0 + F)b \exp[c(X0 + F)] \quad (2)$$

In a field experiment with wheat, the soil equivalent for silicon from Pelic Vertisol calculated is X0 = 4.417. The model was obtained in the form (2).

$$Y = 461.3946*(4.417+F))1.3054*exp(-0.05667*(4.417+F)) \qquad (3)$$

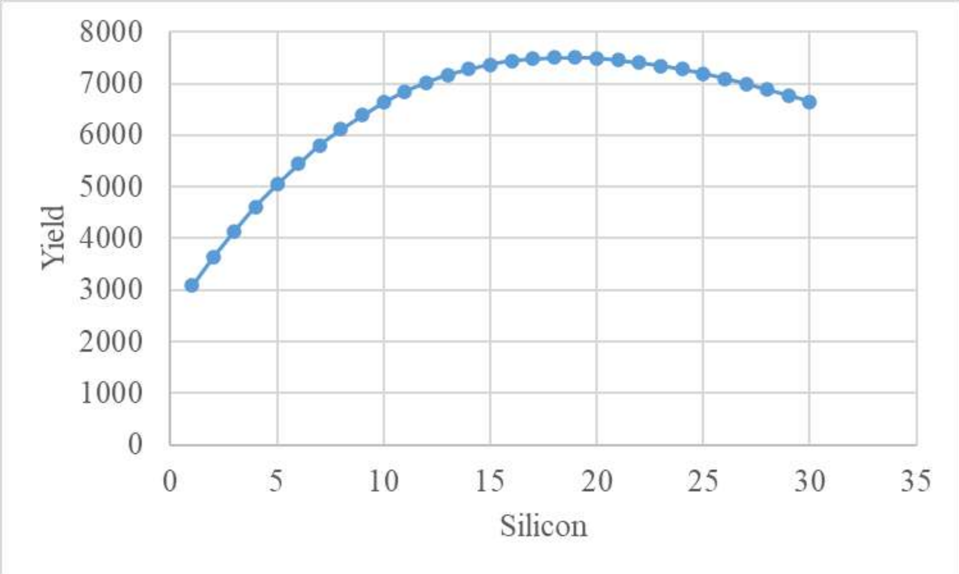

Figure 1.

The optimization gives the following result:

The necessary quantity of silicon F = 1.909 kg/ha to give maximum yield Y = 7274.9 kg/ha.

The soil equivalent for silicon from Eutric Fluvisol calculated is X0 = 4.033.

The equation was obtained

$$Y = 2402.144*(4.033+F)0.4773*exp(-0.021657*(4.033+F)) \qquad (4)$$

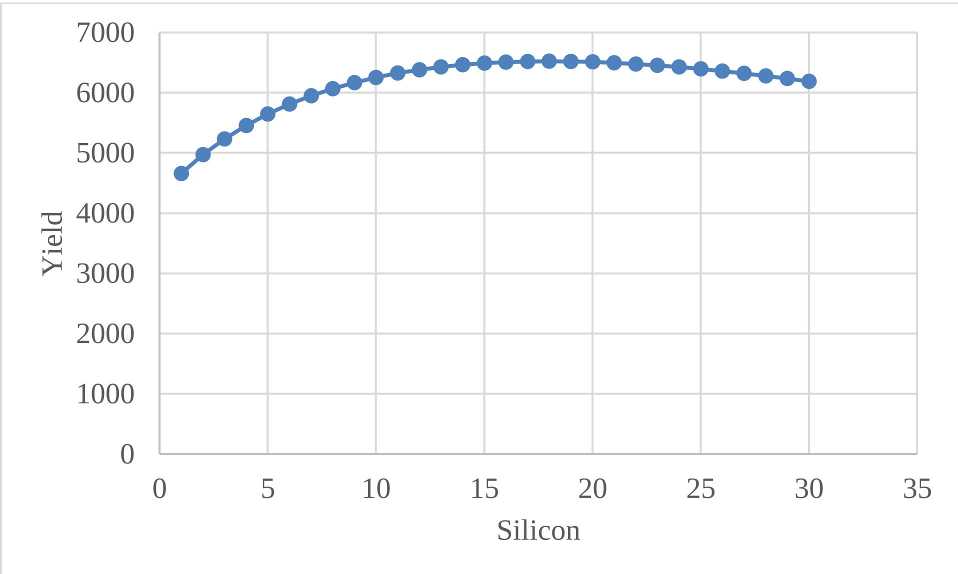

Figure 2.

The necessary quantity of silicon F = 16.05 kg/ha gives maximum yield Y = 7094.7 kg/ha

A comparison of the quantity of soil silicon determined at sowing and harvest shows depletion of this nutrient (see Table 4).

Table 4. Changes of soil silicon - mg/kg

Variants	Bozhurishte			Tsalapitsa		
	26.5.2021	19.7.2021	Diff.	11.5.2021	7.7.2021	Diff.
1	270	178	-92	37	137	-100
2	340	242	-98	34	234	-200
3	492	345	-147	451	492	-41
4	325	296	-29	390	336	54
5	397	297	-100	317	292	25
6	292	199	-93	302	407	-105
7	341	246	-95	315	341	-26
8	283	223	-60	275	283	-8
9	64	50	-14	444	44	400

It is evident that in almost all variants there is soil silicon depletion for both soils. This is confirmation of the need for silicon fertilization.

The depletion of available silicon in soil is an important soil-related factor that may be closely associated with progressive yield declines experienced in various crops. To date, the issue of silicon nutrition in crop production remains largely unexplored. Identifying and implementing optimal silicon nutrition management strategies may play a very critical role in reversing declining yield trends in crop production. There is a need for applied research to elaborate optimum silicon rate and the best time and methods of its application. This is imperative so that the application of silicon may be one of the available pathways to improve crop growth and its production (Meena et al., 2014).

Conclusion

A comparison of the quantity of soil silicon determined at sowing and harvest shows depletion of this nutrient. The presented examples from experiments confirm the practical benefit of using the soil equivalent in processing the results of field experiments. To assess the efficacy of silicon treatment, convenient, wide-ranging, and long-term field experiments should be taken into consideration to enable plants to evolve various resistance mechanisms to deal with several adverse abiotic factors. It is recommended for soil and crop scientists to conduct extensive studies on the influence of silicon on different crops.

Acknowledgments

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The relationship between soil and insects in the ecosystem

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Abstract
Soil plays a critical role in ecosystems as an essential component that supports biodiversity and influences ecosystem functions. Soil supports the healthy growth of vegetation by providing nutrients necessary for plant growth. In addition, soil plays an important role in the water cycle, contributing to water retention, filtration and storage. Insects are important organisms that play an essential role in soil ecosystems and support biodiversity. Soil has a wide range of physical, chemical and biological properties as one of the key components of an ecosystem. These properties can affect the distribution and activities of insect populations living in soil. There are many positive contributions that insects make to the soil. In view of the important role of soil in the ecosystem, insects have beneficial roles in soil aeration, decomposition of organic matter, soil mixing, improvement of soil structure, activation of soil micro-organisms and prevention of soil erosion. In addition, the level and population of insects in the environment is significantly affected by the different properties of the soil. In particular, soil properties such as physical structure, chemical structure, PH value, soil wetness and soil temperature are very important. In this article, the various relationships of insects with soil were investigated. In addition, the effects of soil structure and properties on insect populations are emphasized.
Keywords: Soil, Insect, Natural Equilibrium, Biodiversity

Introduction

Soil is a fundamental element of nature's complex balance and plays a vital role for the sustainability of ecosystems. Soil is a critical resource for plant growth, the water cycle, biodiversity and many ecosystem services (Bird, 1921; McColloch and Hayes, 1922; Heinen et al., 2018). Therefore, the importance of soil in ecosystems requires a great deal of emphasis. Soil provides a growth medium for plant roots. Plants grow using minerals and water found in the soil. This growth process underpins the flow of energy in the ecosystem. Plants convert solar energy into chemical energy through photosynthesis and transfer this energy as food to other organisms in the ecosystem. In addition, soil has the capacity to hold water, which provides effective control over the water cycle. With rainfall, soil absorbs and stores water, which helps to prevent floods and use water resources in a sustainable way. Soil also plays a critical role in biodiversity. Soil is the habitat of many different organisms such as microorganisms, insects and earthworms (Petchey and Gaston, 2006; Heinen et al., 2018). These organisms enrich the soil ecosystem and maintain the balance in the ecosystem as part of the food chain.

Soil is vital for many organisms in ecosystems, including insects (Altieri and Nicholls, 2003). The soil-insect relationship is often related to soil health and organization in ecosystems. Soil is the home and habitat of many organisms, among which insects play an important role (Pineda et al., 2010; Kos et al., 2015). Insects in soil are important for the functionality of soil ecosystems. This article will focus on the relationship of insects with soil and the effect of soil structure and properties on insects (Culliney, 2013; Bülbül et al., 2022).

Insects Relationship with Soil

These roles of insects in soil contribute to the healthy and balanced functioning of ecosystems (McColloch and Hayes, 1922). Therefore, soil conservation and sustainable use are important for many species, including insects. Some of the roles of insects in soil are given below as sub-headings.

- Food Source: Soil is a natural food source for many insect species. Organic matter and other living things in the soil are an important food source, especially for insects living in the soil. For example, larvae living under the soil feed on organic materials in the soil (McColloch and Hayes, 1922; Hunter, 2001).

- Decomposition of Organic Matter: Insects also play an important role in the decomposition of organic matter in the soil; Insects contribute to the formation of humus by decomposing organic matter in the soil. This is a process that increases soil fertility. Insects in the soil support the cycle of organic matter in the soil by decomposing dead plants, animal droppings and other organic materials. This releases nutrients in the soil and makes them available to plants (Bot and Benites, 2005; Neher and Barbercheck, 2019).

- Improving Soil Structure: Insects improve soil structure by mixing and breaking down the soil. For example, subsoil-dwelling insects create tunnels, aerating the soil, facilitating the passage of water and allowing plant roots to grow better (Bird, 1921; Bottinelli et al., 2015).

- Maintaining Soil Vitality; Insects can increase the overall biodiversity in the soil ecosystem. This diversity can contribute to different organisms living in the soil and maintaining the balance of the ecosystem (Vandegehuchte et al., 2010; Samoilova et al., 2015).

- Circulation in the Soil: Insects undertake an important circulation task in the soil. Those living in the subsoil break down organic matter and provide nutrients to the root system of plants. This is important for the growth of plants and the sustainability of the soil ecosystem (Heinen et al., 2018; Furmancyzk et al., 2021).

- Pest Control: Some soil insects can act as natural enemies in the control of harmful organisms. Some insects protect plants by eating or competing with pest species. This can reduce chemical control in agricultural areas and maintain ecosystem balance (Alyokhin et al., 2020).

The Effect of Soil Structure and Properties on Insects

Most insects spend a certain part of their lives in the soil. The life and population of soil-dwelling insects are directly or indirectly affected by soil structure, temperature, wetness, pH, etc.

- Effect of Soil Structure on Insects: Soil structure determines the soil properties in a region and these properties can vary depending on many factors. Soil contains nutrients that are important for plant growth and is also the habitat of many organisms, including insects. Therefore, soil structure has direct and indirect effects on insects. For example, clay soils harbor very few insects due to the difficulty of movement. The highest number of insects is found in loamy soils where it is easy to make roads or trenches. A good example of the effect of soil structure on an insect population is Agrotis orthogonia Morrison (Lepidoptera: Noctuidae). Although this species was once scarce in the central parts of North America, later, as a result of the degradation and cultivation of grasslands, the insect's proliferation caused great damage to crops. This is because these caterpillars, which like light soils, have achieved this desire by cultivating the soil (Yıldırım, 2012). Cockhafers Melolontha sp. and Polyphylla spp. like sandy soils (Öncüer, 1997). Many insects cannot live in soils with unsuitable physical structure. For example, Viteus (=Phylloxera) vitifoliae (Homop.) does not like sandy soils. On the contrary, species of the family Scarabaeidae (Col.) prefer relatively light soils. Generally, insects tunneling in the soil do not like hard soils (Kansu, 1994). For example, Leptinotarsa decemlineata burrows in the soil at the end of summer in Montana, USA, and remains there in diapause during the winter. Although it burrows 35-60 cm deep in light sandy soils, it can only burrow 20 cm deep in heavy soils. As a result, it is affected differently by winter cold (Önder 2004).

- The Effect of Soil Temperature on Insects: Insects are generally highly sensitive to environmental factors, so a number of factors, including soil temperature, can have an impact on the life, development and behavior of insects. However, because the diversity of insects in general is so great, the effect of soil temperature on a particular insect species can vary depending on the species' characteristics and adaptations. Soil temperature affects the rate of arrival of insects, reproductive behavior, activity level, feeding, habitat selection. Most insects are affected by soil temperature, affecting the rate at which they transition from the larval to the adult stage (Orozco-Santos et al., 1995; Haridas et al., 2016). Higher temperatures can often accelerate larval development. However, extreme temperatures can also be fatal. The mating and egg-laying behavior of soil-dwelling insects is temperature-dependent. Some species are more active within a certain temperature range or at a certain temperature. Insects generally adapt their body temperature to the ambient temperature.

Therefore, soil temperature can affect an insect's activity level during the day. The metabolism of insects can vary depending on soil temperature. Higher temperatures generally increase metabolism, which may cause insects to require more nutrients. Soil temperature can also affect insect habitat selection. Some species prefer certain temperature ranges and survive in soils at the appropriate temperature (Smith, 1956; Ellsbury et al., 1998; Kaya, 2018; Kuczyk et al., 2021).

Soil temperature is closely linked to atmospheric temperature and soil structure. It is a known fact that dark soils will heat up and cool down more quickly than light colored soils and sandy soils than clay soils. It is obvious that insects living in such soils will gain activity earlier than insects living in other soils.

-Effect of Soil Wetness on Insects: Soil wetness is an important environmental factor affecting many biological processes. Soil wetness is an important factor for many insect species and can affect insect reproduction and larval development, feeding, nest building and shelter, and mobility. However, these effects can often vary depending on the insect species, soil type, climatic conditions and other environmental factors. Some insect species prefer moist or wet soils for laying eggs and developing larvae. When the soil surface is wet, food sources may become more readily available for some insects. Moist environments, especially those with plants containing sap, for example, can be attractive to pests. Wet soil provides a favorable environment for nesting and shelter for some insect species. This is especially true for insects that live underground (Harris, 1964; Ekesi et al., 2003; Li et al., 2019). Some insect species may be more active in wet soils. For example, insects that need water may be more active in wet soils. However, at the same time, excessive wetness can also be disadvantageous for some insect species. For example, some water-loving insect species may find it difficult to survive even in extremely moist soils because it can affect their respiratory system or cause their nests to collapse. Soil wetness varies according to soil structure, vegetation and climatic factors. Annual variations in wetness have a significant impact on the fauna (Kung et al., 1991; Cheng et al., 2017). Species belonging to the orders Collembola and Protura, which have thin cuticle, need soil moisture for their activities in the soil. Termites also react to drought and live comfortably at 50% soil moisture. If there is no suitable moisture, they burrow deeper in search of it. Species accustomed to rainy places are not affected by soil wetness. Likewise, desert insects adapt to increased drought (Yıldırım, 2012).

As there is a difference between insect species in terms of soil wetness demand, there is also a difference in demand between the biological periods of the same species. Many insect species that spend their pupation period in the soil require increased soil wetness in order for their pupae to open. Likewise, soil wetness must reach certain values in order for grasshopper and beetle eggs in the soil to open (Yıldırım, 2012). Different conditions of soil wetness have different effects on some insects. For example, in a cotton field, the highest viability of Platyedra gossypiella. is observed at 16% soil wetness: At complete dryness - and 28% wetness - the viability rate is zero. According to this situation, irrigation of arid soils causes the pink bollworm population to increase, while more irrigation causes it to decrease (Önder, 2004).

- Effects of Soil Chemicals and pH on Insects: Chemicals and pH levels in the soil can affect the life and behavior of insects. The effect of these factors on insects can be diverse and depends on many factors. Insects can be affected by pesticides and fertilizers in the soil. Pesticides used in agricultural fields can affect insect populations in the soil. In addition to killing the targeted pests, pesticides can also affect other organisms in the soil. In addition, excessive use of fertilizers can cause chemical imbalances in the soil, which can affect insect populations (Weidenhamer and Callaway, 2010; Strawn et al., 2015). Nitrogen levels in particular can become attractive to some insect species. In terms of pH values, acidic soils may be unsuitable for some insect species. When the growth conditions of plants living in such soils change, insect species may find it difficult to adapt to these changes. Alkaline soils can also affect some insect species. Changes in soil pH levels can affect the feeding, reproduction and general behavior of insects (Throop and Lerdau, 2004; Hiel et al., 2018; Stevens et al., 2018). Plants grown in N-rich soil are susceptible to many insect species, especially stinging and burrowing insects. Because N fertilizers cause plant tissues to be loose and watery (Öncüer, 2004). The tissues of plants growing in soils rich in phosphorus and potassium are tighter. For this reason, they are more resistant to stinging sucking insects than plants growing in nitrogen-rich soils. The looseness of plant tissues in nitrogen-rich soils accelerates the destruction of these insects. The amount of lime in the soil has also been found to have an effect on plant resistance. Soil pH also has an important place in insect life. Insects have different pH requirements. For example, Elateridae family species live in slightly acid soils (De Boer et al., 2010; Kagata et al., 2012; Yıldırım, 2012; Antoniadis et al., 2023).

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Effect of liquid organic manures on growth of amaranthus

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Abstract

Vegetables are heavy feeders of nutrients and requirements mainly met through inorganic fertilizers. Injudicious application of chemical fertilizers can result in decline of soil health and environmental pollution. In order to address this problem, organic manure fertilization can be taken. It has been observed that applying organic manures in combination with chemical fertilizers increases crop yields. The present study was carried out to test the effect of liquid organic manures on the growth and yield of amaranthus. Amaranthus (Amaranthus sp. L) is the most important leafy vegetable cultivated and consumed in Southern India. The experiment was carried out at College of Agriculture, Vellayani, on amaranthus variety Co-1 from April to May 2023. Liquid organic manures like panchagavya, vermiwash, fish amino acid and egg amino acid of one per cent foliar spray are analyzed against water spray. The experiment was laid out in Completely Randomised Design (CRD) with five treatments and four replications. Organic liquid manures were applied 15 Days After Transplanting. The study reveals that the panchagavya proves to be an effective fertilizer which contributes the growth of plants. This organic liquid manure enhanced the growth parameters of amaranthus like plant height, girth, number of leaves, yield etc. It was also observed that the plants treated with panchagavya were disease- and pest-resistant. Thus, panchagavya can be used as a plant growth booster. So, organic spray with inorganic fertilizer promotes environmentally sound and sustainable agricultural practices.

Introduction

Amaranthus (*Amaranthus* sp. L.) holds a pivotal role as a vital leafy vegetable in southern India, often referred to as the 'poor man's spinach.' Widely cultivated and consumed in states like Kerala, Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, and Telangana, it stands out as one of the most affordable, accepted, and commercially grown leafy vegetables. Known for its nutritional richness, especially during the summer and rainy seasons, it is a valuable source for combating undernutrition and malnutrition (Ramesh et al. 2018). With impressive levels of iron, calcium, vitamin A, and vitamin C, it fits well into crop rotations due to its short-duration and high yield.

However, the heavy nutrient demands of vegetables, often met through inorganic fertilizers, pose challenges to soil health, environmental sustainability, and overall ecosystem balance. The injudicious use of chemical fertilizers can lead to various issues, such as soil degradation, pollution, and the development of pesticide-resistant pests. In response to these challenges, organic farming emerges as a compelling solution, promoting biological activity, biodiversity, and ecological sustainability.

Organic waste, unlike chemical fertilizers, lacks toxins and carcinogenic materials, contributing positively to soil structure, water holding capacity, microbial biomass, and nutrient availability (Joong, 2011). Reducing inorganic fertilizer use through organic waste recycling aligns with sustainable waste management and agriculture practices.

Foliar feeding, a controversial yet impactful technique, involves applying liquid fertilizer directly to plant leaves, quickly responding to plant growth (Linda, 2007). Panchagavya, an organic compound derived from cow products, stands out for its potential to enhance plant growth and immunity. Comprising milk, urine, dung, curd, and clarified butter, panchagavya is rich in essential macro and micro-nutrients, growth hormones, and beneficial microorganisms (Xu and Xu., 2000).

Fish amino acid, another liquid organic manure sourced from fish waste, proves valuable for plant and microbial growth due to its nutrient and amino acid content (Ghaly *et al.,* 2013). The fermentation process converts fish waste into a useful organic manure without generating foul odours, offering an economically viable resource for agriculture.

Vermiwash, derived from vermicomposting, plays a crucial role in promoting plant growth, root development, and crop production. With its growth-promoting effects and biopesticidal properties, vermiwash contributes to increased soil organic matter and nutrient availability (Sundararasu et al.,2014).

Egg amino acids, an excellent compound for pest control and growth acceleration, can be easily prepared at home using eggs. In this context, our experiment aims to evaluate the impact of various organic liquid manures on the Co-1 variety of amaranthus growth.

Material and Methods

An experiment was carried out at College of Agriculture Vellayani to study the effect of liquid organic manures on the growth and yield of green amaranthus variety Co-1 during April -May 2023. Planting was done in earthen pots filled with potting mixture. Potting mixture was prepared by mixing soil, sand and vermicompost in 1:1:1 ratio. Earthen pots were filled with 5kg potting mixture and green amaranthus seedlings were transplanted on 19/04/2023 and watered twice a day.

Observations on growth parameters like plant height, number of leaves, girth, yield, pest and disease scoring were recorded. Nutrient analysis of the potting mixture and nutrient content of leaf were done. Preparation of different liquid manures are enlisted below.

Liquid Organic Manures

Panchagavya

Panchagavya, an organic liquid manure which has the potential to promote the plant growth as well as provide immunity. Panchagavya consists of five products derived from cow namely- “cow dung, cow urine, cow milk, cow curd and cow ghee” along with other products like jaggery, banana, tender coconut and water which when suitably mixed and used have miraculous effects.

Method of Preparation

Cow dung – 7 kg, cow ghee – 1 kg

Mix the above two ingredients thoroughly both in morning and evening hours and keep it for 3 Days.

Cow urine – 10 litres, water- 10 litres

After 3 days, mix cow urine and water and keep it for 15 days with regular mixing both in morning and evening hours. After 15 days, mix the following

Cow milk- 3 litre, cow curd – 2 litre, Jaggery – 3kg, well ripened poovan banana.

All the above items can be added to a wide mouthed mud pot, concrete tank or plastic can as per the above order. The container should be kept open under shade. The content is to be stirred twice a day both in morning and evening. The panchagavya stock solution will be ready after 30 days. It can be stored and used upto 6 months. Daily stirring for minimum 10 minutes is must. (Care should be taken not to mix buffalo products. The products of local breeds of cow are said to have potency than exotic breeds. It should be kept in the shade and covered with a wire mesh or plastic mosquito net to prevent houseflies from laying egg & the formation of maggots in the solution)

Method of application

Spray system

Three percent solution (*ie*. 3 litres of panchagavya in 100 litres of water) was found to be most effective compared to the higher and lower concentrations. The power sprayers of 10 litres capacity may need 300 ml/tank. When sprayed with power sprayer, sediments are to be filtered and when sprayed with hand operated sprayers, the nozzle with higher pore size must be used.

Flow system

The solution of panchagavya can be mixed with irrigation water at 50 litres/ha and can be supplied either through drip irrigation or flow irrigation.

Seed / seedling treatment

Three percent solution of panchagavya can be used to soak the seeds or dip the seedlings before planting. Soaking for 20 min is sufficient. Rhizomes of turmeric, ginger and sets of sugarcane can be soaked for 30 minutes before planting.

Seed storage

Three per cent of panchagavya solution can be used to dip the seeds before drying and storing them.

Fish aminoacid

Fish extract helps to provide nutrients in the most natural way which is a health tonic.

Ingredients

Native fish - 1kg, Jaggery – 1 kg

Method of preparation

Remove the fish intestines (preferably sardine) and chop into fine pieces (using intestines is not harmful but it smells bad). Powder the jaggery and add it.

Add the two to broad-mouthed glass jar (best) or plastic jar that is just the right size (not too big), cover the jar with the lid (cap), tighten it, and mix it well by shaking the jar. Don't add water. In 30 days, this will be fermented. Filter the brown colored viscous liquid (honey like syrup) using nylon mesh to get 300-500ml solution. This is a great nutrient source for plants and can be stored upto 4-6 months.

Method of application

Diluting it at 2 ml/litre and foliar spraying at 2 weeks interval from 4 leaf stage. It could also be sprayed as repellent against rice bug and pod bugs of pulses at the rate of 15-20 ml per litre.

Egg extract (egg amino acid)

Egg aminoacid is an effective liquid organic manure which is made up of eggs, lemons and jaggery.

Ingredients

7 – 10 eggs, juice of 10-15 lemons, 250gm jaggery.

Method of preparation

Place 7 to 10 eggs in a jar and pour lemon juice in it until the eggs are completely immersed. Keep it airtight for 2 weeks with lid closed. After 2 weeks smash the eggs and prepare the solution. Add equal quantity of thick jaggery syrup to it & set aside for 1 week. The solution will then be ready for spraying. This is a great nutrient for the plants just like fish extract and will boost plant growth.

Method of application

Add 1-2 ml of this with one litre water for spraying.

Vermiwash

Vermiwash, a liquid organic manure is an aqueous extract of a column of freshly formed vermicompost and surface washings of earthworms which contains beneficial microorganisms and water-soluble fractions of substances present in both vermicompost and body surface of the earthworms. Vermiwash is highly alkaline in nature which suggests its potential for liming as well.

Method of Production

The system consists of a plastic basin having a capacity of 20 litres, a plastic perforated wastepaper basket and a PVC pipe of 5 cm diameter and 30 cm length. The wastepaper basket is covered with a nylon net and placed at the centre of the basin upside down. A hole is made at the bottom of the wastepaper basket so that a PVC pipe of 5 cm diameter can be placed at the centre of the basin upside down. A hole is made at the bottom of the wastepaper basket, so that a PVC pipe of 5 cm diameter can be placed into the basin through the hole in such a way that one end of it touches the basin. The PVC pipe is perforated so that the leachate from the basin seeps through the wastepaper basket and collects in the PVC pipe, which can be siphoned out by a kerosene pump. The basin outside the wastepaper basket, is lined with a layer of brick pieces at the bottom and a 2-3 cm thick layer of coconut fibre of 2-3 cm placed above it. After moistening this, 2 kg worms (about 2000nos) are introduced into it and 4 kg kitchen waste is spread over it. After one week, the kitchen waste turns into a black well decomposed compost. Two litres of water are sprinkled over the compost containing worms. After 24 hours, the leachate collected in the PVC pipe is removed by siphoning. The collected leachate is called vermiwash, which is an extract of compost containing worms. This is used for soil application and foliar spray in different crops. Vermiwash is honey brown in colour with an alkaline pH.

Results And Discussion

Various growth parameters were assessed after spraying different types of liquid organic manures. Observations on height, girth, number of leaves, yield, pest and disease scoring were recorded and done statistical analysis. The different treatments applied were one percent foliar spray of egg aminoacid, fish aminoacid, panchagavya, vermiwash and water were given. The details of treatments are given in Table 2.

Table 2. Details of treatments

Treatment notation	Description
T_1	One percent foliar spray of egg amino acid
T_2	One percent foliar spray of fish amino acid
T_3	One percent foliar spray of panchagavya
T_4	One percent foliar spray of vermiwash
T_5	Foliar spray of water

Details of nutrient contents of these liquid organic manures are tabulated in Table 3.

Table 3. Nutrient contents of liquid organic manures

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Egg aminoacid	0.87	0.72	6.20
Fish aminoacid	0.95	0.98	10.50
Panchagavya	0.77	0.86	5.00
Vermiwash	0.23	0.42	6.80

Height at different stages of crop growth

The data presented in table 4 showed the effect of different treatments on plant height of amaranthus. Fish amino acid treatment recorded the highest initial height (11.55 cm) followed by vermiwash (11.53 cm), panchagavya (10.73 cm), water (9.97cm) and egg aminoacid (9.75 cm).

At 15 DAT the highest plant height was recorded by egg aminoacid (36.80 cm) followed by panchagavya (36.60 cm), fish aminoacid (34.38 cm), vermiwash (33.68 cm) and water (32 cm).Panchagavya treatment recorded maximum plant height (70.50 cm) at 30 DAT and was significantly superior to all other treatments and followed by fish aminoacid (62.93 cm), egg aminoacid (61.53 cm), water (56.18 cm) and vermiwash (56.03 cm).This may be due to the positive influence of growth promoting hormones.

Similar trends were also reported by Swain et al. (2015) in chilli (*Capsicum annum* L), Yadav et al. (2017) in Chickpea (*Cicerarietinum* L) and Sailaja et al. (2014) in *Spinaciaoleracea*. Sailaja et al., (2014) reported that there is an increase in biomass, shoot length and root length in panchagavya treated plants. The plant growth substances present in panchagavya help to bring rapid changes in phenotypes of plants and improves the productivity of chilli (Swain et al., 2015). James et al., (2023) reported that Panchagavya significantly improved most of the growth as well as yield parameters of tomato.

Table 4. Effect of liquid organic manure on height of Amaranthus plants

Treatment	Initial height (cm)	Height 15 DAT*(cm)	Height 30 DAT (cm)
T_1	9.75	36.80	61.53^{ab}
T_2	11.55	34.38	62.93^{ab}
T_3	10.73	36.60	70.50^{a}
T_4	11.53	33.68	56.03^{b}
T_5	9.97	32.00	56.18^{b}
C.D.	-	-	9.05
SE(m)	0.93	1.40	2.99
SE(d)	1.31	1.98	4.22
C.V.	17.35	8.08	9.78

*DAT-Days After Transplanting

Number of leaves at different stages of crop growth

Number of leaves was significantly influenced by treatments and it is indicated in Table 6. Foliar spray of panchagavya (T_3) recorded maximum initial number of leaves (9.25) and it is followed by egg aminoacid (8.75), water (8.75), fish aminoacid (8.50) and vermiwash (8.50). Panchagavya also recorded maximum number of leaves (20.75, 28.75) at 15 DAT, 30 DAT respectively and was significantly superior to all other treatments. The lowest number of leaves was recorded in vermiwash treated plants. The increase in branches, number of leaves and leaf area may be due to the hormonal effect of panchagavya.

Perumal et al., (2006) reported that presence of growth regulatory substances such as indole acetic acid (IAA), Gibberellic acid (GA_3), Cytokinin and essential plant nutrients from panchagavya caused tremendous influences on the growth rate of *Allium cepa*. The present finding is in consonance with the report of Swain et al. (2015) in Chilli (Capsicum annum L) and Veeranan et al., (2018) in Holy Basil (*Ocimum Sanctum* L)

Table 6. Effect of liquid organic manure on number of leaves of Amaranthus plants

Treatment	Initial number of leaves	Number of leaves 15 DAT	Number of leaves 30 DAT
T_1	8.75	18.00^{a}	21.50^{b}
T_2	8.50	18.00^{a}	22.50^{ab}
T_3	9.25	20.75^{a}	28.75^{a}
T_4	8.50	18.25^{a}	22.50^{ab}
T_5	8.75	12.00^{b}	16.75^{b}
C.D.	-	4.29	6.7
SE(m)	0.41	1.42	2.20
SE(d)	0.59	2.01	3.11
C.V.	9.45	16.36	19.85

Nutrient concentration on various treatments

The plant nutrient concentrations of various treatments were recorded in table 7. Foliar spray of Fish amino acid recorded highest concentration of N (3.27%) and foliar spray of vermiwash was also recorded greater amount of K (19.07%). Highest amount of P (3.31%) was recorded in plants treated with water.

Table 7. Effect of liquid organic manures on nutrient content of Amaranthus plants

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	2.80	2.85	18.04
T_2	3.27	3.02	17.17
T_3	2.64	2.98	16.00
T_4	2.02	2.64	19.07
T_5	3.11	3.31	17.60
C.D.			
SE(m)	0.34	0.13	0.94
SE(d)	0.48	0.19	1.32
C.V.	21.34	7.65	9.28

Pest and disease scoring of Amaranthus

Pest and disease incidence and severity in amaranthus was determined by assessing the extent of spread of disease. These plants were assessed visually for expression of disease symptom. Then disease incidence was calculated as the number of plants infected expressed as a percentage of total number of plants assessed (Manandhar *et al*., 2016).

$$\text{Disease incidence (\%)} = \frac{\text{Number of plants infected} \times 100}{\text{Total number of plants assessed}}$$

Disease and pest attack was less in plants treated with panchagavya as compared to the rest. Swaminathan et al. (2007) also reported that panchagavya shows its greater beneficial effect in reducing disease and insect attack and work as a pest repellent. Selvaraj et al. (2007), also recorded similar finding. Panchagavya is superior to carbendazim in increasing the fruit yield and suppressing the plant disease index of tomato (Selvaraj et al., 2007). Banana wilt can be controlled by the application of panchagavya. Tomato wilt can be controlled by the soil drenching of panchagavya slurry at the rate of 10% (Priyanka et al. 2020).

Table 8. Effect of liquid organic manures on pest and disease of Amaranthus plants

Treatment	Pest score	Disease score
T_1	5.91	4.00
T_2	6.41	3.28
T_3	4.79	3.02
T_4	5.24	5.32
T_5	5.79	5.05
C.D.	-	-
SE(m)	0.59	0.76
SE(d)	0.83	1.08
C.V.	20.79	36.87

Yield of Amaranthus plants on various treatments

After 50 days of transplanting the plants are harvested and fresh weight is noted. Panchagavya (410.62g) recorded highest fresh weight and it is significantly superior to all other treatment. Vermiwash (404.18g) treatment was on par and followed by T_3. The lowest yield was recorded by water (294.71g).

The highest dry matter yield was also obtained by plants treated with panchagavya (58.03g). And it was followed by vermiwash (54.40g), fish aminoacid (44.56g), egg aminoacid (38.63g) and water (34.30g). It might be due to adequate supply of nutrients at different growth stages of the crop as well as presence of growth regulators in panchagavya contributing to higher yield. The lowest yield was recorded by plants treated with water.

Being a leafy vegetable crop, yield of amaranthus can be considered as a function of growth characters (Pillai and Sheela, 2015). According to Patil et al. (2012) the cow dung in panchagavya act as a medium for the growth of beneficial microbes and cow urine provides nitrogen which is essential for crop growth upon fermentation with other ingredients in panchagavya has beneficial effect on growth and yield. Improvement in yield of amaranthus with increase in plant height and leaf number was observed by Niranjana (1998). Similar findings was observed by Veeranan et al., (2018) in *Ocimum sanctum*. The cow dung in panchagavya act as a medium for the growth of beneficial microbes and cow urine provides nitrogen which is essential for crop growth uponfermentation with other ingredients in panchagavya has beneficial effect on growth and yield (Patil et al.,2012).

Table 9. Effect of liquid organic manure on yield of amaranthus plants

Treatment	Fresh weight (g)	Dry weight (g)
T_1	308.15^{b}	38.63^{bc}
T_2	338.88^{b}	44.56^{b}
T_3	410.62^{a}	58.03^{a}
T_4	404.18^{a}	54.40^{a}
T_5	294.71^{b}	34.30^{c}
C.D.	50.56	7.91
SE(m)	16.62	2.60
SE(d)	23.51	3.68
C.V.	19.46	11.32

Conclusion

The result of study revealed that foliar application of organic liquid manure panchagavya showed significant growth and yield in amaranthus. The study reveals that the panchagavya proves to be an effective fertilizer which contributes the growth of plants. This organic liquid manure enhanced the growth parameters of amaranthus like plant height, girth, number of leaves, yield etc. It was also observed that the plants treated with panchagavya were disease resistant and pest resistant. Although panchagavya shown to be a good liquid manure, vermiwash also demonstrated similar characteristics. Highest amount of potassium recorded in plants treated with vermiwash. Fish amino acid recorded highest concentration of nitrogen while highest amount of phosphorus was observed in plants treated with water. Panchagavya has no significance in nutrient analysis, but it showed tremendous growth, yield and pest/disease resistance. Thus, panchagavya can be used as a plant growth booster.

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A review on: Approaches to comprehensive Soil health assessment for sustainable agriculture

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Abstract
Soil health is the holistic measure of a soil's capacity to function as a living ecosystem, encompassing its physical, chemical, and biological attributes that collectively support plant growth and maintain environmental sustainability. Soil health assessment systematically examines quantifiable properties, including physical, chemical, and biological indicators, to guide decision-making processes related to planting, fertilizing, and soil management practices. Given the inherent challenge of direct measurement of soil health, its evaluation necessitates the examination of quantifiable properties, including physical, chemical, and biological indicators. This review paper focuses on a) indicators for soil health assessment: physical, chemical, and biological b) contemporary soil assessment techniques and recent technological progressions, and c) prevailing challenges and future directions in soil health assessment. Our analysis emphasizes that effective soil health assessment considers physical, chemical, and biological properties, tailored to specific agroecosystems. Looking forward, the paper anticipates future advancements that may involve the integration of technologies such as remote sensing and infrared screening which ensures quick and efficient estimation of indicators, acquisition of accurate soil data, and precise data interpretation, thereby contributing to the advancement of the field of soil health assessment for promoting the resilience of agricultural systems.

Keywords: Assessment techniques, Indicators, Management practices, Soil health

Introduction

Soil health is “the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans” (USDA-NRCS., 2019). A holistic characterization encompassing the pertinent physical, chemical, and biological attributes defines soil health within ecosystems. Soil degradation, arising from the natural or anthropogenic erosion of intrinsic physical, chemical, and/or biological soil properties, leads to the attenuation or complete destruction of vital ecosystem services. The robustness of global food security faces a substantial jeopardy due to the pervasive issue of deteriorating soil health. Evident manifestations of degradation within agricultural soils encompass a noteworthy reduction in organic content, heightened erosion, compaction, salinization, pollution, and a discernible decline in biodiversity (Nunes, Fábio Carvalho, et al., 2020., Pereira, Paulo, et al., 2017). While the infusion of increased energy, fertilizers, and pesticides may yield transient benefits in the realm of intensive agricultural output, the imperative for sustainable agriculture underscores the indispensability of soil health restoration. The restoration of agricultural soils from a state of degradation to a condition of "health" capable of facilitating optimal food and fiber production, along with the provision of essential ecosystem services, necessitates the implementation of judicious and effective management strategies (Kibblewhite, 2008). This strategic approach ensures the harmonization of agricultural productivity with the preservation of soil health, thereby addressing the multifaceted challenges posed to global food security in a sustainable and enduring manner.

The state of "healthiness" in soil is discernible through the examination of pertinent physical, chemical, and biological attributes. The assessment of a soil property's significance in relation to soil health is typically conducted by examining the response of specific soil functions to a tangible alteration in the said soil property (NRCS U. 2015).

The first tier of soil health indicators, known as Tier 1, is characterized by its widespread effectiveness in evaluating soil health. These indicators are defined regionally and organized based on soil groupings, acknowledging the inherent diversity in soil types. Tier 1 indicators establish known thresholds, providing clear benchmarks to assess outcome-based soil health status. Notably, these indicators are responsive to various land use and management practices aimed at enhancing soil functions. Examples of Tier 1 indicators include soil texture, bulk density, aggregate stability, available water-holding capacity, saturated hydraulic conductivity, soil pH, electrical conductivity, cation exchange capacity, base saturation, and various extractable elements and compounds such as P, Ca, Mg, K, Fe, Mn, Cu, Zn, Al, As, B, Ba, Cd, Co, Cr, Mo, Ni, Pb, Si, Sr. Additionally, soil total nitrogen content, nitrogen mineralization rate, soil organic carbon content, short-term carbon mineralization, and crop yield contribute to the comprehensive suite of Tier 1 indicators, collectively providing a robust assessment of soil health.In the second tier of soil health indicators, referred to as Tier 2, these metrics have demonstrated their proven relevance to assessing soil health. Clear impacts on soil health trends have been identified, and recognized ranges with outcome-based thresholds exist for specific regions. These indicators provide valuable insights, allowing for the suggestion of improvement strategies. However, Tier 2 indicators still require additional research for further validation and refinement. Notable examples within Tier 2 indicators include soil sodium adsorption ratio, macro-aggregate stability, soil stability index, soil active carbon, soil protein index, soil β-glucosidase, soil N-acetyl-β-D glucosaminidase, soil phosphomonoesterase, soil arylsulfatase, soil phospholipid fatty acid (PLFA) profile, soil fatty acid methyl ester (FAME) profile, soil microbial genomics, and soil reflectance. These indicators collectively enhance the comprehensive evaluation of soil health, providing nuanced insights into improvement strategies while acknowledging the evolving nature of soil science research and validation.In the third tier of soil health indicators, denoted as Tier 3, these metrics exhibit the potential to serve as soil health indicators. However, further research is essential before users can confidently rely on their measurement, utilization, and interpretation. Examples within Tier 3 include soil microbial community structure and soil microbial DNA extraction and sequencing. These indicators hold promise for enriching our understanding of soil health dynamics, but ongoing research is crucial to solidify their reliability and applicability in practical soil health assessments (SHI. 2021)

The “healthiness” of a soil can be indicated by the relevant physical, chemical, and biological attributes. When assessing soil health, an ideal approach involves assigning equal importance to the three types of soil properties—physical, chemical, and biological. Historically, there has been a propensity to prioritize the measurement and interpretation of soil physical and chemical parameters due to their perceived ease of assessment, often overshadowing the significance of biological processes (Lehmann, Johannes, et al. 2020). In response to this historical bias, recent advancements in soil health assessment systems have incorporated a diverse array of biological indicators, with a specific emphasis on understanding soil microbial activities and dynamics. This strategic inclusion aims to rectify the previous imbalance, resulting in a more comprehensive and equitable evaluation of soil health.

Sojka and Upchurch's (1999) critique underscores the limited applicability of the concept of soil quality to all soil types and uses. The selection of soil quality indicators should be informed by various factors, including soil use, management practices, soil properties, and environmental conditions. Consequently, this review emphasizes a comprehensive exploration of widely used chemical, physical, and predominantly biological indicators of soil health before delving into specific and specialized topics. This approach acknowledges the need for a nuanced understanding of soil health that considers the diverse contexts in which soils are utilized and managed.

Quantitative Assessment of Soil Health

According to Radhika Mankotia (2019) the assessment of soil health involves three key steps:

1. Selection of Appropriate Indicators for Minimum Data Set (MDS): Determining suitable indicators for the Minimum Data Set is crucial. Both qualitative and quantitative soil health indexes have been proposed. Larson and Pierce (1991) emphasized quantifiable soil properties, while Doran and Parkin (1994) focused on soil functions related to sustainable productivity and environmental quality.

2. Transformation of Indicator Values to Scores: After defining variables for the MDS, each observation is translated into scores. Linear and non-linear scoring functions are applied based on whether higher values are favorable or unfavorable. Non-linear functions include bell-shaped or sigmoid curves.

3. Integration of Scores into Index: Integration can be simple or weighted. In simple integration, adjustments are made according to site conditions or priority ranks. Weighted integration assigns weights based on the importance of each indicator.

Table 1. Indicators for Soil Health Assessment

Category	Example	Characteristics
Physical Indicators	Texture, Bulk Density, Porosity, Aggregate Stability, AWC, Soil Structure, Infiltration, Slaking, Soil Crusts, Water holding capacity, Saturated hydraulic conductivity, Surface and subsurface hardness, Penetration resistance, Rooting depth	Quick, cost-effective assessment. Correlations with hydrological processes. Dynamic interactions with soil management.
Biological Indicators	POM (Particulate Organic Matter), PMN (Potentially Mineralizable Nitrogen), Earthworms, Soil Enzymes, Soil Respiration, Soil microbial biomass, Enzyme activity, Microbial biodiversity, Nematode communities, Root pathogen pressure assessment, Cellulose decomposition rate, Weed seed bank, Soil proteins.	Insights into living components. Dynamic properties responding to changes. Significance in nutrient cycling.
Chemical Indicators	Soil pH, Reactive Carbon (RC), Electrical Conductivity (EC), Nitrate-Nitrogen, Phosphorus-Phosphates Electrical conductivity, Organic matter, Available nutrients, Cation exchange capacity, Adsorption, Soil acidification, Soil salinization, Exchangeable sodium, Heavy metals	Profound effects on soil reactions. Direct impact on nutrient availability. Sensitivity to management changes.

Monitoring of Soil Health:

According to Sujaina et al., (2023) monitoring of soil health entails various approaches like;

•Soil Sampling: Representative samples at multiple depths capture soil profile differences.

•Laboratory Analysis: Quantifiable data on pH, nutrient content, organic matter, microbial activity, etc., aids in identifying deficiencies or imbalances.

•Field Observations: Regular visits assess soil color, texture, structure, compaction, root development, and soil organism presence.

•Remote Sensing: Satellite or aerial imaging provides insights into vegetation indices, biomass, and spatial patterns related to soil health metrics.

•Soil Moisture Monitoring: Critical for water availability assessment and preventing waterlogging or drought stress.

•Data Management and Analysis: Organizing data aids in long-term tracking and comparison, enabling identification of patterns, trends, and changes in soil health.

•Long-term Monitoring Networks: Collaboration facilitates data sharing, protocol standardization, and comprehensive understanding of soil health dynamics.

Evaluation Methods for Soil Health Assessment

Sujaina et al., (2023) mentioned various evaluation methods including Soil Health Indices, Comparison to Soil Health Benchmarks, Longitudinal Analysis, Statistical Analysis, Expert Evaluation, Integration with Agronomic Outcomes, and Participatory Evaluation. These methods contribute to a comprehensive understanding of soil health, guiding informed decision-making and sustainable practices. Continuous monitoring is essential for effective soil management.

Soil Health Assessment Methods

1: Farmer Perceptions of Soil Health (Guo, M. 2020)

Criteria	Categories/Indicators
Soil Health Assessment Method	Farmer Perceptions of Soil Health
Method Description	Farmers estimate soil health through direct sense-based examination, considering soil color, aroma, structure, surface crusting, compaction, infiltration, drainage, and ease of tilth.
Validation Study	Gruver and Weil (2006) investigated farmer perceptions of soil health with 75 farmers in the U.S. Mid-Atlantic region, showing significant agreement with soil health indexes.

2: Soil Health Card Methods (Guo, M. 2020; Maryland Soil Health Card. 2018; USDA-NRCS. 1999)

Criteria	Categories/Indicators
Soil Health Assessment Method	Soil Health Card Methods
Method Description	Soil health cards list indicators selected by farmers, allowing field assessment without lab instruments. Descriptive ratings guide users in estimating soil health.
Example	Maryland Soil Health Card with seven indicators: surface cover, infiltration, compaction and root growth, OM content, soil structure/aggregation, earthworms and macroinvertebrates, and soil odor.
Interpretation	Total score categorizes soil health as excellent, good, fair, or poor. Adopted by U.S. and Indian governments for soil management.

3: Solvita Soil Health Tests (Guo, M. 2020; Ward Laboratories. 2021)

Criteria	Categories/Indicators
Soil Health Assessment Method	Solvita Soil Health Tests
Method Description	Toolkit measures OM content, WSOC, aggregate stability, soil basal respiration (Solvita CO2 burst), and Solvita soil labile amino-N (SLAN) to generate a soil health score.
Validation Study	Used in Canada to evaluate crop rotation, tillage, and fertilizer nitrogen effects on soil health, showing high certainty and correlation with soil organic C and total N contents.

4: Haney Soil Health Test (Guo, M. 2020; Ward Laboratories. 2021)

Criteria	Categories/Indicators
Soil Health Assessment Method	Haney Soil Health Test
Method Description	Laboratory dual extraction estimates overall soil health by analyzing soil for total N, NH_4-N, NO_3-N, PO_4-P, organic C, and other elements. Soil CO_2 burst is quantified for scoring.
Evaluation	Relatively simple and convenient for quick assessment, but requires further research validation and locality adaptation.
Correlation Study	Correlated with CO_2-burst indicator, accounting for variations in optimum N rate. Some studies question its reliability.

5: Comprehensive Assessment of Soil Health (CASH) (Guo, M. 2020; Moebius 2017)

Criteria	Categories/Indicators
Soil Health Assessment Method	Comprehensive Assessment of Soil Health (CASH)
Method Description	Intensive laboratory-based protocols assess soil health based on 12 indicators, covering physical, chemical, and biological properties. Overall health score is categorized.
Example	CASH includes indicators like soil AWC, hardness, aggregate stability, OM, active C, respiration, protein index, pH, extractable P, K, and minor nutrients.
Challenge	Challenges in constructing a robust soil health rating system, requiring substantial funds, time, and effort.
Other Models	Similar models exist, such as SMAF and SHAPE, refining soil health indicator selection based on various factors. SHAPE is proposed as an improved version of CASH.

Recent Advancements in Soil Health Assessment

Recent advancements in soil health assessment technologies are taking into account the acquisition of accurate soil data, improving the field measurement of soil properties, and ensuring precise interpretation of the collected data. The emphasis on these aspects has the potential to directly enhance soil health analysis and interpretation. Certain soil properties, including organic carbon, bulk density, soil depth, soil pH, soil water holding capacity, and electrical conductivity, are considered crucial for assessing soil health. Presently, the application of remote sensing technology is directed towards accurately quantifying these properties, aiding in soil quality assessment. Additionally, biological soil health indicators such as organic carbon, total nitrogen, ß-glucosidase activity, active carbon, microbial biomass carbon, particulate organic matter carbon, and soil respiration have been effectively estimated using reflectance spectroscopy method, primarily in the visible-near-infrared (VNIR) wavelengths (Veum et al., 2017). For example, Kaniu & Angeyo, (2015) developed the method in which energy dispersive X-ray fluorescence and scattering spectroscopy (EDXRFS) is used for the characterization of complex materials. The method utilizes weak isotope source X-ray fluorescence and scatter peaks from test matrices and is considered to be an extension of conventional XRF analysis. This approach creates multivariate analytical models for quality assurance (QA) by leveraging both fluorescence and scatter (referred to as EDXRFS spectra. The full spectrum contains explicit and implicit signatures related to the material's chemical and physical properties, allowing for multivariate chemometrics in trace quantitative and exploratory analyses. Integrating EDXRFS spectroscopy into a portable XRF spectrometer could enable a point-of-care soil sensor for intelligent precision agriculture given EDXRFS proven capability to swiftly and directly analyze and characterize numerous soils and soil types across various agro-ecological zones in Soil Quality Assessment (SQA). In an another study, De Paul Obade & Lal, (2016) developed a new Soil Quality Index (SQI) using partial least squares regression (PLSR) to identify the interlinkage of on farm soil quality and crop yields. The study utilized the NIPALS algorithm, a non-linear iterative Partial Least Squares Regression (PLSR) method, to link 12 site characteristic predictor parameters (soil types, management, and soil layers) with 10 soil physical and chemical response variables. These variables encompassed available water capacity, field capacity, soil bulk density, pH, permanent wilting point, soil organic carbon concentration, electrical conductivity, nitrate, nitrite, and C/N ratio. The algorithm then produced regression coefficients specific to soil type, management category, and soil layers for the identified soil physico-chemical attributes. Using PROC PLS in SAS 9.2 at a 5% significance level, PLSR transformed soil attribute and management data into a Soil Quality Index (SQI). In the study the crop yield managed under Natural Vegetation (NV), No-Till (NT), and Conventional Till (CT) was compared and it was found that Pw (Pewamo silty clay loam) soil under NV had higher quality than GWA (Glynwood silt loam), kbA (Kibbie fine sandy loam), CrA (Crosby silt loam), and CtA (Crosby Celina silt loams) soil. Soil attributes such as bulk density (ρb), electrical conductivity (EC), available water capacity (AWC), and soil organic carbon (SOC) significantly influenced SQI, especially at the surface.

Similarly, Rinot et al., (2019) proposed a multivariate-complex SH approach which comprises three steps: a) collection of soil samples from diverse sources, measure the various chemical, biological, and physical attributes to form a comprehensive database followed by minimizing the dataset using quantitative statistical models, selecting key soil attributes crucial for portraying soil's ability to provide essential Ecosystem Services (ES), b) conversion of raw data into normalized scores i.e. data of soil ecosystem services are defined, quantified and are used as the target value of soil functioning assessment, c) least squares models assign coefficients to attributes, indicating their contributions to individual Ecosystem Services (ES) and the overall model. This process eliminates attributes with low contributions, and multiple least squares models are applied for each ES, leading to a comprehensive model that includes all relevant ES. Through this approach, the most significant and universal attributes for quantifying the relative contribution of each attribute to each ES will be identified which then could be used for assessing soil health. Likewise, Ros et al., (2022) devised an open-source framework that comprehensively assesses the soil health of agricultural fields and provides tailored farming recommendations. It hierarchically links soil properties, functions, indicators, scores, and management advice. While initially designed for sustainable crop production assessment, the Open Soil Index (OSI) can be expanded to address broader ecosystem functions. Leveraging existing agronomic knowledge and routine laboratory data, the OSI is a cost-effective solution adaptable to specific regions and objectives. The framework was successfully applied to over 700,000 Dutch agricultural fields, offering reasonable evaluations for diverse field pairs and illustrating its potential for designing sustainable soil management programs. Furthermore, recent research shows that, an improved estimates of overall Soil Management Assessment Framework (SMAF) scores as well as the individual chemical, biological, and physical soil health scores was obtained when data obtained from visible and near-infrared (VNIR), ECa, and penetration resistance sensors were fused together, as opposed to using single-sensor data (Veum et al., 2017).

Challenges and Future Directions

It is challenging to find one such method that would be applied to characterized the soil, its properties and overall functioning. The difficulty in soil quality assessment due to its complex nature of the soil is mentioned by many researchers in their works. For example, Rinot et al., (2019) mentioned the difficulty of characterizing one single assessment techniques is due to the inherent differences among the soil types and the composition of the soil. In conventional technique of assessment, a large number of soil samples is collected followed by sample preparation and laboratory analysis by wet chemistry-based methods. Despite the potentially high accuracy offered by these methods, their use is limited by the tediousness of sample preparations, high expenses, and the risk of chemical contamination. Similarly, Kaniu & Angeyo, (2015) mentioned the limited applicability of spectrometric (especially optical) techniques in rapid soil quality assessment (SQA) due to the complex soil matrix, soil heterogeneity and the quality assurance of multivariate (SQA) data. Lehmann et al., (2020) suggest for wide adoption of certain soil parameters like aggregation, infiltration, earthworm abundance, organic C and N fractions in soil health testing and addition of N-mineralizing enzyme activity for soil health assessments for plant production. They further suggested of considering indicators that addresses non-agricultural soil services such as human health and water quality during soil assessment.

The goal of soil health assessment is to establish a globally recognized framework that not only quantifies soil health comprehensively but also guides sustainable land management practices, aligning with broader environmental and societal objectives. Appropriate indicators and methodologies should be identified to establish comprehensive soil health index which used be applicable for decision making and in policy interventions in support of sustainability goals. Governmental or intergovernmental bodies, should lead the establishment of standards for quantifying soil health. The emphasis should be on developing and integrating technologies, such as remote sensing and infrared screening, to ensure the quick and efficient estimation of indicators, the acquisition of accurate soil data, and precise data interpretation. These technologies appear promising for advancing the field of soil health assessment.

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Determination of spatial distributions of some macro nutrient element contents of Engiz Sub-basin Soils

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Abstract

This study was carried out on an area of approximately 4758 ha in the Lower Engiz basin located in the Ondokuzmayıs District of Samsun Province. Based on the paddy farming carried out on almost flat lands within the basin soil, it was aimed to determine the contents of total nitrogen (N), available phosphorus (P) and available potassium and map their spatial distribution. In the study area, total 250 sample points were determined by the grid method. These samples were brought to the laboratory and analyzed. According to these results, spatial distribution maps of the N, P and K in the study. In order to generate distribution maps, it was made by evaluating 15 different semivariogram of three different interpolation methods in the GIS program. When the obtained geostatistical data were evaluated with the FAO classification, it was determined that they were sufficient in terms of N, P and K. It has been observed that the areas of the area where intensive agricultural production is carried out are especially high in terms of N but sufficient for P and K elements. When evaluated in terms of agricultural activities, it has been determined that nitrogenous fertilizers can be applied as top dressing in the periods when the plant needs it, and since the amount of alluvial and clay in the area is high, P and K fixation may occur and there is no need for these fertilizations.

Keywords: Nutrient Elements, Interpolation, GIS

Introduction

Soil is a living and natural resource that constitutes the direct or indirect source of life of the majority of living things (Candemir and Özdemir 2010). Land, whose formation process takes many years and whose amount cannot be increased any further, is under ever-increasing pressure due to reasons such as the increasing needs of the increasing population and the increase in public spaces. The basis of the socio -economic development of countries depends on the richness of their natural resources and the policies for using these resources (Dengiz and Sarıoğlu, 2011) . Only 26.54 ha of Turkey's land can be used for cultivated agricultural production (Sarı 2006) . In terms of sustainable agricultural production, factors such as intensive agricultural production, applied management techniques and fertilization affect the physicochemical and biological properties of the soil. In addition, soils can show different characteristics even over very short distances. This situation occurs especially in alluvial foothill lands. For this reason, in order to carry out crop production at the highest productivity levels and in a sustainable manner, it is necessary to determine the characteristics of soils by classifying them appropriately through detailed soil survey studies, to produce soil maps by classifying them appropriately, and to create land use plans and maps to determine land use types that support sustainable, efficient and economical agricultural production. It needs to be done (Dengiz, 2002) . On the other hand, ensuring maximum proximity to the final goals of both agricultural and non-agricultural projects planned to be carried out on our country's territory depends on the existence of a soil database that includes location-based, qualitative and quantitative features (Çullu, 2012). Methods such as how plant nutrient map studies will be carried out and which models will be used must be determined precisely. In general, geostatistical methods are used to estimate the distribution of the investigated parameter in the distances between the points where soil samples were taken. For these estimates, researchers use interpolation and extrapolation methods to determine spatial correlation (Ersoy and Yünsel, 2008). The data obtained from these sample points are transferred to the computer and distributed using spatial interpolation techniques to produce distribution maps (Heuvelink 2006). It is very important to follow, determine and interpret all variability processes affecting soil fertility and to develop an effective management style (Aydin and Dengiz 2019).

In this study, it is aimed to determine plant nutrient distribution maps in terms of N, P, K in cultivation areas of the of the Engiz sub-basin and to evaluate the use of fertilizers in terms of sustainable agriculture.

Material and Methods

Engiz Basin lies within the borders of Ondokuzmayıs District of Samsun province. The study area includes an area of 4758 hectares, which forms the lower part of this basin (Figure 1).

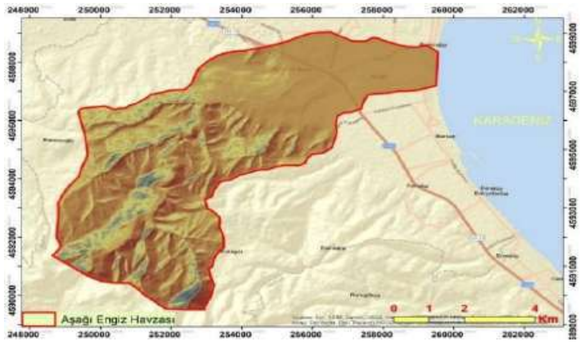
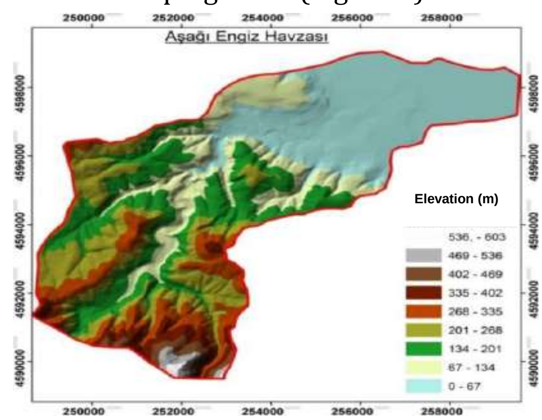


Figure 1. Study area location maps Figure 2. Study area elevation and slope maps

When the study area is examined, it is seen that it has an altitude varying between 603 meters above sea level, the steepest areas (20% and above) are the mountainous areas in the southern part, the areas close to flat (0 - 2%) are the agricultural areas in the northeast of the area, and among these, there are light areas. It is seen that it consists of sloping areas (Figure 2).



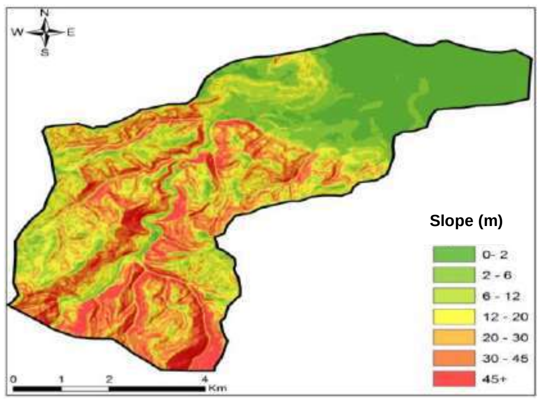


Figure 2. Study area elevation and slope maps

According to the Old American Soil Classification System of 1938, in terms of major soil group the area contains mostly gray brown podzolic and brown forest soils. In addition, alluvial soils are seen in small areas where there are some flat lands in the north-eastern parts of the basin. When the basin is examined in terms of geology, while there are old alluvial accumulations in the northeastern parts of the basin, there are volcanic sedimentary rocks in a small area in the western parts and sandstone and mudstone in the southwestern parts.

The closest meteorological station to the basin is Ondokuzmayıs Meteorological Station. According to Ondokuzmayıs Meteorology station data, the annual average temperature is 13.8 ° C, the annual average evaporation value is 752.31 mm and the annual average precipitation is 717.5 mm. Soil moisture regime when calculated by Newhall Simulation model in terms of temperature regime is ustic, subclass is wet Tempustic and temperature regimes were determined as mesic.

Soil Sampling and Laboratory Studies

In the study area, 292 sampling points were determined with 400 x 400 m intervals by the grid method, and soil samples were taken from 0 - 40 cm soil depth from 250 of these suitable points and brought to the laboratory and analyzed (Figure 3).

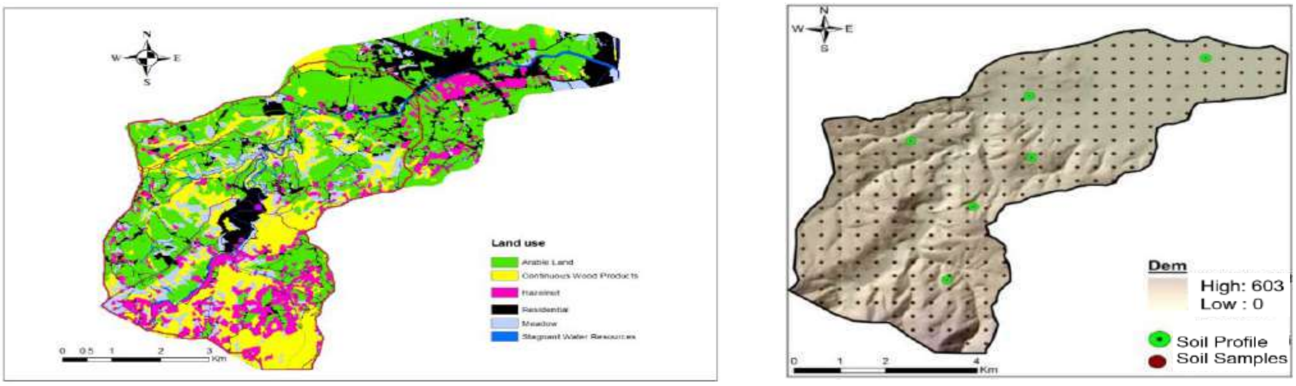


Figure 3. Land use and soil sampling pattern of the study area

In 250 soil samples taken, total nitrogen (N) was determined according to the Kjeldahl method (Bremner and Mulvaney 1982), available potassium (K) content was determined according to (Jackson 1958), and available phosphorus (P) was determined according to the method specified by (Olsen 1954). Additionally, Table 1 was used for the total N, P and K sufficiency levels of the soils.

Table 1. Classification of the soils according to their threshold

	N (%)	P(ppm)	K(ppm)
Very little	< 0.045	< 2.5	< 50
Little	0.045 - 0.09	2.5 - 8.0	50 -140
Sufficient	0.09 - 0.17	8.0 - 25.0	140 - 370
More	0.17 - 0.32	25.0 - 80.0	370 -1000
Too much	0.32 <	80.0 <	1000 <

42% of the study area is cultivated agricultural areas and around 12% is hazelnut farming. Apart from these, approximately 46% of unused lands such as pastures, meadows and pastures are It forms an area of (Table 2).

Table 2. Spatial oath ration distribution of the land use in the study area

Land Cover	**Area (ha)**	**Ratio (%)**
Arable Land	2008	42.23
Mixed Agricultural fields	0.24	0.01
greenhouses	1.21	0.03
Natural Bare areas	4.36	0.09
Indoor Woody Vegetation	917	19.3
meadow	474	9.96
Grassland with Woody Vegetation , dominated by Grassland	32	0.67
meadow with Woody Vegetation without meadow dominance	2.15	0.05
Grassland dominated meadow with bare fields	33	0.69
Artificial areas Without Construction	103	2.16
Transportation Network	159	3.34
Hazelnut	577	12.14
continuous wood Products	1.2	0.03
residential	359	7.54
Stagnant Water Resources	0.23	0.01
Flowing Natural Water bodies	84	1.77
Total	4754	100

Interpolation Methods

To determine the areal distribution of point data obtained from soil analyses, the most appropriate model was determined by using interpolation models and distribution maps of total N, P and K contents of the study area soils were produced. Spatial distribution maps were prepared with the ArcGIS 10.8.2 program, using the analysis results of the soil samples taken from the sampling points whose coordinates were determined in the study area and the geographical data of the study area using interpolation methods. Within the scope of this study, Radial, one of the deterministic methods, Basis Functions (RBF), Inverse Distance Weighting (IDW) method is one of the stochastic methods. Kriging (OK), Simple Kriging (SK), Universal Kriging (UK) methods were compared. In the study, first, second and third power (IDW-1, IDW-2, IDW-3) were used in the IDW method and Completely power was used in the RBF method. Regularized Spline (CRS), Thin plate Spline, (TPS), and Spline with Tension (SWT) models were used, and Spherical, Exponential and Gaussian models were used in Kriging methods. ArcGIS 10.8.2 '' Geosatistical Extension" program uses the criteria of mean error of prediction (ME) and standardized root mean square error of prediction (RMSE) in the maps produced (Çelik and Dengiz, 2018). In the prepared maps, it is understood that the closer the average error of the prediction is to 0 and the closer the square root of the standardized average errors of the prediction is to 1, the more accurate the map is (Johnstone, 2001).

Comparison of Methods and Evaluation

In choosing the most appropriate method among the methods, it is seen that different comparison methods are also taken into consideration in the literature to question the relationship between measured values and estimated values as a result of interpolations and to choose the method that gives the closest result to the measured values (Emadi and Baghernejad, 2014). The most used methods in comparing and evaluating methods are Root Mean Square Error (RMSE) and mean absolute error (MAE) are methods that use correlation values between predicted and observed values. In this study, the Root Mean Square Error (RMSE) method was used to compare the methods to select the most appropriate methods. In model determination, the method that gave the lowest RMSE value was considered the most appropriate method. Equation 1 below was used to calculate RMSE values (Ding, Wang and Miao, 2011).

$$RMSE = \sqrt{\frac{\Sigma(Z_{i*} - Z_i)}{n}} \quad (1)$$

In equality; Zi: is the predicted value, Zi * is the measured value and n is the number of samples.

Results And Discussion

Descriptive statistics and interpolation analysis

Descriptive statistics of total N, P and K analysis results of soils taken from 0-40 cm depth from sampling points within the research area are shown in Table 3. According to (Wilding, 1985), those whose coefficient of variability is less than 15% are considered low, those between 15-35% are considered medium, and those whose coefficient of variability is more than 35% are considered high. Accordingly, when the total N, P, K coefficients of variation in the study area soil samples were examined. The dominant soil type of the study area is alluvial soil. The most important feature of soil properties in alluvial lands is that they are expected to show high variability over short distances. In addition, it is thought that the soil being under intense agricultural activities is the reason for the variability in macronutrients. RMSE results of the 15 interpolation models were given in Table 3. Spherical semivariogram of the Simple Kriging was determined for N while, Gaussian semivariogram of the Simple Kriging were found the most suitable model for P. In addition, Exponential semivariogram of the Simple Kriging was detected for K.

Table 3. RMSE values of the interpolation methods for the study area's soils

Parameters		IDW			RBF			Kriging								
		1	2	3	CRS	SWT	TPS	Ordinary			Simple			Universal		
								S	E	G	S	E	G	S	E	G
N	None	0.09	0.081	0.09	0.089	0.088	0.10	1,01	0.088	0.088	0.086	0.088	0.088	0.088	0.088	0.087
P	log	27.01	27.97	29.31	27.92	27.54	36,40	26.52	26.48	26.53	26.11	26.13	26,10	26.52	26.48	26.53
K	log	132.1	135.6	140.5	135.4	134.3	162.1	128.9	128.9	129.1	125.1	125.0	125.1	128.9	128.9	129.1

G: Gaussian, E: Exponential, S: Spherical. The values written in bold black and underlined in the table are the data regarding the least square root mean error values selected as the appropriate interpolation method. OK: Ordinary Kriging, SK: Simple Kriging, UK: Universal Kriging

Total Nitrogen Distribution

The source of nitrogen is organic matter or humus, along with nitrogen in the atmosphere. 92 -96% of nitrogen is organic in soil. Nitrogen, one of the essential macronutrients that must be present in the soil for optimal growth and development of plants in agricultural production, significantly affects soil fertility depending on the selected soil management methods. The total nitrogen content of the study area soils, which are used as an intensive agricultural production environment, varies between 0.18% and 0.27 % (Table 1). In addition, it was determined that the total nitrogen values of 250 soil samples fell into the excess class range on average (Figure 4).

While the northeastern part of the area is higher in terms of nitrogen distribution, it has been observed that the amount of nitrogen decreases towards the southern parts where the slope increases. When the quantitative variability of nitrogen is examined, it is seen that the north-northeast part, where intensive agricultural production is carried out, has an intense nitrogen excess due to the effect of nitrogen fertilization.

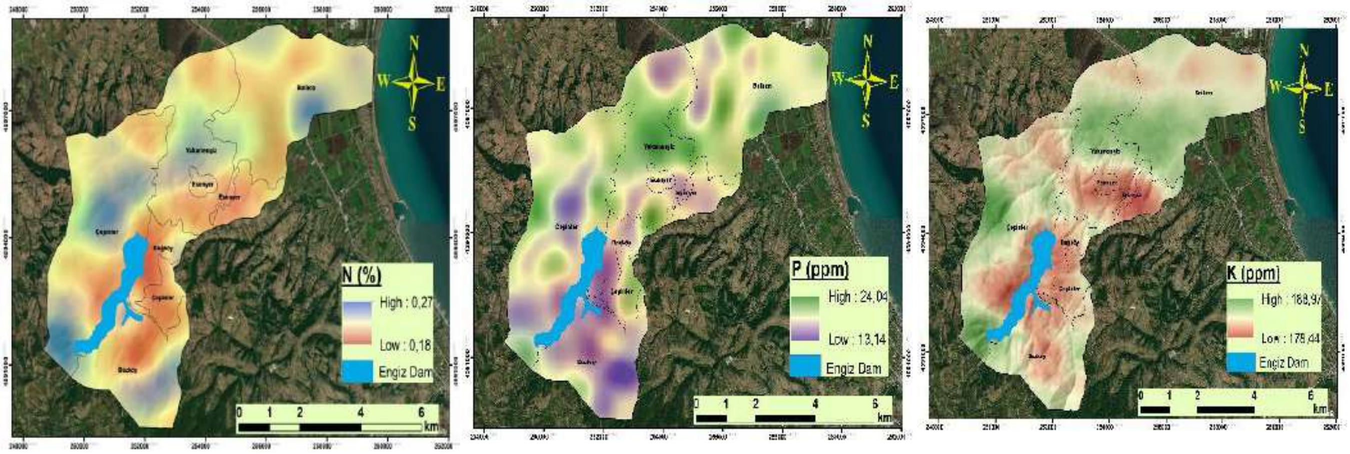


Figure 4. Distribution map of N, P, K in the study area

Distribution of Available Phosphorus

Phosphorus is an indicator of soil fertility. It is a very important macronutrient element as it increases the plant's root development, maturation, fertilization, early seed formation and resistance to diseases and pests. Since the fixation of phosphorus in the soil is high, its availability for plants varies greatly depending on natural environmental conditions and soil management practices. P contents of the soils in the study area vary between 13.14 mg kg $^{-1}$ and 24.04 mg kg $^{-1}$ (Table 1). P content was found to be sufficient in all soil samples (Figure 4). According to the distribution map, it was determined that the soil samples were relatively more abundant in the flat areas of the area where agricultural production was intense, and that there was a decrease in P content as a result of the increase in slope. It has been observed that the areas where phosphorus is low are generally in the southeast of the research area.

Distribution of Available Potassium

The process of retaining potassium in the soil or transforming it back into a form useful for plants has not yet been fully clarified (Bilen and Sezen, 1993). However, it is known that changes in soil reactions affect the dynamic structure of potassium in the soil. The distribution of potassium in the soil varies because some other soil properties such as clay amount and type, lime content, pH value have an impact on processes such as the release or retention (fixation) of potassium in the soil. The K contents of the soils in the study area vary between 178.44 ppm and 188.97 ppm (Table 1). Considering the limit range values in Table 1, soils are classified between sufficient and too much limit values in terms of K.

Conclusion

In this study, the spatial distributions of the changes in the total N, P and K contents of the soil samples taken from the surface soil depth (0-40 cm) at 250 different sampling points in an area of approximately 4754 ha where irrigated and dry farming is done, depending on the distance, were determined by the most appropriate interpolation method. Thus, by preparing the land use pattern in a geographical information system environment, the maps created have become an important resource for revealing whether the change has been affected positively or negatively and for making suggestions such as what measures should be applied in the negatively affected areas. For this purpose, IDW, RBF, SK, UK and OK methods were tested. In the verifications, the Kriging subroutine, Simple, was found to be the most suitable, and the Spherical method of this procedure in terms of N, the Gaussian method, which gave the lowest RMSE values in the distribution of P values, and the Exponantial methods, which gave the lowest RMSE values in the distribution of K values, gave the best results. In order to obtain high-quality and high-quality products in agricultural production, it is very important to provide the plant nutrients needed by the plant to the soil in sufficient quantities and in accordance with the procedure. In line with the evaluations made, it is seen that the nitrogen content of the soil in general is sufficient or excessive, although it is low at some sampling points in the study area.

When the results obtained from the field determination studies and soil analysis were evaluated, it was understood that only a small part of the nitrogen source was from organic matter, and especially due to excessive nitrogenous fertilizer (ammonium nitrate, ammonium sulfate, DAP, Urea) applications made unconsciously by farmers at the wrong time, an excess of nitrogen is observed. While insufficient nitrogen in the soil negatively affects plant development, excessive amounts of nitrogen content also negatively affect plant development. In addition, nitrogen losses through leaching from the soil can also cause environmental pollution by reaching water bodies such as groundwater, lakes and dams. Therefore, this situation can cause negative consequences both ecologically and economically.

A similar situation also applies to the phosphorus and potassium content of the research area. It was determined that the potassium content of the soil of the study area was concentrated in a sufficient class range. Alluvial soils are seen in the soils of the study area, especially as we move towards the north-northeast, and phosphorus and potassium fertilizer applications are not recommended due to the high clay content of these soils and increased phosphorus and potassium fixation. As a result, the findings we obtained in this research reveal that soil properties change with land use. Carrying out fertilizer management planning in these areas, taking into account these changes and plant characteristics, will be one of the important elements of successful soil management.

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The potential of kitchen waste compost and *Bacillus megaterium* var. *phosphaticum* on improving soil health

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Abstract

There is a huge amount of kitchen waste in the world, produced by restaurants, households, and other institutions. The plastic-bagged food waste that is dumped on the land contributes to global warming. It can release methane (CH_4) and carbon dioxide (CO_2) into the atmosphere due to microbial activity under uncontrolled anaerobic conditions in landfills. This has become one of the major issues contributing to harmful gas emissions, leachate contamination of groundwater, loss of landfill capacity, and pest infestation. On the other hand, kitchen waste has the potential to contain a high level of organic matter and nutrients when processed into compost. In addition, kitchen waste compost reduces environmental risks by minimizing the use of chemical fertilizers. Priority should therefore be given to the reuse, recycling, or recovery of waste in agriculture. The latest research findings confirm the role of kitchen waste compost in nitrogen uptake. In addition to nitrogen, phosphorus is an essential nutrient for plant growth, which plays a role in the biological function of plant cells. The use of phosphorus fertilizers often hurts soil and environmental health. Soil microorganisms are considered a good indicator of soil quality and play an important role in agroecosystems by recycling soil nutrients and maintaining and improving the soil microbiome. The use of biological fertilizers can be an alternative solution. Bacillus megaterium var. Phosphaticum is a bacterium capable of releasing inaccessible forms of phosphorus and converting them into plant-available phosphates and also has a positive effect on the soil environment.

Keywords: *Bacillus megaterium*, Kitchen waste compost, Soil health, Sustainable agriculture.

Introduction

The majority of food waste is dumped on land, resulting in odor nuisance, attraction of vermin, harmful gas emissions, contamination of groundwater by leachate, and loss of landfill capacity (Yang and Wen, 2018). Among other factors (pesticides, traffic, urbanization), kitchen waste poses a serious threat to the emission of nutrients into the environment. Nitrogen emissions from food production and consumption, for example, are a significant burden on the environment. Food production depends on the use of fertilizers. The nutrients from fertilizers are found in food, where they can be recovered using various processes (Kuligowski et al, 2023). There is also a risk of pest and disease infestation when kitchen waste is dumped here and there. Usually, such organic kitchen waste is disposed of in plastic bags in rubbish bins or landfills, which can release methane, a greenhouse gas that is even more dangerous than carbon dioxide. Global warming is caused by the release of methane (CH_4) and carbon dioxide (CO_2) into the atmosphere from microbial activity under uncontrolled anaerobic conditions in landfills. The term "kitchen waste" refers to organic waste from restaurants, hotels, and households. Food waste, raw meat, fish, and eggs are just some of the things that are generated in kitchens and cannot be disposed of in landfills.

Recycling is a modern solution to the problem of waste. By replacing natural resources with secondary resources, we are realizing the assumptions of a resource-efficient, low-emission economy and supporting sustainable development (Kuligowski et al, 2023). Among the various options, kitchen wastes have enormous potential for recycling into kitchen compost as they contain abundant carbon and nutrients (macro and micronutrients) and thus can benefit plants and reduce environmental impact by minimizing the use of chemical fertilizers (Shukla and Juneja, 2016). The raw materials are readily available and can be collected in both rural and urban areas. Compost from kitchen waste, an eco-friendly and promising option for kitchen waste management, can improve soil health and crop productivity in an environmentally friendly manner. The reuse, recycling, or recovery of waste should be prioritized whenever possible, as we live in a world where waste production is constantly increasing and the economic activities associated with it continue to grow.

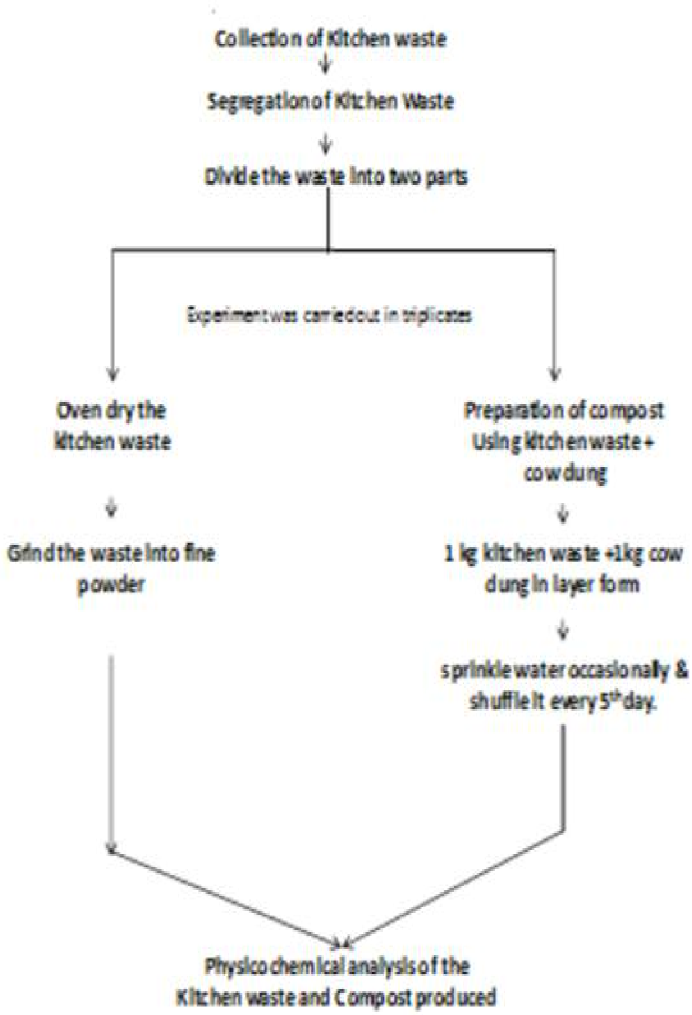
Phosphorus is the second important macronutrient, which is essential for the growth and development of plants and plays a role in basic biological functions. The use of phosphorus fertilizers causes some heavy metals such as Cd, Cr, Pb, and Ni, which are present in the structure of fertilizers, to penetrate into the soil and plant structure and can have negative effects on soil and environmental health (Haque et al., 2020). Soil microorganisms are usually considered good indicators of soil quality and play an important role in the performance and functions of agroecosystems by recycling soil nutrients, and maintaining and improving the soil microbiome (Suleiman et al., 2013; Zhao et al., 2014). It is known that microorganisms dissolve insoluble phosphate by producing organic acids (malic acid, acetic acid, indole acetic acid) and chelating oxoacids from sugars (Dawwam et al., 2013). Studies have shown that inoculating the soil with phosphate solubilizing bacteria (PSB) increases the solubility of fixed soil phosphorus, leading to higher crop yields (Batool and Iqbal, 2019). The use of biological fertilizers can be an alternative solution. Bacillus megaterium var. Phosphaticum is a bacterium capable of releasing inaccessible forms of phosphorus and converting them into plant-available phosphates and also has a positive effect on the soil environment.

Kitchen Waste Compost

Kitchen waste from households, restaurants, catering services, care facilities, and food processing companies is classified as biodegradable household waste (Demirbas, 2011). Direct composting of kitchen waste is rather recalcitrant due to its physicochemical properties (Peng et al., 2022). Therefore, the production of organic compost from these wastes for use in agriculture could be a solution to this problem, with the use of organic compost instead of synthetic fertilizers being more environmentally friendly (Bhadwal et al., 2022). Composting can be a profitable business and provide income and employment opportunities for small farmers.

Composting is a method of treating organic solid waste. In-barrel composting is one of the most affordable, simple, and cheapest methods of producing compost, which can reduce the weight and volume of waste and produce a harmless and useful product (Islam et al.,2011). Composting is the best and most cost-effective alternative for reducing the problems caused by biodegradable waste. Composting kitchen waste is one such method that can be done with zero effort and produces additions to the home garden.

There are three basic requirements for composting. Green (wet) waste, which includes vegetable peelings, fruit peelings, rubbish, etc. Brown (dry waste), which includes dry leaves, flowers, etc., and water. The right amount of water together with brown and green waste is all we need for composting. Having both green and brown coal in the pile will help maintain the nutrient composition and proper decomposition of the materials (Grandhi et al, 2022). Temperature is an essential component of composting. When organic material decomposes, heat is generated. This heat creates an environment in which the microorganisms can work to break down the material.



Kitchen waste provides a good amount of nutrients for the microbes living in it, which are neither pathogens nor a threat to human health. However, they tend to develop a strong odor during decomposition (Shukla et al.,2016).

Table 1. Nutritional Content Available Materials

No	Materials	Nitrogen (%)	Phosphorus (%)	Potassium (%)
1.	Mango peels	1.5	0.40	1.4
2.	Cattle dung	3	2	1
3.	Dry flowers	0.66	0.02	0.09
4.	Plantain peels	0.06	0.016	0.03
5.	Eggshell	0.4	0.01	0.3

Bacillus megaterium var Phosphaticum Bacteri

Bacillus megaterium var. phosphaticum is a large rod-shaped Gram-positive bacterium commonly referred to as a phosphobacterium. Bacillus megaterium var. phosphaticum belongs to the plant growth-promoting rhizobacteria (PGPR) and is known for its ability to dissolve rock phosphate material (Schilling et al., 1998). Bacterial sporulation is a sequence of integrated biochemical reactions that are independent of their vegetative growth and can be interrupted at certain susceptible stages. Bacterial sporulation was induced by inoculation of Bacillus megaterium var phosphaticum (PB-1) culture in an additional nutrient medium15 with (g L^{-1}): Nutrient broth, 13.0; glucose, 1.00; $MgSO_4$, 0.25; KCl, 1.00; $CaCl_2.2H_2O$, 0.15; $MnSO_4$. $4H_2O$, 3.96; $FeSO_4$. $7H_2O$, 278; pH 7.0, and incubated at 32^o C, 500 rpm for about 24 hour in any shaker. A phosphobacterial broth culture with a cell count of 109 cfu ml-1 was aseptically inoculated into a sterile additional culture medium in polybags using a sterile plastic syringe with an injection needle. The prepared vaccine packages were stored at refrigerated temperature (5^oC) and at room temperature (32^oC). The bacterial population was estimated using the pour plate technique (Gomathy et al, 2007).

This group of bacteria includes Phosphate-Solubilizing Bacteria can convert insoluble phosphates into soluble forms through acidification, chelation, exchange reactions, and production of organic acids (Rodríguez and Fraga, 1999). They are found in soil but usually, they are not enough in population, therefore inoculation of plants by a target microorganism at a higher concentration than that normally found in soil is necessary (Vessey, 2003).

Although it is known that Bacillus megaterium var. phosphaticum dissolves phosphate. In their studies, Leo Daniel et al. found that in addition to TCP and rock phosphate, it can also dissolve zinc oxide, zinc carbonate, and K-bentonite. Solubilization of zinc and other test minerals can be achieved by a number of mechanisms, which include the excretion of metabolites such as organic acids, proton extrusion, or the production of chelating agents. In addition, the production of inorganic acids such as sulphuric acid, nitric acid, and carbonic acid could also facilitate solubilization. It is also noted that the highest iron concentration was recorded in the soil treated with Bacillus megaterium var. phosphaticum + L-alpha proline according to Anna Plaza et al. The study by Almaraj et al. (2012) showed that Bacillua megaterium var. phosphaticum is able to reduce the use of chemical fertilizers in Helianthus annus by 25% by increasing the uptake of phosphate, potash, Zn, Fe, Mn, and nitrogen uptake.

Table 2. Nutrient solubilisation by B.megaterium var phosphaticum after 15 days of inoculation

Substrate	Solubilization zone (mm)	Percent solubilization	Solubilization efficiency (E)
Tricalcium phosphate	2.8	3.1	35
Rock phosphate	17.8	19.77	254.2
Zinc oxide	28	31.11	400
Zinc carbonate	32	35.55	457
K-bentonite	20.7	23	295.7

According to a study by Zhang et al. (2021), the integration of kitchen waste compost with Bacillus megaterium improves Olsen phosphorus status, organic matter content, bacterial diversity, and the activity of P-mobilising bacteria in the soil. In another study, Ahmad et al. (2018) concluded that the combined use of Bacillus and compost can improve certain physical properties of the soil, such as increasing root surface area and water-holding capacity. In Rahman´s study, the use of compost and bacteria significantly increased the carbon status of the microbial biomass. This shows that the compost and Bacillus megaterium provided organic carbon to the soil microflora for their higher growth and multiplication, which ultimately improved the microbial enzyme functions in the soil. Compost can provide a favorable environment for the growth and development of the bacillus, with these bacteria in turn helping plants to escape heavy metal stress through certain enzymatic activities. It means that the application of compost and Bacillus megaterium improved the chemical and biological properties of the soil.

Conclusion

The integrated application of kitchen waste compost and Bacillus megaterium var phosphaticum bacteria is recommended on the basis of the relevant studies to improve the chemical, physical and biological properties of the soil. This application is a promising option to improve soil health and plant productivity in an environmentally friendly way.

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The effect of zinc application on corn yield and leaf zinc content

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Abstract

Zinc (Zn) deficiency appears to be the most widespread and frequent micronutrient problem, especially resulting in severe losses in yield and nutritional quality. In this study, Zn fertilizer (with ZnSO4.7H2O containing 21% Zn) was applied to corn plants from soil application by seed sow at rate of 0 - 0.25 - 0.5 - 1 - 2 - 4 kg Zn da-1 doses. The experiment was established as a randomized complete block design with 6 Zn applications and 3 replications. In the study, Zn applications were found that significantly increased the grain yield and leaf Zn content of corn plants compared to the control (P<0.01). The highest corn grain yield and leaf Zn content were found at 0.5 Zn kg da-1 dose as 906.33 kg da-1 and 47.93 mg kg-1. Also, it was that the percentage of Zn use of the corn plants increased the grain yield and leaf Zn content at 0.5 kg Zn da-1 dose, respectively as 14.43% and 142.32%. At the end of the study, the optimal rate of Zn application dose for achieving significant grain yield response of corn plant was recommended 0.5 kg Zn da-1 dose.

Keywords: Zinc, Soil Application, Corn, Grain Yield, Leaf Zn Content

Introduction

Zinc (Zn) is one of the most necessary micro-nutrients both for the growth of plants and for human beings. It is needed by plants in small but critical concentrations and if the available amount is not adequate, the plants or animals will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions (Alloway, 2008; Graham, 2008). In India, critical concentration of Zn used in the interpretation of plant tissue analysis for whole plant of corn is 22 mg kg^{-1} (Srivastava and Gupta, 1996).

Crops such as corn, rice and beans are highly sensitive to Zn deficiency, and losses of yield of 20% or more as a result of hidden Zn deficiency can have an economic impact on the farmer (Alloway, 2008). Zinc deficiency in soils has been reported worldwide, particularly in calcareous soils of arid and semiarid regions. The regions with Zn-deficient soils are also the regions where Zn deficiency in human beings is widespread, for example in India, Pakistan, China, Iran and Turkey (Alloway, 2004; Hotz and Brown, 2004).

Zinc fertilizers (by soil or foliar application) increase both the yield and quality of corn (Potarzycki and Grzebisz, 2009) and several crops, including wheat (Hu et al., 2003; Cakmak, 2008), rice (Liu et al., 2003), and peas (Fawzi et al., 1993). Soil applications of 9-22 kg Zn ha^{-1} on calcareous soils in South Australia have been found to have a beneficial residual effect for about ten years (Alloway, 1990). Alloway (2008) reported that application rates of Zn fertilizers generally used in India are; 11 kg Zn ha^{-1} for wheat and rice; 5.5 kg Zn ha^{-1} for corn. Zinc applied to soil through broadcasting and mixing into the topsoil proved to be more effective than top dressing, side-dressing, band placement.

The objective of this study was to determine the effect of Zn applications on the corn grain yield and Zn content of leaf by soil application.

Material and Methods

Study area and Zn applications

The experimental location was conducted in the province Amasya at Suluova district in the central Black Sea Region (40°36´-40°49´ latitude, 35°14´-35°39´ longitude) in northern Turkey. The climate is semi-arid, with average annual precipitation and evaporation levels of 433.8 mm and 870.7 mm, respectively. Evaporation varies between 4.5 mm in January and 187.3 mm in July, and average temperatures vary from -1.7°C in January to 29.7°C in July. Altitude of the study area ranges from 415 m to 489 m. In the area wheat, sugar beet, onion, corn and sunflower are the most common crops grown during the irrigation season.

In the soil Zn application experiment, the genotype *Zea mays* L. a Zn-efficient corn variety used by small farmers was sowed. The experimental design was nested classified randomized complete block design with 6 treatment 3 replications. Experimental plots were 5.0 × 6.0 m with 0.70 m row spacing. The soil was fertilized with 150 kg ha-1of P2O5, 60 kg ha-1 of K2O (plant and side dress). Zinc sulfate ($ZnSO_4.7H_2O$) was used as a standard Zn fertilizer and NPK commonly applied by farmers as standard macronutrient fertilizer. Zinc sulfate was soil applied at the rates of 0-0.25-0.5-1.0-2.0 and 4.0 kg Zn da^{-1} in the experiment.

Corn plant sampling

Corn leaf samples were collected at the harvesting time. That time, five corn plants composed of four 1-m long rows were randomly sampled from each plot for nutrient analysis. The harvested corn plants were threshed after air-drying, and then corn grains were weighed at for 15 ºC dry weight basis. All plant leaf samples were washed twice with tap water and threefold with distilled water, and then, it was dried in the oven at 65°C hours and then ground in a steel mill.

Chemical analysis

Leaf Zn concentration of corn plants were determined according to the digestion method (HNO_3 : $HClO_4$, 4:1 v/v) in atomic absorption spectroscopy (Perkin Elmer AA-200) (Kacar, 1972). Sample analysis results were reported as the mean of three replicates.

Also, the routine tests in soil samples were determined as follows: mechanical analysis according to the Demiralay, 1993; lime by Hızalan and Ünal, 1965; pH at saturation mud by Kacar, 2009; salinity by Richards, 1954; KDK 1N NaOAc by Sağlam, 1997; available phosphorus with 0.5M $NaHCO_3$ by Olsen et al. (1954); exchanching potassium 1N NH_4OAc method by Sağlam, 1997; organic matter with 1N $K_2Cr_2O_7$ modificated Walkley-Black by Nelson and Sommers, 1982; and total-N with kjeldahl digesting by Kacar (2009), and available Zn was determined by DTPA-extractable (Lindsay and Norvell, 1978). Some of the physical and chemical properties of the experiment soils are given in Table 1.

Soil sample from experimental field was collected at 0 cm to 30 cm depth before seeding for basic soil property analysis. The characteristics of the experimental soil are listed in Table 1.

Statistical analyses

All data were analyzed using SPSS 17.0 of the SAS software package. The homogeneity of the variances was verified and the data were subjected to ANOVA. Tukey values were calculated and used to compare treatment means. The level of significance was at P<0.05.

Table 1. Some properties of the soil sampled from experimental field

Soil property	Value
pH*	8,05
EC, mS cm^{-1}	1,17
$CaCO_3$, %	12,65
OM, %	2,28
Sand, %	27,34
Mil, %	34,77
Clay, %	37,89
Total N, mg kg^{-1}	1360
Available P, mg kg^{-1}	8,35
Available K, mg kg^{-1}	282
Available Zn, mg kg^{-1}	0,36

*:Saturated; OM: Organic matter; Lime: $CaCO_3$

Results And Discussion

The effects of zinc application on corn grain yield

In the study, the effect of Zn application on the corn grain yield and Zn content of leaf and their rate of change are given in Table 2. Increasing Zn applications to the soil increased significantly ($P<0.01$) the corn grain yield compared to the control. Between corn grain yield and Zn applications was found a significant ($P<0.05$) positive correlation relationship ($r=0.729^*$) and the highest grain yield (906.33 kg da^{-1}) as obtained from 0.5 kg Zn kg da^{-1} dose (Figure 1). Also the highest rate of change (increasing) in the grain yield was determined as 14.43% at same Zn application dose. Then, it showed that declined depending on increasing Zn doses due to the diminishing yield law. Soil Zn application to Zn-deficient soil corrected the visible symptoms of Zn deficiency and significantly increased the total biomass and grain yield as well as Zn concentrations of grain, and increased corn grain yield by more than 22% (Orabi et al., 1981). Several studies have been shown that a small amount of nutrients, particularly Zn and Mn applied by foliar spraying can significantly increase the yield of crops (Gadallah, 2000; Hebbern et al., 2005; Mirzapour and Khoshgoftar, 2006; Sarkar et al., 2007).

In our study, the corn plants showed a high response to Zn uptake due to the low Zn content of the experimental soil (0.36 mg kg^{-1}). Çakmak et al. (1999) reported that highest increases in grain yield (>100%) were found at locations where DTPA-extractable Zn concentrations were 0.12 mg kg^{-1} soil. There was still a large increase in grain yield at the DTPA extractable Zn level of 0.38 mg kg^{-1} soil, but not at 0.64 mg kg^{-1} soil. This indicates that wheat grown in calcareous soils containing <0.4 mg kg^{-1} DTPA extractable Zn, as Central Anatolia, will significantly respond to Zn fertilization. Critical DTPA-Zn levels were reported 0.6 mg kg^{-1} for wheat (Singh et al., 1987) and 0.4 mg kg^{-1} for corn and sorghum (Martens and Westermann, 1991).

Table 2. The grain yield and Zn contents of corn plants depended on Zn applications

Zn application	Grain yield		Leaf Zn content	
kg da^{-1}	kg da^{-1}	Rate of change, %	mg kg^{-1}	Rate of change, %
Control	792,07c*	-	19,78cd	-
0.25	864,33b	9,12	34,73bcd	75,58
0.5	906,33a	14,43	47,93ab	142,32
1.0	870,33b	9,88	37,23bc	88,22
2.0	903,67a	14,09	32,57bcd	64,66
4.0	866,67b	9,42	40,53ab	104,90

*Values in the same column followed by the same small letter are not significantly different by Tukey's test ($P\leq0.05$).

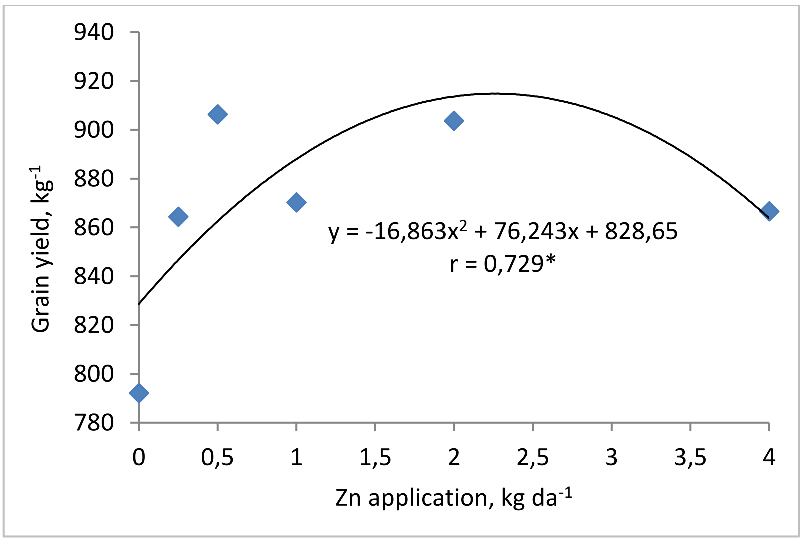

Figure 1. The relationship between Zn doses and grain yield of corn

The effect of zinc application on zinc content of corn plant

Zinc applications to the soil increased significantly ($P<0.01$) the Zn content of corn leaf compared to control (Table 2.) The highest Zn content of corn leaf was determined as 47.93 mg kg^{-1} at 0.5 kg Zn kg da^{-1} dose compared to control (Figure 2). A significant ($P<0.05$) positive relationship was found between corn grain yield and Zn content of corn leaves ($r=0,858^*$, Figure 3). Also, the highest increasing was obtained as 142.32% at 0.5 kg Zn dose compared to control. However, the leaf Zn content of corn decreased depending on increasing Zn doses after the 0.5 kg Zn kg da^{-1} dose. These results show that corn grain yield is directly related to the Zn content of the corn leaf. When Zn is applied to a Zn deficient soil or to a plant whose Zn content is below the critical level, it increases both the plant's nutrient uptake and its growth and development (Aktaş, 1994; Kacar and Katkat, 2009). Aref (2011) reported that Zn spraying use increased leaf Zn content from 33 to 48.3 mg kg^{-1} (47% increase relative to the no Zn use), but Zn application to the soil had no significant effect on the leaf Zn content.

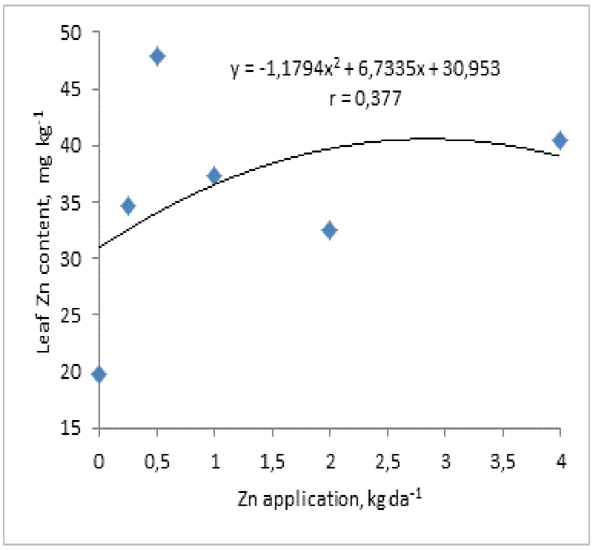

Figure 2. The effect of Zn doses on leaf Zn content

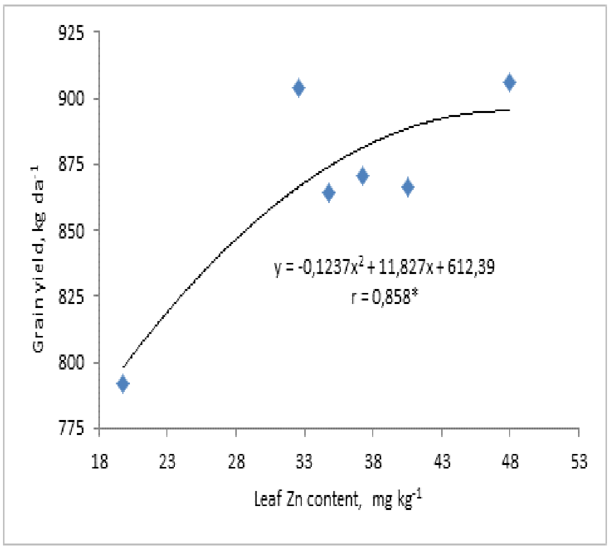

Figure 3. The relation between leaf Zn content and grain yield depending on zinc applications

Conclusion

At the end of the study, the soil Zn application increased both the grain yield and leaf Zn content of corn plants. The highest grain yield and leaf Zn content were obtained from 0.5 kg Zn da^{-1} application. As a conclusion, the most effective and economical way to optimize the efficiency of Zn use efficiency in human and animal nutrition is to increase the bioactivity of Zn in corn plants.

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Effect of vermicompost and biochar applications on plant growth under water stress

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Abstract

In the twenty-first century, the problems caused by the change in the world climate, drought and the increase in the world population have revealed nutrition problems along with the decrease in agricultural lands. The term stress is defined as an external factor that has a negative effect on the plant growth, and stress factors are examined under two headings: biotic and abiotic factors. Living groups such as viruses, bacteria and nematodes constitute biotic stress factors. Abiotic stress factors include some factors such as drought or water stress, salinity, radiation, high temperature, high heavy metals and frost. Water stress is one of the leading factors that causes significant yield losses in agricultural production and negatively affects plant growth and development. The most important abiotic stress factor is water stress. Various methods are used to combat water stress. Since reclamation work requires many years, there has recently been a transition to environmentally compatible organic fertilizer applications. Among these applications, the use of vermicompost and biochar become very common recently. Vermicompost is created by decomposing vegetable and fruit waste and passing it through the digestive system of worms. Biochar is a carbon-rich, decomposition-resistant and porous material obtained by changing biomass of plant and animal origin under high temperatures in an oxygen-free or low-oxygen habitat. This review focused on determining the effect of vermicompost and biochar applications into growing media on the growth and development of plants subjected to water stress.

Keywords: Abiotic stress factors, Biochar, Vermicompost, Water stress

Introduction

Global warming, which has emerged as a widespread concern, is primarily caused by human activities (Cook et al., 2016). This problem leads to the deterioration of ecosystems across the world. Climates changes and unsustainable land usage practices have resulted in precipitation pattern changes, upsetting the soil-water equilibrium (Özdemir, 1995). This imbalance has a significant impact on natural habitats, biodiversity, and agricultural productivity. Therefore, plants cultivated in the unfavorable environmental conditions caused by global warming are subjected to stress.

Plants are exposed to various environmental stresses throughout their natural and agricultural life. While any change in the internal metabolic balance of the plant in its natural habitat that disrupts growth conditions is defined as stress (Shulaeva et al., 2008), stress generally significantly affects a plant's viability, productivity, growth or primary assimilation processes (carbon dioxide and mineral uptake). Stress factors can be divided into two main categories: biotic and abiotic. Biotic stresses are caused by living groups such as viruses, bacteria and nematodes. Abiotic stress factors include insufficient or excessive water availability for plant survival (water stress), salinity, excessive or insufficient light, temperature, chemical toxicity, and oxidative stress (Mahajan and Tuteja, 2005; Akula and Ravishankar, 2011; Kalefetoğlu and Ekmekçi, 2005). Data on how plants respond to biotic and abiotic stresses and the effects of stressors on developmental processes in the plant life cycle have led to the emergence of new approaches in this field (Wasternack, 2007). One of these approaches is to mitigate the negative effects of water stress by adding organic matter to the soil. In this study, effects of water stress on plants growth were reviewed under the conditions of vermicompost and biochar applications into growth media.

Abiotic Stress Factors

Abiotic stress conditions, including drought and salinity, are among the primary reasons for yield loss in agricultural production. They are globally recognized as hazardous and risky, particularly due to the combination of global warming and irrigation errors, which results in abiotic stress-induced yield loss. (Deikman et al., 2012). Abiotic stress is a highly complex mechanism that affects many cellular activities at physiological and molecular levels (Krasensky and Jonak, 2012).

Abiotic stresses have adverse effects on all living organisms on Earth. These unfavourable conditions can impede plant growth and development, lessen productivity, and, in more severe instances, result in plant mortality (Crispet et al., 2016; Dixon and Pavia, 1995; Krasensky and Jonak, 2012).

Temperature: Temperature stress can harm plants by causing permanent damage or even death in all stages of growth (Kranner et al., 2010). Severe physical and mechanical damage occurs in plants when they experience extremely low temperatures beyond their tolerance limit. At freezing temperatures, intracellular spaces may freeze, causing severe cell disruption due to pressure on cell walls and membranes (Olien and Smith, 1977; Sazzad, 2007), or they may undergo cell drying due to fluid movement from within the cell to extracellular spaces. Under high-temperature stress, nutrient absorption, and plant growth decrease, while transpiration from stomata increases. If prolonged, this can result in dehydration, permanent damage, and death.

Light: Under light-related stress conditions, limited light availability can lead to a decrease in plant photosynthetic rate and, consequently, a decrease in energy and metabolite production, slowing growth rates and reducing yield (Mosa et al., 2017). Prolonged exposure of plants to light can cause photosynthetic damage and increased production of reactive oxygen species (Adamiec et al., 2008; Barta et al., 2004).

Salinity: Minerals and nutrients in the soil are essential for plant growth and metabolism. However, the presence of soluble salts such as sodium sulphate, sodium nitrate, sodium chloride, sodium carbonate, potassium sulphate, calcium sulphate, magnesium sulphate and magnesium chloride in high concentrations can lead to salinity in plants. This can lead to severe osmotic stress in plants (Flowers et al., 1977). Salinity is an important environmental factor that adversely affects plant growth and productivity, particularly in arid and semi-arid regions.

Heavy metals: Anthropogenic processes such as mining, agricultural practices and industrialisation have long-term negative impacts on the climate. As a result of these processes, concentrations of heavy metals in soil, water and air are increasing. Heavy metals such as zinc, copper, molybdenum, manganese, cobalt and nickel are essential for biological processes and plant development (Salla et al., 2011). When the levels of these heavy metals exceed thresholds, plants exhibit morphological and metabolic disorders, leading to a reduction in yield.

Water stress: Water stress is one of the major abiotic stresses that adversely affect plant growth and development, resulting in loss of productivity. It occurs when plants are unable to obtain the water they need. Water stress accounts for 26% of the stress factors on available agricultural soils worldwide (Kalefetoğlu and Ekmekçi, 2005).

One of the main factors leading to significant yield losses in agricultural production is water stress, which is the most important of all stress factors. Water stress can be studied in two different categories: water excess and water deficiency. In the case of excess water, plants experience oxygen stress because the roots do not have access to oxygen. Stress resulting from water shortage is defined as drought stress, which is a shortage situation that occurs at uncertain times. Drought in a general sense is a meteorological concept, but it also implies inadequate water availability for plant development due to a decrease in soil moisture (Akhoundnejad and Daşgan, 2020). Since drought is an important environmental stress factor, it significantly reduces crop development and yield.

Pugnaire et al (1994) reported that water stress not only affects plant growth, but also has a significant effect on the yield of crops. A reduction in turgor potential in leaves under stress conditions leads to smaller cell sizes. In this situation, leaves remain small, resulting in a decrease in photosynthetic products (Kaçar et al., 2009). Water stress is particularly effective when it occurs during the fruit and grain filling stages. In such cases, inadequate water uptake by xylem vessels negatively affects fruit and kernel filling, resulting in yield loss (Kacar et al., 2009).

The effect of different irrigation levels on wheat growth was investigated for 25%, 50% and 100% of available water capacity by Gülser and Kızılkaya (2020). While the level of irrigation water reduced from 100% to 25%, plant height, total biomass, grain yield reduced 23%, 56% and 53%, respectively. Water use efficiency of total biomass and seeds, and also transpiration ratio of wheat plant significantly affected by the water stress during the growing period (Figure 1). They concluded that soil moisture level is an important factor for plant growth, and also water use efficiency, plant growth and yield values decrease with reducing photosynthesis rate due to decreasing soil moisture amount.

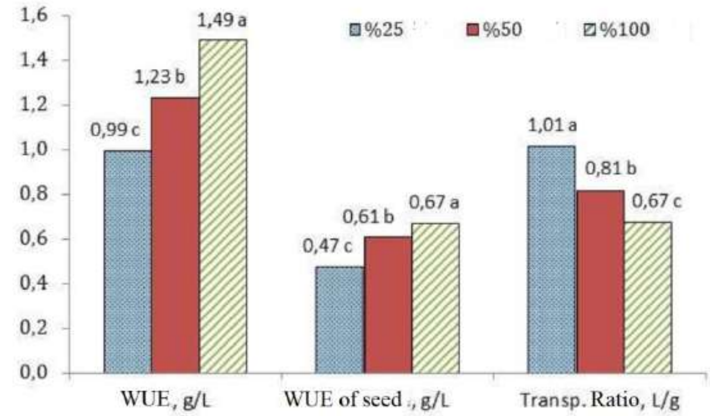

Figure 1. Effect of different irrigation levels for available water contents at 25, 50 and 100% on water use efficiency (WUE) and transpiration ratio of wheat plant (Adapted by Gülser & Kızılkaya, 2020).

In another study, effects of drought stress on plant growth, some physiological and biochemical properties of bean were investigated by Kılıçaslan et al. (2020). They determined that water stress significantly reduced dry weight and leaf area of bean plant at the 60% irrigation level (Table 1). The leaf fresh weight, stem fresh weight, root fresh weight, leaf dry weight, stem dry weight and root dry weight significantly reduced by 17%, 33%, 55%, 57%, 60% and 52% respectively when the irrigation level decreased 100% to 60% (Table 1).

Table 1. Effect of water stress on plant growth parameters in bean (Adapted by Kılıçaslan et al., 2020)

Irrigation Level	Leaf Area	Leaf fresh weight	Stem fresh weigh	Root fresh weigh	Leaf dry weigh	Stem dry weight	Root dry weigh
(%)	(cm^2)			(g)			
100	209 a***	6,24 a***	3,20 a***	2,71 a***	1,85 a***	1,17 a***	0,58 a***
80	202 a	5,80 b	2,66 b	1,98 b	1,04 b	0,59 b	0,35 b
60	171b	5,18 c	2,15 c	1,22 c	0,79 c	0,47 c	0,28 c

Studies on Vermicompost and Biochar Applications

Effects of different vermicompost and soil moisture levels on pepper (Capsicum annuum) grown and some soil properties were investigated by Alaboz et al. (2017). The doses of vermicompost incorporated to the soil were 0 (V0), 0.75 (V1), 1.5 (V2), 2.25 (V3)% (weight/weight) and irrigation levels were 18.5% at field capacity (FC) and 30.5% at pot capacity (PC) (Table 2). When the amount of irrigation water increased from FC to PC, the plant parameters generally increased. They found that application of vermicompost improved plant parameters under the higher irrigation level compared with the lower irrigation. They also reported that root weight and total yield increased with increasing vermicompost doses under the lower irrigation amount applications.

Table 2. Effects of different levels vermicompost and irrigation applications on pepper yield (Adapted by Alaboz et al., 2017)

Vermicompost Aplications	Soil Moisture Levels (80%)	Plant Height (cm/pot)	Plant Weight (g/pot)	Root Weight (g/pot)	Chlorophyll (SPAD)	Yield (g/pot)
V0	FC	38.9bcd*	35.1cd	4.6	64.9	26.1
	PC	44.4ab	51.9b	11.0	67.7	59.2
	Mean	41.6	43.5B	7.7B**	66.3	42.7
V1	FC	35.8bcd	37.4bcd	12.2	60.7	31.5
	PC	50.9a	80.5a	14.2	67.4	60.9
	Mean	43.4	58.9A	9.4AB	64	46.2
V2	FC	32.6d	33bcd	8.7	63.1	40.2
	PC	49.5a	78.8a	15.6	67.2	50.4
	Mean	41.1	55.9A	12.1A	65.1	45.3
V3	FC	35.0cd	33.3d	5.8	63.9	32.6
	PC	42.5abc	51.3bc	14.6	67.1	53.8
	Mean	38.8	42.3B	10.2AB	65.5	43.2
Mean	FC	35.6b	34.7b	5.9b***	63.1b	32.6b
	PC	46.8a	65.6a	13.8a	67.3a	56.1a

Effects of acidified vermicompost produced from pomace on soil properties and pepper growth at different irrıgation levels in a calcareous soil were investigated by (Karapıçak, 2022). The use of vermicompost on pepper plants subjected to 50% water stress conditions has led to a noteworthy rise in the total biomass yield at a significant statistical level ($p < 0.05$), as indicated in Figure 2. In comparison to the control, the study observed an increase in the total biomass values following the implementation of the vermicompost treatment. All vermicompost applications increased plant biomass according to the control treatments under different irrigation levels (Figure 2).

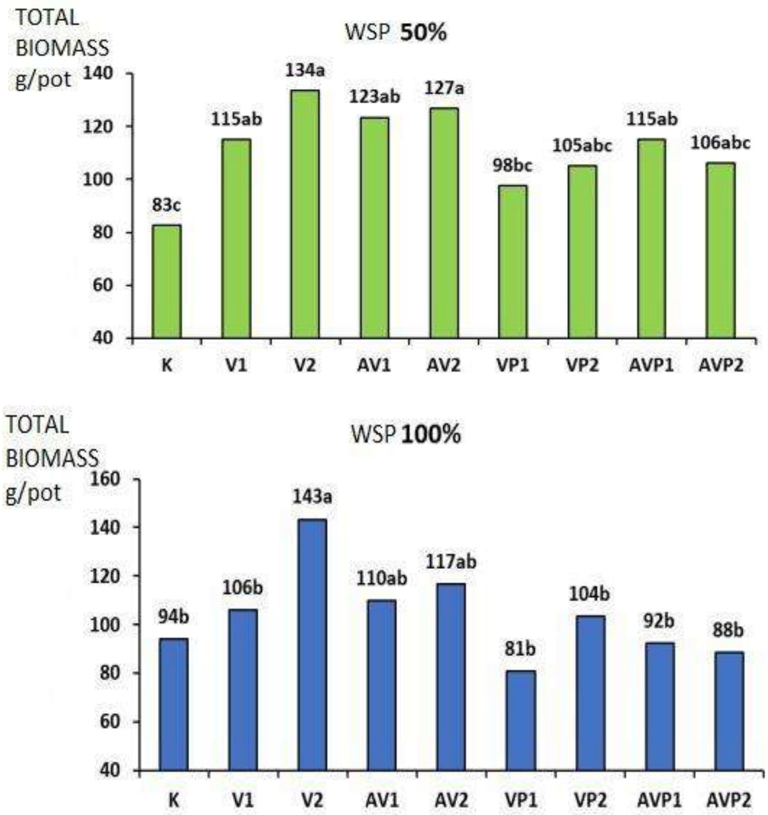

Figure 2. The effects of two different vermicomposts on the total biomass at 50% and 100% of available water applications ($p<0.05$) (Adapted by Karapıçak, 2022). (K: control, V1: manure vermic. 1%, V2: manure vermic. 2%, AV1: acidified manure vermic. 1%, AV2: acidified manure vermic 2%, VP1 (pomace vermic. 1%, VP2: pomace vermic 2%, AVP1 (acidified pomace vermic. 1%, AVP2: acidified pomace vermic. 2%).

Effects of biochar-based fertilizer applications on peanut growth under water stress were investigated by Zheng et al. (2021). They reported that biochar based fertilization alleviated the adverse effect of water stress and increased plant yield due to increasing main stem height, leaf area, chlorophyll content, photosynthetic rate, and total N and K uptake (Figure 3). They concluded that 0.75 ton/ha biochar-based fertilization under around field capacity improves plant growth and yield.

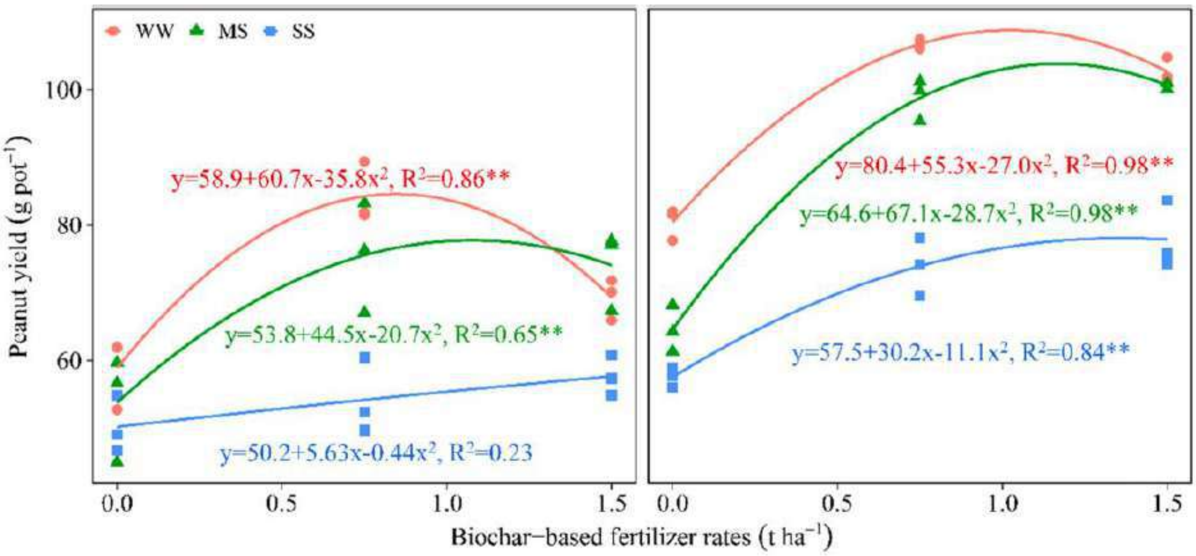

Figure 3. Effect of biochar based fertilization on peanut yield under well-watered (WW), moderate water stress (MS) and severe water stress (SS) conditions (Adapted by Zheng et al., 2021).

Conclusion

Water stress is one of the major abiotic stresses factors and adversely affects plant growth and development. Water stress reduces growth and productivity of plants by negatively affecting leaf water contents, photosynthesis, chlorphyll content and nutrient uptake.

Using biochar and vermicompost as soil conditioners help to improve soil structure, aggregate stability, water holding and aeration capacity, soil biological activity.

Most of the studies indicated that biochar and vermicompost applications under water stress conditions improved plant growth and yield due to improving soil physical, chemical and biological properties.

Under arid and semiarid conditions, those materials can be suggested as soil conditioners to alleviate water stress effect on plant growth.

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Silphium perfoliatum L. – A promising plant for phytoremediation of heavy metal-contaminated soils

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Abstract

Silphium perfoliatum is a perennial plant in the Asteraceae family that occurs naturally in eastern and central North America. It is resistant to drought and frost, which makes it suitable for growing in Europe on anthropogenic soils that are not used for growing other crops. This review analyzes the phytoremediation potential of Silphium perfoliatum, biomass yield, and quality and characteristics as feedstock for bioenergy production (calorific value and chemical composition) and other purposes (in medicine and pharmacology). The heavy metal content in different plant organs during the growing season have been established. The bioaccumulation factor (BAF), translocation factor (TF), metal uptake (MU), and removal efficiency (RE) of Zn, Cd, and Pb by Silphium perfoliatum were determined. Preliminary results indicate that Silphium perfoliatum may be an alternative in the phytoremediation of heavy metal-contaminated soils.

Keywords: Anthropogenic, Bioaccumulation factor, Heavy metal, Phytoremediation, Translocation factor

Introduction

Phytoremediation, the use of plants to extract, immobilize, or transform pollutants, has gained attention as an environmentally friendly and sustainable approach to remediate heavy metal-contaminated soils (Haq et al., 2020). Silphium perfoliatum L., commonly known as cup plant, has emerged as a promising candidate due to its unique characteristics. This plant exhibits a robust and extensive root system, enabling it to explore a large volume of soil and access heavy metal contaminants distributed heterogeneously (Peni et al., 2020). Additionally, Silphium perfoliatum L. showcases adaptability to diverse soil environments, thriving in conditions ranging from acidic to alkaline soils and from sandy to clayey textures. Its slow but steady growth contributes to resilience, allowing it to acclimate effectively to various environmental conditions. The species-specific metal uptake of Silphium perfoliatum L., favoring certain metals over others, provides an opportunity for targeted remediation efforts (Sumalan et al., 2020). Furthermore, the plant's clonal propagation capability offers a practical advantage in rapid population establishment and increased biomass production, critical factors in effective phytoremediation strategies. These key characteristics collectively position Silphium perfoliatum L. as an adaptable and efficient candidate for sustainable phytoremediation practices.

Heavy metal contamination in soils poses a significant environmental threat, adversely affecting ecosystems, human health, and agricultural productivity (Alloway, 2013; Ahmad et al., 2015). As industrialization and anthropogenic activities continue to escalate, the urgency to address this issue intensifies. Phytoremediation, an eco-friendly and cost-effective approach utilizing plants to remediate contaminated soils, has gained prominence in recent years. Among the myriad plant species explored for their phytoremediation potential, Silphium perfoliatum L., commonly known as cup plant, emerges as a particularly promising candidate due to its unique physiological and ecological characteristics. (Behera et al., 2021).

The genus Silphium encompasses several perennial species, with S. perfoliatum L. standing out for its adaptability to a wide range of soil types and environmental conditions (USDA, 2021). This adaptability is crucial in the context of phytoremediation, as contaminated sites often exhibit heterogeneity in terms of soil composition and pollutant distribution. The resilience of Silphium perfoliatum L. to diverse conditions positions it as a versatile tool for remediating heavy metal-contaminated soils across various geographical locations.

Research on phytoremediation using Silphium perfoliatum L. has gained momentum in recent years, driven by the need for sustainable and ecologically sound remediation strategies. The plant's ability to accumulate heavy metals, coupled with its distinctive architectural features, makes it a compelling subject for exploration (Sumalan et al., 2023). In the pursuit of sustainable solutions, understanding the mechanisms behind Silphium perfoliatum L.'s heavy metal uptake and its performance in real-world scenarios becomes imperative.

This review aims to provide a comprehensive synthesis of existing literature on Silphium perfoliatum L. as a phytoremediator of heavy metal-contaminated soils. By examining the physiological, biochemical, and ecological aspects of the plant, we seek to elucidate its potential, challenges, and future prospects in the realm of phytoremediation. The intricate interplay between Silphium perfoliatum L. and heavy metals, coupled with insights from field trials and case studies, will be critically evaluated. This examination will contribute not only to the scientific understanding of plant-based remediation strategies but also to the broader discourse on sustainable environmental management.

Table 1: The Taxonomy (Scientific Classifiaction) of *Silphium perfoliatum* L.

Rank	Scientific Name
Kingdom	*Plantae*
Subkingdom	*Tracheobionta*
Superdivision	*Spermatophyta*
Division	*Magnoliophyta*
Class	*Magnoliopsida*
Subclass	*Asteridae*
Order	*Asterales*
Family	*Asteraceae*
Genus	*Silphium* L.
Species	*Silphium perfoliatum* L.

USDA, 2023

The global challenge of heavy metal soil contamination: Heavy metal contamination of soils is a widespread global concern, primarily resulting from industrial activities, mining operations, and improper disposal of waste (Alloway, 2013). Metals such as lead, cadmium, zinc, and copper, among others, persist in soils for extended periods, posing threats to the environment and human health (Simon et al., 2014). The consequences of this contamination extend far beyond soil degradation; they encompass the contamination of water bodies, disruption of ecosystems, and the bioaccumulation of toxic metals in the food chain (Jayakumar, 2021). The magnitude of this challenge necessitates innovative and sustainable remediation strategies.

Phytoremediation has emerged as a promising, environmentally friendly alternative to conventional remediation methods. This approach harnesses the unique abilities of certain plants to absorb, accumulate, and, in some cases, transform heavy metals (Moosavi et al., 2013). Compared to traditional methods such as excavation and soil replacement, phytoremediation is cost-effective, aesthetically pleasing, and minimizes soil disturbance (Rehman et al., 2023). Silphium perfoliatum L., as a member of the phytoremediation arsenal, holds particular promise due to its robust nature and adaptability to varying environmental conditions.

Silphium Perfoliatum L. – A Promising Plant

Physiological and biochemical mechanisms of silphium perfoliatum l. In heavy metal uptake: Silphium perfoliatum L. exhibits remarkable physiological and biochemical adaptations that contribute to its effectiveness in heavy metal uptake. Root exudates, metal transporters, and the synthesis of metal-binding ligands are among the mechanisms employed by the plant (Sumalan et al., 2023). Understanding these intricate processes is essential for optimizing Silphium perfoliatum L.'s potential in phytoremediation.

Adaptability and resilience in silphium perfoliatum l.: One of the plant's standout features is its adaptability to diverse soil types and environmental conditions. This adaptability is a critical factor in its potential as a phytoremediator, allowing it to thrive in contaminated sites characterized by varying soil compositions and pollutant concentrations (Mocek-Płóciniak et al., 2023). Silphium perfoliatum L.'s resilience positions it as a versatile tool for remediating heavy metal-contaminated soils across different geographical locations.

Biomass yield and quality: An essential aspect of Silphium perfoliatum's utility in phytoremediation is its biomass yield. The volume of biomass produced by the plant influences its capacity to sequester heavy metals from the soil (Cumplido-Marin et al., 2020). Moreover, assessing the quality of the biomass, including its chemical composition, is imperative for understanding its suitability for various applications.

Feedstock for bioenergy production: Silphium perfoliatum's potential as a feedstock for bioenergy production is a critical component of its multifaceted utility. Evaluating its calorific value and chemical composition provides insights into its suitability for bioenergy applications (Cumplido-Marin et al., 2020). Understanding how Silphium perfoliatum can contribute to sustainable energy production is integral to exploring its broader environmental and economic impact.

Utilization in medicine and pharmacology: Beyond its applications in environmental remediation and bioenergy, Silphium perfoliatum exhibits promise in medicine and pharmacology (Crosby, 2017). This will explore studies investigating the plant's medicinal and pharmacological properties. Analyzing its potential applications in these fields broadens our understanding of the diverse benefits Silphium perfoliatum may offer beyond its role in phytoremediation.

Table 2: Challenges and Limitations

Challenges and Limitations	Description	Citations
Slow,Growth Rates	*Silphium perfoliatum* L. exhibits slow growth rates, potentially impacting remediation efficiency and timeframes.	(Cumplido-Marin *et al*., 2020)
Limited Biomass Production	Limited biomass production in the early stages poses challenges for achieving substantial metal uptake. Ongoing research focuses on enhancing biomass through growth optimization and nutrient management.	(Malik, 2004)
Ecological Impacts	Introducing *Silphium perfoliatum* L. raises concerns about potential ecological impacts, necessitating careful consideration of interactions with local flora and fauna. Site-specific assessments and ecological monitoring are essential.	(Anne *et al*., 2023)
Climate Sensitivity	*Silphium perfoliatum* L.'s performance is influenced by climate conditions, exhibiting sensitivity to temperature and precipitation variations. Ongoing research aims to understand adaptability and incorporate climate projections into remediation planning.	(Zimmerman *et al*., 2019)

Future prospects and recommendations

Recent studies have laid the genetic foundation for targeted modifications, positioning Silphium perfoliatum L. as a tailored phytoremediator for diverse environmental scenarios. Precision phytoremediation is highlighted as a strategy for optimizing Silphium perfoliatum L.'s impact, emphasizing site-specific considerations and advanced sensing technologies for real-time data on plant health and metal concentrations. Integrative remediation approaches, combining phytoremediation with microbial remediation and other techniques, aim to amplify overall efficacy, demonstrated through synergistic effects with metal-resistant microbes (Raklami et al., 2022). Addressing climate change, the review emphasizes climate-adaptive strategies to prepare Silphium perfoliatum L. for environmental variability, including the selection of resilient varieties or genotypes. Finally, adaptive management plans are advocated for continuous monitoring and flexibility in response to evolving challenges, ensuring the sustained efficacy of Silphium perfoliatum L. in phytoremediation.

Bioaccumulation factor, translocation factor, metal uptake, and removal efficiency: Quantifying Silphium perfoliatum's bioaccumulation factor (BAF), translocation factor (TF), metal uptake (MU), and removal efficiency (RE) for specific heavy metals (e.g., Zn, Cd, Pb) is essential for evaluating its effectiveness in phytoremediation (Sumalan et al., 2023). These factors offer quantitative insights into the plant's ability to uptake, transport, and remove heavy metals from the soil.

Table 3: Phytoremediation Parameters

Phytoremediation Parameters	Description	Citations
Bioaccumulation Factor (BAF)	Reflects the plant's capacity to accumulate metals from the soil. *Silphium perfoliatum* exhibits a notable BAF for Zn, Cd, and Pb, indicating efficacy in absorbing heavy metals.	(Nescu *et al.*, 2022)
Translocation Factor (TF)	Measures the plant's ability to transport absorbed metals from roots to above-ground parts. *Silphium perfoliatum* demonstrates a considerable TF for Zn, Cd, and Pb, indicating efficient translocation.	(Wie, 2008)
Metal Uptake (MU)	Quantifies the total amount of metals taken up by the plant. *Silphium perfoliatum* exhibits significant MU for Zn, Cd, and Pb, acting as a reservoir for these heavy metals.	(Mulholland, 2019)
Removal Efficiency (RE)	Gauges the plant's effectiveness in reducing the concentration of heavy metals in the soil. *Silphium perfoliatum* demonstrates noteworthy RE for Zn, Cd, and Pb, mitigating soil contamination.	(Manooch, 1991)

The assessment of BAF, TF, MU, and RE in Silphium perfoliatum underscores its promising role in phytoremediation strategies aimed at alleviating heavy metal contamination in soils. The documented efficiency of this plant in absorbing, transporting, and accumulating Zn, Cd, and Pb signifies its potential as a valuable tool in sustainable environmental remediation practices. These findings contribute valuable insights to the broader understanding of Silphium perfoliatum's capabilities and reinforce its candidacy for practical applications in heavy metal phytoremediation initiatives.

Conclusion

In the pursuit of effective solutions, for phytoremediation Silphium perfoliatum L. Stands out as a contender showing great promise in cleaning up soils contaminated with heavy metals. This thorough review has explored aspects of Silphium perfoliatum L.s potential for phytoremediation delving into its mechanisms, performance in real world trials challenges faced, future prospects and strategic recommendations. We have examined Silphium perfoliatum L.s root structure, metal transporters and metal binding agents to gain an understanding of how it adapts to absorb heavy metals. The extensive study of its performance in field trials demonstrates that Silphium perfoliatum L. Can adapt well to soil conditions offering opportunities for improvement through soil amendments, clonal propagation techniques and tailored remediation strategies. However this journey comes with its set of challenges. Slow growth rates and limited biomass production initially pose obstacles that require interventions to enhance efficiency. The ecological impact, species specific absorption capabilities and regulatory considerations highlight the importance of taking an responsible approach when implementing Silphium perfoliatum L. in phytoremediation projects. Looking ahead into the future holds possibilities for Silphium perfoliatum L.s role in phytoremediation efforts. Genetic enhancement holds the key, to unlocking its potential by allowing customization of traits based on remediation needs. Various techniques such, as precision phytoremediation integrating approaches and adapting to climate conditions can help maximize the effectiveness of remediation, in environmental settings.

In a nutshell, Silphium perfoliatum L. stands at the precipice of transformative change in the field of phytoremediation. Through a concerted and interdisciplinary effort, researchers, policymakers, communities, and industry stakeholders can collaboratively guide its trajectory towards becoming a stalwart ally in the remediation of heavy metal-contaminated soils. The journey ahead requires innovation, responsibility, and a shared commitment to environmental stewardship, as Silphium perfoliatum L. charts a course towards a sustainable and revitalized landscape.

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Soil health and crop productivity: implications of integrating biofertilizers with chemical fertilizers

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Abstract

Conventional farming systems rely on the use of chemical fertilizers, herbicides, and pesticides. The unintended consequences of these chemicals range from reduced soil fertility to soil degradation, biodiversity loss, and environmental pollution, among others. Despite these well-reported adverse environmental impacts of chemical fertilizers, their role in achieving high crop yields cannot be disregarded. Biofertilizers provide a promising alternative by promoting nutrient cycling, supplying vital micronutrients to crops often deficient in conventional chemical fertilizers, and minimizing the environmental footprint of conventional agriculture. The aim of this article is to review the recent research on the combined application of biofertilizers and chemical fertilizers towards optimization of their use for preserving soil health and crop productivity. This approach could bring a balance to the need to achieve high crop yields in an environmentally sustainable manner and reasonable prices for everyone, minimize the high use of chemical fertilizers, and enhance soil health.

Keywords: Biofertilizers, Chemical fertilizers, Crop productivity, Nutrient management, Soil health.

Introduction

Over the past decade, the global shift towards sustainable agriculture has increased organic farmland from 31.7 million hectares in 2000 to 76.4 million hectares in 2021 (Martin, 2021). In the same vein, the adoption of alternative nutrient management strategies such as the use of biofertilizers has increased. This trend can be partly attributed to the unintended negative consequences of prolonged use of chemical fertilizers and pesticides such as soil degradation, biodiversity loss, environmental pollution, and climate change (Zulfiqar et al., 2019; Atieno et al., 2020; Vejan et al., 2021). This trend is also part of a robust traction toward the quest for more sustainable options in agriculture. Organic farming is among these sustainable options and at the moment receives additional governmental financial support, but organic outputs generally command higher prices (European Commission, 2023). This suggests that while organic farming yields may be lower, they are sold at premium prices to offset the high costs of production making some of these products unaffordable for some customers.

Despite that NPK chemical fertilizers are the backbone of conventional agriculture, they have been reported for their inability to provide essential micronutrients to crops (Arora et al., 2022). Highlighting the importance of micronutrient supply, biofertilizers could play a crucial role in providing these elements to plants thus contributing to the optimal growth and overall development of crops. An approach of mixing biofertilizer with chemical fertilizer has been reported to significantly improve the growth of oil palm trees supplying balanced and adequate nutrients while also preserving the beneficial microorganisms in the soil (Zainuddin et al. 2022). As the need for a more balanced and cost-effective approach becomes evident, an opportunity arises to integrate biofertilizers with chemical fertilizers in a synergistic manner. This integrated approach aligns with a broader commitment to cultivating crops that are both environmentally responsible and economically viable, striking a balance between the demands of food production and the preservation of ecosystems. The beneficial effects of combining biofertilizer with reduced doses of chemical fertilizer have been reported by several researchers (Kaur and Reddy, 2015; Ning et al., 2017; Yao et al., 2018; Wang et al., 2023).

This article reviews the results of several fertilization research focusing on the combined use of biofertilizers and chemical fertilizers and sheds light on these approaches as strategies incorporated into sustainable agricultural systems.

The role of chemical fertilizers since the Green Revolution

Chemical fertilizers have long been recognized as a cornerstone of agriculture and to date are still continuously used in agricultural production in conventional farming practices (Zainuddin et al., 2022). In fact, chemical fertilizers were the fulcrum that brought success to the era of the Green Revolution, a period in the mid-20th century marked by agricultural intensification that led to increased agricultural yields, and the reduction in global hunger and poverty (John et al., 2021). Chemical fertilizers provide a quick and efficient way to deliver essential nutrients to crops, often resulting in impressive yield increases (Esmaeilian et al., 2022). However, the growing demand for increased crop production makes conventional farming systems dependent on the heavy use of chemical fertilizers and pesticides, which have often resulted in nutrient imbalances, soil acidification, soil degradation, loss of biodiversity, and environmental pollution (Zulfiqar et al., 2019; Atieno et al., 2020; Vejan et al., 2021; Kumar et al., 2022). Particularly, when chemical fertilizers are applied in abundant quantity the plants cannot use them immediately and completely, and the excess leaches into the groundwater causing soil fertility to decline (Zulfiqar et al., 2019). This triggers a cycle of reapplications which inevitably results in higher production costs. Additionally, conventional chemical fertilizers typically lack the capacity to provide necessary micronutrients to crops (Arora et al., 2022). Deficiency in micronutrient supply has the potential to hinder the optimal growth and overall development of crops. Therefore, there is a need to explore avenues to combine new sustainable fertilization approaches such as biofertilizers with chemical fertilizers to produce enough food for the teaming human population while causing minimal damage to the environment.

The application of biofertilizers as environmentally responsible and sustainable option in agriculture

Biofertilizers offer a viable solution as a more environmentally responsible and sustainable alternative to chemical fertilizers (Bhattacharyya et al., 2020; Atieno et al., 2020). Arora et al. (2022) put it more emphatically that "chemical fertilizers caused risks to the environment but biofertilizers came to the rescue of the environment". Generally, biofertilizers are comprised of formulations of live beneficial microbes such as bacteria, fungi, and archaea. Some of them could establish symbiotic relationships with plants and others remain in the bulk soil or in the rhizosphere and succeed in enhancing plant growth and soil fertility through various mechanisms, as shown in Figure 1, including nitrogen fixation, phosphate solubilization, biocontrol qualities, and plant growth-promoting compounds (Arora et al., 2022). These microorganisms play a crucial role in enhancing nutrient availability to crops. For example, nitrogen-fixing bacteria can transform atmospheric nitrogen into a form that plants can readily utilize, thereby decreasing the reliance on chemical nitrogen fertilizers (Guo et al., 2023). Mycorrhizal fungi form mutualistic associations with plant roots and could increase nutrient uptake, especially for phosphorus-containing compounds (Frew et al., 2018). These microorganisms, as a primary concept in the biofertilizer formulations, equally have the potential to enhance soil structure and to promote nutrient cycling, which is expected to have, especially in the long-term, a positive impact on soil health (Singh et al., 2020). Due to the numerous benefits, a great deal of research has focused on developing biofertilizers using a combination of inoculants including Bacillus sp., Acinetobacter sp., Pseudomonas sp., Azotobacter sp., and Azospirillum sp. Currently, the produced biofertilizers are applied as a component of an integrated fertilization approach but very often are accompanied by other strategies (Seenivasagan et al., 2021; Kumar et al., 2022; Zainuddin et al., 2022).

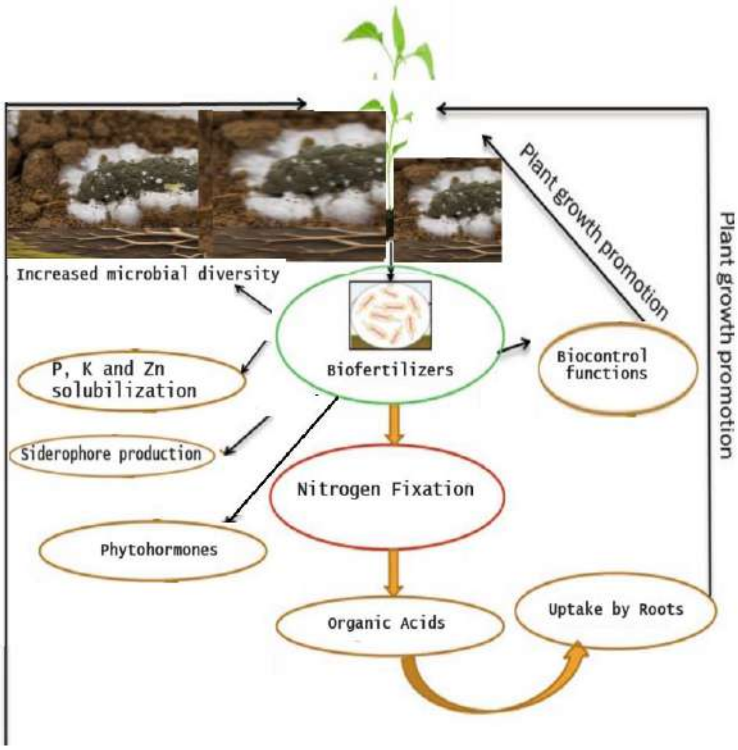

Figure 1. Biofertilizer roles and mechanisms of action *Source:* Mushtaq *et al*. (2021)

Finding the sustainable balance between fertilization strategies, crop yield, and environmental protection

Finding a balance between economic well-being and environmental sustainability has become a major focus of government policy worldwide (Khan et al., 2022). The bulk of this emphasis is focused mainly on minimizing the utilization of chemical fertilizers and pesticides and preserving the natural environment and its resources (Sharma et al., 2023). Thus, adopting alternative nutrient management strategies has gained significant momentum with biofertilizers emerging as promising tools to balance the equation of agricultural sustainability.

Furthermore, with the increasing trend of organic farmland area globally, prices of organic produce have remained on the high side. For instance, farmland under organic farming in the European Union increased by 5.7 % in 2012 and 9.9 % in 2021 (European Commission, 2023). These increases come with very high EU financial support and even so, outputs from organic farms sell at higher prices to be able to recuperate these costs of production. These are factors that must be balanced in the quest for sustainability. Developing environmentally friendly and sustainable food production systems will remain one of the most significant issues in the coming decades (Samani et al., 2019). The answer to the sustainability questions must be the one that brings a recipe that balances the need for high crop yields with minimal environmental impacts at reasonable production prices. This calls for an integrated and holistic approach that reflects a broader commitment to cultivating crops in a manner that is both environmentally responsible, and economically viable, and balances the needs of food with the preservation of ecosystems and essential resources.

Precision agriculture techniques, such as soil testing and nutrient mapping, can help to tailor fertilizer applications with specific crops and soil requirements. Before applying any fertilizers, it is advisable to conduct a thorough soil sample testing in order to determine soil nutrient levels. This information will guide decisions about which nutrients are lacking and which are in excess. In a recent study, Micha et al. (2022) found that soil testing can result in the reduction of chemical fertilizer usage. This finding is also linked to landscape characteristics and farm intensity, highlighting the importance of implementing specific management strategies for decision-making at the farm level. This targeted approach minimizes waste and maximizes the efficiency of nutrient utilization. The successful integration of biofertilizers and chemical fertilizers in agriculture is a critical step that has the potential to revolutionize agricultural practices and provide solutions to both immediate and long-term challenges toward achieving sustainability. By understanding the unique strengths of each approach and employing them strategically, farmers can nurture healthy soils, reduce environmental harm, and continue to meet the global demand for food at affordable prices.

Biofertilizers and chemical fertilizers integration: implications for crop yield and productivity

Biofertilizers and chemical fertilizers serve different purposes in agriculture (Figure 2). Biofertilizers play a crucial role in supplying plants with necessary macro and micronutrients and improving soil health, ultimately leading to enhanced crop yields. On the other hand, chemical fertilizers are efficient at supplying essential nutrients but lack the other benefits associated with biofertilizers. In a recent study, Zainuddin et al. (2022) reported that using a mix of chemical fertilizer and biofertilizer resulted in significant improvements in various growth parameters (plant height, meristem diameter, frond count, leaf area, and dry weight of the leaves) of oil palm trees. According to Jin et al. (2022), the combined application of biofertilizers and reduced doses of chemical fertilizers significantly increased lettuce yield and quality. Esmaeilian et al. (2022), in their three-year experiment with a saffron plant, reported that the combined application of biofertilizer and chemical fertilizer increased the average plant's leaf dry weight, flower number, yield, and dry weight. They further hinted at the possibility of substituting chemical fertilizers with organic and biofertilizers to attain satisfactory yields in areas comparable to the experiment location. Wang et al. (2023) also reported that the combination of biofertilizer and chemical fertilizer significantly improved maize growth, resulting in higher dry matter and nitrogen accumulation and yield, with 8.1% and 7.4% increases compared to only chemical fertilizers in two consequent years (2021 and 2022). This trend was observed by Bam et al. (2022) who found that the incorporation of biofertilizers with other nutrient sources on mungbean crops in Nepal resulted in improved crop yields and increased economic returns. Also, based on the evaluations of the economic and environmental implications of various fertilizer reduction strategies, Wang et al. (2020) reported that the integrated utilization of organic and chemical fertilizers emerged as the best fertilizer reduction treatment. In Indonesia, Simarmata et al. (2018) stated that the integrated use of biofertilizers with chemical fertilizers increased rice grain yield from 5-6 to 6-8 tons ha^{-1}. Similarly, Cong et al. (2011) and Banayo et al. (2012) reported significant rice yield increases following the interaction effects of different chemical fertilizer rates, and biofertilizers.

Some results imply that the combination of biofertilizers and chemical fertilizers provided results that are similar to those obtained with the combination of organic fertilizer and biofertilizer. For instance, Saikia et al. (2018) reported that a consortium of biofertilizers combined with enriched compost at a rate of 3 tons per hectare, seemed a viable alternative to the recommended doses of chemical fertilizer and resulted in increased yields and quality of French beans. Similarly, Wang et al. (2023) found that the utilization of organic fertilizer and biofertilizer under deficit irrigation resulted in significant increases in N uptake, leaf area index, and the rate of photosynthesis. In another study conducted in Zhejiang Province of China, Wang et al. (2020), reported that the highest quality and quantity of tea were produced using a 50% ratio of organic and chemical fertilizers. When compared to chemical fertilizers alone, the addition of biofertilizers increased the output and could offset a 50% reduction in chemical fertilizers (Ennab, 2016). Ennab (2016) recommended that farmers should use 50% NPK plus 55 kg farmyard manure plus biofertilizers to get the best results for lemon trees.

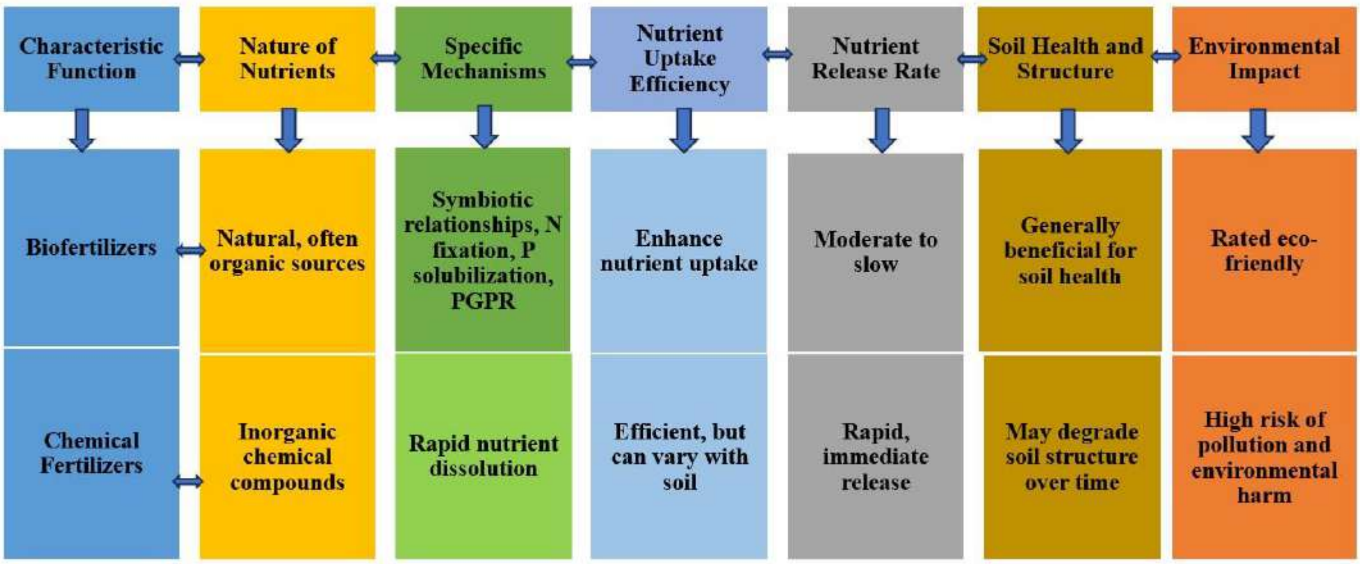

Figure 2: The main features of chemical fertilizers and biofertilizers

Biofertilizers and chemical fertilizers integration: implications for soil health

The stand-alone and prolonged use of chemical fertilizers has been reported to have negative effects on soil health and fertility. It results in the decline of organic matter content in the soil, a decrease in pH levels, and a reduction of essential soil nutrients and minerals which ultimately lead to reduced microbial activity and lower crop yield (Salehi et al., 2017; Pahalvi et al., 2021). According to Zainuddin et al. (2022), the application of biofertilizers along with a reduced amount of chemical fertilizer improved soil health parameters relative to the separate utilization of biofertilizers or chemical fertilizers. Yao et al. (2018) reported that substituting 25% of urea-N with Azolla biofertilizer significantly improved nutrient use efficiency, increased yield, and effectively reduced N loss over the three-year period in China's highly intensive rice cropping systems. Simarmata et al. (2018) reported a substantial reduction (25-50%) in the application of inorganic fertilizers by incorporating 2-5 tons ha^{-1} of biofertilizer which led to improved soil health. Moreover, the combined application of biofertilizer and ground magnesium limestone proved effective in improving rice growth parameters by increasing soil pH and mitigating the widespread aluminum and/or iron toxicity in acid-sulfate soil (Panhwar et al., 2014). Soil pH and soil organic matter (SOM) were reported to be significantly higher in the lettuce plots with the combined application of reduced chemical fertilizers and biofertilizers (Jin et al., 2022). In a two-year field study, Kaur and Reddy (2015) noted that in comparison to chemical P fertilizer (diammonium phosphate, DAP), the combined application of two phosphate-solubilizing bacteria (PSB), Pantoea cypripedii and Pseudomonas plecoglossicida, with rock phosphate significantly improved soil fertility, crop growth, and economic returns in maize and wheat crops. Therefore, the use biofertilizer comprised of phosphate-solubilizing bacteria and its combination with rock phosphate could be a sustainable and cost-effective alternative to the chemical phosphate fertilizer (Kaur and Reddy, 2015).

Furthermore, it is interesting to note that the pattern observed in crop yield and productivity also applies to soil health when biofertilizers and organic fertilizers are combined. There was a strong correlation between the soil quality index and the addition of organic fertilizers and biofertilizers (Du et al., 2022; Du et al., 2023). Integrating organic fertilizers with chemical fertilizers rather than relying entirely on chemical fertilizers is a reasonable method which was applied in various agricultural ecosystems and has been frequently reported to improve the soil's capacity to supply N, P, K, and C (Ning et al. 2017; Salehi et al., 2017, Fayaz et al., 2020; Du et al., 2022; Du et al., 2023). Du et al. (2022) concluded that using a combination of different fertilizers soil fertility could be enhanced and highlighted the crucial role of fungal diversity in sustaining the economic forest tree production. Similarly, Ning et al. (2017) reported that substituting chemical fertilizer with up to 40%-60% with organic fertilizer led to a significant increase in the soil catalase and urease activities as well as organic matter content. According to Fayaz et al. (2020), the combination of four biofertilizers with organic fertilizers had a significant effect on nitrogen, phosphorus, potassium, and microbial populations in the pummelo seedlings (Citrus maxima L) nursery.

However, the application of biofertilizers was not as effective for low phosphorus (P) fertilization as it was for low nitrogen (N) fertilization (Cong et al., 2011). Additionally, Jin et al. (2022) reported increased bacterial community richness and diversity while the fungal community decreased. Achieving a balance between biofertilizers and chemical fertilizers involves adopting synergistic approaches that utilize the strengths of both. Please, remove this figure.

Conclusions

The implications of combining chemical fertilizers with biofertilizers pose many benefits for soil health and crop productivity. The beneficial activities of microorganisms in the biofertilizers alongside the rapid nutrient release of chemical fertilizers could offer a complementary effect towards nutrient deficiencies in the soil. The application of a reduced dosage of chemical fertilizer in combination with biofertilizers could utilize these complementary attributes and provide beneficial interactions toward the optimization of crop productivity and the promotion of long-term soil health. The obtained results may vary from soil to soil, and crop to crop, but this approach could balance the need to simultaneously achieve high crop yields in an environmentally sustainable manner and make this produce available to everyone at reasonable and affordable prices. In the coming years, the wider adoption of the combined use of biofertilizers and chemical fertilizers will depend on the optimization of application and the continued positive effects on maximizing crop yields without destabilizing the agricultural ecosystems.

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Soil reclamation after the oil extraction industry

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Abstract

The extraction of crude oil is a vital sector of the world economy, supplying raw materials and energy. But it also presents serious environmental problems, degrading ecosystems and soil. The interaction between soil, plant, and water is disrupted, and soil toxicity is increased as a result of oil spills, leaks, and inappropriate waste disposal from these oil extraction industries. The effects affect human health, wildlife, and the integrity of the ecosystem as a whole. Soil reclamation operations are essential to addressing these problems. In order to remediate these contaminated soils, a variety of techniques are used. One such technique is bioremediation, which uses microorganisms to break down and neutralize pollutants in the contaminated soil. More recently, enzymes from the microorganisms have been extracted and injected directly into the soil for remediation. The use of plants to break down, absorb, or immobilize oil contaminants. Physical and chemical remediation includes chemical oxidation, excavation, thermal desorption, soil washing, and electrokinetic soil processing. These methods seek to lower oil concentrations, stop more contamination, and improve soil quality. In conclusion, a variety of elements must be considered when selecting the best soil reclamation methodology, and successful remediation that frequently necessitates a combination of approaches. Adherence to local legislation and consultation with environmental specialists are crucial when organizing and carrying out oil extraction-related soil reclamation projects. This review seeks to explore in detail the various techniques used for rehabilitating soil and restoring ecosystems after oil extraction activities.

Keywords: Oil Companies, Petroleum, Reclamation, and Soil health

Introduction

Businesses that investigate, extract, refine, transport, and sell crude oil and its byproducts are known as crude oil extraction industry. Crude oil is a naturally occurring liquid petroleum product composed of hydrocarbon deposits and other organic materials formed from the remains of animals and plants that lived millions of years ago (Eneh, 2011; Walters, 2017; Mawad, 2020). As a source of energy and raw materials for other sectors, oil extraction is essential to the world economy. About 90 million barrels of crude oil were produced daily worldwide in 2022, with 28% produced offshore and 72% onshore (Dong et al., 2022). In terms of crude oil production in 2022, the top five nations were Saudi Arabia, Russia, the US, Iraq, and Canada (Zuoqian et al., 2022). On the other hand, in 2022, Saudi Aramco, Rosneft, ExxonMobil, PetroChina, and Chevron were the top five industry producing crude oil (Blondel and Bradshaw, 2022). The size and position of reservoirs, the kind and quantity of wells, the facilities and infrastructure, and the environmental laws all affect how much land is used by crude oil extraction industries. Nonetheless, it is estimated that 0.01 hectares of land are used on average for every barrel of oil produced (Cordes et al., 2016; El-Houjeiri et al., 2013; Emmanuel et al., 2006).

Crude oil are been refined into products such as gasoline, jet fuel, and other petroleum products due to its constituent.

Saturated aliphatic and aromatic compounds, including alkene, cycloalkene, benzene, toluene, xylene, naphthalene, phenol, and several polycyclic aromatic hydrocarbons (PAHs), such as anthracene, benzofluorene, chrysene, phenanthrene, and pyrenes, make up crude oil and other products produced by these extraction industries, such as oil sludge (El Gendy and Nassar, 2018). They also contain pyridines, thiophenes, naphthenic acids, and mercaptans, which are important resin constituents. The oily sludge also includes a range of heavy metals, including zinc (Zn), lead (Pb), copper (Cu), nickel (Ni), and chromium (Cr), in addition to the materials already described (Das et al., 2018). When these substances leak into nearby soil or water, they cause significant environmental problems.

Concerns have grown, meanwhile, because of the effects that oil extraction has on the environment, especially in places of extreme natural beauty. The site may become contaminated due to industrial equipment failure, oil spills, leaks, deliberate damage to manufacturing facilities, and the discharge of unprocessed waste from companies (Ogolo et al., 2022). The deterioration of ecosystems and soil near oil extraction facilities is one of the main environmental problems. In addition to polluting groundwater, the oil seeps into the land. cause restricted growth, poor seed germination, and nutrient deficiencies. Because oil is highly viscous and can cover soil surfaces and clog soil pores, it decreases water retention in the soil (Ossai et al., 2020; Yavari et al., 2015).

As a result of the huge negative impact caused to soil and ecosystems during oil extraction activities, has necessitated soil reclamation efforts. This review seeks to provide an in-depth exploration of the strategies and technologies employed in rehabilitating soil and restoring ecosystems following oil extraction activities.

Environmental Impact of Oil Extraction Industries

Oil extraction and processing releases pollutants and greenhouse gases into the environment, water, and soil during the drilling, pumping, refining, shipping, and burning processes. Environment impact may result from improper waste management, noise, and possible spills (Ogolo et al., 2022). They have the following effects on the environment:

When crude oil spills frequently onto agricultural soils, the soil becomes poisonous and unusable, especially in the top layer. The majority of the vital nutrients for plant growth and development are no longer available due to the oil's reduction of the soil's fertility (Adesipo et al., 2020). Mangrove vegetation, which is located close to oil extraction companies and has been disappearing recently, is a prime example of the extreme toxicity of oil spills on crop performance (Adesipo et al., 2020). Because spilled crude oil is denser than water, it decreases and restricts permeability and fills soil pores, which forces water and air out of the soil and deprives plant roots of them (Ossai et al., 2020). Texture, infiltration, hydraulic conductivity, moisture content, and density are among the degradable soil qualities that are engaged in the interplay between soil, plant, and water (Essien and John, 2010). Improper discharge of generated water onto land or into surface water bodies can raise the salinity of the soil. Furthermore, oil seeps may seep into the ground, mingle with subterranean water systems, and flow into streams that provide inhabitants in the area with drinking water (Ngene et al., 2016). Additionally, the soil's porosity and ability to hold water can be decreased by compacting it with heavy machinery and equipment employed in oil extraction operations.

The following factors may have a negative influence on ecological resources during the extraction of natural gas and crude oil: nearby human activities and noise that disturbs wildlife (Ngene et al., 2016). Some species may experience disruptions to their migratory patterns and other activities due to the existence of an oil or gas field. In reserve pits and water management facilities, wildlife is always vulnerable to come into touch with petroleum-based products and other contaminants. They can swallow harmful amounts of oil by preening for birds or licking their fur for animals, or they can get stuck in the oil and drown. Additionally, it's possible that pollution from the oil extraction sector contributed to the emergence of new health issues, such as a rise in the incidence of miscarriages, eye infections, skin infections, and even blindness among women (Varjani et al., 2017).

Methods of Soil Reclamation

Soil reclamation, also known as soil remediation, is the process of restoring soil quality and fertility after it has been impacted by activities like oil extraction. Here are some common methods of soil reclamation from oil extraction:

Bioremediation

Bioremediation an example of the reclamation process that uses microorganisms. Bacteria have been shown to be particularly effective at remediating soil, to eliminate or neutralize pollutants from a contaminated area (Das and Dash, 2014). The hazardous contaminants found in the oil are broken down, mineralized, sequestered, and biotransformed throughout the bioremediation process, where the materials provide the microorganisms with nourishment and energy (Das and Dash, 2014). The microorganisms utilized in bioremediation can be native to the area, naturally occurring, or cultured in a lab once the top performers are chosen. Utilizing these microbes in both in situ and ex situ bioremediation techniques is a popular strategy for cleaning up contaminated areas. Numerous investigations conducted worldwide have found individual microbes and consortiums capable of oil degradation (Sarma et al., 2017).

According to Zafra et al. (2017), PAHs (Polycyclic Aromatic Hydrocarbons) have been degraded in the soil by a consortium of five native bacterial strains; Pseudomonas aeruginosa B6, Klebsiella pneumoniae B1, Klebsiella sp. B10, Stenotrophomonas maltophilia B14 and Bacillus cereus B4) and four fungal strains (Aspergillus flavus H6, Aspergillus nomius H7, Rhizomucor variabilis H9, and Trichoderma asperellum H15) and five fungal strains (Aspergillus flavus H6, Aspergillus nomius H7, and Trichoderma asperellum H15 (Zafra et al., 2017). Also reducing the amount of PAH in soil has been accomplished with success used of the product BioTiger, which is composed of twelve naturally occurring environmental isolates (Zhang and Zhang, 2022). The biodegradation of crude oil was greatly accelerated by co-cultivating a microbial consortium consisting of foreign fungus Scedosporium boydii and native bacteria primarily Paraburkholderia sp. and Paraburkholderia tropica. Modern technology has made it possible to extract enzymes from these microorganisms such as lipases, cellulases, peroxidases, oxidoreductases, and proteasesand inject them straight into the soil to aid in the oil's biodegradation (Zhang and Zhang, 2022).

Phytoremediation

Table 1: Example of plant species with a high remediation rate of soil contaminated with Crude oil (Modified from Yavari et al., 2015),

Plant species	Percentage of petroleum hydrocarbon removed	Period of remediation (days)	Reference
Sebastiania commersoniana	94%	424	Ramos et al 2009
Chromolaena odorata	80%	180	Atagana, 2011
Canna indica	80%	21	Boonsaner et al., 2011
Cyperus brevifolius	86%	360	Basumatary et al., 2012
Astragalus membranaceus	77% - 99%	80	Lee et al., 2018
Impatiens balsamina	18.13 %– 65.03%	120	Capuana, 2020

Using plants to break down, absorb, or immobilize oil contaminants in the soil is known as phytoremediation (Yavari et al., 2015). Because plants can bioaccumulate petroleum hydrocarbons in their vacuoles, release enzymes from their roots like laccase, nitroreductase, peroxidase, and dehalogenase, and stimulate microbial activity through root exudates, they help reduce the amount of crude oil in the soil (phytostabilization) (Yavari et al., 2015). Additionally, some plants physical and morphological traits enable their roots to draw in more microbes and promote the breakdown of hydrocarbons (Ansari et al., 2023). For instance, the roots of apple trees (Malus domestica) and mulberries (Morus spp.). By inoculating the plants being used with bacteria that break down hydrocarbons, bacteria that promote plant development, or mycorrhiza, the phytoremediation process can be improved. It has been observed that annual ryegrass (L. multiflorum Lam.) injected with an AMF (Glomus intraradices) under greenhouse conditions increases phytoremediation of crude oil-contaminated soils (Hoang et al., 2021). More so, inoculating plants with Lactic acid bacteria (LAB) will turn to enhance the phytoremediation process. Lactic acid bacteria improve the ability of plants to withstand stressful environments like oil site by protecting plants from abiotic stresses or by altering the stress response of the plant through the effect of the organic acid, or other secondary metabolites they are producing, thus improving the survival of the entire phtomicrobiome (Sama et al., 2022).

Physical Remediation

Excavation, soil cleaning, thermal desorption, solidification, electrokinetic soil processing, landfarming, and stabilization are examples of physical remediation techniques (Aparicio et al., 2022). These techniques seek to lower the amount of oil present in the soil, stop more pollutant migration, and improve the function and quality of the soil. The most popular physical remediation technique is excavation, which entails removing the contaminated soil and moving it to a facility where it will be treated before being disposed of. Water and chemicals are used in the soil washing procedure to remove oil from soil particles. The method known as "thermal desorption" involves heating the soil in order to evaporate the oil and collect it in a gas stream. A fluidized bed incinerator or rotary kiln can be used for this. By applying an electric field to the contaminated soil, electrokinets soil processing causes charged particles to move and makes it easier for contaminants to migrate to collection electrodes. In order to increase microbial activity and encourage biodegradation, contaminated soil is spread out over a treatment area and periodically tilled or mixed. This process is known as landfarming. This technique is effective even for light soil contamination. Cement, lime, or other binders are used in the solidification and stabilization processes to immobilize the oil in the soil matrix (Aparicio et al., 2022).

Chemical Remediation

Chemical degradation of crude oil and related products can be accelerated with the application of oxidation methods (Islam, 2015). This method works well with a variety of oxidants, including permanganate, hydrogen peroxide, hypochlorite, ozone, Fenton's reagent, and persulfate (Hu and Zeng, 2013). According to Hu and Zeng. (2013), these substances produce hydroxyl radicles that react with both organic and inorganic substances to speed up the oxidation process. According to studies, applying the reagents with cobalt, manganese oxide, goethite, hematite, magnetite, or Fe^{2+} can boost the oxidation process' effectiveness by up to 90% (Hu and Zeng, 2013). These substances function as catalysts in the oil's oxidation process. It was observed that 80% of the oil-polluted soil could be remedied by treating it at a neutral pH using hydrogen peroxide and persulfate, along with magnetite mixed with Fe^{2+} (Satapanajary et al., 2017). These substances can be sprayed directly onto the soil that has been contaminated by oil. The fact that chemical treatment is non-selective and unaffected by the toxicity of the contaminant is a significant benefit (Bartolomeu et al., 2018). Conversely, overuse of the chemical could be more detrimental to the environment. Thus, only a recommended amount should be added in order to prevent additional environmental contamination.

Case Studies

Crude oil spilled into Kuwait, contaminating more than 40 km^2 of land and generating lakes in the damaged oil wells of ten oil fields. With funding from the United Nations Compensation Commission, Kuwait National Focal Point and Kuwait Oil Company worked together on a cooperative initiative to clean up about 26 million cubic meters of highly contaminated soil (UNCC). The region will be completely cleaned up and rehabilitated during the course of this project, which was started in 2007 (Das et al., 2018). Reclamation initiatives in the Nigerian Niger Delta and Canada's Athabasca Oil Sands are two notable examples.

Future Directions

Oil has long been utilized as a fuel source. Globally, the oil and hydrocarbon industry has been through significant upheavals that have boosted industrial activity in the hydrocarbon processing sector. Consequently, numerous oil spills have occurrences worldwide

The remediation industry's current global market size is estimated by Das et al. (2018) to be between USD 30 and USD 35 billion. Additionally, the pre-projection range of USD 1.5 billion per year indicates that the application of bio-based remediation technologies is expanding at a rapid pace. In many developed nations, including the United States, Canada, Western European nations, Japan, and Australia, the market for soil remediation was already steady. Coming up with more economical and sustainable reclamation techniques, improving monitoring and assessment technologies, and fortifying regulatory frameworks should be the main areas of future research.

Conclusion

The kind and degree of contamination, site-specific conditions, legal requirements, and financial considerations are some of the variables that influence the choice of soil reclamation technique. For efficient soil remediation, a mix of these techniques is frequently employed. When preparing for and carrying out soil reclamation projects associated with oil extraction, it's critical to confer with environmental specialists and adhere to local legislation.

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Determination of soil quality index for production of hazelnuts in Ordu provinces, Turkey

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Abstract

Land suitability analysis is a prerequisite to ensure optimum utilization of the available land resources for sustainable agricultural production. Identification of the soil quality index for a given crop is required for effective and better production. Therefore, the main aim of this study is to determine the soil quality index for hazelnut production by integrating key soil properties, nutrients and land parameters in Ordu provinces using a standard scoring function and analytical hierarchy process. A total of 22 soil parameters were determined from 461 soil samples based on the respective principles. The soil quality index was determined by using the integrated soil quality index method which considers standard scoring function and Analytical hierarchy approach. These soil parameters were grouped into four major classes, soil physical properties, soil chemical properties, nutrient content, and land parameters. The soil quality index was calculated both in linear and nonlinear scenarios. The results of the study revealed that the highest SQI value obtained was 0.83, which indicates areas with higher slopes and shallow soil depth are more suitable for hazelnut production. About half (49%) of the study area is under moderate to highly suitable range of suitability. The SQI classification ranged from "Very low" to "highly suitable" based on the Jenks' optimization techniques in ArcGIS, providing valuable insights into land suitability for hazelnuts in the region

Keywords: Analytical hierarchy process, Hazelnuts, Soil quality index, Soil quality indicator

Introduction

Soil quality assessment is an essential part of environmental and agricultural management which includes an analysis of the many physical, chemical, and biological aspects of the soil. It offers insightful information on whether a certain soil is suitable for a range of land uses. The SQI assessment defines multiple indicators with various numerical scales and uses scoring procedures to standardize the data. It typically begins with the collection of a data set. The normalization of soil quality parameters yields non-dimensional indicators, which are then further aggregated using addition, multiplication, or weighted average techniques (Dengiz, 2020; Andrews et al., 2002).

Assessing soil quality requires a systematic and integrated approach that takes into account various soil parameters. Physical properties include texture, structure, and porosity, which affect water retention, aeration, and root penetration. Chemical properties involve the analysis of pH, nutrient content, and contaminants, providing insights into a soil's fertility and potential pollution risks. Biological properties assess the presence and activity of microorganisms, earthworms, and other organisms that contribute to soil health and nutrient cycling (Doran and Parkin, 1994).

The world's largest producer of hazelnuts, Turkey, has demonstrated that supply can vary significantly, resulting in peak prices and unstable markets (Król and Gantner, 2020). Ordu produces more than 45,000 t of hazelnuts annually from its Palaz and Cakildak varieties (Özdemir and Devres, 1999).

The evaluation of soil quality is a complex procedure that is essential to environmentally sound land management, productive agriculture, and sustainable land management. It frequently makes judgments on crop choice, land use, and soil management techniques using a combination of field surveys, lab analyses, and data interpretation. Low crop productivity is a result of inadequate knowledge about the optimal combination of soil quality indicators for the crop (Dengiz, 2013). This study aims to determine the soil quality index for hazelnut production by integrating key soil properties, nutrients and land parameters in Ordu provinces using a standard scoring function and analytical hierarchy process.

Material and Methods

Study area description

The province of Ordu which covers 5952 km2 is located in the northern part of Turkey, which is situated in the eastern part of the Black Sea region of Turkey. Ordu has a diverse landscape with a combination of mountains, valleys, and a lengthy coastline along the Black Sea. Ordu has a humid subtropical climate influenced by its proximity to the Black Sea. The area experiences a significant amount of rainfall throughout the year, which adds to the lush green landscapes and dense forests (Kocaman et al., 2020). Ordu is a desirable site for ecological and environmental research due to its forests, which serve as a habitat for a diverse range of plant and animal species (Orhan and Özdemir, 2015). The region of Ordu is well known for its hazelnut cultivation, and it significantly contributes to Turkey's exports of hazelnut. The elevation ranges between -23 and 1867 m.a.s.l. Figure 1 shows the location of the study.

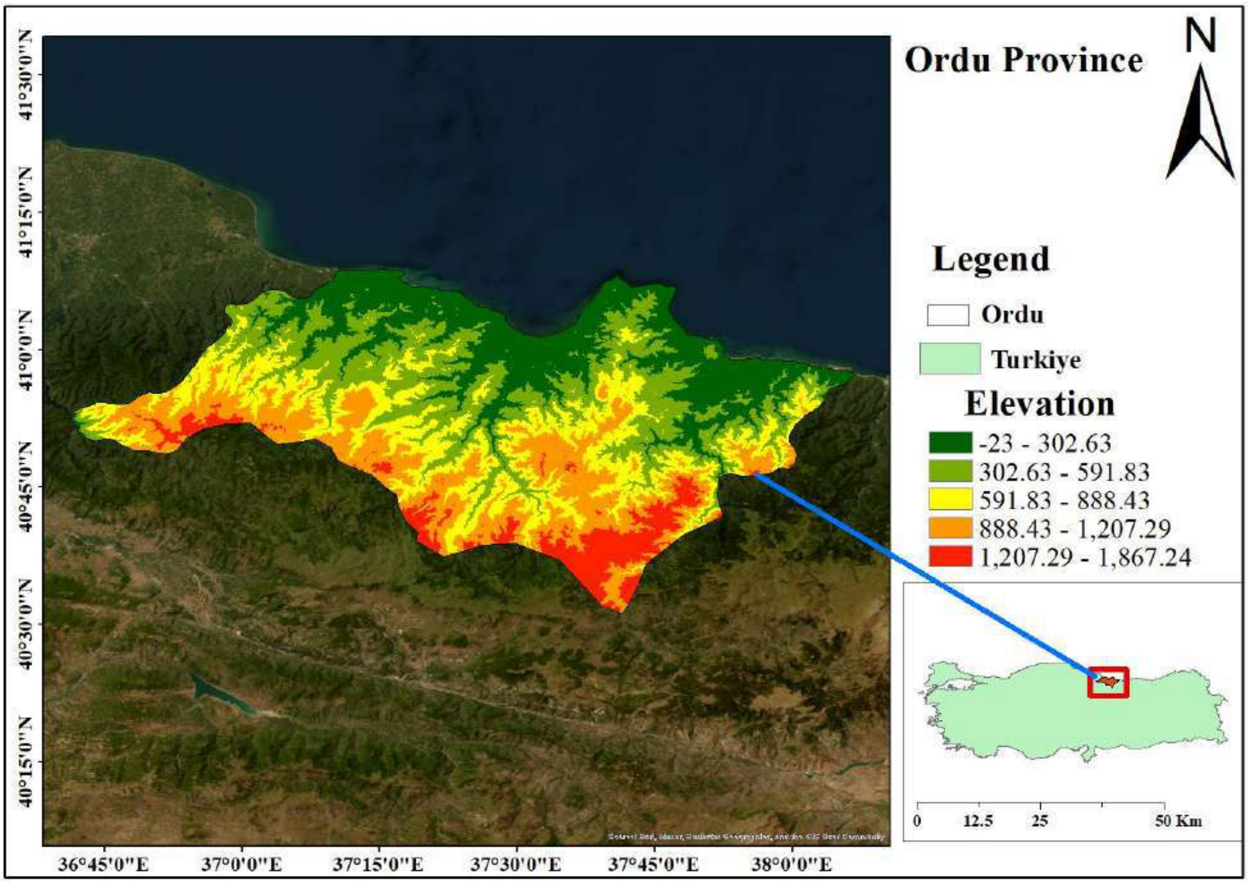

Figure 1. Location Map

Soil Sampling

A total of 461 soil samples were taken from Ordu province on the surface soil from a depth of (0-20 cm). Their spatial location was recorded using the Geographic Positioning System (GPS). A total of 22 soil quality parameters were selected such as soil textural class (Percentage of sand, silt and clay), bulk density, slope, soil erosion(ton/ha/year), available water content of the soil, pH, electrical conductivity, calcium carbonate

($CaCO_3$), Organic matter content of the soil, phosphorus, Total Nitrogen, potassium, calcium, magnesium, sodium, iron, copper, zinc and manganese (Table 1).

Those soil quality parameters are categorized as Less Better (LB) and More Better (MB) based on their contribution to soil quality. More Better includes Soil depth, The clay content of the soil, available water capacity, pH, calcium carbonate ($CaCO_3$) nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper and zinc. Less better parameters include bulk density, sodium, electrical conductivity, slope, soil erosion rate (tons/ha/year), and the amount of sand and silt in the soil. A standard scoring function (SSF) (Andrews et al., 2002) for both linear and nonlinear scenarios was used to normalize the variation in the units of the indicators, and scores ranging from 0 to 1 were obtained based on the following formulas.

$$\text{SSF More Better (Linear)} = \left((0.9) * \frac{(X - Min)}{(Max - Min)})) + (0.1\right) \tag{1}$$

$$\text{SSF Less Better (Linear)} = \left((1 - (0.9) * \frac{(X - Min)}{(Max - Min)}))\right) \tag{2}$$

$$\text{SSF More Better (Nonlinear)} = (1/(1 + (x/Mean)^{-2.5})) \tag{3}$$

$$\text{SSF Less Better (Nonlinear)} = (1/(1 + (x/Mean)^{2.5})) \tag{4}$$

Where X; Soil quality parameter. Min; Minimum Value. Max; Maximum Value. Mean; Average Value.

Table 1. Soil quality parameters and principles

Parameters	Principles	References
Texture	Hydrometer method	Bouyoucos (1951)
Bulk density	SPAW Model	Soil water characteristics
Available water content	SPAW Model	Soil water characteristics
pH	Soil water suspension	Soil Survey Laboratory (1992)
Electrical conductivity	Soil water suspension	Soil Survey Laboratory (1992)
Organic Matter	Walkley-Black wet digestion	Nelson & Sommers (1982)
$CaCO_3$	Scheibler Calcimeter	Soil Survey Staff (1993)
Slope	DEM	USGS Earth Explorer website
Total nitrogen	Kjeldahl	Bremner & Mulvaney (1982)
Phosphorus	Bray and Kurtz	Kacar (1994)
K, Ca, Mg, Na	Ammonium acetate extraction, flame spectrometry detection	Soil Survey Laboratory (1992)
Fe, Cu, Zn, Mn	DTPA extraction, AAS detection	Lindsay & Norvell (1978)

Weighting soil quality parameters

The pairwise comparison matrix in the analytical hierarchy process is used to measure the weight of each soil quality parameter as per the requirement of Hazelnuts. Those parameters are further divided into four categories including Soil physical properties (clay, sand, silt, bulk density and available water content), chemical properties (pH, Electrical conductivity, Organic matter and $CaCO_3$), fertility (N, P, K, Ca, Mg, Zn, Fe, Mn, Cu and Na) and land parameters (soil depth, erosion and slope). The optimum value of the parameters is determined based on different literatures and different weight is given for each parameter. The aim of weighting is to indicate the importance or preference of each factor relative to other factors for hazelnut production. Weights are determined by comparing two elements at a time on a Saaty (1980) scale that ranges from 9 to 1/9 (Table 2). A rating of 9 means that the row factor is more significant than the column factor and vice versa. They have a rating value of 1 when the column and row variables are equally significant.

The consistency of the developed comparison matrix is evaluated by dividing the consistency ratio by a random index. The value of the random index is displayed in Table 3. To ensure consistency in the matrix, a value of CR must be < 0.1.

$$CR = CI/RI \tag{5}$$

$CI = (\lambda max-n)/(n-1)$ where: CI is the consistency index, λmax is the largest or principal value of the matrix and n is the order of the matrix.

Table 2. Analytical Hierarchy scale Assessment Scale (Satty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two variables are required equally to the intended objective
3	Weak importance of one over another	One variable is slightly more important than the other variable being compared
5	Essential or strong importance	One variable is strongly important over the other variable being compared
7	Demonstrated importance	Intermediate scale between the two adjacent comparisons
9	Absolute importance	One variable is very strongly important over the other variable being compared
2, 4, 6, 8	The reciprocal of the above non-zero values	When a compromise is necessary

Table 3 Values of Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Soil Quality Index

Soil quality index is estimated after the determination of the standard scoring function and weight of each parameter (Doran and Parkin, 1994).

$$SQI_H = \sum_1^n (SSF \ X \ Wi) \quad (6)$$

Where SQI_H; Soil quality index for hazelnuts, SSF; Standard scoring function of the parameter, Wi; Weight of the parameters According to Jenks' optimization techniques, The suitability of the area is classified into five classes ranging from very low to highly suitable (Table 4).

Table 4. Classes of soil quality index

Class	Name	Soil Quality Index Value
I	Very Low	0.21-0.35
II	Low	0.35-0.41
III	Moderate	0.41-0.48
IV	Suitable	0.48-0.58
V	Highly Suitable	0.58-0.83

Results And Discussion

Soil Physio-chemical Properties

The physio-chemical properties and macro and micronutrients of the whole soil sample are determined as per the principles stated above in Table 2. Table 5 presents the descriptive statistics for this study, which include the means, minimum, maximum, standard deviation and coefficients of variation of the physico-chemical parameters of the soil samples. The soil samples had pH values ranging from 3.6 to 8.07 and electrical conductivity values ranging from 0.16 dS m−1 to 2.96 dS m−1. The mean value of pH, electrical conductivity, bulk density and available water content is 5.66, 0.49, 1.36 and 12.11 respectively. The content of sand fluctuated between 80.86% and 19.12 %, and the clay content between 4.15% and 60.8 % with an average value of 51.13 and 50.72 respectively. The coefficient of variation (CV) was used for evaluating the variability of soil parameters. According to Wilding et al. (1994) and Mulla and McBratney (2000), variability is categorized as low when the CV is less than 15%, moderate when it is between 15% and 35%, and as high when it is more than 35%. The present investigation found that SQIH in both linear and nonlinear scenarios, the contents of pH, available water content, sand and silt have moderate variation whereas Clay, $CaCO_3$, organic matter, AvP, ExK, EC, Na, TN, ExK, AvP, TN and AvZn had high CVs. Only bulk density has a low coefficient of variation.

Table 5. Descriptive statistics of soil physio-chemical properties

Parameters	Max.	Min.	Mean	Std.	CoV	Skewness	Kurtosis
Clay	60.80	4.15	50.72	12.87	53.33	0.61	-0.3
pH	8.07	3.6	5.66	1.10	19.44	0.3	-0.99
CaCO3	58.84	0.12	2.9	8.77	301.73	4.36	19.74
AWC	21.4	5.9	12.11	1.89	15.57	0.48	2.68
OM	10.95	0.64	3.87	1.70	44.00	1.12	1.70
Phosphorus	124.22	0.14	9.95	14.98	150.64	3.30	14.41
Total Nitrogen	0.6	0.07	0.23	0.09	38.77	1.12	1.57
K	1675	31	219.57	191.37	87.16	2.91	12.92
Ca	16120	80	4870.03	3016.65	61.94	0.76	0.36
Mg	1146.94	27.66	245.66	182.89	74.44	1.68	3.84
Fe	180.9	3.11	42.17	28.33	67.18	1.46	2.99
Cu	29.3	0.07	2.49	2.47	99.15	5.30	47.17
Zn	24.8	0.06	1.44	2.50	173.71	5.90	42.57
Mn	202.63	1.03	38.71	32.99	85.22	1.75	4.16
Sand	80.86	19.12	51.13	14.19	27.76	-0.21	-0.85
Silt	47.05	6.49	24.74	5.50	22.22	0.52	1.40
Bulk density	1.57	0.9	1.36	0.11	8.29	-1.12	1.64
EC	2.96	0.16	0.49	0.32	64.84	3.11	13.78
Na	1785	42	106.27	119.07	112.04	9.77	117.23
SQI_H(Linear)	0.81	0.21	0.43	0.13	29.87	0.94	0.43
SQI_H(Nonlinear)	0.83	0.29	0.53	0.11	20.65	0.45	-0.26

Land Parameters

The rate of soil erosion is taken from a previous study reported in Turkey. The slope of the area which varies from 2 to 56 percent is obtained from a digital elevation model using the Spatial analyst tool in ArcGIS. The depth of soil ranges from 20 and 120 cm with a mean value of 24.14cm. Figure 2 shows the spatial variability of land parameters, namely soil depth, slope and soil erosion. The rate of soil erosion is higher in the steep slope area.

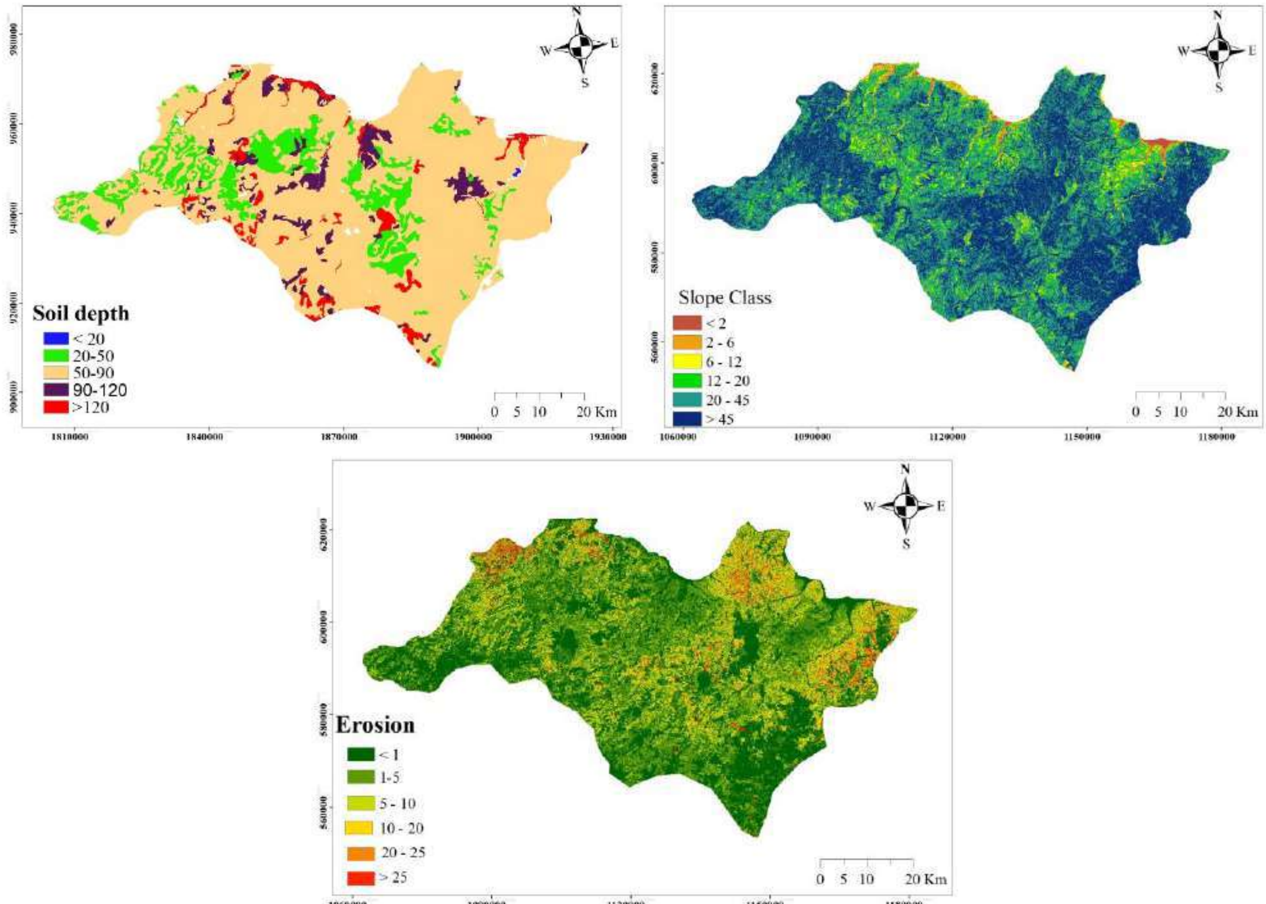

Figure 2. Land parameters

Weighting soil quality parameters

A total of 22 soil quality parameters were selected based on different literature. The evaluation scores with a consistency ratio smaller than 0 were produced using the AHP technique. A specific weight was given for each parameter in Table 6. The highest value is found in land properties about 48% (0.4827) followed by soil physical properties 25% (0.2472). soil chemical properties and soil fertilities encompass the lower value, 18% (0.1761) and 9% (0.0939) respectively. Furthermore, the highest contribution of the indicators in the whole soil quality parameters is found in slope (0.5278), organic matter (0.4335) and available water content (0.4072) (Table 6).

Table 1. The AHP's calculation of the weight of soil quality parameters

		Physical	Chemical	Fertility	Land	Total	Combined weight
		0.2472	0.1761	0.0939	0.4827	1.000	
Physical	Sand	0.1151					0.0285
	Silt	0.0705					0.0174
	Clay	0.1393					0.0344
	BD	0.2681					0.0663
	AWC	0.4072					0.1007
Chemical	OM		0.4335				0.0763
	CaCO3		0.1645				0.0290
	pH		0.3085				0.0543
	EC		0.0939				0.0165
Fertility	N			0.2153			0.0202
	P			0.1889			0.0177
	K			0.1482			0.0139
	Ca			0.1189			0.0112
	Mg			0.0961			0.0090
	Na			0.0218			0.0020
	Fe			0.0719			0.0068
	Cu			0.0369			0.0035
	Zn			0.0567			0.0053
	Mn			0.0453			0.0043
Land	Slope				0.5278		0.2548
	Erosion				0.1396		0.0674
	Depth				0.3325		0.1605
Total							1.0000

Soil Quality Index for Hazelnuts

After the assignment of weight based on AHP and the standard scoring function soil quality index for hazelnuts was calculated for both linear and nonlinear scenarios.

$SQI_H = \sum_1^n (SSF\ X\ Wi)$

Where SQIH; Soil quality index for hazelnuts

SSF; Standard scoring function of the parameter

Wi; Weight of the parameters

The interpolation method was performed to change the value of the soil quality index from point to polygon covering the whole study area. The perfection of the interpolation method was determined by the RMSE value in Table 8. The lower the value of RMSE the better prediction capacity. The inverse distance weight method with a power 2 was used to get a better prediction for the SQIH Linear and Radial basis function with completely regularized spline was used to determine SQIH of nonlinear scenarios. The maximum and minimum values SQI for hazelnuts in linear scenarios were found to be 0.81 and 0.21. The maximum and minimum values SQI for hazelnuts in nonlinear scenarios were found to be 0.83 and 0.29 (Figure 3). The higher the SQIH value the greater the land suitability for the production of hazelnuts. The results reveal that an area with a higher slope and shallow soil depth is suitable for hazelnut production. In general, 49% of the entire area is moderate to extremely suitable for hazelnuts. 18% of the land falls into the category of very low suitability (Table 7).

Table 2. Area of Suitability class

Class	Name	SQI	Area (Km^2)	Percent
I	Very Low	0.21-0.35	704	17.87
II	Low	0.35-0.41	1307	33.17
III	Moderate	0.41-0.48	1093	27.74
IV	Suitable	0.48-0.58	606	15.38
V	Highly Suitable	0.58-0.83	230	5.84
		Total	3940	100

Table 3. RMSE Values of interpolation methods

Interpolation	Semi variogram	RMSE (Linear)	RMSE (Nonlinear)
Inverse distance weight	1	0.1100	0.0942
	2	0.1090	0.0946
	3	0.1100	0.0956
RBF	Thin Plate Spline	0.1250	0.1129
	Completely Regularized Spline	0.1097	0.0939
	Spline with Tension	0.1096	0.0939
Ordinary kriging	Gaussian	1.0230	1.0258
	Exponential	1.0360	1.0180
	Spherical	1.0217	1.0231
Universal Kriging	Gaussian	1.0233	1.0258
	Exponential	1.0360	1.0180
	Spherical	1.0216	1.0232
Simple	Gaussian	0.9998	0.9860
	Exponential	1.0268	1.0020
	Spherical	0.9983	0.9865

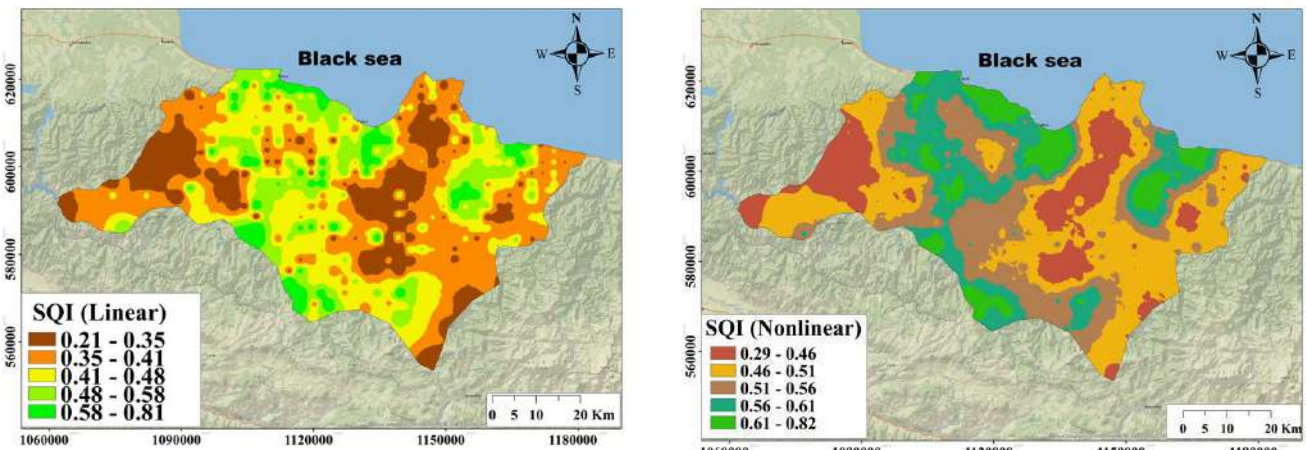

Figure 3. Soil quality index for hazelnuts

Conclusion

This study advances our understanding of the suitability of land in hazelnut-producing regions, which is important for sustainable agricultural production and environmental management. The comprehensive evaluation of soil quality for hazelnuts provided by this research is crucial for making well-informed decisions on crop selection and land use, as it incorporates many soil factors and applies scoring functions and AHP. The study's findings showed that the greatest SQI value was 0.83, indicating that regions with shallower soil depth and greater slopes are more suited for hazelnut production. Based on the values collected, the SQI categorization varied from "Very poor" to "Excellent/The most suitable," offering important insights about the suitability of the land for hazelnuts in the area. The results of this study can help Ordu Province farmers, policy makers, and environmental managers make well-informed decisions that will maximize hazelnut output and promote sustainable land management techniques. Knowing the quality of soil is essential to guaranteeing the sustainability of agriculture and preservation of the environment in the long run.

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Digital soil mapping in Türkiye: Insights from a systematic bibliometric analysis

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Abstract
The research objective aimed at determining the diversity within the heterogeneous environment naturally located the soil, which is the focal point of soil survey and mapping science, remains persistent. Nowadays, advancements in information processing technology and the increasing abundance of open accessible earth observation data, the rise in digital representation of soil formation factors enables this process to be carried out inclusively, encompassing its quantitative uncertainties. Therefore, Pedometrics, as a scientific discipline, focuses on a wide array of research questions globally, significantly analyzing regional research orientations. This study aims to evaluate the scientific outputs obtained from the Web of Science (WOS) database regarding digital soil mapping through bibliometric analysis, with a focus on Türkiye. The 38 studies related to "digital soil mapping" that encompassed the years 2018 to 2023 and were associated with "Turkey" or "Turkiye" in the countries/region section were exported from the WOS database under the "topic" section (searching title, abstract, author keywords, and Keywords Plus). The 22 selected publications authored by individuals with a minimum of two publications on the subject were subjected to bibliometric analysis using the open-source VOSviewer 1.6.20 software. The results indicated publications in the index concerning the increasing trend since 2018. Co-authorship-based outcomes highlight the existence of international integration. The bibliometric analysis revealed that more than 10 researchers generated two or more scientific outputs, while the results of the co-occurrence-based analysis provide insights into the focused topics for future studies. The results facilitate Turkish scholars working in this field to reference regional studies and gain rapid access to pertinent information.
Keywords: Bibliometric Analysis, Challenges, Digital Soil Mapping, Insights, Pedometrics, Soil Science

Introduction
The science of soil survey and mapping is undergoing a data-driven paradigm shift, highlighted by the increase in representing soil formation factors through spatial observation data and the discoverability of processes in soil formation mechanisms through machine learning, presenting opportunities for advancement (Weindorf and Chakraborty, 2023). Digital soil mapping (DSM) methodology integrates field-based soil analyses, soil morphology, and the impacts of soil formation factors into a raster-based format by combining spatial environmental data. Spatial inference or prediction is achievable through machine learning algorithms, allowing the discovery of relationships between continuous or categorical soil data at coordinates and digital data representing soil formation factors.

Since the beginning of the 21st century, DSM has been the subject of scientific research within specific countries and has also found applications for various purposes within different national contexts. While acknowledging the global nature of science, examining studies conducted on a national scale using information technology techniques can offer significant insights to those interested in the subject.

The effective evaluation of the progress within the scientific field, both regionally and globally, involves analyzing the number of publications over time and their trends. Bibliometric analysis is the numerical analysis of publications produced by individuals or institutions within a specific field, period, and region, along with the relationships among these publications.

Bibliometric studies are not new in soil science. On a global scale, the output of bibliometric analysis provides significant benefits by offering a perspective on the progress already made in a specific field, particularly to researchers, especially the new generation and young researchers. Simultaneously, identifying challenges and opportunities through bibliometric analysis presents an opportunity to contribute to the continuity of progress by recognizing hurdles and opportunities for advancement.

Countries such as Türkiye, aspiring to attain more refined spatial soil information, perceive DSM as an opportunity to bridge the knowledge gap of sustainable land use that fosters supportive production activities. Given the limited granularity of existing soil maps in Türkiye concerning land use details, DSM is expected to significantly contribute to effectively complementing this dataset. The adoption of DSM in Türkiye represents a relatively emergent field, with the initial scholarly article on DSM in Turkish soils published around 2018. However, there is a lack of precise information regarding the extent of scientific output related to DSM in Türkiye or the specific number of researchers actively involved in this domain.

In this context, the objective of this study is to characterize the scientific output related to DSM in Türkiye between 2018 and 2023, based on a series of bibliometric indicators. This study aims to identify the characteristics of national scientific output concerning DSM, shedding light on the landscape of scholarly research and publications in this field within specified timeframe.

Material and Methods

Material

Thirty-eight studies related to "digital soil mapping" conducted between 2018 and 2023 and affiliated with "Turkey" or "Turkiye" within the countries/region classification were extracted from the internationally accepted Web of Science (WOS) core collection database utilizing the "topic" section, which involved searching within the title, abstract, author keywords, and Keywords Plus (search carried out 04-11-2023). Among these, a subset of 22 publications authored by individuals who had contributed a minimum of two publications on this subject matter was chosen for bibliometric analysis.

Method

The bibliometric analysis was conducted using the open-source VOSviewer 1.6.20 software (Van Eck and Waltman, 2023). Figure 1 depicts the flowchart summarizing the execution process of this study. Co-occurrence and co-authorship-based analyses were conducted, employing network and overlay visualizations. Create map based on bibliographic data and integration of reference management file types options were incorporated into the study (Van Eck and Waltman, 2023).

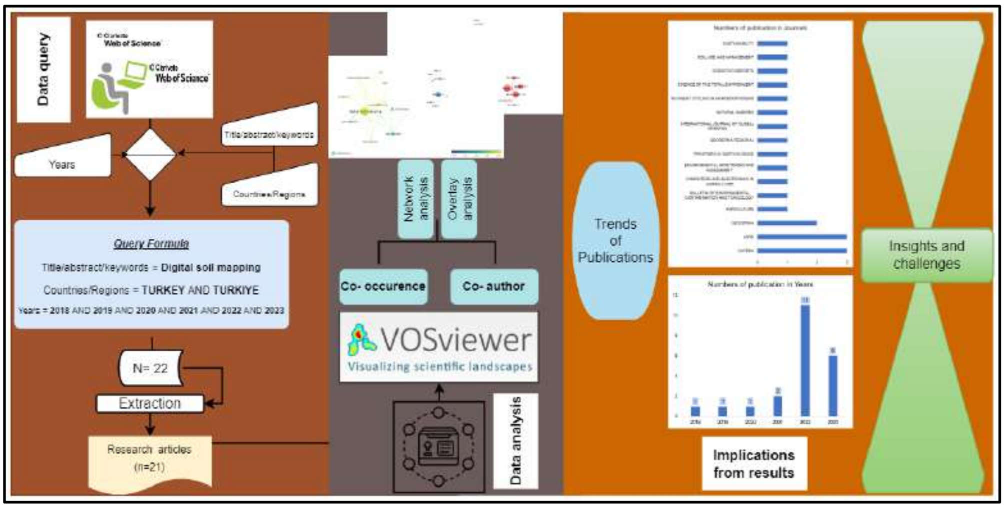
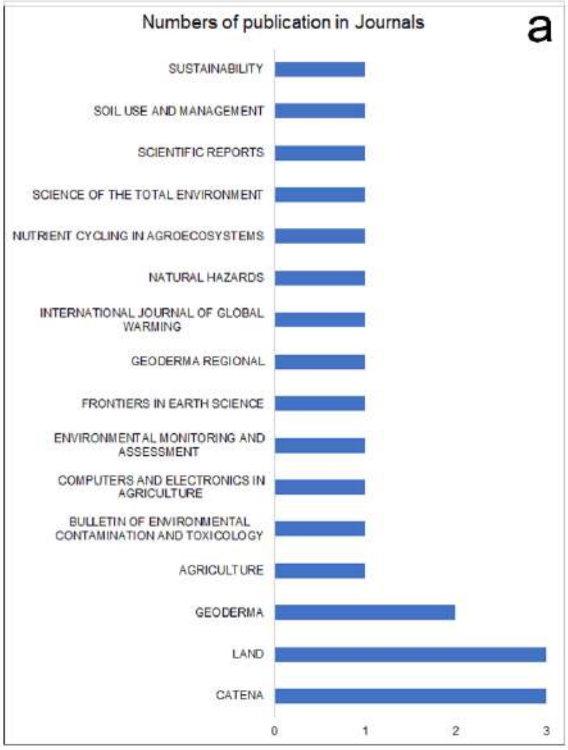


Figure 1. Flowchart of this study.

Results and Discussion

Results of descriptive statistics

Publications related to DSM with a focus on Türkiye affiliations exhibit diversity; however, they are most prevalent in Catena, Land, and Geoderma journals (Figure 2-a). Until 2020, there was one publication per year with a Türkiye affiliations, but in 2021, it increased to two, and notably surged to eleven by 2022, indicating a rapid escalation (Figure 2-b).



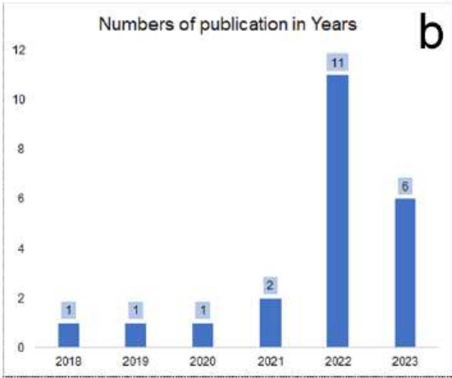


Figure 2. Main journals with relevant publications according to the bibliometric analysis results (a) and number of publications (b) according to the result of bibliometric analysis annually between 2018-2023 (search was carried out on 04-11-2023).

The results of the co-authorship network analysis, conducted with the condition of a minimum of 2 publications by an author, have been delineated into four distinct clusters (Figure 3). Considering 16 authors meeting this criterion, a clearer depiction of representative academicians in Türkiye-affiliated DSM publications emerges, showcasing highly collaborative and cohesive research teams with strong international integration (Figure 3). The presence of authors affiliated with Turkey in DSM publications, starting with researchers integrated into overseas research processes in the year 2018 (Keskin and Grunwald, 2018), has evolved into a different dimension with the focus of early-career researchers engaged in soil survey and mapping science.

Figure 3. Co-authorship network analysis of publications affiliated with Türkiye.

Figure 4. Co-authorship overlay analysis of publications affiliated with Türkiye.

Through a co-occurrence map of keywords, the unique connection between technological advancements such as Geographic Information Systems (GIS) integration into Soil Mapping and the integration of machine learning into Digital Soil Mapping can be observed (Figure 5). While traditional soil maps are recognized as a form of "prediction," it is essential to emphasize the aspect of "prediction" in DSM as well (Figure 6).

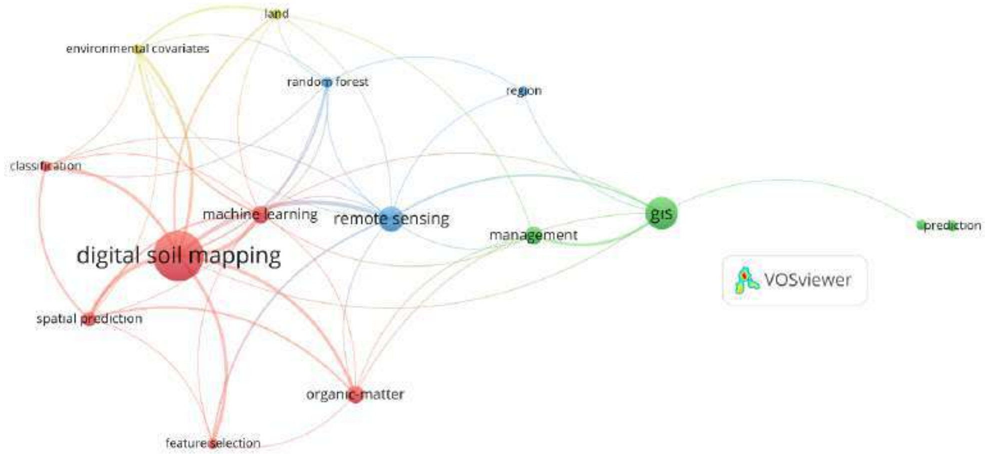


Figure 5. Co-occurrence network analysis of publications affiliated with Türkiye.

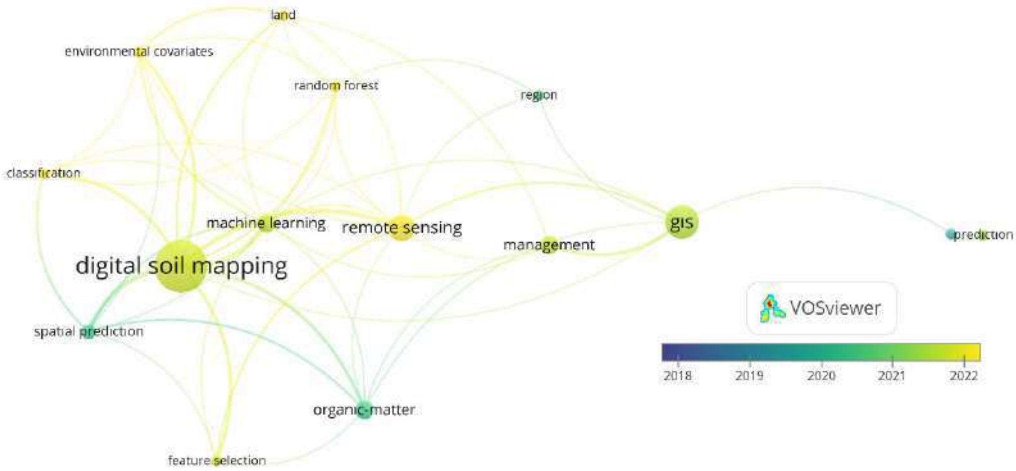


Figure 6. Co-occurrence overlay analysis of publications affiliated with Türkiye

The classified studies in Table 1 facilitate Turkish academicians working in this field to reference regional studies and quickly access relevant information.

Table 1. Related studies

References	Article Subjects	Publication Year
Keskin and Grunwald (2018)	Regression based DSM techniques	2018
Keskin et al., (2019)	Regression based DSM techniques	2019
Ozkan et al.,(2020)	Site suitability analysis- fuzzy multi-criteria decision analysis	2020
Keshavarzi, et al., (2020)	Different interpolation methods	2021
Alaboz et al., (2021)	Regression based DSM techniques	2021
Kaya and Başayiğit (2022)	Classification based DSM techniques	2022
Kaya et al., (2022a)	Regression based DSM techniques	2022
Gozukara et al., (2022a)	Vis-NIR and pXRF spectra of a soil profile	2022
Gozukara et al., (2022b)	Vis-NIR and pXRF spectra of a soil profile	2022
Kaya et al., (2022b)	Classification based DSM techniques	2022
Dindaroglu et al., (2022)	Linear model techniques	2022
Kaya et al., (2022c)	Regression based DSM techniques	2022
Kaya, Nursac et al., (2022)	Regression based DSM techniques	2022
Alvyar et al., (2022)	Regression based DSM techniques	2022
Keshavarzi et al., (2022)	Regression and classification based DSM techniques	2022
Ozlu et al., (2022)	Different interpolation methods	2022
Istanbullu et al., (2023)	Different interpolation methods	2023
Saygin et al., (2023)	Regression based DSM techniques	2023
Mohammed et al., (2023)	Regression based DSM techniques	2023
Sulieman et al., (2023)	Classification based DSM techniques	2023
Kaya et al., (2023)	Regression based DSM techniques	2023
Keshavarzi et al., (2023)	Regression based DSM techniques	2023

Conclusion

This research conducted bibliometric analysis on 38 "digital soil mapping" studies associated with Turkey between 2018 and 2023 from the Web of Science database, revealing an increasing trend in publications. Co-authorship analysis indicated international integration, while identifying more than 10 researchers producing multiple outputs. Co-occurrence analysis highlights potential future research topics. The findings aid Turkish scholars by facilitating access to relevant regional studies for reference and swift information retrieval.

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Addressing soil salinity in Bulgaria: Challenges and innovative solutions

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Abstract

Soil salinization, impacting more than 800 million hectares of land globally, is a significant concern in Bulgaria, with natural and anthropogenic factors contributing to the problem. This issue affects approximately 1% of the country's total land area, including 35,500 hectares affected by natural salinization and 25,000 hectares influenced by industrial and drainage activities. Soil salinization in Bulgaria primarily results from intensive irrigation and tectonic events like earthquakes. Climate change and extended summer seasons have further increased salinity levels, as drier soils accumulate higher salt concentrations. The effects of soil salinity in Bulgaria are far-reaching, affecting plant growth, soil structure, water dynamics, and the cultivation of roses, a significant contributor to the country's economy. To address this issue, the objective of this study is to propose a range of proven solutions to reduce or eliminate salinization in Bulgaria. Researchers have also proposed several innovative solutions to tackle this problem among which chemical amelioration with chalk has proven to be an effective method. However, this method is expensive and laborious. Therefore, cultivating halophytic crops (deep-rooted salt-tolerant plants) offers a sustainable approach to lower groundwater levels and combat salinization. These innovative approaches provide a comprehensive framework to tackle soil salinization in Bulgaria, safeguarding agricultural productivity.

Keywords: Anthropogenic factors, Chemical amelioration, Drainage, Halophytic crops, Salinization.

Introduction

Salinity impacts more than 800 million hectares of land globally (Rozema & Flowers, 2008). These soils, characterized by high salinity and pH levels, have been the subject of research in many countries including Bulgaria. This is because 1% of the total land area in Bulgaria is covered by saline soils Penov et al. (2009) which accounts for approximately 55,000 hectares, comprising 35,500 hectares affected by natural salinization and 25,000 hectares influenced by industrial and drainage activities (Hristov, 2021). This is because the overall geographical characteristics of Bulgaria positions it within the transit salt-regime zones, which are conducive to the development of salinization (Andreeva & Poushkarov, 2020). In essence, soil salinization can be categorized into two primary types based on the predominant influence of natural processes and anthropogenic factors known as primary salinization and secondary salinization respectively (Zhang et al., 2023). Salinization in Bulgaria is often a result of intensive irrigation, known as secondary salinization Penkov et al. (1985) and historical and ongoing tectonic events like earthquakes known as primary salinity. The factors contributing to soil salinization are varied and can manifest across various climatic conditions (Shahid et al., 2018). While saline soils are generally regarded as challenging environments for life, they indeed support thriving and diverse microbial communities (Chaparro et al., 2012). In Bulgaria, salinization has affected the lowlands of 8 provinces with 2 of them serving as significant unresolved areas of concern (Table 1). Previous studies in Bulgaria primarily focused on the biological Hristov (2009, 2010), and chemical composition (Andreeva & Poushkarov, 2020; Penov et al., 2011; Shishkov & Kolev, 2014) of saline soils, and a few considered new innovations and ways of curbing the problem (Teoharov & Hristov, 2017). It has been observed that saline environments can induce physiological stress on microorganisms and plants, leading to significant shifts in their composition and associated ecosystem functions (Herbert et al., 2015). Other studies have also shown that higher levels of salinity lead to significant alterations in soil structure, water dynamics, and plant growth Artiola et al. (2019) and that is currently the case in Bulgaria. The country is known for its tremendous cultivation of rose and production of rose oil (Shishkova et al., 2022), therefore, if salinization is not addressed this can influence their productivity and economy. The primary objective of this study is to propose proven solutions to address the soil salinity problem in Bulgaria.

Table 1: Areas in Bulgaria with salinity problems. Source: (EEA, 2018; Shishkov & Kolev, 2014)

Areas with minimized salinity		Strongest hotspots of salinization	
Province	Municipalities and Villages	Province	Villages
Pleven	Gorna Studena, Dabovan, Zagrajden	Plovdiv	Belozem, Kostievo, Benkovski, Radinovo, Tsaratsovo, Saedinenie, Rakovski, Stryama, Trastikovo
Yambol		Varna	
Burgas			
Veliko Tarnovo			
Sliven			
Stara Zagora	Radnevo		

Causes and effects of salinity in Bulgaria

The majority of soil salinity in Bulgaria is caused by natural and anthropogenic factors (Figure 1). The primary determining factor is hydrology, which outweighs climate as the depth of the groundwater table fluctuates seasonally, and salt movement follows a localized circulation pattern (Shishkov & Kolev, 2014). This mostly occurs in the black sea regions and is mostly influenced by the topographic nature of lands in Bulgaria (Penov et al., 2009). Periodic droughts is also one of the predominant causes of salinization (Hristov, 2021). Bulgaria is not an exception to the current global challenge of climate change. Summers in the country have become notably longer and significantly hotter than in the past (The World Bank Group, 2021). This has directly affected salinity levels, as drier soils tend to accumulate higher salt concentrations due to the absence of significant net leaching (Herbert et al., 2015). In terms of anthropogenic causes intensive agricultural activities particularly irrigation (Figure 1), have been a major contributor to the development of secondary salinization in many cultivated regions of Bulgaria (Popandova, 1978). This is a result of inadequately managed tailwater used for crop irrigation. Furthermore, research conducted by Raykov et al. (1989) indicated that industrial pollution, characterized by the release of sodium chloride (NaCl), is a significant concern and has caused elevated salt levels in some of the most fertile soils of Bulgaria, particularly chernozems. This occurred in the vicinity of the Provadiya-Devnya salt pipeline, as well as in areas surrounding saltworks and salt mines.

The effects of salinity in Bulgaria can be traced back to 2011 when a researcher investigated the impact of salinization in Plovdiv, a city highly affected by salinity. According to his survey, nearly all farmers in that region faced significant challenges when cultivating salt-affected soils. Salinization was consistently ranked as the most prominent soil issue in the area, receiving a rating of 4.11 for lands outside the farm and 3.50 within the farm. The study involved 18 farmers, among whom 11 reported noticeable changes in plant growth attributed to salinization in the region, with 14 of them observing this problem on their own farms. Additionally, fifteen respondents reported the presence of salt crusts in the village fields. Theoretically, lower levels of salinity do not impact plant yield, but higher salinity levels have detrimental effects on plant growth and yield (Figure 1). Soil salinity triggers the generation of reactive oxygen species, which include chemically reactive oxygen molecules such as hydrogen peroxide, superoxide radicals, hydroxyl radicals, and singlet oxygen. This, in turn, results in oxidative stress (Peleg & Blumwald, 2011). Oxidative stress leads to protein denaturation, lipid peroxidation, and nucleotide disruption, potentially impacting plant physiology and even causing plant mortality (Demidchik, 2015). Another effect of salinity is the impact it has on soil microorganisms (Figure 1) (Zhang et al., 2023). Saline water contains multiple ions that can modify the dynamics of inorganic chemical interactions, shift the prevailing biogeochemical reactions, and induce changes in microbial communities responsible for elemental cycles (Herbert et al., 2015). Another adverse impact of salinity is on soil structure which involves the disruption of soil aggregates, a decrease in water infiltration and conductivity, and an increase in soil compaction and erosion (UC DAVIS, 2019).

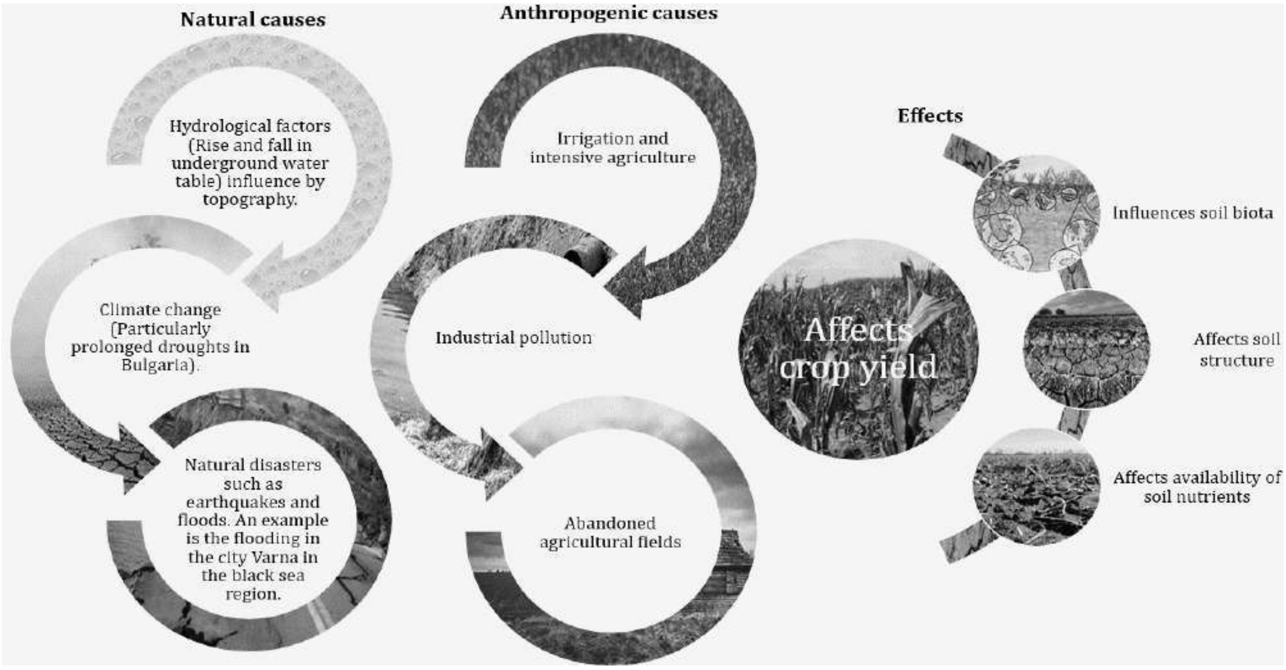

Figure 1. Conceptual illustration of the causes and effects of salinity in Bulgaria

Proposed solutions

Many researchers in Bulgaria have proposed the use of chemical amelioration with chalk to treat saline soils (EEA, 2018; Teoharov & Hristov, 2017). This is quite an effective method as it has the ability to reduce salinity for many years. In fact, this method was used in 1960-1970 to reclaim lands affected by salinization in a small town called Belozem (Penov et al., 2009). However, the suitability of this method depends on the specific soil drainage characteristics and the groundwater table level (Qadir et al., 2000). In order to maintain a salt-free root zone, it is essential to prevent evaporation from the groundwater, thus ensuring that the groundwater table remains at a depth that prevents rapid soil salinization through the implementation of effective drainage practices (FAO, 1976). This makes this method quite expensive Dagar et al. (2023) as the groundwater table of Bulgarian soils is usually high due to the topographic nature of the land. Therefore, in regard to this, we propose the cultivation of halophytic crops to lower the groundwater levels after which other methods can be used to reduce salinity. Holophytic crops, preferably deep-rooted salt-tolerant crops have been used by several countries to reclaim salt-affected fields. It has also been recommended by several researchers (EEA, 2018; Mustafa and Akhtar, 2019) as a more favourable option than abandoning the land, which only worsens salinization. Strategies such as deep tillage, subsoiling, topsoil replacement, and improved irrigation management are also top-notch in curbing this problem (Sarwar et al., 2011). The adoption of climate-smart agricultural techniques and the utilization of microbial-assisted phytoremediation could present an innovative approach to mitigate soil salinity (Sultan et al., 2023). Salt-affected soils are primarily populated by microorganisms that are halophilic or halotolerant, belonging to distinct phylogenetic categories. These microorganisms show significant promise in the remediation of saline soils through the production of specialized enzymes (Arora & Vanza, 2017). They produce antioxidants that neutralize harmful free radicals, providing protection to plant cells from oxidative stress and stress induced by salinity (Hasanuzzaman et al., 2020).

Effective use of good quality water for irrigation is essential for reducing the buildup of salts in the root zone. This approach has been advocated by various sources (Hoffman et al., 2007; Pereira et al., 2009). Irrigation should be planned to satisfy the water requirements for evapotranspiration while also addressing the necessity for leaching to preserve a beneficial salt balance within the root zone. The concept of leaching requirement is practical, as Bulgaria experiences the Mediterranean summer. However, due to climate change there can be significant rainfall immediately after the leaching process leading to non-steady state salinity is the concentration of rainfall within a short period (Minhas et al., 2020). Another useful technique in managing salinity is the use of remote sensing and GIS modelling as they serve the purpose of mapping and continuously monitoring soil salinity (Yuvaraj et al., 2021). Geostatistical techniques, like ordinary inverse distance weighted interpolation and Kriging interpolation, have been widely employed for the assessment and examination of the spatial relationships and spatial heterogeneity of soil properties (Bouasria et al., 2021).

With the aid of remote sensing data, it becomes feasible to predict and anticipate the areas affected by salinity (Mustafa and Akhtar, 2019).

Conclusion

The accumulation of salts in Bulgarian soils presents a severe challenge to agriculture. Its impact is manifested in a general reduction in crop yields often leading to the abandonment of fields by farmers. To ensure sustainable agriculture on such soils, it is crucial to understand options for reclaiming saline soils. One commonly employed technique for mitigating salinity is chemical amelioration with chalk. However, the cost involved in implementing this method is high and labor-intensive. Nevertheless, proper irrigation and drainage, growth of halophytic crops, and microbial-assisted phytoremediation serve as a more feasible alternative method. Additionally, remote sensing and GIS modelling can help monitor and predict areas affected by salinity. Continued research and the implementation of effective strategies is the key to mitigating the impact of soil salinity in Bulgaria and beyond.

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Determination of landslide susceptibility with the Fuzzy-Analytical Hierarchical Process- Andırın Example

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Abstract

Landslide susceptibility is a term that expresses the probability of a landslide disaster occurring in a region. Producing susceptibility maps before a landslide occurs in any region is important in terms of recognizing geological hazards in advance and managing topographic processes in a more controlled manner. In the study, Landslide susceptibility map of Kahramanmaraş's Andırın district was obtained by using slope, aspect, elevation, major soil groups, rainfall amount, normalized difference vegetation index (NDVI), distance to fault lines, distance to the stream, distance to the road, lithology and land use parameters. Priority values were obtained by weighting the evaluated parameters with Fuzzy AHP and landslide susceptibility was evaluated in 5 classes: very low, low, medium, high and very high. As a result of the study, approximately 19% of the area was evaluated as high and very high, and approximately 10% was evaluated as low in landslide susceptibility classification.

Keywords: Andırın, Landslide, Fuzzy AHP, Geographic Information Systems, Land Use

Introduction

Landslide, one of the most destructive and significant natural events (Panchal and Shrivastava, 2020), is defined as the movement of soil or rock mass in the direction of the slope (Highland, 2008; Shen et al., 2012). While landslides can cause damage to structures, they also have an impact on agriculture (Aghlmand et al., 2020) and forest areas. Irregular and intense rainfalls occurring as a result of the global climate experienced throughout the world trigger the number and size of landslides, causing loss of life and property. Landslide disaster poses a high risk, especially in developing countries, as a result of unplanned urbanization due to rapid population growth, expansion of settlements towards mountainous areas and global warming (Mijani and Neysani Samani, 2017). The most important method to reduce the damages caused by landslides is to determine the areas that are susceptible to the disaster. Identifying and mapping landslide-prone areas is important in minimizing the possible damages of landslides that may occur in a region (Mohammady et al., 2010, Yeon et al., 2010). In studies conducted to determine landslide susceptibility, the selection of parameters is evaluated by taking into account their contribution to the formation of landslides. Four approaches are generally preferred in parameter selection. These approaches: a) deterministic (Thiebes, 2011; Akgün and Erkan, 2016), b) intuitive (Nefeslioglu et al., 2013; Roodposhti et al., 2013), c) statistical (Nefeslioğlu et al., 2008; Althuwaynee et al., 2012) and d) landslide They are known as probabilistic approaches based on inventory (Melchiorre, et al., 2011; Akgün, 2018). In recent years, the use of GIS and UA applications has brought great convenience in obtaining high-precision maps.

The analytical hierarchical process (AHP) method, which can evaluate many qualitative and quantitative criteria together, is widely used in the literature (Aghlmand et al., 2020; Bahrami et al., 2021; Aydın et al., 2022). However, since AHP does not reflect the human thinking style (Başlıgil, 2005), the Fuzzy AHP method was developed to solve hierarchical fuzzy problems (Kuo et al., 2002). To eliminate the methodological challenge, the Fuzzy-AHP model was developed as a result of integrating the AHP into the traditional fuzzy logic method (Özkan et al., 2020). The Fuzzy-AHP approach can be considered as an example successfully used in landslide susceptibility maps. Moharrami et al. (2020) noted the Fuzzy-AHP approach to be based on a scientific approach derived through the fuzzification of pair-wise comparison matrices between the parameters.

The aim of this study is to prepare a landslide susceptibility map by weighting the parameters affecting landslides within the borders of Kahramanmaraş Andırın district with the Fuzzy AHP method.

Material and Methods

Study area

Andırın district of Kahramanmaraş, located in the northeast of the Mediterranean region, is located in the transition area between the Mediterranean climate and the continental climate (Vermez et al., 2018). Andırın district covers a total area of 1178 km2 (Anonymous, 2023). The annual average temperature value is 12.6 °C. The hottest month in the region is August with 22.3 °C, and the coldest month is February with 2.8 °C. The month with the highest rainfall in Andırın district is January with 192.2 mm. The least rainfall occurs in August with 14.9 mm (Öztürk, 2008).

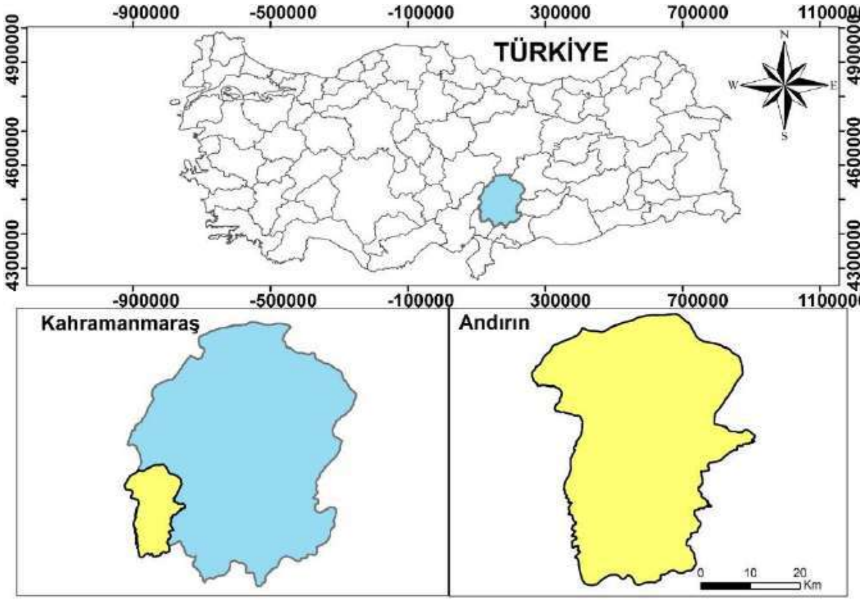

Figure 1. Location map of study area

Parameters evaluated in the study

Many factors in nature affect landslide disasters (Hashemi Tabatabaei, 1998; Uromeihy and Mahdavifar, 2000; Aghlmand vd., 2020). Frequently used in landslide studies after literature review (Kayastha et al., 2013; Demir, 2018; Özşahin, 2018); 11 parameters including slope, aspect, elevation (DEM), land use, soil classes, lithology, precipitation, NDVI, distance to streams, distance to fault lines, distance to roads were taken into consideration. Distribution maps produced for the parameters are given in Figure 2.

Slope: Slope is one of the main factors causing landslides in different areas. Increasing the slope level increases the risk of landslides (Mijani and Neysani Samani, 2017).

Aspect: The position of the topography against the sun is important in the preparation of sensitivity maps (Guzzetti et al., 1999; Nagarajan et al., 2000).

DEM: It has been reported that the elevation change of the topography is an effective factor in the formation of landslides (Kayastha et al., 2012).

Land use: Forest areas with dense land cover are less affected by landslides than agricultural and residential areas (Dağ, 2007).

Soil: The soil covering the surface of the topography also causes landslides (Özşahin and Kaymaz, 2013).

Litoloji: The effect of lithology on landslide formation is due to the sensitivity of rocks to landslides (Özşahin, 2015).

Precipitation: The soil becomes saturated with water due to precipitation and the soil becomes susceptible to landslides as the groundwater level rises.

NDVI: Areas covered with healthy vegetation are more resistant to landslides than areas with shallow vegetation.

Distance to streams: The distance to the streams factor affects the landslide formation by controlling the saturation degree of the material on the slopes and the stability of the slope (Yalçın, 2008).

Distance to fault lines: Generally, fault planes with high slope values are taken into account in landslide studies as they are quite suitable for landslide formation (Özşahin, 2015).

Distance to roads: Especially on sloping lands, there is a high probability of being exposed to landslides since there is no connection or area that can carry the load of the part on the road.

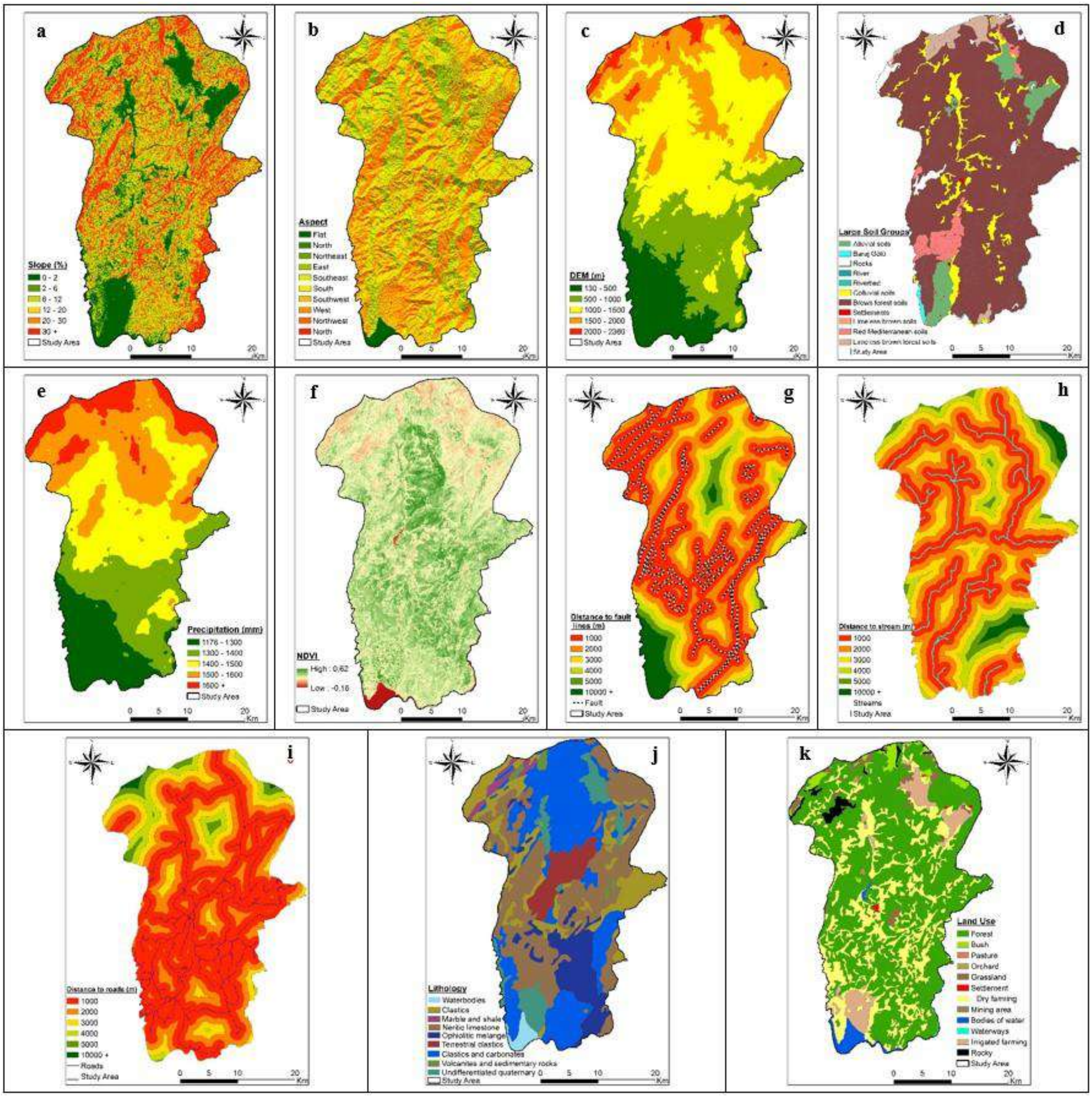

Figure 2. Slope (a), Aspect (b), DEM (c), Large soil groups (d), Precipitation (e), NDVI (f), Distance to fault lines (g), Distance to stream (h), Distance to roads (i), Lithology (j), Land use (k) parameters

Fuzzy Analytical Hierarchical Process Approach

It has introduced a new approach in handling F-AHP by using triangular fuzzy numbers for the pairwise comparison scale of the Fuzzy Analytic Hierarchy Process (F-AHP) and the rank analysis method for artificial rank values of pairwise comparisons. The study by (Bellman and Zadeh, 1970) stands out as the first attempt to apply fuzzy set theory to multi-criteria analyses. In fuzzy set logic, the degree of belonging to a set is denoted by (μ) and takes values between “0” and “1”. While the value “0” indicates not belonging to the cluster, the value “1” indicates belonging to the cluster. Triangular fuzzy numbers are represented by the expressions (l, m, u). Chang's (1996) approach represents pairwise comparisons with triangular fuzzy numbers. This method aims to minimize estimation errors. According to Chang's methodology, each criterion is taken into account and rank analysis is applied for each goal (Table 1). As a result, m order analysis values are obtained for each criterion.

Table 1. Fuzzy importance scale

Numerical Value	Linguistic Expression	Triangle Fuzzy Number Value	Correspondence Triangle Fuzzy Number Value
1	Equal	(1,1,1)	(1,1,1)
2	Weak Superiority	(1,2,3)	(1/3,1/2,1)
3	Not Bad	(2,3,4)	(1/4,1/3,1/2)
4	Preferred	(3,4,5)	(1/5,1/4,1/3)
5	Good	(4,5,6)	(1/6,1/5,1/4)
6	Fairly Good	(5,6,7)	(1/7,1/6,1/5)
7	Very Good	(6,7,8)	(1/8,1/7,1/6)
8	Absolute	(7,8,9)	(1/9,1/8,1/7)
9	Perfect	(8,9,9)	(1/9,1/9,1/8)

The F-AHP method supported by the extended analytical process proposed by Chang can be explained as follows.

Let X = {x1, x2,.......xn } be a set of objects and U = {u_1 ,u_2 ,.....u_n } be a set of objectives. According to the extended analysis method, each object is considered to fulfill a goal. The term extended refers to the extent to which this object fulfills the objective. Thus, m extended analysis values are obtained and shown as follows.

$$M_{gi}^{1}, M_{gi}^{2}, M_{gi}^{3}, \ldots, M_{gi}^{m} \qquad i = 1, 2, \ldots, n$$

All Mj (j=1, 2, ..., m) values here are triangular fuzzy numbers. Chang's F-AHP steps can be summarized as follows.

Step 1: The fuzzy magnitude value for object i is defined as follows:

$$S_i = \Sigma_{j=i}^{m} M_{gi}^{j} \otimes [\, \Sigma_{l=1}^{n} \Sigma_{j=1}^{m} M_{gi}^{j}]^{-1}$$

Where Si is the synthesis value of the i. objective Mj extended for each objective value of the value.

Step 2: The likelihood of the event M2 = (l2, m2, u2) ≥ M1 = (l1, m1, u1) V (M2 ≥ M1) = supy≥x [min ((x), (y))] and is defined.

V(M2 ≥ M1) = height (M1 ∩ M2) = μM2 (d) =

$$\begin{cases} 1 \\ 0 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \end{cases}$$

, $m2 \geq m1$

, $l1 \geq u2$

in other cases

Where d is the ordinate of the highest D intersection point between $\mu M1$ and $\mu M2$. To compare M1 and M2, both values V (M1 ≥ M2) and V (M2 ≥ M1) are needed.

Step 3: The degree of likelihood that a convex fuzzy number is greater than k fuzzy numbers, Mi (i=1,2,...,k), is defined as follows:

V (M ≥ M1, M2,...,Mk) = V[(M ≥ M1) and (M ≥ M2) and...and (M ≥ Mk)]

= min V (M ≥ Mi), i = 1,2,3...,k.

In this case, the following assumptions are made for Sjs: d' (Ai) = min V (Si ≥ Sk) for k = 1, 2, ..., n ; k ≠j.

Then the weight vector, Ai (i = 1, 2, 3,...,n) consisting of n elements is expressed as W'(d'(A1), d'(A2),..., d'(An))

Step 4: Normalization shows that the normalized W is not a fuzzy number

W = (d(A1), d(A2), ..., d(An))T

The weightings with Fuzzy -AHP are given in Table 2.

Table 2. Sub-criteria and weight values for the parameters considered in the AHP

Criteria	Layers	Weight Values	Criteria	Layers	Weight Values
Distance to stream	1000 m	0.0237	Distance to Fault Lines	1000 m	0.0234
	2000 m	0.0265		2000 m	0.0262
	3000 m	0.0216		3000 m	0.0214
	4000 m	0.0166		4000 m	0.0165
	5000 m	0.0116		5000 m	0.0115
	10000 m	0.0067		10000 m	0.0066
Land Use	Bare Cliff	0.0145	Distance to roads (m)	1000 m	0.0195
	Mine Quarry	0.0132		2000 m	0.0218
	pasture	0.0125		3000 m	0.0178
	Forest	0.0136		4000 m	0.0137
	Agricultural Field	0.0082		5000 m	0.0096
	Orchards	0.0060		10000 m	0.0055
	Residential	0.0042	DEM (m)	130-500	0.0051
Slope	0-2	0.0276		500-1000	0.0089
	2-6	0.0241		1000-1500	0.0094
	6-12	0.0216		1500-2000	0.0110
	12-20	0.0226		2000-2360	0.0136
	20-30	0.0129	Precipitation (mm)	1176-1287	0.0140
	30+	0.0090		1287-1399	0.0245
Slope Shape	1	0.0563		1399-1511	0.0260
	2	0.0434		1511-1622	0.0302
	3	0.0302		1622-1734	0.0374
Soil	Bare Cliff	0.0178	NDVI	The bare areas and water surfaces	0.0093
	Alluvial	0.0144		There is a thicket. But the vegetation is shallow.	0.0076
	Colluvial	0.0124		Semi-bare areas with Ndvi value close to 0	0.0065
	Settlement	0.0117		Moderately healthy plants	0.0061
	Other Lands	0.0066		Areas covered with healthy plants as vegetation	0.0035
Lithology	Split Quaternary	0.0407	Aspect	North	0.0404
	Clastics	0.0351		South	0.0348
	Limestone	0.0270		East West	0.0268
	Marble	0.0188		Flat Areas	0.0186

Results And Discussion

The weight values obtained for the parameters discussed in the study were overlapped with the help of ArcGIS 10.8 program. For this, ArcTool Box -Spatial Analysis Tools- Overlay-Weighted Sum module was used. The susceptibility map obtained is categorized into 5 classes (Table 3, Figure 3).

Table 3. Spatial and proportional values of landslide susceptibility classes in the study area

Number	Landslide Classes	Landslide Susceptibility Values	Area (Hectares)	Ratio (%)
1	Very Low	0.0971- 0.2192	11444.85	9.72
2	Low	0.2192- 0.2574	44003.09	37.35
3	Moderate	0.2574- 0.2910	40259.38	34.18
4	High	0.2910- 0.3253	17026.49	14.45
5	Very High	0.3253 – 0.3782	5066.10	4.30
Total			117800,00	100

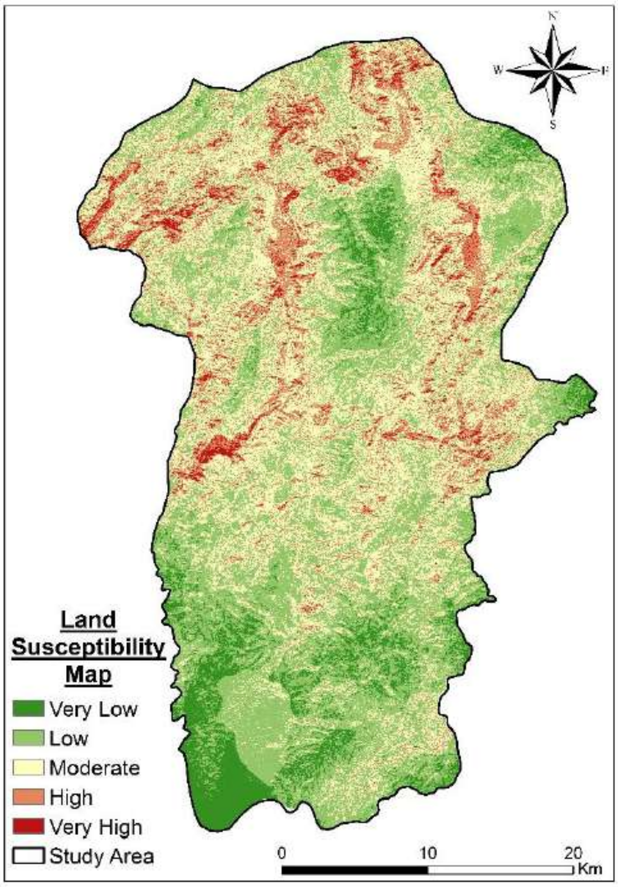

Figure 3. Landslide susceptibility map of study area.

In Andırın district, which has an area of 117800.00 ha, landslide susceptibility is very low (11444.85 ha), low (44003.09 ha), medium (40259.38 ha), high (17026.49 ha), and very high (5066,000 ha). It is categorized in 5 classes: 10 ha). Accordingly, approximately 10% of the area was evaluated in the high and very high sensitivity class. Çellek et al., (2015) prepared a landslide susceptibility map for Sinop province and its immediate surroundings using the AHP method. In the study, factors such as aspect, lithology, land use class, slope curvature, slope, elevation, proximity to the main road, stream and structural elements were taken into consideration. As a result, they determined that 10.77% of the area was very low landslide susceptible, 10.59% was low landslide susceptible, 52.64% was moderately susceptible to landslides, 25.66% was highly susceptible to landslides, and 0.34% was very highly susceptible to landslides. Mijani and Neysani Samani, (2017) produced a landslide susceptibility map in Sari city of Iran using Fuzzy-based Fuzzy-AHP, Fuzzy Gamma and Fuzzy-OR models and compared the model results. Based on the landslide hazard maps obtained, Fuzzy-AHP, Fuzzy Gamma and Fuzzy-OR stated that 13, 26 and 35 percent of the study area, respectively, were at a very high-risk level. Aghlmand et al., (2020) aimed to produce a landslide susceptibility map using AHP in Ardabil city of Iran. In the study, land use, rainfall amount, distance to faults, lithology, distance to river networks, elevation, slope, aspect and distance to the road parameters were taken into account. They classified the sensitivity map they created into 5 groups: "very high, high, medium, low and very low". Saygın et al., 2023. In their study in Samsun city center, they created a landslide susceptibility map using Fuzzy AHP and Decision Tree approach. According to the results, the 'very low' and 'low' sensitivity class, corresponding to 29.8% of the total area in the sensitivity map, was predicted with 100% accuracy through the decision tree algorithm.

In the fuzzy-AHP generated map, 70.2% of the total area specified in the 'medium' (%H3-68.6%) and 'high' (%H4-1.6) sensitivity classes is in the 'medium' sensitivity class, As a result of the prediction, although the H1, H2 and H3 classes were successfully predicted using the weights obtained with the Fuzzy-AHP approach with the help of the decision tree algorithm ($p < 0.05$), the prediction accuracy of the H4 class was in the 'low' (AUC) class.

Factors such as earthquake shaking, slope and intense rainfall can trigger landslides (Dai et al., 2002). In addition, areas with high slopes, heavy rainfall, weak vegetation, and areas close to roads and streams are described as regions with high landslide risk (Dai et al., 2002; Dikshit et al., 2020; Gorokhovich and Vustianiuk, 2021; Mallick et al., 2021; Sim et al., 2022; Yousefi et al., 2022). Alluvial soils with flat and almost flat slopes are less risky regarding landslide risk. In this study, similar to previous studies, it was determined that the risk of landslides was higher in areas with slopes, weak vegetation, heavy rainfall, and close to roads and streams (Figure 3).

Conclusion

The number and severity of landslides, which are said to have the most devastating effects among natural disasters, are increasing day by day due to the effect of climate change. Various factors such as topography, lithology, vegetation, soil structure and rainfall have a serious impact on the formation of landslides. Determining the impact level of all these factors on landslides plays an important role in determining landslide-prone areas in advance. A landslide susceptibility map was created as a result of weighting with the Fuzzy AHP method, taking into account the parameters affecting the landslide within the borders of Kahramanmaraş Andırın district. As a result of the study, it was seen that approximately 20% of the area was in high and very high-risk areas. All actions to be taken by taking into account the landslide susceptibility map created within the district borders will reduce the effects of landslides on loss of life and property.

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İmpacts of biochar on tropical soil quality: A review

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Abstract

Biochar has gained considerable attention due to its potential for soil health improvement, fertility enhancement, and positive effects on both soil quality and crop productivity. Multiple nutrient deficiencies together with severe soil quality degradation are regarded as the major constraints on highly weathered soils that hinder sustainability of agriculture in a tropical region. Several research studies have reported significance effect of biochar on improving properties of tropical soils. This review article aims to discuss the effects of biochar on tropical soil quality based on selected soil quality parameters (SOC, pH, total N, BD, MWD, porosity, FC). Various type of biochars have found to improve soil quality of typical highly weathered soils. Biochar hold potential to rejuvenate degraded tropical soil. The properties of both biochar material and recipient soil should be considered carefully prior to application.

Keywords: Biochar, Soil quality, Tropical

Introduction

Tropics refers to regions of the world that lies between tropic of Cancer and Capricorn, 23'27' north and south of the equator (Balek, 1983). The regions cover 4,950 million (approx. 5 billion) hectares, that is 38% of the global land mass (Chesworth, 2008). The prevalence of hot and humid climate with high annual rainfall in the tropical environment, severe and intense weathering together with active and continuous processes of soil formation resulting to highly weathered tropical soils (Buringh, 1970). Tropical soils are characterized with inherit low pH (pH ≤ 5.0) and small quantity of basic cations, soils of the tropics are well known for their inherent marginal fertility due to soil acidity, and low cation exchange capacity (CEC) (Fujii et al., 2018). The ability of tropical soils to support crops is limited by their inherent properties that are different from temperate soils and that define tropical soils with special management techniques to realize their yield potential (Basak et al., 2022). The major soils of the wet (sub)tropics are Oxisol, Ultisols, Alfisols and lnceptisols (Survey Staff, 2022). The WRB major soil groups important for the wet (sub)tropics, are Plinthosols, Ferralsols, Alisols, Nitisols, Acrisols and Lixisols (International Union of Soil Sciences Working Group World Reference Base, 2022). The most typical soils of the dry subtropics Aridisols (Survey Staff, 2022), the WRB major soil groups important for the dry subtropics and tropical deserts are: Solonchaks, Solonetz, Gypsisols, Durisols, Calcisols and Arenosols. Intensive use of land resources through agricultural practices in the highly weathered soils may further lead to degradation of the tropical soils with severe impact on productivity (Anda et al., 2015). As the key to soil quality, restoring and improving soil organic matter through carbon-rich soil amendments can help to regenerate extremely degraded tropical soils (Basak et al., 2022).

Biochar concept has advanced considerably with important key findings on soil quality, soil acidity, soil fertility, soil health, agronomic benefits, carbon sequestration, and greenhouse gas emissions (Agegnehu et al., 2016). Biochar is the carbon-rich product obtained when organic material underwent pyrolysis in a limited supply of oxygen at relatively low temperatures (< 700°C) (Lehman & Joseph, 2009). İBİ (2015) defines biochar as solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. Biochar generally considered for application to soil, with the aim to improve soil functioning and increase carbon sequestration as opposed to charcoal which is produced for use as source of energy (Brassard et al., 2016). Biochar as a product of biomass pyrolysis in an oxygen depleted atmosphere contains porous carbonaceous structure with an array of functional groups, and molecular structure with high degree of chemical and microbial stability (Lehman and Joseph, 2009). The properties of biochar are highly determined by pyrolysis condition (temperature, residence time) together with type of feedstock material (Hossain et al., 2020; Zhang et al., 2017). Wide range of raw materials can be used as feedstock such as wood waste, industrial waste, municipal waste as well as agricultural waste (Agegnehu et al., 2017). The elemental characteristics of biochar composed of carbon, nitrogen, hydrogen, and some lower nutrient element, such as K, Ca, Na, and Mg (Agegnehu et al., 2017; Ding et al., 2016). The carbon content of the biochar increased with increasing pyrolysis temperature, while the contents of nitrogen and hydrogen decreased. Biochar has also reported with a high specific surface area with variety of polar or nonpolar substances, which has a strong affinity to inorganic ions such as phosphate, and nitrate (Ding et al., 2016).

Due to its beneficial characteristics, biochar has a high potential for enhancing soil quality (Palansooriya et al., 2019). Soil quality is major determinant of soil resilience to degradation and crop yields can be defined as the capacity of a soil to function within the ecosystem boundaries and to interact positively with surrounding ecosystems (Karlen et al., 2003). The soil capacity to function can be reflected by measurable soil properties known as soil quality indicators (Shukla et al., 2006). Monitoring trends with time of these soil quality indicators provide information on the extent and severity of soil degradation. Evaluation of soil quality in terms of indicators is important for sustainable land management as it reflects environmental soil quality, soil productivity, food security and economic profitability (Imaz et al., 2010). There is a growing need to combat soil degradation in tropic by monitoring the status of soil quality and the trend of soil quality deterioration for sustainable agriculture production and land management practices (Moebius-Clune et al., 2011). Previous studies (Shukla et al., 2006) identified soil organic carbon (SOC), field water capacity (FC), air-filled porosity, pH, soil bulk density (BD), mean weight diameter of aggregates (MWD) and total nitrogen (N) are key attributes of soil quality indicators. This review intends to consider biochar effects on the above-mentioned soil physicochemical properties for tropical soils. The impact of biochar on key attributes of soil quality indicators in highly weathered soils is highlighted.

Effect of Biochar on Soil Quality Parameters

Soil Organic Carbon (SOC)

Soils from tropics are characterized with insufficient soil organic matter and low SOC (Adiaha, 2017). Climatic characteristics in combination with intensive cultivation contributes to the decline of SOC contents of soils in the tropics (Glaser et al., 2002). SOC has widely reported with significance effect on soil health, microbial activity, nutrient cycling, and water retention (Alkharabsheh et al., 2021). Applying biochar in weathered soil could increase SOC (Basak et al., 2022). Table 1 shows influence of different biochars on various soils from tropics. SOC increased linearly with application rates of rice husk biochar in tropical Alfisol (Oladele, 2019). Previous studies highlighted the recalcitrant nature of biochar may attributed to biochar organic content (Lehmann et al., 2003). Biochar consists of recalcitrant aromatic ring structures and degradable aliphatic and oxidized carbon structures (Abiven et al., 2011). The range of carbon forms within a biochar particle may depend on the feedstock composition, charring conditions and the process condition (condensation of volatiles or direct charring of plant cells (Agegnehu et al., 2017). SOC is powerful attribute and dynamic soil quality indicator as it affected by management practice (Shukla et al., 2006). Thus, impact of biochar could be temporary and re-application might be necessary after certain period of time to prolong the beneficial effects of biochar in weathered tropical soil (Basak et al., 2022).

Soil reaction (pH)

Weathered tropical soils are considered acidic in nature with poor availability of macro- and micro-nutrients consequently limit crop growth and yield reduction (Fujii et al., 2018). Soil pH is an important parameter that determine soil fertility (Wang et al., 2023). Changes in soil reaction can modify the soil media and improve soil nutrient availability for plant growth (Agegnehu et al., 2017). The modification of the soil environment could also create favorable condition for microbial activity (Alkharabsheh et al., 2021). Soil pH affects biomass yield and decomposition of biomass in the soil (Shukla et al., 2006). Several studies reported application of biochar into soil can change pH value (Ding et al., 2016; Glaser et al., 2002; Tusar et al., 2023). The beneficial effect could more relevant for tropical acidic soils due to the alkaline nature of many biochar materials (Palansooriya et al., 2019). Biochars have high ash contents which provides more basic substances, a property feature that determine biochar alkalinity potential (Allohverdi et al., 2021). Table 1 shows the liming effects of biochar in different acidic soils of tropics. A single application of wood biochar at 20 t ha^{-1} had increase soil pH and plant nutrients for four subsequent years in tropical savanna oxisol (Major et al., 2010). However, effectiveness of biochar in soil pH modification is affected by various factors such as feedstock composition, pyrolysis condition (pyrolysis temperature, heating rate and resident time), rate of application, and inherent properties of the recipient soil (Basak et al., 2022).

Nitrogen (N)

Among all the nutrients nitrogen is required in larger quantities than any other plant nutrient, Nitrogen is an essential component of various proteins, vitamins, amino acids, alkaloids, plant hormones, chlorophyll, ATP (adenosine triphosphate), and DNA (Alkharabsheh et al., 2021). Application of biochar in weathered tropical soil could improve dynamic and availability of nitrogen (Basak et al., 2022). Table 1 shows the influence of different type of biochars on soil total N. Application of wood biochar increased soil N in two consecutive cropping seasons of degraded ultisol (Mbah et al., 2017). A five-year field trial conducted in red soil of subtropical monsoon region revealed significant increase of total N when the biochar application rate exceeded 5 t ha^{-1}, the type of biochar used was wheat straw biochar pyrolyzed at 450 °C (Jin et al., 2019). Moreover biochar application impacts soil pH and microbial activity, thereby, altering the cycling of nitrogen in the soil (Palansooriya et al., 2019). However, biochars with higher C:N ratio affects availability of soil nitrogen (Yao et al., 2017). High C:N has negative effects on microbial community structure, consequently cause nutrient immobilization and accelerating native soil organic matter loss (Muhammad et al., 2016).

Bulk Density (BD)

Studies in weathered soils indicated biochar has positive impact more for the physical attributes than chemical indicators (Basak et al., 2022; Oladele, 2019). The effects of different biochar on soil BD are presented in Table 1. Biochar has reported with effective effect of decreasing BD of weathered tropical soil in different regions of the world (Jien et al., 2021; Mbah et al., 2017). Soil BD is primary indicator of soil health with significance effects on compaction and soil aeration, it also influences water infiltration, rooting penetration of plants and movement of nutrient (Alkharabsheh et al., 2021). The less dense and porous nature of biochar cause physical dilution of dense soil matrix lead to an increase in soil porosity, a mechanism that attributed to decreased bulk density (Basak et al., 2022). (Obiahu et al., 2020) presented a reduced bulk density values with response to different biochar application rates in a highly-weathered nitisol. Other authors (Jin et al., 2019) reported the same trend of result in five year field trial of red soil although bulk density weakened but significantly reduced over time. Integration of biochar with compost has significantly improved bulk density of highly weathered tropical soil (Jien et al., 2021). The quality of biochar material, rate of application, the properties of recipient soil, and type of plants grown on the recipient soil are reported with considerable influence on biochar's impact on soil bulk density (Basak et al., 2022).

Table 1: Changes in soil quality parameters with biochar applications for tropical soils

Biochar feedstock	Application rate	Soil type	SOC	pH	N	BD	MWD	FC	Porosity	Reference
Willow wood	10 t ha^{-1}	Chromosol	6.5% (↑)	4.4% (↑)	11% (↑)	9.3% (↓)	---	---	---	(Bass et al., 2016)
Zelkova wood	4% (w/w)	Ultisols	19% (↑)	33% (↑)	17% (↑)	5% (↓)	43% (↑)	16% (↑)	5% (↑)	(Jien et al., 2021)
Leucaena spp wood	5% (w/w)	Ultisols	37% (↑)	28% (↑)	---	23% (↓)	8.8% (↑)	---	27% (↑)	(Jien & Wang, 2013a)
Sugarcane bagasse	1.8% (w/w)	Entisols	183% (↑)	4% (↑)	---	18% (↓)	---	92% (↑)	-	(Araújo Santos et al., 2022)
Cogon grass biochar	20% (W/W)	Entisols	----	8.3% (↑)	25% (↑)	17% (↓)	---	---	57% (↑)	(Michael, 2020)
Corn Cob Biochar	0.68% (w/w)	Acrisol	66% (↑)	10% (↑)	----	----	52% (↑)	----	----	(Amoakwah et al., 2017)
Rice husk biochar	3.4%(w/w)	Arenosol	----	----	----	9% (↓)	---	13% (↑)	9% (↑)	(Obia et al., 2016)
Wheat straw	40 t ha^{-1}	Tropic red soil	----	----	----	---	28% (↑)		---	(X. Liu et al., 2014)
Corncob	10 g kg^{-1}	Acrisol	91% (↑)	9% (↑)	10% (↑)	---	---	---	---	(Frimpong et al., 2021)
Rice husk	10 g kg^{-1}	Acrisol	96% (↑)	6% (↑)	40% (↑)	---	----	---	---	(Frimpong et al., 2021)
Wastewater sludge	4% (w/w)	Ultisols	94% (↑)	3.7% (↑)	18% (↑)	---	9% (↑)	12% (↑)	---	(Zong et al., 2018)

Mean Weight Diameter of Aggregate Stability (MWD)

For sustainable agriculture soil aggregation is important as it influences the soil physical and biological properties (Demisie et al., 2014). The distinction between water stable aggregate and MWD is that, the latter allow measurement of disaggregated when soil degraded by external energy forces (Franzluebbers, 2022). Table 1 shows impact of biochar on MWD of various weathered soils. Oat hull biochar significantly improved the MWD by 54% and 50% upon application to Inceptisol and Ultisol respectively (Curaqueo et al., 2014). 2% and 4% application of wood biochar significantly increased MWD relatively to control in highly weathered Ultsoils (Jien et al., 2021). The key processes of biochar's improvement on aggregate stability in weathered soil need to be validated with further research (Basak et al., 2022). Previous studies (Jien et al., 2021) suggested biochar amendment cause circular aggregates in the soil that increase the soil aggregate stability. Biochar with high oxidized surface could bind and adsorb soil and clay particles and form macro-aggregates in soil (Jien and Wang, 2013). Soil enzymatic activities related to biochar could have important role in the formation of soil micro-aggregates, high activity of soil β-glucosidase enzyme linked to polysaccharides formation could have allowed the improvement of soil aggregate stability in red soil (Demisie et al., 2014).

Air Filled Porosity

Porosity is term refers to pore space between soil particles (Alkharabsheh et al., 2021), it has considerable effects on soil aeration, nutrient retention, and water movement within the soil (Shukla et al., 2006). The porous internal structure of biochar causes increase of soil porosity, increased soil porosity increases the surface area of soil for retention and infiltration of water (Agegnehu et al., 2017). Various tropical soils have reported with improved porosity with response to biochar applications (Table 1). (Curaqueo et al., 2014) reported increased values of porosity relatively to control upon biochar application to inceptisol. Similar results were also reported by (Mbah et al., 2017) for ultisol. Some studies showed insignificant effect of biochar on porosity to nitisol (Obiahu et al., 2020), ultisol (Curaqueo et al., 2014). The deviation could be attributed to differences in soil type and soil textural classes (Alkharabsheh et al., 2021). Previous studies (Alghamdi, 2018) suggests that coarse-textured soil has low porosity compared to fine soil with higher porosity, as a result coarse-textured soils exhibit a great increase in soil porosity compared to fine-textured soil when amended with biochar.

Field Capacity Water (FC)

Several studies have demonstrated that soil application of biochar has increased water retention capacity and positively affected field water capacity (Table 1). The improvement of soil water retention characteristics of biochar application is due highly porous nature of biochar (Basak et al., 2022). Biochar particles also have intrapore space (space inside the particles) that provide additional storage for water retention at different matric potentials (Liu et al., 2017). Biochar application increased water at field capacity from 0.2219 $cm^3\ cm^{-3}$ in the control to 0.2678 $cm^3\ cm^{-3}$ in the treatment amended with 40 t biochar ha^{-1}, presented values are based on average for field trial conducted for five years on upland red soil (Jin et al., 2019). Hydraulic properties of soils are closely related to soil aeration, aggregation and BD (Curaqueo et al., 2014) which suggest that set of soil quality parameters are interconnected.

Conclusion

A lot of information from literature indicates that biochar has beneficial effects on soil quality and crop yield. Biochar has the potentials to reclaim degraded tropical soils through enhancement of soil properties that improve basic soil functions. Suitability of biochar to improve quality of weathered soil is determined the composition of biochar materials. Biochar composition depend on type of feedstock and charring temperature. The possible constraints of biochar -soil interaction on tropical condition need further research attention. Biochar seems to be a potential material that can be integrated in soil to improve soil ecosystem services in tropical region.

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Acidic soils amelioration; Past, current and future direction for sustainable agricultural productivity

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Abstract
Soil acidification is increasingly hindering sustainable Agricultural productivity and a major driver of land degradation. The effects of soil acidity overlap influence on nutrients availability and toxicity of harmful elements. Hence, playing key roles in crops yield and quality. This is worrying by the need to increase food production to meet demands of increasing world population and changing climates. Several approaches have been adopted to ameliorate these effects. Notably, mineral lime has been predominantly used with expanding interest for other options. This paper employed three key techniques 1) Systematic literature mapping; 2) Snowballing and 3) Systematic literature review; to critical review acidic soils amelioration; past, current and future direction for sustainable Agricultural productivity.
Keywords: Ameliorants, Climate Change, Soil Acidity, Sustainable Production

Introduction

Soil acidification is increasingly hindering sustainable Agricultural productivity. It is primarily the process of generating hydrogen ions or exchangeable aluminum ions in the soil, leading to the leaching of soil base cations and a decrease in soil pH (Krug and Frink 1983). It is estimated that 30% of the world's ice-free land is acidic, of which 50% is arable (Li et al. 2010; Sikiric et al. 2011; Von Uexüll and Mutert 1995). Natural (parent materials) and anthropogenic activities account for both direct and indirect acidic conditions.

The acidity of soils pose detrimental effects on crop's growth and development mainly through aluminum (Al^{3+}) toxicity and soil infertility. Acidic soil impede roots development, which in turn negatively affects water and nutrients-use efficiency (Long et al. 2017; Yang et al. 2013) and availability of essential nutrients (Bona et al 2008).

In this sense, various methods are employed to manage or correct soil acidity. The application of mineral lime is the most used corrective method, especially for correcting surface acidity (Belkacem and Nys, 1995; Fageria and Baligar, 2008; Goulding, 2016). Further research questions led to growing interest towards finding options to ameliorate soil acidity in more sustainable ways by involving industrial by-products. A notable by-product in this direction is alkaline slag (AS), which has the capacity to alleviate both surface and sub-surface soil acidity because of their high alkaline and $CaCl_2$ substances (Li et al., 2015; Masud et al., 2015). Another by-product in this direction is biomass ash (BA), gotten from combusting biofuels. These by-products have positive effects on ameliorating soil acidity and fertility of acidic soils (Antonkiewicz et al. 2020; Shi et al., 2017b). Another method for correcting soil acidity is the use of biochar. Here, biomass is taken through pyrolysis under no or limited oxygen environment (Lehmann and Joseph, 2015). The use of biochar have proven to enriched mineral nutrients, improved physical, chemical and biological properties (He et al. 2020). It is also worthy to mention the direct use of some plant materials to neutralize soil acidity.

Notwithstanding the evidences of various measures to improve acidic soils, there are also concerns of the declining production of the majorly used lime as highlighted by Goulding and Annis, (1998). This has become more worrying by the need to increase food production to meet demands of the increasing world population and changing climates. Therefore, this paper aims to conduct a systematic literature review on acidic soils amelioration in the past, current and future direction for sustainable Agricultural productivity.

To achieve the aim of this write-up, three key techniques were adopted 1) Systematic literature mapping (SLM); 2) Snowballing (SB); 3) Systematic literature review (SLR).

Step 1) Systematic literature mapping (SLM) through selection of appropriate keyword search, platforms and scientific databases, covered the period from 1983 to 2024, to ensure broad spectrum of articles were selected. Keywords were identified based on the topic under consideration and within the scope of the following questions 1) How do soils become acidic? 2) What are the effects of soil acidity on sustainable Agricultural production 3) What are acidic soil ameliorants and methods of application 4) What is the future direction of ameliorating soil acidity. These questions served as a guide for screening articles retrieved from the main research repositories and a baseline for discussing later in this review.

To have means of entry into scientific databases, the web portal of Center for Agriculture and Biosciences International (CABI) was used through the online library platform of Ondokuz Mayis University, Samsun-Türkiye. All the selected articles for this write-up plummeted within Scopus, Web of Science and Science Direct, which are the main research repositories in the world.

Step 2) Snowballing (SB) was performed by using references or citations of papers to identify new papers. This method systematically complemented initially searched and screened resources. The information for this paper was performed according to the following steps; 1) Retrieval of studies from databases (1,916); 2) Getting rid of duplicates (1,103); 3) Selection after title screening (212); 4) Selection after abstract screening (84); 5) Selection after manuscript screening (46); 6) Extra papers from snowballing (12)

Soil acidification And Amelioration

The questions asked earlier were quoted to enhance a practical and guided discussion. Results from the selected articles are entirely based on various approaches of correcting soil acidity, covering several scientific journals across the world.

How do Soils Become Acidic

Generally, soils become acidic by natural (parent material) and anthropogenic processes. The parent material from which soils are formed and other natural processes such as leaching of bases from the soil profile due to excessive precipitation, formation of carbonic acid (H_2CO_3) originating from a reaction of Carbon dioxide (CO_2) produced by microbial and root respiration and water (H_2O), organic acids in the soil from roots and organic matter decomposition and acidified rainfall or atmospheric deposition with sulfuric (H_2CO_3) and nitric acids (HNO_3) are known but relatively slow contributors of soil acidification (Sumner and Noble, 2003; Alewell, 2003). Soil acidification gets accelerated by anthropogenic processes, the application of nitrogen fertilizers on arable lands (Tao et al, 2019; Yang et al, 2018), at rates of global concerns especially in China (Guo et al, 2010). Another accelerated source of soil acidification is the intense agricultural production, which leads to the removal of essential cations whilst releasing H^+ in the solution (Tarkalson et al 2006).

Effects of Soil Acidity on Sustainable Agricultural Production

Soil acidification is linked to decreases in soil pH, which adversely influence the performance of plants and soil microorganisms. Soil acidification potentially influences aluminum, manganese, iron toxicities, and phosphorus, calcium, magnesium and potassium deficiencies (Sparks et al, 2024). Acid soil reduces rhizobium population thereby affecting legume's ability to fix atmospheric nitrogen (Angle, 1998; Slattery et al 2001). Soil microbial activities are largely dependent on soil pH. So, soil acidity plays crucial roles in soil carbon and nitrogen cycling (Rousk et al., 2010). Robertson and Groffman (2015), explains the influence of soil acidity on various soil nitrifiers. And to some account, an accumulation of a potential green house gas (Nitrious oxide, N_2O) by Zhu et al., (2013). Also, soil acidity is directly involved in arbuscular mycorrhizal fungi distribution, which indirectly affects nutrients availability in ecosystems and agroecosystems (Guo et al., 2012). Soil acidity does not only affect soil health and yields but the extra financial burden for correcting soil acidity, lack of support from governments (removal of subsidies) and the poor supply of some of these correctives. Importantly, the uncertainties on return of investment; Haak et al., (1990) reported loose in income conversely to Bongiovanni Lowenberg-Deboer (2000), who reported increased economic returns. Consequently, the above pinpoints some of the bottlenecks faced in Agricultural productivity and raises questions on how to solve these challenges to increase sustainable production.

Acidic Soils Ameliorants and Methods of Application

Acidic soil amelioration is basically an approach of applying products that contain anions (OH^-) to neutralize acid protons (H^+ and Al^+) which are source of soil acidity. Here, means of applying ameliorants to target areas is as much important as the choice of ameliorants. So, various studies have reported approaches of applying ameliorants; Kibiria et al. (2020), reported on foliar application; Belkacem and Nys. (1995) reported on top dressing or surface application and Tang et al. (2013), reported on subsurface incorporation or applying ameliorants. Selection of products that are capable of releasing anions to neutralize acid causing protons is prudent in correcting soil acidity (Alcarde and Rodella, 2003; Rossato et al. 2009). These ameliorants are mostly oxides, calcium, magnesium silicates or carbonates, hydroxides (Alarde and Rodella, 2003; Anghinoni, 2007; Anders et al., 2013). The influence and impact of these ameliorants have been explained by the following research groups; Lime application and efficiency (Fageria and Baligar, 2008; Goulding, 2016; Adams, 1984), using various industrial by-products (Illera et al. 2004; Li et al. 2010; Shi et al 2016; Masud et al. 2014, 2015; Shi et al. 2017a; Park et al. 2020; Antonkiewicz et al. 2020), directly using plant materials (Noble, Zenneck and Randall 1996; Yan, Schubert and Mengal 1996; Pocknee and Summer 1997; Tang et al. 1999; Xu and Coventry 2003; Xu Tang and Chen 2006; Wang, Li and Xu 2009; Wang, Xu and Li 2011; Mao et al. 2010), effects of biochar on soil acidity and properties (Hasan, 2018; He et al. 2020; Šimanský, et al 2020). It is important to mention that, choice of ameliorants and approach of application depends on several factors. For instance, subsurface and surface acidity, different crop types (legumes and non-legumes), different climates (tropical, subtropical, temperate), form of ameliorants (liquid and solid), production systems (screenhouse, field) may not yield the same output for equal treatments. Thus, critical assessment of prevailing soil acidity is needed to make optimum decisions.

Future Direction for Ameliorating Soil Acidity

Once soil gets acidic the best management practices should be put in place to regain former productivity. It is well known and documented about the already existing productive and sustainable methods of ameliorating soil acidity, but there's the need to adapt to meet evolving trends of sustainable Agricultural production. Acidic soil amelioration techniques started at a very traditional scale by making use of locally available materials. Here, mostly subsistence farmer's slash-and-burn field and the logs and foliage burnt release nutrients and raise soil pH. Similarly, farmers in Savanna regions where trees are scarce, grasses are cut and put in bunds and covered with top soil materials. The grasses inside are burnt and later crops planted on the bunds at the onset of rains.

With the development of large farms which involved mechanized clearing, considerable research was directed towards managing soil acidity on long-term bases. This for a long time centered on lime application and lime requirement based on soil analysis, which are now well documented including economic models to understand profit balance between lime inputs and crop yields (Ejigu et al., 2023). Also, growing interest to expand soil acidity amelioration for specific needs led to the use of industrial by-products (Alkaline slag, Biomass ash), directly using plant materials and biochars. However, current techniques for ameliorating soil acidity are with gaps that need to be explored to achieve both large and small scale crops production needs. Firstly, current efforts are still overly dependent on climatic conditions. Climate- resilient Agriculture technologies needs to be developed with capacities to assess impact of climate change on soil pH, this includes adapting to changing precipitation and temperature fluctuations. Adopting crop production systems that enhance concurrent use of resources, example; applying ameliorants through irrigation would be bright direction in this regard. Finally, current methods do not allow real-time monitoring of soil pH. Implementing advanced sensor technologies that allows application of ameliorants precisely to where they are needed would help farmers to optimize resources.

Conclusion

This review highlighted many techniques and materials for ameliorating soil acidity. Acidic soil ameliorants are mainly from oxides, calcium, magnesium silicates or carbonates, hydroxides sources. This includes ameliorating soil acidic conditions from both natural and anthropogenic sources.

This review also indicated growing interest for soil acidity amelioration because of its impacts on sustainable agricultural production and ecosystems and key roles on land degradation.

The studies also pinpointed gaps from current amelioration methods and indicated need to be exploited to meet current and evolving demands of crop production under acidic conditions.

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Humic and fulvic acids and their role in sustainable agriculture

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Abstract

Currently, one of the biggest challenges for agriculture is to reduce the dependence on chemical fertilizers, in order to preserve soil health and fertility but to retain expected crop yield. The prolonged use of mineral fertilizer was justified by higher and consistent crop yield, but the chemicals turn out to be one of the major underground water and soil pollutants. The replacement of chemical fertilizer in agriculture would require different approaches depending on factors such as: soil type, climate conditions, management systems, available machinery, and financial resources. Among the available options for chemical fertilizer`s reduction is application of humic and fulvic acids. The aim of the current review paper is to discuss the most important characteristics of humic and fulvic acids and their role in sustainable agriculture. Humic and fulvic acids are natural components of soil organic matter, but they can be extracted from various sources. The application of humic and fulvic acids is related to their positive effect on plant growth through stimulation of plant`s biochemical pathways and acquisition of nutrients. One of the important advantages of humic substances is that they can be combined with organic fertilizers and could substitute chemical fertilizers. It is expected that the application of humic acids in agriculture is about to increase, especially if the non-renewable resources like brown coal (leonardite) and peat which are used for their production are replaced by sustainable sources based on agricultural or food wastes.

Keywords: Biostimulants, Humic Substances, Renewable Resources, Soil Health

Introduction

The use of inorganic fertilizer in agriculture during the twentieth century was of fundamental importance to lower the hunger indexes in a scenario of a continuous world population growth. However, the consequence of fertilizers use has brought environmental problems in the long- term and are considered involved in a global climate change (Yang, et al., 2020; Tripathi et al., 2020). Nitrate is one of the most used inorganic fertilizers and the pollution it causes is relatively common because the portion of N which has not been utilized by plants may leach down to underground and surface water bodies (Craswell, 2021). The fate of fertilizes depends also on the clay content, soil texture and pH (Ashitha et al., 2021). The management of soil properties like pH is of fundamental importance not only to secure food but also to contribute to sustainability goals towards improving soil health (Lehmann et al., 2020). The soil health or soil quality is the soils capacity to grow crops without resulting in soil degradation (Acton and Gregorich, 1995). Contrary to this definition Lal (2016) states that soil health and soil quality should not be used interchangeable. According to researcher the soil quality is related to its functions, whereas the soil health refers to soil as a living biological entity that affects plant growth and development.

The future of soil health concept would depend on the development of sustainable management systems, their rules and principles which could change over time (Doran and Zeiss, 2000). Studies in different types of systems were able to improve the efficiency of N use such as: crop rotation (Gill, 2018), use of inoculants or biostimulants (Adesemoye et al, 2009), manure incorporation with mineral fertilizer (Duan et al., 2016). In the group of plant biostimulants are classified substances with different properties and mechanisms of activity and humic substances are important part of the group (Calvo, et al., 2014).

Properties of Humic Substances

The humic substances are naturally present in the soils as part of the soil organic matter and in the water sources they appear due to the breakdown of animal and plant residues. The humic substances are classified as humic, fulvic acid and humins on the basis of their solubility in water and its pH. The fulvic acids are compounds which are highly soluble in water irrespectively to its pH, the humic acids are soluble at the pH values higher than 2 and humin substances are insoluble at all pHs (MacCarthy et al., 1990; Jones and Brian, 1998). Their elemental composition varies depending of their source material. As an effort to find a general elemental composition Rice and Maccarthy (1991) used statistical tools and elemental composition data from 650 samples of humic substances and have suggested the following ratio for the main elements. For humic acids the ration of C, H, N, S, O, was 55.1; 5.0; 3.5; 1.8; 35.6for fuvic acids , 46.2; 4.9; 2.5; 1.2; 45.6, and for humins 56.1; 5.5; 3.7; 0.4; 34.7, respectively.

The humic substances are depicted as dynamic entities arising from the intricate breakdown of organic materials. Their self-assembly results in a heterogeneous composition, characterized by a multitude of small molecules, as described by the supramolecular theory of the structure of HS in aqueous solution (Figure 1) (Simpson, 2002).

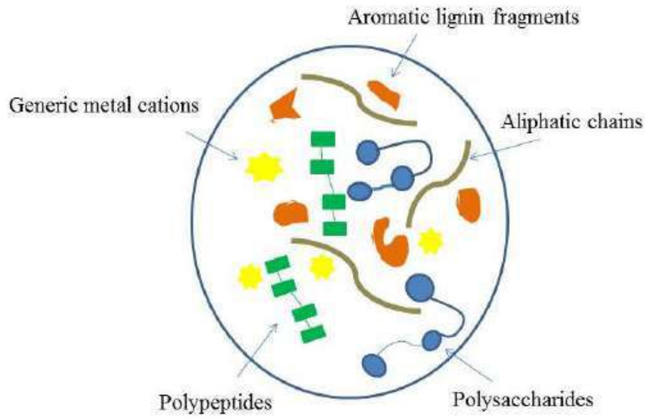

Figure 1. Humic acid structure Simpson (2002)

These supramolecular characteristics of humic acids are consistent across various sources, with the behavior of humic acids in solutions being largely independent of the origin matrix. The only noticeable variations involve minor shifts in measured distributions, indicating a tendency for slightly larger particles with higher molecular weight in some cases or smaller particles with lower molecular weight in others (Širůček, et al., 2021). Klučáková (2018) detected two to three fractions with different size. The large macroparticles were with a size larger than 1 μm, the medium fractions in fulvic submicroparticles have, an average, diameters of 500–1.200 nm, and in humic acids even smaller - 300–600 nm. The small nanoparticles (<100 nm) were detected mainly in alkaline solutions. In comparison to other humic acids, the fulvic acids can form more easily bigger particles with more functional groups. The colloidal humic acids are more stable but the stability of fulvic acids could increase with increase of the pH values. In general, the increase in particle size of humic acids is usually associated with a higher stability. The structure of humic and fulvic acids are linked to the organic matter from where they have been extracted. As an example, under some conservation technologies such as no-till, the aromatic and aliphatic chemical structures of the aggregates were very well preserved (Machado, et al., 2020).

The soil humic acids also can bound iron ions and this interaction depends on soil pH. This binding capacity was estimated to be 2-fold higher at pH 7 than at pH 5 with average values of 117 and 57 cmol/kg, respectively (Boguta et al., 2019). The humic acids are promising for sustainable management of heavy-metal polluted soils as they can significantly decrease the availability of Cu, Cd, Pd, and Zn. They also could modify soil properties such as soil pH, electrical conductivity total organic carbon, water-soluble organic carbon, and nitrate-nitrogen ratio (Zhao et al., 2022).

Humic and fulvic acid as biostimulants

The natural formation of humic substances in soil is a lengthy process and it depends highly on the presence of organic materials. The soil analysis performed in a sandy soil land, poor in organic matter and unused for a period of 30 years showed that there were no changes in the elemental and/or fractional composition of humic substances (Mielnik et al., 2021).

The development of products based on sustainable sources of humic substances (e.g. organic wastes) is necessary since most of the humic substances used in agriculture are currently derived from non-renewable resources like coal and peat (Canellas, et al., 2015). However, the humic substances are not only natural but could be extracted from various sources and even engineered (Yang, et al., 2021). Such options make humic acids more available for application in agriculture.

The use of humic and fulvic acids as plant biostimulants is related to their positive effects on plant growth and utilization of nutrients (Table 1). They play an important role as growth promoters due their biological activity in plants. Their functional groups trigger responses in plants physiology similar to activity of phyto-hormones. The humic substances affect mainly the plasma membrane H+ ATPases, nutrient transporters, cell division and hormone routes. The induction of the H+ ATPases activity made by humic substances energizes secondary ion transporters and promote nutrient uptake (Nardi et al., 2021). The humic acid application has been shown to improve growth and antioxidant activity of yarrow (Achillea millefolium L.) resulting in 80% increase in shoot dry mass when compared to the control treatment, and the phenolic content of leaves treated with 5 kg ha-1 of HA were 59% higher when compared to the control treatment (Bayat et al., 2021).

The source material for obtaining humic acids can affect their biological activity. As an example, the leonardite which is an important raw material used to manufacture products rich in humic and fulvic acid, did not affect significantly the growth and nutritional parameters in the study with pot grown olive (Arrobas, et al., 2022). The humic and fulvic acids obtained from leonardite alone does not seems to have effects on plants, but when applied together with mineral fertilizers they can improve some of the nutrients uptake. Lüdkte et al. (2021) found that when humic and fulvic acids were applied together with mineral fertilizers they provided the greatest increase in the studied parameters such as: plant height and diameter, leaf number per plant and root length. The improved uptake of K and Fe by lettuce and their accumulation in the aerial parts were observed in the same study (Lüdkte et al., 2021). Although the high number of studies included leonardite (brown coat) as the main source of HS, their results did not imply that it is the most efficient source of HS. According to Rose at al. (2014) for both root and shot growth response, brown coat and peat were less efficient sources of humic substances when compared to green waste compost, manure compost and soil sources of HS.

Foliar application of humic acids is reported to increase the yield of diverse crops like canola, chilli and table grape (Ferrari and Brunetti, 2008; Sani, 2014; Jan et al., 2020). Apart from the yield the foliar application of humic acids resulted also in a higher production of anthocyanin and phenol contents in olive trees. Additionally, the HS combination with amino acids resulted in changes in the oil, protein and chlorophyll content, and boosted the activity of antioxidant enzymes in the olive trees (Nargesi et al., 2022).

Table 1. Effects of humic substances on plant growth and yield

Plant	Application	Concentration	Source of humic substance	Effect	Reference
Tomato	soil and foliar	10 ml/l and 20 ml/l	commercial product	higher yield	Yildirim, 2007
Maize	hydroponic solution	0, 10, 20, and 50 mg C/L	weathered coal	increase uptake of N, P, and K of seedlings	Jing et al., 2020
Letuce	hydroponic solution	100, 1000 $mg.L^{-1}$	humus forest soil	increased photosynthetic activity	Haghighi et al., 2012
Pepper, tomato, watermelon, and lettuce	mixed with growing media	1% by volume (v/v)	lignite-derived solid	mitigate yield decreases	Qin and Leskovar, 2020
Soybean	Soil	5 kg ha^{-1} at sowing + foliar application	vermicompost (0.2%)	higher grain and haulm yield and nutrient uptake of N, P, K	Savita and Girijesh, 2019
Basil	Soil	0.02, 0.10 and 0.20 $g.kg^{-1}$	humified green compost	increase bioactivity and antibacterial properties of essential oils in leaves	Verrillo et al., 2021
Wheat	soil and foliar	5.04, 7.56 & 10.08 $kg.ha^{-1}$; 1.0, 2.0 and 4.0 $g.L^{-1}$;	commercial product	improve nutritional status and increase grain yield	Awad et al., 2022
Potato	soil	1 $g.kg^{-1}$	leonardite	increase growth and yield	Akimbekov et al., 2020
Onion	seedlings submersion	0.30 $g.L^{-1}$; 0.40 $g.L^{-1}$; 0.60 $g.L^{-1}$;	commercial product	increase yield	Gemin et al., 2019

The humic substances help to improve the rate of N taken by plants and they are potential strategy towards sustainable agriculture and soil health. The advantage of using humic and fulvic acids is that they are naturally found in soil, they are resources highly available, and they do not affect the soil fauna (Tahat et al., 2020).

Conclusions

The application of humic and fulvic acids presents an eco-friendly approach in sustainable agriculture. Their positive impacts on plant growth, soil health, and nutrient uptake warrant for further research about their application. As the agricultural community moves forward, emphasizing the development of products from renewable sources of humic substances in agriculture is about to expand.

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Microplastics in soil: A critical review of their effects on soil quality parameters

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Abstract
Microplastics (MPs) have emerged as a significant environmental pollutant, with particles measuring less than 5 mm in diameter introduced into the environment through various pathways. This review aims to systematically analyse the effects of microplastics on different soil properties, summarising the current knowledge on the occurrence and characteristics of microplastics in various soil environments. MPs have been found to alter the fundamental properties of the soil biophysical environment, with the extent of impact dependent on the type, size, shape, and concentration present in the soil. Specifically, MPs affect the physical properties of soil, including soil aggregate stability, bulk density, porosity, and water-holding capacity. Furthermore, the impact of MPs on soil fauna is evident, leading to a reduction in microbial activity and diversity in the soil. It is noteworthy that different types of microplastics exhibit varying effects on the soil, encompassing both positive and negative outcomes. These effects can cascade through food webs, influencing microbial functioning, nutrient cycling, and the overall soil ecosystem. By shedding light on the potential of MPs to alter fundamental soil properties and their subsequent implications for soil ecosystems, this review aims to provide a comprehensive understanding of the effects of MPs on soil quality parameters.

Keywords: Microplastics, Soil fauna, Soil pollution, Soil properties, Physical properties of soil, Soil quality parameters

Introduction

Microplastics (MPs) have emerged as one of the most concerning environmental pollutants in recent years, with their prevalence in various ecosystems posing a hazard to both environmental and human health. Microplastics are plastics with sizes ranging from 5mm to 1μm. Microplastics are classified into two types: primary microplastics and secondary microplastics. Primary microplastics are those produced in small sizes for uses, whereas secondary microplastics are created when larger plastic waste fragments due to external factors (de Souza Machado et al., 2018). Microplastic pollution is prevalent in various soil environments, including agricultural/farmland, greenhouse, home garden, coastal, industrial, and floodplain soils (Hirt and Body-Malapel, 2020). Microplastic loadings in European agricultural land are predicted to vary from 63,000 to 430,000 tonnes per year, with recorded concentrations ranging from 700 to 4000 plastic particles per kilogram of soil by dry weight (Boots et al., 2019). Compost, agricultural mulching, sewage sludge, and littering have all been recognized as substantial sources of microplastics in agricultural soils (Yu et al., n.d.). Soil microplastics can come from industrial activities, sewage sludge, synthetic textiles, tire wear, roadside debris, plastic packaging, and personal care products (Horton et al., 2017). As MPs are persistent and have the potential to affect soil quality and biodiversity, there is rising worry about their accumulation in terrestrial ecosystems. MPs are widely distributed and may have ecological effects because they have been found in a variety of environmental systems, including soil, freshwater systems, and agricultural fields (Henseler et al., 2022; Lin et al., 2020a; Zhao et al., 2021). MPs in soil have been demonstrated to impact soil pH, reduce microbial activity, and affect soil aggregation, affecting soil quality and health (Liu et al., 2023). Furthermore, MPs have been reported to harm soil fauna while increasing microbial activity, showing complicated ecological effects on terrestrial ecosystems (J. Zhang et al., 2021).

Occurrence and characteristics of microplastics in soil

Microplastics come from a variety of sources, which contributes to their common occurrence in a variety of environments. MPs are mostly intentionally produced tiny plastic particles such as pre-production pellets, cosmetic microbeads, glitters, and stabilizers (Malankowska et al., 2021; Napper et al., 2015). Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyamide (PA6), Polyester, and Polyvinyl Chloride (PVC) are some of the most prevalent plastics detected as MPs (Hu et al., 2022; X. M. Zhang et al., 2022). These MPs contribute to environmental contamination because they are intended to be smaller and are released directly through wastewater. Furthermore, synthetic textiles—which shed many microfibers during regular washing—are a significant source of primary MPs in aquatic environments. In addition, everyday products like plastic packaging can also contain primary MPs, which may pose a risk to the environment (De Falco et al., 2020; Hwang et al., 2020a). Secondary MPs, on the other hand, are formed from the fragmentation of bigger plastic materials, including macroplastics that enter the environment through spills or wastewater. These secondary MPs are created when larger plastic residues break down by chemical, physical, and biological fragmentation and are then released into the environment (Duis & Coors, 2016; Hwang et al., 2020b). Littering, street runoff, atmosphere deposition, wastewater irrigation, and the application of soil additives such as compost made from biowaste or sewage sludge are all pathways for MPs to enter soil habitats (Möller et al., 2020; Müller et al., 2020). Plastic waste, which breaks down into smaller particles, is a key source of secondary microplastic particles in the soil (Hwang et al., 2020b). MPs can vary in composition, size, form, and surface characteristics, influencing their behaviour and interactions in soil environments. MPs in the soil can change soil properties, affect plant performance, and impact the soil's biophysical environment. MPs have been proven in studies to influence soil pH. (Zhao et al., 2021), for example, discovered that MPs can increase soil pH, causing changes in soil characteristics depending on the type of microplastic.

Effects of microplastics on soil physical properties

Microplastics have the potential to alter the physical characteristics of soil drastically. Studies have proven MPs can alter soil properties such as bulk density, water retention capacity, soil aggregation, and soil permeability. MPs change the bulk density of soil, reflecting changes in compaction and porosity. The lower specific density of plastic particles reduces bulk density by substituting the volume of a weight-equivalent part of soil with lighter MPs. This indicates that MPs may alter soil structure and bulk density by substituting soil volume with lighter plastic particles, increasing porosity and aeration. MPs can reduce water-stable aggregates, impairing soil structure and perhaps limiting the diversity of soil microenvironments (De Souza Machado et al., 2018). It has been found that MPs of high-density polyethylene (HDPE) and polylactic acid (PLA) may interfere with the stability and production of bigger macroaggregates by causing direct changes within the soil's binding processes (Boots et al., 2019). (Lozano et al., n.d.) demonstrated that MPs reduced soil aggregation, resulting in lower oxygen diffusion inside soil pores and effects on water flows. Microplastic fibres have a detrimental impact on soil aggregate stability, but microplastic beads and particles have a mixed influence on soil aggregation (Lehmann et al., 2021). The study by (Lozano et al., n.d.) discovered that MPs of all forms and polymer types reduced soil aggregation by around 25%. The findings revealed that the impacts of MPs on plant characteristics and soil physical and biological qualities were considerably affected by polymer type and shape rather than concentration. Overall, soil MPs improved shoot and root mass by 46% and 48%, respectively, while lowering soil aggregation and microbial activity by 25% and 6%, respectively. The incorporation of MPs into soil increased contact angle and saturated hydraulic conductivity while decreasing bulk density, water storage capacity, and soil permeability (Yu et al., n.d.). MPs in soil can cause changes in soil physical properties, affecting plant performance, soil carbon mineralization, and soil erosion. Furthermore, the presence of MPs in soils might influence soil macro- and microporosity, the nitrogen cycle, and plant performance, ultimately jeopardizing the sustainability of agroecosystems (Maqbool & Gómez, 2023).

Effects of microplastics on soil fauna

Microplastics in soil can substantially impact soil fauna, potentially affecting soil biodiversity and ecosystem function. MPs in soil have been discovered to have a variety of effects on soil respiration, including changes in soil pH, microbial activity, enzyme activity, and ecosystem multifunctionality. Microplastic form, polymer type, exposure time, and interactions with other contaminants all have an impact on these consequences. MPs alter the functional connection between microbial activity and water-stable aggregates, implying possible implications for soil enzyme activities and nutrient cycling (De Souza Machado et al., 2018). The presence of MPs has been related to a decrease in the diversity and richness of bacterial communities, as well as a decrease in the stability and complexity of soil microbial networks, including connectivity, network size, and the number of module and keystone species (Shi et al., 2022). (Lozano et al., n.d.) found a drop in microbial activity, notably with 0.4% polyethylene (PE) films, which could be linked to decreased soil aggregation and the effects on water flows. Furthermore, adding MPs affects the microbial community structure and increases soil carbon dioxide emissions in vegetable-growing soil (Gao et al., 2021). (Kim et al., 2020) found that polyethylene terephthalate (PET) fragments and polyacrylic nitrile (PAN) fibres showed the highest toxicity. In contrast, high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS) fragments induced relatively less adverse effects on nematodes. Changes in soil hydrologic characteristics due to MPs may alter soil microbial biodiversity, with implications for nutrient cycling and soil respiration. Microplastic fibres can influence enzyme activity, which could impact soil biodiversity (Liang et al., 2021). The presence of MPs in soil has been shown to change the structure of the microbial community, promote soil carbon dioxide emissions, and influence soil N2O emissions (Gao et al., 2021). Furthermore, it has been discovered that the impact of MPs on soil enzymes, respiration, and ecosystem multifunctionality depends on soil water conditions (Lozano et al., 2021). A study in which different types of MPs (biodegradable polylactic acid (PLA) and conventional high-density polyethylene (HDPE)) were added to soil containing earthworms and perennial ryegrass discovered that, MPs changed plant development, earthworm health, and basic soil parameters, potentially altering soil ecosystem functioning. The biomass of Aporrectodea rosea (rosy-tipped earthworm) exposed to HDPE was considerably reduced compared to control samples (Boots et al., 2019). In a Study, it was discovered that Eisenia fetida were affected by the toxic accumulation of polyurethane foam microparticles (3.9-33.4 µm) in their bodies (Gaylor et al., 2013). Toxic effects of low-density polyethylene (LDPE) microplastics (150 µm) on Lumbricus terrestris have been shown by the death of the organism (Huerta Lwanga et al., 2017). When Eisenia andrei was exposed to Polyethene microplastics (250-1000 µm), the immune system was damaged (Rodriguez-Seijo et al., 2017). In Nematode, cholinergic and GABAergic neurons were damaged by polystyrene microplastics (1-5µm) (Lei et al., 2018). Collembolan exposed to PVC microplastic (80-250µm) exhibited restricted mobility (Kim and An, 2019). PET fibre (1257.8 µm) influenced the oxidative stress of Achatina fulica snails (Song et al., 2017). PS residues (0.1-500µm) were found to produce oxidative damage in Caenorhabditis elegans (Lei, Wu, et al., 2018). LDPE Particles (300µm) boosted the addition of PAHs as well as PCBs in Eisenia fetida (Wang et al., 2019). MPs have also been found to have a deleterious impact on soil fauna while stimulating microbial activity, which could influence soil carbon and nitrogen cycling and, hence can reduce plant growth and nutrient uptake. This indicates that MPs may limit the buffering capacity of plants to mitigate changes in soil nutrition (Bansal & Singh, 2022; Lin et al., 2020b).

Effects of microplastics on soil food webs

Soil property changes due to MPs can have a cascading effect on the soil food web, affecting the habitat and resources accessible to soil organisms (De Souza Machado et al., 2018). A microcosm experiment to explore the interaction effects of MPs and drought on soil microbial, protist, and nematode populations in the soil micro-food web discovered that dryness may ameliorate the deleterious impacts of MPs on the complexity and stability of the soil micro-food web. This suggests that intricate interactions between environmental stressors and microplastic contamination can alter soil food webs (de Souza Machado et al., 2018). MPs might alter plant diversity and community composition by influencing soil structure and microbial diversity. These plant community changes can have direct and indirect consequences on the soil food web, impacting resource availability and habitat for soil organisms (Sharma et al., 2023). MPs build in soil and are consumed by soil organisms such as protists and soil fauna. Ingestion of MPs by soil biota raises concerns regarding microplastic transmission across the soil food chain and the potential for negative impacts on soil organisms (Kanold Eric et al., n.d.; Maxwell Helmberger S et al., n.d.). (Yao et al., 2023) emphasized the impact of MPs on the soil metabolome and their impact on the formation of the eco-corona and adsorption processes on microplastic surfaces. This shows that MPs can operate as pollutant sources, sinks, or vectors, influencing the bioavailability and fate of contaminants to plants and soil-dwelling creatures and potentially disrupting the soil food web.

Conclusion

Microplastics have been shown to affect soil health and ecosystem functioning by influencing numerous physical and chemical properties of soil. MPs alter the biophysical properties of soil like bulk density, soil aggregate stability, soil permeability, porosity, soil microbial activity, and enzyme activity, but the intensity depends on the type, concentration, and shape of MPs. In isolation, MPs may not be the most harmful (lethal or sublethal) environmental pollutant. However, there are continuous historical, present, and future tendencies worldwide of rising near-permanent plastic contamination of natural habitats (Geyer et al., 2017). According to the current research, soil contamination with MPs is a major concern because it affects not only soil physicochemical properties but also flora and fauna. However, very few studies in this field limit our understanding of the effects of MPs on soil, plants, and crops. Given the growing amount of microplastic pollution in soils worldwide, the impact of diverse forms of MPs (e.g., different polymer types, shapes, and sizes) on belowground biota and their associated ecological functioning deserves careful consideration. Future research on the effects of MPs on soil ecosystems should focus on key areas to better understand and mitigate possible hazards to soil health and sustainability. These future directions should underline the significance of MPs as a serious environmental concern, emphasizing filling information and understanding gaps about their effects on soil ecosystems.

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The effects of *Azotobacter chroococcum* inoculation on some microbiological characteristics in soils with different organic waste added

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Abstract
In this study analyzed, with a greenhouse test, the impact of Azotobacter chroococcum indigenous isolate inoculation on the microbial respiration and microbial biomass C content of soils with different organic waste added. For this purpose, wheat straw, rice straw, tobacco waste, soybean stem were used as organic waste while RK49 race was used as the indigenous A. chroococcum isolate. 5% over dry weight doses of organic wastes was added to loamy soil within pots of 5 kg, and afterwards, the soils were inoculated adding 10 ml of A. chroococcum isolate from liquid culture (109 CFU/ml). The seeds of wheat (Triticum aestivum) were planted manually to each pot (15 pieces/pot). The test lasted for 124 days. The microbial respiration (BSR) and microbial biomass C (Cmic) contents of soil samples obtained from each pot was determined at the end of harvest, and changes in microbiological characteristics of soils caused by the applications were analyzed. At the end of the experiment, it was determined that the BSR and Cmic content of the soils increased considerably as a result of the application of different organic materials. It was also determined that the BSR and Cmic content increase of the soils inoculated with A.chroococcum RK49 isolate besides different organic wastes was higher than that of soils without inoculation. While the highest BSR content was attained in tobacco waste application in soils without A.chroococcum RK49 isolate inoculation, the highest Cmic content was determined where A.chroococcum RK49 was inoculated with tobacco waste.
Keywords: Organic Waste, Azotobacter Chroococcum, Soil Respiration, Microbial Biomass

Introduction

Organic matter is extremely important for the physical, chemical and biological properties of the soil, for soil quality and fertility, and for the nutrition of soil microorganisms (Coşkan et al. 2006; Kacar, 1986). A closely relationship between organic matter and soil microorganisms activity in the soil. Organic materials added to the soil will create a food source for the heterotrophic microbial population (Yan et al. 2003; Kızılkaya et al. 2010; Durmuş and Kızılkaya 2022). Plant residues of agricultural origin, animal residues, urban and agricultural industry residues are widely used in agriculture as organic matter (Çakmakçı, 2005).

Free-living bacteria are dependent on soil organic matter as a food source, their activities increase in appropriate environmental conditions, and they perform important biological events for soil such as nitrogen fixation and P solubility (Çakmakçı, 2005). Azotobacter is a free living N_2 fixing bacterium. It can successfully grow in the rhizospheric zone of wheat, maize, rice, sorghum, sugarcane, cotton, potato, brinjal, cabbage and many others and fix 10-20 kg N ha^{-1} cropping $season^{-1}$ (Jadhav et al., 1987). Azotobacter sp. is an aerobic bacterium that lives freely in the soil (Kızılkaya et al. 2010), and the most common known species is A. Chrooccum (FAO, 1982).

In this study, the effects of some organic wastes on soil respiration and microbial biomass carbon were investigated by applying together with Azotobacter chroococcum and without Azotobacter chroococcum inoculation.

Material and Methods

Experimental Soil

The soil used in the greenhouse experiment was taken from the agricultural land in the Bafra district of Samsun. Soil samples were then air-dried and passed through a 2 mm sieve, and soil texture was determined by the hydrometer method, soil reaction (pH) and electrical conductivity (EC) in a 1:1 soil-pure water suspension were determined by pH meter and EC meter, respectively, soil organic matter (SOM) by the modified Walkley–Black method, $CaCO_3$ was determined by Scheibler calcimetric method, all soil properties were determined according to Rowell (1996).

Organic wastes

Wheat straw, rice straw and soybean straw were collected during the grain harvest season. Tobacco waste was taken from the tobacco production industry. All organic wastes were dried and sieved into less than 0.50 mm. The properties of the organic wastes were expressed on a dry weight basis and were analyzed by standart procedures as given in Ryan et al. (2001).

Azotobacter Chrococcum

Indigenous Azotobacter chrococcum RK49 strain was provided by the Soil Microbiology Laboratory in Ondokuz Mayis University, Samsun, Türkiye. The indigenous Azotobacter chrococcum RK49 strain were cultivated by nitrogen-free Ashby medium. Pure culture of indigenous Azotobacter chroococcum RK49 strain used for inoculation were grown in N-free Ashby agar at 30 °C. A single colony from each strain was transferred to a 50 mL flask, containingnitrogen anda gar free Ashby medim, and grown aerobically in flasks 72 hours, on a rotating shaker (125 rpm) at 30 °C. Azotobacter chroococcum strain grown liquid Ashby medium was then diluted with sterile distilled water, containing 0.0025% tween 20 to a final concentration of 109 CFU mL^{-1}. For seed treatments, wheat seeds were placed in bacterial suspensions of 109 CFU mL^{-1} for 30 min before sowing under sterilized conditions and then transferred unsterilized soil.

Experimental Design

This study was conducted as a pot trial in a greenhouse under controlled conditions. The greenhouse experiment consisted of a total of 90 pots (10 treatments, 3 replications = 30 pots). Application subjects consisted of control (C), wheat straw (5%), rice straw (5%), tobacco waste (5%), soybean straw (5%), wheat straw 5% + A. Chroococcum (10 ml – 109 CFU/ml), rice straw 5% + A. Chroococcum (10 ml – 109 CFU/ml), tobacco waste 5% + A. Chroococcum (10 ml – 109 CFU/ml), soybean straw 5% + A. Chroococcum (10 ml – 109 CFU/ml) and A. Chroococcum (10 ml – 109 CFU/ml). Each flowerpot was filled with 4 kg of dry soil, and 15 piece/pot the seedlings were planted (Triticum aestivum) by bringing the moisture content of the soil to the level of the field capacity.

Soil Biological Analyses

Microbial biomass carbon was determined by the substrate-induced respiration method by Anderson and Domsch (1978). A moist sample equivalent to 10 g oven-dried soil was amended with a powder mixture containing 40 mg glucose. The CO_2 production rate was measured hourly using the method described by Anderson (1982). The pattern of respiratory response was recorded for 4 h. MBC was calculated from the maximum initial respiratory response in terms of mg C g^{-1} soil as 40.04 mg CO_2 g^{-1} + 3.75. Data are expressed as mg CO_2-C g^{-1} dry soil.

Basal respiration at field capacity (CO_2 production at 22 °C without the addition of glucose) was measured, as reported by Anderson (1982); by alkali ($Ba(OH)_2 8H2O$ + $BaCI_2$) absorption of the CO_2 produced during the 24 h incubation period, followed by titration of the residual OH− with standardized hydrochloric acid, after adding three drops of phenolphthalein as an indicator. Data are expressed as mg CO_2 g^{-1} dry soil.

Results and Discussion

The experiment soil is clay loam texture, slightly alkaline (7.40–7.90), salt-free (0.98–1.71 dS/m), medium organic matter (2.10-3.00), medium lime content (5–15) (Table 1).

Table 1. Some properties of experiment soil.

Soil properties	Value
Clay %	34.60
Silt %	31.93
Sand %	33.47
pH	7.52
EC (dS/m)	0.84
Organic matter %	2.44
$CaCO_3$ %	6.27

Among the organic wastes used in this study, wheat straw had the highest organic matter while that of tobacco waste was the lowest. Regarding N content, tobacco waste had the highest N content (1.93%) and the lowest N content belong to wheat straw (0.48%). C:N ratio of the organic wastes ranged from 22 to 100 and the highest-level C:N ratio observed in wheat straw while that of lowest is tobacco waste. The order of organic waste associated with C:N ratio was Tobacco waste > Rice waste > Soybean waste > Wheat straw. In addition these OW contained major nutrients such as P, K and Ca which are agronomically important.

Table 2. Composition of organic wastes in measured variables

Organic Material	OM %	C %	N %	C/N	P %	K %	Ca %
Wheat straw	82.75	48.00	0.48	100	0.10	2.81	0.41
Soybean waste	88.00	51,04	0.58	88	0.06	3.77	0.55
Rice Waste	78.00	45.24	0.52	87	0.08	2.17	0.21
Tobacco Waste	73.20	42.46	1,93	22	0.18	3.66	2.86

Basal Respiration (BR) (μgCO2/g-soil/24h)

When the results were evaluated, it was observed that the highest increase occurred in the application of tobacco waste without A. Chrooccum inoculation. The least increase occurred in pots, inoculated with A. Chrooccum without adding organic waste and on the A. Chrooccum applied with rice straw (rice straw + *Azotobacter Chroococcum RK49*).

Table 3. Results of Basal Respiration

Applications	Basal Respiration (μgCO_2/g-toprak/24h)
Control	1310,28 ∓ 91,35 bc
Wheat straw	1366,30 ∓ 189,22 bc
Tobacco waste	2845,89 ∓ 441,67 a
Rice waste	1216,29 ∓ 120,86 bc
Soybean waste	1560,57 ∓ 98,37 b
Wheat straw + *A. Chroococcum RK49*	1770,01 ∓ 364,08 b
Tobacco waste+ *A. Chroococcum RK49*	1156,47 ∓ 30,16 bc
Rice waste + *A. Chroococcum RK49*	841,02 ∓ 129,11 c
Soybean waste + *A. Chroococcum RK49*	1135,39 ∓ 23,03 bc
Azotobacter Chroococcum RK49	686,69 ∓ 105,34 c

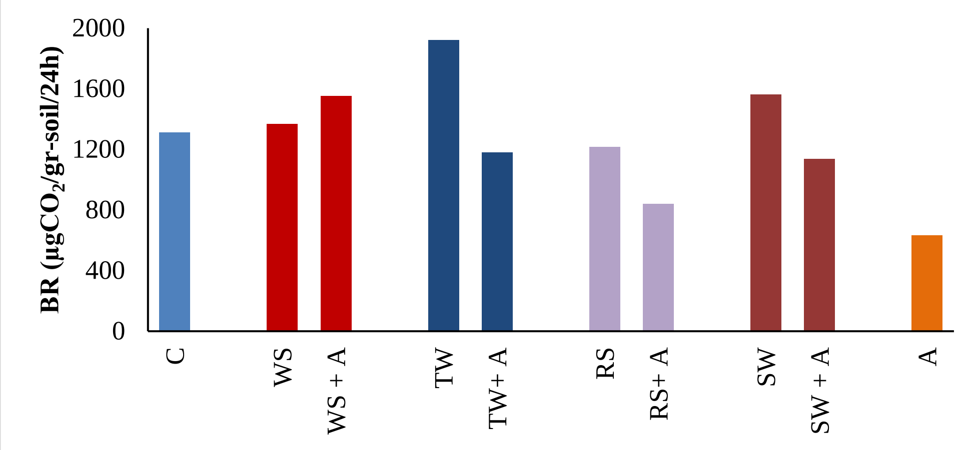

Figure 1. Results of Basal Respiration. C: Control, A: Azotobacter Chroococcum RK49, WS: Wheat straw, TW: Tobacco waste, RS: Rice waste, SW: Soybean waste

In a study investigating the effects of tobacco waste, farm manure and mineral fertilizers on the basal respiration; it was determined that the highest CO_2 value occurred in tobacco waste application (Kara, 1996). In a study where tobacco waste and barn manure were used without composting for the production of vermicompost; It was found that the highest CO_2 value at the end of the vermicomposting process was in the non-composted tobacco waste (Kayıkçıoğlu et al., 2016).

According to the analysis results, it is seen that the highest MBC value is in Tobacco Waste + A. Chroococcum RK49 application. The lowest MBC values were determined in Rice Straw + A. Chrococcum RK49 and Rice Straw + A. Chrococcum RK49 applications.

Table 4. Results of Microbial Biomass Carbon

Applications	MBC (mgCO_2-C/100 gr Soil)
Control	531,55 ∓ 15,52 *d*
Wheat straw	804,27 ∓ 81,68 *bcd*
Tobacco waste	996,29 ∓ 89,84 *ab*
Rice waste	1036,59∓137,43 *ab*
Soybean waste	880,54 ∓ 71,03 *abc*
Wheat straw + *A. Chroococcum RK49*	963,05 ∓ 102,98 *ab*
Tobacco waste+ *A. Chroococcum RK49*	1151,62 ∓ 21,75 *a*
Rice waste + *A. Chroococcum RK49*	779,60 ∓ 146,71 *bcd*
Soybean waste + *A. Chroococcum RK49*	952,50 ∓ 184,05 *ab*
Azotobacter Chroococcum RK49	604,59 ∓ 9,24 *cd*

In the study investigating the relationship between A. Chroococcum population of soils and MBC, it was determined that there was a positive relationship between MBC and A. Chroococcum (Kızılkaya, 2009).

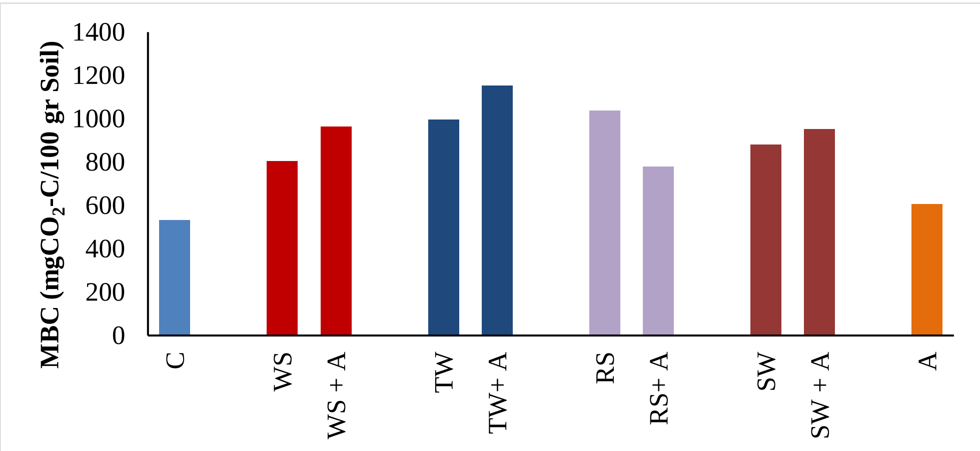

Figure 2. Results of Microbial Biomass Carbon. C: Control, A: Azotobacter Chroococcum RK49, WS: Wheat straw, TW: Tobacco waste, RS: Rice waste, SW: Soybean waste

Conclusion

When the effect of only organic wastes on soil respiration was examined without Azotobacter chroococcum, a serious increase in soil respiration occurred when tobacco waste was applied. This may be due to the low C:N ratio of tobacco waste. In MBC results, the highest increase occurred with rice waste, but tobacco waste and soybean waste showed similar results. In applications where organic wastes and azotobacter were given together, there was a significant increase in basic respiration only in the application of wheat straw + Azotobacter chroococcum, while decreases were found in other applications. When organic wastes and Azotobacter chroococcum were applied together, there was a significant increase in basal respiration only with wheat straw + Azotobacter chroococcum, while decreases were found in other applications. When organic wastes and Azotobacter chroococcum were applied together, there was a significant increase in MBC with tobacco waste + Azotobacter chroococcum. This study shows that type and structure of the wastes to be applied to the soil should be considered, because the added organic wastes have a direct effect on the biological and microbiological properties of the soils.

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Supervised classification of Sentinel-2A MSI data using GIS-based support vector machine and random forest algorithms

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Abstract

Determining the land use/land cover classes' current distributions and analyzing the changes in land use/land cover are the fundamental aspects of the studies made in many fields such as economy and socio-cultural. For this reason, land use/land cover needs to be classified systematically and produced at certain standards. With this study, we aimed to apply support vector machine (SVM) and random forest (RF) classification algorithms based on geographical information systems (GIS) for Ladik district. For the classification process, high resolution Sentinel-2A MSI was used to create 6 different land use/land cover classes as ''water bodies'', ''forests'', ''heathlands'', ''bare rocks'', ''agricultural lands'' and ''artificial surfaces''. As a result, it has been observed that both SVM and RF classification algorithms gave the same results for overall accuracy (86%) and kappa coefficient (0.83). Within the context of our study, the SVM and RF classification algorithms achieved the highest precision (SVM:1.00, RF:1.00) and F1-score (SVM:0.98, RF:0.94) for the ''water bodies'' class. Simultaneously, the sensitivity (recall) metric exhibited its peak values for the ''artificial surfaces'' class in both SVM (0.96) and RF (0.96) classifications. The study's findings suggest that Sentinel-2A MSI, in combination with SVM and RF classification algorithms, provides reliable results for monitoring land use/land cover for the study area.

Keywords: Sentinel-2A MSI, Random Forest, Support vector machine, Supervised classification, Land use/land cover classification, Geographical information system

Introduction

The studies related with land use/land cover and change detection are being made generally to make the spatial usage appropriate and sustainable. It's important to identify and handle clearly the units belonging to the area for the land use studies. Although this kind of studies are done with remote sensing (RS) and GIS based on satellite imagery, controlling with soil survey studies and planning with on-site observation techniques are crucial. Studies conducted using RS technology are crucial for monitoring and efficiently utilizing agricultural lands in a sustainable manner, while also providing valuable insights for the formulation of agricultural policies. In particular, satellites are being designed and developed for purposes related to agricultural, natural land cover, and forestry (Üstüner et al., 2014). GIS are computer-aided systems designed for collecting, monitoring, analyzing, and visualizing spatial data. GIS offers a comprehensive suite of tools for monitoring, analyzing, processing, querying, and mapping objects and cases. RS and GIS are being used in many areas and disciplines as agriculture (Demir et al., 2018), ecology (Selim and Demir, 2018), transport, geology (Orhan et al., 2020) and planning.

In the literature, classification methods are typically categorized into two groups: supervised and unsupervised classification. Various machine learning methods, such RF, SVM, and CART, fall under these categories. Last twenty years, advanced methods as k-nearest neighbors (K-NN) (Samaniego et al., 2008), RF (Breiman, 2001), neural networks (Civco, 1993) and SVM (Melgani and Bruzzone, 2004) has been used for land use/land cover classification (Carranza- García et al., 2019). Our goal in this study was to perform pixel-based supervised classification of Sentinel-2A MSI data, creating land use/land cover classes, and assessing the accuracy and evaluation metrics of both classification algorithms for Ladik district using GIS-based SVM and RF algorithms.

Material and Methods

The study area, established on the foothills of Akdağ, at the 12th km of the Erzincan Road, which starts with the Toptepe (Doruk) junction on the Ankara-Samsun Highway, is 80 km away from the city center. Notably, its elevation of 950 meters above sea level sets it apart from other provinces in Samsun, giving it a unique climate and natural environment. Ladik is situated on the slopes of the northern part of Ladik plain, which is located along the North Anatolian fault line. It shares its borders with Taşova to the east, Havza to the west, Suluova to the south, and Kavak and Asarcık provinces to the north. Ladik covers an area of 596 km2 and has a population of approximately 16000. The basin is primarily characterized by agricultural lands and forests. The most significant agricultural products are grains, influenced by the district's climate. In addition to grains, there is a substantial presence of sunflower and non-commercial corn farming (Bahadır and Uzun, 2021). Agriculture is complemented by livestock, which serves as a crucial source of income. Cattle and buffalo are primarily raised in pasture areas, while sheep and goats are also prevalent in stock farming.

In this study, a Sentinel-2A MSI dated May 2021 of the Ladik district was used (Figure 1). Satellite image was obtained from the Copernicus Open Access Hub started in May 2017 (https://scihub.copernicus.eu/). Sentinel-2A MSI has a spatial resolution of 10 m in 4 bands, 20 m in 6 bands and 60 m in the other 3 bands (Table 1).

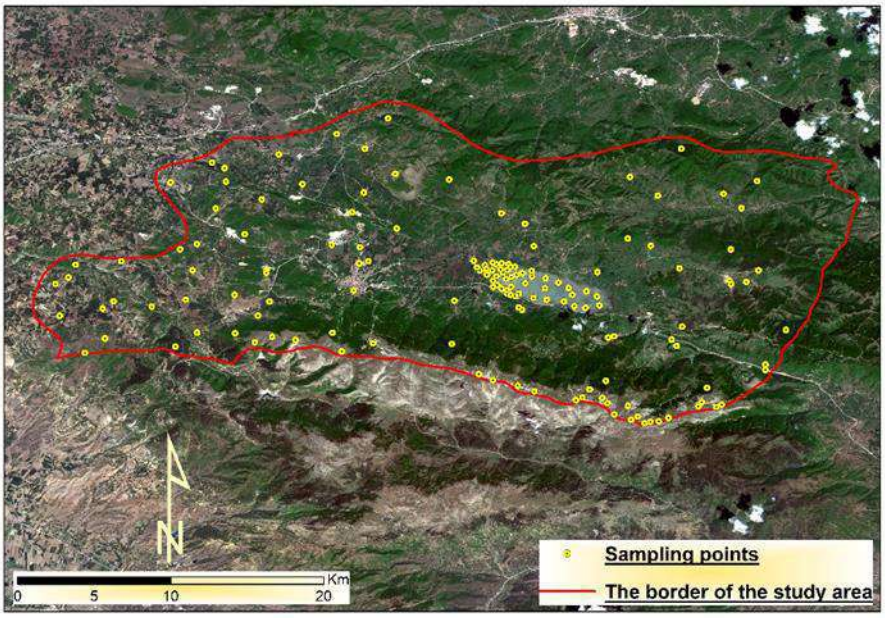

Figure 1. Sentinel-2A satellite image of 18th May of 2021

Table 1. Characteristics of the Sentinel-2A satellite sensor

Band	Band Name	Wavelength (nm)	Band Width (nm)	Spatial Resolution (m)
B1	Coastal Aerosol	443	20	60
B2	Blue	490	65	10
B3	Green	560	35	10
B4	Red	665	30	10
B5	Vegetation Red-Edge	705	15	20
B6	Vegetation Red-Edge	740	15	20
B7	Vegetation Red-Edge	783	20	20
B8	Infrared	842	115	10
B8A	Vegetation Red-Edge	865	20	20
B9	Water vapor	945	20	60
B10	Cirrus	1380	30	60
B11	Shortwave Infrared (SWIR)1	1610	90	20
B12	SWIR2	2190	180	20

Training and ground truth data

To get high accuracy results, it's important to create a training set with equally distributed ground truth data rather than using an excessively large set (Gumma et al., 2020). In this study, 25 ground truth data for each class, total 150 ground truth data has been chosen using Google Earth Pro. To construct the training set and land use/land cover classes for both SVM and RF classifications, ArcGIS 10.7v software was utilized. Overall, 6 classes were created for supervised image classification: ''water bodies'', ''forests'', ''heathlands'', ''bare rocks'', ''agricultural lands'' and ''artificial surfaces'' using the training set.

Classification algorithms

The reason for using SVM and RF classification algorithms in this study is that SVM and RF typically demonstrate better performance when compared to other conventional supervised classifiers (Khatami et al., 2016). SVM and RF classification algorithms are the latest progresses in the computational views of image classification. Having the skills to make the classification errors at minimum level, make SVM and RF classification algorithms more excellent compared the other parametric classifiers including maximum likelihood (Pal and Mather, 2005).

The SVM is a regression and supervised learning algorithm that was suggested in 1995, based on statistical learning theory and structural risk minimization (Tehrany et al., 2015). SVM operates on the principle of minimizing the upper boundary of generalization error, known as structural risk minimization in statistical learning theory. It aims to reach the minimum of the upper limit of the user's error probability by balancing between the training set and the capacity. The core approach in SVM is to identify a hyperplane that provides the best separation between the two classes. The algorithm aims to maximize the multidimensional space between the class clusters. This hyperplane is developed using the subset known as the training set, and its ability to generalize is verified using the independent subset called the test data.

In terms of supervised learning algorithms and regression tasks, RF is well-known in machine learning applications and its popularity is increasing (Cunningham et al., 2008). Method is relied on ensemble learning which leads to making use of the classifications for raising the model's performance and solving the more complex problem. RF, in particular, is a classification method that averages the decision tree's results trained on the different parts of the specific dataset (Rodriguez-Galiano et al., 2012). RF collects predictions of each decision tree, and its final prediction relies on a mostly voted decision tree instead of being dependent on a single tree. It provides superior predictive accuracy and minimizes the risk of model overfitting (Pouyan et al., 2021). Versatility of RF algorithms provides excellent performance for the categorization problems.

It's so crucial to build a confusion matrix which represents the quantitative accuracy assessment (Vikas and Suryanarayana, 2019). It can be analyzed which classification algorithm is more effective with the accuracy comparison. A confusion matrix is represented by a table that shows how classification results match the categories assigned to reference images, which are based on the actual categories in the reference data. ArcGIS 10.7v software was used for the classification and accuracy assessments. In this study, 6×6 confusion matrix transformed into a one-versus-all matrix (binary-class confusion matrix) to compute class-specific metrics such as accuracy, sensitivity (recall), precision and F1-score. Accuracy, sensitivity (recall), precision, and F1-scores were used as standard classification performance metrics to compare the success of the SVM and RF classification algorithms for each land use/land cover class. Definitions and explanations for each evaluation metric are provided in Table 2.

Producer's accuracy quantifies the probability that values in a particular class have been correctly classified.

$$Producer's\ accuracy = \frac{Area\ properly\ identified\ in\ a\ classification\ method}{Area\ in\ the\ reference\ ground\ truth} \quad (1)$$

The user's accuracy represents the likelihood that a predicted value assigned to a specific class indeed belongs to that class.

$$User's\ accuracy = \frac{Area\ properly\ identified\ in\ a\ classification\ method}{Total\ area\ calculated\ from\ the\ method} \quad (2)$$

The kappa coefficient assesses the concordance between classification and actual values. A kappa value of 1 signifies a complete agreement, whereas a value of 0 signifies no agreement (Lillesand et al., 2000).

$$Kappa\ coefficient = \frac{Observed\ accuracy - Expected\ aggreement}{1 - Expected\ agreement} \quad (3)$$

The overall accuracy is determined by dividing the number of correctly classified pixels by the total number of pixels in the confusion matrix.

Table 2. Performance metrics

Metric	Definition	Explanation
Sensitivity (Recall)	$\frac{TP}{TP+FN}$	The proportion of true positive samples that are correctly classified.
Precision	$\frac{TP}{TP+FP}$	The proportion of correctly classified samples among all the samples identified as positive.
F1-score	$\frac{2 * Precision * Sensitivity\ (Recall)}{Precision + Sensitivity\ (Recall)}$	Harmonic value of sensitivity and accuracy.

TP: True Positive, the number of positive samples that were accurately predicted as positive. TN: True Negative, the number of negative samples that were accurately predicted as negative. FP: False Positive, the number of negative samples that were predicted as positive samples. FN: False Negative, the number of positive samples that were predicted as negative samples.

Results and Discussion

Table 3 shows that both SVM and RF algorithms yield identical and satisfactory overall accuracy results of 86% and kappa coefficients of 0.83. Kappa coefficient ≥ 0.81 indicates perfect agreement between observers (Özdemir and Özkan, 2003; Çelik, 2006). Despite these matching overall accuracy and kappa coefficient results, differences are observed in user accuracy and producer accuracy for each algorithm. In the case of SVM, the user accuracy percentages (Table 3) indicate that water bodies, heathlands, bare rocks, agricultural lands, and artificial surfaces are classified with user accuracy percentages of 100, 100, 75.86, 71.43, 87.5, and 88.89, respectively. On the other hand, for RF, the user accuracy percentages are 100, 91.30, 74.19, 74.07, 90.48, and 92.31 for the water bodies, heathlands, bare rocks, agricultural lands, and artificial surfaces land use/land cover categories.

Table 3. Confusion matrices and classification methods accuracy based on ground-truth data

Support Vector Machine Classification

Classes	Ground truth Water bodies	Forests	Heathlands	Bare rocks	Agricultural lands	Artificial surfaces	Grand total	Us.Acc %
Water bodies	24	0	0	0	0	0	24	100
Forests	0	18	0	0	0	0	18	100
Heathlands	0	2	22	3	2	0	29	75.86
Bare rocks	1	3	2	20	1	1	28	71.43
Agricultural lands	0	2	1	0	21	0	24	87.5
Artificial surfaces	0	0	0	2	1	24	27	88.89
Grand total	25	25	25	25	25	25	150	
Prod.Acc. %	96	72	88	80	84	96		
Overall Acc.	86%							
Kappa Coe.	0.83							

Random Forest Classification

Classes	Ground truth Water bodies	Forests	Heathlands	Bare rocks	Agricultural lands	Artificial surfaces	Grand total	Us.Acc %
Water bodies	22	0	0	0	0	0	22	100
Forests	0	21	0	0	2	0	23	91.30
Heathlands	2	1	23	3	2	0	31	74.19
Bare rocks	1	2	1	20	2	1	27	74.07
Agricultural lands	0	1	1	0	19	0	21	90.48
Artificial surfaces	0	0	0	2	0	24	26	92.31
Grand total	25	25	25	25	25	25	150	
Prod.Acc. %	88	84	92	80	76	96		
Overall Acc.	86%							
Kappa Coe.	0.83							

Us; User, Prod; Producer, Acc; Accuracy, Coe; Coefficient

These results suggest that water bodies are classified with 100% user accuracy in both classification algorithms. Additionally, bare rocks, agricultural lands, and artificial surfaces are classified more successfully by the RF algorithm, while forests and heathlands are classified more successfully by SVM. If we look at producer accuracy results (Table 3), for SVM, water bodies, heathlands, bare rocks, agricultural lands, and artificial surfaces are classified with producer accuracy percentages of 96, 72, 88, 80, 84 and 96, respectively. Conversely, for RF, the producer accuracy percentages are 88, 84, 92, 80, 76 and 96 for the water bodies, heathlands, bare rocks, agricultural lands, and artificial surfaces classes.

According to Table 4, for SVM and RF classification algorithms, the forests class covered most of the study area for both classification algorithms, with percentages of 39.59% and 37.8%, respectively. Meanwhile, the water bodies class covered the study area the least for both classification algorithms, with percentages of 1.95% and 1.97%, respectively.

Table 4. The areal distribution of land use/land cover classes in the study area

	SVM		RF	
Classes	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)
Water bodies	1059	1.95	1068	1.97
Forests	21455	39.59	20465	37.8
Heathlands	8450	15.59	6906	12.74
Bare rocks	7669	14.15	7768	14.33
Agricultural lands	12654	23.35	14320	26.42
Artificial surfaces	2910	5.37	3670	6.77
Total	54197	100.0	54197	100.0

From Table 5, we can observe that for the water bodies class, precision and F1-score demonstrated the highest results for both the SVM and RF classification algorithms, while the sensitivity (recall) metric showed the highest values for the artificial surfaces class for both SVM and RF classification algorithms. The F1-score is determined by the harmonic mean of precision and sensitivity (recall), and it ranges from 0 to 1 where 0.7 are generally considered well-performing (Goutte & Gaussier, 2005). The closer the score is to 1, the more successful the results are deemed. However, the observation of low F1-scores in the land use/land cover classes indicates that it is misclassifying most of the minority class 'Yes', while overall accuracy may still be high (Alduayj and Rajpoot, 2018).

Table 5. Comparison of SVM and RF classification algorithms for each land use/land cover classes. The values in bold font indicate the best metric values

	Precision		Sensitivity (Recall)		F1-score	
	SVM	RF	SVM	RF	SVM	RF
Water bodies	1.00	1.00	0.96	0.88	0.98	0.94
Forests	1.00	0.91	0.72	0.84	0.84	0.88
Heathlands	0.76	0.74	0.88	0.92	0.81	0.82
Bare rocks	0.71	0.74	0.80	0.80	0.75	0.77
Agricultural lands	0.88	0.90	0.84	0.76	0.86	0.83
Artificial surfaces	0.89	0.92	0.96	0.96	0.92	0.94

Classification algorithms' outputs can be found in Figure 2 and Figure 3 for SVM and RF, respectively.

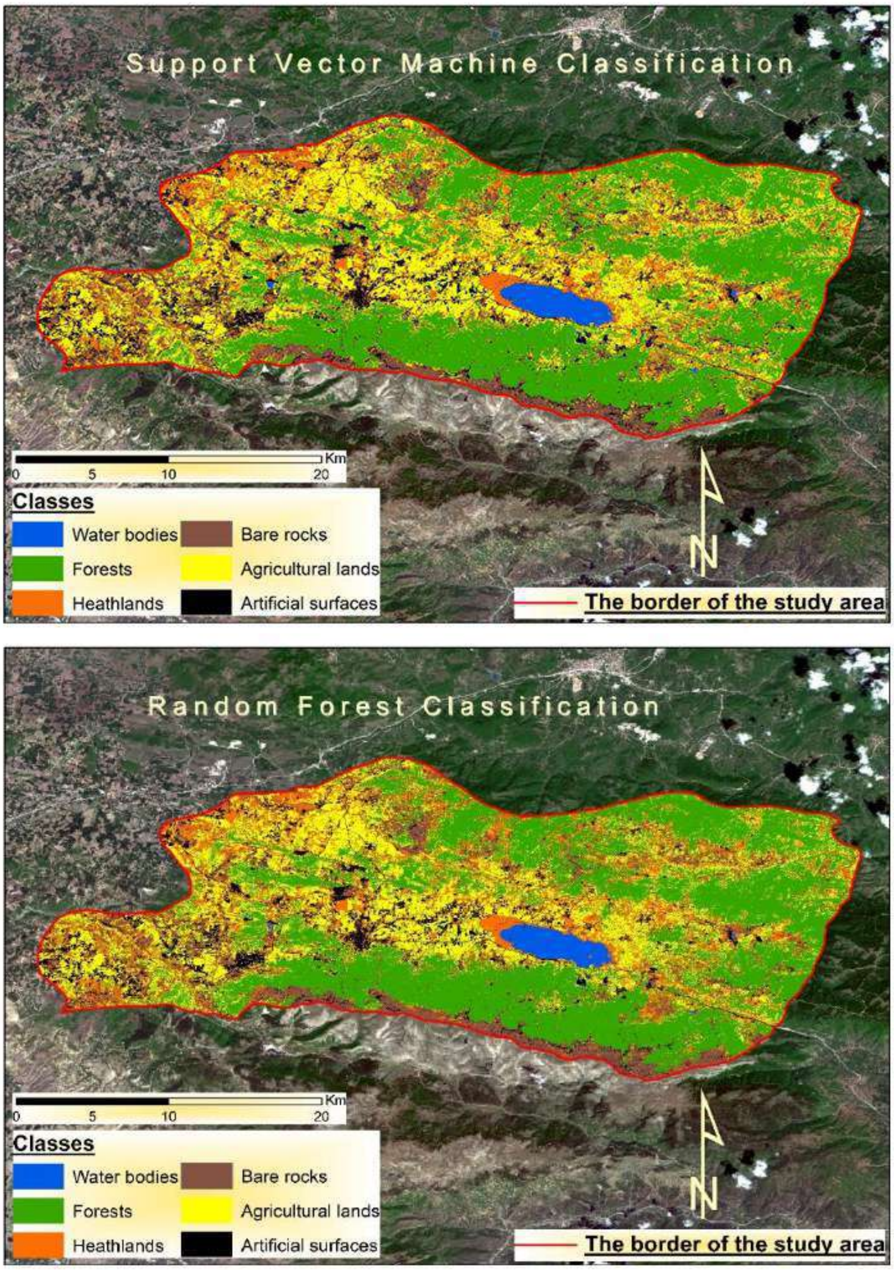

Figure 3. Supervised classification method output: RF classification

Conclusions

In this study, SVM and RF classification algorithms were applied to the study area to assess the performance of both classification algorithms. Both SVM and RF algorithms achieved identical results with an overall accuracy of 86% and a kappa coefficient of 83.2 using Sentinel-2A MSI data. The accuracy of both classification algorithms exceeded 80%, indicating their precision and reliability. Additionally, the kappa coefficient results, surpassing the 0.80 threshold, signify a perfect agreement between observers. The F1-score results mostly demonstrated promising outcomes overall, nearing the ideal value of 1. However, the observation of low F1-scores in the land use/land cover classes indicates that it is misclassifying most of the minority class 'Yes'. Addressing these challenges is crucial for enhancing the accuracy of land use/land cover classification for further studies.

Today's technology enables us to access a wealth of information in a shorter time. The combination of RS and GIS provides more accurate results for larger areas. The reliable outcomes of this study highlight that GIS can be successfully integrated with SVM and RF algorithms. This indicates the potential for developing these techniques as standard and efficient approaches for shaping agricultural policies.

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Estimation of weathering indices and determination of effective soil properties

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Abstract

Soil formation: It occurs as a result of dynamic events such as physical disintegration of rocks and minerals, their decomposition by chemical and biological events, and the recombination of some decomposed materials to form new compounds. Weathering indices are widely used in in situ formations and are also evaluated in determining soil development and soil fertility status. However, determining these parameters is long and laborious. For this purpose, in the study; Using the basic soil properties of soils formed on sedimentary rocks, soil properties effective on Chemical Alteration Index (CIA), Chemical Weathering Index (CIW) and weathering indices were determined. Additionally, using these features, predictability was examined with artificial neural networks (ANN). Soil properties affecting the CIA index were determined as Mg, K, organic matter, pH, silt, CaCO3. In CIW, these features were detected as Mg, silt, EC, CEC and clay. In prediction with ANN, both indices were predicted with approximately 91% accuracy. As a result of the study, it was demonstrated that weathering indices, which are difficult to determine, can be predicted by artificial neural networks using basic soil properties.

Keywords: Soil Formation, Pedotransfer Functions, Parent Material, Machine Learning

Introduction

Soil parent material has a significant direct influence on soil nutrient contents, which is more pronounced in young soils and decreases with increasing soil age and soil weathering. The best way to determine this effect is to determine the mineral content of the rocks that make up the parent material. Apart from surface transport, the composition that will be released by the release originates from the minerals present in the in-situ profiles. After physical, chemical, and biological decomposition, many plant nutrients pass from primary minerals to the soil solution. The physical and chemical properties of the mineral as well as the climate are also factors in the transfer to the solution and in fragmentation weathering events. Minerals with low resistance to fragmentation and weathering are quickly incorporated into the soil solution, while minerals with high resistance have low release. As the level of weathering increases, the capacity to supply nutrients through the weathering of primary minerals decreases. Although fragmentation weathering indices are widely used in in situ formations, they are also used to determine soil development and soil fertility (Price and Velbel, 2003).

Modeling studies have become a frequently studied subject in soil science as in many other fields. Pedotransfer functions (PTFs) are often defined as mathematical models for predicting soil properties measured by laborious, time-consuming, and expensive methods from easily measured soil properties (Pachepsky and Van Genuchten, 2011). Some statistical methods used in the creation of models include path analysis, which determines the direct and indirect effects of dependent and independent variables, multiple linear regression to measure the relationship between multiple independent variables (Igwe et al., 2013) and artificial neural networks using different algorithms (Usta et al., 2018). Today, machine learning algorithms are one of the widely used methods in predicting soil properties (Alaboz et al., 2021). Machine learning is the process of learning from data by using the necessary algorithms and formulations and reaching a level where you can make decisions about the relevant subject. Silva et al (2020) reported successful prediction of clay and sand content of soils using support vector machine and silt content using random forest algorithm. Alaboz et al., (2021) stated that soil quality and crop yield can be successfully predicted with the artificial neural network's algorithm. Artificial neural networks are one of the widely used algorithms. Artificial Neural Networks (ANN) make significant contributions to obtaining accurate and rapid results in a short time in solving various problems that are difficult and complex to achieve.

For this purpose, it was tried to reveal the change in soil fertility status depending on the parent material within the scope of the study. In the study, some weathering indices such as CIW and CIA were estimated by artificial intelligence algorithm using the physico-chemical properties of soils formed on sedimentary rocks.

Material and Methods

The study area includes Sandıklı and its surroundings within the borders of Afyon province. While the areas in and around Sandıklı district have an altitude of 1000-1200 m, this altitude increases further in the east, north-east and south-east directions. According to the Corine 2012 classification, more than 30% of the area is used as agricultural land, while about a quarter (25.1%) is covered with pasture and 15.5% is covered with forest cover. In addition, approximately 1.5% of the area consists of artificial areas.

In-situ soils from geologic parent materials including igneous, sedimentary and metamorphic rocks were sampled on a profile basis as indicated on the geological map of the study area.

Physical Analysis

Descriptive physical and chemical analyses were performed on soil samples sieved through a 2 mm or 0.5 mm sieve. Particle size distribution was determined by hydrometer method (Bouyoucus, 1951). Bulk density was determined by dividing the volume of intact samples taken in 100 cm^3 metal cylinders by the volume of the cylinder after drying at 105°C (Blake and Hartge, 1986). The color of the soils was determined by using Munsell color chart (Anonymous, 1993) in dry and moist state.

Chemical Analyses

The pH, EC and salt concentration of soils will be determined in saturation sludge (Anonymous, 1954). Lime contents were determined as CaCO3 equivalents by Scheibler calcimeter and volumetric method (Kacar, 2009). Organic matter determination according to the modified Walkley-Black method (Jackson, 1958). Cation exchange capacity (CEC) values were determined by extracting the soils with ammonium acetate after saturation with Na-acetate and reading the extracted sodium in an atomic absorption spectrophotometer (Kacar, 2009). Exchangeable cations, Mg^{++}, Ca^{++}, Na^+ and K^+ will be determined in an atomic absorption spectrophotometer after the soils are extracted with ammonium acetate (Kacar, 2009). The amounts of useful micronutrients (Fe, Cu, Zn, Mn) were determined by the DTPA method proposed by Lindsay and Norvell (1978). Free Fe_2O_3 and Al_2O_3, free iron oxide and aluminum oxide contents of soils will be determined by atomic absorption device after citrate dithionite bicarbonate (d) extraction (Anonymous, 1973). SiO_2, Fe_2O_3 and Al_2O_3, silicon oxide, iron oxide and aluminum oxide contents of soils will be determined by atomic absorption after extraction with ammonium oxalate (o) (Blakemore, 1983).

$$\text{CIA (Chemical alteration index)} = (100)\,[Al_2O_3/(Al_2O_3+CaO^*+Na_2O+K_2O)]$$

CaO* value is the CaO value originating from silicate minerals and is used with carbonate and apatite correction. In the calculation of the CIA index, if the CaO value is lower than the Na_2O value during apatite correction, CaO is used; if it is higher, Na_2O value is used instead of CaO (Mclennan et al., 1993).

$$\text{CIW (Chemical weathering index)} = (100)\,[Al_2O_3/(Al_2O_3+CaO+Na_2O)]$$

Descriptive statistics of soil properties were determined by using IBM SPSS 23 program. Kolmogorov-Smirnov test was used to check whether the examined soil properties were normally distributed or not and log and square root transformations were performed for soil properties that did not show normal distribution. Multivariate regression equation was used in the creation of prediction models, and evaluations were also made with the stepwise method of variable elimination and addition in the multiple regression model. Coefficients of determination (R2) were obtained. In addition, prediction with artificial neural networks, one of the machine learning algorithms, was carried out using the "nftool" package in MATLAB program. In the prediction with artificial neural networks, features selected with the stepwise method are included in the Input layer. 10 neurons were used in the hidden layer and an architecture was created with an output layer (CIW/CIA). Levenberg-Marquardt algorithm (LM) was evaluated using the feed-forward back propagation technique in the prediction to be created with artificial neural networks.

Results and Discussion

Seventeen soil profiles were opened on the sedimentary bedrock. In 3 soil profiles, the B horizon is developed, while in the other profiles the horizons have A-R, A-AC-C or A-C horizon arrangement. Descriptive statistics of soils formed on sedimentary rocks in the study area are given in Table 1. The clay silt and sand contents of the soils varied between 11.54-59.26, 8.50-52.67, 15.45-76.51 % respectively. There is no salinity problem in the soils with neutral and slightly alkaline reaction, and the lime contents are distributed in the medium calcareous and very high calcareous classes. The P, Na, Zn, and Cu contents of the soils are very low-sufficient, K, "little", Ca, "much", Fe, "medium-much", Mg, "very little-much". Mn was distributed between "very little - very much". When the skewness and kurtosis characteristics showing the distribution of soil properties are analyzed, pH, CIW, properties show a left-skewed (-) distribution and other properties show a right-skewed (+) distribution. Sedimentary rocks are rich in calcium and sulfur, but low in phosphorus and potassium (Anderson, 1988). While the phosphorus content of the soils of the study area is high, their potassium content is low. Indeed, phosphorus contents are 0.075% in shales, 0.035% in sandstone and 0.081% in limestone (Anderson, 1988). The P2O5 values of the study area were determined as 0.11% in total, which is similar to the literature. Sedimentary rocks, which constitute the weakest rock group in terms of resistance to fragmentation and decomposition, are the most resistant to soil solution.

Table 1. Descriptive statistics of the properties of soils formed in sedimentary rocks

	Min.	Maxi.	Mean	Stdv.	Skewness	kurtosis
pH	7.475	8.340	7.978	0.173	-0.563	0.517
EC (dS/m)	0.074	0.368	0.156	0.051	1.912	6.763
Clay (%)	11.540	59.261	34.502	12.388	0.271	-0.682
Silt (%)	8.498	52.668	27.429	8.989	0.626	0.944
Sand (%)	15.451	76.512	38.069	13.217	0.380	0.138
$CaCO_3$ (%)	4.663	77.857	28.562	19.755	0.669	-0.368
Na cmol(+)kg $^{-1}$	0.017	0.494	0.118	0.091	2.046	6.079
K cmol(+)kg $^{-1}$	0.030	14.584	0.981	2.221	5.884	36.527
Ca cmol(+)kg $^{-1}$	21.430	79.331	43.353	13.291	1.000	0.966
Mg cmol(+)kg $^{-1}$	0.216	9.492	2.621	2.731	1.154	0.009
Cu mg kg^{-1}	0.094	3.542	1.454	0.925	0.414	-0.604
Mn mg kg^{-1}	2.243	175.664	30.467	35.330	2.936	8.978
Femg kg^{-1}	1.613	14.666	7.757	3.642	0.233	-1.278
Zn mg kg^{-1}	0.149	1.912	0.459	0.414	2.461	5.903
CEC(cmol kg^{-1})	8.057	55.775	26.202	13.038	0.661	-0.180
P (mg kg^{-1})	1.632	11.423	4.757	1.989	1.386	2.966
OM (%)	0.249	4.316	1.423	1.017	1.176	0.940
CIA	67.156	92.032	76.349	5.773	0.429	0.182
CIW	87.047	99.432	94.307	2.908	-0.250	-0.310

The CIA index, which is based on the removal of basic cations from minerals through chemical weathering, reflects the ratio of primary and secondary minerals in the soil. With advanced fragmentation and decomposition, this ratio increases and can reach up to 100. This index, which reflects the degree of decomposition of feldspars into clays after hydrolytic weathering, reaches up to 100% in residual clays such as kaolinite, where weathering is intense and abundant in the environment; It can decrease up to 50% in the upper crust, where weathering is in the initial stages (Fedo et al. 1995; Şenol et al., 2014). Nesbit and Young (1982) classified CIA values as slightly decomposed (50-60), slightly decomposed (60-80), highly decomposed (80-90) and extremely decomposed (90-100) percentages. CIW values are 50% in rocks that have not undergone fragmentation and weathering, and this index approaches 100% depending on the increasing degree of fragmentation. CIA's classification is valid for CIW.

Prediction equations were created through stepwise regression with the total data set (Table 2). In the regression equation obtained when the variable elimination and addition method (stepwise) is used in the multiple regression model; The entire data set was included as the independent variable, and the numerical data used to determine fragmentation decomposition rates were estimated as the dependent variable.

The coefficients of determination obtained using the stepwise regression method were determined as 0.844, 0.621, respectively. High accuracy predictions (R2>0.8) were obtained for CIA using Mg, K, OM, Fe, pH, silt, CaCO3 properties. Especially by using OM and K features, the prediction of the features in question can be predicted accurately at a rate of approximately 70%. Therefore, it is recommended to use these features in prediction models.

Table 2. Estimation of weathering indices with stepwise regression

Stepwise Regression (CIA)	R^2
$=65.22+6.08\sqrt{Mg}-6.89\log K+6.1\log OM$	0.759
$=63.83+4.79\sqrt{Mg}-6.94\log K+5.3\log OM+0.42\,Fe$	0.798
$=14.93+4.53\sqrt{Mg}-5.93\log K+5.5\log OM+0.59\,Fe+5.7\,pH+0.092\,Silt$	0.826
$=2.3+4.31\sqrt{Mg}-6.21\log K+6.2\log OM+0.48\,Fe+7.6\,pH+0.117\,Silt-0.057CaCO_3$	0.844
Stepwise Regression (CIW)	R^2
$=79.52+1.96\sqrt{Mg}+0.160\,silt-7\log EC+0.071\,CEC$	0.581
$=76.26+1.58\sqrt{Mg}+0.184\,silt\ 7.7\log EC+0.097\,CEC+0.054\,Clay$	0.621

OM: organic matter, CEC: cation exchange capacity

Prediction error rates and regressions of the CIW and CIA parameters in prediction with ANN are shown in Figures 1 and 2.

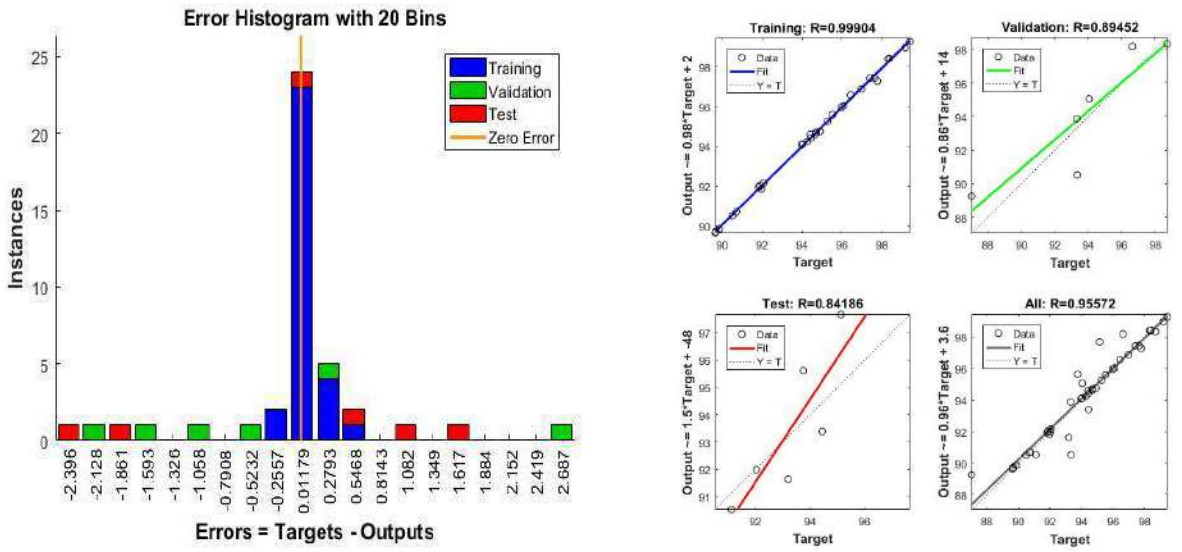

Figure 1. Prediction error rates and regression plots of the CIW

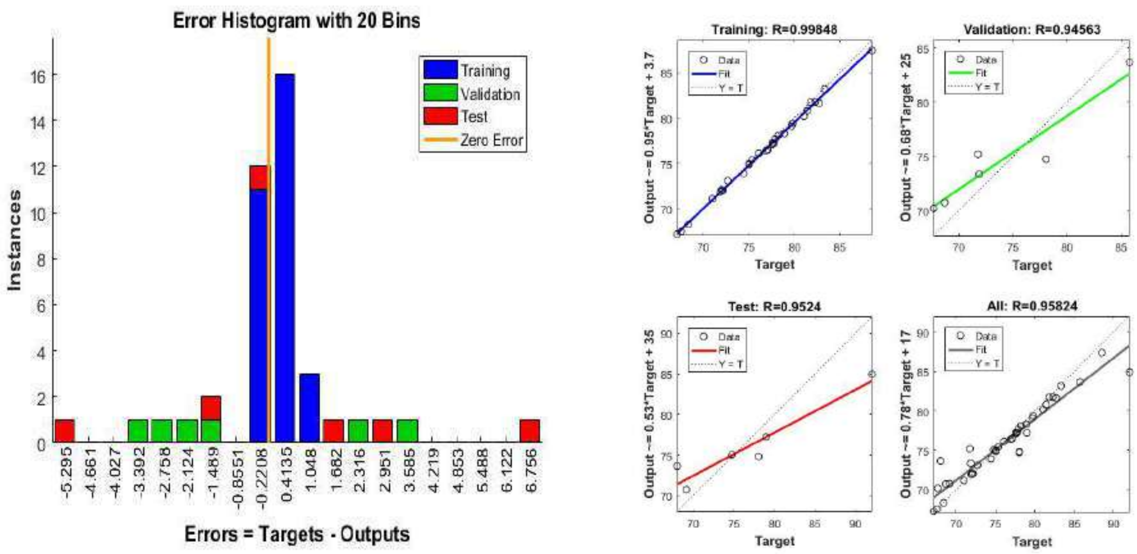

Figure 2. Prediction error rates and regression plots of the CIA

While CIA could be predicted at a rate of 82% and CIW at a rate of 62% with multivariate regression analysis, this rate increased to 91% with ANN. In CIW estimation, R: 0.99 in the training phase and R: 0.84 in the testing phase. For CIA, it was determined as 0.99 and 0.95. CIW was predicted more successfully during the validation and testing phase. While the error rate in CIW estimates is close to 0, negative and positive errors were determined in CIA. Studies have also demonstrated that ANN can successfully predict soil properties in large data sets (Saygın et al., 2023; Tunçay et al., 2023).

Conclusion

In this study, the basic soil properties of soils formed on sedimentary rocks were examined. Additionally, weathering indices such as CIW and CIA were determined. The predictability of the CIW CIA parameter, which is difficult to determine, has been determined with artificial neural networks. Effective soil properties were determined using the Stepwise method. Soil properties affecting the CIA index were determined as Mg, K, organic matter, pH, silt, CaCO3. In CIW, these features were detected as Mg, silt, EC, CEC and clay. In the resulting prediction model, R2s were determined as 0.91 for both features. As a result of the study, it was demonstrated that CIW and CIA can be predicted successfully with ANN.

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A review on the potential of biochar to abate toxic level of copper and manganese for plant growth

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Abstract

Metal contamination in agriculture is becoming increasingly common throughout the globe. Metals such as copper (Cu) and manganese (Mn) are essential part for plant metabolism in trace amount. It is only when these metals are present in bioavailable forms at excessive levels that they have the potential to become toxic to plants. Adsorption of heavy metals on carbonaceous materials i.e., biochar has received considerable attention to remove toxic metals due to its large surface area and high porosity. It is important that we understand the toxicity responses of plants to heavy metals so that we can utilize appropriate dosage of biochar in the rehabilitation of contaminated areas. This article details the toxic symptoms of Cu and Mn contaminated soil on green leafy vegetables and the potential of biochar to retain and limit the plant uptake of heavy metals (Cu, and Mn) present in the soil at toxic level. Based on research achievements of biochar remediation of heavy-metal-contaminated soils in recent years, it is found that the effect of biochar on heavy metal mobility and bioavailability includes two conflicting aspects: immobilizing heavy metals to reduce bioavailability or mobilizing heavy metal to increase bioavailability. The adsorption mechanisms of heavy metals on biochar include physical adsorption, ion exchange, electrostatic interaction, complexation and precipitation. At concentrations of 100 to 200 p.g L-1, Cu disturb metabolic processes and growth. Copper toxicity often causes foliar interveinal chlorosis, the leaf becoming necrotic with increasing exposure. In Mn toxicity, symptoms include chlorosis of older leaves, necrotic spotting and a symptom on young foliage known as ìcrinkle leafî. It has been found that application of biochar decreased the concentrations of Cu and Mn in cilantro by 42.5%, and 34.3% respectively as compared to control.

Keywords: Heavy metal, Toxicity, Abatement, Biochar

Introduction

Heavy metals (HMs) such as Cu, and Mn are essential micronutrients for plants and animals (Wintz et al. 2002) whose uptake in excess to the plant requirements result in toxic effects (Monni et al. 2000; Blaylock and Huang 2000). The use of organic additions for immobilizing heavy metals (HMs) in polluted soil has rapidly increased globally (Méndez et al., 2014; Bogusz and Oleszczuk, 2020). Because of their existence in the ambient matrix in trace (10 mg kg^{-1} or mg L^{-1}) or ultra trace (1 lg kg^{-1} or lg L^{-1}) amounts, they are also known as trace elements. The hazards to human health may rise if these heavy metals (HMs) bioaccumulate in vegetables cultivated on polluted soils. Bioaccumulation of these HMs in plants and vegetables grown on contaminated soils can increase human health risks.

The use of organic additions for immobilizing heavy metals (HMs) in polluted soil has rapidly increased globally (Méndez et al., 2014; Bogusz and Oleszczuk, 2020). By decreasing their mobility in the soil, organic amendments like biochar lower the absorption of heavy metals (HMs) in food crops (Waqas et al., 2014; Khan et al., 2015; Ok et al., 2015; Ahmad et al., 2017; Turan, 2019; Eid et al., 2019). According to numerous studies, adding biochar to soil is an inexpensive, environmentally friendly way to improve water retention, boost crop growth in less fertile soil, and immobilize heavy metals (HMs) like copper and manganese (Mn) in contaminated soil (Clemente et al., 2007; Angelova et al., 2011; Khan et al., 2013; Qi et al., 2016; Eid et al., 2017; Turan et al., 2018; Silvani et al., 2019; Gonzaga et al., 2020). Thus, biochar application can be a potential solution for the reclamation of soils polluted with heavy metals. Although, specific impact on micro-nutrient levels and toxicity for leafy vegetables is not well-studied.

Based on these evidences, this paper reviews the recent research progress of biochar application in heavy metal (Cu and Mn) contaminated soil remediation in the fields of agricultural, soil and environmental sciences. The primary objective of this review is to investigate the potential of biochar to retain and limit the plant uptake of heavy metals (Cu, and Mn) present at soil in toxic level.

Materials and Methods

This review analyzed literature on biochar's use in soil remediation, focusing on organic and inorganic pollutants, heavy metal pollution, and health risks. Primary sources included published papers in English-language journals, with articles discussing biochar's effects on soil contamination. Articles with unclear information or beyond the review's scope were disqualified.

Results and Discussion

Toxic effect of Copper and Manganese

The essential heavy metals (Cu, and Mn) play biochemical and physiological functions in plants and animals. Two major functions of essential heavy metals are the following: (a) Participation in redox reaction, and (b) Direct participation, being an integral part of several enzymes. It is only when these metals are present in bioavailable forms and at excessive levels, they have the potential to become toxic to plants. Among the plant species, vegetables are most important component of food intake worldwide and consumption of vegetables contaminated with HMs is a major pathway of exposure for humans than other routes like dermal contact. (Loutfy et al., 2006; Khan et al., 2010; Yang et al., 2011). Moreover, leafy vegetables excessively accumulate HMs as compared to other food crops (Bortey-Sam et al., 2015). Cilantro (C. sativum) and spinach (S. oleracea) are the leafy vegetables that can accumulate higher amounts of HMs in their leaves when grown in contaminated soils (Chopra et al., 1986; Al Jassir et al., 2005).

Cu is necessary in the range of 5–20 mg/kg for plants normal growth (Shah et al., 2010). Concentration lower than 5 mg/kg is insufficient for vegetables growth and may cause negative effects on nutritional value of the plants (Kabata-Pendias and Pendias, 2001; Shah et al., 2010), and if Cu concentration exceeds 20 mg/kg it causes phytotoxic effects (SEPA, 2005). Baszynski et al., (1998) reported that the most visible symptom of Cu toxicity in spinach is the striking loss of chloroplast membrane constituents such as ChI, carotenoids and lipoquinones. Copper at the concentration of 100 μM has shown to decrease the germination of Lactuca sativa L. (Shams et al., 2018). Copper toxicity modifies certain morphological and physiological characteristics in plants; common symptoms include stunted root growth, altered leaf area, reduced stem size, under-developed and reduced branching in roots, and enhanced cell wall thickening. Excess accumulation of Cu decreased stem size in Brassica napus L. and Brassica juncea L. compared to control (Feigl et al. 2013). Necrotic brown spotting on leaves, petioles and stems and a symptom on young foliage known as ìcrinkle leafî is a common symptom of Mn toxicity (Wu 1994). This spotting starts on the lower leaves and progresses with time toward the upper leaves (Horiguchi 1988). Compared to other metals, Mn uptake is relatively fast process that typically leads to depression of productivity in various crops (Gangwar et al., 2010; Shi, and Zhu, 2008). Likewise, high doses of Mn and Cu can cause Alzheimer's and Manganism (Dieter et al., 2005).

Soil pH and Mobility of Toxic Metals

Some of the factors responsible for the bioaccumulation of HMs in vegetables are atmospheric depositions, concentration of HMs in soil, climatic conditions, soil type and the degree of maturity of plant (Muchuweti et al., 2006). Basically, the bioavailability of heavy metals increases with decreasing pH. Therefore, manganese and copper excess could represent risk for plant growth in acidic soils (Hernandez-Soriano et al., 2012). Although some reports did not match this fact. For example, potato contained more Mn at less acidic pH (Sarkar et al., 2004). At low pH, biochar functional groups present are positively charged (Kołodyńska et al., 2012).

Biochar Applications for Remediation of Soils Contaminated with Heavy Metals

Many studies have focused on the immobilization and mitigation of contaminants, respectively, in soil and effluents (Marchal et al., 2013). Biochar has many oxygen-containing groups on its surface, and ions could effortlessly outcompete molecules of water for these functional groups for the formation of robust surface complexes (Chen et al., 2007). Metal ion rapid sorption is attributable to the sorbent highly porous structure which offers ready access for great surface area adsorption for the metal ions to the active binding sites (Demirbas ,2008).

The adsorption efficiency of biochar tends to be influenced by properties of biochar, like competitive anions, adsorbent dosage, deashing treatment, temperature and pH (Kołodyńska et al., 2012). Biochar has high adsorption capacity for metallic pollutants owing to surface heterogeneity (Kasozi, 2010). In addition, many biochars have a high surface area with a network of well distributed pores, including macropores (> 50 nm), mesopores (250 nm), and micropores (< 2 nm) (Mukherjee et al., 2011). Biochars with high pore volumes and high surface area have great metal ion affinity as ions can be sorbed physically onto the char surface and retained inside the pores (Kumar et al., 2011). Conversely, biochar may also mobilize the heavy metals from soil particles to soil solutions. For example, As and P have competitive adsorption on the surface of biochar. The addition of biochar increased P in the soil, and therefore forced more As to be leached out due to the competitive adsorption (Hartley et al., 2009).

The exchange of cations with heavy metals during the sorption process can be influenced by the type of biochar and the presence of exchangeable cations, such as Ca^{2+}, K^{+}, Mg^{2+}, and Na^{+}, in biochar. This can enhance the stabilization process in acidic polluted soils (Krzyszczak et al., 2021). Ennaji et al. (2020) also demonstrated that the primary mechanism causing this exchange was the heavy metal exchange with K^{+}, Na^{+}, Mg^{2+}, and Ca^{2+} from sludge-derived biochar; however, the contribution of monovalent cations (K+, Na+) was insignificant. Therefore, it might be said that, in real-world field settings, the sorption process that biochar generates in metal-contaminated soils mostly depends on the kind of soil and the cations that are present in both biochar and soils; as a result, metal remediation in polluted soils may vary. Mahmud et al. (2021) showed that because these salts may precipitate with metals and reduce their bio-availability, the mineral elements in the biochar, such as phosphates and carbonates, play a significant role in stabilizing the metals in soil.

According to Chen et al. (2020), the alkalinity of biochar can also promote metal precipitation in soils. Palansooriya studied the biochar's pH fluctuation in 2022 and found that the mean value was pH 8.0. Because biochar has a greater ash content than equivalent biomass materials, its pH value rises with processing temperature (Pande et al., 2022). As a result, a lot of biochars are simple in nature and work as a mulch to assist reduce the mobility of heavy metals in contaminated soils (Eckert et al., 2021). On the other hand, various types of heavy metals have varying removal capacities for different types of biochar. According to Khan et al. (2020), applying hard wood biochar reduced the amounts of Mn and Cu in cilantro by 34.3% and 42.5%, respectively, as compared to the control. Cu 70.1% and Mn 78.0% values in spinach were lower than those in the control. When planted on improved soils, HWB substantially ($P < 0.01$) decreased the uptake of HMs in spinach compared to control.

Conclusion

By increasing the binding of heavy metals to soil, biochar reduced both their phyto-availability and mobility in soil solutions. Because of its unique qualities, biochar may efficiently adsorb harmful metals and other pollutants from water and soil, making it a great, economical, and environmentally responsible way to reduce soil contaminants. Physical adsorption, ion exchange, electrostatic interaction, complexation, and precipitation are the heavy metal adsorption processes on biochar. Decreased phyto-availability thus led to a decrease in the estimated daily intake from vegetable eating. But occasionally, using biochar could also cause heavy metals in the soil to become more mobile. Lastly, recommendations for future study are made, such as developing a standard biochar categorization standard, investigating how well biochar works to clean up areas with multiple pollutants, and demonstrating how biochar interacts with heavy metals in complicated soil environments. extending the scope of the study from short-term, laboratory experiments to lengthy, large-scale investigations.

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Synergistic Effects of Bio-char and Other Eco-Friendly Fertilizers on Soil Health and Plant Productivity

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Abstract

Soil deterioration is a result of intensive agricultural soil cultivation that uses toxic chemicals to raise productivity in order to fulfill the rapidly rising demand for food. This highlights the necessity for sustainable soil management. Applying bio-char to agricultural soils has gained a lot of interest lately since it has been shown to have a number of positive effects on improving soil quality as a soil conditioner and plant productivity as a fertilizer. Additionally, it serves as an adsorbent to remove pollutants from the soil and promotes greenhouse gas mitigation by increasing the soil carbon pool; yet, by itself, bio-char typically lowers plant N availability. Given that the effectiveness of bio-char is dependent on a number of variables, including feed stock, soil type, biotic interactions, and temperature during production, it may potentially prove to be harmful in certain situations. These issues might be resolved by using bio-char in conjunction with either organic N sources or Plant Growth Promoting Microbes (PGP-Ms) as bio-fertilizers. An excellent source of nitrogen and microbes that are vital to soil and plants are other eco-friendly fertilizers prepared out of several agricultural wastes and macro-micro-organisms. Therefore, the purpose of this review paper is to investigate the combined application of bio-char and other eco-friendly fertilizers for improving soil health and plant productivity in an unsuitable situation involving soil pollution and nutrient scarcity. This review study also hopes to pave the way for upcoming scholars by providing an understanding of the field that requires investigation.

Keywords: Greenhouse Gas, Bio-fertilizers, Sustainable Soil Management, Soil Carbon

Introduction

Global hunger, as measured by the prevalence of malnutrition, was much higher in 2022 than pre-COVID-19 pandemic levels and around 600 million people are estimated to be chronically malnourished by 2030 (FAOSTAT, 2023). This increasing rate can be attributed to inappropriate farming practices. Regular extensive application of chemical fertilizers and pesticides degrades soil health and have a severe influence on the environment, contributing to greenhouse gas emissions (Shikha et al., 2023). This, in turn, diminishes the soil quality and crop productivity. Furthermore, foods grown in nutrient-poor soil often have insufficient nutrition contributing to global hunger, which is a serious problem. Global hunger in 2022 that affected 9.2 percent of the global population was higher than pre-COVID-19 pandemic levels that affected 7.9 percent (FAOSTAT, 2023). Thus, it is imperative to substitute the malpractice of using chemical fertilizers for transient heavy crop production with the environment-friendly measures for sustainable food production.

Eco-friendly fertilizers are the finest alternatives to chemical fertilizers, and bio char is one of the best EFFs. Biochar is a carbon-rich material created at high temperatures (>300 °C) under oxygen-limited conditions from organic feedstocks (Ibrahim et al., 2023). Among the different methods of producing biochar, pyrolysis is widely used by many researchers, in which raw materials are heated by admitting a limited quantity of oxygen or nitrogen at ambient pressure (Yan et al., 2020). During this process, some of the volatilities, such as

H_2, CH_4, CO, H_2O, and so on, are evolved, and the carbon-rich solid mass that remains is known as biochar, which is widely used in a variety of fields (Saravana Sathiya Prabhahar et al., 2020). By combining the right chemical or metal salts with the feedstocks, several researchers can create engineered biochar to their specifications by calcining it at high temperatures (Jang & Kan, 2019). It's interesting to note that engineered biochar displays superior performance qualities compared to pure biochar, which is more efficient (Jeyasubramanian et al., 2021). This can be linked to improvements in characteristics such as increased surface area, active sites, diversity in superficial functional groups, pore volumes, etc (Kazemi Shariat Panahi et al., 2020), Bio-char is a porous material having a large specific surface area, increased porosity, long-term stability, strong cation exchange capacity, etc. (Li et al., 2017; Chabi et al., 2020) that increase plant growth and microbial activity even in contaminated soil (Barna et al., 2020). It has gained popularity due to its high carbon sequestration capacity (Lehmann et al. 2010), Despite all of these advantages, biochar alone cannot always be sufficient.

Biochar made at high temperatures often has a higher ash content than biochar made at low temperatures. It was thus expected that the negative effects could be triggered on plants cultivated in soils treated with high-temperature biochar (Butnan et al., 2015). Another disadvantage of biochar is its ability to adsorb nitrogen as well as important elements such as Fe, which can be detrimental to plant growth (Kim et al., 2015). To address this issue, a combination of biochar and different fertilizer is capable of improving soil nutrient status, reducing soil bulk density, and increasing water holding capacity (Oladele et al., 2019). Biological fertilizers are one of the best EFFs and are inoculants containing active chemicals derived from live creatures that operate to bind certain nutrients and increase the availability of various minerals in soil for plants (Kumar et al., 2021). Due to their biodegradability, a diverse array of living organisms can be used as biofertilizers, boosting soil fertility without polluting the environment and promoting sustainable development in agriculture through soil maintenance (Ammar et al., 2023). Thus, the combination of biochar and other EFFs have the potential to improve soil quality, fertilization efficiency, and crop productivity even under uneven circumstances.

Common Materials Used In Eco-friendly Fertilizers

Chemical fertilizer pose a huge challenge for maintaining the sustainability of modern agriculture. Environmentally friendly fertilizers, created to suit the demands of increasing yields without damaging the environment, are fertilizers that can prevent pollution from nutrient loss by delaying or even limiting nutrient delivery into soil (Chen et al., 2018). Eco-friendly biofertilizers can be made from a broad variety of living creatures, including bacteria, microalgae, microfungi, as well as macro organisms including macroalgae, macrofungi, and higher plants (Ammar et al., 2023). The coatings of the environmental friendly fertilizers are derived from the natural material. Some of the common materials used as coatings are chitosan, sodium alginate, starch, cellulose, lignin, agricultural residues, biochar, and polydopamine (Chen et al., 2018). In general, biofertilizers can be divided into three categories: N_2 fixing (free-living, symbiotic, and associative symbiotic); phosphate solubilizing (bacteria and fungi); and phosphate mobilizing (rhizobacteria that promote plant growth, ecto mycorrhiza, ericoid mycorrhizae, orchid mycorrhiza, and arbuscular mycorrhiza) (Rastegari et al., 2020). We will be discussing in brief about the materials used in environmental friendly bio-fertilizers in this review:

Bacteria **-** A wide variety of plant growth-promoting rhizobacteria (PGPR) have long been used as bio-fertilizers worldwide. The demand for bacterial-based bio-fertilizers is growing, and bacterial inoculation methods are being produced and used more and more frequently (Garcia-Gonzalez & Sommerfeld, 2016). The bacteria used in making bio-fertilizers can be broadly categorized into two categories: a. Nitrogen fixing bacteria- As the name suggests, these bacteria help in fixing the atmospheric nitrogen into nitrogen compounds usable by plants. Example includes Azotobacter that was found to promote plant growth in rice (Dar et al., 2021), Anabaena azollae that was known for increasing soil fertility by expanding the microbial populations in the soil (Adhikari et al., 2020; Abd El-Aal, 2022), and Azospirillum that was reported for alleviating abiotic stress (Raf and Charyulu, 2021). b. Phosphate solubilizing bacteria- Many bacteria are known for solubilizing the phosphate. Example includes Rhizobium leguminosarum known for enhancing production of faba bean (Fikadu, 2022), Azotobacter chroococcum recognized for superior performance with phosphate-solubilizing mutants in wheat (Nosheen et al., 2021), and Pseudomonas fuorescens for increasing yield in sweet potato (Santana-Fernández et al, 2021).

Fungi **-** Beneficial fungi benefit the plant by creating siderophores, gluconase antagonists, antibiotics, and cell wall lysing enzymes such as cellulases and glycosidase, among other plant growth-promoting properties (Ammar et al., 2023). Thus, bio-fertilizers are made of biologically active fungal strains that enhance, add, conserve, and change nutrients from an unusable form to a usable form (Rastegari et al., 2020). Also, fungi supplies soluble phosphorus without harming the environment, they are therefore also seen as an alternative option to chemical fertilizers (Devi et al. 2020). The four most important fungi that promote plant growth are Phoma, Fusarium, Trichoderma, and Penicillium (Ammar et al., 2023). Trichoderma spp. are employed as cellulose decomposers and vesicular-arbuscular (VA) mycorrhiza are used as nutrient mobilizers in biofertilizers (Kar et al. 2021). Aspergillus awamori, Aspergillus niger, and Penicillium digitatum are other species that are utilized as biofertilizers and are phosphate solubilizers that aid in respiration, photosynthesis, energy transfer, signal transduction, energy accumulation, cell division, and macromolecular biosynthesis (Ammar et al., 2023).

Algae - Considerable byproducts are produced by the algal pathway, and its physicochemical behavior results in an effective biofertilizer that improves soil health (Ammar et al., 2023). In addition to improving soil fertility and quality, microalgae can produce metabolites such as polysaccharides, antibacterial compounds, and plant growth hormones to boost plant growth (Guo et al. 2020). Common photosynthetic microalgae are prokaryotic blue algae and eukaryotic green algae that provide significant promise for use in contemporary agriculture because of their ability to enhance soil nutrient enrichment and macro- and micronutrient intake (Ammar et al., 2023). Certain crushed marine macroalgae are mixed with soil to act as biofertilizers and include as yet undiscovered sources of physiologically active substances that are found naturally (Nabti et al., 2017). Examples include A. nodosum, other brown algae such as Fucus spp., Laminaria spp., Sargassum spp., Turbinaria spp. & Ecklonia maxima (Osbeck) Papenfuss (Ammar et al., 2023).

Plant residues - Several agricultural residues like banana peel, pomegranate peel, spent coffee grounds, grass pea, etc. can be excellent sources of macro- and micro nutrients for plants and used as bio fertilizers. Biochar from banana peels can be a great source of K amendment for sustainable agriculture and can be used in place of artificial fertilizer (Islam et al. 2019). Coffee grounds are utilized to make biochar as well as a low-cost adsorptive material for the adsorption of heavy metals (Cd, Cr, Cu, and Pb) from aqueous solutions (Kyzas, 2012). Spent coffee grounds have the potential to boost soil fertility, but further research is needed to improve the use of SCG as an amendment (Cervera-Mata et al. 2018). Pomegranate peel is considered an organic fertilizer, accounting for around 500 g/kg of total fruit weight (Aviram et al., 2000). Pomegranate powder was composted efficiently by combining it with and without banana peels at a humidity level of 50.5% and the biofertilizer produced utilizing both of these procedures improved germination, shoot development, root length, and leaf chlorophyll content (el Barnossi et al., 2021). Grass pea is a good green manure that promotes soil fertility by supplying roughly 67 kg/ha of extra nitrogen in a single growing season due to its effectiveness in fixing nitrogen and has implications for future non-legume crops in terms of productivity and protein (Singh et al., 2013).

Limitations of Sole Biochar Application

Contrary to popular belief, the beneficial effects of biochar have been shown to be soil specific which means it may not be beneficial to all soil types (Zhu et al., 2015). It should also be emphasized that most of biochar research were conducted in temperate soil locations. As a result, its effects on boreal habitats are still unknown (Anyanwu et al., 2018). According to Vaccari et al. (2015), the effect of biochar on agricultural productivity was dependent on plant species or the targeted section of the plant. They discovered that applying biochar at 14 t ha^{-1} increased tomato plant vegetative growth but not fruit yield (Vaccari et al., 2015). Besides soil type, location, plant species, and the targeted section of the plant, there are other limitations as well. To begin with, biochar inhibits soil aging, and occasional addition of fresh biomass may be required for optimal nutrient cycling and soil-water environment in a soil (Kavitha et al., 2018). In one study, Anyanwu et al. (2018) discovered that biochar aged in soil has a deleterious influence on the growth of earthworms and/or fungi. Furthermore, the aged biochar reduced the subsurface root biomass of Oryza sativa and Solanum lycopersicum and has been shown to reduce soil thermal diffusivity to mirror biochar's low thermal diffusivity (Zhao et al., 2016). Safaei Khorram et al. (2018) discovered that applying biochar at relatively high rates of 15 t ha^{-1} resulted in a 200% increase in weed growth during lentil culture, implying that repeated applications of biochar may not be beneficial for weed management. Additionally, biochar application may cause plant flowering to be delayed (Hol et al., 2017). Biochar's ability to absorb contaminants was also proven to be selective when it's amendment had no effect on pesticide uptake of dichlorodiphenyltrichloroethane (DDT) in soil (Denyes et al., 2016). Ultimately, the source of biochar is critical as Gonzaga et al. (2018) found that soils treated with coconut husk biochar improved 90% of the Zea mays biomass, whereas orange bagasse biochar applied at a same dosage had no effect. Contamination of the biochar source has been shown to be harmful to plant growth (Jones and Quilliam, 2014).

Combined Effects of Biochar and Eco-Friendly Fertilizers

Effects on Plants

The biochar-based inoculant boosted both shoot and root biomass, nodulation, and uptake of nutrients as reported by Egamberdieva et al. (2017). Individual and combined biofertilizer and biochar applications enhanced rice grain yield by 16.5-38.3% (Sun et al., 2021). In contrast, Guilayn et al. (2020) found that bio stimulants had greater impacts on roots than on above-ground biomass, which may explain the modest effects on chlorophyll activities. Regardless of biochar amendment, Antón-Herrero et al. (2021) discovered no significant differences on soil plant analysis development chlorophyll index and photochemical reflectance index (PRI) of pepper leaves between plants irrigated with conventional fertilizer solutions and bio stimulant fertilizer solutions. Increased soil microorganisms as a result of biochar-based rhizobium inoculants boosted soil NO3, resulting in increased N uptake, enhancing plant development and increasing nut output (Shikha et al., 2023). When comparing the biochar treatment to the fertilizer treatments (conventional and biostimulants), the nutritional shortfall resulted in decreased aerial growth but similar root growth (Antón-Herrero et al., 2021). Biochar treatment led in the highest concentration of As and Pb in leaf, whereas conventional and bio stimulant fertilizer treatments resulted in lower As and Pb content. Except in plants treated with biofertilizer treatment, the application of biochar resulted in a substantial reduction of the foliar concentration of Cd compared to the unamended soil, indicating a strong interaction between biochar and fertilization treatments (Antón-Herrero et al., 2021). In all four stages of plant growth (seedling, fowering, pod formation, and harvesting), biochar-based rhizobium inoculants boosted nodulation, root weight, shoot weight, nut production, and soil nutrient uptake (Shikha et al., 2023).

Effects on Soil and Environment

Shikha et al. (2023) reported that biochar-based rhizobium inoculants modulated the abundance of functional microbes by increasing soil nitrification and decreasing denitrification when compared to N-use treatments. The combination of biochar and fertilizer, specifically bio stimulant fertilization, reduced the percentage of acid-soluble Cd in soils (Antón-Herrero et al., 2021). The combined effect of the biochar's adsorption ability via chemisorption and complexation mechanisms, as well as the biostimulant action to promote nutrient uptake, resulting in a higher plant status with decreased Cd uptake (Mosa et al., 2018: Antón-Herrero et al., 2021). The biochar and bio-fertilizer treatments had the lowest plant Pb content and their combination produced synergistic effects from both items (Antón-Herrero et al., 2021). The combined application of these agronomic inputs resulted in soil-plant system benefits (Antón-Herrero et al., 2021). As the observed nodulation numbers increased in biochar and biofertilizer treatments that come from the N_2, which might then be fixation by the nodule formation, Shikha et al. (2023) predicted that other GHG of N_2O breaks down to form the atmospheric N_2, resulting in a reduction of GHG emissions in the atmosphere. The use of biofertilizer and biochar together reduced the GHGI by 15.2% ($P<0.05$) (Sun et al., 2021). The soil amended biochar as a carrier of rhizobium inoculants had the highest soil organic carbon stock approximately 26% higher than other treatments, saving 6.6 kg CO_2 eq ha^{-1} GHG emissions and promoting environmental sustainability toward climate-smart agriculture (Shikha et al., 2023).

Conclusion

Although bio char has been promising in solving various soil-plant related issues, from serving as a fertilizer to raising the soil carbon supply, it still has several drawbacks. Utilizing biochar in conjunction with other fertilizers that are known to improve soil health and environmental sustainability can help to some extent in overcoming these restrictions. Several researches have demonstrated the positive combined effects of incorporating bio char with these fertilizers. However, the most optimal timing and optimum dose of these bio fertilizers are still unknown, and if discovered, will alleviate many of the farmers' and researchers' present concerns. Moreover, incorporating nano particles into bio-fertilizers may be more effective because it will be able to detect the tiniest stress to plants and call for the appropriate remedy. Advanced artificial intelligence techniques should be used to study plant diversity in various regions and determine the bio fertilizers needed to stimulate a species' growth and suitability of organisms at extracting this biofertilizer. Finally, to discover the most suitable pairings, a compatibility study of bio char with various EFFs is necessary. Thus, combining biochar with other EFFs is the way forward for sustainable agriculture.

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Investigating the impact of NPK fertilizer and seed rates on barley 'Celilabad-19' production in the arid conditions of Gobustan, Azerbaijan

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Abstract
This study is based on field trials conducted over a three-year period on the "Celilabad-19" barley variety in the Gobustan region. The research aims to address a significant knowledge gap by investigating the impact of varying NPK fertilizer application rates and seed quantities on barley yield and soil nutrient availability. The Gobustan district, characterized by distinct climate patterns and evolving agricultural practices, provides a complex setting for barley cultivation, particularly in arid regions like Azerbaijan. The study focuses on Chestnut soils, known for their moderate drainage and fertility levels, which play a pivotal role in shaping barley yield and quality in the region. Climate change introduces uncertainties in temperature and precipitation patterns, emphasizing the need for adaptive agricultural approaches. The role of agricultural irrigation gains prominence in ensuring a consistent water supply for crops in these semi-arid climates. Through a randomized complete block design with four replications, the study explores the responses of the "Celilabad-19" barley variety to different NPK fertilizer application rates and seed quantities. The experimental design includes varied seed rates (120 kg/ha, 140 kg/ha, and 160 kg/ha) and NPK fertilizer doses (30 kg/ha, 45 kg/ha, and 60 kg/ha). Results from the field trials reveal significant dependencies of above-ground biomass on irrigation and fertilizer norms during plant development phases. The absence of fertilization during the summer growing season led to a variation in above-ground biomass, with notable increases observed with mineral fertilizer applications. The influence of seed rate and fertilizer norms on biomass was particularly pronounced during heading and full maturity phases. This study contributes valuable insights into sustainable barley farming practices in the Gobustan region, crucial for addressing challenges posed by changing climatic conditions and evolving agricultural landscapes.
Keywords: Barley cultivation, NPK fertilizer, Seed rates, Celilabad-19 variety

Introduction
Cultivation of the soil in spring is very important to get a high and quality crop. New approaches and methods of modernization are needed to protect the environment, maintain the sustainability and productivity of land resources (Sainju 2013). Barley grain has a high nutritional value. The protein of this plant contains all essential amino acids, especially lysine, tryptophan (Campillo et all. 2010). Barley is especially valuable in beer production. Despite the presence of yeast-containing plants (corn, rice), barley is widely used as an indispensable raw material for the production of high-quality beer. 90% of the elite seed for malting barley is considered as a quality product. Seed productivity depends on planting density, vegetation period, temperature, diseases and pests. Increasing the planting density leads to an increase in the number of spikes per 1m2, which results in smaller grain size, higher protein content and lower starch content (Brisson et al. 2010, Jolankai et all. 2008).

In recent years, due to climate changes, the productivity of barley has varied considerably. It is shown in the literature that the high productivity of barley depends on atmospheric precipitation and fertilizer rates (Netwon 2011, Kosolapova et al. 2016).

The productivity and quality of cereal crops varies depending on the sowing rate, cultivation technologies, and biological characteristics of the variety. The weight of 1000 grains was 33.0-41.2 g in experiments conducted with soft wheat varieties in the chestnut soils of Nagorno-Shirva, which are not fully supplied with moisture; the amount of protein in the grain is 13.5-14.8%; it was noted that the natural mass of the grain is 667-758 g/l. Many researchers report that the genetic influence on seed size is greater than the environmental influence. Interaction of genotype and environmental factors on yield and quality (Ruza 2010, Madic et al. 2009).

Productivity and the nutrients used to produce one centner of grain depend on the type of soil, the rates and proportions of mineral fertilizers. In order to ensure the formation of high and quality crops, the fertility of the soil should be increased, and the annual rates of organic and mineral fertilizers should be determined based on the balance calculation. Studying the physiological indicators of nitrogen nutrient efficiency can be achieved by a multi-pronged approach to winter grain cultivation (Pathak et al. 2008). The application of nitrogen fertilizer makes it possible to transform part of the nutrients in the soil into a form that is easily absorbed by the plant. The assimilation and use of nitrogen depends on the genotypic potential of the roots, as well as the amount of soil moisture and nutrients. Differences between wheat and barley cultivars have been studied for nitrogen uptake (Knezevic et al. 2015, Knezevic et al. 2011, Rashid 2008, Shrawat et al. 2008).

Barley, the fourth most-produced cereal globally, holds critical importance in agriculture, particularly in arid regions like Azerbaijan. The Gobustan district, characterized by Chestnut soils, distinct climate patterns, and evolving agricultural practices, provides a complex backdrop for barley cultivation. Despite its significance, there is a notable gap in understanding how factors such as varied NPK fertilizer application rates and seed quantities influence barley yield and soil nutrient availability in Gobustan.

Chestnut soils, known for their moderate drainage and fertility levels, play a pivotal role in shaping barley yield and quality in the Gobustan region (Aliyev, 2021). As climate change introduces uncertainties in temperature and precipitation patterns, adapting agricultural approaches becomes crucial. Moreover, the role of agricultural irrigation gains prominence in ensuring a consistent water supply for crops.

This study aims to address the existing knowledge gap by exploring the responses of the "Celilabad-19" barley variety under different NPK fertilizer application rates and seed quantities over a three-year period. Harvesting mature barley plants and analyzing plant samples at various developmental stages will provide valuable insights into barley cultivation, particularly in the absence of irrigation, focusing on the Chestnut soils of the Gobustan district. Understanding these interactions is essential for the development of sustainable barley farming practices in this region.

Material and Methods

Experimental Site

The study was carried out in the Mereze area of the Gobustan Experimental Station, affiliated with the Azerbaijan Research Institute of Crop Husbandry, from 2016 to 2019 (40031’07.6372”N, 48053’50.8362”E). The experiments were conducted in rainfed conditions on open, dry chestnut soils typical of the Gobustan district, located in the Mountainous Shirvan region of Azerbaijan. The Gobustan district experiences a semi-arid warm temperate desert climate in the southern part and a semi-arid warm temperate steppe climate in the northern part. The average annual temperatures range from 6 to 14°C, with the coldest months experiencing temperatures of 2 to 4°C, while the warmest period sees temperatures ranging from 15 to 25°C. Annual precipitation varies from 360.3 mm to 542.9 mm, with an average of 412 mm. The distribution of rainfall during the crop vegetation period varies across years, impacting agricultural practices and water management strategies. A soil sample from the chestnut soil type was collected at the beginning of the experiment, and its chemical properties were analyzed following the methods outlined by Rowell (1996) and Jones (2001).

Experimental Design

The study employed the "Celilabad-19" barley variety, known for its resilience to drought and rust diseases, and extensively cultivated in the region. The field trial, conducted from 2016 to 2019, used a randomized complete block design with four replications, resulting in a total of 48 plots. Each plot measured 50 m^2 (25 m x 2 m), with a 0.30 m spacing between adjacent plots. Barley seeds were sown 5 cm below the soil surface in the second week of October each year using agricultural mechanization tools. Plant harvesting occurred in June, aligning with the climatic conditions of the region, and the preceding crop in the rotation was a leguminous plant mixed with the soil.

Different seed rates and NPK fertilizer doses were chosen as experimental factors. The seed rates included 2.67 million/ha (120 kg/ha), 3.11 million/ha (140 kg/ha), and 3.55 million/ha (160 kg/ha). NPK fertilizer treatments consisted of application doses of 30, 45, and 60 kg/ha (Table 1). Nitrogen fertilizer was Ammonium Nitrate (34% N), phosphorus fertilizer was Superphosphate (20.5% P_2O_5), and potassium fertilizer was Potassium Sulfate (46% K_2O). For phosphorus and potassium fertilizers, the entire dose, along with 30% of the nitrogen fertilizer, was applied at seeding, while the remaining 70% of the nitrogen fertilizer was applied during the tillering stage of barley plants in March.

Table 1. Experimental design

Treatments	Seed Rate (kg/ha)	Nitrogen fertilizer rate (kg/ha)	Phosphorus fertilizer rate (kg/ha)	Potassium fertilizer rate (kg/ha)
120-$N_0P_0K_0$	120	0	0	0
120-$N_{30}P_{30}K_{30}$	120	30	30	30
120-$N_{45}P_{45}K_{45}$	120	45	45	45
120-$N_{60}P_{45}K_{45}$	120	60	45	45
140-$N_0P_0K_0$	140	0	0	0
140-$N_{30}P_{30}K_{30}$	140	30	30	30
140-$N_{45}P_{45}K_{45}$	140	45	45	45
140-$N_{60}P_{45}K_{45}$	140	60	45	45
160-$N_0P_0K_0$	160	0	0	0
160-$N_{30}P_{30}K_{30}$	160	30	30	30
160-$N_{45}P_{45}K_{45}$	160	45	45	45
160-$N_{60}P_{45}K_{45}$	160	60	45	45

Throughout the three-year trial, no artificial irrigation or plant protection chemicals were used. The design aimed to investigate the impact of different seed rates and NPK fertilizer doses on the growth, development, and yield of the "Celilabad-19" barley variety under the natural climatic and soil conditions of the Gobustan district, providing insights into sustainable cultivation practices for barley in the region.

Harvesting and Plant Sampling

Mature barley plants were harvested to determine grain and straw yields during the three-year field trial from 2016 to 2019. Plant samples were also collected at various developmental stages, including tillering, booting, heading, and full maturity, to determine plant biomass in the soil.

Data Analysis

Statistical analysis of the research results was performed using the SPSS26 program.

Results And Discussion

Table 2 presents the findings derived from soil samples collected at depths of 0-25 cm, 25-50 cm, and 50-70 cm, aimed at delineating the soil properties of the trial area characterized by Chestnut soil. The results reveal a notable pattern wherein an increase in subsoil depth corresponds to a rise in soil pH, attributed to an augmentation in calcium carbonate ($CaCO_3$) content. Conversely, in the uppermost soil layer (0-20 cm), higher concentrations of organic matter, total nitrogen (N), mineral nitrogen forms (NH_4-N and NO_3-N), available P_2O_5, and exchangeable K_2O were observed. As the subsoil depth increases, a consistent decrease in these components becomes evident.

Table 2. Characteristics of Chestnut soil type in the experimental area

Soil Dept, cm	pH	$CaCO_3$, %	Organic Matter, %	Total N, %	NH_4-N, mg/kg	NO_3-N, mg/kg	Available P_2O_5, mg/kg	Exchangeable K_2O, mg/kg
0-25	8,25	4,34	2,23	0,165	18,2	14,0	30,45	292
25-50	8,45	5,90	1,37	0,099	12,8	8,5	12,60	167
50-70	8,60	7,70	0,73	0,056	8,2	5,2	5,75	112

Field trials conducted in the Gobustan district from 2016 to 2019 using the "Celilabad-19" barley variety revealed that the harvest of above-ground biomass during the plant development phases is dependent on both irrigation and fertilizer norms. In the absence of fertilization during the summer growing season, the above-ground biomass varied between 1.103-1.228 t/ha over three years. A significant increase, ranging from 0.125 t/ha to 11.33%, was observed when compared to the 120 kg/ha seed rate.

The application of mineral fertilizers resulted in substantial variations in above-ground biomass during the summer growing season. For instance, in the 120 kg/ha seed rate category, the biomass varied from 1.357-1.490 t/ha, while in the 140 kg/ha and 160 kg/ha seed rate categories, it ranged from 1.481-1.604 t/ha and 1.499-1.632 t/ha, respectively. The increase was notable, ranging from 0.124-0.150 t/ha or 7.65-10.46% and 8.31-9.14%, respectively.

The influence of seed rate and fertilizer norms on biomass was more pronounced during the heading and full maturity phases. In these stages, the application of $N_{45}P_{45}K_{45}$ and $N_{60}P_{45}K_{45}$ fertilizer norms at 140 kg/ha and 160 kg/ha seed rates significantly increased above-ground biomass compared to the 120 kg/ha seed rate. The biomass increase in these cases ranged from 1.415-1.523 t/ha or 14.73-17.55% and 1.350-1.640 t/ha or 14.97-17.69%, respectively. Table 3 presents the influence of seed rate and fertilizer norms on above-ground biomass at different growth stages, with the values representing the average figures for the years 2016 to 2019.

Table 3. The influence of seed rate and fertilizer norms on above-ground biomass at different growth stages

Seed rate, kq/ha	Fertilizer norms, kq/ha	Tillering, t/ha	Booting, t/ha	Heading, t/ha	Full maturity	
					Grain yield, t/ha	Straw yield, t/ha
120	Control	1,103	2,668	6,315	2,848	4,662
	$N_{30}P_{30}K_{30}$	1,357	3,347	7,877	3,852	6,008
	$N_{45}P_{45}K_{45}$	1,437	3,678	8,677	4,274	6,628
	$N_{60}P_{45}K_{45}$	1,490	3,781	9,162	4,473	7,127
140	Control	1,228	3,054	7,280	3,196	5,185
	$N_{30}P_{30}K_{30}$	1,481	3,686	8,687	4,137	6,508
	$N_{45}P_{45}K_{45}$	1,541	4,095	10,177	4,831	7,741
	$N_{60}P_{45}K_{45}$	1,604	4,339	10,577	5,141	8,310
160	Control	1,223	3,017	7,042	2,885	5,382
	$N_{30}P_{30}K_{30}$	1,499	3,762	8,532	4,103	6,710
	$N_{45}P_{45}K_{45}$	1,588	4,225	10,200	4,761	7,938
	$N_{60}P_{45}K_{45}$	1,640	4,450	10,512	4,873	8,399

Additionally, research conducted with the "Celilabad-19" barley variety in the mountainous region of Shirvan revealed that, during the summer growing and heading phases, an increase in both seed rate and fertilizer norms ($N_{60}P_{45}K_{45}$) led to a corresponding rise in above-ground biomass. However, during the milk ripening and full maturity phases, the highest above-ground biomass was observed at a seed rate of 140 kg/ha and with the $N_{60}P_{45}K_{45}$ fertilizer norm. This observation can be attributed to the fact that as the seed rate increased, the plants were more densely populated, resulting in thinner spikes and a lower mass of 1000 grains during the milk ripening phase.

Conclusion

Barley cultivation in the Gobustan district, characterized by Chestnut soils and unique climatic conditions, demands a comprehensive understanding of the intricate interactions between various factors influencing yield and soil health. This study, conducted over three years from 2016 to 2019, aimed to address the existing knowledge gap regarding the impact of NPK fertilizer application rates and seed quantities on the "Celilabad-19" barley variety in this region.

Our findings underscore the critical role of fertilization in enhancing above-ground biomass during the summer growing season. In the absence of fertilization, the above-ground biomass demonstrated considerable variability, emphasizing the necessity of adequate nutrient supply for optimal barley yield. The application of mineral fertilizers, particularly at higher seed rates, showcased significant increases in biomass, with the most pronounced effects observed during the heading and full maturity phases. The study also shed light on the complex relationship between seed rate, fertilizer norms, and above-ground biomass during different growth stages. Notably, the combination of $N_{60}P_{45}K_{45}$ fertilizer norm and a seed rate of 140 kg/ha emerged as the most favorable for maximizing above-ground biomass during the milk ripening and full maturity phases. The observed phenomenon, where higher seed rates resulted in densely populated plants with thinner spikes, highlights the need for careful consideration of seeding rates to optimize both quantity and quality aspects of barley cultivation. Furthermore, the research conducted in the mountainous region of Shirvan revealed additional insights into the interaction between seed rate, fertilizer norms, and above-ground biomass during various growth phases. This comprehensive understanding is vital for devising sustainable barley farming practices, especially in regions like Gobustan, where Chestnut soils and specific climate conditions pose unique challenges.

In conclusion, the outcomes of this study contribute valuable insights into the nuanced dynamics of barley cultivation in arid regions, providing a foundation for the development of sustainable agricultural practices tailored to the Gobustan district. As climate uncertainties persist and agriculture faces evolving challenges, the knowledge generated in this research serves as a cornerstone for future endeavors aimed at enhancing crop productivity and ensuring food security in similar agroecological contexts.

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The pathogenicity of *Bipolaris sorokiniana* and *B. spicifera* in wheat plants and the effect on plant development.

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Abstract

Bipolaris sorokiniana (Sacc.) Shoemaker is one of the major causes of root and crown rot, causing significant yield and quality losses in wheat in the world. The study examined four isolates of *B. sorokiniana* isolated from wheat plants, and seven of *Bipolaris spicifera* isolates in terms of disease severity, root length, leaf length and biomass. For this purpose, the seeds of the Altındane wheat variety were surface disinfected and allowed to germinate for three days. Two sterile papers were placed inside the nine-cm-diameter petri, and the papers weted. Isolates were inoculated in a potato dextrose agar medium, and 10 pieces were placed on Petri, cutting discs of six mm in diameter from the cultures. The germinated seeds are also grounded on the fungus discs. Ten days later, the developing plants were evaluated. A second repetition of the experiment was done 15 days later. The evaluation resulted in the highest disease severity of isolates of *B. sorokiniana* 32, 37, 40 and *B. spisifera* 2 and 45 compared to control. When the root length was studied, it was determined that *B. spicifera* isolate 2 affected the roots most, but that inoculated plant isolates 67 and 46 were into a different class, with roots developing better than controlled. *B. sorokiniana*'s 32 and *B. spicifera*'s 62 isolates have also been found to reduce the length of the plant's leaf. *B. sorokiniana*, 32, 37, 47 and *B. spicifera*, isolates 8 and 42, were found to increase root weight compared to control in plants, while *B. spicifera* isolate 67 increased root weight relative to control. A study of weight in the leaf also found that *B. sorokiniana*'s 32, 37 and 40 isolates resulted in a significant reduction in weight. As a result, some *B. spicifera* isolates have been found to be both non-pathogenic and promoting plant development in plants. On the other hand, *B. sorokiniana*'s 32 and 37 isolates have been found to have high virulence, resulting in reduced plant weight and shortened plant length.

Keywords: *Bipolaris Sorokiniana, Bipolaris Spicifera*, Altındane, Root Rot

Introduction

Wheat (*Triticum aestivum* L.) is one of the most widely produced and consumed cereal crops in the world and in our country. It is known that yield losses in wheat production are between 3-50% every year and a significant part of these losses are caused by root and crown rot fungal disease agents (Finci ,1979, Hill et al. 1983, Wiese 1987, Aktaş et al. 1996, Bateman and Murray 2001, Araz et al. 2009). As root and crown rot fungal agents in our country; *Bipolaris sorokiniana* (syn. *Drechslera sorokiniana*), *Alternaria* spp., *Fusarium* spp., *Dreschlera* spp., *G. graminis* var. *tritici*, *Microdochium nivale.*, *Nigrospora oryzae* ,*Pythium* spp.

Among these agents, *B. sorokiniana* causes significant yield losses in our country and in the world (Nelson and Kline, 1962; Aktaş, 1982; Duveiller et al., 1998; Tunali et al., 2008). It is reported that *B. sorokiniana* is the main pathogen causing root rot in wheat and barley in Central Anatolia in Turkey and Saskatchewan in Canada (Hill et al., 1983; Windels and Holen, 1989; Fernandez and Jefferson, 2004; Tunali et al., 2008). As a result of a study conducted in the Central Anatolia region, it was determined that the prevalence of root rot caused by *B. sorokiniana* was 1/3 of the barley cultivated areas (Aktaş and Tunalı, 1994). It was determined that *B.*

sorokiniana caused spot blotch, black point and root rot in barley and wheat cultivated areas in Turkey and in the world (Mitra, 1930; Clark and Dickson, 1958; Iren, 1962; Karaca, 1968; Aktaş and Bora, 1981; Eken and Demirci, 1998; Chaurasia et al, 2000).*Pseudocercosporella herpotrichoides*, *Phoma* spp., *Ulocladium atrum*, *Rhizoctonia* spp., *Waitea circinata* var *circinata* etc. were detected (Yılmazdemir, 1976; Ataç, 1977; Soran and Damgacı, 1980; Aktaş, 1982; Kınacı, 1984; Muratçavuşoğlu and Hancıoğlu, 1995; Aktaş et al., 1996; Demirci, 1998; Eken and Demirci, 1998; Aktaş et al., 1999, 2000; Arslan and Baykal, 2001; Demirci and Dane, 2003; Uçkun and Yıldız, 2004; Tunalı et al., 2008; Uğuz et al., 2009; Araz et al., 2009, 2010).

Bipolaris spicifera, which is included in *Bipolaris* genera such as *B. sorokiniana*, is widespread in tropical and subtropical regions of the world (Ellis 1971; Koo et al. 2003). *B. spicifera* has been isolated from plants such as barley, wheat, wild cereals, maize, rice, sorghum (Domsch et al., 1980; Liu and Pu, 2004; Ünal et al., 2011; Fajolu, 2012) and fruits such as watermelon and pomegranate (Mhadri et al., 2009; Kadri et al., 2011). This fungus has been isolated from soil and air and found in at least 77 different plant species (Domsch et al., 1980). In the USA and Italy, *B. spicifera* was found to cause 5-11% of turfgrass diseases (Koo et al., 2003). *B. sipicifera* causes 32-60% yield loss in sorghum plants as a result of foliar symptoms (Mohan et al. 2009). In a patogenicity study conducted in Morocco, it was determined that B. sipicifera caused 88-90% disease in wheat and barley (Qostal et al., 2019).

The aim of this study was to determine the effects of *B. sorokiniana* and *B. spicifera* isolates isolated from barley and wheat plants collected from different agro-ecological regions of our country on plant growth and pathogenicity of Altındene wheat variety.

Material and Methods

The fungal material used in the study was obtained from wheat and barley plant samples from different regions and obtained from the culture collection of Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Mycology Laboratory.

Fungal inoculum and pathogenicity

Bipolaris sorokiniana and *B. spicifera* isolates were transferred to potato dextrose agar (PDA) and kept in darkness for 12 hours and under black light + daylight fleurosan for 12 hours for nine days. On the ninth day of the development of the isolates, 10 discs were cut from each isolate with the help of a 6 mm diameter cork borer and placed in Petri dishes containing two layers of sterile blotting paper and saturated with distilled water. "Altındane" wheat variety, which is sensitive to *B. sorokiniana,* was used in the study and healthy seeds were selected for superficial disinfection of the seeds and kept in 2% sodium hypochlorite solution for three minutes, then rinsed twice in distilled water and left to dry on sterile blotters. After the seeds were dried, two layers of blotting papers were placed in a plastic cuvette, saturated with distilled water, and the seeds were placed on the discs and the cuvette was covered and pre-germinated at room temperature of 20-25°C for 48 hours. Seeds with healthy coleoptile and root development were selected from the germinated seeds and placed on 6 mm diameter discs cut from fungal isolates developed for seven days. As a control, discs were cut from PDA medium and healthy seeds were placed on them. The prepared Petri dishes were incubated in an incubator at 23°C ± 2 for 7 days.

Disease assessments

In this study, 11 different isolates were used and the experiment was established according to the random plots experimental design with 3 replications and a total of 30 seeds for each isolate. At the end of the incubation period, shoot length, root length, root and shoot wet weight and dry weight of the plants in each Petri were measured. Disease evaluation was based on a 0-3 disease severity scale (Ledingham et al., 1973). Scale values: 0 = no disease (no discolouration); 1 = weak disease: lesions were punctate; 2 = moderate disease: linear lesions enlarged but not completely surrounding the root collar; 3 = severe disease: at least 50% discolouration and lesions completely surrounding the lower internode.

Analysing the Data

One-way ANOVA test was used to determine the statistical differences between *B. sorokiniana* and *B. spicifera* isolates used in the study and the development and disease severity values of "Altindane" wheat variety. Levene's test was used for homogeneity between variances (Levene, 1960) and Duncan's multiple comparison test was used to find significant differences between isolates (Duncan, 1955). SPSS v.21 statistical package programme (IBM Statistics, OMU 500 user licensed) was used in the analyses.

Results and Discussion

In this study, the data of root length, shoot length, disease severity (%), wet and dry weights (g) of wheat plants as a result of in vitro pathogenicity test with different *B. sorokiniana* and *B.spicifera* isolates using "Altındane" wheat variety are given in Table 1.

When the disease severity of the isolates on wheat plants is analyzed, it is seen that the isolate from Şanlı Urfa caused the highest disease severity with 94.3% and was in a separate group. It was followed by *B. spicifera* isolates from Diyarbakır with 59.8% disease severity and *B. sorokiniana* isolates from Ankara with 57.4%. *B. spicifera* from Konya with 40.2% disease rate, another isolate from Ankara with 37.5% and *B. sorokiniana* isolate from Konya with 35.5% disease severity were in a different group from the control (Figure 1).

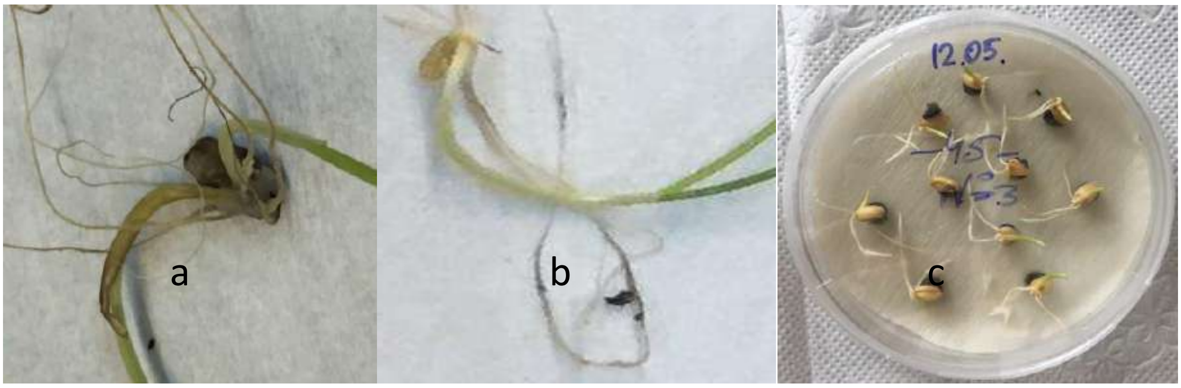

Figure 1. a-. Diseased shoot and root b- Heathy shoot and root c- Petri trial with Altındane variety

Disease symptoms also occurred in control plants and *B. sorokiniana* was isolated by reisolation. This indicates that the seeds of the cultivar used were contaminated with *B. sorokiniana* but the level of contamination was low. Ünal et al. (2010) carried out pathogenicity test of *B. spicifera* isolates isolated from samples collected from Sakarya province with wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), paddy (*Oryza sativa* L.), oat (*Avena sativa* L.), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) etc. plants under greenhouse conditions. As a result, it was reported that the agent did not cause disease in wheat plant. As a matter of fact, Koo et al. (2003) conducted pathogenicity test of *B. spicifera* on tall fescue (*Festuca arundinacea*), meadow kelp-tail (*Phleum pratense*), pigweed (*Dactylis glomerata*), Bermuda grass (*Cynodon dactylon*), barley (*Hordeum vulgare* L.), paddy (*Oryza sativa* L.), maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.), but not on wheat (*Triticum aestivum* L.) and meadow fescue (*Poa* sp.).

In studies conducted in different parts of the world, yield losses as a result of damage caused by *B. sorokiniana* under field conditions were determined as 23.8% in Nepal (Shrestha et al., 1997) and 18-22% in India (Singh and Srivastava, 1997). In another study, it was reported that 12Mha area was affected by *B. sorokinana* in South Asia (Nagarajan and Kumar, 1998; Ruckstuhl, 1998). In a study conducted in Azerbaijan, it was determined that *B. sorokiniana* had higher virulence than *B. spicifera* in wheat seedlings (Özer et al., 2020). In this study, as in our study, *B. spicifera* was found to be pathogenic, but *B. sorokiniana* was more pathogenic.

When root length was examined, it was determined that the roots of the plants inoculated with Ş.Urfa and Sivas isolates of *B. sorokiniana* developed the least, whereas Sivas -Şarkışla and Tokat -Merkez samples of *B. spicifera* had the longest root length and were in a different group from the control. When shoot development was analysed, it was observed that Ş.Urfa isolate of *B. sorokiniana* caused the shortest shoot, followed by Ankara isolate and all other isolates were in the same group with the control Table 1.

Table 1. The effects of Bipolaris sorokiniana and B. spicifera on disease severity, shoot and root length and shoot and root wet weights.

Isolate Code/Number	Bipolaris spp. Morphology	Disease severity (%)/group	Root length (cm)/group	Shoot length (cm)/group	Root Fresh weight (g)/group	Shoot fresh weight (g)/group
Ş50-KB1/N32	B.sorokiniana	94,3% e	7.34 a	6.83 a	0.185 a	0.302a
D21-K5-4/N45	B.spicifera	59,8% d	12.66 bcd	8.80 bcd	0.374 bc	0.516 bc
B3-K2/N37	B.sorokiniana	57,4% d	9.99 abc	8.07 ab	0.190 a	0.298 a
B17-K1/N2	B.spicifera	40,2% bc	10.47 abc	9.77 bcde	0.259 ab	0.514 bc
B3-K2/N62	B.spicifera	37,5% b	12.51 bcd	8.59 bc	0.360 abc	0.473 abc
B17-KB2/N40	B.sorokiniana	35,5% b	13.77 cd	8.54 bc	0.399 bc	0.385 abc
MU25-KB1/N8	B.spicifera	31,8% ab	14.01 cd	10.05 cde	0.340 abc	0.538 abc
S14-35-4K/N47	B.sorokiniana	29,4% ab	9.27 ab	9.10 bcd	0.257 ab	0.531 bc
B32-K1/N42	B.spicifera	28,9% ab	12.76 bcd	9.51 bcd	0.232 ab	0.355 bc
S31-KB2/N46	B.spicifera	19,3% ab	15.71 de	10.49 de	0.441 c	0.753 de
B2-KB1/N67	B.spicifera	10,8% a	17.85 e	11.37 e	0.513 c	0.801 e
CONTROL	B.sorokiniana	23,6% ab	11.34 cb	10.01 cde	0.352 abc	0.593 cd

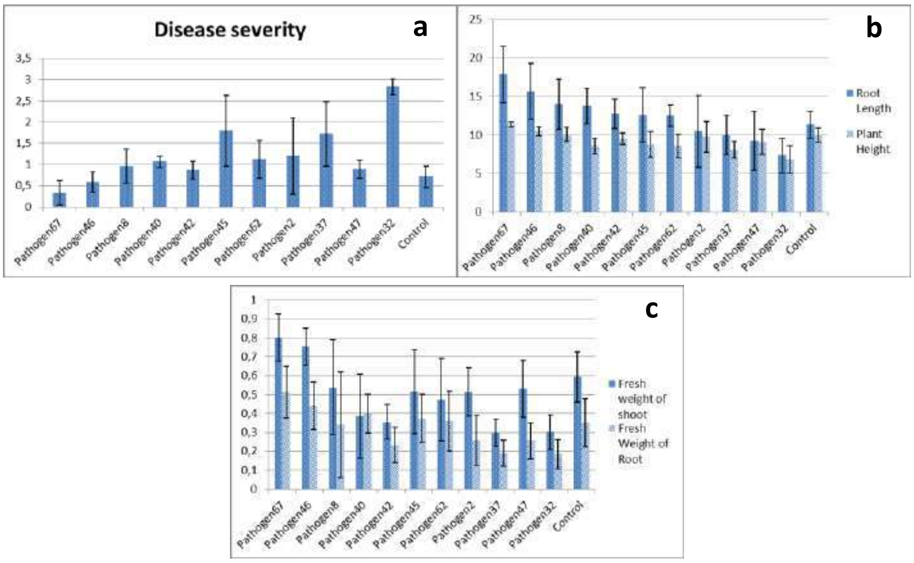

Figure 2. a. Disease severity, b.Root lenght and Shoot lenght c. Shoot wet weight and Root wet weight

In our study, when root wet weights were analysed, it was determined that there was no statistical difference with the control plants. Shoot wet weight, like shoot length, was lowest in plants inoculated with Diyarbakır isolate of *B. sorokiniana* and Ankara isolate. The plants with the highest shoot wet weight were the plants inoculated with Tokat -Merkez isolate of *B. spicifera*. Aktaş and Bora (1981) reported that the disease severity of *B. sorokiniana* in wheat and barley fields in the Central Anatolia region of Turkey was 8.25% and yield loss was 123 kg/ha on average due to the fungus. Tunalı et al. (2023) reported that all *B. spicifera* and *Bipolaris australiensis* isolates used in the experiment were in the same group with the control in terms of disease severity. In the same study, the wet weight of the plants in the control group was less than the wet weight of

Conclusion

In this study, the effects of *B. sorokiniana*, an important soil-borne pathogen, and *B. spicifera* isolates, which are frequently isolated from wheat plants, on disease severity, plant root and shoot length, and plant root and shoot wet weight of wheat plants were investigated. Some of the *B. sorokiniana* isolates were found to have high virulence while others had lower virulence. However, some of the *B. spicifera* isolates had very low virulence or showed at most moderate virulence. Some of them even did not cause disease and increased root and shoot length and weight of plants. We believe that it would be useful to analyse these isolates in pot trials and to examine their effects on some cereal diseases and plant growth.

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Impact of biostimulants on soil quality

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Abstract

The soil constitutes the basis for economic and cultural activities in our ecosystem. Nonetheless, factors such as population growth, climate change, intensive agriculture, and excessive grazing have led to deteriorating soil quality and health. Consequently, soil productivity and sustainability have decreased. Scientists have developed numerous soil quality models, and soil monitoring programmes have been initiated in response. The adoption of synthetic fertilisers has enhanced productivity. However, their prolonged use has resulted in leaching, leading to mixing with groundwater and consequent water pollution, poor water quality, and at times, eutrophication. Researchers have hence focussed on reducing synthetic fertiliser use and turning to biostimulants containing animal and plant material. This research investigated the effects of biostimulants, specifically ekofertile® and microfertile®, produced by the ECOLIVE corporation, on soil quality. The study was conducted in a controlled greenhouse environment, utilizing two distinct soil types—clayey and sandy-loam—each replicated three times. The experiment involved five treatments: control, inorganic fertilization, and two biostimulants at doses of 2.5%, 5%, and 10%, arranged in a complete randomized design. At the trial's conclusion, physical, chemical, and biological analyses were performed on the soil of each pot. Using the analytic findings, the soil qualities were determined using the SMAF model. Based on the results obtained, the most effective approach to enhancing soil quality in clayey soil was the application of 10% ekofertile®, which improved soil quality from 72.09 to 77.93. For sandy loam soil, the application of microfertile® at a 5% dose proved to be the most effective, resulting in a significant increase in soil quality from 76.53 to 78.19.

Keywords: Organic acids, Microbes, Ekofertile® and Microfertile®, SMAF model, Wheat

Introduction

Soil is a vital natural resource on our planet, holding immense significance for humanity. The quality of soil significantly impacts plant growth, food production, water cycles, and the health of ecosystems. It is essential to take immediate measures to preserve the quality of soil for future generations to come. However, presently, soil quality is progressively declining. There are various factors that influence soil productivity, including agricultural practices, urban expansion, industrial activities, and climate change. These factors lead to a gradual decline in soil quality, which reduces its productivity and sustainability over time. Furthermore, the application of synthetic fertilizers to enhance agricultural productivity results in problems such as water pollution, lower water quality, and occasionally, the onset of eutrophication (Koli et al., 2019; Pahalvi et al., 2021). Moreso, the application of these fertilizers has been linked to the inclusion of harmful substances, such as cancer-causing agents, in the food supply (Zhang et al., 2018; Rahman and Zhang, 2018). In order to secure healthy food production, efforts have been made to decrease the application of synthetic fertilizers and identify sustainable substitutes. As a result, biostimulants have arisen as potential solutions to alleviate climate change stresses and lower reliance on synthetic fertilizers (Garcia-Fraile et al., 2017; Swift et al., 2018). While researchers continue to debate the definition of biostimulants, they generally comprise natural plant and animal materials and have been grouped into various categories by the European Commission (European Parliament, 2019). Biostimulants are environmentally-friendly options intended to enhance agricultural productivity by boosting nutrient absorption, nutrient utilization efficiency, tolerance to non-biological stressors, and product quality. Moreover, they improve the accessibility of limited nutrients in the soil or plant rhizosphere (Garcia-Fraile et al., 2017; Chiaiese et al., 2018). The sustainability of biostimulants and their capacity to enhance soil properties has motivated researchers to include them in studies aimed at enhancing soil quality.

Soil quality is affected by various factors, which can be both challenging and expensive to determine. Therefore, it is crucial to choose appropriate indicators for evaluating soil quality (Negiş and Şeker, 2019). Currently, there are several methods available for assessing the quality of land and soil, such as the Land Quality Index method, Dynamic Multivariable Land Quality method, Land Test Kits, Soil Management Assessment Framework (SMAF), and Cornell Soil Health Assessment (Andrews et al., 2004; Gugino et al., 2009). Other approaches such as the Müencheberg Soil Quality Rating, LSRS (Land Suitability Rating Index), VSA (Visual Soil Assessment), and MicroLEIS DSS have been created to incorporate soil quality ratings on a global scale, resulting in more accurate assessments and close associations with crop yields[12, 13, 14] (Alaboz et al., 2022). The USDA's SMAF model is utilized to appraise quality indicators for soil quality analyses. This approach illustrates the dynamic quality of soil, which is more influenced by applied management than by genetic factors. It considers critical soil formation aspects, including climate, topography, parent material, and so on. SMAF includes various indices including electrical conductivity, pH, organic carbon, aggregate stability, sodium adsorption ratio, available potassium and phosphorus, microbial biomass carbon, bulk density, water-filled pore space, available water content, βeta-Glucosidase enzyme activity, microbial biomass carbon, and potential mineralizable nitrogen (Andrews et al., 2004).

Thus, this study was setup to investigate the impact of two distinct biostimulants produced by ekolive, namely ekofertile® and microfertile® on soil quality as predicted by SMAF model under greenhouse cultivation of wheat.

Material and Methods

Study site description

The study was carried out at the greenhouse in the Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey. The site coordinates are 264201 E and 4582754 N (WGS-84, Zone37 and UTM m). The average annual maximum and minimum temperatures range from 5°C to 27.7°C, while the relative humidity is 73%. The average annual precipitation is 937.26 mm.

Candidate Biostimulants

In this investigation, two products developed by the ekolive company in Slovakia were analyzed for their biostimulant activity in order to ascertain their potential as biostimulants, as indicated by the laboratory analysis of their composition, following the methodology of Yahkin et al. (2017). Table 1 presents the organic acid content of ekofertile® and microfertile® plant biostimulants. For ekofertile®, Tables 2 and 3 outline the chemical and biological constituents and their functions respectively. The same applies to microfertile®, where Tables 4 and 5 showcase the chemical and biological constituents and their functions respectively.

Table 1. Organic acid constituent of ekofertile® and microfertile® plant biostimulants

Sample	Formic acid (mg/l)	Lactic acid (mg/l)	Acetic acid (mg/l)	Propionic acid (mg/l)	Butyric acid (mg/l)	Methanol (mg/l)	Ethanol (mg/l)
ekofertile® plant	<5	9320	1550	19*	900*	8.6**	610
microfertile® plant	<5	<5	<5	<5	<5	<5	<20

*= HS-GC-MS measurement with internal standard calibration (4-methyl valeric acid)
**=HS-GC-MS measurement with external standard calibration

Table 2. Chemical and microbial constituents of ekofertile® plant (sand based) biostimulant

Chemical content			Microbial content	
Constituent	Unit	Quantity	Genus	Species
Dry matter	%	0.91	Lactobacillus	*Lactobacillus satsumensis*
Organic matter	%	0.27		*Lactobacillus diolivorans*
Ash	%	0.53		*Anaeromassilibacillus senegalensis*
Total Nitrogen	%	0.040		*Lactobacillus bifermentans*
NH_4^+	%	0.01		*Lactobacillus perolens*

NO_3^-	%	< 0.01		*Lactobacillus nagelii*
Available Nitrogen	%	0.01	Clostridium_IV	*Clostridium tyrobutyricum*
Carbamide N	%	< 0.05		*Clostridium ljungdahlii*
P_2O_5 mineral acid soluble	%	< 0.01	Clostridium_sensu_stricto	
K_2O	%	0.0840		
Total MgO	%	0.0275	Bifidobacterium	*Bifidobacterium mongoliense*
Total CaO	%	0.0855		
Total Sulphur	%	0.025	Leuconostoc	*Leuconostoc fallax*
Sodium	%	0.0895		
Silicon	%	< 0.0100	Acetobacter	*Acetobacter indonesiensis*
Alkaline active components	%	0.44	Macellibacteroides	*Macellibacteroides fermentans*
Boron	mg/kg	< 2.00		
Cobalt	mg/kg	0.117	Bacteroides	*Bacteroides luti*
Iron	mg/kg	142		
Copper	mg/kg	< 2.00		
Manganese	mg/kg	6.58		
Molybdenum	mg/kg	< 0.100		
Zinc	mg/kg	< 2.00		
pH		4.5		
Salt content	% KCl	0.782		

Table 3. Role of beneficial microbes found in ekofertile® plant biostimulant

		Coal	
	Genus	Species	Function
1	Lactobacillus	*Lactobacillus satsumensis*	Catalyzes the hydrolytic depolymerization of polysaccharides in soil. Breakdown of complex polysaccharides, including starch, to a readily available form of glucose, extracellular polymeric substances secretion & fermentation
		Lactobacillus diolivorans	Solubilize insoluble inorganic phosphate
		Anaeromassilibacillus Senegalensis	
		Lactobacillus bifermentans	
		Lactobacillus perolens	
		Lactobacillus nagelii	
2	Clostridium_IV	*Clostridium tyrobutyricum*	Free Nitrogen fixation release polysaccharides and carboxylic acids like tartaric acid and citric acid to solubilize K, breakdown organic matter releasing citric acid, formic acid, malic acid, and oxalic acid, making K available, fermentation
		Clostridium ljungdahlii	Obligatory anaerobic heterotrophs only capable of fixing N2 in the complete absence of oxygen, isolated from rice fields
3	Clostridium_sensu_stricto		Fermentation
4	Bifidobacterium	*Bifidobacterium mongoliense*	Degradation of non-digestible carbohydrates, protection against pathogens, production of vitamin B, antioxidants, and conjugated linoleic acids, and immune system stimulation.
5	Leuconostoc	*Leuconostoc fallax*	Catalyzes the hydrolytic depolymerization of polysaccharides in soil. Breakdown of complex polysaccharides, including starch, to a readily available form of glucose, fermentation
7	Macellibacteroides	*Macellibacteroides fermentans*	Fermentation
8	Bacteroides	*Bacteroides luti*	Pathogen-suppressing contributes prominently to rhizosphere phosphorus mobilization, express constitutive phosphatase activity, and organic matter degradation

Table 4. Chemical and microbial constituents of microfertile® plant (milled silicified rock residues after coal mining based) biostimulant

Chemical content			Microbial content	
Constituent	Unit	Quantity	Genus	Species
Dry matter	%	< 0.32	Thiobacillus	
Organic matter	%	< 0.01	Shinella	
Ash	%	0.4	Comamonas	
Total Nitrogen	%	0.020	Bosea	
NH_4^+	%	< 0.01	Thermomonas	*Thermomonas koreensis*
NO_3^-	%	< 0.01	Clostridium_sensu_stricto	*Clostridium saccharobutylicum*
Available Nitrogen	%	< 0.01	Pseudomonas	*Pseudomonas* sp.
Carbamide N	%	< 0.05	Unclassified at the Genus level	
P_2O_5 mineral acid soluble	%	< 0.01	Castellaniella	*Castellaniella daejeonensis*
K_2O	%	< 0.0285	Petrimonas	*Petrimonas sulfuriphila*
Total MgO	%	0.0155	Tepidibacillus	*Tepidibacillus fermentans*
Total CaO	%	0.023		*Sedimentibacter saalensis*
Total Sulphur	%	0.0465		
Sodium	%	0.102		
Silicon	%	< 0.0100		
Alkaline active components	%	0.555		
Boron	mg/kg	< 2.00		
Cobalt	mg/kg	0.361		
Iron	mg/kg	12.2		
Copper	mg/kg	< 2.00		
Manganese	mg/kg	< 2.00		
Molybdenum	mg/kg	< 0.100		
Zinc	mg/kg	4.30		
pH		7.8		
Salt content	% KCl	0.574		

Table 5. Role of beneficial microbes found in microfertile® plant biostimulant

		Coal	
	Genus	Species	Function
1	Thiobacillus		Release polysaccharides and carboxylic acids like tartaric acid and citric acid to solubilize K, breakdown organic matter releasing citric acid, formic acid, malic acid, and oxalic acid, making K available
2	Shinella		Biosurfactant producers capable of degrading crude oil components within 14 days, bioremediations.
3	Comamonas		Alleviate salinity stress, and degrade phenol and 4-chlorophenol mixtures completely through a meta-cleavage pathway, beneficial for enhanced cell growth and the biotreatment of both compounds, bioremediation, biofertilizer
4	Bosea		Bioavailability of nutrients, N-fixation, denitrifier.
5	Thermomonas	*Thermomonas koreensis*	Nutrient cyclings, such as nitrogen respiration, nitrate reduction, nitrate respiration, fermentation, and cellulolysis
7	Clostridium_sensu_stricto	*Clostridium saccharobutylicum*	Fermentation
8	Pseudomonas	*Pseudomonas* sp.	Free Nitrogen fixation, solubilize insoluble inorganic phosphate and K Indole-3-acetic acid, wheat, A combined bio-inoculation of diacetyl-phloroglucinol producing PGPR and AMF and improved the nutritional quality of the wheat grain, organic compounds degradation, auxins
9	Castellaniella	*Castellaniella daejeonensis*	Acid phosphatase and invertase activities,

			available potassium and iron, and organic matter content
10	Petrimonas	*Petrimonas sulfuriphila*	Anaerobic and fermentative, Degradation of high insulable organic molecules, plant residues decomposition
11	Tepidibacillus	*Tepidibacillus fermentans* *Sedimentibacter saalensis*	Ferment yeast extract and mono-, oligo-, and polysaccharides, including starch and xanthan gum

Experimental Design

The experimental design of the greenhouse is a split-plot design, comprising two factors (Table 6). These factors pertain to dosage and biostimulant type and were evaluated on two soil types (loam soil from Samsun Turkey Bafra plain and clay soil from the Faculty of Agriculture practicing field). Technical term abbreviations are explained upon first use. Factor 1, dosage, was studied across 5 levels (control, inorganic fertilization, 2.5%, 5%, and 10% biostimulant), and biostimulant types included ekofertile® and microfertile® plant biostimulants. Ten treatments were applied to each soil type and replicated three times in the greenhouse. A total of 300kg of soil was collected from the field, with 150kg from the Faculty of Agriculture practicing field at Ondokuz Mayis University and another 150kg from the Bafra plain in Samsun, Turkey. The soil was left in the shade to air dry for two weeks before being crushed and sieved through a 4mm sieve to obtain fine particle soil suitable for crop growth in the greenhouse. Three kilograms of soil were placed in a 5L bucket with no perforations to prevent leaching on a surface area of 0.031 m^2. The field capacity of the soil was estimated by measuring moisture content. Following the treatments detailed in Table 6 and the layout presented in Table 7, wheat seeds were sown accordingly. Each pot contained 15 seeds as 500 seeds are sown per square metre, and they were watered following seeding. The wheat crops were irrigated up to field capacity in the evenings, following a schedule of intervals of two days, to prevent drought stress. Manual weeding was also performed.

Table 6. Treatments combination

Loam Bafra Soil	Biostimulant	ekofertile®					microfertile®				
	Dosage	Control	Inorganic F.	2.5%	5%	10%	Control	Inorganic F.	2.5%	5%	10%
Clay School Soil	Biostimulant	ekofertile®					microfertile®				
	Dosage	Control	Inorganic F.	2.5%	5%	10%	Control	Inorganic F.	2.5%	5%	10%

Inorganic F: Inorganic fertilization

Table 7. Greenhouse layout

Replicate 1		Replicate 2		Replicate 3	
ekofertile®	microfertile®	ekofertile®	microfertile®	ekofertile®	microfertile®
Control	Control	Control	Control	Control	Control
Inorganic F.	Inorganic F.	Inorganic F.	Inorganic F.	Inorganic F.	Inorganic F.
2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
5%	5%	5%	5%	5%	5%
10%	10%	10%	10%	10%	10%

Inorganic F: Inorganic fertilization

A 160-day trial, running from September 7th, 2022, to March 16th, came to a close with the harvest of plants. A set of soil samples were extracted from 48 pots to undergo biological analysis and then stored in a refrigerator at -4 degrees Celsius. The rest of the soil was properly dried, broken down with a wooden mallet, and sieved through a 2mm sieve for physicochemical analysis.

The soil samples' bulk density was determined using the approach reported by Blake and Hartge (1986). Meanwhile, Klute's method (1986) was employed to compute the field capacity and wilting point. The available water content in the soils was calculated by subtracting the moisture content at the wilting point from the moisture content at field capacity (Klute, 1986). Aggregate stability was evaluated by Kemper and Rosenau (1986). Analysis of available phosphorus was accomplished per the Olsen et al. (1954) method, while extractable potassium was evaluated employing a 1 N ammonium acetate solution[21] (Bertsch, 1985). Saturation extracts were used to measure soil pH and Electrical Conductivity (EC) values via a pH-EC meter, following Rhoades et al. (1999). Microbial biomass carbon was measured using Anderson and Domsch's

(1978) substrate-induced respiration method. The Sodium Adsorption Ratio (SAR) was calculated according to Soil Survey Staff (1996) (Equation 1), using the concentrations of Na, Ca, and Mg obtained from saturation extract filtrates.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{[Ca^{+2}]+[Mg^{+2}]}{2}}} \qquad \text{(Equation 1)}$$

Assessment of Soil Quality

The SMAF model assesses the ability of soils to satisfy both agricultural productivity and ecological functions. Within the SMAF model, the physical attributes of soil are evaluated, including bulk density (BD), water-filled pore space (WFPS), aggregate stability (AS), and available water content (AWC). In addition, chemical properties, which comprise organic carbon (OC), electrical conductivity (EC), pH, potential mineralizable nitrogen (PMN), sodium adsorption ratio (SAR), available phosphorous (P), and potassium (Ex-K), are also appraised. Furthermore, biological indicators, such as microbial biomass carbon (MBC), are taken into consideration (Andrews et al., 2004). Twelve indicators, excluding βeta- Glucosidase enzyme activity, were used in this study. The model for scoring employs non-linear functions. The scoring curves employ three distinct approaches: "less is better," "the midpoint is optimum," and "more is better." To determine quality contributions for scoring, consideration is given to all three scoring functions. The model utilizes an algorithm or alternate algorithms for each property's non-linear scoring curve. Normalization and scoring for each indicator are computed by using the algorithms found in the model. The evaluations are executed on 150 crop varieties within the model. Scoring values pertaining to indicators may differ based on the crop variety, climate, and soil classification. Furthermore, regional climate data, mineralogical, and pedological properties, along with soil classification are taken into account. The SMAF model uses an incremental index called the Soil Quality Index (SQI) method (Equation 2) for this purpose.

$$SQI = \frac{\sum_{n}^{i} x_i}{n} \times 100 \qquad \text{(Equation 2)}$$

Results And Discussion

Eight applications were performed on soils with two different textures, namely clayey and loam. The figures below display the distribution of scores for 12 parameters used to assess soil quality after application. Figure 1 presents AWC, BD, and WFPS, Figure 2 shows AGG, EC, and Ex-K, Figure 3 covers pH, PMN, and SoilP, while Figure 4 illustrates SAR, SOC, and MBC.

Upon analysis of the data in Figure 1, one can observe the distribution of soil quality parameters, including AWC, BD, and WFPS. It is evident that loamy soils demonstrate more favorable quality scores for wheat growing across all doses in comparison to clayey soils. These findings are based on the physical attributes of the soil, which vary according to soil texture. The SMAF model evaluates soil quality according to the specific plant's soil requirements, and hence suggests that loamy soils offer wheat cultivation with better quality conditions. Upon separate evaluation of clayey and loamy soils, the parameter with the highest quality score within clayey soils was found to be WFPS, whilst in loamy soils it was determined to be BD.

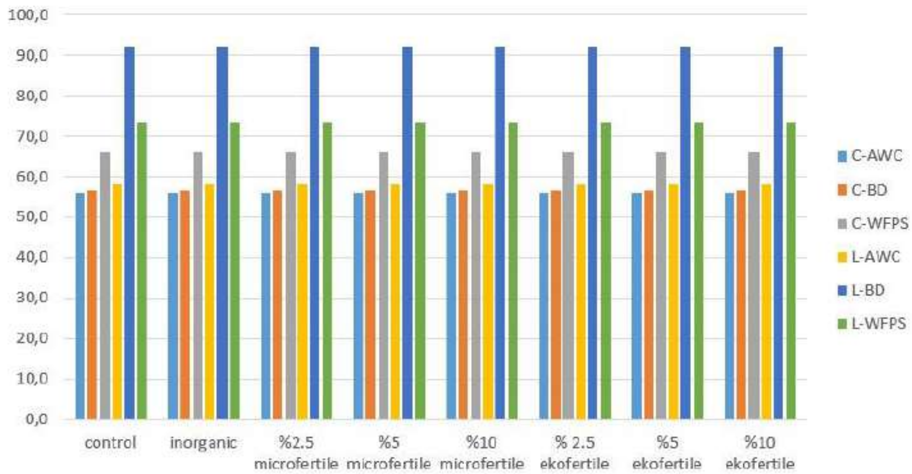

Figure 1. Distribution of quality scores for AWC, BD, WFPS parameters.

Upon examination of Figure 2, the distribution of soil quality parameters AGG, EC, and Ex-K are observed. It is evident that AGG is notably higher in clayey soils compared to loamy soils. Among clayey soils, 2.5% microfertile application has the highest AGG score among the doses, whereas among loamy soils, an inorganic application has the highest score. In clayey soils, EC scores are higher in the control group, and at 2.5% and 5% microfertile doses. However, in other doses, loamy soils yield higher quality scores. For both soil types, Ex-K values consistently demonstrate high quality scores across all doses.

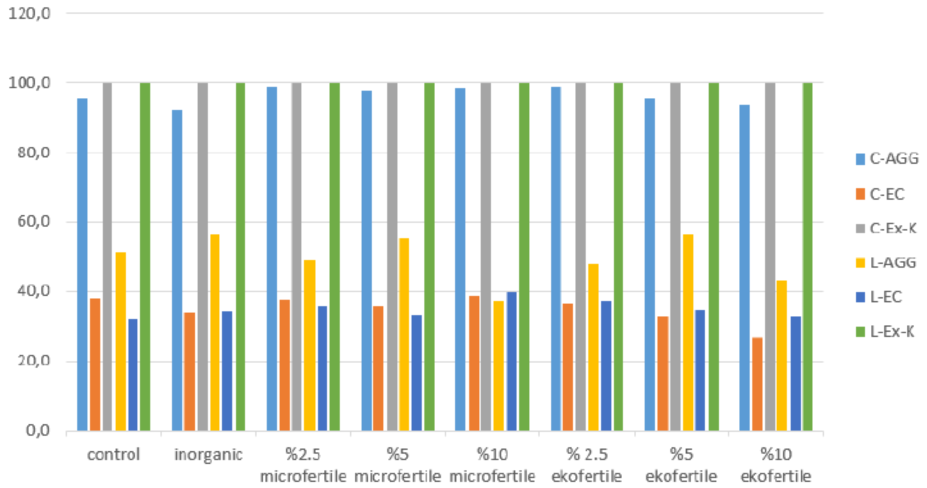

Figure 2. Distribution of quality scores for AGG, EC, Ex-K parameters.

When examining Figure 3, the distributions of soil quality parameters; pH, PMN, and SoilP can be observed. It is evident that the pH level is higher in clayey soils when compared to loamy soils. The application with the highest pH score among the doses for clayey soils is determined to be 5% ekofertile. On the other hand, for loamy soils, the highest score is associated with an inorganic application. The PMN quality scores of both soil types are high quality for all doses. SoilP quality scores are comparatively higher in loamy soils than in clayey soils. It is noteworthy that SoilP doses do not vary among loamy soils. On the other hand, the highest quality score among clayey soils is determined to be the 10% dose of ekofertile. Technical abbreviations such as SoilP and dose have been clearly explained upon their first use.

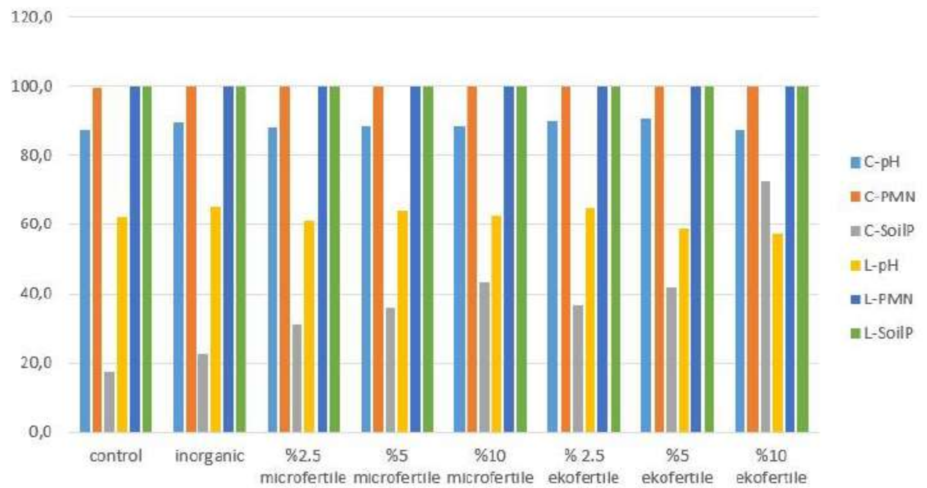

Figure 3. Distribution of quality scores for pH, PMN, SoilP parameters.

Upon examining Figure 4, it is apparent that SAR, SOC, and MBC are the soil quality parameters that can be seen. In terms of the SAR parameter, it is observable that the control condition without any applications yields a lower SAR in the clayey soil when compared to all other doses for both clayey and loamy soils. Noteworthy is that the highest quality score for SAR is achieved by an inorganic application in both clayey and loamy soils. In terms of SOC quality scores, it has been observed that the score is higher in clayey soils compared to loamy soils. However, it has been determined that in both clayey and loamy soils, the application with the highest SOC score is the 10% dose of ekofertile. With regards to MBC quality scores, although generally similar, it was found that in clayey soil, all doses except for 2.5% microfertile, 2.5% ekofertile, and 10% ekofertile have lower scores than in loamy soils. In loamy soils, the application yielding the highest MBC quality score was found to be the 5% dosage of ekofertile.

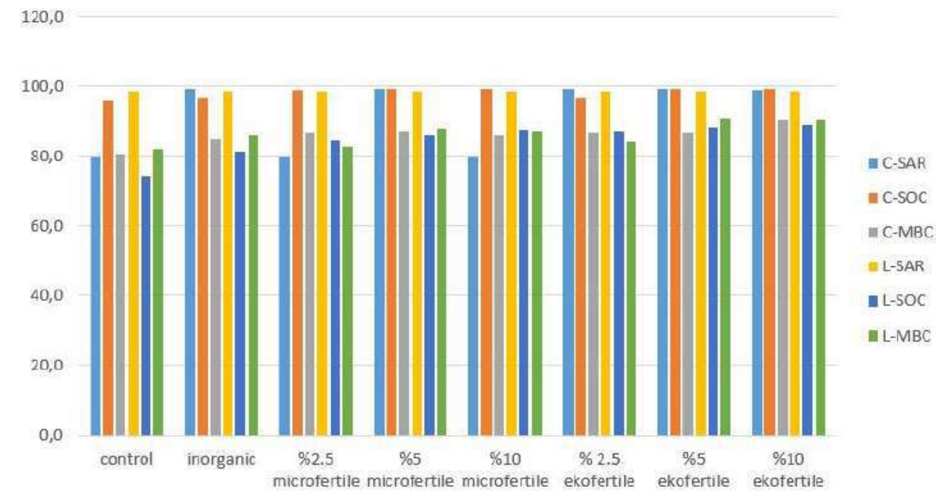

Figure 4. Distribution of quality scores for SAR, SOC, MBC parameters.

The comparison of soil quality values, obtained from twelve quality parameters for clayey and loamy soils, is depicted in Figure 5. The analysis suggests that loamy soils score higher in soil quality for wheat cultivation across all applications except for the 10% dose of ekofertile application. The most effective ekofertile dose turned out to be 5%.

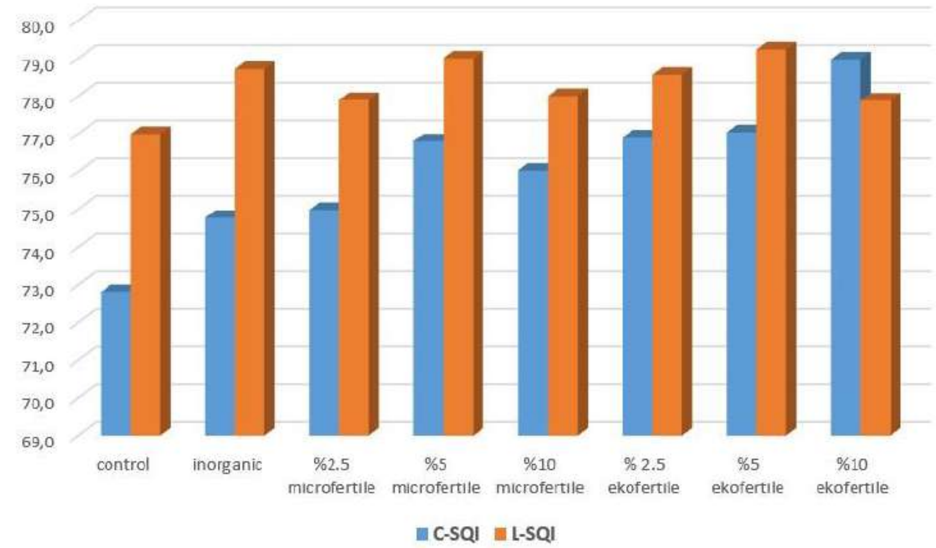

Figure 5. Soil quality scores for clay and loam soils at 8 different doses

Conclusion

The study showed that biostimulants are effective alternatives in enhancing soil quality at wheat rhizosphere. While 10% ekofertile® enhanced soil quality the most in clay soil, 5% microfertile® was most effective in general soil quality enhancement across the two soils and biostimulants dosages. We therefore recommend the usage of biostimulants to enhance soil quality.,

Acknowledgement

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Isolation of nucleic acids from sugar beet roots by using fibrous cellulose for the detection of soil-borne viruses and their vector *Polymyxa betae*

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Abstract
Rhizomania is a common soil-borne viral plant disease that occurs in sugar beet (Beta vulgaris L.) fields and causes high decreases in yield and sugar content. The disease is caused by Beet necrotic yellow vein virus (BNYVV) and transmitted by the soil-inhabiting protozoan plasmodiophorid vector Polymyxa betae Keskin. This vector also transmits other sugar beet viruses such as Beet virus Q (BVQ), Beet soil-borne virus (BSBV) and Beet soil-borne mosaic virus (BSBMV).In this study, BNYVV, BVQ and P. betae were propagated by the bait plant technique using BNYVV-susceptible cultivar (cv. Ansa). Then, total nucleic acids (NAs) from the lateral root samples of the bait plants were purified by using fibrous cellulose. A small amount (1.5 g) of root sample was sufficient in total NA isolation. One-step reverse transcription-polymerase chain reaction (RT-PCR) have been applied to identify BNYVV, BVQ and P. betae. As a result of the study, the expected sizes (997 bp, 291 bp and 350 bp) of DNA fragments were obtained for BNYVV, BVQ and P. betae, respectively. This cellulose-based NA isolation method was found to be highly economical and recommended for detection of the soil-borne viruses and their vector in sugar beet.

Keywords: BNYVV, BVQ, *P. betae*, Cellulose Fibres, ITS, RT-PCR

Introduction

Cellulose powder has been used to isolate nucleic acids for many years, especially in isolation and characterization of double-stranded (ds) forms of ribonucleic acids (Jackson et al., 1971). The affinity of cellulose fibres for nucleic acids helped to develop several methods to identify plant, animal, fungi and bacteria viruses. Most of plant viruses consist of single-stranded (ss) RNA which produce dsRNA molecules as intermediate copies of virus genome; therefore, dsRNA extraction analysis can be considered as a promising tool in virus identification for both ssRNA and dsRNA viruses (Morris and Dodds, 1979). Up to now, several attempts have been done to extract dsRNAs from many different plants such as barley (Morris and Dodds, 1979), grapevine (Azzam et al., 1991), sour cherry (Zhang et al., 1998), rice (Okada et al., 2015), potato (Blouin et al., 2016), bean, *Chenopodium quinoa*, *Gomphrena globosa* (Khabbazi et al., 2017) and persimmon (Çankaya and Arlı-Sökmen, 2022).

According to the previous studies, plant host could be one of the main factor interfering dsRNA extraction (Tzanetakis et al., 2008). High quantity of tannins, phenolic compounds and polysaccharides in some plants could be problematic for nucleic acid extraction (Loomis, 1974). To facilitate the extraction in such recalcitrant plants, the methods have been improved and established (Rezaian et al., 1991); however, some of the protocols have been time consuming, labour-intensive (Speiegel, 1987; Li et al., 2007), and have required a large amount of plant tissue (Velverde et al., 1990). Also, some of the previous methods included Whatman CF-11 type cellulose, which is no longer available. Khankum *et al*. (2015) used fibrous cellulose (Sigma-Aldrich, St. Louis, MO, USA) to extract dsRNAs from virus-infected plants and fungi.

In this study, Sigma-Aldrich's cellulose was used to investigate the availability of it for isolation of total NAs, and detection of soil-borne viruses and *Polymyxa betae* by RT-PCR with virus-specific and internal transcribed spacers (ITS) region-specific primers, respectively.

Material and Methods

Bait plant test

A soil sample originating from a sugar beet field, which has previously been determined to be heavily infested with soil-borne viruses (BNYVV and BVQ) and their vector *P. betae* in Konya province, was used in this study. Also, a non-infested soil collected from a sugar beet field in Samsun province was added to the experiment as healthy control. The non-infested soil was autoclaved at 121°C and 1.1 atm pressure. Both *P. betae/*virus-infested and non-infested soil samples were mixed with autoclaved-sand in a ratio of 1: 2 (soil: sand, by weight). Afterwards, seven-day-old sugar beet seedlings of rhizomania-susceptible genotype (cv. Ansa-*rz1*) were planted in 300-ml plastic pots containing each soil sample. The plants were grown under controlled conditions of 12-h photoperiod, at 20°C (night) and 25°C (day) temperatures. After six weeks of growth, plants were removed from pots, the taproot was washed under running water. The roots of bait plant were divided into two parts. One part was used for total nucleic acid isolation, the other part was used for total RNA isolation.

Isolation of nucleic acids

The total nucleic acids (NAs) were extracted from the rootlets of bait plants by using fibrous cellulose (Sigma-Aldrich, St. Louis, MO, USA, catalog No: C6288). NA isolation was carried out by homogenization of 1.5 g fresh root sample in 2 ml lysis buffer (200 mM Tris, 500 mM NaCl, 10 mM $MgCl_2$, 3% SDS, 10% Ethanol, 1% 2-Mercapto ethanol), and divided into 6 tubes. After vortexing of 10 seconds, tubes were incubated at 37°C in a thermal heating block for 10 minutes and centrifuged at 11.300 rpm for 20 min at 4°C. The upper layer was transferred into a new tube and chloroform added in 1: 1 ratio, and followed by a 7 min centrifugation at 11.300 rpm at 4°C. The upper layer was placed into a new tube; 0.2 ml absolute ethanol was added for each 1 ml of the supernatant, inverted for several times and followed by a 5 min centrifugation (11300 rpm at 4 °C). In order to provide binding of nucleic acids to the cellulose particles, 15 mg of cellulose fibers were added to each tube, mixed vigorously, and maintained at room temperature for 15 min. After a 7 min centrifugation at 11300 rpm (4 °C), the upper phase was removed, and 1 ml washing buffer (1X STE [100 mM NaCl, 10 mM Tris-HCL, 1 mM EDTA, pH 8.0] 16% ethanol) was added and mixed vigorously. After centrifugation of 5 min, the pellet and aqueous phase were separated. Transparent phase was removed and washing step repeated. To elute the pellet after removing upper phase, 150 µl 1XSTE without ethanol was added and incubated at room temperature for 15 min. After centrifugation for 5 min at 11300 rpm, the upper phase was transferred into a fresh tube. Divided samples of the same type were collected in one tube. Absolute ethanol was added in twice the volume of the solution and kept at -20 °C for an hour. To precipitate the total NAs, tubes were centrifuged at 11300 rpm for 20 min at 4◦ C. The pellet was exposed to dry for 15 min, then dissolved in 30 µl ddH_2O and maintained at -20 °C.

On the other hand, total RNAs were also isolated from the rootlets of the bait plants by using the RNeasy Plant Mini Kit (Qiagen) according to the manufacturer's instructions, and two NA isolation methods were compared in the detection of sugar beet pathogens.

RT-PCR detection

In the current study, primers used for amplifying of soil-borne viruses (BNYVV and BVQ) and their vector *P. betae* are listed in Table 1. Initially, 3 µl the extracted NA sample was preheated at 80°C for 5 min and then chilled on ice prior to RT-PCR.

For the detection of BNYVV, one step RT-PCR was performed using a Superscript I One step RT-PCR kit (Invitrogen). The upstream (RT-4F) and the downstream (RT-4R) primers specific for BNYVV RNA-4 including the whole P31 gene were used (Table 1). The following reaction conditions were employed: 50°C for 30 min (RT) and 94°C for 2 min followed by 35 cycles of 94°C for 15 s, 50°C for 30 s, 72°C for 1 min, and with a final elongation for 7 min at 72°C.

Table 1. List of primers used in polymerase chain reaction, base sequences and the expected band sizes

Primer	Nucleotide (5'⟶3')	Target RNA and region	Expected product lenght (bp)	Literature
RT-4F RT-4R	*CAGTCTATCAGTAAGGGGTAG* GAGCCCGTTAATACAATTATAC	BNYVV RNA-4, P31	997	Chiba et al., 2011
BVQ/F BVQ/R	GCTGGAGTATATCACCGATGAC AAAATCTCGGATAGCATCCAAC	BVQ RNA-1	291	Meunier et al., 2003
P. betae/ F *P. betae*/ R	CTGCGGAAGGATCATTAGCGTT GAGGCATGCTTCCGAGGGCTCT	*P. betae* 5.8s + ITS	350	Ward and Adams, 1998

For the investigation of BVQ and *P. betae*, one-step RT-PCR was performed (Mouhanna et al., 2008), as described in the Qiagen's manual using forward and reverse primers, which are specific for BVQ RNA-1 and the 5.8s rDNA along with the internal transcribed spacer (ITS) region of *P. betae*. The RT-PCR reaction included the following: 5.3 µl of RNase-free water, 0.4 µl of dNTPs mix (400 µM), 2 µl of 5X Buffer, 0.6 µl each of forward and reverse primers (0.6 µM), 0.2 µl of RNase inhibitor, 0.4 µl of QIAGEN One step RT-PCR enzyme mix, and 0.5 µl of RNA sample for positive control / 2.5 µl of the extracted NA sample. The 30 min RT at 50°C was followed by 15 min at 95°C for initial denaturation in a thermal cycler (Bio-Rad). The other reaction steps included 35 cycles of denaturation for 30 s at 94°C, annealing for 30 s at 58°C (BVQ)/ 55°C (*P. betae*) and elongation for 2 min at 72°C. The reactions were completed with a final elongation for 7 min at 72°C.

After PCR amplification, the samples were analyzed on 1% agarose gel prepared in TBE buffer and containing 1% ethidium bromide, by the Gel Doc 2000 Imaging System (Bio-Rad).

Results And Discussion

BNYVV and BVQ have been widely recorded in sugar beet growing areas in Turkey (Erkan and Kutluk Yilmaz, 2016; Kutluk Yilmaz et al., 2016). In the present study, a soil sample taken from Konya province in Turkey, where severe BNYVV and BVQ infections have been previously recorded, was used in bait plant test based on the rhizomania-susceptible sugar beet cultivar. Initially, P31 coding region of the BNYVV isolate was tested by RT-PCR to compare both extraction methods. PCR products of the expected size (997 bp) were obtained by both methods (Fig. 1A). Also, the presence of other soil-borne virus, namely BVQ, in co-infection with BNYVV, was checked by RT-PCR in bait plants using two extraction methods. Both of the tested samples were found to be positive for BVQ (Fig. 1B).

BNYVV and BVQ are transmitted by the same vector, *P. betae*, and share similar host plants (Abe and Tamada, 1986). The result of RT-PCR showed that approximately 350-bp DNA fragment expected for the ITS and the 5.8s rDNA regions of *P. betae* was obtained from the roots of the rhizomania susceptible sugar beet cultivar using both cellulose fibres and RNeasy isolation methods (Fig. 2). Rysanek et al. (2008) suggested that the PCR method would be useful for verifying the presence of *P. betae* in the case of low numbers of cystosori, especially in host range studies. Moreover, in some plant species, plasmodia or zoosporangia could be present without cystosori, PCR could reveal such hidden infections.

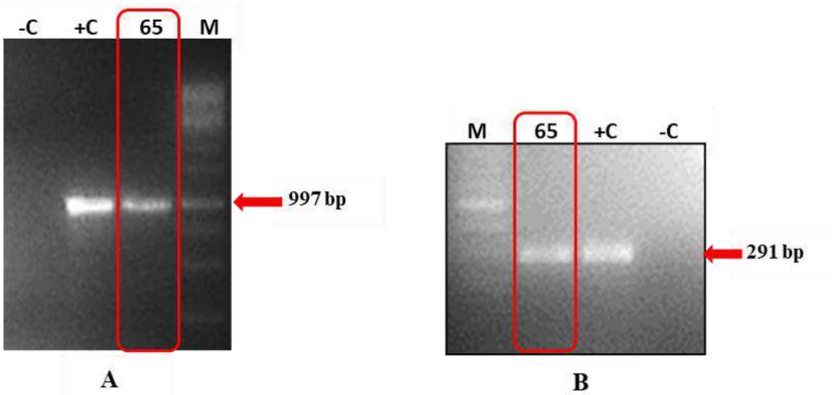

Fig. 1. A: The detection of BNYVV using total nucleic acids purified from the soil sample 65 by cellulose fibres and RT-PCR method followed by agarose gel analysis.

(-C: negative control, +C: Total RNAs isolated by the method of Qiagen (as positive control), M: 1 Kb Ladder (Promega). B: The detection of BVQ using total nucleic acids purified from the soil sample 65 by cellulose fibres and RT-PCR method. -C: negative control, +C: Total RNAs isolated by the method of Qiagen (as positive control), M: 1 Kb Ladder (Promega))

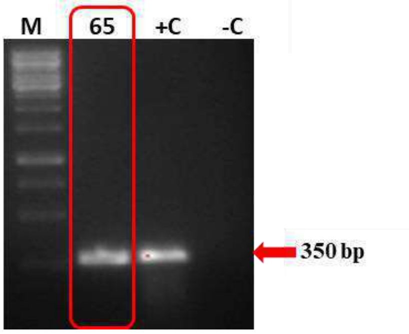

Fig. 2. The detection of *P. betae* using total nucleic acids purified from the soil sample 65 by cellulose fibres and primers-specific for 5.8s rDNA and ITS regions by RT-PCR method.

(-C: negative control, +C: Total RNAs isolated by the method of Qiagen (as positive control), M: 1 Kb Ladder (Promega))

Conclusion

In this study, we modified the method of Khabbazi et al. (2017) to accommodate the need for NA extraction from some challenging virus/plant combinations. In the current study, total NAs were isolated from 1.5 g fresh root tissue, unlike majority of the methods based on cellulose fibres, which requires relatively large amount of plant tissue. This is especially important in the case the access to infected plant material is restricted. Moreover, extra costs of extraction kits and some reagents such as liquid nitrogen, phenol, PVP and bentonite are excluded in the extraction procedure. Additionally, the method did not involve any chromatographic columns or ultracentrifuge, which are absent in some laboratories.

Since plant host and virus are the main factors in the success of nucleic acid extraction, for soil-borne viruses+vector/sugar beet roots, this procedure would be useful and economical for future studies.

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Comparison of the effect of vermicompost and mineral fertilizer applications on some properties of loam texture soil and pepper yield

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Abstract

In this study, comparison of the effects of vermicompost doses and mineral fertilizer applications on the properties of loam texture soil and the yield of pepper grown were investigated. According to the data obtained at the end of the experiment, the doses of vermicompost significantly increased the organic matter, total nitrogen, EC, Mg, Fe, P, K content and porosity values of the soil compared to the control. The pH, bulk density, suspension percentage, aggregation percentage and structure stability index values of the soil decreased statistically with the application of vermicompost. There were no statistically significant changes in the particle density, lime content, field capacity, wilting point, available water, aggregation percentage obtained by wet sieving, and Cu, Na, Ca, Zn, K, Mn values that can be taken by plants with vermicompost applications. A statistically significant increase was determined in the yield of pepper compared to the control with vermicompost applications. When vermicompost applications are compared with mineral fertilizer applications; It was determined that the bulk density value of the soil showed a statistically significant decrease with vermicompost applications compared to mineral fertilizer application. With vermicompost applications, soil organic matter, soluble salt, porosity, total N, Available P and Mg values increased statistically significantly compared to mineral fertilizer application. Pepper yield was statistically in the same group with 2 and 3 t/da doses of vermicompost application and mineral fertilizer application. Due to the positive effects of vermicompost on some soil properties and yield of pepper, it may be preferred to use it as a fertilizer material and soil conditioner instead of mineral fertilizer.

Keywords: Mineral Fertilizer, Pepper Yield, Soil Properties, Vermicompost

Introduction

Today, providing a sufficient level of organic matter in the soil is the basic condition for sustainable soil fertility. For this purpose, it is common to apply farmyard manures and compost from organic wastes to the soil. In recent years, vermicompost applications are also made as an organic fertilizer.

Vermicompost is a plant nutrition product, as well as a soil conditioner, produced by various earthworms (Eisenia spp. and Lumbricus rubellis,), organic plant materials and cattle feces by passing them through their digestive systems. Vermicompost gave birth to a new production sector called vermicompost production plant in India, America and European countries. Studies have shown that solid/liquid vermicompost products improve the chemical, biological and physical properties of the soil at significant levels, along with the plant nutrition effect; showed that it can provide plant available nutrients alone (Arancon, 2004; Edwards et al., 2004, 2006). In a study, it was determined that vermicompost applied to the soil at 300 kg/da increased the amount of nitrogen and phosphorus that the plant can take from the soil and the protein and dry weight of sugar corn (Jat and Ahlawat, 2006).

Material and Methods

The trial was established at the EGET Foundation Armutçuk Agricultural Enterprise. The land where the experiment was conducted is located in the Armutçuk neighborhood of Ula town Muğla city in Türkiye. The annual average rainfall is 1072 mm at the experimental area. With 7 mm of precipitation, August is the driest month of the year. With an average of 244 mm of precipitation, the highest precipitation is seen in December. The difference in precipitation between the driest and wettest months of the year is 237 mm. The average temperature is 20.7 °C throughout the year and varies. The climate is temperate and hot.

The soil of the experimental area has a loam texture. Its reaction is slightly alkaline. It has low organic matter content and rich in lime content. Some chemical and physical properties and plant nutrient content of the soil sample taken from the experimental area are given in Table 3.2.

Experiment establishment

In the experiment, solid vermicompost suitable for use in agriculture was supplied from EGET Foundation Economic Enterprise, which is the provincial dealer of İlpasol company in Muğla. In addition, 15.15.15 NPK fertilizer and CAN Fertilizer were used for the comparison group. Pepper was the test plant. The experiment was set up according to the randomized plot design with 3 replications. In the study, Şehzade F1 variety sweet green pepper was used as the test plant.

Table 1. Some chemical and physical properties and plant nutrient content of the soil sample taken from the experimental site.

Parameters	Units	Value	Parameters	Unit	Value
pH		7,79	P	Available (mg kg^{-1})	1,20
Electrical conductivity	µmhos/cm	566,33	K		57,61
Lime	%	27,811	Mg		58,83
Organic matter (OM)	%	0,529	Ca		3764,71
Texture		Loam	Na		28,83
Sand	%	44,96	Zn		1,61
Silt	%	34,16	Fe		2,94
Clay	%	20,88	Mn		2,81
Total N	%	0,054	Cu		0,42

The treatments consisted of control without any application as control (C); mineral fertilizer (MF);10 t ha^{-1} (V1), 20 t ha^{-1} (V2), 30 t ha^{-1} (V3) of vermicompost applied to the soil and then mixed with soil. Before planting pepper, 350 kg/ha of 15.15.15. fertilizer was applied to the mineral fertilizer plots as basic fertilizer. 200 kg/ha of CAN fertilizer was given in the intermediate hoe of peppers to the mineral fertilizer plots. Before the first pepper harvest, 100 kg/ha of CAN fertilizer was applied to the mineral fertilizer plots. The plots are arranged in 1x1 m dimensions, with a 60 cm space between them. 9 pepper seedlings were planted in each plot, with 40×40 cm spacing between rows and rows, and 15 plots were formed. The period between planting and harvest is 2 months. Harvest period is 4 months. Pepper plants were irrigated with drip irrigation. Some properties of vermicompost used in the experiment were given in Table 4.

Table 2. Some properties of vermicompost used in the experiment.

Parameters	Units	Value	Parameters	Units	Value
pH (24 °C)		6,9	C/N	(%)	8,2
EC (24 °C)	dS/m	3,7	Organic N	(%)	1,3
Organic Matter (70°C-550°C)	(%)	32,2	Total N	(%)	2,04
Moisture (70°C)	(%)	32,1	Total P as P_2O_5	(%)	1,3
Organic C	(%)	16,08	Water soluable K as K_2O	(%)	0,93
Total (humic+fulvic) (Rc:0,56)	(%)	11,6			

Soil Analysis

Soil samples were taken at a depth of 0-15 cm 4 months after pepper planting. Plant available Fe, Zn, Cu, and Mn were determined by diethylenetriaminepentaacetic acid (DTPA) extraction method (Lindsay and Norvell, 1978). Determination of available Na, Ca, Mg, K was carried out by ammonium acetate (1 N NH4 Oac pH:7) method (Kacar, 1995). Available P was analyzed using Olsen method (Olsen et al.,1954). Organic Carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). OM was calculated by multiplying OC content by 1.724. The modified Kjeldahl method was used for determination of total nitrogen (Bremner, 1965). Bulk density was estimated by cylinder method (Hunt and Gilkes,1992). particle size distrubition was analysed by bouyoucos method (Bouyoucos. 1962). Soil moisture and saturation percentage were obtained using oven drying method (Black, 1965) and pore space saturation method (Richards, 1954), respectively. A pressure plate was used to determine field capacity and wilting point at pF of 2.54 and 4.2, respectively. Available water was calculated by the difference between these two features (U.S. Salinity Laboratory Staff, 1954). A pH meter was used for soil pH measurement (Jackson, 1967). The calcimetric method was applied for lime measurement. (U.S. Soil Survey Staff, 1951). Water soluble total salt was determined as electrical conductivity by EC meter (U.S. Soil Survey Staff, 1951). Aggregation percentage, dispersion percentage, structure stability index, and aggregate stability were calculated using methods presented by Kemper and Roseneau (1986).

Determination of Pepper Yield

In the trial, the first harvest of peppers was made on July 20, 2020, and the last harvest was made on December 10, 2020. As the temperatures dropped, it was decided to end the harvest. Yield was obtained by weighing the peppers collected during harvest.

Statistical Analysis

The collected data were subjected to variance analysis (ANOVA) using the R 3.5.1 version software. Comparison of means was performed with LSD test at a significance level of α = 0.05 and 0.01.

Results And Discussion

Effect of vermicompost and mineral fertilizer on physical, chemical properties and plant nutrient content of soil and pepper yield was given in Table 1.

The organic matter content of the soil was affected by the applications, and the 30 t/ha vermicompost (V3) application increased the amount of organic matter in the soil to the highest level. Azarmi et al. (2008) found that organic matter in the soil can be increased by applying vermicompost to a soil where field tomatoes are grown. The lowering effect of vermicompost on soil pH has been reported in many studies (Lee et al., 2004; Gutierrez-Miceli et al., 2007; Azarmi et al., 2008; Tavalı et al., 2014). Sağlam et al. (1993) state that humus formed by mineralization of organic matter increases soil acidity. In the study, it is thought that weak organic acids produced by mineralization of vermicompost slightly reduce soil pH.

While the soil was saturated with water, the electrical conductivity value increased with fertilizer and vermicompost applications. However, this increase is not at a level that will cause negative effects in plant breeding. It has been reported in some studies that vermicompost does not significantly increase soil salinity (Anonymous 1992; Doube and Brown 1998; Lee et al. 2004; Gark et al. 2009). Özkan et al. (2016) determined in their study that the vermicompost they applied to the soil did not have a statistical effect on the lime content.

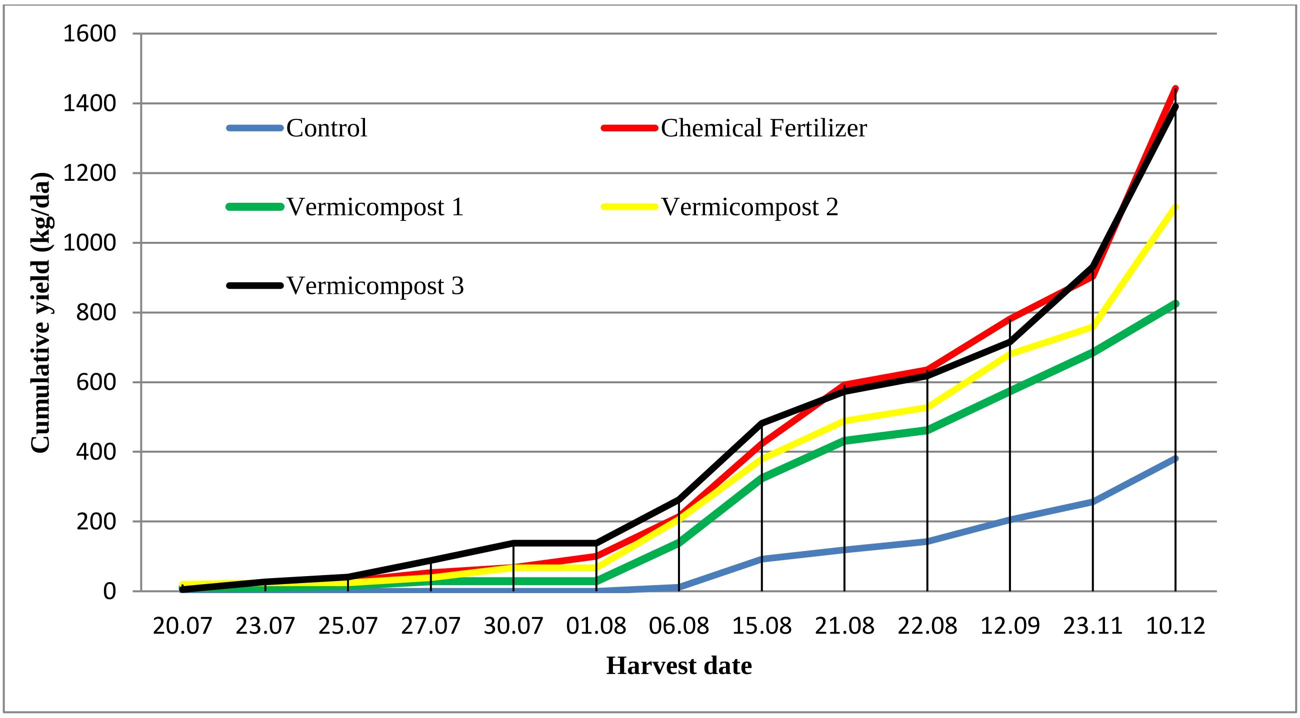

Figure 2. Effects of applications on pepper yield

Table 1. Effect of vermicompost and mineral fertilizer on some physical and chemical properties of soil

Organic matter (%)					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
0,329 c	0,374 c	0,626 b	0,753 b	1,133a	0,157
pH					
Control	Fertilizer	V1	V2	V3	*LSD $_{0,05}$
7,797 ab	7,757 ab	7,730 ab	7,857 a	7,660 b	0,188
EC (µS/cm)					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
566,333 b	722,000 ab	717,333ab	835,000 ab	984,667a	404,969
$CaCO_3$ (%)					
Control	Fertilizer	V1	V2	V3	*LSD $_{0,05}$
27,811 b	28,166 ab	29,821 a	28,360 ab	27,751 b	0,188
N (%)					
Control	Fertilizer	V1	V2	V3	*LSD $_{0,05}$
0,054 b	0,054 b	0,065 ab	0,071 ab	0,082 a	0,020
Available P (mg/kg)					
Control	Fertilizer	V1	V2	V3	*LSD $_{0,05}$
0,012 b	0,227 b	4,507 ab	11,939 ab	18,874 a	14,670
Ca (mg/kg)					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
3764,717 ab	3601,033 b	3699,243ab	3862,927 a	3633,770 b	173,581
Mg (mg/kg)					
Control	Fertilizer	V1	V2	V3	*LSD $_{0,05}$
58,833 b	57,500 b	96,667 ab	60,267 b	164,867 a	97,690
Porosity (g/cm^3)					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
38,245 b	40,276 ab	39,397 ab	40,553 ab	45.427 a	7,165
Aggregation percentage					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
27,220 a	23,783 a	22,533 a	20,753 bc	22,190 c	6,787
Structure stability index					
Control	Fertilizer	V1	V2	V3	**LSD $_{0,01}$
38,667 a	39,333 a	32,000 b	36,000 ab	36,000 ab	5,793

Increasing doses of vermicompost applied to the soil statistically increased the total nitrogen content of the soil. It has been reported that vermicompost, which can increase the amount of nitrogen in the soil, has the feature of promoting plant growth, and vermicompost contains high values in terms of nitrogen (Lazcano et al., 2008). Studies have shown that vermicompost can increase the amount of nitrogen in the soil (Kalembasa 1996; Nethra et al., 1999). Increasing doses of vermicompost applied to the soil statistically significantly increased the available P content of the soil by plants. V2 and V3 application doses made the P level in the soil sufficient (FAO, 1990). Vermicompost with high P content (Phosphorpentaoxide 1.3%) can be expected to increase the P content of soils. Mahmoud and Ibrahim (2012) and Özkan et al. (2016) stated in their study that vermicompost applied to the soil significantly and statistically increased the P content of the soils. In the experiment, it was determined that the applications made to the soil did not statistically change the K content of the soil. Özkan et al. (2016) stated in their study that the effect of vermicompost applied to soils on the K content of soils did not have a statistically significant effect. Again, in a different study, they stated that the applied vermicompost increased the available K content in the soil noticeably and this difference was statistically significant (Mahmoud and Ibrahim 2012). The amount of K contained in vermicompost may vary depending on the parent material from which the vermicompost is made. It was observed that the amount of Ca in the soil was high as a result of mineral fertilizer and vermicompost applications, including the control (FAO, 1990). A statistically significant difference was found between the applications and the highest available Ca value was obtained in the V2 application. When the analysis results of the control and mineral fertilizer application were examined, it was observed that the amount of Mg was evaluated as very low, but there was a statistically significant increase depending on the increasing doses of vermicompost applications.

The highest result was seen in the V3 application. In V3 application, Mg reached a sufficient level with a value of 164 mg kg^{-1} (FAO, 1990). When the analysis results of the control and mineral fertilizer application were examined, it was observed that the amount of Fe was considered moderate, while the available Fe in the soil increased depending on the increasing doses of vermicompost applications, although it was not statistically significant. The highest result was seen in the V3 application. While V1 was moderate and sufficient as 3,089 mg kg^{-1}; The value of V2 4.617 mg kg^{-1} and V3 5.030 mg kg^{-1} (DTPA) was evaluated as excessive (Lindsay and Norvell, 1969).

Mineral fertilizer and vermicompost applications to the soil did not cause a statistically significant change on the amount of available Cu, Zn and Mn, particle density, field capacity, wilting point and available water of the soil. Vermicompost contains a high amount of organic matter and it is known that organic matter regulates aggregation in the soil, thus increasing the porosity and decreasing the bulk density as a result of the increase in macropores (Aktaş 2018; Erhart and Hartl 2010).

An increase in pepper yield was determined with the applications, and the highest values were reached in the V3 application with mineral fertilizer. A statistically significant difference was found between the control and the applications. According to Jahan et al. (2014) investigated the effects of traditional compost and vermicompost applications on cauliflower and found that the application of vermicompost with chemical fertilizers was more effective on yield than traditional compost application.

High organic matter content, which is one of the most important indicators of soil fertility, is necessary for sustainable agricultural production, protection and improvement of soils.

For this reason, it should be one of our main goals to recycle all organic wastes, which are rich in organic matter and do not contain risks, by using them in our soils.

In order to increase the fertility of soil in agricultural production, the use of mineral fertilizers can be reduced while soil organic matter is increased by using organic fertilizers like vermicompost. This practice can also contribute economically to producers.

Conclusion

Due to the positive effects of vermicompost on some soil properties and yield of pepper, it may be preferred to use it as a fertilizer material and soil conditioner instead of mineral fertilizer.

High organic matter content, which is one of the most important indicators of soil fertility, is absolutely necessary for sustainable agricultural production, protection and improvement of soils. For this reason, it should be one of our main goals to recycle all organic wastes and wastes, which are rich in organic matter and do not contain risks, by using them in our soils. In agricultural production, alternative solutions can be produced with the help of vermicompost to increase the amount of organic matter in the soil; With the increase in yield, since chemical fertilizers are not used, it can contribute to the producers economically and much healthier products can be grown; It is thought that soil fertility and sustainability can be achieved while preserving soil health.

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Environmental threats in conflict zones: Assessing the fallout of white phosphorus munitions on soil and water in the Jordan River Basin

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Abstract

The substances released by white phosphorus (WP) munitions can be harmful to soil and agriculture. White phosphorus is a highly reactive and toxic substance that can cause damage to the environment. When a white phosphorus bomb is detonated, it releases phosphorus pentoxide (P4O10) and other phosphorus oxides, which can react with moisture in the air to form phosphoric acid (H3PO4). Phosphoric acid is corrosive and can lead to soil acidification. This can have detrimental effects on soil fertility and plant growth. The acidification of soil can alter its pH, making it less suitable for many crops and disrupting nutrient availability. Additionally, the release of phosphorus compounds into the environment can contribute to water pollution if not properly contained. Furthermore, white phosphorus is highly flammable, and its combustion can result in the production of toxic by-products, including phosphorus pentoxide and phosphoric acid. These by-products can pose risks to both the environment and human health. In summary, the substances released by white phosphorus bombs can indeed be harmful to soil and agriculture, contributing to soil acidification and potential water pollution. The impact on the environment depends on factors such as the scale of the release, the local ecosystem, and the measures taken to mitigate the environmental impact. The objective of this study is to assess the repercussions resulting from the detonation of white phosphorus munitions on the soils in the Jordan Valley Basin, a region of agricultural significance.

Keywords: White Phosphorus, Soil Contamination, Soil Acidification, Soil Fertility, Water Pollution, Jordan River Basin

Introduction

In recent decades, the use of white phosphorus (WP) in military arsenals has raised growing concern about its profound environmental consequences. White phosphorus, a highly reactive and toxic substance, is commonly employed in incendiary munitions, including bombs used in various conflict zones globally. The detonation of white phosphorus bombs releases intense thermal energy and generates chemical by-products, notably phosphorus pentoxide (P4O10) and phosphoric acid (H3PO4) (Stockman, 2017). This review provides a comprehensive examination of the environmental impact of the Israeli Occupation's deployment of white phosphorus bombs on the Jordan river basin region, which is located in two countries, Jordan and Palestine, with a particular emphasis on the effects on soil quality and agricultural ecosystems.

The chemical properties of white phosphorus, characterized by its reactivity, flammability, and toxicity, underscore the potential for wide-ranging environmental ramifications. Upon detonation, white phosphorus undergoes combustion, producing phosphorus pentoxide and phosphoric acid. These by-products, when released into the environment, have been associated with soil acidification and alterations in nutrient availability. The consequences extend beyond soil, affecting nearby water bodies and posing challenges to both terrestrial and aquatic ecosystems (UNIDIR, 2015).

The urgency of understanding and addressing the environmental impact of white phosphorus bombs is underscored by the potential long-term repercussions on biodiversity, agricultural productivity, and water quality. This review seeks to synthesize existing knowledge, drawing upon a range of scientific studies, case reports, and expert analyses, contributing to a nuanced understanding of the environmental challenges posed by the deployment of white phosphorus in military operations (OPCW, 2015).

As we delve into this exploration, it is essential to acknowledge the interdisciplinary nature of the topic, encompassing fields such as chemistry, environmental science, agriculture, and geopolitics. Through a multidimensional lens, this review aims to shed light on the intricacies of the environmental impact of white phosphorus bombs and lay the groundwork for future research and policy considerations.

Understanding the environmental impact of white phosphorus bombs is crucial for several reasons:

Ecological Consequences: The combustion of white phosphorus releases phosphorus pentoxide and phosphoric acid, leading to soil acidification, nutrient imbalances, and potential harm to plant and animal life.

Water Pollution: Residues from white phosphorus can contaminate water sources, causing water pollution that affects aquatic ecosystems, poses risks to human health, and hampers the availability of safe drinking water.

Long-Term Effects: The persistent nature of white phosphorus residues may result in long-term environmental consequences, influencing biodiversity, soil health, and ecosystem resilience.

Human Health Risks: The proximity of affected areas to human populations raises concerns about the direct and indirect health impacts, emphasizing the need for comprehensive risk assessments.

Chemical Composition and Properties of White Phosphorus:

Chemical Structure: White phosphorus (P4) exists as a tetrahedral molecule composed of four phosphorus atoms. Each phosphorus atom forms three single bonds with the other three atoms in the molecule, resulting in a tetrahedral arrangement. The P4 molecule has a characteristic tetrahedral structure with an angle of approximately 60 degrees between adjacent P-P bonds (Emsley, 2001; Holleman et. al, 2007; Greenwood and Earnshaw, 1997).

Physical Properties:

Color: White phosphorus is a translucent, waxy, yellowish-white solid.

Odor: It has a distinct, garlic-like odor.

Density: The density of white phosphorus is around 1.82 g/cm^3.

Melting Point: White phosphorus melts at approximately 44.15 degrees Celsius.

Boiling Point: It has a low boiling point of 280.5 degrees Celsius.

Reactivity:

Flammability: White phosphorus is highly flammable and spontaneously ignites in air at relatively low temperatures, emitting a bright flame.

Reactivity with Oxygen: It reacts vigorously with oxygen, leading to the formation of phosphorus oxides (P4O6 and P4O10) during combustion.

Toxicity:

Inhalation Hazard: Inhalation of white phosphorus vapors or particles can cause respiratory irritation and may lead to more severe health effects.

Skin Contact: Contact with white phosphorus can cause chemical burns and deep-seated, painful wounds on the skin.

Ingestion: Ingesting white phosphorus can result in systemic toxicity.

Flammability:

Spontaneous Ignition: White phosphorus can ignite spontaneously in air, especially in the presence of oxygen and light.

Smoke Production: When burned, white phosphorus produces a dense white smoke, contributing to its use in smoke screens.

Detonation Process and By-Products:

Ignition and Combustion:

The detonation process of white phosphorus bombs begins with ignition, typically initiated by impact, friction, or a pyrotechnic charge. White phosphorus undergoes rapid combustion, characterized by a luminous flame and the release of intense heat (Fetterolf & Schulz, 1964).

Chemical Reactions:

The combustion of white phosphorus involves its reaction with oxygen in the air, leading to the formation of phosphorus oxides. The primary reactions are:

4 P4+5 O2→P4O64 P4+5 O2→P4O6 P4O6+O2→P4O10P4O6+O2→P4O10

Formation of By-Products:

Phosphorus Pentoxide (P4O10):

Formed as an intermediate product during the combustion of white phosphorus. Highly reactive and hygroscopic, readily reacting with water vapor in the air.

Phosphoric Acid (H3PO4):

Resulting from the reaction of phosphorus pentoxide with water vapor. A strong acid that contributes to soil acidification and water contamination (NATO, 2006).

Potential Pathways of Environmental Impact:

Soil Contamination:

The deposition of phosphorus pentoxide and phosphoric acid onto soil during detonation can lead to soil contamination. Soil acidification, nutrient imbalances, and toxicity to soil microorganisms may result, affecting plant growth and ecosystem health.

Water Pollution:

Runoff from contaminated soil can transport phosphorus compounds into nearby water bodies. Phosphoric acid and other phosphorus oxides can contribute to water pollution, affecting aquatic ecosystems and potentially posing risks to human health.

Long-Term Environmental Consequences:

The persistence of phosphorus compounds in the environment can lead to long-term consequences. Chronic exposure may affect the health of plants, animals, and microorganisms, influencing ecosystem dynamics (U. S. Army, 2007).

Soil Impact:

White phosphorus bombs can have severe and lasting effects on soil quality and fertility (ICRC, 2016). The key impacts include:

Soil Acidification:

The combustion of white phosphorus produces phosphorus pentoxide, which, upon contact with moisture in the air or soil, forms phosphoric acid. Phosphoric acid is highly acidic, leading to soil acidification. Soil acidification affects the pH balance, potentially making the soil inhospitable for many plant species (UNEP, 2009).

Nutrient Imbalance:

The increased acidity can alter the availability of essential nutrients in the soil. High levels of phosphoric acid can lead to the leaching of important nutrients such as calcium, magnesium, and potassium, disrupting the balance required for healthy plant growth.

Toxicity to Microorganisms:

The presence of phosphorus compounds, especially in elevated concentrations, can be toxic to soil microorganisms. Soil microorganisms play a crucial role in nutrient cycling and maintaining soil health (Bo and Chen, 2012).

Long-term Effects on Plant Growth:

The altered soil conditions and nutrient imbalances can negatively affect plant growth. Reduced plant growth and yield may persist over an extended period, affecting both agricultural productivity and natural ecosystems.

Agriculture Impact:

Impact of White Phosphorus Bombs on Agriculture

White phosphorus bombs, when deployed in conflict zones, can have significant and detrimental effects on agricultural systems (FAO, 2003; ICRC, 2016, 2019).

Crop Damage:

The intense heat generated by the detonation of white phosphorus bombs can lead to direct burning and destruction of crops in the affected area. Crop damage may occur not only due to the heat but also because of the subsequent fire caused by the incendiary properties of white phosphorus.

Soil Contamination:

The release of phosphorus pentoxide and phosphoric acid into the soil can contaminate agricultural lands. Soil contamination can affect the growth of crops and alter the nutrient composition of the soil, affecting the overall health and productivity of agricultural systems.

Water Contamination:

Phosphorus compounds produced by the combustion of white phosphorus can leach into nearby water sources, contaminating rivers, lakes, and groundwater. Water contamination can affect irrigation water quality, potentially harming crops and leading to long-term environmental consequences.

Long-term Agricultural Productivity:

The cumulative impact of soil and water contamination, along with direct crop damage, can lead to long-term reductions in agricultural productivity. The recovery of agricultural systems may be slow, and the socio-economic consequences for communities relying on agriculture can be severe.

Water Pollution:

Potential for Water Pollution from White Phosphorus Bomb Detonations

The detonation of white phosphorus bombs poses a significant risk of water pollution, with the following potential impacts. Following the detonation of white phosphorus bombs, the resultant substances may manifest in gaseous form. Notably, detonations predominantly occur in the western and northern sectors of the Jordan River basin. The prevailing annual wind patterns in this region generally emanate from the west (Figure 1), facilitating the transport of these substances through the atmosphere. Consequently, when precipitation events transpire, the descending substances have the potential to directly infiltrate water bodies, including the Jordan River.

Figure 1: Palestine and Jordan map showing the average annual wind direction (in the black arrows) and Jordan River Basin location (in the blue box).

Leaching of Phosphorus Compounds:

White phosphorus bombs release phosphorus pentoxide and phosphoric acid into the environment. These phosphorus compounds can leach into soil and subsequently enter water bodies, contributing to water pollution (EUC, 2008).

Runoff into Water Sources:

Rainfall or other forms of water runoff can transport phosphorus compounds from the bomb site into rivers, lakes, and other water sources. Runoff can be a major pathway for the introduction of phosphorus into aquatic ecosystems (Gromet and Duaime, 1984).

Effects on Aquatic Ecosystems:

Phosphorus is a key nutrient, but an excess can lead to eutrophication, algal blooms, and oxygen depletion in water bodies. Elevated levels of phosphorus from white phosphorus bomb residues can disrupt aquatic ecosystems, affecting the health of fish and other aquatic organisms (US EPA, 1999).

Human Health Risks:

Contaminated water sources may pose risks to human health, particularly in areas where local populations rely on these water bodies for drinking water or irrigation. Ingestion or contact with water contaminated by phosphorus compounds can have adverse health effects.

Mitigation Strategies:

Mitigation Strategies for Environmental Impact of White Phosphorus Bomb Detonations (UNIDIR, 2015; ATSDR, 2001; UNEP, 2014).

Containment Measures:

Immediate Site Management: Swift and effective containment of affected areas can minimize the spread of phosphorus residues. This may involve the use of barriers, controlled burning, or physical removal of contaminated soil.

Engineering Controls: Implementing engineering controls such as barriers or trenches to prevent the migration of phosphorus compounds into water bodies can be crucial.

Remediation Techniques:

Phytoremediation: Certain plant species can absorb and accumulate phosphorus. Implementing phytoremediation techniques involving the cultivation of specific plants may assist in reducing soil contamination.

Bioremediation: The use of microorganisms to break down phosphorus compounds in soil and water can be explored as a remediation strategy.

Water Treatment:

Activated Carbon Filtration: Activated carbon can be effective in adsorbing phosphorus from water, aiding in the treatment of contaminated water sources.

Chemical Precipitation: Adding chemicals to water sources to precipitate phosphorus compounds, making them easier to remove, is a common water treatment technique.

International Efforts:

Chemical Weapons Conventions: International agreements, such as the Chemical Weapons Convention (CWC), aim to prevent the use of chemical weapons, including white phosphorus, and establish protocols for the destruction of stockpiles.

Environmental Conventions: Treaties and agreements, like the Stockholm Convention on Persistent Organic Pollutants, address the environmental impact of certain substances, although white phosphorus is not specifically covered.

Conclusion

In conclusion, the use of white phosphorus (WP) in military operations, specifically demonstrated by the Israeli Occupation's deployment of white phosphorus bombs in the Jordan River basin region, has become a significant and urgent environmental concern. The chemical properties of white phosphorus, characterized by its reactivity, flammability, and toxicity, instigate extensive environmental consequences upon detonation, generating phosphorus pentoxide and phosphoric acid. These by-products exacerbate challenges such as soil acidification, nutrient imbalances, and water pollution, posing substantial threats to both terrestrial and aquatic ecosystems. The imperative to comprehend and address the environmental impact is magnified by the potential long-term repercussions on biodiversity, agricultural productivity, and water quality, emphasizing the gravity of the issue at the intersection of military activities and environmental sustainability.

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A comprehensive overview of humic substances as plant biostimulants for sustainable agriculture

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Abstract

In a world confronted with the dual challenges of feeding a growing global population and addressing environmental concerns, plant biostimulants have emerged as a promising avenue to enhance crop productivity and sustainability. This study elucidates the potential of humic substances as a sustainable and eco-friendly solution to the challenges facing modern agriculture while also addressing associated limitations, aiming to promote environmentally friendly agricultural practices. Humic substances, including fulvic acid, humic acid, and humin, derived from the decomposition of plant and animal matter in soil and sediments, have gained attention for their effectiveness as plant biostimulants. These compounds, abundant in carbon (C) and characterized by complex molecular structures, play a pivotal role in promoting plant growth and development. Additionally, the advantages of utilizing humic substances may align with the goals of sustainable agriculture, as evidenced by their ability to improve nutrient absorption, enhance soil health, and bolster stress resilience in plants. However, challenges and limitations, such as variations in commercial product quality, application methods, and associated costs, must be addressed to maximize the benefits of humic substances in agriculture. Developing standardized guidelines for their application emerges as a crucial step towards cultivating a more resilient and environmentally responsible food production system to meet the demands of the 21st-century global population.

Keywords: Environmental impact, Humic substances, Plant biostimulants, Sustainable agriculture

Introduction

Modern agriculture faces numerous challenges, from feeding a growing global population to addressing environmental concerns such as soil degradation and overreliance on chemical fertilizers (Gomiero, 2016; McKenzie and Williams, 2015). In this context, plant biostimulants have seemed as a promising solution to enhance crop productivity and sustainability (Rouphael and Colla, 2018). Plant biostimulants are those substances, when applied to plants or soil, promote growth, development and stress tolerance without being detrimental as traditional fertilizers (Calvo et al., 2014). They can play a vital role in establishing a more resilient and environmentally responsible agricultural system for food production to meet the demands of the world's growing population in the 21st-century.

Humic substances, a group of naturally occurring organic compounds, are gaining attention as effective plant biostimulants. These substances, which are a mixture of humic acid, fulvic acid, and humin, are produced when plant and animal matter decomposes in soil and sediments (Mahler et al., 2021). Humic acid is the dark, insoluble fraction, while fulvic acid is a lighter, water-soluble fraction, and humin is the least soluble part. These compounds are rich in carbon (C) and are well-known for their complex molecular structures, consisting of various functional groups such as phenolic, carboxylic, and quinone moieties (Mahler et al., 2021).

Using environmentally friendly and sustainable agricultural practices has become essential worldwide due to concerns about greenhouse gas emissions, soil health, water quality, and the depletion of non-renewable resources (De Corato, 2020; Omer, 2008). Conventional agriculture, heavily dependent on synthetic fertilizers and pesticides, has raised questions about its long-term sustainability. As a result, there is a growing recognition of the necessity to shift towards more sustainable practices that ensure food security without compromising the environment. Plant biostimulants, particularly humic substances, offer a viable pathway toward achieving this balance. These biostimulants contribute to the reduction of the environmental impact of agriculture by enhancing nutrient efficiency, strengthening plant resistance to stressors, and improving soil health (Rouphael and Colla, 2020). This study explores the potential of humic substances as a sustainable and eco-friendly solution to the challenges confronting modern agriculture while also addressing associated limitations, aiming to promote environmentally friendly agricultural practices.

Types of humic substances and their chemical properties with characteristics

Humic substances can be categorized into three main types: humic acid, fulvic acid, and humin. Each of these substances has distinct chemical properties and characteristics (Mahler et al., 2021) Humic acid, the most substantial fraction, has a higher molecular weight, exceeding 1,000 Daltons, is relatively less soluble in water, and appears dark brown to black in color, typically found in soil organic matter. It contains a similar array of functional groups as fulvic acid, including carboxyl, phenolic, and quinone groups, but in humic acid, they are often more condensed. Fulvic acid, being the most water-soluble component, features a low molecular weight, typically less than 1,000 Daltons, and appears as a lighter-colored solution, with a yellow to light brown hue. It contains functional groups such as carboxyl, phenolic, and quinone groups, contributing to its chelating properties. Humin, the least soluble and most insoluble fraction, consists of highly condensed, complex macromolecules, and presents as a dark, solid material in soil, albeit without direct involvement in nutrient transport or interactions with plants (Canellas et al., 2002; Schnitzer, 1978).

How humic substances promote plant growth, improve nutrient uptake, and enhance stress tolerance

Humic substances, comprising fulvic acid, humic acid, and humin, benefit plant growth and development through several key mechanisms. These mechanisms not only enhance nutrient uptake and utilization but also boost stress tolerance in plants, making them effective plant biostimulants (Du Jardin, 2015).

Improved nutrient uptake and utilization

Humic substances, such as humic acid and fulvic acid, play a pivotal role in improving plant growth and nutrient utilization through several interconnected mechanisms. The high solubility and chelating properties of fulvic acid enable it to form complexes with essential minerals and trace elements in the soil, thereby increasing the availability of these nutrients for plant uptake. This enhancement in nutrient availability includes crucial elements such as iron, calcium, and zinc, which can be absorbed by plant roots more efficiently (Canellas et al., 2002). Due to its small size and water solubility, fulvic acid can move freely within plant tissues and form complexes with ions, facilitating the efficient transport of nutrients across cell membranes. This can promote the overall growth and development of plants (Du Jardin, 2015). Additionally, humic substances, particularly humic acid, serve as an energy source for beneficial soil microorganisms. These microorganisms, in turn, enhance nutrient mineralization and availability, creating a more nutrient-rich environment for plants. This stimulation of microbial activity contributes significantly to nutrient cycling in the soil-system (Nardi et al., 2002). Together, these mechanisms signify the vital role of humic substances in optimizing nutrient uptake and utilization in plants while promoting their overall health and development in agriculture.

Enhanced stress tolerance

Humic substances, play a multifaceted role in enhancing plant resilience and growth through several interconnected mechanisms. Notably, these substances aid in osmotic regulation by helping to maintain the plant's water balance and mitigating the impacts of drought stress (Chen et al., 2022). Fulvic acid contributes to reduced water loss via transpiration and the retention of water within plant tissues, ensuring optimal hydration and turgor pressure (Yakhin et al., 2017). Additionally, humic substances exhibit antioxidant properties, containing phenolic compounds and quinones that act as scavengers of reactive oxygen species (ROS) within plant cells. This inherent antioxidant capacity effectively reduces oxidative stress and bolsters the plant's ability to withstand various abiotic stressors, such as salinity and heavy metal toxicity (Nardi et al., 2002). Moreover, humic substances influence root architecture and development, fostering a more extensive and efficient root system. This increased root biomass not only enhances the plant's capacity for nutrient and water uptake but also augments its resilience to environmental stressors, including nutrient deficiency, thereby promoting overall plant health and productivity (Canellas et al., 2002).

Hormonal Regulation

Humic substances exhibit significant interactions with plant hormones, including auxins and cytokinins, resulting in the stimulation of plant growth and development by influencing processes such as cell division, elongation, and differentiation. These interactions promote the formation of lateral roots, flowering, and fruiting, ultimately contributing to the improvement of crop yield and quality (Zandonadi et al., 2013). Furthermore, humic substances have been proved to have a positive impact on seed germination, breaking seed dormancy, and enhancing early seedling vigor. This effect is ascribed to their capacity to regulate hormone levels and activate genes associated with seed germination, thereby promoting a more robust and efficient crop establishment (Calvo et al., 2014).

Case studies and research findings: benefits of using humic substances in various crops

The application of humic substances in agriculture has gained significant attention and research across various crops, showcasing promising results. Numerous case studies and research findings illustrate the advantages of incorporating humic substances into agricultural practices. For instance, in a study on tomato cultivation, the addition of fulvic acid-based biostimulants led to increased fruit yield, improved fruit quality, and enhanced nutrient content (Colla et al., 2014). In another case, the use of humic substances in wheat cultivation demonstrated enhanced seed germination, early seedling vigor, and overall crop productivity (Tahir et al., 2011). Research on maize crops revealed that the application of humic acids positively affected root development, lateral root emergence, and the activity of plasma membrane H+-ATPase, resulting in improved nutrient uptake and plant growth (Canellas et al., 2002).

Increased yields, improved quality, and reduced environmental impact

The implementation of humic substances in agriculture not only increases crop yields but also enhances crop quality. These substances aid in the efficient absorption of essential nutrients, improving the nutrient content of crops and ensuring healthier, more robust plant development. Furthermore, the positive effects of humic substances extend to stress tolerance in plants, enabling them to withstand adverse environmental conditions, ultimately leading to increased yields (Rai et al., 2021). In addition to benefits for crop production, the use of humic substances aligns with the goals of sustainable agricultural practices. Humic substances contribute to reduced environmental impact by improving nutrient use efficiency and decreasing the need for synthetic fertilizers, thereby lowering greenhouse gas emissions (GHGs), and minimizing nutrient run-off into water bodies (De Corato, 2020; Omer, 2008).

Challenges and limitations

While humic substances offer numerous advantages, there are challenges and limitations associated with their use (Olk et al., 2018). One key challenge is the variability in the composition and quality of commercial humic products (Jung et al., 2021), which can affect their effectiveness. The application methods and timing of humic substances can also influence outcomes (Olk et al., 2018), making it essential to tailor their use to specific crops and conditions. Additionally, the cost of humic products can be a limiting factor for some farmers, especially in large-scale agriculture. Addressing these challenges and developing standardized guidelines for the application of humic substances will be crucial to maximize their benefits in sustainable and productive agriculture.

Conclusion

In conclusion, humic substances, comprising humic acid, fulvic acid, and humin, hold significant promise as plant biostimulants to address the challenges of modern agriculture. These organic compounds play a pivotal role in enhancing crop productivity and sustainability by improving nutrient uptake and utilization, bolstering stress tolerance in plants, and influencing hormonal regulation. The advantages of using humic substances are substantiated by various case studies across different crops, showcasing increased yields, improved crop quality, and reduced environmental impact. By facilitating nutrient absorption, promoting soil health, and enhancing stress resilience, humic substances align with the goals of sustainable agriculture. Their interactions with plant hormones and their capacity to break seed dormancy further contribute to improved crop yield and quality. However, challenges and limitations, including variations in commercial product quality, application methods, and costs, must be addressed to maximize the benefits of humic substances for sustainable agricultural purposes. Developing standardized guidelines for their application can help maximize their benefits, ensuring a more resilient and environmentally responsible food production system for the 21st century growing global population.

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Global impact of conservation agriculture on crop yields improvement and soil erosion control review

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Abstract
Erosion can be accelerated by violated engagement of cultivation that results in a total breakdown of soil structure and overall soil quality. Tillage-induced unevenness significantly influences the process and extent of runoff and erosion, and therefore runoff occurring in the field will greatly cause the topsoil washed away. Crop production from such areas can't be sustained to meet the food demand of people. Nowadays conservation agriculture is promoted as an Innovative strategy that enables farmers to produce more food from less land while preserving resources sustainably. It advances minimum soil disturbance, permanent soil cover, and diversified plant species hence enabling the natural and biological life forms above and below the soil surface. Novel conservation agriculture is practiced widely to reduce or avoid practices that take a toll on the environment, enabling the soil to be mineralized and intensive mobilization of soil fertility. From this review, most literature proved that conservation agriculture can be practiced as an alternative for soil erosion control and sustainable crop production though short-term effects are not anticipated and its impact varies from place to place due to agro-climatological diversities. Finally, it is concluded that practicing conservation agriculture targeting the long-term benefit could resolve food insecurity problems and then meet the demand of the growing population for the coming decades while maintaining the natural environment healthy.

Keywords: Conservation agriculture, Crop yield, No-tillage, Soil erosion

Introduction
Conservation agriculture (CA) based on the principles of disturbing the soil as little as possible, diversified crop rotation, and keeping the soil covered as much as possible is becoming popular in many parts of the world as an alternative to sustainable agriculture (Dumanski et al., 2006). Its role as a sustainable farming method to amend soil quality, and increase crop yields and food security, at minimum input costs is highly advocated (Swanepoel et al., 2018). Some literature revealed that the historic instigation of conservation agriculture practice began in the mid-20th century with the introduction of herbicides. Direct-planting of crops without tillage was first successfully demonstrated in the US in the 1950s and turned out to be practiced more in Brazil, Latin America, and South Asia as a policy measure for the crisis of increase in soil erosion and land degradation as a result of conventional agriculture intensification (Harrington, 2008). Erosion can be accelerated by violated engagement of cultivation onto increasingly steep slopes due to the coupled causes of increasing population and food demands. Barton et al., (2004) reported that erosion rates under conventional tillage compared with other conservation treatments were high. Controlling tillage and mulch management to increase water infiltration and lessen water loss from the soil surface in crop fields has the potential to substantially improve crop yields and soil conditions in the semi-arid tropics (Adekalu et al., 2007; Tarkalson

et al., 2006). Permanent soil covers as one of the principles of conservation agriculture can decrease the runoff and soil loss and increased the apparent infiltration (Wang et al., 2014). Huang et al., (2013) have extensively discussed that vegetation cover has vital benefits for maintaining runoff as well as infiltration improvement. In many parts of the world soil erosion as a result of human-induced factors has led to a decline in yields and soil fertility (Lee and Thierfelder 2017). Now a day's food insecurity problem is being aggravated due to the cause of climate change, global warming, and agricultural land intensification coupled with poor resource management. These highly affect the smallholder farmers who are limited to access resources and unable to incur input costs to reverse the production challenge (Machethe et al., 2004; Mweta et al., 2007) as cited by (Kutu, 2014).

Global concern has grown over the relationship between conservation agriculture practices' effects on crop yield and the escalating severity of food insecurity (Nawaz et al., 2015). Although it varies depending on specific practices, regional climates, and crop types, a meta-analysis study on field experiments conducted in China for more than five years showed that the impact of conservation agriculture on crop yield compared with conventional practices was significantly higher (Zheng et al., 2014). Strategies that could double food production and close yield gaps while significantly reducing the environmental impacts of agriculture are desperately needed. Feeding the increasingly demanding global population with reasonably priced agricultural inputs and minimal environmental impacts under the most variable and extreme climatic conditions is currently very difficult (Godfray and Garnett 2014; Foley et al., 2014; Lobell et al., 2008; Tilman et al., 2011). Among the alternative measures to intensify agricultural production while preserving ecosystem services Conservation agriculture (CA) will appear first in everyone mind who reviewed literature related to this topic (Lestrelin and Castella, 2011). conservation agriculture will have a pertinent role in meeting the goal of sustainable food production from less land through efficient use of natural resources and minimal impact on the environment while the population grows for the next decades (Hobbs et al., 2008). Despite novel conservation agriculture is advocated low adoption and Lack of appropriation and the need for proceeded utilization of adjusted and progressed agricultural production innovations among farmers has been recognized as one of the most common reasons for the low agrarian efficiency in most developing nations (Mlenga and Maseko, 2015). The aim of this paper is to review different research findings related to conservation agriculture and its role in controlling soil erosion and crop yield improvement considering the knowledge contributes little to eradicating adoption problems through magnifying its multi-dimensional benefit for sustainable agricultural production system and in turn to assure food security.

Review Methodology

The taking-after strategies were connected to find conservation agriculture inquiries about yields or interventions countrywide: (1) a precise writing aspect of looking into the literature, and (2) exploiting the CA community and network to get to grey literature (Swanepoel et al., 2018). As it were outputs published in 2000 afterward were included. The review focuses mainly on conservation agriculture research findings globally in accordance with basic rulebooks of sustainable production systems as a land degradation and crop productivity lessening solution.

ResearchGate databases, the Google search engine, and Google Scholar were used to search resources like journal articles, published books, chapters, and grey literature from the Web (Figure 1).

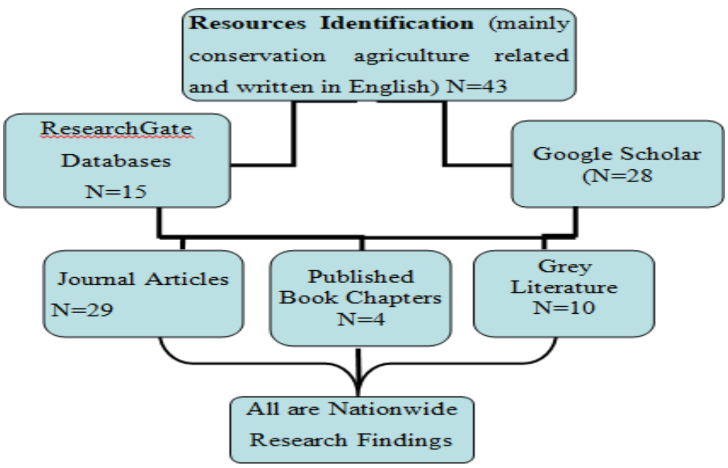

Figure 1. Materials and searching methods diagram

Concept of Conservation Agriculture (CA)

Conservation agriculture is defined as „an approach to managing agroecosystems for improved and sustained productivity, increased profits, and food security while preserving and enhancing the resource base and the environment" (FAO, 2012). In other words, conservation agriculture places emphasis on enhanced and sustained agricultural production while at the same time protecting the natural resource base. Conservation agriculture (CA) is a farming system that advances minimum soil disturbance (i.e., no-tillage), supports a permanent soil cover, and diversification of plant species (Rusinamhodzi and Corbeels, 2011; FAO, 2005; FAO, 2008). It enhances biodiversity and natural biological forms above and underneath the ground surface, which contribute to increased water and nutrient use efficiency and to progressed and sustained crop production (FAO, 2005). CA revolves around three principles: no-till (or minimal soil disturbance), soil cover, and crop rotation (Giller et al., 2015). The first two principles are that a mulch cannot be maintained when the soil is plowed. "True" CA is regarded to be practiced as it were when all three principles are simultaneously connected (Derpsch et al., 2014). However, agriculturists have practiced varieties of the constitutive CA components long before the term was coined. Crop rotation and cover crops provide diversification, and no-tillage is used continuously and permanently to accomplish conservation agricultural systems (Séguy et al., 2006; Sturny et al., 2007). Then, conservation agriculture might be carried out in a way that doesn't harm the environment, emit greenhouse gases, or worsen the effects of climate change. On the other hand, using sustainable farming practices can enhance climate change resilience, save biodiversity, and manage natural resources in an environmentally responsible manner (Mlenga, 2015). Farmers may encounter challenges in implementing conservation agriculture, despite the fact that it offers numerous advantages to both the environment and farmers. Adoption may be difficult on soils with poor drainage or wetlands. There may not be enough crop residues for the soil cover when there are few available because farmers usually use them for fodder first. Appropriate seeders are required to begin conservation agriculture, however, not all farmers may have access to or be able to invest in these (FAO, 2010). Because conservation agriculture requires a lot of information, not all farmers may have access to the education and experience needed to implement conservation. Unsustainable elements like tillage-based farming are decided to be reduced as worldwide consensuses for responding to global food security concerns.

Principles of Conservation Agriculture (CA)

There are three key principles that producers (farmers) need to practice in the process of Conservation Agriculture (FAO, 2012). These guiding principles emphasize minimizing mechanical soil disturbance, commonly achieved through practices like no-tillage while facilitating direct seed and/or fertilizer placement. Additionally, they underscore the importance of maintaining a permanent soil organic cover, ensuring a minimum of 30 percent coverage with crop residues and/or cover crops. Species diversification is encouraged through varied crop sequences and associations involving at least three different crops (refer to Figure 4). These principles of Conservation Agriculture (CA) are designed to be universally applicable across diverse agricultural landscapes and land uses. Local adaptation of practices is integral to their implementation, as highlighted by Mundawarara in (2012). The approach involves reducing interventions such as mechanical soil disturbance to an absolute minimum or avoiding them altogether. External inputs, including agrochemicals and plant nutrients sourced from mineral or organic origins, are applied optimally and in quantities that do not disrupt or interfere with biological processes.

Figure 4. CA trial at Sirinka Agricultural Research Center (SARC); Ethiopia (Wudu et al., 2021 Unpublished)

Impact of CA on Soil Erosion Control and Crop Yield Improvement

No-tillage /reduced soil disturbance/ Effects

Sustainability is constantly constrained by soil erosion problems as a result of natural ground cover destruction and conventional tillage-based annual crops growing in many places of the world (Tuan et al., 2014). Tillage left the soil bare by removing any plant debris that may have been covering it. The millions of microorganisms and insects that make up healthy soil biology are also killed or relocated by tilling. Deep tillage over an extended period of time can turn healthy soil into a dead-growing medium that needs chemical inputs to be productive. By leaving crop residue on the soil's surface, no-till farming practices preserve the soil's structure while also protecting it. The capacity of the soil to absorb and permeate water is increased by improved soil structure and soil cover, which decreases soil erosion and runoff and keeps pollutants out of surrounding water sources. Mlengera et al., (2017) reported that Conservation agriculture (CA) practice, i.e., reduced tillage with cowpea intercrop, has shown a highly significant ($P < 0.05$) reduction of soil loss compared to the conventional practice. When soil becomes exposed to erosion by water it loses important macro (N, P &K) and micronutrients (Ca, Mg, S, and others) valuable for plant growth and then it causes a tremendous grain yield decline. Tillage systems and nutrient management influence soil chemical properties that can impact the long-term sustainability of dry land production systems (Tarkalson et al.,2006). The physical parameter-soil bulk density was improved, compared to the conventional system due to the advancement of the microenvironment beneath the soil surface that suits microorganisms to perform their mineralization process and in turn, it amends the soil structure to have increased pore spaces. In comparison to the typical method, soil moisture also rose in all variations with minimum and no-tillage at varying percentages, ranging from 1 to 15% v/v (Rusu et al., 2015). As a result of long-term no-tillage practices, it in turn significantly contributes to the retention of soil moisture. Winter wheat (1966–1983) and grain sorghum (1964–1988) yields were observed to be higher for no-tillage (2718 and 4125 kg ha^{-1}) than for CT (2421 and 3062 kg ha^{-1}). Long-term tillage treatments had a substantial effect on water runoff and soil erosion, with the effects being greatest in the NT > MP ratio and 1.85:1.6:1 in the first scenario (Table 1).

Table 1. Effect of tillage practices on soil erosion and surface runoff and leachate

Tillage Practices	Soil runoff(gm^{-2})	Surface runoff($1m^{-2}$)	Splash(gm^{-2})	Leachate($1m^{-2}$)
Moldboard ploughing	44.0	4.45	50.0	0
Chisel Ploughing	29.0	3.98	21.0	0.20
No-tillage	10.0	2.40	20.0	0.56

Source: (Choudhary & Dick, 1997).

As shown above in the table No-tillage has significantly decreased surface water runoff volume due to a reduction in tillage intensity. short-term research on conservation tillage conducted at Adigudom, Northern Ethiopia by Tigist *et al*., (2010) also showed improvement in SOM and aggregate stability in conservation tillage compared to the other treatments, although the difference was not significant. The survey result of Romero & Cheesman (2014) in Mexico also provides a piece of evidence to demonstrate long-term adoption of CA in a steep-slope region can help to control soil erosion whilst allowing farmers to produce their staple crops. Some research findingsstrongly suggested not concluding conservation agriculture and zero tillage advantages on yield and resource use efficiency of smallholder farmers without conducting a large number of field studies that provide quantifiable and explanatory data from key crops and representative cropping systems (Brouder and Gomez-Macpherson, 2014; Tigist *et al*., 2010). Though different literatures agreed on the long-term positive effect of No-tillage on sustainable crop production systems local research involving farmers avoiding short trial periods, poor reporting, and insufficient data collection is pertinent to aid interventions for different agro-ecological zones (Swanepoel *et al*., 2018). Tillage alters soil structure and increases the porosity of the upper layer enhancing the initial infiltration and then saving the soil not to being eroded by run-off while mulch reduces raindrop impact on the soil surface, increasing infiltration of rain-water and reducing evaporation. It is also obvious that any practices having a positive influence on soil health will certainly sustain a higher-yielding crop production system.

Mulching /Permanent Soil Cover/ Effects

One of the most effective agronomic techniques for preserving soil moisture and improving the physical environment of the soil is mulching. Because it decreases surface runoff, increases water infiltration into the soil, and slows soil erosion, protecting the soil's surface with mulch either organic or inorganic is an efficient way to conserve both soil and water. Adekalu et al. (2007) demonstrated that employing more elephant grass to cover the soil resulted in significant reductions in soil loss (30%) and runoff (27%). This was due to a significantly enhanced infiltration rate, with variations observed that were attributed to variations in soil texture, organic matter content, and slope steepness. Associations among residues as a soil cover, enhanced water infiltration, and reduced evaporation for better soil water content that suits plant growth leads advantageous even for the adoption of conservation agriculture since it could respond highest crop grain yield for smallholder farmers (Hobbs et al., 2008). A lot of literature indicated the burning and removal of crop residues highly affect the availability of bacteria, actinomycetes, fungi, earthworms, and nematodes that soil biology seems healthy as the number of soil fauna was found higher where mulch is left on the ground compared with bare soil surface with tillage plots (Clapperton, 2003; Birkas et al., 2004; Riley et al., 2005). Mulching reduces weed growth, regulates water evaporation, and stops runoff and soil loss, all of which slow down the deterioration of the soil. As a result, it makes it easier for soil moisture to be retained, aids in temperature regulation, enhances the physical, chemical, and biological qualities of soil, adds nutrients to the soil, and eventually improves crop growth and yield. Furthermore, it has been reported that mulching increases yields in rain-fed situations by 50–60% compared to not mulching, with the caveat that mulches keep the root zone too moist, preventing oxygen circulation if applied closer to the stem, and creating an environment that is conducive to the development of pests and disease (Patil et al., 2013). In areas where rainfall is scarce and limited irrigation conditions, mulching will be beneficial for wheat as it is able to maintain comfortable soil-plant-water association, resulting in higher grain yield and enhanced water use efficiency (Chakraborty et al., 2008). An experiment by Khurshid et al. (2014) containing factorial arrangements of three tillage systems and four levels of mulch conducted at the University of Agriculture, Faisalabad resulted in an increase in soil moisture content, soil organic matter, decreased soil bulk density (Table 2.) and much significantly affected grain yield and yield related parameters of maize (Table 3.)

Table 2. Effect of tillage and mulch on soil physical properties

	Treatment	Soil Bulk density (Mg cm^{-3})	Soil Organic matter contents (%)	Soil moisture contents (%)
Tillage	Minimum tillage	1.4	0.87	16.80
	Deep tillage	1.38	0.84	17.14
	Conventional tillage	1.41	0.73	18.51
Mulch	Mulch (0 Mg ha^{-1})	1.53	0.74	16.15
	Mulch (4Mg ha-1)	1.44	0.79	17.71
	Mulch (8 Mg ha-1)	1.34	0.84	17.66
	Mulch (12 Mg ha-^{1})	1.37	0.88	18.43

Table 3. Effect of tillage and mulch on growth parameters of Maize

	Treatment	Plant height(cm)	Grain yield (Mg ha^{-1})	Plant biomass (Mg ha^{-1})
Tillage	Minimum tillage	193.15	5.37	20.50
	Deep tillage	211.68	5.57	32.13
	Conventional tillage	214.94	5.38	23.40
Mulch	Mulch (0 Mg ha^{-1})	180.63	4.92	20.54
	Mulch (4Mg ha-1)	205.71	5.38	27.10
	Mulch (8 Mg ha-1)	217.35	5.774	26.55
	Mulch (12 Mg ha-^{1})	217.67	5.709	27.18

Source: (Khurshid *et al.*, 2014)

By applying various mulching mechanisms, the impact of water management practices will vary depending on crop types, cover materials, and the corresponding Physico-chemical properties of the soil. This will increase crop production, achieve food security, and promote sustainable development of dryland agriculture. It is reported that high soil erosion may be attributed to I) Lack of the protective effects of crop residue mulch, II) Decline in infiltration rate due to plowing, and III) Increased susceptibility to surface sealing and crust formation (Lal, 2015).

Crop rotation /plant diversity/ Effects

A crucial component of conservation agriculture, crop rotation ensures that crops grow in a systematic sequence with grasses and legumes to preserve the sustainability and efficiency of cropland over an extended period of time (Onduru et al., 2008). When deep-rooted legumes displace grass-type crops, this technique breaks up the soil's hard pan and allows moisture and nutrients to be drawn up from below the surface of the soil. Crops with shallow roots have profited from surface-level nutrient uptake. Plants cannot use atmospheric nitrogen, even though it makes up 78% of the atmosphere. They require a "fixed" form of nitrogen from the soil, such as nitrate, nitrite, or ammonia. legume crops play a role in fixing atmospheric nitrogen with the help of symbiotic soil fauna and their biomass also becomes decomposed to the soil enabling soil organic matter to be built. Because certain weeds, insects, and diseases may flourish when the same crops are planted year after year. Replanting crops every season disrupts their life cycle and stops them from proliferating, which is why it has been used as a weed, pest, and disease control strategy. All these beneficial aspects lead to balanced nutrient usage, reduced erosion, and increased grain yields, hence maximizing profits. (Mutua et al., 2014). Farmers can profit from carbon sequestration by using crop rotation, conservation tillage, and permanent vegetation on highly eroded soils. These advantages include increased soil productivity, a less erosive environment, and enhanced physical and biological characteristics of the soil that lead to increased crop yield (Al-kaisi, 2008). The most common obstacle cited as impeding smallholder farmers' adoption of conservation agriculture techniques is weed management. Crop rotations that preserve live soil cover can reduce weed competition with crops, which will hinder weed establishment (Blackshaw et al., 2008; Shrestha et al., 2002). Crop rotation seems to be a very successful weed management strategy in semi-arid areas.

Erosion is a global issue that contributes to issues that currently affect agriculture, such as topsoil loss, detrimental agricultural practices that raise the risk of flooding, and landslides because of the soil's limited ability to hold water. Crop rotation, as opposed to conventional maize and soy monoculture farming, reduces erosion by nearly 90%, according to UCSUSA (2017). For the following reasons, crop rotation can lower crop yield by reducing erosion; (I) reduced soil disturbance: conservation agriculture with a crop rotation system unlike monoculture crop farming allows longer periods of reduced disturbance to soils and it helps the structural stability to retain much more water. (II) Cover crops: The splash factor causing the soil to be eroded fast can be controlled through cover crops placed on the land for most of the rotation cycle. Plants protect soil in place and minimize its direct exposure to rain and wind the main agents causing erosion. (II) Diverse root systems: a mix of plants with different heights and shapes of root systems ensures that soil particles lead to better aggregate stability. (IV) Spacing: Crops have a different vegetative nature and it makes them demand space. Agronomists leave larger spaces for some crops and smaller or no rows at all in between rows for others to avoid competitive factors. So, this varying spacing demand of crops enables crop rotation to shorten the period of leaving some parts of soil directly exposed because the subsequent crops will most likely need shorter spacing or none at all. (V) Healthy soils: Improved soil structure and water-holding capacity prevent the damage done by heavy rainfall or flooding which are the common triggers of erosion (Derpsch et al., 2014). Generally, it is possible to infer that all conservation agriculture including crop rotation is a fundamental principal result of improved soil structure though varying situations occur in space and time. If soil structure is poor, plants will not develop a healthy root system and will not grow well (Rusinamhodzi & Corbels, 2011). This triggers a set of negative consequences for farmers, as they will not only lose crop yield, but their farmlands become much more vulnerable to erosion and surface runoff, leaking away nutrients and further decreasing fertility.

Conclusion

Taken as a whole, the fate of soil in responding to reduced erosion and achieving higher agricultural yields depends on practices involving varying levels of disturbance resulting from continuous tillage. Techniques such as direct seeding of crops, which only affect the soil cover where the seed is planted, ideally should not disturb the soil in any way. The objective of conservation agriculture is to systematically preserve natural resources while managing agricultural systems to enhance and sustain productivity, increase profits, and ensure food security. Conservation agriculture avoids tillage and cropping strategies that diminish soil organic matter levels, impair soil structure, cause compaction, and increase soil erodibility. It advocates for no-till practices, maintaining permanent soil cover, and encouraging plant diversity to advance agricultural production systems. This results in increased water retention in the soil, reduced erosion, and a greater abundance and variety of life in and on the soil. Given the global concern for food security and the ongoing crisis of declining soil quality attributed to soil tillage, the adoption of conservation agriculture in crop production becomes crucial. Region-specific conservation agriculture practices should be applied, considering the temporal and spatial variations of their impacts.

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Effects of groundwater salinity on soil salt accumulation and pH values for sweet maize under shallow groundwater depths

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Abstract

Controlling saline groundwater at shallow depths increases the risk of salt accumulation in the root zone, leading to increased salinization and reduced agricultural productivity. Understanding how saline groundwater affects salt accumulation in the root zone is of great significance for the sustainability of agriculture and use of freshwater resources. Therefore, the present investigation was conducted during the 2019-2020 growing season in Samsun, Black Sea region of Türkiye, on sweet maize in a drainable lysimeter under rain-shelter conditions. The study investigated the effects of three groundwater depths (30, 55, and 80 cm) and three groundwater salinity levels (0.38, 5.0, and 10.0 dS m-1) on the dynamic changes in soil salinity and pH at different soil depths at the end of the maize growing season. The results showed that soil salinity was remarkably changed by lowering the groundwater depth under all groundwater salinity conditions. Besides, soil salinity ranged from 3.9 to 21.9 dS m-1 for 30 cm groundwater depth, from 2.7 dS m-1 to 8.9 dS m-1 for 55 cm groundwater depth, and from 1.2 dS m-1 to 6.9 dS m-1 for 80 cm groundwater depth. The soil pH values varied between 7.6 - 8.1 at all groundwater depths. The higher salt accumulation rate (80.23%) was observed at 15 cm soil depth under combination of 30 cm groundwater depth and 10 dS m-1 groundwater salinity. However, the lowest salt accumulation rate (3.41%) was found at 15 cm soil depth under 80 cm groundwater depth and 0.38 dS m-1 groundwater salinity conditions. Finally, controlling the groundwater at a depth of 80 cm with a salinity level equal to or less than 5.0 dS m-1 will be beneficial for decreasing soil salinity risk and ensuring environmental safety and sustainable agriculture.

Keywords: Soil salinity, Sweet maize, Shallow groundwater, Sustainable agriculture, Salt accumulation.

Introduction

In many parts of the world, over-exploitation of freshwater resources threatens food security. As a result of population growth and climate change, sectoral changes in water demand indicate that it will be difficult to manage freshwater resources sustainably (Kummu et al. 2016). A new water management strategy must be developed to address future water demand problems in the agricultural sector. For this reason, managing groundwater, which can provide a significant proportion of crop water needs as an alternative to freshwater resources in regions with groundwater, and integrating it into irrigation management can reduce irrigation water needs and production costs in agricultural production (Kiremit and Arslan, 2023; Osman and Arslan, 2022). However, groundwater management is important for dryland and irrigated agricultural production in regions with high groundwater levels, considering factors such as groundwater depth, groundwater quality, crop type and characteristics, climatic conditions, soil hydraulic properties, irrigation interval, and crop growth phase (Kahlown et al. 2005; Gao et al. 2017; Gou et al. 2020).

Many researchers have reported that, under controlled drainage conditions, a significant proportion of seasonal irrigation water requirements can be met by controlling the water table at the optimum level for the crop (Kahlown et al. 2005; Ghamarnia et al. 2012; Fidantemiz et al. 2019; Kiremit et al. 2022) . This shows that irrigation water requirements can be reduced without a significant reduction in crop productivity in groundwater regions, thus efficiently using water resources (Gou et al. 2020). However, poor groundwater quality causes problems such as secondary salinization or sodium in the soil (Jalili et al. 2011). The presence of saline groundwater close to the plant root zone significantly reduces plant growth, development, and productivity (Xia et al. 2016; Narjary et al. 2021). Exposure of plants to saline groundwater close to the root zone causes excessive levels of toxic minerals such as Na^+ and Cl^- to accumulate in the leaves and stems of plants, severely limiting plant growth. Rising groundwater depth is one of the main causes of salinization over large areas, as rising groundwater brings salt from deep layers of soil to the surface by evaporation (Xie et al. 2011). Therefore, the effectiveness of preventing and controlling secondary soil salinization at shallow groundwater levels can be improved by studying the migration characteristics of salt in the soil at different groundwater levels (Xia et al. 2016). To sum up, the amount of salt accumulated in the root zone must be constantly monitored to ensure sustainable agricultural production under controlled drainage conditions. Therefore, this study aimed to understand how much salt accumulates in root zone under different groundwater depths and salinities. Also, we investigated in which soil depth how much salt accumulated under different groundwater depths and salinities. The present result of this study could be providing a valuable insight into sustainable management of the controlled drainage system.

Material and Methods

Experimental Site and Design

This study was conducted between June and September 2020 in a rain-protected area, open on four sides, in the research and application area of the Faculty of Agriculture of Ondokuz Mayıs University. The air temperature was ranged between 17.6 °C and 33.4°C, while relative humidity was varied from 45.1% to 100% during the growing period. Drainable lysimeters with a height and diameter of 100 cm and 60 cm respectively were used in the experiment. The physical and chemical properties of the soil used in the study are given in

Table 1. Experimental soil composition

Parameter	Value	Parameter	Value
Sand	43.4%	pH	8.0
Clay	31.3%	Phosphor	9.8 kg da^{-1}
Silt	25.3%	Potassium	0.6 kg da^{-1}
Field capacity	34.2%	Calcium	18.2 kg da^{-1}
Permanent wilting point	20.9%	Magnesium	12.2 kg da^{-1}
Saturated soil salinity	0.27 dS m^{-1}	Sodium	2.0 kg da^{-1}
		Organic Matter	2.4 kg da^{-1}

The trial soil was first air-dried in a sheltered area and then sieved using a 4 mm sieve. Before filling the lysimeters with soil, the bottom of each lysimeter was filled with 5 cm of gravel and 5 cm of sand to facilitate the flow of water from the Mariotte bottle into the lysimeter. It was then filled with 330 kg of air-dried soil and compacted. The experiment was conducted in 3 different groundwater depths (30 cm, 55 cm, and 80 cm) and 3 different groundwater salinities (0.38 dS m^{-1}, 5.0 dS m^{-1} and 10.0 dS m^{-1}) in 3 replications according to a randomized completely block design. Vega F1 hybrid sweet maize was used in the study. According to the soil analysis results, 25 kg da^{-1} N, 9 kg da^{-1} P_2O_5, and 6 kg da^{-1} K_2O were fertilized in each lysimeter. Potassium and phosphorus fertilizers were applied by mixing them with the soil at a depth of 10 cm in each lysimeter before planting the seeds. Nitrogen fertilizer was applied with the irrigation water in two different periods. 8 maize seeds were planted in each lysimeter on 15 June 2020, and after 14 days, thinning was carried out so that 5 seedlings with homogeneous seedling development remained on each lysimeter surface. During the experiment, chemical pesticides were applied against diseases and pests, and weed control was done manually.

Creation of Groundwater Depth and Soil Moisture Measurement

To ensure seed emergence in the lysimeters, 20 mm of irrigation water was applied to each lysimeter using tap water (0.38 dS m^{-1}) for 15 days. The chemical salts NaCl and $CaCl_2$ were used in a 1:1 ratio to produce 5 and 10 dS m^{-1} saline water. After preparation of saline waters, the lysimeter was saturated from the bottom with different groundwater salinity using the Mariotte principle to create 30, 55, and 80-cm groundwater depths in the lysimeters. The water level in the Mariotte bottles was checked daily, and the remaining water was added according to the salinity. A drainage pipe was placed in each lysimeter to prevent the water table from rising above the desired level. The water from the drainage pipe was collected in drainage containers and measured daily. During the experiment, soil moisture was measured with a 503 Dr neutron probe [CPN 503 Dr Hydro probe, CPN International, Inc. (Martinez, CA), USA], and irrigation water was applied when available soil moisture decreased by 40%.

Determination of the Soil Salinity and Ph

Following harvest, soil samples were taken from 15 cm depth from lysimeters with 30 cm groundwater depth, from 15, 30, and 45 cm soil depth from lysimeters with 55 cm groundwater depth, and from 15, 30, 45, and 60 cm depth from lysimeters with 80 cm groundwater depth. A total of 198 soil samples were taken from all lysimeters. These samples were air-dried, crushed, and sifted through a 2 mm sieve. Each sample's electrical conductivity and pH was determined in ratio of 1:1 [20 g dry soil: 20 mL diluted water] method, and the electrical conductivity and pH values were determined with an EC and pH meter [Eutech pc510 EC/pH]. Thereafter, the EC1:1 values were converted to the saturated paste EC [ECSP];

$$ECSP = 1.55 \times EC1{:}1 - 0.972 \qquad R2 = 0.95 \qquad P < 0.001 \qquad (1)$$

Statistical Analysis

The saturated soil salinity and pH values for different groundwater depths and salinity were illustrated in bar graphs using Microsoft Excel 365 Office Software. The vertical line in each bar is presented as the ± standard error of the 3 replications. Also, salt content before and after study in each soil depth was calculated and expressed as g kg-1 unit.

Results and Discussion

Changes of the Soil Salinity

As seen in Fig. 1, the soil salinity was significantly increased with increasing groundwater salinity (GWS) under all groundwater depths (GWD). At 30 cm GWD, the greatest soil salinity value (21.9 dS m^{-1}) was observed at 10 dS m^{-1} GWS condition, while the lowest value (3.9 dS m^{-1}) was found at 0.38 dS m^{-1} condition (Fig. 1a). As depicted in Fig. 2b, the highest soil salinity value was realized at 15 cm depth under 55 cm GWD at all GWS conditions. The soil salinity value was linearly decreased from 15 cm to 45 cm soil depth under 55 cm GWD conditions (Fig. 1b). The highest soil salinity value (8.9 dS m^{-1}) was observed at 15 cm soil depth under the combination of 55 cm GWD and 10 dS m^{-1} GWS, while the lowest soil salinity value (2.7 dS m^{-1}) was realized at 45 cm soil depth under combination of 55 cm GWD and 0.38 dS m^{-1} GWS (Fig. 1b). However, changes of soil salinity under 80 cm GWD were realized opposite of 55 cm GWD (Fig 1c). According to that, soil salinity was decreased with increasing soil depth from 15 cm to 60 cm (Fig. 1c). The highest soil salinity was found at 60 cm soil depth, while the lowest value was observed at 15 cm soil depth (Fig. 1c). Besides, the soil salinity was changed between 1.19 and 2.96 dS m^{-1} for 0.38 dS m^{-1} GWS, 1.24 and 3.33 dS m^{-1} for 5 dS m^{-1} GWS, 1.67 and 6.49 dS m^{-1} for 10 GWS (Fig 1c). Basen on the results, it could be noted that, soil salinity was directly affected by groundwater depth and salinity. When the groundwater depth is rise to soil surface, soil salinity remarkably increased due to capillarity rise and evaporation from soil surface. Especially, the highest soil salinity was observed at 30 cm GWD, this could be due to the highest capillarity realized at 30 cm GWD compared to the 55 and 80 cm GWD. Xia et al. (2016) reported that as groundwater depth increases, water and mineral transport into the root zone decreases due to capillary rise, thus reducing soil salinity and soil moisture in the upper region. The contribution of groundwater to evapotranspiration promotes the movement of water and salt minerals into the upper part of the soil by capillarity, which causes a relatively higher salt accumulation in the surface layers of the soil (Jalili et al. 2011; JiuSheng et al. 2012). Considering all, controlling groundwater depth at <55 cm and 5 dS m^{-1} or higher groundwater salinity is not suitable for sweet maize cultivation and sustainable agriculture.

Changes of pH Value

The soil pH was significantly varied under groundwater depth and salinity (Fig. 2a-c). At 30 cm GWD, the soil pH was decreased with increasing groundwater salinity, and it changed from 8.1 to 7.6 (Fig. 1c). At 55 cm GWD, the soil pH value increased with increasing soil depth from 15 to 45 cm at all groundwater salinity conditions (Fig. 2b). However, soil pH value did not remarkably change between 0.38, 5 and 10 dS m^{-1} groundwater salinity under 55 cm groundwater depth. According to that, soil pH value ranged from 7.9 to 8.1 for 0.38 dS m^{-1}, 7.8 to 7.9 for 5 dS m^{-1}, 7.6 to 7.8 for 10 dS m^{-1} (Fig. 2b). At 80 cm GWD, soil pH value decreased with increasing soil depth from 15 to 60 cm under all groundwater salinity (Fig. 2c). The highest soil pH value was realized at 15 cm soil depth for all groundwater salinity (Fig. 2c). Also, the maximum soil pH (8.11) value was found at 15 cm soil depth under 5 dS m^{-1} groundwater salinity, while the lowest (7.71) was found at 60 cm soil depth under 10 dS m^{-1} groundwater salinity. The change in soil pH could be caused by the water solubility of groundwater salt minerals, plant nutrient uptake, cation exchange capacity of the soil, and microorganism activity, depending on the groundwater depth.

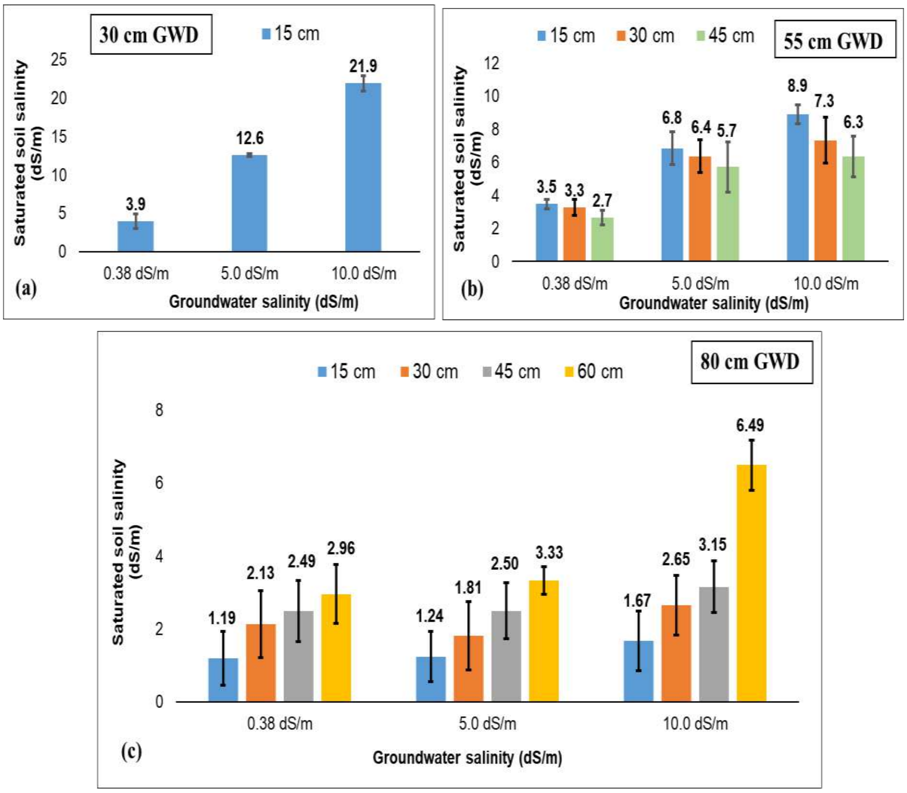

Figure 1. The changes of soil salinity according to different groundwater depth and salinity

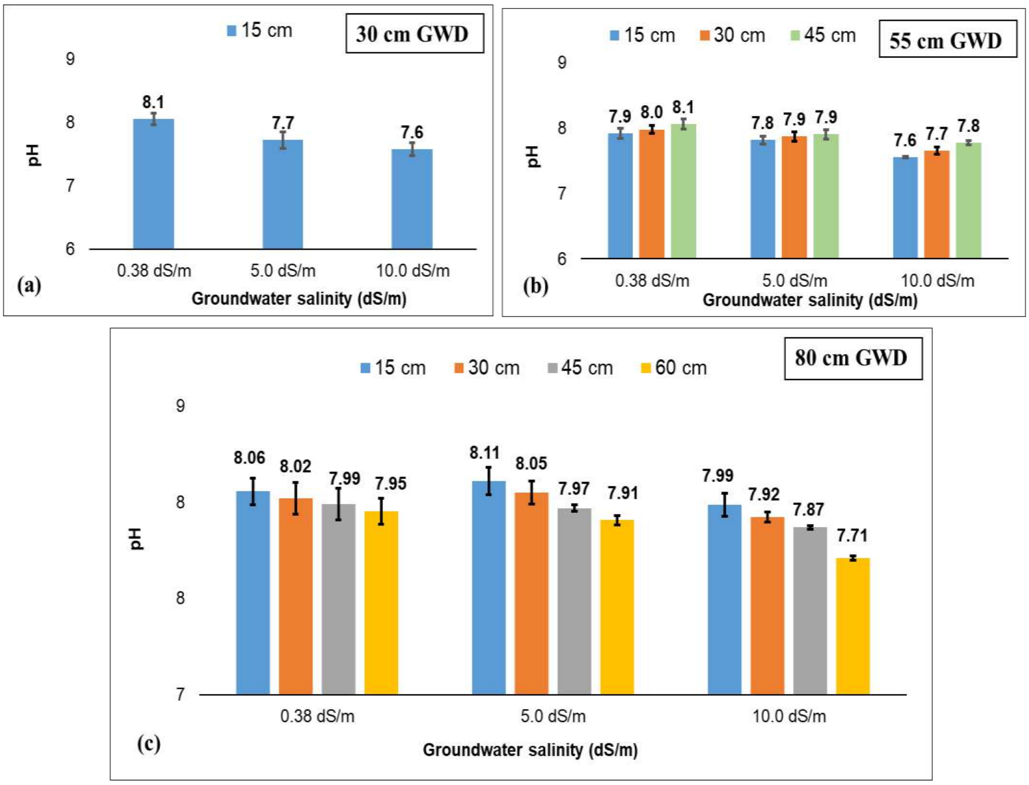

Figure 2. The changes of soil pH according to different groundwater depths and salinities

Salt Accumulation Rate

Salt accumulation rate was significantly varied under groundwater depths and salinities. Also, the salt accumulation in soil profile was increased with increasing groundwater salinity at all groundwater depth conditions (Table 2). The highest salt accumulation rate (80.23%) was observed at 15 cm under combination of 10 dS m^{-1} GWS and 30 cm GWD condition. At 55 cm GWD conditions, the salt accumulation rate was increased from 45 cm to 15 cm soil depth. In other words, the highest salt accumulations were observed at 15 cm under 55 cm GWD conditions, while the lowest salt accumulations were occurred at 0.38 dS m^{-1} GWS condition (Table 2). However, at 80 cm GWD conditions, the salt accumulation rate was decreased linearly with increasing soil depth at all groundwater depths and salinities (Table 2). The salt accumulation rate was varied between 3.41 and 9.95% for 0.38 dS m-1 GWS, 3.59 and 11.32% for 5 dS m^{-1}, 5.18 and 23.05% for 10 dS m^{-1} under 80 cm GWD condition (Table 2). Considering all the results obtained, the rate of salt accumulation in the soil profile mainly depends on the salinity of the groundwater and the depth. Similar results were reported by Xia et al. (2016). When the groundwater has a high salinity, it leads to more movement of salt minerals in the soil profile with increasing capillarity. In particular, the highest capillarity occurred at 30 cm GWD, resulting in the highest salt accumulation rates under 30 cm GWD. However, with increasing groundwater depth, the contribution of groundwater to evapotranspiration decreased, resulting in less movement of salt minerals into the upper soil depth. Also, salt accumulation rate in soil profile under shallow and saline groundwater conditions could be affected by soil texture, climate conditions, irrigation intervals, crop water consumption, crop growing stage (Ayars et al. 2006; YongBao et al. 2014).

Table 2. Groundwater salinity and depth effects on salt accumulation rate at various depths in the soil.

Groundwater depth	Groundwater Salinity	Soil depth	Salt content before the study (g/kg)	Salt content after harvest (g/kg)	Salt accumulation (g/kg)	Salt accumulation rate (%)
30 cm	0.38 dS m^{-1}	15 cm	0.17	2.52	2.35	13.60
	5.0 dS m^{-1}		0.17	8.07	7.89	45.68
	10.0 dS m^{-1}		0.17	14.04	13.86	80.23
55 cm	0.38 dS m^{-1}	15 cm	0.17	2.23	2.06	11.91
		30 cm	0.17	2.08	1.91	11.06
		45 cm	0.17	1.70	1.53	8.83
55 cm	5.0 dS m^{-1}	15 cm	0.17	4.38	4.21	24.37
		30 cm	0.17	4.08	3.90	22.59
		45 cm	0.17	3.66	3.48	20.16
55 cm	10.0 dS m^{-1}	15 cm	0.17	5.70	5.52	31.97
		30 cm	0.17	4.69	4.52	26.14
		45 cm	0.17	4.06	3.89	22.49
80 cm	0.38 dS m^{-1}	15 cm	0.17	0.76	0.59	3.41
		30 cm	0.17	1.36	1.19	6.88
		45 cm	0.17	1.59	1.42	8.22
		60 cm	0.17	1.89	1.72	9.95
80 cm	5.0 dS m^{-1}	15 cm	0.17	0.79	0.62	3.59
		30 cm	0.17	1.16	0.98	5.69
		45 cm	0.17	1.60	1.43	8.25
		60 cm	0.17	2.13	1.96	11.32
80 cm	10.0 dS m^{-1}	15 cm	0.17	1.07	0.90	5.18
		30 cm	0.17	1.69	1.52	8.81
		45 cm	0.17	2.02	1.85	10.68
		60 cm	0.17	4.16	3.98	23.05

Conclusion

With rising groundwater depth to the soil surface, soil salinity increased markedly in different soil profiles, and variations in soil salinity increased markedly with increasing groundwater salinity. Considering all soil profiles, salt accumulation varied with groundwater depth. The highest soil salinity was observed at a groundwater salinity of 10 dS m^{-1} for all groundwater depth conditions. Regarding salt accumulation rate, a shallow groundwater depth of 55 cm was identified as the critical depth value for sweet maize production and salinity control. Also, when the groundwater salinity is higher than 5 dS m^{-1}, the groundwater should be controlled at a depth of at least 55 cm or higher for salinity management to sustain arid irrigated agriculture.

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Physical-mechanical composition and properties of dark grey soils of Georgia in Imereti region

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Abstract

Georgia, in particular, the dark grey soils of the middle belt of the Imereti mountain-forest zone are widespread. This soil is of bioclimatic type which analogues are found in many regions of the world forest zone and are formed in geographical and landscape conditions similar to Georgia. According to the vertical zoning, forest dark grey soils are spread from 600-900 meters above sea level to 2000-2100 meters. In Imereti, in the lower zone of the distribution of these soils, they border the yellow and red soils, and in the upper zone, the subalpine soils of the mountain-meadow. They, like the relief of the territory of all mountainous countries, the relief strip of forest dark grey soils in Imereti is very difficult in relief. It is fragmented, which in turn is related to the geological structure, lithological composition of rocks, tectonic processes, erosion-denudation occurrences and more. The thickness of the soil changes with the inclination of the slope, gravel, properties, the greater the slope, the less soil moisture, the slower the soil is washed away, and the dryness of the soil is known to be unfavorable for the plant. Under these conditions, a very small amount of humus-accumulation horizon is formed, which is unsatisfactory in terms of soil protection importance and fertility. At the same time it is noteworthy that the soils of the southern exposure are hotter than those of the north. Dark grey soils are developed on the Tertiary and post-Tertiary sandstones, clays and their overcrop products in the southern Imereti region, which includes the northern slopes of the Meskheti Range, within the Zestafoni, Bagdati, Samtredia, Vani districts. Soil-forming rocks are Lower and Middle Eocene sandstones, marls, clay-shales, erupted (andesites, tuffs) rocks. These soils are developed under broadleaf (hornbeam, chestnut, oak) and deciduous-coniferous forest cover. Sandy soils are spread in Khoni, Baghdati, Vani, Tkibuli, Chiatura, Kharagauli, Imereti region.

Keywords: Dark grey soil, Imereti, Marls, Overcrop, Shale, Soil

Introduction

Georgia is characterized by a particularly interesting soil cover. A number of soil types were first described and studied in Georgia, and subsequently they were allocated in many countries around the world. One of the main laws of soil geography, "vertical zoning of soils", was established based on the study of soils in the Caucasus, in particular, Georgia. Out of 32 types of soil in the world, 22 types of soil are common in Georgia. Our work presents the dark grey soils of the central belt of the Imereti mountain forest zone, which is characterized by a wide distribution. These soils are of the bioclimatic type, and they originated in surroundings that are comparable to Georgia's in terms of geography and topography. Analogs of these soils may be found throughout the world's forest zone. Forest dark grey soils are distributed between 600–900 meters and 200–2100 meters above sea level, depending on the vertical zoning. Imereti's subalpine soils of mountain-meadow form the upper boundary of these soils' distribution, while yellow earth soils border them in the lower zone (Urushadze et al., 2011).

Dark gray soils can be found widely throughout Georgia, especially in the central belt of the Imereti mountain-forest zone. These soils are of the bioclimatic type, and they originated in surroundings that are comparable to Georgia's in terms of geography and topography. Analogs of these soils may be found throughout the world's forest zone. Forest dark grey soils are distributed between 600–900 meters and 200–2100 meters above sea level, depending on the vertical zoning. Imereti's subalpine soils of mountain-meadow form the upper boundary of these soils' distribution, while yellow earth soils border them in the lower zone. In addition to the relief of the entire region of all mountainous countries the Imereti forest's dark grey relief strip presents a highly challenging relief situation. It is fragmented, which is related to tectonic processes, lithological composition of rocks, geological structure, occurrences of erosion and denudation, and other factors (Lortkipanidze, 2015).

The thickness, roughness, and other characteristics of the soil vary along with the slope's inclination; the more inclined the slope, the less moisture the soil retains and the slower the soil is washed away. The soil's dryness is recognized to be detrimental to plants. Under the aforementioned circumstances, a very thin humus-accumulation horizon forms, which is unacceptable in terms of fertility and the significance of soil conservation. It should be mentioned that the southern exposure's soil is hotter than the northern one at the same time. in the southern Imereti region, which covers the northern slopes of the Meskheti mountain, in the districts of Zestafoni, Baghdati, Samtredia, and Vani—dark grey soils are formed on Tertiary and post-Tertiary sandstones, clay-shales, and associated depletion products. Rocks that form soil include sandstones from the lower and middle Eocene, marls, clay-shales, and erupted rocks like andesites and tuffs (Lortkipanidze,2010).

The Imereti region's broadleaf (beech, chestnut, oak, and decidious-coniferous) forest cover provided the environment in which these samples were developed. In the districts of Khoni, Baghdati, Vani, Tkibuli, Chiaturi, Khaaragauli, Tskaltubo, Zestaponi, Terjola, Sachkheri, and Samtredia, dark grey soils are widely distributed. Vegetable crops (vines, tea, mulberries, fruit trees, and corn) occupy a portion of the medium and deep dark grey soils, while woodlands and grasslands occupy a greater portion. While some are plowed under and replaced with annual crops, thin, washed-out variety remains in the natural vegetation cover. When it comes to minor slopes, the detrimental impact of soil erosive processes is particularly noticeable on the slopes that are utilized for cultivating crops (Urushadze et al., 2011).

The dark gray soil profile is not well differentiated based on genetic horizons; the humus horizon is 30–35 cm thick, and the lesser horizons gradually blend into one another. This is the structure of the soil profile: A_0-(A_1)-A1-AB-BC-C.

Throughout the whole profile, dark grey soils are distinguished by an acidic or weakly acidic reaction in the upper layers, melting of the metamorphic horizon, a feeble sediment fraction extraction from the upper layers, noncoarseness of bases in the absorbed complex, and a high humus content in the accumulation layer that decreases rapidly at first and then progressively. Acidity and fulvousness are the hallmarks of humus (Walker et al., 2007).

Material and Methods

We do not dispute the presence of the podzole subtype, but our data clearly identify the following categories of acidic and weakly non-acidic subtypes of dark grey soils: ordinary, residual carbonate, and residual acidic. Their limited dispersion prevented them from showing up on the soil map.

The acidic dark grey soils are characterized by an overall acidity in their profile. particularly the upper horizons' strong and medium acid response, where the absorbing complex's bases have a high percentage of non-coarseness and a limited exchange capacity. They are typically distinguished by advantageous physical attributes. Their structure is watertight, their porosity is high, they have strong air capacity, and the higher horizons are water permeabile.

We took a soil section according to the genesis horizons, using the classical method in field conditions.It brings us to the village of Vani district, in the territory of Upper Vani, on the south-western slope of the forest. Morphological description of #1.

Horizon: A_0 0-3 cm	Dead Cover
Horizon: A_1 3-25cm	Dark brown, granular-dusty structure, heavy loam, loose, roots, large amount of plant residues, humid, does not whoosh
Horizon: B 25-55cm	The same, a little bit lighter, thick structure, heavy loam, compact, roots in small quantity
Horizon: C 80-100cm	Small pieces of rock, moist, does not whoosh

It is evident from the morphological description of the mentioned soil that the top strata have a high degree of aggregation and are dark gray in hue. The quantity of fine, undecomposed plant remains and the amount of humus are both connected to the dark color. In the depth, the horizons' hue gradually turns pale brown. It is evident from the mechanical analysis data of the dark grey, acidic soils that their mechanical composition is primarily clayey and clayey (Talakhadze and Mindeli, 1976).

In most situations, the physical clay fraction (<0.01 mm) grows gradually downward in the profile and ranges between 33.4 to 78.8%. 9.2-40.59% is the quantity of finely scattered (<0.001 mm) fraction. In the metamorphic horizon (B), the index of a size fraction in a natural sediment clearly increases, indicating weak melting. The provided figures demonstrate a significant variation in the fine part's mechanical composition, with some of them having weakly to moderately coarse textures. Most sediments have some degree of roughness, which greatly affects their hydrological characteristics. (Walker et al., 2007). Linking restoration and ecological succession)

In acidic soils with natural cover, such as meadows, woodlands, and bushes, humus is often minimal. Its thickness ranges from 20 to 40 cm. The range of humus content is 1.12–5.21%. Its rate decreases to 0.60–1% with depth. Humus and total nitrogen have a correlation that ranges from 0.061-0.209%. These are all brought on by water-borne erosion, which results in sporadic and feeble soil cover washing. (Ran and Sobti, 2020).

Exceptions in dark grey types are soils occupied by meadows and forests. Kharagauli (Moliti), where humus content is 6.11-8.32%. Total nitrogen corresponds to humus - 0.235-0.418%.In most situations, the humus concentration in the soil described falls between 2.20 and 6.31% in the upper horizon; this range is comparatively higher in the types that are used.

The content of humus is relatively higher in the utilized varieties, in most cases the humus in the mentioned soil varies within the range of 2.20-6.31% in the upper horizon. In the territory of Tobobuli region, the areas assimilated for perennial vegetation contain humus up to 6.34-8.64%. The thickness of the humus layer reaches 50-60 cm in totally assimilated types. The humus rate in the lower layers drops to 0.80-1.34%. Total nitrogen is correlated with humus - it is 0.106-0.448% (Kvesitadze and Urushadze, 2016).

Different dark gray soil types have different nutritional element contents. The amount of soluble phosphorus in the soil depletes it. In the soil, its value ranges from 1.54 to 33.15 mg per 100 g. Certain areas have very little soluble phosphorus, such as the area around the village of Gordi in the Khoni district. In Chiatura (Zodi pastures), there is a significant amount of mobile potassium present in the soil, with a value of 28.61–29.15 mg/100 g.

The utilized soils have a moderate supply of soluble phosphorus and a low phosphorus concentration. The range of its value per 100 g is 1.25–48.67 mg. Its rate is high (62.01-67.84 mg) in the soil, as well as in the soil of the Chiaturi district's Zodi area, where vineyards and arable land are located. There are not many absorbed bases in total. Its rate (10.64-33.15 ml equivalent) varies depending on the types of soil. Along with the absorbing complex (Ca+ Mg), hydrogen also participates. Its rate is especially high in the upper layers, which indicates a high noncoarseness of the bases. (Lortkipanidze, 2010).

The reaction of the examined soils is acidic. In many cases, the low level of acidity is observed in the humus horizon, the acidity increases with depth, according to analytical data, the pH in the water discharge is equal to 4.0-5.5. The profile of dark grey, harmful residual carbonate soils in the lower layers contains carbonates in the amount of 1.60-2.80%. Therefore, their reaction in the upper layers is moderately acidic, while the lower layers are characterized by a weak acidic and neutral reaction (pH=5.5-7.0).

In contrast to acidic soils, weakly alkaline soils have a brownish color, a weak acid reaction throughout the profile, a low percentage of non-acidity with bases in the absorbent complex, and a significant absorption capacity (Remmert, H., 1980).

We took a soil section according to the genesis horizons, using the classical method in field conditions.It brings us to the territory of the village of Dzirula, Zestafoni district, on the south-western slope, in the pasture. Morphological description of #2:

Horizon: A 0-17cm	Dark brown, granular-hardy, loamy, loose, roots and plant residues, moist, not wet; does not whoosh
Horizon: B 17-40 cm	Light-colored, hard structure, loamy, compact, roots in small quantity, fragments of rock in small quantity, does not whoosh
Horizon: B/C 40-70 cm	Cool grey, transitional to bedrock, poorly defined structure, loamy, rock fragments, moist, does not whoosh
Horizon: >70 cm	Clay-shale depletion products

Results And Discussion

From the morphological description, it can be seen that the upper horizons of these soils have a blackish-red or dark brown color and high aggregate, the color of the horizons gradually becomes red with depth.

Dark grey, loamless soils are characterized by uneven distribution of mechanical fractions in the profile. By mechanical composition, the soils of all subtypes mainly belong to medium and light loams, and some belong to heavy loams and clayey soils. The fraction of physical clay (<0.01mm) is mostly within the range of 23.7-40.2%, in other cases the fraction of physical clay reaches 44.6-73.9%; 1- 0.25 mm fraction content changes, some differences are weak and on average coarse. Clay soils of small thickness contain stones from the surface. The different content of the 1-0.25 mm fraction was caused by the influence of the parent material. In most cases, the content of physical clay and silt increases significantly with increasing depth (Margvelashvili, 2010).

In weakly loamless soils with natural cover, humus is typically present in trace levels. Its percentage ranges from 1.03 to 4.36% in growth horizons. The layer of humus is minimally thick. The only exception are the soils found in woodland groves and lawns, where the humus content ranges from 4.77-93.55%.

The thickness of the humus layer reaches 30-40 cm, total nitrogen is correlated with humus. Its rate varies between 0.054-0.498%. These soils are provided with hydrolytic nitrogen content on average. Its value changes to 7, 28-11,81mg per 100g. in the soil.

loamless soil varieties are used with medium and low humus content. The thickness of the layer is 35-50 cm, and in some places, it reaches 60-70 cm Humus in the arable layer varies between 1.66-5.76%. Total nitrogen is correlated with humus - 0.048-0.262%; hydrolytic nitrogen is 8.40mg per 100g in the soil (Horstet al., 2020). Dark gray soil has a low soluble phosphorus level and is only minimally supplied. Its value varies based on the kind, ranging from 2.49 to 24.2 mg.

The majority of the soluble phosphorus variants that are used are of poor to average quality. The range of its value is 1.51-43.68 mg. Perennial crop-occupied soils have high concentrations of soluble phosphorus (58.0–80 mg). Regarding the mobile potassium content, the same is true. Its rate is variable, ranging from 5.6 to 74 mg. The majority of soils that lack loam have a medium to high capacity for absorption.

In the profile, the total amount of absorbed bases ranges from 26,54 to 54,54 milliequivalents (mEq). Weakly loamless ordinary types have absorbed bases that add up to little more than 10.87–26.18 mEq. In the absorbed complex, hydrogen is a participant in addition to Ca and Mg. It is not overly coarse as seen by the fact that its percentage is less than 20% of all bases. CaCo2 is present in the bottom layers of residual carbonate species in trace levels (0.40-2.24%). The outermost layers of the soil exhibit a weakly acidic reaction (P-6.2–6.8), while the deeper layers exhibit a neutral to slightly alkaline reaction. pH = 7.0–7.4, which indicates the residual carbonation of the mentioned kinds of soil (Urushadze et al., 2011).

general, the reaction of loamless soil is weakly acidic. The pH in the aqueous extract is equal to 5.5-6.8, and the reaction in the remaining mobile species is weakly acidic in the upper layers, and neutral and weakly alkaline in the depth. pH in the extract with water is 6.4-7.4.

Conclusion

Dark grey soils have quite a lot of utilize in agriculture. They are utilized for maize crops, fruit trees, and vines. Dark grey forest soils are characterized by complex relief structure, frequent hygrographic network, deep valleys and steep slopes, where human's wrong agricultural activity, deforestation and wrong soil cultivation contribute to the development of erosion processes.

Tillage brings the detrimental effects of erosive processes particularly on sloping lands. The following measures should be taken in order to maintain and improve the fertility of these soils: all agro-technical activities should be completed on the utilized slopes timely and with high quality. This stipulates overturning, loosening, and applying organic and mineral fertilizers in the amounts specified by the agrochemical cartograms in the spring. Ploughing in green manure produces positive outcomes.

The problem can be minimized by introducing rotational grazing, protecting against overgrazing, and sowing the necessary perennial grasses on the slopes left for grazing. In regions where woods are present, only sanitary clearing should be permitted; forest cutting should be outlawed. The proper arrangement of water conveying and water-conducting channels, along with an appropriate soil cultivation system, is crucial for controlling atmospheric precipitation runoff and drainage system to prevent soil erosion in the area.

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Estimation of soil aggregate stability by different regression methods

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Abstract

Histosols or internationally known as peat bog soils or organic soils are formed from inadequately decomposed plant tissues They are exclusively found in arctic and subarctic zones and also in temperate regions especially lowlands, enormous hill ranges while a very low percentage of them found in the tropical areas of the world. Soil organic carbon content ranges from above 20 percentage in this soil type. Studies are mainly being conducted to analyse the presence of dominant trace metals like notably Cu, Zn, Cd, Pb, Ni and Cr in organic soils. Based on review with other literature suggest that organic matter is they key factor in retention, release and bioavailability of heavy metals. Thereby, Organic soils generally have more trace metals accumulated compared to the mineral soils. The deposition of toxic metals is not constant and are affected by organic soil development, climate and biological activity of plants. Accumulation of potentially toxic metals, in these organic soils can affect the vegetation of that particular area. The accumulation of heavy metals in these soils can be due to anthropogenic and natural activity during the earlier centuries.

Keywords: Heavy Metals, Peat Soil, Organic Matter, Urban Area

Introduction

In Histosols or peat soils, organic matter by weight are at least 20 – 30% and thickness more than 40cm whereas bulk densities are very low. They have a characteristic colour range from brown to black. As oxygen is a main factor for decomposition, histosols have very limited oxygen supply. In addition, they are also acidic in nature. The process of histosol formation is known as peatification. They act as a major carbon sink and constituent of global carbon cycle. Therefore, these are also known as carbon rich soil. They store approximately 30% of global soil carbon, 10% global soil nitrogen and 10% global fresh water (Limpens et al., 2008). Based on the plant that form the peat, peat soil habitat comprises mainly of 4 classes: blanket bog, upland raised bog, lowland raised bog, and fen. The global peatland area is estimated to be 4.23 million km^2, or approximately 2.84% of the global land area (Holden et al., 2018). In Europe, Histosols covers about 5% of soil cover. Peat soils are the most widespread of all wetland types in the world, representing 50 to 70% of global wetlands. It is estimated that 15% of global peatlands have been drained and are currently being used for agriculture and forestry (Joosten and Clarke, 2002). They are prone to adverse conditions of increased moisture content, low oxygen content, and toxic elements. The properties of organic formations in these soils are basically determined by vegetation, from which they originate. Slope peats compared to terrace ones, are characterized by increased content of macro elements (Al, Ca, Fe, Mg, P) and almost all microelements. Higher content of elements could be associated with the increased ash content in peats and partly with more intensive manuring (influence of avifauna) (Klimowicz, Melke and Uziak,1997). This concerns above all, a fast increase and a slow decomposition of the detritus, so as it could be deposited as a peat. (Klimowicz et al., 1997). Geochemical studies of historical human activities in peatlands are not confined to Europe but have been performed worldwide (Hu, X.; Wang, C.; Zou, L. 2011).

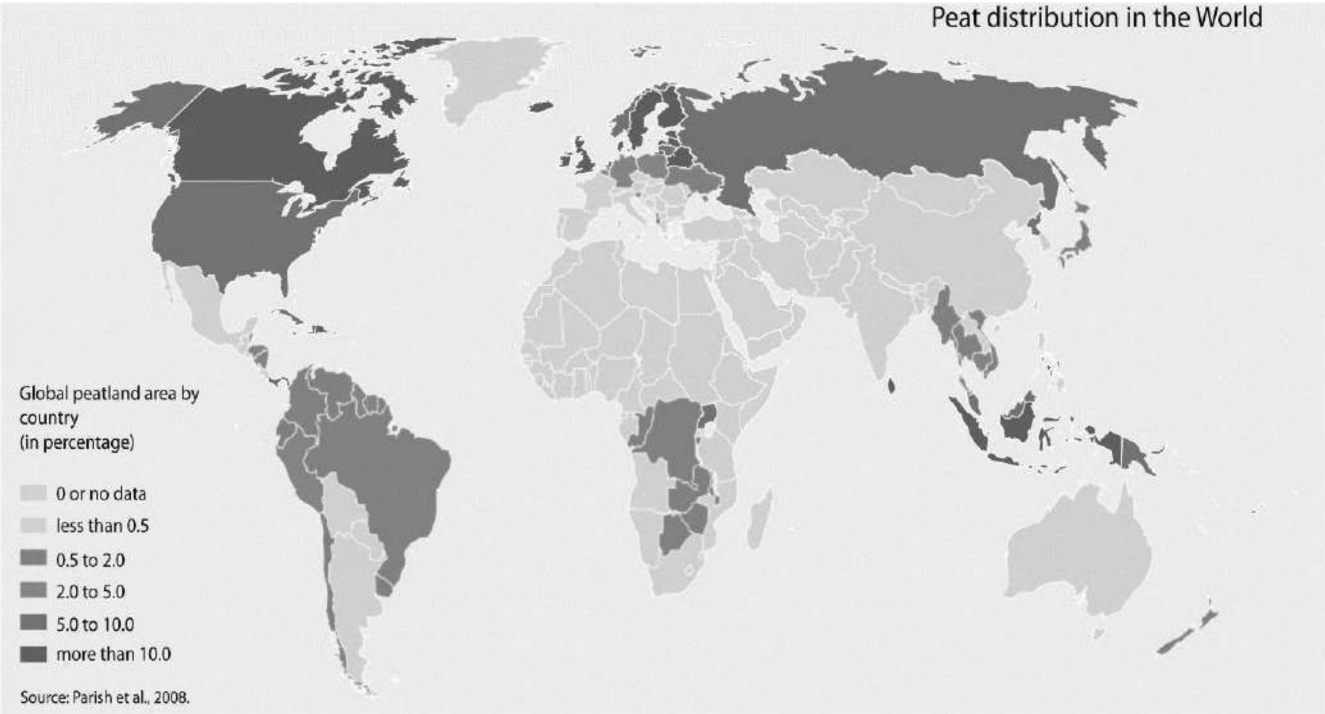

Figure 1. The global peat-land distribution (Parish et al., 2008)

Heavy metal contamination

Pollution through heavy metals in soil is the most serious ecological hazard to the natural resources. In soil, metals are found in one or more of several "pools" of the soil, as described by Shuman (1991): dissolved in the soil solution, occupying exchange sites on inorganic soil constituents, specifically adsorbed on inorganic soil constituents, associated with insoluble soil organic matter, precipitated as pure or mixed solids, present in the structure of secondary minerals; and/or present in the structure of primary minerals.

Anthropogenic deposition is linked with above 5 pools while natural deposition can be linked to any but might depend on geography of the area. In peatlands located near pollution sources such as smelters or coal-fired power plants, deposition of heavy metals in the form of particulate matter is more important than that in a dissolved state (Batonneau et al., 2004, Rausch et al., 2005).

Accumulation of heavy metals in soil is greatly influenced by the organic matter present in them. Because organic colloids (e.g., humic acids) are major players in the retention of heavy metals (Borgulat et al., 2018). In this regard, organic soils or peat soils have excessive deposition of trace metals when compared to mineral soils. A discussion of the nature of soil organic matter and its role in the retention of metals in soil is given by Stevenson (1991) and Stevenson and Fitch (1990).

Symptoms of the harmful effect of cadmium in plants occur at concentrations of 5-30 $mgkg^{-1}$. The critical limit of lead toxicity for plants is 30-300 $mgkg^{-1}$. The critical deficiency content of zinc amounts to >15-20 $mgkg^{-1}$ and the toxic level is 100-300 $mgkg^{-1}$(Borgulat et al., 2018).

Metals toxicity in peat soil

Various studies reveal that the concentration of heavy metals in the upper layers of many European peatlands is higher than in the deepest layers; a fact directly related with the increased atmospheric pollution of the last 100-160 years (Shotyk et al., 1998, Coggins et al., 2006, De Vleeschouwer et al., 2007). There are various types of peat bogs depending on the age, plants, and conditions that created the bog. According to (Borgulat et al., 2017), study was conducted to determine the current level of accumulation of heavy metals in peat bogs subjected to different intensities of anthropopression. Peat and soil collected from a depth of 0-30 cm were used as material for analyses. Heavy metal analyses usually carried out after mineralisation using nitric acid and microwaves for plant samples and aqua regia in an open system for soil samples. Heavy metal content was established by the inductively coupled plasma (ICP) mass spectroscopy technique for plants and ICP-optical emission spectrometry for soil samples. In a majority of the researched soils the highest content of the analyzed elements was assessed in the surface horizons (Zadrozny and Nicia, 2009).

Horizons	Cd	Pb	Zn
	mg · kg^{-1}		
Surface organic	0.45–1.25	17.51–46.20	29.01–99.65
Organic lying on mineral substratum	0.11–0.31	2.30–20.65	13.55–205.35
Underlying mineral	tr.–0.15	2.30–4.91	4.50–14.60
WA	1.45–11.36	(0.85) 3.66–6.76	(0.22) 2.24–5.46

Fig 2. Changes of heavy metal concentrations in the surface and underlying horizons of the analyzed soils and accumulation coefficients (Zadrozny and Nicia, 2009).

	As	Cu	Ni	Pb	Zn	Mn	Fe	Co	
	Recommended value (mg/kg)								
Canadian Council of Ministers of Environment (2009)	59	35.7	37	35	123	-	-	-	
Soil Quality Guidelines (SQG)	50	70	50	200	63	-	-	-	
International Standard Quality Guidelines (*ISQG*) low	8	65	-	75	200	-	-	-	
International Standard Quality Guidelines (*ISQG*) high	70	270	-	218	270	-	-	-	
Pre-Industrial Level	15	70	80	175	50	-	-	-	
Predicted effect level (PEL)	17	197	-	91.3	315	400	-	-	
Threshold effect level (TEL)	5.9	36.7	18	35	123	-	-	-	
Crust Courage Martínez et al. 2020)	18	70	80	13	132	950	50,000	38	

Figure 3. Heavy metals concentration recommended value (Wahab, Abdul, et al. 2021)

The toxicity degree of elements depends on types of compounds in which those metals exist, their chemical forms, absorption ways and metabolic activity. The organic matter at low pH value (5-5.5) enhanced the absorption of elements Pb, Cr, Ni and Cu in the peat soil profile. (Zamri, S. N. M., H. Saleh, and B. Musta, 2022).

Conclusion

Peatlands can record the history of environmental pollution, as they reflect human activities fairly accurately and also play a vital role in the global carbon cycle (Bandara, S.2017). Heavy metals being highly toxic and difficult to degrade, can be transferred and enriched in the food chain through multiple media such as sediment and soil, thus endangering human health and causing irreversible damage to the environment (Zuzolo et al., 2017). The high concentration of heavy metals is considered critical for influencing the potential impact on ecosystems, human health, and sustainable environmental protection (Kusin et al., 2018). Thus, this review has outlined the importance of peat soil and its properties along with negligence of heavy metals accumulation specific to them. Apart from this, there are several areas that are still yet to be addressed. The reclamation of these areas can be considered as a topic for research.

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Effects of organic amendments on aggregate stability in three different textured soils

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Abstract

This study was carried out to examine the effects of the addition of garbage compost (GC), barnyard manure (BM), wheat straw (WS) and vetch straw (VS) on soils in three different texture classes (silty clay loam, clay, and clay loam) on aggregate stability and thus erosion susceptibility under laboratory conditions. The study was carried out in factorial order and in three parallels (3x4x5x3). Four kg soil samples were placed in plastic containers and organic residues were mixed into these samples at 0.0, 0.5, 1.0, 2.0 and 4.0% based on dry weight. Tap water was dripped into the boxes until they reached the field capacity. The samples moistened with tap water were weighed once every two days and tap water was added to the boxes until they reached field capacity again when 75% of the available moisture in the soil was depleted. Soil samples were incubated under these conditions for ten weeks. During the incubation, the laboratory temperature ranged between 20±2 ^{0}C. Soil samples were used in the relevant analyzes after they were crushed by hand at the end of the incubation period. Soils are soils with fine to moderately fine texture, low organic matter content, medium and low lime content, and no alkalinity problem. These soils with low initial stability are susceptible to erosion. The organic residues, which are the subject of the experiment, mixed with these three soil teksture classes, it statistically significantly increased the amount of water-stable aggregates larger than 250 microns and their resistance to erosion. The activities of organic residues differed among themselves and according to soil teksture groups. The effectiveness of garbage compost in this regard was lower than that of barn manure, wheat straw and vetch straw.

Keywords: Soil texture, Physical properties, Susceptibility to erosion, Organic conditioners

Introduction

Improving physical soil conditions is very important for plant cultivation and soil protection. Increasing the stability of aggregates by promoting the structural development in the soil causes the formation of a suitable plant growth environment and a significant reduction in erosion damage. Organic matter is a substance that has important effects or contributions in improving the physical properties of soils, increasing the structural stability, and reducing its susceptibility to erosion (Özdemir, 2013; Esmaeilzadeh et al., 2014; Sithole et al., 2019). The organic matter content of the soils varies depending on the land use type and the type and amount of organic residues added (Burkr et al., 1989; Pulleman et al., 2000; Seddaiu et al., 2013). In this regard, different researchers applied different levels of barn manure (Aran, 1986; Du et al., 2020; Rayne et al., 2020), wheat straw (Christensen, 1986; Limon-Ortega et al., 2009), green manure (Gür, 1981; Tejada et al., 2008; Karaca, 2022), garbage compost (Pikul and Allamaras et al., 1986; Fisher, 2012). and some other organic residues (Guidi et al., 1981; Palm et al., 1997) have investigated this development and change.

Aggregate size and stability in soil is a vital factor of soil physical quality, reflecting the impact of soil management and land use on soil degradation (Castro et al., 2002; Sithole et al., 2019). In this, soil organic matter serves as the main binding agent of mineral particles to aggregates, while soil aggregates protect soil organic matter from rapid decomposition by microorganisms and act as a reservoir for C and other important soil nutrients (Elliott, 1986). Soil organic matter also stimulates the activities of soil biota (Ayuke et al., 2011) and maintains soil physiochemical conditions such as cation exchange capacity (CEC) and pH (Vanlauwe et al., 2005). Annabi et al., (2004) investigated the effect of conventional farm manure and two types of municipal waste compost on aggregate stability in a loamy soil in laboratory and field conditions and the relationship of this effect with microbial activity. After the study, the researchers; they emphasized that there are close relationships between soil organic matter and aggregate stability and the rate of decomposition of the added fertilizer.

This study was carried out to examine the effects of mixing organic residues such as garbage compost, barn manure, wheat straw and vetch straw on aggregate stability and hence susceptibility to erosion of three soil texture clases (silty clay loam, clay, clay loam) under laboratory conditions.

Material and Methods

The The study was carried out under laboratory conditions using surface (0-20 cm) soil samples of three different texture classes. Barnyard manure, wheat straw, vetch straw and garbage were obtained from different institutions and organizations.

Table 1. Some properties of soils and organic residues used in the experiment (barnyard manure, wheat straw, vetch straw and garbage compost)

Properties		Soils		
		1	2	3
Sand, s		44	16	28
Silt, %		22	24	33
Clay, %		34	60	39
Teture class		SiCL	C	CL
Reaction pH (1:2.5)		7.6	8.0	8.2
Lime ($CaCO_3$), %		0.4	1.1	10.3
Organic matter, %		1.5	1.4	1.5
Cation exhange capacity (me/100 g)		34	57	41
Exchangeable sodium, %		2.2	1.7	2.4
	Organic waste			
	Barnyard manure	Wheat straw	Vetch straw	Garbage compost*
Total O.M, %	69.15	89.10	87.65	24.70
Total-C,%	40.44	52.04	50.52	14.32
Total-N , %	1.70	0.56	2.22	0.91
Total-P_2O_5 ; %	0.10	0.41	0.18	0.08
Total-K_2Ox10-1, %	0.21	0.15	0.16	0.19
Total-Ca, %	1.96	1.26	1.15	1.64
Total-Mg; %	0.44	0.42	0.23	0.38
Total-Nax10-2 %	0.60	0.16	0.15	0.59
C/N ratio	23.79	92.93	22.76	15.73

*: maximum grain diameter, 10 mm; coarse sand (0.2-2 mm) 22%; stone, gravel, glass etc. (2-10mm)

In this study, four types of organic residues were applied to three different texture classes soils at five different doses with control. The experiment was established in three parallels (3x5x4)x3 and conducted in factorial design. In this experiment which was conducted under laboratory conditions, subsamples of 4 kg each were taken from the soils which were air dried and sieved through a 2 mm sieve and placed in plastic containers. The samples were mixed with barnyard manure, wheat straw, vetch straw and garbage compost at 0.0, 0.5, 1.0, 2.0 and 4.0 % levels on dry weight basis. The mixtures were transferred to sheet metal boxes with dimensions of 25 cm x 25 cm x 10 cm. Tap water was added drop by drop to the boxes until the trials and mixtures were brought to field capacity. The boxes were weighed once every two days. When 75% of the available moisture was depleted, tap water was added to the boxes until they reached field capacity again. This process was continued for 10 weeks, during which time the laboratory temperature was kept at 20 ^{0}C± 2 ^{0}C. At the end of this incubation period, the samples and mixtures were crumbled by hand and made ready for analysis.

Particle size distribution was determined by sedimentation method (Demiralay, 1993); soil pH was determined by pH meter in 1:2.5 soil-water suspension (Kacar, 1994); lime content by volume (Kacar, 1994); organic matter content by Walkley-Black method (Kacar, 1994); cation exchange capacity by Bower method (Kacar, 1994). Some properties of barnyard manure, wheat straw, vetch straw and garbage compost used in the experiment were determined based on (Harris, 1970). The aggregate stability values of the soils were determined by wet sieving method (Demiralay, 1993).

SPSS computer package program was used for data evaluation (analysis of variance and Duncan multiple comparison test).

Results and Discussions

Some physical and chemical properties of the soils used in the study determined before the experiment are presented in Table 1. As can be seen from this table, the soils are fine and moderately fine textured. Soil number two (clay) is fine textured, while soils number one (silty clay loam) and number three (clay loam) are moderately fine textured. The pH (1:2.5) values of the soils are between 7.6 and 8.2 and the soils are slightly alkaline (sample number 1, 7.6) and moderately alkaline (sample number 2, 8.0 and sample number 3, 8.2) in terms of reaction. The lime content of the soils was very low (sample 1, 0.4% and sample 2, 1.1%) and moderate (sample 3, 10.3%). Organic matter content was low in all three soils, around 1.5%. The cation exchange capacities of the soils ranged between 34 and 57 me/100 g and this value was highest in sample number 2 with 60% clay content. The percentage of exchangeable sodium in the soils is below 15 and there is no alkalinity problem (Mallah and Bagheri-daghabadi, 2022).

By utilizing the textural properties of the soils, as a first approach, a preliminary judgment can be made about their stability and erodibility. If the soils selected for the experiment are evaluated based on silt/clay ratio, they can be characterized as unstable soils (Doğan and Güçer, 1976, Özdemir, 2013). When the clay ratio ((sand + silt)/clay) of sample number 2 is taken into consideration, it can be said that it is more resistant to erosion than the others. The clay ratio values of these soils with the same organic matter contents are 1.94, 0.67 and 1.57 respectively. A small clay ratio (Bryan, 1968; Morgan 2005; Özdemir, 2013) indicates that the soil is more resistant to erosion. The cation exchange capacity of the same soil is the highest. This gives the impression that the soil in question is less susceptible to erosion.

Agregateb Stability

The aggregate stability values (average of 3 values) obtained by mixing different levels of barnyard manure, wheat straw, vetch straw and garbage compost are given in Figure 1. It can be seen from this plot that all four organic residues significantly increased the aggregate stability of the soils depending on the level of application. This increase was higher in soil sample number 1 which had low stability (denet 21%).

The results of the analysis of variance for the aggregate stability values of the soils at the end of the experiment are presented in Table 2. As can be seen from the results of this analysis, the mean of squares ($p<0.01$) for the aggregate stability values of the experimental soils was significant.

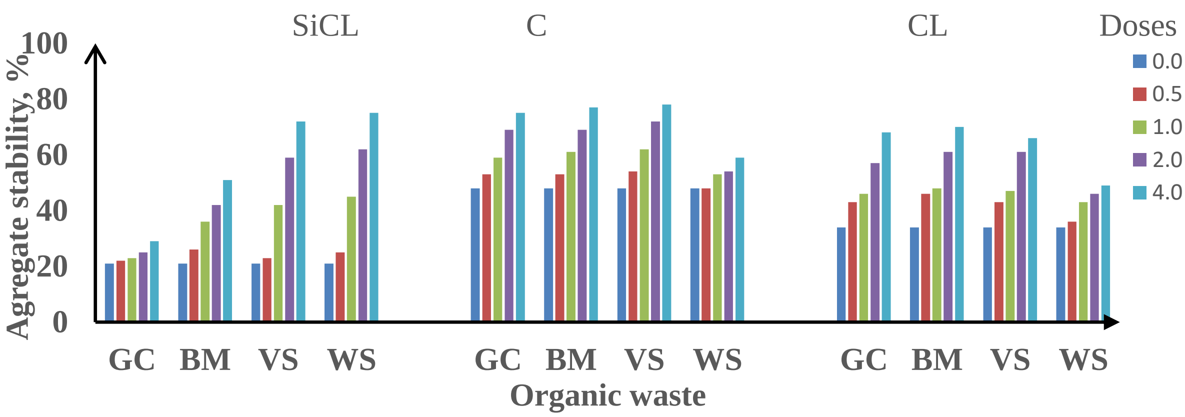

Figure 1. Changes in aggregate stability values of soils incorpareted with organic residues at different levels (%).

In other words, the soils differed in terms of aggregate stability values at the end of the experiment. It is also seen from the same table that the means squares of fertilizers and applied fertilizer levels were also significant ($p<0.01$). This result shows that the fertilizers used in the experiment such as barnyard manure, wheat straw, vetch straw and garbage compost and the applied fertilizer levels have different effects on aggregate stability. Analysis of variance results also show that the soil x fertilizer interaction was significant.

Table 2. Analysis of variance results for aggregate stability values of soils amended with different levels of organic residues.

Sources	Degrees of freedom	Sum of squares	Mean of squares
Soils	2	14896.5	7448.24**
Fertilizers	3	5200.3	1733.43**
Levels (Fertilizers)	16	24378.9	1523.68**
Soil x Fertilizer	6	992.9	165.48**
Error	152	2161.1	14.22
General	179	47629.7	

**: Significant at 1 % level.

The average increases (%) in aggregate stability compared to the control (no fertilizer) are given below. In all three soils, the increases obtained with garbage compost were much lower. Nevertheless, these increases are physically significant.

Fertilizers	Soils		
	1	2	3
Barn manure	84.5	33.3	57.4
Wheat straw	146.4	35.4	65.4
Vetch straw	133.3	38.5	59.6
Garbage compost	17.9	11.5	27.9

The average increases (%) in the aggregate stability values of the fertilizer levels applied to the soils were different in each soil as can be seen below.

Soils	Fertilizer Level			
	0.5	1.0	2.0	4.0
1	14,3	73,8	123,8	170,2
2	8,3	22,4	37,5	50,5
3	23,5	35,3	65,4	86

The mean increases (%) in aggregate stability of soils caused by barnyard manure, wheat and vetch straw and garbage compost showed significant differences among the fertilizers. The mean increases (%) in aggregate stability of soils caused by the fertilizer levels of these four fertilizers are given below.

	Fertilizer Level			
	0.5	1.0	2.0	4.0
Barn manure	18,4	36,9	63,1	88,3
Wheat straw	20,4	49,5	86,4	115,5
Vetch straw	16,5	46,6	86,4	109,7
Garbage compost	2,9	15,5	21,4	33

Scheffe's multiple comparison test was applied to the data for the comparison of experimental soils and applied fertilizer levels according to the mean aggregate stability values at the end of the experiment

	Soils		
	1	2	3
Average	59.38 a	48.20 b	37.10 c

As it can be understood, the soils differed significantly in terms of the mean aggregate stability at the end of the experiment. By applying the aforementioned test, the fertilizer levels were grouped as follows according to the mean aggregate stability at the end of the experiment.

	Fertilizer Level				
	0.0	0.5	1.0	2.0	4.0
Average aggregate stability	34.33 a	39.33 b	47.08 c	56.42 d	64.08 e

In this grouping, the differences between fertilizer levels were found to be significant ($p<0.01$) (the values shown with separate letters are significant at 1% level according to the mentioned test).

Conclusion

In this study conducted under laboratory conditions, organic residues such as barnyard manure, wheat straw, vetch straw and garbage compost mixed into the soils increased the amount of water-resistant aggregate in the experimental soils, improved some physical and mechanical properties and reduced the susceptibility of the soils to erosion. In this respect, the efficacy of garbage compost was lower.

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Removal of biogenic elements by spelt plants depending on the influence of experimental factors

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Abstract
The use of such agrotechnical factors as foliar fertilization and the use of growth regulators and microfertilizers is actively spreading in spelt growing technologies. The yield of spelt is limited not only by moisture and macronutrients, but also by a low level of basic micronutrients in most regions of Ukraine. Micronutrients play a key role in plant development, and their deficiency negatively affects yield and crop quality. According to the removal of biogenic elements of wheat crops, spelled assimilated 158.4 kg/ha of nitrogen, 71.1 kg/ha of potassium and 131.3 kg/ha, while the values of 163.5, 73.8, 136, 2 kg/ha, for the Europe cultivar - 170.8, 76.6, 141.3, and for the Atterhauer Dinkel cultivar - 140.8, 62.8, 116.5 kg/ha, respectively. According to the influence of research factors on the removal of macroelements, it was established that during the treatment of crops with humate of potassium GK-17 in the earing phase, in general, the yield was 2.1 kg/ha more nitrogen, 1.1 kg/ha phosphorus and 2.6 kg/ha more potassium, and during the treatment of Humate potassium GK-17 crops in the earing phase and again in the milk ripeness phase - 10.7, 4.1, 9.2 kg/ha. Also, the treatment of crops with a growth stimulator contributed to the fact that plants carried 2.6, 1.5, 2.4 kg/ha more nitrogen, phosphorus and potassium. According to the amount of removal, we determined that during the processing of crops Humate potassium GK-17 in the earing phase and again in the phase of milk ripeness in combination with the application of Agriflex Amino in the earing phase in Zorya of Ukraine cultivars, nitrogen removal was 170.6 kg/ha, phosphorus - 77.0 kg/ha, and potassium was 141.4 kg/ha, in Europe cultivars – 186.9, 83.8, 154.2 kg/ha, and in Atterhauer Dinkel cultivars – 149.9, 66.4, 123.8 kg/ha, respectively.
Keywords: Biogenic Elements, Spelt, Cultivars, Growth Regulator, Plant Density, Removal

Introduction

The use of such agrotechnical factors as foliar fertilization and the use of growth regulators and microfertilizers is actively spreading in wheat growing technologies (Dobermann and Cassman, 2002). The yield of winter wheat is limited not only by moisture and macronutrients, but also by a low level of basic micronutrients in most regions of Ukraine. Micronutrients play a key role in plant development, and their deficiency negatively affects yield and crop quality. Researchers, analysing the balance of the main trace elements (molybdenum, cobalt, boron, zinc, manganese, copper) in agriculture, came to the conclusion that the deficit of these trace elements ranges from 66 % to 96 %. They recognized that trace elements play a crucial role in realizing the potential of cultivated crops. Thus, the results of the study showed a significant improvement in the use of basic fertilizers when changing crop rotation, when microfertilizers were used (Field, 2007).

Studies show that the influence of trace elements contributes to an increase in the content of both macroelements and trace elements in grain. Therefore, it is important to combine foliar fertilization with trace elements and humates with the main application of fertilizers that compensate for losses of nitrogen, phosphorus, potassium and trace elements. Scientists hypothesize that trace elements introduced in the form of chelates through the leaf blade stimulate plant growth, as the plant organism can meet its needs for trace elements from soil reserves. Therefore, it is more appropriate to introduce trace elements into the soil to increase their availability.

Macronutrients play an important role in the formation of the commercial wheat crop, as well as a basis for the construction of the plant organism. That is, without sufficient provision of a sufficient level of nutrition, plants will not be able to effectively grow, develop and form a grain crop (Lukashchuk, 2012; Balyuk et al., 2019; Zaryshniak, 2015).

The relevance of the issue of studying the need of plants for macronutrients is increasing as crop cultivation systems are biologized, especially when it is necessary to provide crops with biologically pure nutrients that are not synthesized chemically [Dobermann and Cassman, 2002; Gospodarenko et al., 2020).

Thus, studies by various authors show that winter wheat takes from 31 to 34 kg of nitrogen, from 11 to 14 kg of phosphorus and from 19 to 22 kg of potassium for one ton of grain and the corresponding amount of straw. At the same time, the economic removal of nitrogen ranges from 84 to 130 kg/ha, phosphorus from 32 to 53 kg/ha, and potassium from 49 to 85 kg/ha (Talbert et al., 1998; Vaguseviciene et al., 2012; Halysh, 2007).

Material and Methods

In 2020-2022 field trials were carried out in the experimental field of SPC of Bila Tserkva NAU, situated in the Right-bank Forest-steppe zone – in Bug-Middle Dnipro area. The relief of the experimental field is a slightly-wavy plain with a small slope of the surface from the south to the south-west.

In the years when the research was conducted (2020-2022) the weather conditions differed from long-term indicators. However, generally they were favourable for the growth and development of spelt.

Research methods. The field method was used to observe the growth and development of plants, environmental conditions, assess the components of cultivation technology and determine the agrotechnical and economic advantages obtained as a result of the implemented measures. The laboratory method was used to analyse indicators of crop quality. The measurement and weight method were used to record changes in growth and yield. The computational and comparative method was used to determine the effectiveness of research results from the point of view of their economic and energy feasibility. Mathematical-statistical method - allows you to assess the degree of reliability of differences between different research options.

Results and Discussion

Let's evaluate the parameters of macronutrient removal by spelled crops, depending on the influence of the experimental factors (Table 1).

In general, according to the removal of nitrogen, it was determined that the plants absorbed 158.4 kg/ha, while the Zorya variety of Ukraine obtained an indicator of 163.5 kg/ha, the Europa variety – 170.8, and the Atterhauer Dinkel variety – 140.8 kg/ha.

If we analyse the regularities of removal of this element from the influence of the experimental factors, then with the application of potassium humate GK-17 in the earing phase, in general, a yield of 2.1 kg/ha more nitrogen was recorded, and with the treatment of crops with potassium humate GK-17 in the earing phase and again in the phase of milk ripeness - 10.7 kg/ha. Also, the treatment of crops with a growth stimulator contributed to the fact that plants carried 2.6 kg/ha more nitrogen.

According to the intensity of the influence of the complex of factors of the experiment, it was determined that during the treatment of crops with Humate potassium GK-17 in the earing phase and again in the milk ripeness phase in combination with the application of Agriflex Amino in the earing phase in the Zorya varieties of Ukraine, 170.6 kg/ha of nitrogen was recorded. in the Europe variety - 186.9 kg/ha, and in the Atterhauer Dinkel variety - 149.9 kg/ha.

It was investigated that with the removal of phosphorus, the crops assimilated 71.1 kg/ha, while the Zorya variety of Ukraine obtained a value of 73.8 kg/ha, the Europa variety - 76.6, and the Atterhauer Dinkel variety - 62.8 kg /Ha.

It was also established that when applying potassium humate GK-17 in the earing phase, in general, 1.1 kg/ha more phosphorus was removed with the harvest, and when the crops were treated with potassium humate GK-17 in the earing phase and again in the milk ripeness phase - 4.1 kg/ha. Also, the treatment of crops with a growth stimulator contributed to the fact that the plants carried 1.5 kg/ha more phosphorus.

Table1. Removal of macronutrients by spelled crops, kg/ha, on average for 2020-2022.

Cultivar	Foliar fertilizer	Growth stimulator	Nitrogen	Phosphorus	Potassium
Zoriia Ukraiiny	Control	Control	159.8	73.0	132,5
	Potassium humate GK-17 in the earing phase	without a stimulant	162,7	73,9	136,0
		Agriflex Amino in the earing phase	164,1	74,3	137,5
	Potassium humate GK-17 in the phase of milk ripeness	without a stimulant	158,4	71,5	132,0
		Agriflex Amino in the earing phase	160,0	71,6	133,1
	Potassium humate GK-17 in the phase of earing and re-milk ripeness	without a stimulant	168,6	75,1	140,7
		Agriflex Amino in the earing phase	170,6	77,0	141,4
Evropa	Control	Control	169,1	75,8	139,1
	Potassium humate GK-17 in the earing phase	without a stimulant	169,2	75,6	140,4
		Agriflex Amino in the earing phase	169.3	77.4	141.0
	Potassium humate GK-17 in the phase of milk ripeness	without a stimulant	168.1	75.3	138.8
		Agriflex Amino in the earing phase	160.4	72.2	134.0
	Potassium humate GK-17 in the phase of earing and re-milk ripeness	without a stimulant	172.7	76.4	141.9
		Agriflex Amino in the earing phase	186.9	83.8	154.2
Atterhauer Dinkel	Control	Control	136.6	60.7	112.8
	Potassium humate GK-17 in the earing phase	without a stimulant	138.2	61.7	113.8
		Agriflex Amino in the earing phase	139.9	62.8	115.4
	Potassium humate GK-17 in the phase of milk ripeness	without a stimulant	136.9	61.0	113.9
		Agriflex Amino in the earing phase	137.3	61.7	113.8
	Potassium humate GK-17 in the phase of earing and re-milk ripeness	without a stimulant	146.8	65.0	121.8
		Agriflex Amino in the earing phase	149.9	66.4	123.8
	$SSD_{0,05}$		5.6	2.4	4.2

During the treatment of crops with humate of potassium GK-17 in the earing phase and again in the milk ripeness phase in combination with the introduction of Agriflex Amino in the earing phase, 77.0 kg/ha of phosphorus was recorded in the Zorya varieties of Ukraine, and 83.8 kg/ha in the Europe varieties, and in the Atterhauer Dinkel variety - 66.4 kg/ha.

It was also investigated that 131.3 kg/ha were assimilated by the potassium uptake by the crops, while the figure of 136.2 kg/ha was obtained for the Zorya Ukraine variety, 141.3 for the Europa variety, and 116.5 for the Atterhauer Dinkel variety. kg/ha.

According to the regularities of the removal of this element from the influence of the research factors, when the crops were treated with Humate of potassium GK-17 in the earing phase, in general, a yield of 2.6 kg/ha more potassium was recorded, and when the crops were treated with Humate of potassium GK-17 in the phase of heading and again in the phase of milk ripeness - 9.2 kg/ha. Also, the treatment of crops with a growth stimulator contributed to the fact that the plants carried 2.4 kg/ha more potassium.

It was also determined that during the treatment of crops with Humate potassium GK-17 in the earing phase and again in the milk ripeness phase in combination with the application of Agriflex Amino in the earing phase, the removal of potassium was 141.4 kg/ha in the Zorya varieties of Ukraine, and 154 kg/ha in the Europe varieties .2 kg/ha, and in the Atterhauer Dinkel variety – 123.8 kg/ha.

Conclusions

According to the removal of biogenic elements of wheat crops, spelled assimilated 158.4 kg/ha of nitrogen, 71.1 kg/ha of potassium and 131.3 kg/ha, while the values of 163.5, 73.8, 136, 2 kg/ha, for the Europe variety - 170.8, 76.6, 141.3, and for the Atterhauer Dinkel variety - 140.8, 62.8, 116.5 kg/ha, respectively.

According to the influence of research factors on the removal of macroelements, it was established that during the treatment of crops with humate of potassium GK-17 in the earing phase, in general, the yield was 2.1 kg/ha more nitrogen, 1.1 kg/ha phosphorus and 2.6 kg/ha more potassium, and during the treatment of Humate potassium GK-17 crops in the earing phase and again in the milk ripeness phase - 10.7, 4.1, 9.2 kg/ha. Also, the treatment of crops with a growth stimulator contributed to the fact that plants carried 2.6, 1.5, 2.4 kg/ha more nitrogen, phosphorus and potassium.

According to the amount of removal, it was determined that during the treatment of crops with Humate potassium GK-17 in the earing phase and again in the phase of milk ripeness in combination with the introduction of Agriflex Amino in the earing phase in the Zorya varieties of Ukraine, nitrogen removal was 170.6 kg/ha, phosphorus - 77 ,0 kg/ha, and potassium was 141.4 kg/ha, in Europe varieties – 186.9, 83.8, 154.2 kg/ha, and in Atterhauer Dinkel varieties – 149.9, 66.4, 123 .8 kg/ha, respectively.

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Effects of tree species on soil organic carbon: A comprehensive review

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Abstract

(Soil organic carbon (SOC) is a cornerstone of terrestrial ecosystems, influencing soil structure, nutrient cycling, and carbon sequestration. As trees contribute substantially to above and belowground biomass, their impact on SOC is pivotal for understanding ecosystem dynamics. Tree species traits, such as litter quality and root architecture, emerge as critical determinants influencing SOC dynamics. Environmental context, including climate and soil conditions, further modulates these effects, highlighting the context-specific nature of the tree-SOC relationship. Empirical evidence suggests both positive and negative impacts of specific tree species on SOC, emphasizing the complexity of these interactions. Mechanisms such as litter quality influencing decomposition rates and root-microbe interactions shaping nutrient cycling contribute to a holistic understanding. Recognizing the practical implications for ecosystem management, including strategic afforestation, is crucial for mitigating climate change effects. Despite progress, research gaps persist, necessitating future studies to explore long-term stability and interactive effects in diverse ecosystems. This ensures a nuanced comprehension of the intricate dynamics between tree species and SOC. This comprehensive review delves into the intricate relationship between tree species and SOC, synthesizing diverse literature to elucidate the underlying mechanisms shaping these interactions.

Keywords: Soil organic carbon (SOC), Tree species, Root microbe

Introduction

Soil organic carbon (SOC) is a fundamental component of terrestrial ecosystems, playing a pivotal role in soil fertility, nutrient cycling, and carbon sequestration (Smith et al., 2020). As the largest terrestrial pool of organic carbon, SOC is a dynamic reservoir that influences soil structure, water retention, and microbial activity (Lehmann & Kleber, 2015). The intricate relationship between tree species and SOC has gained increasing attention in the scientific community due to its profound implications for ecosystem health, sustainable land management, and global carbon cycling.

The importance of SOC lies in its multifaceted contributions to soil functionality. It acts as a source of energy for soil microorganisms, playing a crucial role in microbial processes that decompose organic matter and release nutrients (Mikutta et al., 2006). Furthermore, SOC enhances soil structure by promoting the formation of stable aggregates, which improves water infiltration and root penetration (Six et al., 2004). This, in turn, has significant implications for plant growth and overall ecosystem resilience. Additionally, SOC sequestration contributes to climate change mitigation by removing carbon dioxide (CO_2) from the atmosphere and storing it in the soil, thereby helping to alleviate the effects of anthropogenic greenhouse gas emissions (Don et al., 2023).

One key determinant of tree species' impact on SOC is their specific traits. The quality of tree litter, including its chemical composition and decomposition rates, significantly influences SOC dynamics (Aerts, 1997). Deciduous trees, for instance, often shed leaves with lower lignin content, leading to faster decomposition and increased carbon input to the soil compared to the often slower-decomposing needles of many conifers (Hou et al., 2020). The rate of organic matter decomposition affects the turnover of SOC, influencing its storage in the soil.

Mycorrhizal associations, particularly arbuscular mycorrhizal fungi, further contribute to the intricate relationship between tree species and SOC. These fungi form symbiotic relationships with tree roots, enhancing nutrient uptake and influencing the decomposition of organic matter (Yin et al., 2021). The mycorrhizal network acts as a conduit for carbon transfer from plants to the soil, influencing SOC dynamics and nutrient cycling in the ecosystem. In addition to species traits, the impact of tree species on SOC is strongly influenced by environmental factors, emphasizing the context-specific nature of these interactions (Schlesinger & Amundson, 2019). Climate, for instance, plays a crucial role in shaping the effects of tree species on SOC. In arid environments, certain tree species may act as "soil engineers," enhancing soil water retention and promoting microbial activity, ultimately influencing carbon sequestration (Fahad et al., 2022). This comprehensive review aims to synthesize existing knowledge, identify patterns and trends, and explore the mechanisms underpinning the diverse effects of tree species on SOC.

Factors Influencing Tree Species Effects on SOC

- Tree Species Traits

The intricate relationship between tree species traits and soil organic carbon (SOC) dynamics is a central focus in ecological research, reflecting trees' pivotal role in shaping terrestrial ecosystems. Litter quality is a critical tree species trait that profoundly influences SOC dynamics. The chemical composition of tree litter, encompassing elements such as lignin, cellulose, and nutrient content, varies significantly among species and plays a pivotal role in dictating the decomposition rate and subsequent nutrient cycling in the soil (Aerts, 1997). Deciduous trees, exemplified by species such as Quercus and Acer, often contribute high-quality litter characterized by lower lignin content and higher nutrient concentrations, accelerating microbial activity and promoting faster decomposition rates, ultimately enriching SOC levels (Zhang et al., 2023).

Table 1. Effect of tree species on Soil Organic carbon

S.N	Specie Name	Depth	PH	SOC %	Reference
1	Acer saccharum (D)	0-10	4.00	5.9	Riha et al. (1986)
	Pinus resinosa (C)		3.83	5.1	
	Picea abies (C)		3.76	4.9	
2	Dipterocarpus tuberculatus (D)	0-10	6.20	0.2	Yadava and Devi (2007)
3	Fagus sylvatica (D)	0-10	3.70	5.0	Kooijman et al. (2009)
4	Castanopsis carlesii and Litsea acuminata (M)	0-20	4.50	3.9	Owen et al. (2010)
5	Gmelina arborea (D)	0-30	7.30	2.7	Adekunle et al. (2011)
6	Tectona grandis (D)	0-30	8.3	1.1	
7	Populous davidiana (D)	0-10	6.14	10.6	Miao et al. (2013)
8	Eucalyptus grandis (E)	0-10	5.9-6.0	1.8	Guedes et al. (2016)
9	Oak field (D)	0-10	5.6	1.9	Zhou et al. (2019)
10	Quercus rubra (D)	0-10	3.7	1.1	Stanek et al. (2020)

Beyond litter quality, root architecture is another key trait shaping the interaction between trees and SOC. The belowground structures of trees, including root depth, distribution, and morphology, influence the accessibility of organic matter to soil microbes. Deep-rooted species, such as certain oak trees, facilitate the incorporation of organic matter into deeper soil horizons, impacting both the quantity and quality of SOC (Pierret et al., 2016). The depth to which roots extend influences the depth of carbon inputs, with implications for long-term carbon storage and sequestration in the soil profile. Mycorrhizal associations represent a symbiotic interaction between trees and soil fungi that significantly influences SOC dynamics. Arbuscular mycorrhizal (AM) fungi enhance nutrient uptake by tree roots, promoting carbon transfer from plants to the soil (Finzi et al., 2015). This relationship contributes to the diverse forms of SOC and highlights the interconnectedness of above- and below-ground processes in shaping carbon dynamics.

Root turnover, another facet of tree species traits, contributes significantly to SOC dynamics. The rate at which roots die and are replaced affects the quantity and quality of organic inputs to the soil. Studies, such as those by Matamala et al. (2003), have demonstrated that species like Pinus contorta exhibit rapid root turnover rates, contributing substantially to the organic carbon pool in the soil.

- **Climate and Soil Conditions**

The intricate interplay between climate and soil conditions is pivotal in unraveling the complex dynamics of soil organic carbon (SOC). As a primary driver, climate profoundly influences the types of vegetation that thrive in a given region, thereby shaping the overall carbon dynamics of terrestrial ecosystems. In arid environments characterized by limited precipitation and high temperatures, certain tree species function as "soil engineers," enhancing carbon sequestration by improving soil structure and water retention (Fahad et al., 2022). The ability of specific tree species to thrive in arid conditions is crucial for predicting carbon sequestration patterns and ecosystem resilience in the face of changing climates.

Conversely, in humid climates with abundant rainfall, microbial activity intensifies, potentially accelerating organic matter decomposition and influencing SOC turnover patterns. The increased moisture availability in such environments can lead to dynamic interactions between plant species, microbial communities, and soil properties, ultimately shaping the fate of organic carbon (Pugnaire et al., 2019). Understanding how climate modulates these interactions is essential for comprehending the broader implications for SOC dynamics.

Soil characteristics, including texture, nutrient content, and pH, further modulate the impact of climate on SOC dynamics. Tree species can alter these soil properties through their root activities and litter inputs, influencing microbial communities and decomposition rates. The interaction between tree species and soil conditions is multifaceted, emphasizing the need for context-specific approaches to understand and predict the intricate dynamics of SOC within diverse ecosystems (De Graaff et al., 2006).

- **Positive Effects on SOC**

Empirical evidence consistently highlights the positive influence of tree species on soil organic carbon (SOC) dynamics, elucidating the pivotal role these arboreal entities play in terrestrial carbon sequestration. Numerous field studies across diverse ecosystems support that specific tree species traits significantly enhance SOC levels. For instance, deciduous trees, characterized by high-quality litter with lower lignin content and elevated nutrient concentrations, foster microbial activity, accelerating decomposition rates and ultimately enriching SOC content (Aerts, 1997). The deep-rooted nature of certain tree species further amplifies their positive impact, facilitating the incorporation of organic matter into deeper soil horizons and influencing both the quantity and quality of SOC (Pugnaire et al., 2019). Such empirical observations underscore the importance of considering tree species as key determinants in the carbon dynamics of ecosystems, providing valuable insights for sustainable land management and climate change mitigation strategies.

- **Negative Effects on SOC**

Contrarily, empirical evidence also underscores instances where specific tree species can negatively impact soil organic carbon (SOC) dynamics. In certain ecosystems, particularly those dominated by evergreen trees with recalcitrant litter, the slow decomposition rates can hinder carbon turnover and potentially lead to SOC depletion (Lu et al., 2021). For instance, coniferous trees are known for producing litter with high lignin content and low nutrient concentrations, creating conditions that impede microbial activity and result in a slower release of organic carbon into the soil (Rahman et al., 2013). Additionally, allelopathic compounds released by certain tree species can inhibit the growth of soil microorganisms, further influencing SOC dynamics negatively (Qu et al., 2021).

Mechanisms Underlying Tree-SOC Interactions

- **Litter Quality and Decomposition**

The interactions between tree species and soil organic carbon (SOC) dynamics involve intricate mechanisms, and a fundamental aspect of this relationship lies in the quality of the litter produced by trees and its subsequent decomposition. Litter quality, encompassing factors such as lignin content, nutrient concentrations, and the chemical composition of leaves, plays a pivotal role in determining the fate of carbon inputs into the soil. Deciduous trees, typified by species like Quercus and Acer, contribute to high-quality litter characterized by a lower lignin-to-nitrogen ratio and elevated nutrient levels, making it more palatable to soil microorganisms (Aerts, 1997). The accelerated microbial activity and increased nutrient availability in the litter create conditions conducive to faster decomposition rates, promoting the breakdown of organic matter and facilitating the incorporation of carbon into the SOC pool (Zhang et al., 2023). This decomposition process involves a complex interplay of enzymatic activities, microbial diversity, and soil fauna. Microorganisms, such as bacteria and fungi, produce extracellular enzymes that break down complex organic compounds, releasing simpler molecules into the soil. The chemical composition of the litter influences the enzymatic activity, with lower lignin content and higher nutrient concentrations promoting more efficient decomposition (Prescott, 2002).

- **Root-Microbe Interactions**

The intricate relationship between trees and soil organic carbon (SOC) dynamics involves a complex interplay of processes, with the interactions between tree roots and soil microbes emerging as a crucial component. Understanding the mechanisms underlying these belowground dynamics is essential for unraveling the complexities of carbon cycling in terrestrial ecosystems.

Tree roots, extending into the soil matrix, play a pivotal role in shaping SOC dynamics by releasing various compounds known as root exudates. These exudates, comprising sugars, amino acids, organic acids, and other soluble compounds, create a carbon-rich microenvironment around the roots, commonly called the rhizosphere (Finzi et al., 2006). The carbon inputs from root exudates serve as a significant energy source for soil microorganisms, initiating a symbiotic relationship that profoundly influences carbon cycling. This below-ground carbon flux forms the foundation for the intricate interactions between trees and the soil microbial community.

The rhizosphere, enriched by root exudates, becomes a hotspot for microbial activity. Soil microbes in this zone are fueled by the carbon compounds released by tree roots, increasing microbial biomass and heightened enzymatic activity (Bais et al., 2006). These microbial processes, stimulated by the input of labile carbon, significantly influence SOC dynamics. Microorganisms break down complex organic compounds in plant residues and root detritus into simpler molecules, releasing carbon into the soil. As influenced by tree species traits, the litter composition further modulates these microbial processes, influencing the rate of decomposition and the quality of the SOC formed (Prescott, 2002). The intricate dance between root-derived carbon inputs and microbial activity highlights the interconnectedness of above- and belowground processes in shaping the carbon dynamics of terrestrial ecosystems.

Root turnover, the process by which roots die and are replaced, represents another dimension of tree-root interactions influencing SOC dynamics. As tree roots senesce and decay, they contribute organic matter to the soil, constituting a direct source of carbon inputs. The rate of root turnover varies among tree species, influencing the quantity and quality of carbon released into the soil.

Implications for Ecosystem Management

The intricate interplay between trees, soil microbes, and soil organic carbon (SOC) dynamics bears profound implications for ecosystem management, offering insights into targeted strategies for carbon sequestration and sustainable land use. Acknowledging the underlying mechanisms of tree-SOC interactions enables the development of nuanced approaches informed by scientific principles. In afforestation and reforestation initiatives, aligning tree species selection with specific soil conditions emerges as a strategic avenue for maximizing carbon sequestration potential. The positive influence of certain tree species traits, such as high-quality litter production and mycorrhizal associations, underscores the importance of deliberate species choices that capitalize on these dynamics (Prescott, 2002; Finzi et al., 2006).

Sustainable land management practices prioritizing the conservation of belowground processes further underscore the implications for ecosystem management. The positive effects of tree roots on soil structure, nutrient cycling, and microbial diversity necessitate adopting practices that safeguard these intricate networks. Reduced tillage and minimal soil disturbance represent strategies that preserve the integrity of root-microbe interactions, fostering SOC persistence (Bais et al., 2006). Incorporating cover crops in agricultural systems, promoting root exudation and a carbon-rich rhizosphere, aligns with these principles, sustaining soil microbial communities and contributing to SOC accumulation (Kuzyakov & Domanski, 2000). Such practices, grounded in scientific understanding, harmonize with agroecological principles that advocate for integrating ecological processes into agricultural systems to enhance sustainability.

Beyond carbon sequestration, the implications for ecosystem management encompass broader facets of soil health and ecosystem resilience. The positive effects of specific tree species on soil biodiversity and ecosystem functioning contribute to overall soil health (Bardgett et al., 2014). Ecosystem managers can leverage this knowledge to design interventions that sequester carbon and enhance the multifunctionality and adaptive capacity of terrestrial ecosystems.

Future Directions and Research Gaps

Exploring the effects of tree species on soil organic carbon (SOC) dynamics unveils critical insights, yet several research avenues and gaps in knowledge beckon further investigation. Future directions should prioritize a mechanistic understanding of how specific tree species traits influence SOC accumulation. Advanced techniques such as molecular biology and isotopic analyses can elucidate the molecular processes governing root exudation, microbial interactions, and mycorrhizal associations. Furthermore, there is a need to explore the variability in belowground carbon allocation patterns among different tree species, considering factors such as root turnover rates and exudate composition. Investigating the impacts of climate change on tree species-SOC dynamics is imperative, as alterations in temperature, precipitation patterns, and atmospheric CO_2 concentrations can significantly influence carbon cycling. A trait-based approach, incorporating tree functional traits into research frameworks, offers a promising avenue for understanding the diverse mechanisms that drive SOC dynamics.

Conclusion

In conclusion, the intricate relationship between tree species and soil organic carbon (SOC) dynamics is fundamental to understanding and managing terrestrial ecosystems. This comprehensive review has highlighted the multifaceted influences of tree species traits, environmental conditions, and intricate biological mechanisms on SOC dynamics. The positive and negative impacts of specific tree species on SOC, mediated by factors such as litter quality, root architecture, and mycorrhizal associations, underscore the complexity of these interactions. Recognizing the context-specific nature of these relationships, shaped by climate and soil conditions, is crucial for predicting and managing the broader implications of tree-SOC interactions. The review emphasizes the importance of SOC in soil functionality, from microbial processes to carbon sequestration, with direct implications for ecosystem health, sustainable land management, and global carbon cycling. The implications for ecosystem management, including targeted afforestation strategies and sustainable land practices, highlight the need for a nuanced understanding of these interactions. Addressing these gaps will enhance our scientific comprehension and contribute to practical strategies for mitigating climate change effects and promoting soil health in diverse ecosystems.

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Morphological properties of soils in natural oil seeps in the Carpathian Mountains

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Abstract
This paper presents the current information available on the morphological and physico-chemical properties of soils in natural oil seeps along the Carpathian Mountains. It also aims to relate this information with the current data on the effects of oil contamination/presence on soil properties. Soils in natural oil seeps along the Carpathian Mountain range has a unique physico-chemical and morphological properties, this is true as compared to similar soils but is influenced by anthropogenic oil contamination. the driving force for the morpho-physical changes is the surface coating and sealing of surface soils which enables the development of gley properties. Illuviation of soil components is also affected through alternations in particle smoothness, aggregation and pore continuity. With this information, a question can be raised on whether oil on natural oil seeps can be considered as a contaminant or an integral component of pedogenic and environmental processes, and what conservation measures should be undertaken to conserve these unique eco-pedological sites.
Keywords: Oil, Seeps, Carpathians, Petroleum Hydrocarbon, Soil

Introduction

The Carpathian region is an economically important area for the oil industry of Central and Eastern European countries. Records suggest that as early as the 18th century, oil exploration and extraction has already begun (Stefaniuk and Tytko, 2014). Most of these oil seeps are located in the Outer Carpathian region shared by Poland, Ukraine and Slovakia. The rich oil and natural gas deposits primarily originated from migration and secondary processes of the Oligocene Menilite parent material (Kotorba et al., 2019). Depth and Temperature are the primary driving factors for oil formation, a temperature of 65 °C at a depth of 2800 m is the ideal temperature and depth needed to convert organic matter into crude oil. Below this depth where temperature tend to increase, organic matter is converted into natural gas (Hyne, 2001). To this date, a number of natural seeps and extracting infrastructure is present in the region. Such undertaking significantly contributes to the economic growth of the countries in the Carpathians and other similar locations (Adeola et al., 2021).

Oil is generally considered as a soil pollutant as it has a number of detrimental effects on soil physical, chemical, biological and geotechnical properties and processes. Oil substances coat the surface of soil particles resulting to surface crusting and pore sealing decreasing in soil permeability groundwater recharge rate (Abosede, 2013; Iloeje and Aniago, 2016). Recent studies suggest limited participation of oil and its derivatives in soils chemical processes because of its inability to mix with water and general chemical characteristics. Oghenejoboh and Puyate (2010) demonstrated that the diffusion of soil in soils in both horizontal and vertical axes is controlled by molecular diffusion and advective flow, respectively. Crude oil also significantly increases in organic carbon content, C:N ratio and salt content of surface soils (Marinescu et al., 2010). To sum up, the degree of influence of oil pollution in soil physico-chemical properties highly depends on the soil type, environmental conditions and oil quantity and persistence (Figure 2).

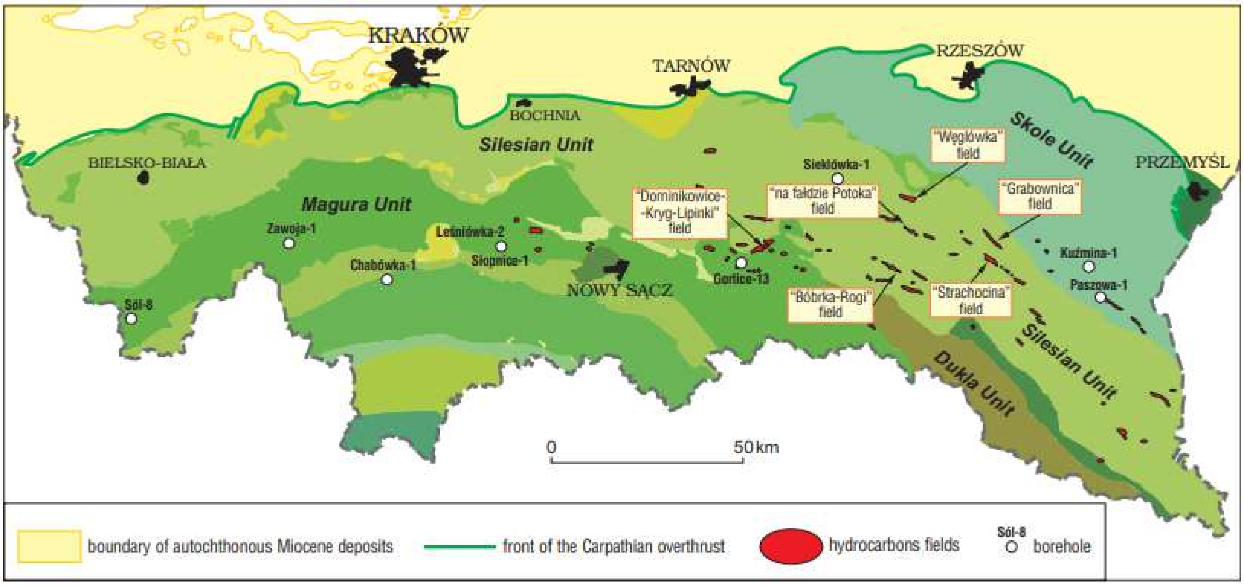

Figure 1. Natural Hydrocarbon (Oil and Natural Gas) Field in the Polish Outer Carpathian Region (Source: Gorka et al., 2007)

The purpose of this review is to present the general impact of oil on soil physico-chemical properties and the unique morphology of soils in the natural oil seeps in the few documented profiles along the Carpathian Mountains. In contrast to the negative connotation of anthropogenic oil contamination, natural oil seeps offer a new perspective on how oil participates soil formation and pedogenic processes.

Natural Oil Seeps in the Carpathian Mountains

The Carpathian Mountain range is located in central and eastern Europe, which spans from Austria-Slovenia and extends to western Romania and northern Serbia. It serves as the eastern continuation of the alpine mountain range. It is divided into eight divisions, and is home to a variety of geological forms and unique flora and fauna (Demek and Bashera, 1984). The outer western and east-western Carpathians, situated in the southern part of present-day southern Poland and western Ukraine, is an oil prolific region. This is due to the presence of large amounts of hydrocarbon rich rocks (Kryzwiec, 2018). In the Polish Carpathians, the migration and secondary processes determine the distribution and composition of oil, most oil seeps are located within the silesian, sub-silesian, skole and dukla nappes. (Kotarba et al., 2020). In Ukrainian Outer Carpathians, oils were discovered along the Mesozoic-Paleogene strata, occurring at the upper cretaceous sandstone and upper Jurassic limestone material (Radkovets et al., 2016).

General Effect of Oil on Soil Physical and Chemical Properties

The presence of oil in soil has a profound effect on soil properties. As an open system, soil actively reacts with fluctuation of matter and energy coming in and out of the system. Soil's response to oil presence depends on soil type, environmental conditions and oil composition (Khodary, et al. 2018).

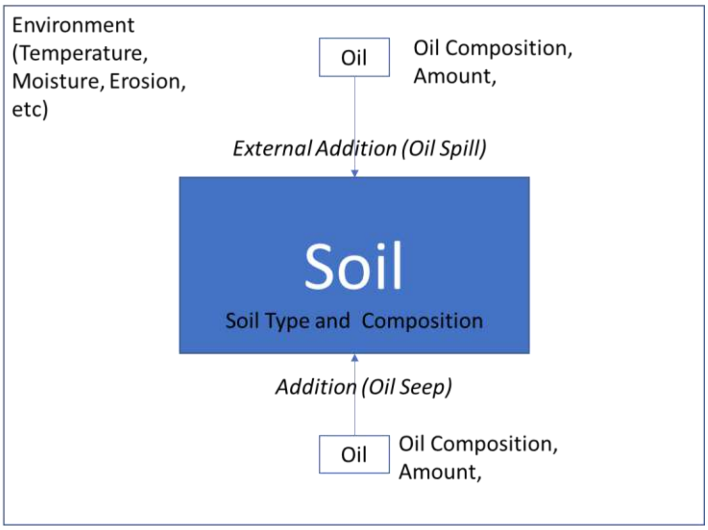

Figure 2. Factors influencing soil dynamics in relation to oil additions.

On a physical domain, oil coats the surface of soil particles. The degree of influence of oil on soil physical properties depends on the nature of soil coating and its interaction between the soil solid phase and liquid phase. Table 1 summarize the physical properties of soils; most studies focus on the physical and geotechnical properties of soils affected by anthropogenic oil spills (n = 9).

Table 1. Physical Properties of Soils in Response to Oil Presence/Contamination.

Property	Influence/Effect	Reference
Hydraulic conductivity and Water Retention	Oil coat the surface of soil particles, clog soil pores and affect pore connectivity, resulting to reduced hydraulic conductivity. Reduced Water Retention	Rasiah *et al*., 1990; Abu-Zreig and Al-Widyan, 2002
Plasticity	Reduction in both liquid and plastic limit (lower cohesiveness and plasticity)	Khodary *et al*., 2018
Soil Structure and Aggregate Size Distribution	Oil coat the surface of soil particles altering its surface characteristics, resulting to increased aggregation, affecting aggregate size distribution. Despite the increased aggregation, aggregate strength is reduced as a result of weak inter-particle and inter-aggregate bonding.	Chun *et al*., 2003; Kavdir and Kelli, 2008
Compaction and Bulk Density	Increased soil compaction as a result of reduced porosity and increased soil mass.	Khodary *et al*., 2018
Infiltration	Due to the hydrophobic nature of oil, surface accumulation tends to reduce infiltration, permeability and increase surface run-off	Khodary *et al*., 2018
Shear Strength and Bearing Capacity	The physical and chemical interaction of oil with interparticle forces leads to reduced shear strength and bearing capacity	Khodary *et al*., 2018; Shin and Das, 2001
Friction Behavior	Reduced frictional resistance of soil, resulting to increased slippage and reduced shear strength.	Shin and Das, 2001
Cohesiveness	Reduced cohesiveness by affecting the forces which hold soil particles together.	Karkush and Kareem, 2017
Color and Reflectance	As oil coat the surface of soil particles, it renders a darkened appearance on the surface of peds and increase reflectance.	Abu-Khasan and Makarov, 2021; Matveeva and Lipatov, 2015

On a chemical perspective, the chemical composition and properties of the oil coating and its subsequent influence on soil solid, liquid and gaseous phases results to the unique chemical response of the soil system. Table 2 summarizes the chemical properties of soil with oil contamination, most studies focus on ecological impact of oil contamination on soil chemical properties (n = 5).

Table 2. Physical Properties of Soils in Response to Oil Presence/Contamination.

Property	Influence/Effect	Reference
CEC	CEC is reduced as a result of the physical coating of soil particles, rendering the colloidal surface unavailable for ion exchange reactions.	Farajzadeh *et al*., 2017
Soil Reaction and Buffering Capacity	Acidification or alkalization of the soil depends on the nature of oil compounds present. Oils that contain organic acids, reduces soil pH; while oils containing bicarbonates and carbonate compounds increase soil pH. Due to the influence of oil on CEC, buffering capacity is greatly reduced.	Kavdir and Kelli, 2008
Electrical Conductivity	The influence of oil on soil electrical conductivity depends on the nature of dissolved salts in it.	Kavdir and Kelli, 2008; Wang et al., 2009
Total Petroleum Hydrocarbon (TPH) and OHC (Oil Hydrocarbons)	The presence of aliphatic and aromatic compound in soil is increased Decreasing amount with depth	Wang *et al.*, 2009; Matveeva and Lipatov, 2015
Total Organic Carbon	TOC and SOM tend to be reduced with increasing oil content, as decomposition rates increase.	Kavdir and Kelli, 2008; Wang et al., 2009

	Oil decomposing microorganisms also degrade native SOM.	
Macro-Nutrient Content (N-P-K|)	A general decrease in available forms, as nutrients are displaced by oil related compounds and similar chemical derivatives.	Kavdir and Kelli, 2008; Wang et al., 2009
Reduction-Oxidation Potential	Oil sealing and its influence on gas and water exchange, depletion in oxygen levels results to a reduction in the soil's redox potential. This leads to the formation of redoximorphic features. In the case of submerge soils, oil don't reduce redox potential.	Levine *et al.*, 2017

Morphological Properties of Soils Around Natural Oil Seeps in the Carpathians

To this date, limited information is available about the morphological, at both micro- and macro-level, properties of soils in sites with naturally occurring oil seeps. Based on unpublished data on the preliminary works along the Polish Carpathians, soil in oil seeps is classified under Gleysols and Histosols (Tchounkew, 2023). Researchers in Ukraine documented a soil profile around an oil seep classified as Albeluvisol (Krabyn et al., 2019). All of these documented soils exhibit gley properties as a consequence of the oil surface sealing and reduced impermeability. Mottling is also observed in the underlying horizons evident of alternating oxidation and reduction states, as a consequence of reduced oxygen diffusion. Figure 3 describes the genetic horizons of documented soil types (n = 2), while figure 4 describes the soil profile of soils affected by oil spill outside of the Carpathian region but has similar climatic condition (n = 1).

In all of these profiles, characteristic decline in THP and OHP content was observed, highest concentration of aromatic and aliphatic hydrocarbons at the surface layers and gradually decrease with depth, the same case is true for tropical soils exposed to oil spills (Amaechi et al., 2022). Krabyn et al. (2018) reported a unique self-cleaning cycle occurring in the oil seep sites, oil content in these sites significantly decrease during the spring and summer, the general increase in temperature, better oxygen diffusion and ice thawing are the primary driving factors to this self-cleaning phenomenon. A decreased in oil degradation was observed during autumn and winter. Additionally, in the seminal works of Tchounkew (2023), there's a significant decrease in silt and clay content in the surface layer as compared to the surrounding soils, the same is true for silt as compared to oil spill soils, but clay and sand fraction are unaffected by oil contamination.

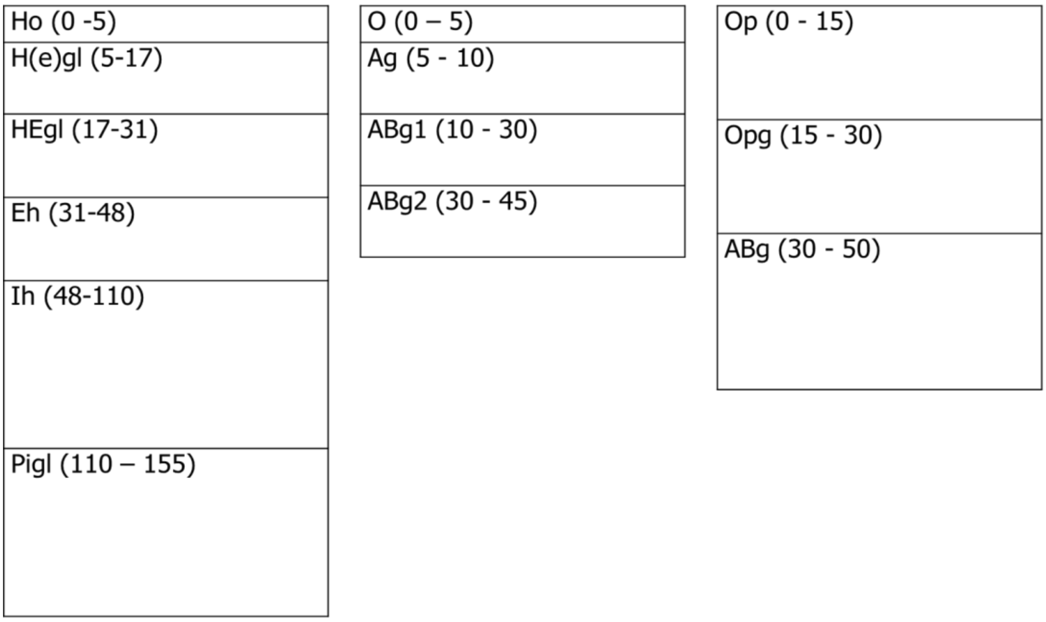

Figure 3. Documented Soil Profiles in Natural Oil Seeps Along the Carpathian Mountains (self-generated figure based from published and unpublished sources; Krabyn et al., 2018; Tchounkew, 2023).

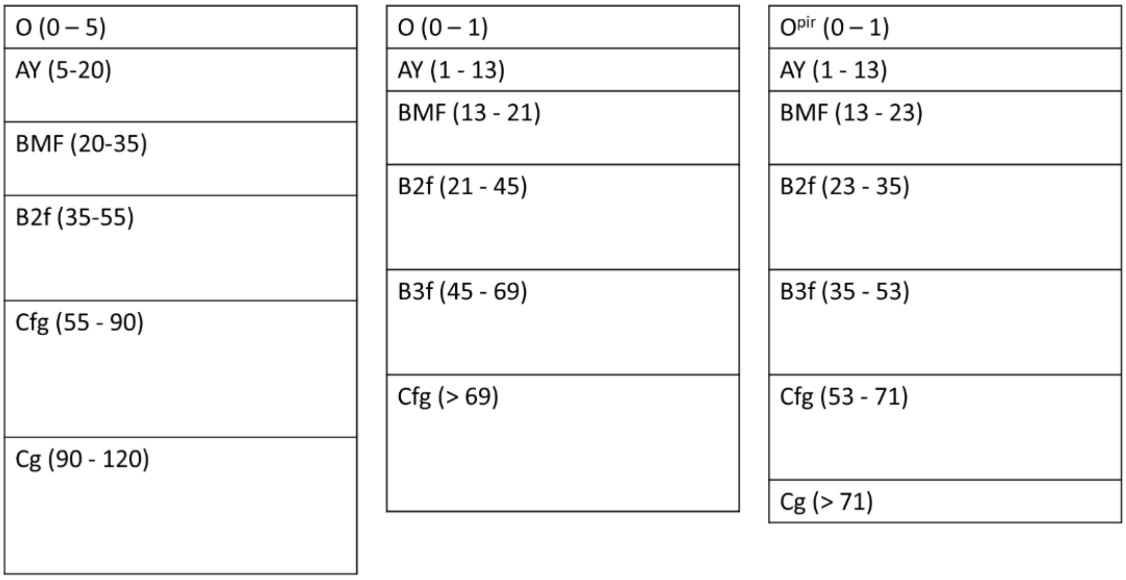

Figure 3. Documented Soil Profile of Rzhavozem soils with oil contamination (self-generated image based on Matveeva and Lipatov, 2015)

Conclusions

The soils in natural oil seeps along the Carpathian Mountains has a unique set of morpho-physical and chemical properties as compared to similar soils affected by anthropogenic oil contamination. Both cases show similar redoximorphic and surface characteristics but different nature of sediment translocation. There are relatively few studies undertaken in this area which presents a research gap that needs to be addressed, it is recommended to explore more of the dynamics of soils in relation to natural oil seeps and the formulation and implementation of a standardized research protocol.

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The effect of some antagonistic fungi against *Bipolaris sorokiniana*, root rot of barley

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Abstract

Barley ranks second after wheat in terms of cultivation area and production amount among the cereal crops grown in Turkey. Fungal diseases are the most important biotic factors affecting production. One of the most important diseases is root and crown rot disease caused by Bipolaris sorokiniana (Sacc) Shoemaker. In addition to root and crown rot disease, it also causes leaf spot blotch and black point in wheat and barley. In this study, the effects of six Chaetomium spp., one Trichoderma sp. and one Fusarium oxysporum isolates on barley plants and the pathogen were investigated against a highly virulent isolate of B. sorakiniana isolated from wheat. Chaetomium spp. culture was grown in potato dextrose liquid medium for 10 days by shaking. The seeds of Fahrettinbey and Oberek barley varieties, which were pre-germinated, were placed in the Chaetomium liquid culture and shaken in the shaker for four hours. Then the seeds were placed on sterile blotting papers and left to dry. On the other hand, two layers of blotting paper were placed on Petri dishes and 10 discs cut from B. sorakiniana cultures with a diameter of 6 mm were placed on the papers and one seed was placed on top of them. A spore suspension of 1x106 spores/ml of Trichoderma T2 and F. oxysporum isolate 24 were prepared and the seeds were kept in this suspension for 3 min. In the same way, the seeds removed from the suspension were dried and placed on fungus discs. The experiment was carried out in triplicate for both varieties. Control plants were treated with sterile distilled water only, while positive controls included only discs of B. sorokiniana culture and uninoculated seeds. The experiment was evaluated after ten days of incubation. In the root and leaf length measurements, it was determined that Trichoderma T2 isolate in Fahrettinbey cultivar showed better development in terms of root and leaf length compared to the positive control, while in Oberek cultivar, Trichoderma T2, F. oxysporum 24, Chaetomium spp., isolates 1, 3 and 4 showed better development in terms of leaf length compared to the positive control. It is understood that there are statistically differences between the varieties in terms of plant height and disease severity. When the disease severity was analysed in Fahrettinbey and Oberek cultivars, it was revealed that Chaetomium spp. could not reduce the disease severity in general, but F. oxysporum 24 and Trichoderma T2 isolacaused a 20-38,9% and 36,6-46,7% reduction in disease severity respectively.
Keywords: Bipolaris, Leaf lenght, Pathogenicity, Root lenght, Root rot

Introduction

Bipolaris sorokiniana (Sacc.) Shoem. (Teleomorph, *Cochliobolus sativus*) is one of the most important fungal pathogens of diseases on wheat and barley. It can affect plant tissues, particularly common root rot and seedling blight as a soilborne and spot blotch and black point as a seedborne diseases (Kumar et al., 2002). Geographically, its infection ranges in the warm and humid cereals-growing belts ofthe world and annual yield losses of various cereals in South Asia, Europe, Latin America, and Canada due to this pathogen has been globally estimated between 10-85% (Murray et al., 1998; Duveiller and Sharma, 2009; Mehta, 2014; Gupta et al., 2018). The management of the diseases due to this pathogen is greatly affected by soil fertility, plant density, developmental stages, biotic conditions, and crop management practices (Gupta et al. 2018). The chemical fungicides such as triazole groups are one of the most effective and fast management methods for this disease (Wei et al. 2021), but their application is restricted and worrying due to harmful effects on human health and environmental concerning. Biological control that an alternative approach to synthetic fungicides is the most common management strategy of plant pathogens worldwide in recent years. Some of the bacterial and fungal biocontrol agents such as *Bacillus*, *Pseudomanas*, *Lysobacter*, *Trichoderma*, *Epicoccum* and *Chaetomium* has been founded antagonistic effects against *Bipolaris* spp. (Monaco et al. 2004; Qin et al. 2009; Perez-Montano et al. 2014; Gouda et al. 2018; Darshan et al. 2020). These microbes inhibit pathogenic development with the mechanisms such as lytic enzymes, toxins, siderophores or activating plant defense signals. In this study, a range of antagonistic fungal isolates included *Chaetomium*, Trichoderma and non-pathogenic Fusarium is aimed to assessment of effect to inhibition of pathogenic B. *sorokiniana* on barley seeds *in vitro* conditions.

Material and Methods

Fungal Cultures

The pathogenic B. sorokiniana and eight antagonist fungal isolates were stored at -80 °C deep-freeze within 15% glycerol vials in Mycology Laboratory of Agriculture Faculty of Ondokuz Mayıs University and all isolates were maintenance on potato dextrose agar (PDA) medium for 7-day old growth cultures. The

Table 1. The properties of fungal isolates used on *in vitro* tests

Isolate Codes	Fungal Genus and Species	Hosts	Collection Date
19B22-3B1*	*Chaetomium* sp.	*Hordeum vulgare* L.	2019
15H10-3B1*	*Chaetomium* sp.	*Triticum aestivum* L.	2015
19W67-3B2*	*Chaetomium* sp.	*Triticum aestivum* L.	2019
17-Y5-4*	*Chaetomium* sp.	*Zea mays* L.	2017
17-Y6-5*	*Chaetomium* sp.	*Zea mays* L.	2017
17-Y6-3*	*Chaetomium* sp.	*Zea mays* L.	2017
T2*	*Trichoderma* sp.	Vegetabels	2014
24*	*Fusarium oxysporum*	Vegetabels	2014
M17-KB1**	*Bipolaris sorokiniana*	*Triticum aestivum* L.	2012

* Antagonist and non-pathogenic fungal isolates

** Pathogenic isolate of *B. sorokiniana* (Tunalı et al. 2023)

Petri Bioassay Tests

The barley seeds of cv. Fahrettin Bey and cv. Oberek were used for the in vitro tests. The seeds surface sterilized with 2% NaOCl for 3 minutes and rinsed in sterilized water three times and these samples were plated on sterile blotting- paper saturated with water in boxes to pre germination of seeds. The 7-day old cultures of all fungal isolates used on preparation of inoculum. Two 5 mm. diameter agar discs of Chaetomium sp. were placed in 100 ml. flasks containing potato dextrose broth (PDB) medium and shaken at 100 rpm for 10 days. After incubation, barley seeds were transferred to the flasks and the seeds were shaken under the same conditions for four hours. Trichoderma sp. and Fusarium oxysporum spore suspensions were adjusted to 1x106 spores/ml with a Haemacytometer and then the seeds were shaken in the spore suspension of the two fungal antagonists for 3 minutes . Seeds were placed on blotting paper to dry.

Bipolaris sorokiniana were growth on PDA for -seven days and ten pieces of 5mm diameter agar discs of the fungus were cut and placed in 9cm diameter Petri dishes with two layers of blotting paper inside. One inoculated seed by antagonist were putted onto each agar plugs within B. sorokiniana and the petri dishes as three replicants were incubated 23±2 °C with darkness for 10 days. Control seeds were not treated with antagonist fungi. Negative control seedlings were not treated with pathogen and antagonists.

Assessment of Bioassay Test

Ten days old barley seedlings were assessed with some plant growing parameters and pathogenicity against two barley cultivars. The seedlings were scored as 0-3 scale of common root rot disease and calculating of diseases severity (DS) (Stach, 1992). Shoot length (PL) and root length (RL) were assessed as plant growth parameters.

Data Analysis

The SPSS v21 statistical packages (IMB, Statistic, OMU Licensed for online users) were used analysis of differences between the variances by One-Way ANOVA. The variance homogeneity was analysis Levene Test (Levene, 1960) and means were grouped by Duncan multiple range test (Duncan, 1955). The determination of differences among the barley cultivars due to the antagonists and pathogen was calculated by independent sample T- Test.

Results

In the petri bioassay, eight antagonist fungal isolates assessed for their positive or negative effects against common root rot disease causal agent *B. sorokiniana* and on seedling growth. *B. sorokiniana* has showed a pathogenic activity on each barley cultivars ranged with 36.6% and 55.3%, respectively. There was no visual disease symptom on that control seedlings without pathogen and antagonist. The disease severity (DS) of antagonists ranged between 20-67.8% on cv. Fahrettinbey and cv. Oberek and it was founded statistically significant compare with that on *B. sorokiniana* and the control (Table 2).

Table 2. The F-Test results of fungal isolates on cv. Fahrettinbey and cv. Oberek to assessed parameters

Fungal	D.S. (%)^x			P.L (cm)			R.L (cm)			H.R.R (%)^x		
Isolates / cv. Fahrettin bey	Means	Std Dev.	**	Means	Std Dev.	**	Means	Std Dev.	**	Means	Std Dev.	**
C. sp. 19B22-3B1	27.8	±18.3	ab	6.2	±2.3	cd	2.6	±2.0	cd	75.5	±16.9	bc
C. sp. 15H10-3B1	54.5	±39.7	ab	3.1	±2.8	def	1.3	±1.3	cd	46.8	±41.0	cd
C. sp. 19W67-3B2	57.8	±20.1	ab	5.8	±1.2	cde	2.5	±1.8	cd	46.5	±22.6	bcd
C. sp. 17-Y5-4	30.0	±13.3	ab	7.8	±1.1	bc	3.6	±0.9	bc	72.5	±12.1	bcd
C. sp. 17-Y6-5	51.1	±21.7	ab	2.8	±1.4	ef	2.1	±1.1	cd	52.9	±20.1	bcd
C. sp. 17-Y6-3	67.8	±20.3	a	1.2	±0.8	f	0.8	±0.2	d	31.9	±20.0	d
Trichoderma sp. T2	36.6	±15.2	ab	10.1	±1.9	ab	5.5	±1.8	b	67.6	±14.7	bcd
F. oxysporum 24	20.0	±13.3	ab	6.2	±2.5	cd	5.2	±1.1	b	81.8	±15.4	ab
B. soroki. M17-KB1	36.6	±5.8	bc	11.7	±1.4	a	8.8	±0.6	a	67.1	±1.4	bcd
Agar Disc (Control)	1.1	±1.9	c	7.42	±1.1	bc	3.6	±1.2	bc	99.6	±0.7	a
Fungal	D.S. (%)^x			P.L (cm)			R.L (cm)			H.R.R (%)^x		
Isolates / cv. Oberek	Means	Std Dev.	**	Means	Std Dev.	**	Means	Std Dev.	**	Means	Std Dev.	**
C. sp. 19B22-3B1	30.0	±8.8	a	6.9	±1.0	bc	2.7	±0.7	d	71.6	±7.3	b
C. sp. 15H10-3B1	55.6	±11.7	a	3.3	±2.5	d	0.9	±0.5	f	47.2	±10.4	b
C. sp. 19W67-3B2	36.7	±31.8	a	7.6	±2.2	b	2.4	±0.5	de	65.7	±30.6	b
C. sp. 17-Y5-4	32.2	±16.5	a	5.9	±0.6	bc	2.8	±0.7	d	72.0	±15.9	b
C. sp. 17-Y6-5	52.2	±8.4	a	4.4	±1.1	cd	1.3	±0.3	f	50.4	±8.1	b
C. sp. 17-Y6-3	51.1	±25.3	a	3.3	±1.9	d	1.6	±0.9	ef	49.8	±25.9	b
Trichoderma sp. T2	46.7	±6.7	a	7.6	±0.9	b	3.1	±0.7	cd	60.7	±5.9	b
F. oxysporum 24	38.9	±7.0	a	7.0	±0.5	b	3.9	±0.5	c	64.5	±7.8	b
B. soroki. M17-KB1	55.3	±4.8	a	11.1	±0.9	a	7.1	±0.6	a	53.0	±4.7	b
Agar Disc (Control)	0.0	±0.0	b	7.3	±0.5	b	5.4	±0.5	b	100.0	±0.0	a

D.S.= Diseases Severity; P.L.= Plant Lenght; R. L.=Root Lenght; H.R.R.=Healty Root Rate

** There is a significant differences between the groups (*P*>0.01); x = The values were transformed by ARSIN

The highest DS was founded at *Chaetomium* sp. (17-Y6-3) by 67.8% on cv. Fahrettinbey, while at *Chaetomium* sp. (15H10) by 55.6% on cv. Oberek. These DS rates were higher than that of *Bipolaris sorokiniana* for each two cultivars. The except of control, the lowest DS was obtained on *F. oxysporum* 24 and *Chaetomium* sp. (19B22) by 20% and 27.8% on cv. Fahrettinbey, respectively. *Chaetomium* sp. (19B22) was also exhibited the lowest DS ration on cv. Oberek by 30%. The means of all isolates for plant growth parameters (PL, RL and HRR) were founded statistically significant differences among each other and for both cultivars (Table 2). *Bipolaris sorokiniana* was showed the highest PL (11.7 and 11.1 for each cv.) and RL (8.8 and 7.1 for each cv.) for both cultivars, while *Chaetomium* sp. (17-Y6-3) was the lowest PL by 1.2 and 3.3 on both cultivars. The *Chaetomium* was also the lowest RL by 0.8 on cv. Fahrettinbey, while the third lowest RL by 1.6 on cv. Oberek after other two *Chaetomium* (15H10 and 17-Y6-5 by 0.9 and 1.3, respectively) isolates. For the HRR of antagonists, there was a similar result on both cultivars (Table 2). Independent T-test results were showed that none of the antagonists had a significant difference between cv. Fahrettinbey and cv. Oberek, except *B. sorokiniana* threatment. Pathogenic *Bipolaris* was exhibited statistically significant differences between cv. Fahrettinbey and cv. Oberek for DS, RL and HRR (Table 2).

Table 3. The independent T-Test results of fungal isolates on cv. Fahrettinbey and cv. Oberek to the parameters

Fungal Isolates	D.S. (%)		Independent T-Test	P. L. (cm)		Independent T-Test	R.L. (cm)		Independent T-Test	H.R.R. (%)		Independent T-Test
	cv.Fah.	cv. Obe.		cv.Fah.	cv. Obe.		cv.Fah.	cv. Obe.		cv.Fah.	cv. Obe.	
Cha. sp. 19B22-3B1	27.8	30.0	t(4)=0.187,p=0.861	6.2	6.9	t(4)=0.463,p=0.668	2.6	2.7	t(4)=0.108,p=0.919	75.5	71.6	t(4)=0.367,p=0.732
Cha. sp. 15H10-3B1	54.5	55.6	t(4)=0.046,p=0.966	3.1	3.3	t(4)=0.101,p=0.925	1.3	0.9	t(4)=0.453,p=0.674	46.8	47.2	t(4)=0.014,p=0.989
*Cha. sp.*19W67-3B2	57.8	36.7	t(4)=0.973,p=0.385	5.8	7.6	t(4)=1.255,p=0.278	2.5	2.4	t(4)=0.157,p=0.883	46.5	65.7	t(4)=0.873,p=0.432
*Cha. sp.*17-Y5-4	30.0	32.2	t(4)=0.180,p=0.866	7.8	5.9	t(4)=2.581,p=0.061	3.6	2.8	t(4)=1.311,p=0.260	72.5	72.0	t(4)=0.040,p=0.970
*Cha. sp.*17-Y6-5	51.1	52.2	t(4)=0.082,p=0.939	2.8	4.4	t(4)=1.572,p=0.191	2.1	1.3	t(4)=0.042,p=0.258	52.9	50.4	t(4)=0.329,p=0.852
Cha. sp. 17-Y6-3	67.8	51.1	t(4)=0.890,p=0.424	1.2	3.3	t(4)=1.721,p=0.160	0.8	1.6	t(4)=1.582,p=0.189	31.9	49.8	t(4)=0.945,p=0.398
Trichoderma sp. T2	36.6	46.7	t(4)=1.043,p=0.356	10.1	7.6	t(4)=2.065,p=0.108	5.5	3.1	t(4)=2.242,p=0.088	67.6	60.7	t(4)=0.752,p=0.494
F. oxysporum 24	20.0	38.9	t(4)=2.180,p=0.095	6.2	7.0	t(4)=0.565,p=0.602	5.2	3.9	t(4)=1.792,p=0.148	81.8	64.5	t(4)=1.743,p=0.156
B. sorokiniana M17-KB1	36.6	55.3	t(4)=4.314,p=0.013*	11.7	11.1	t(4)=0.590,p=0.587	8.8	7.1	t(4)=3.335,p=0.029*	67.1	53.0	t(4)=3.946,p=0.017*
Agar Disc (Control)	1.1	0.0	t(4)=1.0,p=0.374	7.42	7.3	t(4)=0.253, p=0.813	3.6	5.4	t(4)=2.435, p=0.072	99.6	100.0	t(4)=1.0, p=0.374
Means	38.3	39.9	t(58)=0.258, p=0.797	6.2	6.4	t(58)=0.268, p=0.790	3.6	3.1	t(58)=0.839, p=0.405	64.2	63.5	t(58)=0.127, p=0.899

* P<0.05 statistical significant value

Discussion

In the study, agar plug bioassay test had been allowed to assessment of differences among the DS meaning of antagonist fungal isolates on two barley cultivars when compared with diseased control. For both cultivars, *B. sorokiniana* had showed individually a high virulence activity on barley seedlings without antagonist (Tunalı et al. 2023), but its virulence has raised a higher effect than that its individual activity, when the antagonist applied to seeds. Xu et al. (2018) reported that *B .sorokiniana* has been associated with other root and crown rot pathogens such as *Rhizoctonia solani* and *F. pseudograminearum* in soil condition and they can be together increased the diseases severity on plant tissue. In this bioassay, especially some *Chaetomium* isolates had been cooperated with *B. sorokiniana* and increased the DS on the seedlings. *Chaetomium* sp. 19B22 isolate was founded as the highest antifungal effect against *B. sorokiniana* on both barley cultivars. *Chaetomium globosum* has been reported to be a potential biocontrol agent against various soilborne, particularly *B. sorokiniana* (Aggarwal et al. 2004; Moya et al. 2016). This isolate was isolated from *Hordeum vulgare* and only identified as its morphological characteristics at genus level. To understanding of the biological control mechanism and its antagonistic effect to the pathogen, identification of this antagonist isolate is a crucial point as each one of the candidate biological control agents.

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Antogonistic effects of *Trichoderma* spp. and non-pathogenic *Fusarium* spp. on soil-borne Beet necrotic yellow vein virus and its vector *Polymyxa betae* in sugar beet

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Abstract

Beet necrotic yellow vein virus (BNYVV), the causal agent of rhizomania disease, that provokes lateral root proliferation and restricts the main root growth of sugar beet. The virus is in vivo-transmitted by the zoospores and persists in soil via long-lasting cystosori of *Polymyxa betae*. In this study, the ability of *Trichoderma* spp. and non-pathogenic *Fusarium* spp. to suppress to BNYVV and *P. betae* in sugar beet were investigated. For this purpose, 3 *Trichoderma* spp. isolates (Tr-1, Tr-3 and Tr-6) and 2 non-pathogenic *Fusarium* spp. isolates (Fs-6-1 and Fs-24) were isolated from the natural soil samples and used against BNYVV and *P. betae* as a biocontrol agent. Firstly, the isolates of both fungi were applied to the roots of sugar beet seedlings of rhizomania-susceptible and -resistant cultivars (cvs.). After 6 weeks, all plants were harvested and wet root weight, dry and wet leaf weight of the plants were measured. Also, the roots of plants grown in BNYVV-infested soil (BIS) were analysed by ELISA for the presence of BNYVV and checked microscopically for the appearance of *P. betae* cystosori. Fs-24 and Fs-6-1 treatments in BIS had positive effect on plant growth parameters (root weight, leaf weight and dry leaf weight) in BNYVV-susceptible cv., however, these growth parameters were not significantly different than the plant parameters obtained in non-infested soil (NIS) or negative control treatment. The effect of *Fusarium* spp. applications on plant growth parameters were significantly higher than that of *Trichoderma* spp. applications in BNYVV-susceptible cv. In BNYVV-resistant cv. grown in NIS, *Trichoderma* spp. applications generally had more positive effects on plant growth parameters than *Fusarium* spp. applications. Also, non-pathogenic *Fusarium* spp. applications had more positive effect on plant growth parameters of rhizomania-resistant cv. grown in BIS. Except for the isolate Tr-3, the impact of the selected *Trichoderma* spp. and non-pathogenic *Fusarium* spp. isolates on suppressing multiplication of BNYVV in susceptible cv. varied between 19.9 and 64.9%. In the resistant cv., only Tr-6 among the *Trichoderma* isolates was found to be effective with a rate of 11.6%, while the treatment with Fs-6-1 of the *Fusarium* spp. isolate resulted in the complete suppression of BNYVV, and no infection was observed in any replication. Also, in both BNYVV-susceptible and -resistant cvs.; *P. betae* resting spores were abnormally dark in colour and had deformed walls in the Fs-6-1 treatment. Future studies are needed to evaluate the performance of Fs-6-1 in field conditions, and to test other *Trichoderma* isolates for their biocontrol potential against BNYVV and its vector.

Keywords: BNYVV, *P. betae*, Biocontrol agent, *Trichoderma* spp., Non-pathogenic *Fusarium* spp.

Introduction

Rhizomania is a significant disease of sugar beet (*Beta vulgaris* L.) caused by Beet necrotic yellow vein virus (BNYVV) (Tamada, 2007). This virus is transmitted by zoospores of the soil-borne protist *Polymyxa betae* Keskin (Keskin, 1964). Typical symptoms of the disease are characterized by a massive proliferation of lateral roots and constricted growth of tap root resulting in reduction in the sugar content. Resting spores (cystosori) of *P. betae* containing virus particles survive in soil for many years, and this can raise difficulties in the attempts to successfully control of the disease (Rush and Heidel, 1995).

Genetic resistance is the most promising approach in the management of rhizomania (Molard 1988), but there is also increasing interest in the use of bacterial (Resca et al., 2001; Aksoy and Kutluk Yilmaz, 2008) and fungal (D'Ambra et al., 1987; Camporota et al., 1988; Jakubikova et al., 2006; Kutluk Yilmaz and Tunali, 2010) biological control agents against soil-borne phytopathogens such as *P. betae*.

Trichoderma species are free-living fungi that are common in soil and root ecosystems (Sharon et al., 2007). Some species of *Trichoderma* have been successfully used as biological control agents against soilborne fungal pathogens (Papavizas, 1985; Sivan et al., 1987; Harman et al., 2004). These fungi have the ability to colonise on the root surfaces and cortex. Root colonisation by *Trichoderma* spp. generally promotes root growth and development, improves resistance to biotic stresses and promotes uptake and use of nutrients (Altomare et al., 1999; Yedidia et al., 2001; Harman et al., 2004). Biological control is achieved through direct effects upon the targetted fungi via competition, mycoparatism, antibiosis, and systemic induced resistance or through enzymatic hydrolysis (Yedidia et al., 1999; Harman, 2004). Enzymes such as chitinases, glucanases, and proteases seem to be very important in the mycoparasitic process (Haran et al., 1996).

Non-pathogenic fungal species colonize on plant roots without causing any disease symptoms in nature (Joshi et al., 2013). It has been reported that non-pathogenic *Fusarium* isolates efficiently colonize plant roots without causing any cell damage, thus protecting roots and plants from various plant pathogens (Albouvette and Olivain, 2002). Non-pathogenic *F. oxysporum*, as an endophytic fungus, can activate defense responses against plant pathogens in host plants, provide resistance to environmental stress, and also activate the production of hormones such as auxins and gibberellins (Schardl et al., 2004).

This study aimed to investigate the effectiveness of 3 *Trichoderma* spp. and 2 non-pathogenic *Fusarium* spp. isolates selected as biological control agents on the control of both the virus BNYVV and its vector *P. betae* in susceptible (cv. Ansa) and resistant (cv. Serenada) sugar beet genotypes under laboratory conditions.

Material and Methods

Soil samples

A BNYVV and *P. betae*-infested soil sample was taken from a field known for its high level of BNYVV in Cumra district in Konya province. A non-infested soil sample for healthy control treatment was collected in a field from Samsun province where rhizomania disease is not observed and detected.

Isolation of *Trichoderma* spp. and non-pathogenic *Fusarium* spp.

One g of each soil sample was suspended in 500 ml of sterile distilled water. Then, one ml of this mixture was spread on Petri dishes containing water agar (WA). The medium contained one-liter distilled water and 20 g agar (Bacto). The dishes were incubated under natural daylight and blacklight at 22-24°C for 3-7 days. All plates with potato dextrose agar (PDA, Merck) medium were inoculated with fungal colonies from the WA-Petri dishes. *Trichoderma* species were selected and identified after seven days incubation. Identification of the isolates used in this experiment was done on the basis of microscopic examination (Kubicek and Harman, 1998; Samuels et al., 2009). Three *Trichoderma* spp. isolates and two non-pathogenic *Fusarium* spp. isolates were isolated from the soil samples belonging to the rhizospheres of tomato, pepper, and wheat plants in Samsun province and were used in the current study.

Biocontrol studies

Three isolates of *Trichoderma* spp. (Tr-1, Tr-3 and Tr-6) and two isolates of non-pathogenic *Fusarium* spp. (Fs-6-1 and Fs-24) were used in biocontrol experiments. These isolates were grown on PDA at 25°C under 12 h photoperiod for 10 days. Sterile distilled water was added to all cultures and brushed with a brush to allow the spores to pass into the water and suspensions of 10^7 spores/ml for *Trichoderma* spp. and 10^6 spores/ml for *Fusarium* spp. were obtained. A rhizomania-susceptible cultivar (cv. Ansa) and rhizomania-resistant cultivar (cv. Serenada) were used in this experiment. The treatments in this study are given in Table 1.

Table 1. The treatments in the experiment

No	Treatments*	No	Treatments*
1	Tr-1+Ansa+BIS	13	Tr-6+Ansa+NIS
2	Tr-3+Ansa+BIS	14	Fs-24+Ansa+NIS
3	Tr-6+Ansa+BIS	15	Fs-6-1+Ansa+NIS
4	Fs-24+Ansa+BIS	16	Tr-1+Serenada+NIS
5	Fs-6-1+Ansa+BIS	17	Tr-3+Serenada+NIS
6	Tr-1+Serenada+BIS	18	Tr-6+Serenada+NIS
7	Tr-3+Serenada+BIS	19	Fs-24+Serenada+NIS
8	Tr-6+Serenada+BIS	20	Fs-6-1+Serenada+NIS
9	Fs-24+Sereada+BIS	21	Ansa+BIS
10	Fs-6-1+Serenada+BIS	22	Serenada+BIS
11	Tr-1+Ansa+NIS	23	Ansa+NIS
12	Tr-3+Ansa+NIS	24	Serenada+NIS

*Tr: *Trichoderma*, Fs: *Fusarium*, BIS: BNYVV-infested soil, NIS: Non-infested soil

The lateral roots of sugar beet seedlings (7-10 days-old) of the BNYVV-susceptible cv. and -resistant cv. were soaked in fungal suspensions and shaken thoroughly on the rotary shaker at 250 rpm for 5 min at room temperature for the treatments 1 to 20. For the control treatments numbered as 21-24, the roots of seedlings were shaken in the sterile water. Afterwards, ten sugar beet seedlings were planted into 250 ml pots containing a mixture of soil and sterile sand (1: 2, soil: sand, by weight). The pots were placed in a plant growth chamber at 12 h of daylight with alternating temperatures of 20°C (dark) and 25°C (light), watered with Hoagland's solution as needed. The experiment was carried out in a randomized plot design with five replications. After six weeks, the roots were carefully washed under running tap water, all plants of each pot were combined, and their leaves and roots were separately weighted. Then, the combined roots of each pot were divided into two parts. One part was stained in acid fuchsin lactophenol and examined under a light microscope (Leica, Switzerland) to detect the presence of *P. betae* cystosori. The other part was used for ELISA tests. Besides this, in order to determine dry-leaf weight, each sample was wrapped in aluminium foil paper and incubated in an oven at 70°C.

Serological Tests

A double antibody sandwich-enzyme linked immunosorbent assay (DAS-ELISA) was performed for BNYVV using commercial kits (Bioreba) following the manufacturer's instructions. Absorbance reading at 405 nm were obtained 2 h after substrate incubation by using a microplate reader (Tecan Spectra II), and the samples were considered positive when the absorbance values were tree times more than the mean value of the negative controls (Meunier et al., 2003).

Microscopic detection of *Polymyxa betae*

Root samples were stained with lactophenol containing 0.1% acid fuchsin and examined using a light microscope (Leica) to detect *P. betae* resting spores (Abe and Tamada, 1986).

Statistical analysis

The data were analysed by SPSS 17.0 statistical software (SPSS Inc., Cary, NC, USA) according to the randomized plot design and the differences between the averages were determined by Duncan multiple comparison test. Significance was evaluated at $P<0.01$ or $P<0.05$ for all tests.

Results and Discussion

This study focused on the possibility of controlling the severity of sugar beet disease, BNYVV and its protozoal vector *P. betae* using natural *Trichoderma* spp. and non-pathogenic *Fusarium* spp. isolates.

Non-pathogenic *Fusarium* spp. (Fs-24 and Fs-6-1) applications in BNYVV-infested soil had positive impacts on plant growth parameters (root weight, leaf weight and dry leaf weight) of BNYVV-susceptible cultivar and these growth parameters were not significantly different than the plant parameters obtained in non-infested soil or negative control treatment. Effects of non-pathogenic *Fusarium* spp. applications on plant growth parameters were significantly higher than *Trichoderma* spp. applications in BNYVV-susceptible cultivar grown in non-infested soil (Table 2). In BNYVV-resistant cv. grown in non-infested soil, *Trichoderma* spp. applications generally had more positive effects on plant growth parameters than *Fusarium* spp. applications. On the other hand, non-pathogenic *Fusarium* spp. applications had more positive effects on plant growth parameters of rhizomania-resistant cv. grown in BNYVV-infested soil (Table 2). In a previous study, Harman et al. (2004) indicated that *Trichoderma* spp. can increase plant root and shoot growth, probably by direct effect on plants, and via biological control. Moreover, some researchers stated that infection with *Trichoderma* spp. may increase plant growth by solibilisation of nutrients in the soil or by directly enhancing plant uptake of nutrients (Altomare et al., 1999; Yedidia et al., 2001). In a previous study, Nouyati et al. (2018) stated that the antagonist *Fusarium* strains exhibited a significant decrease in the proliferation of BNYVV. They can be effective in preventing diseases such as root rot caused by pathogenic *Fusarium* species. In a different study, it was found that this genus promotes root development and enhances plant growth in their crops (Elshahawy et al., 2017).

Table 2. The effects of Trichoderma spp. and non-pathogenic Fusarium spp. on root weight, leaf weight and dry leaf weight of sugar beet cultivars

Treatments***	n	BNYVV-susceptible cultivar (cv. Ansa) Root weight (g)		Leaf weight (g)		Dry leaf weight (g)		BNYVV-resistant cultivar (cv. Serenada) Root weight (g)		Leaf weight (g)		Dry leaf weight (g)	
Tr-1+NIS	5	0.670	ab**	3.276	a-c*	0.237	a-e*	0.792	a*	3.122	a-c*	0.238	a-c*
Tr-3+NIS	5	0.573	ab	2.870	a-d	0.206	b-e	0.550	a-c	3.834	a	0.310	a
Tr-6+NIS	5	0.610	ab	3.046	a-d	0.241	a-d	0.442	bc	2.368	cd	0.186	a-c
Fs-24+NIS	5	0.624	ab	2.529	b-e	0.181	ce	0.632	a-c	4.042	a	0.276	ab
Fs-6-1+NIS	5	0.550	ab	2.255	b-e	0.277	a-c	0.672	ab	2.530	b-d	0.312	a
Tr-1+BIS	5	0.593	ab	2.858	a-d	0.197	b-e	0.564	a-c	1.916	de	0.174	bc
Tr-3+BIS	5	0.461	b	1.965	de	0.146	de	0.382	bc	1.944	de	0.182	a-c
Tr-6+BIS	5	0.444	b	2.104	c-e	0.173	ce	0.392	bc	1.930	de	0.192	a-c
Fs-24+BIS	5	0.788	a	3.161	a-d	0.190	b-e	0.484	a-c	2.202	c-e	0.224	a-c
Fs-6-1+BIS	5	0.620	ab	3.366	ab	0.316	a	0.682	ab	3.576	ab	0.258	ab
NIS	5	0.774	a	3.814	a	0.290	ab	0.588	a-c	3.148	a-c	0.312	a
BIS	5	0.456	b	1.619	e	0.129	e	0.322	c	1.158	e	0.128	c

*significant at 0.01 level, **significant at 0.05 level.

***Tr: *Trichoderma*, Fs: *Fusarium*, NIS: Non-infested soil, BIS: BNYVV-infested soil

The test involved both the BNYVV-susceptible cv. Ansa and the resistant cv. Serenada. ELISA values of the roots of BNYVV-infected plants were 20.1 times higher than the mean of healthy susceptible plants, and 7.9 times higher than the mean of healthy resistant plants. Except for the isolate Tr-3, the effect of the selected *Trichoderma* isolates and non-pathogenic *Fusarium* isolates on suppressing multiplication of BNYVV in susceptible cultivar varied between 19.9% and 64.9%. On the other hand, in the resistant cultivar, only Tr-6 among *Trichoderma* isolates was found to be effective with a rate of 11.6%, while the treatment with the Fs-6-1 isolate of *Fusarium* resulted in the complete suppression of BNYVV, and no infection was observed in any of the replications (Table 3). In addition, the growth of *P. betae* resting spores in the root tissues of BNYVV-susceptible and -resistant cv. was inhibited in the treatment with Fs-6-1. Also, *P. betae* resting spores were abnormally dark in colour and, had deformed walls (Fig. 1). Jakubikova et al. (2006) found that the efficacy of selected *Trichoderma* isolates to suppress the proliferation of BNYVV varied between 21 and 68%, and their results showed that *T. atroviride* strain I-2 was the most effective in suppressing the occurrence of *P. betae* and the multiplication of BNYVV in roots.

Table 3. ELISA A_{405} absorbance values of control and treatment groups for BNYVV

Treatments*	BNYVV-susceptible cultivar (cv. Ansa) Infected replication number	Mean ELISA absorbance values	ELISA inhibition rates (%)	BNYVV-resistant cultivar (cv. Serenada) Infected replication number	Mean ELISA absorbance values	ELISA inhibition rates (%)
Tr-1	5**/5***	2.29	24.2	4/5	1.51	-58.9
Tr-3	5/5	3.15	-4.3	3/5	2.08	-118.9
Tr-6	4/5	2.42	19.9	4/5	0.84	11.58
Fs-24	5/5	2.40	20.5	3/5	0.98	-3.16
Fs-6-1	1/5	1.06	64.9	0/5	-	100
NIS	0/5	0.15		0/5	0.12	
BIS	5/5	3.02		5/5	0.95	

*Tr: *Trichoderma*, Fs: *Fusarium*, NIS: Non-infested soil, BIS: BNYVV-infested soil

**number of BNYVV-infected replication, ***number of replication

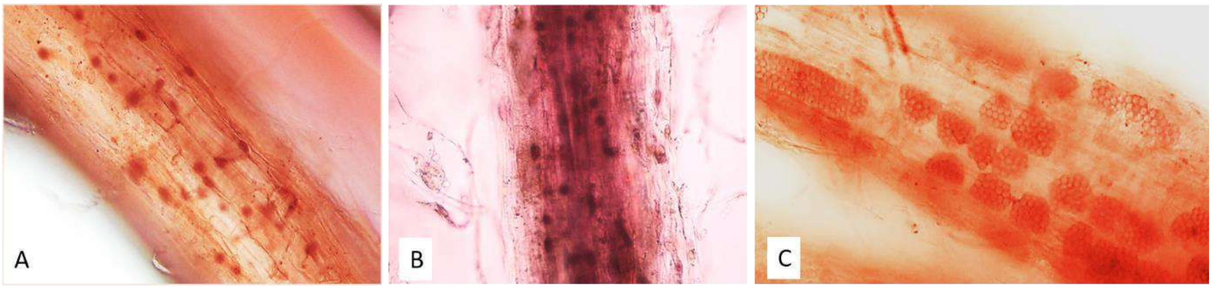

Figure 1. Deformed cystosori of *Polymyxa betae* in BNYVV-infected roots of beet plants grown from the seedlings treated with spore suspension of non-pathogenic *Fusarium* spp. Fs-6-1 in rhizomania-susceptible (A) and -resistant cultivars (B); *P. betae* cystosori in the root tissues in BNYVV-infected control treatment (C)

Conclusion

The treatment of the Fs-6-1 isolate as biocontrol agent resulted in decrease in ELISA absorbance values in the susceptible sugar beet cultivar by 65%, while it completely prevented the formation of BNYVV infection in the case of resistant cultivar for all replicates. In both susceptible and resistant varieties, there was also a noticeable change in the size and structure of *P. betae* resting spores. Further research is needed to identify the potential effect of the isolate Fs-6-1 in field conditions, and to determine other *Trichoderma* and non-pathogenic *Fusarium* isolates against BNYVV and *P. betae* as biological control agents.

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The effect of acid modification on rice husk biochar: pH, EC, and micro-nutrient content

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Abstract

The chemical activation process enhances the surface area and porosity of biochar, making it applicable in various domains such as soil and water contaminant removal and heavy metal remediation. In recent years, acidified biochar has been employed as a soil amendment, especially in calcareous and high pH soils. The aim of this study is to determine the effect of acid type and addition before or after pyrolysis on the pH, EC, total and DTPA Fe, Cu, Mn and Zn content of the rice husk biochar. The highest pH 9.03, total Fe 1752 mg kg^{-1}, and Mn 251 mg kg^{-1} content were found in rice husk biochar (RB) that was not modified with acid. The maximum Cu content 40 mg kg^{-1} was observed in RB + HNO_3, while the highest EC (51.00 dS m^{-1}) and Zn content 35 mg kg^{-1} were found in RB + H_2SO_4. The maximum DTPA Fe, Cu, Mn, and Zn content was found in the post-pyrolysis acidification with H_2SO_4, 705, 9, 174 and 18 mg kg^{-1}, respectively. It was noted that the addition of acid increased some nutrient contents, but there was a significant decrease in pH and a noteworthy increase in EC. The type and concentration of the acid to be applied is very important in terms of obtaining an acid characterized biochar

Keywords: Acid modification, rice husk, DTPA-micronutrient, waste management, H_2SO_4, HNO_3

Introduction

For sustainable agricultural practices, researchers are increasingly looking for innovative solutions to increase soil fertility and crop yields as well as reduce environmental impacts of intensive agriculture practices. The recycling of agricultural wastes as a soil conditioner or fertilizer in agriculture is a very useful practice in terms of both economic and environmental health. In recent years, the application of biochar to soil has significantly increased carbon sequestration, reducing CH_4, CO_2 and N_2O gas emissions, enhance the nutrients availability and preventing leaching, regulate water infiltration and retention (Van Zwieten et al, 2010; Lehmann et al, 2011; Ventura et al, 2013; Pratiwi ve Shinogi, 2016; Liu et al, 2017). Biochar is a stable carbon-rich solid matter produced by thermochemical degradation of organic materials in the absence of oxygen (Lehmann, 2007). A wide variety of organic feedstocks can be used for biochar production, including agricultural and woody residues, industrial and urban waste, etc. Due to its high silicon content, rice husk is very difficult to break down. It is thought to be suitable to be used as biochar. The main purpose of the activation process is to enhance the surface area, pore volume and pore diameter, and increase the porosity of the resultant-activated biochar. Physical and chemical activation are the most used processes for the preparation of activated biochar. Chemical modification mostly includes acid modification, alkaline modification, metal salts or oxidising agent modification etc. (Qian et al, 2015). Chemically activated biochar can be used in a wide range of applications such as soil remediation, water and wastewater treatment, catalysts/activators, supercapacitors, etc. Recently, acidified biochar has been used as a soil conditioner in soils with high pH and high lime content (Demirkaya et al., 2021; Demirkaya and Gülser, 2023a; Demirkaya and Gülser 2023b).

In this study, we examined; the effect of acidification before and after pyrolysis and acid type on pH, electrical conductivity (EC) and total and DTPA extractable iron (Fe), copper (Cu), manganese (Mn) and Zinc (Zn) content of rice husk biochar.

Material and Methods

In the first process, rice husk biochar (RHB) was pyrolyzed in a muffle furnace at atmospheric pressure by applying 400 °C for 2 hours without acid modification. In the second procedure, two different acids (HNO_3 and H_2SO_4) were added to rice husk then dried and pyrolyzed in the same way manner. In the third procedure, the acids were added to the RHB that had been prepared already. The acid/biochar mixture ratio was 1:2.5 (w/v) and the acid concentrations were %1. Biochars that were given acid before pyrolysis were expressed as B+HNO_3 and B+H_2SO_4, and biochars that were given acid after pyrolysis were expressed as A+HNO_3 and A+H_2SO_4. Original rice husk properties that were used in this study; pH 7.46 (1:10 w/v), EC 1.50 (dS m^{-1}), total Fe (134 mg kg^{-1}), total Cu (31 mg kg^{-1}), total Mn (151 mg kg^{-1}) and total Zn (12 mg kg^{-1}).

All experiments were conducted in triplicate and (one-way ANOVA) was used to compare the mean values of each treatment. Significant differences were determined by the Student's t test.

Results And Discussion

The effect of the treatments was found to be statistically significant ($p<0.05$) in all parameters except total Cu and Zn.

Before the pyrolysis process acidification slightly reduced the pH of the rice husk biochar, but after the pyrolysis process, acidification lowered it dramatically when compared to the rice husk biochar. The highest and lowest pH was 9.03 and 1.50 in RHB and A-H_2SO_4 treatment, respectively (Figure 1). The fact that the added acid is lost or changes form during pyrolysis may be an explanation for why the decrease in pH was limited.

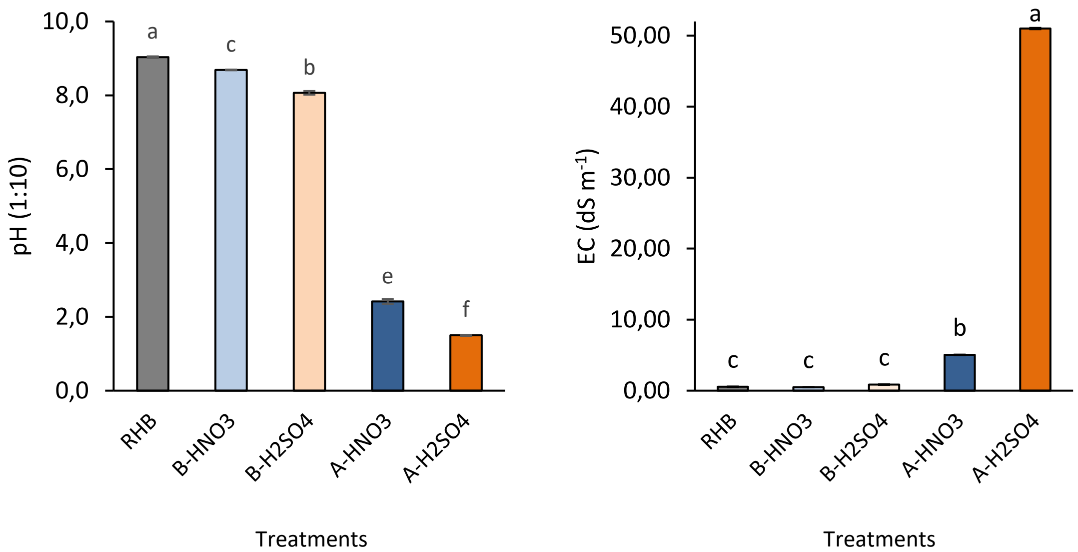

Figure 1. pH and EC values of treatments

As compared to the rice husk, pyrolysis process reduced the EC of biochars except after pyrloysis acidified biochars. The addition of acid before pyrolysis provided the solubility of some of the nutrients in the rice husk, but these elements were lost during pyrolysis or changed their form to become insoluble, which may be the reason for the decrease in EC. The EC value of A-H_2SO_4 was found to be 10 times higher than B-HNO_3, which has the lowest EC value (Figure 1). Adding acid to biochar dissolves minerals, leading to an increase in EC (Demirkaya et al., 2021; Demirkaya ve Gülser 2023a; Demirkaya ve Gülser 2023b). Sahin et al. (2017) obtained acidified biochar by adding HNO_3 and H_3PO_4 to chicken manure before and after pyrolysis. They reported that the nutrient content varied according to the type of acid and when it was added.

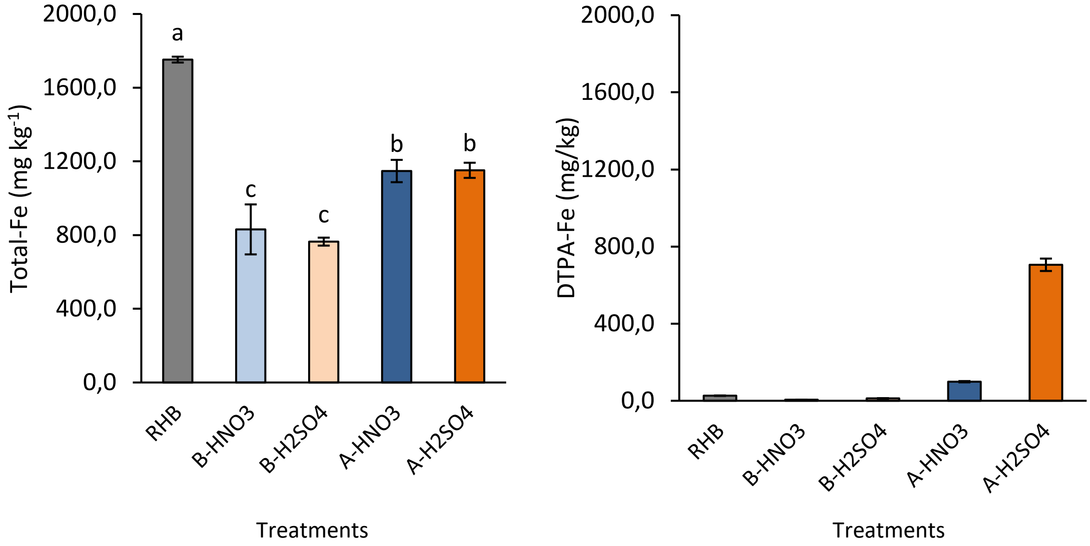

Figure 2. Total and DTPA extractable Fe content of treatments

The acidification process after pyrolysis was more effective in increasing the total iron content compared to the before acidification pyrolysis process but the highest total iron content was obtained from original rice husk biochar 1752 mg kg^{-1} (Figure 2). The DTPA-Fe content decreased before pyrolysis acidification and increased after pyrolysis acidification according to the rice husk biochar. The highest increase occurred in the biochar treated with H2SO4 after pyrolysis as 705 mg kg-1 (Figure 2).

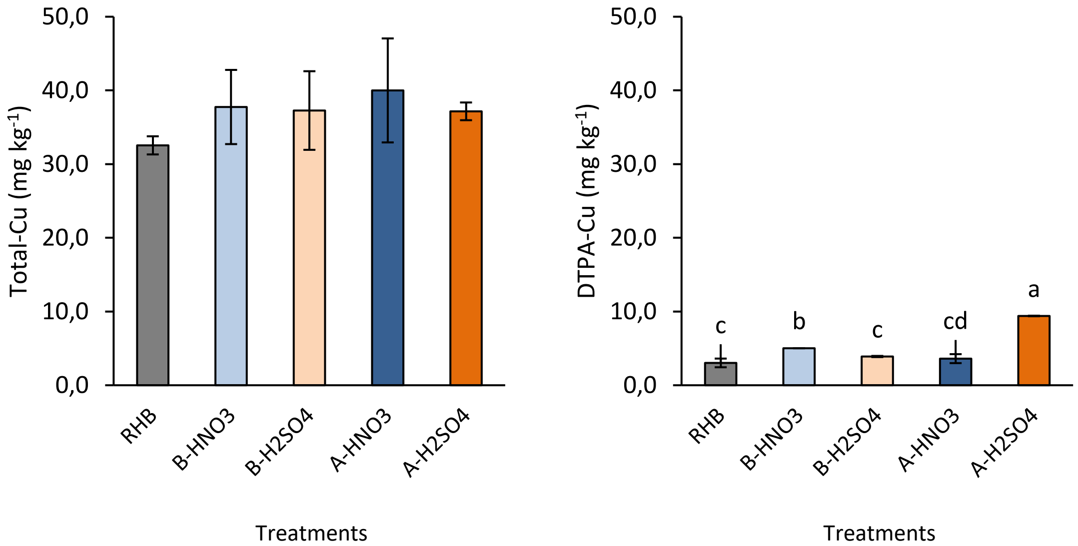

Figure 3. Total and DTPA extractable Cu content of treatments

All treatments were increment the total and DTPA Cu content as compared to the original rice husk biochar (Figure 3). The maximum total and DTPA Cu content was determined in the A-HNO_3 (40 mg kg^{-1}) and A-H_2SO_4 (9 mg kg^{-1}), respetively.

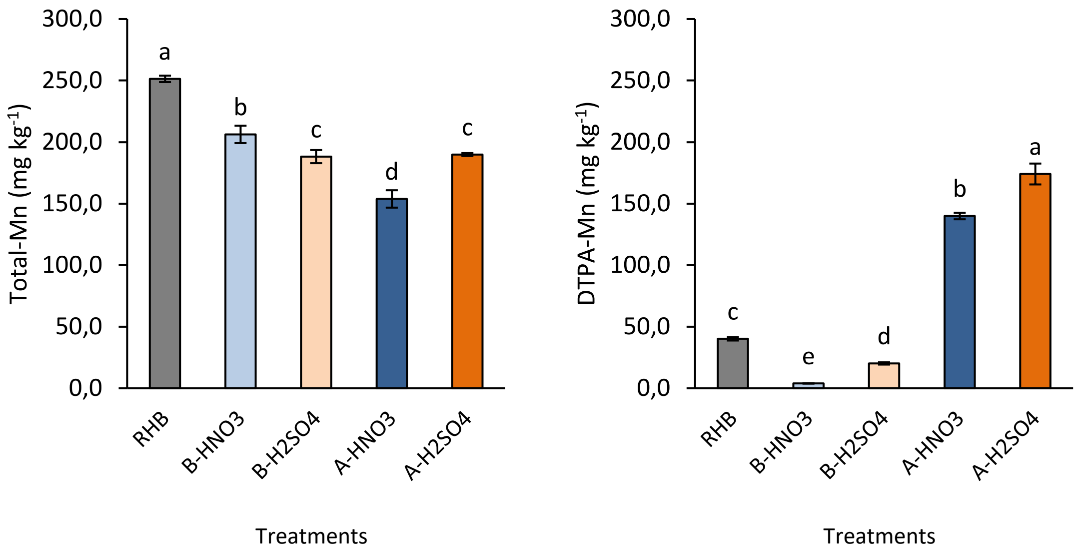

Figure 4. Total and DTPA extractable Mn content of treatments

When total Mn examined acidification treatment had a decreasing effect compared to rice husk biochar. The maximum total Mn content was determined in rice husk biochar (251 mg kg^{-1}). According to the original rice husk, the acidification process before pyrolysis significantly reduced the DTPA-Mn, while the acidification process after pyrolysis significantly increased it. The higher DTPA-Mn was found in the A-H_2SO_4 treatment (174 mg kg^{-1}) which was very close to the total amount (Figure 4).

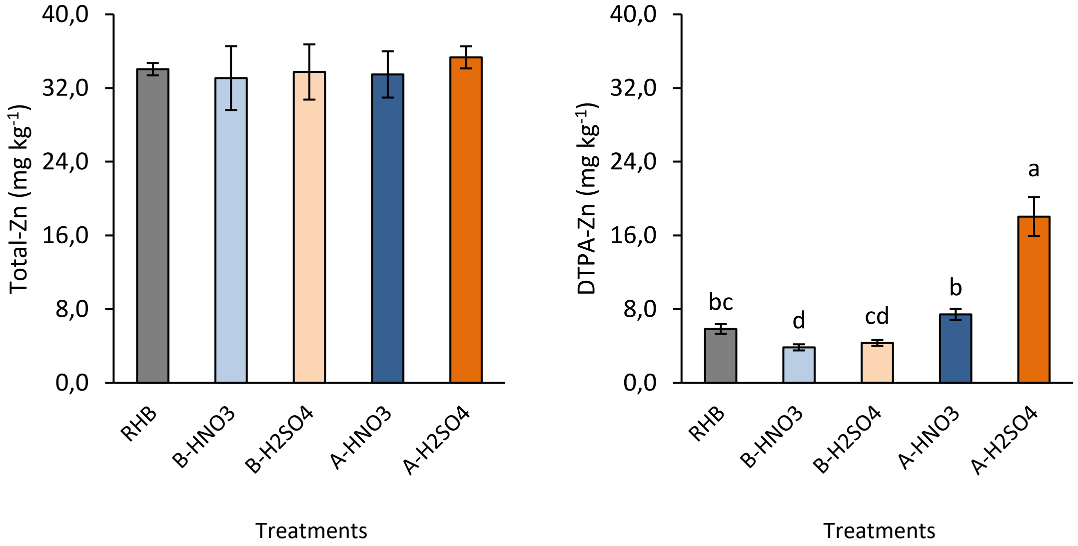

Figure 5. Total and DTPA extractable Zn content of treatments

Except for the A-H_2SO_4 treatment, all treatments reduced the total amount of Zn as compared to the original rice husk biochar. The maximum total Zn content was determined in the A-H_2SO_4 treatment (35 mg kg-1). The addition of acid before pyrolysis decreased the amount of DTPA-Zn, while the addition of acid after pyrolysis increased according to the original rice husk biochar. Same as the total amount the maximum content of DTPA-Zn was found in the A-H_2SO_4 treatment (18 mg kg^{-1}).

Conclusion

According to the results of this study, if rice husk biochar is acidified before pyrolysis, the pH decrease is not very effective. When rice husk biochar was acidified with H_2SO_4 after pyrolysis, the pH decreased too much, and the EC increased extremely. The acidification process reduced the total Fe and Mn content, increased the Cu content, and did not affect the Zn content much. All pre-pyrolysis acidification processes reduced the DTPA content of Fe, Mn and Zn, except for DTPA-Cu, compared to the original rice husk biochar and the post-pyrolysis acidification process had increased the DTPA concentrations of all elements. Acidification after pyrolysis has been found to be more effective when considering the usefulness of the nutrients, but given the pH and EC values, acid solutions at different concentrations should be tested.

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The changes in pH and EC values of lettuce growth soil with salicylic acid application under salt stress

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Abstract

In this study, it was aimed to determine the effects of salicylic acid applications on soil PH and Electrical conductivity. The experiment was conducted according to factorial experimental design with three replications at the controlled chamber room of Soil Science and Plant Nutrition Department of Agricultural Faculty in Yüzüncü Yil University, Türkiye. The total set of 36 pots was used in the experiment in pots including 3 kg soil in each one. Four doses of salicylic acid (SA_0:0, SA_1:1 mM, SA_2:2 mM and SA_3:4 mM) and three doses of NaCl ($NaCl_0$:0, $NaCl_1$:30 and $NaCl_2$:60 mM) were applied. The experiment was ended after 8 weeks. Generally increasing NaCl doses decreased soil pH values and increased EC values. These changes were significant for pH ($P<0.05$) and EC ($P<0.01$) statistically. The effects of SA applications on pH and EC were found as significant ($P<0.01$) statistically. The interactions between in SA and NaCl were significant ($P<0.05$) for soil EC statistically. In NaCl added media SA1 and SA2 applications decreased the EC of the soil, and the pH values make became more alkaline up to 8, while SA3 applications decreased the pH values and increased the EC values. At the SA applications the lowest pH mean were obtained as 7.620 in SA0 application while the highest pH means were in SA1and SA2 applications as 7.970 and 7.853 respectively. The lowest and the highest EC means in SA applications were obtained as 1135.000 µS cm^{-1} and 1546.444 µS cm^{-1} in SA2 and SA3 applications respectively as a result increasing SA applications increased soil pH values while EC values decreased by SA1and SA2 applications under salinity conditions.

Keywords: Salinity, salicylic acid, soil, pH, Electrical Conductivity

Introduction

A significant abiotic factor that lowers the production of a wide range of crops worldwide is salinity. Arid and semi-arid areas make up around one-third of the planet's landmass. Most of these places might have issues with salt, partly because of irrigation techniques (Uttam Kumar et al, 2016). Soil quality and health are crucial factors influencing agricultural productivity and environmental stability. Soil salinity, resulting from the accumulation of soluble salts, poses a significant threat to soil quality and plant growth, particularly in arid and semi-arid regions. Soil salinity adversely affects crop yield, disrupts nutrient uptake, and triggers osmotic stress in plants. In this context, understanding the mechanisms by which salinity influences soil properties and plant responses is crucial for developing sustainable agricultural practices. Soil pH, the measure of acidity or alkalinity of soil, is a critical factor influencing nutrient availability, microbial activity, and plant nutrient uptake (Sposito, 1989). Salinity often leads to soil alkalization due to the accumulation of alkaline cations (e.g., Na^+ and Ca^{2+}), which can affect soil pH (Hossain et al., 2017). Concurrently, electrical conductivity (EC) measures the ability of soil to conduct electrical current, with higher EC values indicating increased ion concentration in the soil solution (Rhoades et al., 1999). Salicylic acid (SA) is a natural phytohormone and signaling molecule that plays diverse roles in plant stress responses and growth regulation (Gawish et al., 2018). In the context of salt stress, SA has been shown to enhance the salt tolerance of various plant species through its effects on ion transport, osmotic regulation, and antioxidant defense systems (Janda et al., 2014;

Rivas-San Vicente & Plasencia, 2011). However, the consequences of SA application on soil pH and EC under salt stress conditions are not yet fully understood. The aim of this study was to investigate the effects of the salicylic acid application on the soil pH and EC under salt stress.

Material and Methods

The experiment was conducted out according to factorial experimental design with three replications at the controlled chamber room of Soil Science and Plant Nutrition Department of Agricultural Faculty in Yüzüncü Yil University, Türkiye. The total number of 36 pots was used in the experiment including 3 kg soil in each one. Four doses of salicylic acid (SA0:0, SA1:1 mM, SA2:2 mM and SA3:4 mM) and three doses of NaCl (NaCl1:0, NaCl2:30 and NaCl3:60 mM) were applied. The total set of 36 soil samples were passed through 2.36mm sieve mesh for analysis. As 1: 2.5 soil-water mixture prepared then put into shaker for 30 minutes, finally, the pH electrode was installed. The soil reaction was determined in a 1: 2.5 soil-water mixture with a glass electrode pH-meter. Soil salinity was determined by measuring the electrical conductivity in a 1: 2.5 soil-water mixture using a conductivity instrument (Black, 1965). The other investigated soil physical and chemical properties were determined by using standard soil analyze methods reported by Kacar (1994). Statistical analysis of the findings was carried out using variance analysis using the SPSS software package program as factorial design and the results were grouped according to Duncan multiple comparison tests (SPSS, 2018).

Table 1. Some physical and chemical results of experimental soil.

Texture	pH	EC dS m^{-1}	$CaCO_3$ %	OM %	P	K	Ca	Mg
					mg kg^{-1}			
Tın	7.81	0.36	3.86	1.32	5.50	298	3034	405

Experimental soil has loam in texture, slightly alkaline, non saline, likely, sufficient in potassium, calcium and magnesium contents (Table 1).

Results and Discussion

According to analysis results generally increasing NaCl doses decreased soil pH values and increased EC values. These changes were significant for pH (P <0.05) and EC (P <0.01) statistically. The effects of SA applications on pH and EC were found as significant (P <0.01) statistically. The interactions between in SA and NaCl were significant (P <0.05) for soil EC statistically (Table 2).

Table 2. The variance analysis results on the effects of different salicylic acid and salt applications on pH and EC.

		pH		EC	
S. O. V.	DF	MS	F	MS	F
SA	3	0.238	8.20**	262139.19	24.61**
Salt	2	0.113	3.89 *	7222961.08	678.11**
SA*Salt	6	0.016	0.58 NS	160405.94	15.06**
Error	24	0.029		10651.61	

The F value indicated by ** is important at the 1% level (P <0.01).
The F value indicated by * is important at the 5% level (P <0.05).
NS: non-significant

At the NaCl applications the lowest and the highest pH means were obtained as 7.683 and 7.878 in NaCl2 and NaCl0 applications respectively. The lowest and the highest EC means in NaCl applications were found as 602.167 µS cm-1 and1808.667 µS cm-1 in NaCl0 and NaCl2 applications respectively. In NaCl added media SA1 and SA2 applications decreased the EC of the soil, and the pH values make became more alkaline up to 8, while SA3 applications decreased the pH values and increased the EC values. At the SA applications the lowest pH mean were obtained as 7.620 in SA0 application while the highest pH means were in SA1and SA2 applications as 7.970 and 7.853 respectively. The lowest and the highest EC means in SA applications were obtained as 1135.000 µS cm-1 and 1546.444 µS cm-1 in SA2 and SA3 applications respectively as a result increasing SA applications increased soil pH values while EC values decreased by SA1and SA2 applications under salinity conditions (Table 3).

As correspond with our results Agrawal et al. (2002) reported that the soil pH2 decreased with increase in the level of saline water irrigation non-significantly. They associated this situation with the low Na ratio in the total salt concentration of the soil solution and the neutral nature of the electrolytes. Similarly, Kumar et al. (2016) reported that the salinity increase in the soil increased with the increase in the salinity of the water and the maximum increase was recorded on the surface, while the pH decreased with the increase in salinity.

By promoting root growth and the exudation of organic materials, salicylic acid also indirectly influences the pH of the soil, this may also improve the soil's capacity to function as a buffer (Joseph et al., 2020). An increasing number of studies have been reported on the protective effect of exogenously applied SA on abiotic stresses such as salinity stress (Khodary, 2004). In this study, increasing salt concentration increased the EC values, but with the addition of salicylic acid, the EC values concentration decreased, especially in SA2.

Table 3. The effects of different salicylic acid and salt applications on soil pH and EC with Duncan letters

	SA	Salt			SA means
		0	1	2	
pH	0	7.717 b-d	7.667 b-d	7.477 d	7.620 B
	1	8.073 a	7.890 a-c	7.947 ab	7.970 A
	2	7.900 a-c	7.933 ab	7.727 b-d	7.853 A
	3	7.820 a-c	7.600 cd	7.583 dc	7.668 B
	Salt means	7.878 A	7.773 AB	7.683 B	
	SA	Salt			SA means
		0	1	2	
EC μS cm 1	0	590.667 e	1173.667 d	2409.667 a	1391.333 B
	1	587.333 e	1219.333 d	2155.000 b	1320.556 B
	2	562.667 e	1226.667 d	1615.667 c	1135.000 C
	3	581.667 e	1710.000 c	2347.667 a	1546.444 A
	Salt means	602.167 C	1201.167 B	1808.667 A	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Conclusion

In recent years, there have been an increasing number of research on the protective impact of externally applied SA on abiotic stresses, such as salinity stresses (Khodary, 2004). SA is known for its ability to increase stress tolerance in various plant species by modulating physiological and biochemical processes. However, the interaction between salicylic acid, soil properties, and salinity remains a subject of ongoing research. This study investigating the relationship between soil pH, EC, salinity, and salicylic acid application may contribute to our understanding of sustainable agricultural practices that can reduce the negative effects of soil salinity and increase crop productivity in challenging environments.

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The effect of biochar and acidified biochar on dehydrogenase activity in soil

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Abstract
This study was carried out to determine the effect of biochar (B) and acidified biochar (AB) on dehydrogenase enzym activity (DHA) of a sandy loam calcareous soil. The biochars were applied as C (%0), %1, %2, %4 doses to each pot with three replicates and incubated for 4w, 8w, 12w and 16w in incubator at 25 ^{0}C. In the B treatments, depending on the dose pH values increased while EC values decreased. pH values decreased and EC values increased by AB treatments. After each incubation period, the highest DHA activity in the B treatments was obtained in the C treatment while in AB treatments, the highest DHA activity was obtained at 1% dose. At the first and last incubation periods determined lowest DHA enzym activity in the soil, while the most DHA activity of the soil measured at the end of 2nd and 3rd incubation period. According to the results of the study, B and AB treatments decreased the DHA activity except for AB1 treatment.
Keywords: Calcareous Soil, Dehydrogenase, Biochar, Acidified Biochar.

Introduction

There are many enzymes such as Oxidoreductases, Hydrolases, Isomerases, Lyases and Ligases that function in biochemical processes in soil (Gu et al., 2009; Burns, 1983; Sinsabaugh et al., 1991). In soil, dehydrogenase enzymes are the main representatives of the Oxidoreductase enzymes class (Gu et al., 2009). The enzyme is shown as an indicator of the microbiological activity of soils (Quilchano and Marañon, 2002; Gu et al., 2009; Salazar et al., 2011), because it is an intracellular enzyme and requires living cells for activity (Moeskops et al., 2010; Zhao et al., 2010). Moreover, dehydrogenase enzyme is known to oxidise soil organic matter by transferring protons and electrons from substrates to acceptors (Doelman and Haanstra, 1979; Kandeler et al., 1996; Glinski and Stepniewski, 1985; Ross, 1971). In addition to the physical, chemical and biological properties of soils, many factors such as climate and vegetation can affect the enzyme activity.

Dehydrogenases are very sensitive indicators of changes in soil structure (Bastida et al. 2008, Gajda et al. 2013, Gałązka et al. 2017), since DHA activity is active in living microbial cells, the structure of existing microbial communities is very important. The DHA enzyme has been shown to be very sensitive to physical and chemical parameters of the soil, such as moisture, temperature and pH (Cirilli et al. 2012, Levyk et al. 2007, von Mersi and Schinner 1991, Wolińska and tępniewska 2012; Ay, and Kizilkaya, 2021; Kizilkaya et al., 2019). Many studies have found that the presence of heavy metal ions (Cu, Pb, Cd) in soil and salinity causes significant inhibition of DHA activity (Mocek-Płóciniak 2010, Telesiński et al. 2015, Xie et al. 2009).

Among the soil properties mentioned, the influence of pH is still unclear. The effect of pH on the enzyme activity varies in studies. Generally, the enzyme activities tend to increase with soil pH (Błońska, 2010; Quilchano and Marañón, 2002). On the other hand, study performed by Włodarczyk et al. (2002) indicated maximum DHA at pH 7.1, similarly to the work of Ros et al. (2003), where optimum for DHA was noted for pH 7.6-7.8.

The use of biochar has received increased attention over the past two decade because its efficiency, productivity along with numerous benefits such as waste management and climate change mitigation (Peiris et al. 2019; Awad et al. 2018). There are many studies stating that biochar improves the chemical, physical and biological properties of soils (Glaser et al. 2002; Ahmad et al. 2014; El Naggar et al. 2015). However, one of the obstacles to the use of biochar in calcareous soils is that biochar has an alkaline pH. Acidification is one of the most used methods to eliminate this obstacle. After acidification, negative charges on the biochar surface increase and may play a regulatory role in calcareous soils (Demirkaya et al., 2021).

This study was conducted to determine the effects of original biochar and acidified biochar on the dehydrogenase enzyme activity of a calcareous alkaline soil over time.

Material and Methods

Soil sample used in the study was taken from Ondokuz Mayıs University Agricultural Study Area, Bafra, Samsun. Then, the soil was air-dried and passed through a 2-mm sieve for analyses. Physicochemical properties of soil were determined following the methods in Table 1.

Table 1. Some physical and chemical properties of the soil

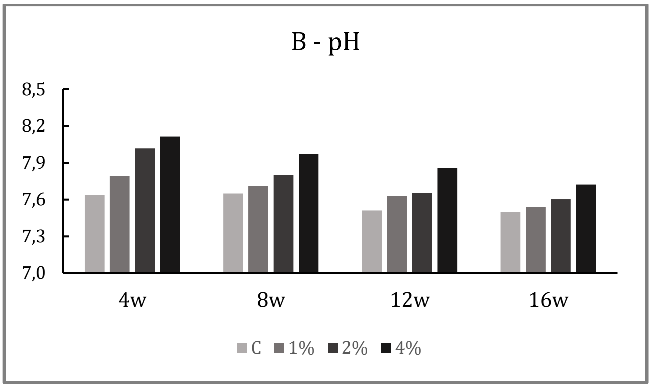
Properties	Results	Method
Texture class	Sandy loam	Bouyoucos (1962)
Organic matter, %	0,90	Walkley and Black (1934)
$CaCO_3$, %	15,53	Rowell (2010)
pH	7,80	Peech (1965), Bower and Wilcox (1965)
Electrical conductivity, μScm^{-1}	212,78	Peech (1965), Bower and Wilcox (1965)
Total N, %	0,07	Bremner (1965).
P, mg kg^{-1}	12,20	Olsen and Dean (1965)
Ca, cmol kg^{-1}	20,30	Heald (1965)
Mg, cmol kg^{-1}	5,10	Heald (1965)
Na, cmol kg^{-1}	0,28	Pratt (1965)
K, cmol kg^{-1}	0,25	Pratt (1965)
Fe, mg kg^{-1}	8,14	Lindsay and Norvell (1978)
Cu, mg kg^{-1}	0,26	Lindsay and Norvell (1978)
Mn, mg kg^{-1}	0,50	Lindsay and Norvell (1978)
Zn, mg kg^{-1}	0,27	Lindsay and Norvell (1978)

Biochar used in the study was produced from wooden at 600 ^{0}C. Two different biochars, B and AB, were used in the study. Their pH values were 9.43 and 6.48, and their EC values were 360 and 2900 µS cm^{-1}, respectively. 100 g of soil sample was weighed in plastic pots. The study treatments are control (C), 1, 2 and 4 % of biochars (B) and acidified biochars (AB). Each pot with three replicates and incubated for 4, 8, 12 and 16 weeks under the laboratory conditions around room temperature (20-25^{0}C). During the study, the pots were weighed daily and kept at field capacity. pH, EC, and DHA activity were determined end of each incubation period. Dehydrogenase activities of soil samples were determined as reported by Pepper et al. (1995).

Results And Discussion

Original biochar (B) and acidified biochar (AB) treatments, doses and incubation times affected the pH, EC and dehydrogenase enzyme activity of the soil statistically (0.05).

Biochar applications increased the pH value of the soil. The highest pH value was determined as 8.11 at the end of 4 week in 4% of B, while the lowest pH value was determined at the end of 16 week in the C treatment. As the doses increased, the pH value also increased in B treatments. B application decreased the pH value of the soil compared to the control. Accordingly, the highest pH value was measured as 7.65 in the C application at the end of 8 weeks, and the lowest pH value was determined as 7.37 at the end of 16 weeks. Also, in AB treatments, the same level of decrease in pH value was not observed with increasing doses. All doses were measured very close to each other. Biochar has a high pH value due to its structure. It has been stated in many studies that it increases the pH value when applied to soil (Chan et al., 2008; Ullah et al., 2018; Chintala et al., 2014; Demirkaya and Gulser, 2023). On the other hand, biochar can have a lowering effect on pH through the acidification process (Ahmed et al., 2021; Demirkaya et al., 2021; Demirkaya and Gulser, 2023).



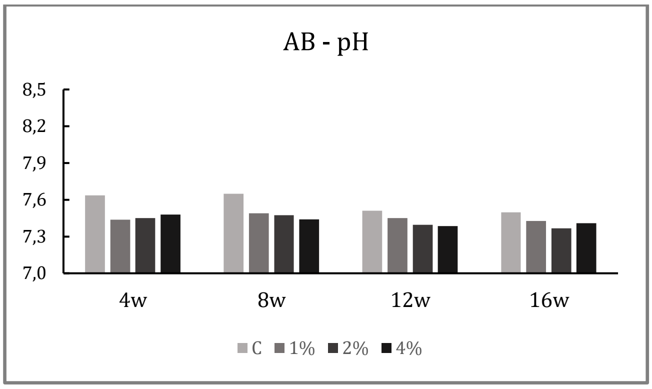
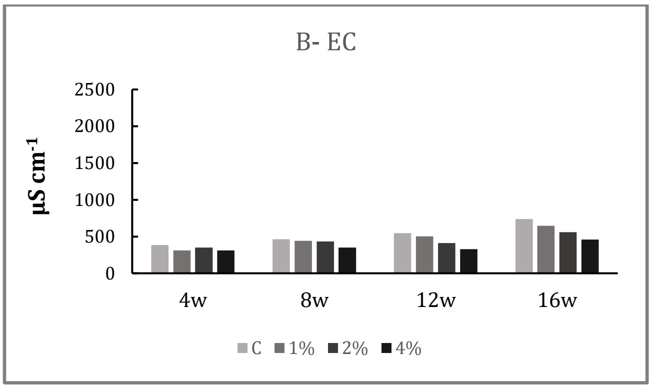


Figure 1. Effects of B on soil pH over time

Figure 2. Effects of AB on soil pH over time

According to Figure 3, EC values decreased with the increase in the dose of B treatments. There were decreases in all of B treatments compared to the control treatment. It can be explained by the high adsorption capacity of the biochars (Dai et al., 2019; Cheng et al., 2021; Demirkaya et al., 2021; Demirkaya and Gulser, 2023). On the other hand, AB applications increased EC values of the soil depending on the doses. When evaluated in terms of incubation periods, EC values increased with increasing time in B and AB treatments. During the acidification process, the pH value of the biochar decreases while the EC value increases. In this case, acidified biochar has an increasing effect on the EC value when applied to soil (Demirkaya et al., 2021; Demirkaya and Gulser, 2023).



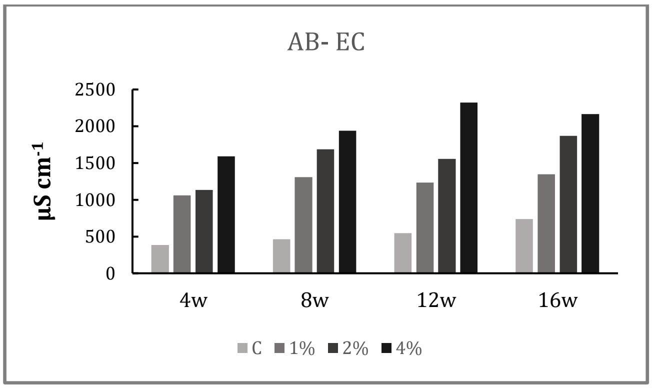
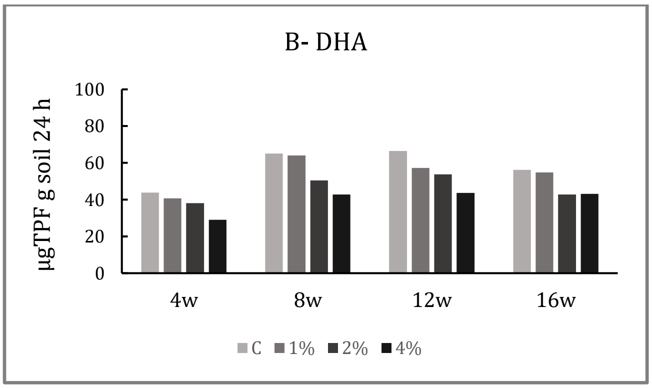


Figure 3. Effects of B on soil EC over time

Figure 4. Effects of AB on soil EC over time

The highest DHA activity was determined at the end of 8 (80.33 µgTPF gsoil 24h) and 12 (84.87 µgTPF gsoil 24h) weeks. On the other hand, the lowest activity was determined at the end of 4 (29.04 µgTPF gsoil 24h) and 16 (42.82 µgTPF gsoil 24h) weeks. All applications except the 1% dose of AB reduced DHA enzyme activity compared to the control. It can be explained by the fact that B treatments increases the pH value and decreases the EC value and thus reduces the microbiological activity of the soil. On the other hand, soil pH decreased and EC incresed by AB treatments. While the enzyme activity increased with the decrease in pH, it decreased due to the salt effect as the dose increased.

DHA activity of alkaline soil was considerably reduced with increase in soil salinity and alkalinity (Batra and Manna, 2009). Brzezinska et al. (2001) reported that the best pH conditions for DHA ranged between 6.6-7.2.



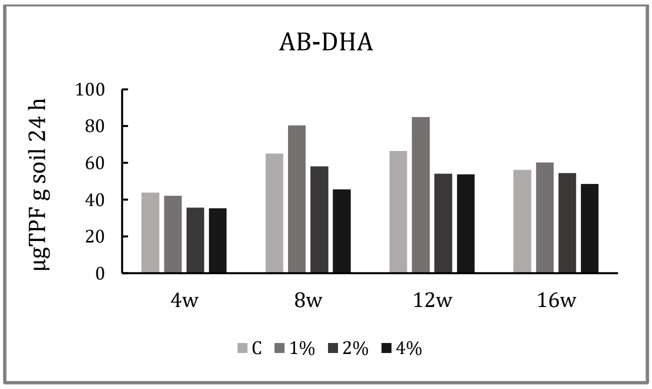


Figure 5. Effects of B on soil DHA activity over time

Figure 6. Effects of AB on soil DHA activity over time

Conclusion

As a result of the incubation study, when original biochar (B) and acidified biochar were added to a calcareous soil, it significantly affected the pH and EC and dehydrogenase enzyme activity of the soil. The original biochar application increased the pH value depending on the dose. EC values increased over time and decreased with increasing dose. The addition of acidified biochar decreased the pH value, but no differences were observed between doses. EC values increased depending on the doses but did not change over time. As for dehydrogenase enzyme activity of soil, when compared to the control, significant increases occurred only at the 1% dose of acidified biochar (AB), and it decreased or did not affect all other applications. As a result, it was obtained from the study that when pH lowering was done with acid biochar, dehydrogenase enzyme activity, which is one of the most important biological indicators of soils, increased. It is thought that studies on different biochars and soil enzymes should be conducted in the future.

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Heavy metal pollution in some urban parks: A comprehensive review

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Abstract

Urban parks, often considered green havens, become focal points in this comprehensive analysis, unraveling the historical evolution and contemporary challenges posed by heavy metal pollution. The exploration begins with an introduction, setting the stage by emphasizing the intricate relationship between nature and human activities in shaping the soil composition of urban parks. The historical echoes, from medieval ore processing to industrial revolutions, imprint distinct patterns in the soil of Planty Park, Krakow, and resonate in the ancient roots of Beijing, Mashhad city, NE of Iran. Seville's parks, adorned with historical significance, mirror global concerns for urban soil health, highlighting the universality of heavy metal pollution challenges. The methodology section details field studies and analyses conducted across these diverse locations, employing various techniques such as ICP-OES, HCA, PCA, ICPMS analysis, and the BCR sequential extraction method. The amalgamation of these methodologies forms the foundation for a comprehensive analysis, shedding light on the historical evolution and dynamics of heavy metal pollution within urban parks. Results from the comprehensive analysis reveal elevated concentrations of heavy metals, including Zn, Cr, Pb, Cu, Ni, As, Hg, and Cd, in urban park soils compared to non-urban soils across the studied locations. Spatial correlations between certain metals suggest shared pollution sources, with influential factors such as soil type, pH, and proximity to the city center identified. Distinct hotspots in spatial distribution maps highlight concentrations of specific metals in different regions. Multivariate analyses and sequential extraction studies provide insights into metal mobility, availability, and contamination indicators, underscoring the complexity of urban park soil dynamics. The discussion section synthesizes the combined insights from the diverse studies, emphasizing the role of historical legacies, urbanization impacts, and the multifaceted nature of heavy metal pollution in urban parks. From Seville's focus on traffic-related factors to Mashhad's nuanced understanding of heavy metal availability and mobility. In essence, this review paper serves as a cohesive narrative, and contemporary challenges of heavy metal pollution in urban parks across different geographical contexts. The shared journey through Krakow, Beijing, Seville, and Mashhad provides a holistic understanding that transcends isolated tales, guiding future endeavors in urban environmental care.

Keywords: Heavy Metal Pollution, Soil Pollution, Urban Parks, Soil Analysis, Environmental Adaptation.

Introduction

Urban parks, the green lungs amidst concrete landscapes, silently harbor a tale of ongoing challenge of heavy metal pollution. Beneath the tranquil veneer lies a complex relationship between nature and human activities, shaping the soil's composition over time.

Soil, a fundamental element of urban life, undergoes change influenced by both natural processes and human actions (Gąsiorek et al., 2017; Liu et al., 2020). Urbanization transforms the soil, making it distinct from its natural state and inadvertently accumulating heavy metals (Chen et al., 2005).

Historical chapters, marked by medieval ore processing and industrial revolutions, imprint Krakow's Planty Park with the echoes of the city's evolution (Gąsiorek et al., 2017; Kowalska et al., 2016). Beijing, with its ancient roots, reveals a parallel story, where heavy metals quietly traverse the soil, leaving a pollution trail (Chen et al., 2005). In China's rapid urbanization, parks become both havens and potential risks, prompting a meticulous examination of heavy metal concentrations, sources, and associated risks (Luo et al., 2012). Seville, adorned with parks and gardens, mirrors global concerns for urban soil health (Madrid et al., 2002). And in Mashhad City marked with the anthropogenic activities such as industrial activities, vehicular emissions, and improper waste disposal call for concern on the investigation of heavy metal contamination in the Urban Park (Mazhari et al., 2018). The distribution of heavy metal contents becomes a microcosm of a worldwide predicament (Bullock & Gregory, 1991).

This review explores urban parks' heavy metal pollution, delving into Krakow, Beijing, Sevielle and Mashhad. We connect these stories and examine the concentrations. As we dig into the soil layers, this review distills collective wisdom, guiding urban environmental care. Ahead, we detail methods, findings, discussions, and conclusions, unraveling the link to metal pollution in urban parks.

Material and Methods

In Krakow's Planty Park, Poland, field studies conducted in June 2014 involved collecting representative soil samples (0–20 cm) from 50 random points (Fig. 1). Soil properties, including texture, pH, Total Organic Carbon (TOC), and Total Nitrogen (Nt), were determined, and heavy metal content was analyzed using Atomic emission spectrometry with inductively coupled plasma (ICP-OES). Pollution indices were calculated based on established formulas (Gąsiorek et al., 2017).

Beijing, China's urban parks in seven central districts, were investigated with topsoil samples (0–5 cm) from 30 parks. Statistical treatments such as hierarchical cluster analysis (HCA) and principal components analysis (PCA) were employed to assess soil quality and pollution indices based on heavy metal concentrations(Chen et al., 2005). In another research conducted by Liu et al., 2020, 121 parks (Fig. 2) were studied in Beijing. Topsoil samples (0–5 cm) underwent inductively coupled plasma-mass spectrometry (ICPMS) analysis for heavy metal(loid)s, and a conditional inference tree model was used to establish relationships between variables.

Seville, Spain, saw 31 sampling sites within public parks and gardens. Composite samples at two depths (0–10 cm, 10–20 cm) were obtained, and soil properties were determined. Heavy metals were extracted using different methods (Madrid et al., 2002).

In Mashhad City, Iran, 23 parks were studied, and topsoil samples (5–20 cm) were collected for analysis. Labile and bioavailable fractions of heavy metals were assessed using the BCR sequential extraction method. Pb isotopes were measured using a Thermo-Finnigan Neptune high-resolution multi-collector inductively coupled-plasma mass spectrometry (MC-ICPMS) (Mazhari et al., 2018).

This amalgamation of methodologies from diverse locations forms the foundation for our comprehensive analysis, shedding light on the historical evolution and heavy metal pollution dynamics within urban parks.

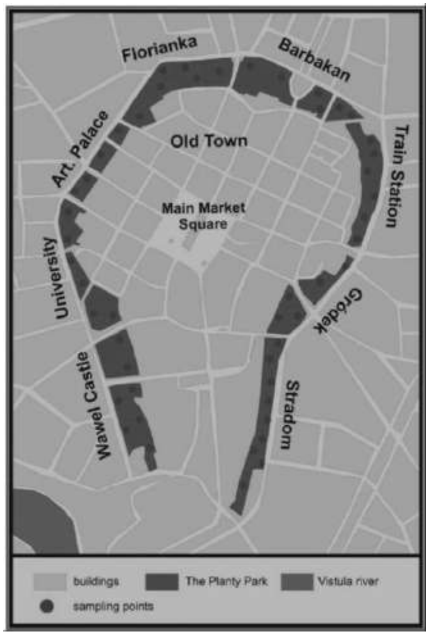

Figure 1. Location of study area.
Planty Park, Krakow (Gąsiorek et al., 2017)

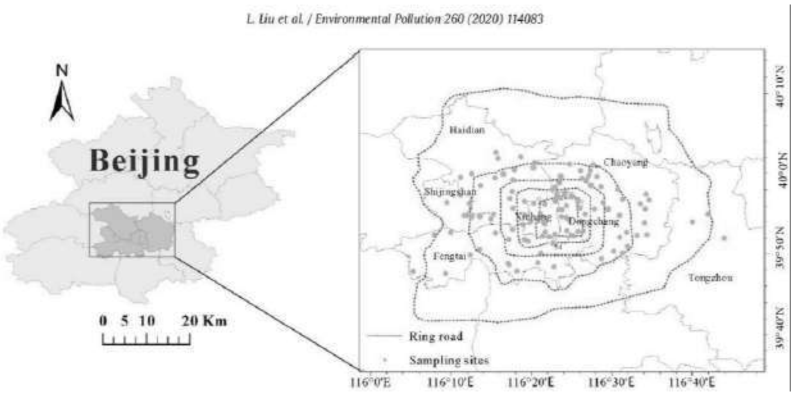

Fig. 2: Sampling sites of soils taken from the Beijing urban parks (Liu et al., 2020)

Results And Discussion

Our comprehensive analysis reveals elevated concentrations of heavy metals, notably Zn, Cr, Pb, Cu, Ni, As, Hg, and Cd (0.49 to 145.68 mg/kg) in urban park soils, reflecting historical evolution and contemporary pollution (Gąsiorek et al., 2017; Liu et al., 2020; Chen et al., 2005; Madrid et al., 2002 & Mazhari et al., 2018). Strong spatial correlations between Pb, Zn, and Cu suggest shared pollution sources. Conditional inference tree analyses highlight influential factors like soil type, pH, and proximity to the city center (Chen et al., 2005; Madrid et al., 2002).

Spatial distribution maps show distinct hotspots, with Cr concentrations in Chaoyang (Fig 2), Pb in the city center, and Cu/Zn in central and northeast regions (Liu et al., 2020). Human health risk assessments indicate risks below acceptable limits, while ecological risk assessments reveal a moderate risk for contamination (Gąsiorek et al., 2017; Mazhari et al., 2018).

Comparative analyses with non-urban soils demonstrate significant enrichments in Cd, Cu, Pb, and Zn in urban park soils (Gąsiorek et al., 2017; Chen et al., 2005; Madrid et al., 2002). Co, Cr, and Ni exhibit variability, requiring further investigation into their sources. Multivariate analyses identify urban contamination indicators, and sequential extraction studies provide insights into metal mobility and availability (Liu et al., 2020; Mazhari et al., 2018).

Table 2. Total content of heavy metal in soil surface of urban parks given in literature.

Author(s)	Location	Cd	Cr	Cu	Ni	Pb	Zn
		mg kg^{-1}					
Gąsiorek et al., 2017	Planty Park (Poland)	0.80	16.3	55.5	10.5	120.5	176.7
Chen et al., 2005	Beijing (China)	-	-	71.2	22.2	66.2	87.6
Luo et al., 2020	Xiamen Island (China)	0.49	63.57	35.49	27.12	36.43	145.68
Madrid et al., 2002	Seville (Spain)	-	39	68	22	137	145
Mazhari et al., 2018	Mashhad (Iran) high silica soils	-	119.12	57.23	110.2	87.6	125.4
	Mashhad city-Low silica soils	-	206.26	83.08	167.76	112.13	166.5

The examination of heavy metal pollution in urban parks across Krakow, Beijing, Seville, and Mashhad reveals a narrative deeply entwined with historical legacies and intensified by rapid urbanization. In Krakow's Planty Park, historical echoes from medieval ore processing and industrial revolutions persist, leaving a lasting impact on contemporary soil composition. Simultaneously, the pervasive influence of urbanization emerges as a common thread, transforming urban soils and inadvertently accumulating heavy metals, creating distinct challenges for environmental sustainability.

A global perspective highlights the interconnected nature of heavy metal pollution challenges in urban parks, emphasizing universal concerns for urban soil health. Commonalities in elevated concentrations of heavy metals such as Zn, Cr, Pb, Cu, Ni, As, Hg, and Cd underscore the shared journey through Krakow, Beijing, Seville, and Mashhad, emphasizing the need for collaborative efforts and a global approach to address the contemporary pollution challenges.

The amalgamation of diverse techniques, including ICP-OES, HCA, PCA, ICPMS analysis, and the BCR sequential extraction method, contributes to a comprehensive analysis of heavy metal pollution dynamics. These methodologies, while robust, should be interpreted considering their inherent limitations and potential biases. Insights from Gąsiorek et al.'s study in Planty Park, which indicate concentrations of Cd at 0.80 mg/kg, Cr at 16.3 mg/kg, Cu at 55.5 mg/kg, Ni at 10.5 mg/kg, Pb at 120.5 mg/kg, and Zn at 176.7 mg/kg, provide valuable data for understanding the specific dynamics of this urban environment. Similarly, findings from Chen et al.'s research in Beijing contribute concentrations of Cu at 71.2 mg/kg, Ni at 22.2 mg/kg, Pb at 66.2 mg/kg, and Zn at 87.6 mg/kg, offering additional layers to the comprehensive analysis. Luo et al.'s investigation in Beijing further enriches the dataset with concentrations of Cd at 0.49 mg/kg, Cr at 63.57 mg/kg, Cu at 35.49 mg/kg, Ni at 27.12 mg/kg, Pb at 36.43 mg/kg, and Zn at 145.68 mg/kg, providing nuanced insights into heavy metal pollution dynamics in this urban context.

The implications of elevated heavy metal concentrations extend beyond environmental concerns to encompass human health and ecological risks. Human health risk assessments indicate risks below acceptable limits, while ecological risk assessments reveal a moderate risk for contamination. Addressing potential discrepancies or uncertainties in these assessments is vital for establishing a more nuanced understanding of the complex interactions between heavy metals and urban ecosystems. Moving forward, the study prompts targeted recommendations for mitigating heavy metal pollution in urban parks. Tailored soil management approaches, considering the unique dynamics shaped by historical legacies and contemporary urbanization impacts, become imperative. Proactive environmental policies, driven by local governments and communities, play a pivotal role in implementing sustainable practices that strike a balance between environmental integrity and human well-being. Lastly, the study suggests future research directions to deepen our understanding of heavy metal pollution in urban parks. Prioritizing the exploration of lesser-studied heavy metals, investigating sources not extensively covered, and addressing emerging pollutants become focal points for interdisciplinary research. Integrating environmental science, urban planning, and public health offers a holistic approach to unraveling the complexities of heavy metal pollution in urban parks and guides informed decision-making for environmental care.

Conclusion

In conclusion, our comprehensive analysis, drawing insights from diverse urban parks globally, underscores the intricate interplay between historical evolution and contemporary heavy metal pollution challenges. The elevated concentrations of metals shared pollution sources and identified influential factors emphasize the need for targeted mitigation strategies. From Krakow to Beijing, Seville, and Mashhad, the review calls for tailored soil management approaches, recognizing the nuanced dynamics shaped by historical legacies and urbanization impacts. This collective understanding guides a holistic approach to address heavy metal pollution in urban parks, safeguarding both environmental integrity and human health. In summary, urbanization profoundly influences heavy metal concentrations in parks, emphasizing the need for targeted mitigation strategies to safeguard environmental and human health.

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Geospatial Technology-Based Soil Erosion and Sediment Yield Models

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Abstract

According to the most recent estimates, almost 36 billion tons of soil are lost year worldwide. Globally, soil erosion is leading to serious environmental concerns such as land degradation, downstream sedimentation, dam siltation, and loss of ecological value. Numerous soil erosion and sediment transport models exist, each with unique advantages and disadvantages. Soil erosion models differ in terms of output production, accuracy, complexity, and input requirements. In general, there are three types of models for soil erosion and sediment: conceptual, physical-based, and empirical. Especially for local or regional forecasting, the Revised Universal Soil Loss Equation (RUSLE) becomes a common option for estimating long-term rates of erosion. However, its limitation in routing sediment through channels restricts its applicability to small areas. Despite its effectiveness in modeling soil loss from storm events, the Watershed Erosion Prediction Project (WEPP) model has limitations because of its non-GIS interface and specific data needs. The soil and Water Assessment Tool (SWAT) model provides extensive evaluation by taking into account the whole hydrologic system of the watershed, spatial variability, and in-depth knowledge of numerous aspects. A model's suitability for a given project is determined by factors specific to it, including cost, project objectives, availability of input data, and simulation of either continuous or single-event processes. geospatial technology plays a crucial role in understanding and addressing soil erosion and sediment yield issues. These models' capacity to forecast the possibility of erosion and the transport of silt is improved by the application of geographic information sciences and data from remote sensing. This review paper shows the limitations and advantages of different soil erosion and sediment yield models.

Keywords: Geographic Information System, Modelling, Soil Erosion, Sediment Yield.

Introduction

The most recent estimates indicate that approximately 36 billion tons of soil are lost annually on a global scale (Borrelli et al., 2017). Soil erosion removes soil particles (nutrients and organic matter) from their origin due to eroding agents, including water, wind, and gravitational force. Land degradation, sedimentation of downstream and dam siltation and loss of ecological value are the major environmental problems occurring worldwide due to soil erosion. Therefore, it is necessary to determine the cause and effect of soil erosion and sedimentation downstream due to soil erosion, and it is used to group areas within the erosion severity class and to provide appropriate conservation measures for areas that are at risk (Wu and Chen, 2012).

There are many soil erosion and sediment transport models with their limitations and effectiveness over one another. Soil erosion models have complexity, accuracy, and different input requirements and output production. Generally, soil erosion and sediment models are classified as empirical models, physical-based models, and conceptual models (Hajigholizadeh et al., 2018) (Table 1). An empirical model is the simplest model which utilizes individual observation to simulate the natural process and it is based on developed regression relationships. The empirical model requires less amount of data than the other physical and conceptual models. The weakness of the empirical model utilization of unrealistic ideas and the ignoring of different characteristics of the watershed (Merritt et al., 2003). A physically based model is based on the law of conservation of mass and energy which requires a large amount of data and its parameter is independently measurable (Dutta and Sen, 2018; Hajigholizadeh et al., 2018). The conceptual model is a product of a physically based model and an empirical model that provides both qualitative and quantitative processes without considering the interaction between factors (Dutta and Sen, 2018). The main aim of this current paper is to review different soil erosion and sediment yield models that utilize remote sensing data and the application of geographic information sciences as this review will also give a clear insight to the readers about the limitations and strength of each soil erosion and sediment yield model.

Table 1. Soil Erosion and Sediment yield estimation models Source (Merritt et al., 2003)

Empirical model	Physical-based model	Conceptual model
USLE (Wischmeier and Smith, 1978)	ANSWERS (Beasley et al., 1980)	AGNPS (Young *et al.,* 1989)
SLEMSA (Elwell, 1978)	CREAMS (Knisel, 1980)	IQQM (DLWC, 1999)
RUSLE (Renard et al., 1996)	WEPP (Nearing et al., 1989)	EMSS (Vertessey et al., 2001)
PESERA (Kirkby et al., 2004)	PERFECT (Littleboy et al., 1992)	SWRRB (USEPA, 1994)
SEAGIS (DHI, 1999)	EUROSEM (Morgan *et al.,* 1998)	
	SWAT	

Revised Universal Soil Loss Equation (RUSLE)

RUSLE is the most popular technique used worldwide to forecast long-term rates of rill erosion and inter-rill erosion from field or farm-size units subject to various management techniques. The main limitation of RUSLE is that the sediment concentration of the flow controls detachment and deposition (Ganasri and Ramesh 2016). RUSLE is the most effective erosion prediction model which is simple to use at the local or regional level. Furthermore, it is simple to combine several factors, including slope and aspect, that are obtained from DEM and LULC (land use land cover) from satellite pictures with RUSLE. Due to its inability to route sediment through channels, RUSLE's applicability is restricted to small areas (Nearing et al., 1989). The model can forecast erosion potential on a cell-by-cell level when it is combined with a raster-based GIS. Finding the geographic patterns of soil loss within a watershed is made easier with this approach. Next, by separating and querying these sites using the GIS, important details regarding how each variable contributes to the reported erosion potential value can be obtained (Milliward, 1999). Because of the lack of availability and poor quality of the necessary inputs, applying over wide, unmonitored areas continues to be highly challenging (Kumar et al., 2022).

Watershed Erosion Prediction Project (WEPP Model)

The WEPP is developed to simulate soil loss from single storm rainfall events for different land use types (Albaradeyia et al., 2011). The method of partitioning the study area into several hill slopes and channels is the initial stage in applying WEPP. The data files can be directly loaded into the WEPP model, or the existing input files can be changed. Each hill slope and the channel have its own set of input files, The Soil input file includes soil characteristics for each hill slope, and In the Slope input file, the slope details are included, and Management input file specifies the management types. As input data, channel properties such as channel width and depth, hydraulic properties, channel bank management details, and soil characteristics are supplied. The simulation of a single storm event was chosen in the climatic input file. The properties (rainfall depth, intensity, pattern) of each rainfall occurrence are included in the climate input data, which are used to calibrate and validate the model. The model is calibrated using observed data from the first rainfall events. The simulation runs for each hill slope individually to compute the sediment yield at the bottom of each hill slope. The quantities are computed at the watershed's outlet after they are transported through channels (Chandramohan et al., 2015).

WEPP is a model that predicts daily soil loss and deposition due to rainfall, snowmelt, and irrigation (Mohammed et al., 2016). Because of its non-GIS interface and unique data requirements relating to sediment output and runoff generation, the model has limitations (Pandey et al., 2021a).

The Agricultural Non-Point Source Model (AGNPS) Model

The agricultural non-point sources model is the conceptual model developed by the integration of the United States Department of Agriculture, agricultural research service, soil conservation services, and the Minnesota Pollution Control Agency in the USA. It is effective in assessing the spatial distribution of soil erosion along with its impact on soil quality and loss of soil nutrients in the catchment, but it requires a large number of input parameters and the modeling approach is complex (Sarkar and Tapas, 2021).

An AGNPS is the revised version of AGNPS developed by USDA with well-defined consideration of daily step simulated results of surface runoff, sediment, soil nutrients, and the impact of pesticides on a larger watershed scale (Shen et al., 2016). The AGNPS model is a physically distributed event-based watershed scale model that requires climate, soil, topography, and land use as input and is capable of predicting non-point source pollution. It is accurate and flexible to use, and it can simulate soil erosion, sediment yield, runoff, and peak runoff rate based on storm events with one step as storm duration. The model has limitations such as being dependent on a single storm event, being data-intensive, having a lower scale of applicability (up to 25 km2), and not being able to simulate subsurface flow (Pandey et al., 2016).

The Pan-European Soil Erosion Risk Assessment (PESERA) model:

The Pan-European Soil Erosion Risk Assessment model (PESERA) is a physically based model that predicts hill slope erosion and sediment movement down a slope by synthesizing data to calculate the quantity and frequency of saturated overland flow in a grid cell using a simple soil moisture storage model. Climate data (monthly average rainfall, potential evapotranspiration, and temperatures), soil data (texture and accessible water capacity), land cover, including crop variety when applicable, and terrain are all needed to run the model. Finally, the model produces monthly sediment yields per grid cell (tones/ha) (Ahamefule et al., 2018).

By using grid data, the PESERA model can be used in two modes: estimating sediment yield data and estimating erosion risk. It is sensitive to soil erodibility factor and calculates soil erosion as the amount of sediment transported to the base of a hillside and delivered to the channel network (Berberoglu et al., 2020). When compared to other models like RUSLE, the model gives less accurate sediment yield while providing better predictions for mean erosion rate (Pandey et al., 2021b). The model is expressly based on sediment supplied to the hillside and does not take into account gully, channel erosion, channel delivery mechanisms, or routing (Cilek et al., 2015).

CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems)

A CREAM is a profile model that uses many average overland slope segments and channel slope segments to characterize the field and its attributes. CREAMS also allow you to make changes to the input parameters during the simulation. CREAMS were designed for a field-sized watershed that can range from less than one hectare to several hundred hectares. CREAMS calculate channel erosion based on user-defined parameters. The other models compute channel erosion only from sediment deposited in the channel during an event, not from any sediment contained in the channel before the beginning of an event (Bingner et al., 1989).

It comprises gully erosion and deposition in addition to overland erosion sources. Soil erosion, sediment deposition, surface runoff, and chemical transfer from agricultural land can all be simulated. This is based on a single storm event, and it is only suited for minor catchments and field sizes, with limited GIS integration (Pandey et al., 2016). It is a physical dynamic model that simulates runoff, erosion, and sediment yield on a daily basis. The model assumes constant terrain and land usage, and it ignores temporal fluctuations in soil erodibility, which is highly unrealistic in practice. For overland flows, CREAMS' erosion component uses USLE and sediment transport (Raza et al., 2021).

SWAT Model

SWAT is a physical-based long-term continuous Hydrological River basin to watershed scale model created by USDA ARS to forecast the effects of land management methods on water, sediment, and agricultural chemical yields with a large and complicated watershed in a range of soil, land use, and management scenarios over a long-time frame (Neistch et al., 2005).

SWAT divides a catchment into several sub-catchments, which are subsequently separated into hydrologic response units (HRUs), which are composed of uniform land use, management, and soil characteristics (Emiru et al., 2022). The hydrological process in the watershed is analyzed based on the water balance equation (Gull and Shah, 2021).

For each HRU surface runoff volumes and peak runoff rates are simulated using daily or sub-daily rainfall amounts using the modification of soil conservation. Digital Elevation Model (DEM), Land use/Land cover, soil cover, and precipitation in the SWAT input format are required in the simulation of a watershed using SWAT. The software generates the watershed boundary, HRU (Hydrological Response Unit) analysis, writes input tables, edits input data, and SWAT simulation. After the completion of this process, the output file can be generated and that helps us to plot the graphs and maps. According to Neistch et al., (2005), the land phase of the hydrological cycle is determined by using the water balance equation.

$$SWt = SW0 + (Rday - Qsurf - Ea - Wseep - Qgw) \quad (1)$$

Where SWt is the final soil water content (mm), SW0 is the initial soil water content on day i (mm), t is the time (days), Rday is the amount of precipitation on day i (mm), Qsurf is the amount of surface runoff on day i (mm), Ea is the amount of evapotranspiration on a day i (mm), Wseep is the amount of water entering from the soil profile on a day i (mm), and Qgw is the amount of return flow on a day i (mm) (Naqvi et al., 2019). Surface runoff is estimated using the soil conservation services curve number method and green and ampt method (USDA Soil conservation services, 1972).

$$S = 25.4\ (1000/CN-10) \quad (2)$$

Where CN = curve number for the day, S= Surface runoff

$$Qsurf = ((R\_day-0.2S))/((R\_day-0.8S)) \quad (3)$$

The soil retention parameter (S) varies regionally with soil type, land use, and management approaches as well as temporally with variations in moisture content. It can also be considered that it changes depending on the total plant evapotranspiration (Al Khoury et al., 2023). Sediment yield is estimated using a modified universal soil loss equation.

$$A= 11.8\ (Qs *qp*Ahru)0.56*K*LS*C*P * Cfrg \quad (4)$$

Where A: Sediment yield (metric tons) Qs: surface runoff volume (mm per hectare), qp: peak runoff rate(m3/s), Ahru: area of hydrologic response unit(hectares), K: soil erodiblity factor, C: cover and management factor, P: support practice factor, LS: topographic factor, Cfrg: coarse fragment factor (Gull and Shah, 2021).

SWAT has been criticized for its high data intensity and input requirements. The model is dependent on a large quantity of spatial and temporal data, and acquiring accurate and comprehensive data for all of the essential parameters may be difficult (Neitsch et al., 2011; Arnold et al., 2012). The SWAT model calibration process can be complicated and time-consuming (Arnold et al., 2012; Moriasi et al., 2007). Another issue is SWAT's sensitivity to input parameters (Moriasi et al., 2007; Abbaspour et al., 2007). The model's complexity may make it difficult for inexperienced users to set up and run efficiently (Abbaspour et al., 2007; Neitsch et al., 2011). Many of these issues are addressable by proper application, calibration, and validation methods.

Model selection criteria

There are some criteria to consider while choosing the best model for a given problem. These criteria are always project-specific, with each project having its unique set of requirements. Furthermore, some criteria are based on the preferences of the user (Subjective). Hydrologic processes must be modeled to accurately anticipate the intended outputs (Can the model simulate single-event or continuous processes?). Availability of input data (Capacity and capability that means can all of the model's parameters be given within the project's schedule, data quality and budget constraints? Price (Does the investment appear to be justified in light of the project's goals?) (Juhar, 2018).

There are distinct advantages to using the SWAT model over the RUSLE. SWAT consider the entire hydrologic system of the watershed while RUSLE focuses on estimating soil erosion on individual plot. It consider the spatial variability of land use, soil properties and hydrological characteristics with in the catchment, allowing for a comprehensive analysis of water resources and sediment yield. It is physically based, rather than using regression equations to describe the link between input and output variables, SWAT consider the complexity of the watershed and relies on detailed knowledge about the weather, soil qualities, terrain, vegetation, and land management activities that occur in the watershed. It is computationally efficient, allowing for the simulation of very large basins or a range of management options without spending too much time or money. While SWAT may be used to investigate more specific processes such as sediment movement, the basic data required to execute a run is easily available from government organizations Neitsch et al., (2005) used in a wide range of scenarios (suitable and yielded positive results). It is easily accessible and unrestricted (Juhar, 2018).

Conclusion

Soil erosion is a serious environmental problem that causes downstream sedimentation, dam siltation, and land degradation. Models of soil erosion and sediment yield have been developed in response to the need for understanding the causes and consequences of soil erosion. These models, categorized as empirical, physical-based, and conceptual, vary in complexity, accuracy, and input requirements. Several well-known models, such as RUSLE, WEPP, AGNPS, PESERA, CREAMS, and SWAT, were emphasized in the literature study. Every model has advantages and disadvantages, depending on factors like the amount of data required how widely it can be applied, and how well it can simulate processes. For instance, RUSLE is frequently used to predict the possibility of erosion at the local or regional level, but it is not very effective at routing sediments through channels. WEPP, while effective in simulating soil loss from single storm events, faces challenges due to its non-GIS interface and unique data requirements.

The AGNPS model is a complicated modeling process and requires many input parameters, but it is useful in evaluating the impact on soil quality and its spatial distribution. While PESERA offers precise mean erosion rate forecasts, it is less accurate in terms of sediment yield when compared to other models such as RUSLE. CREAMS is restricted to small catchments and field sizes, but it covers gully erosion and deposition and allows adjustments to input parameters during simulation. Because of its accessibility, adaptability, and computational efficiency, SWAT is a recommended approach in a variety of situations. This review helps researchers and practitioners make decisions based on their needs by offering insightful information about the advantages and disadvantages of each model.

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