Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 2 No. 3 (October) (2024)

Heavy Metal Stabilization in Agricultural Soils Using Biochar: Case Studies from European and Asian Agricultural Practices

Naheed Sharif (Corresponding Author)
Institute of Chemistry, University of Sargodha, Pakistan.
Email: zaibch767@gmail.com

Talha
Department of Biological Sciences, University of Veterinary and Animal Sciences Lahore, Pakistan

Muhammad Shahbaz
Department of Chemistry, Faculty of Sciences, Superior University, Lahore, Pakistan

Farheen Fatima
Department of Chemistry, Comsats University Islamabad, Pakistan

Zonaira Nasir
Institute of Chemistry, University of Sargodha, Pakistan.

Muhammad Tahir Zaman
Department of Chemistry, School of Science, University of Management and Technology, Lahore Pakistan

Abstract
The increasing number of heavy metal pollutants in agricultural soil poses a significant threat to the safety of food and the sustainability of land management, specifically in Europe and Asia. The practice of intensive agriculture has led to a higher probability of soil degradation. Heavy metals like lead, cadmium, and zinc can be stored in the soil, this adversely affects the health of crops and ultimately reaches the food chain, putting a threat to human health. In this context, biochar has become popular due to its high capacity to adsorb toxins, this enables the immobilization of these toxic metals. This investigation explores the role of biochar in alleviating the pollution of heavy metals across diverse agricultural landscapes in Italy, Poland, Norway, Germany, and Belgium, utilizing lattice models to explain the interactions between biochar and heavy metals. The investigation aims to understand the different levels of efficiency of biochar in different soil types, which are affected by factors like the pH of the soil and its organic content, it also highlights the necessity of region-specific strategies in order to maximize the efficiency of biochar. Through case studies of various European agricultural methods, this paper provides empirical evidence of the effectiveness of biochar, specific to the soil restoration efforts of specific individuals. Additionally, practical advice is provided regarding the best way to utilize biochar in agriculture, the purpose of these practices is to support

sustainable farming and enhance safety of food. Ultimately, this research contributes to the larger conversation about innovative solutions to soil remediation and the sustainable management of polluted agricultural land, advocating for the incorporation of biochar into conventional soil management methods.
Keywords: Heavy metal pollutants, Agriculture soil, Biochar

Introduction

In Europe and Asia, where the land is already under immense pressure, the growing pollution of farming soils by heavy metals poses a major threat to food security and the sustainable use of the land. Especially when it is in combination with the wide incorporation of intensive farming, soil degradation tends to increase and enhances a more frequent presence of toxic heavy metals such as lead, cadmium, and zinc. These pollutants hamper the health and productivity of crops and also enter the food chain to create chronic toxicity to humans. It is now, therefore, one of the most critical challenges for long-term sustainability of agricultural systems and public health protection (Zaib et al., 2023a).
It is only recently that biochar has been considered as an effective remedy in the detoxification of heavy metals in soils. The effectiveness of biochar in adsorption and immobilization of porous structures due to high surface area of toxic metals, thus crops do not take them up. Those heavy metals are bioavailable due to this immobilization, decreasing the amount of heavy metals in the soil. Therefore, biochar is expected to be an option to remediate soil for agricultural purposes. Studies throughout Europe & Asia in different areas show promise for biochar usage in enhancing soil quality and sustainability of agricultural practices (Zeeshan et al., 2023a).
These are some of the case studies done in Italy, Poland, Norway, Germany, and Belgium where biochar has been applied to agricultural soils for the attenuation of heavy metal pollution. The work reviews how effective biochar is in various types of soils considering some important factors that influence the capacity of biochar to stabilize different pH levels, and the amount of organic content in the soils. This case study will therefore indicate some of the region-specific approaches that can be used to optimize the benefits that come from the application of biochar in soil remediation, an area vital in achieving most of the objectives of sustainable land management and food safety in heavily polluted agricultural landscapes.

Biochar Role in Immobilizing Heavy Metals

In fact, it has been realized that biochar has capacity for heavy metals adsorption due to a large number of parameters in its production process and structural properties of biochar. For example, the organic matter structure, polar functional groups, and ash content, under the conventional preparation temperatures are crucial in determining the heavy metal sorption capacities of biochar. Also, markedly improved abilities to adsorb by biochar through different means, for example, radionuclides were obtained after modification with hydrogen peroxide. For example, the work of Gao et al. (2020) stated that the sorption capacity of H2O2-modified rape straw biochars for Pb was three times that for the unmodified material. It supported the statement from the work done by Wang et al. (2018) which revealed that gBio-Pb-III achieved a mean improved

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

sorption capacity for the uptake of Pb when compared to previously reported data a value of 10.6 g Pb/kg compared to the previously established value 2.92 g/kg. A further advantage of these modifications is that they broaden the ranges of pH and ionic strength under which biochar can be used in practice. Research by Zaib et al. (2023b) showed that the thiol-modified pine sawdust biochar greatly sorbed mercury and methylmercury from aqueous solutions, especially when prepared at lower temperatures. In this regard, the material and modifications will continue to be singled out as best suited for specific heavy metal sorption with improved potential for environmental remediation. Apart from modifying the sorption capacities for heavy metals in agricultural soils, the application of biochar also significantly transforms the bioavailability and uptake of these metals by different plants. In both alkaline and acidic pH conditions, garden waste biochar and mulberry biochar reduced the soil phytoavailable levels of Cd and Pb. This reduction in toxic metal availability bears a direct impact to the health and yield of crops. The biochar additions resulted in an increase in essential soil nutrients such as N and P, important for the growth and development of plants. Additionally, biochar's presence in the soil raises the soil pH level, the major criterion in strengthening the adaptation of plants towards toxic metal contamination; this primarily happens in acidic soils. It means that the metal uptake by plants mostly depends on the interaction of biochar with soil properties in addition to pH and nutrient status. Alteration of soil environment by biochar amendments thus reduces not only the uptake of toxic metals by plants but also such practices increase the general soil health and its productivity. This mutual interaction between soil chemistry and the physiological response of plants attests to the diverse advantages resulting from the amendment of biochar in the management of heavy metal pollution in agricultural soils (Zaib et al., 2023c).

Mechanisms enable biochar to immobilize heavy metals

The immobilization mechanisms of heavy metal by biochar are multifold and much influenced by metal or metal oxide modifications. Enhancements in the sorption capacity of biochar brought about by such modifications lead to effective immobilization of heavy metals like Cd and Pb under different soil conditions. Increased sorption capacity results from better ion exchange properties and the introduction of nitrogenous functional groups that ease the absorption of heavy metals. Modification can be done in different ways; for example, the mixing of elements of metals or metal oxides with raw material before pyrolysis or immersing pre-made biochar into metal ions or metal oxides (Zaib et al., 2023d; Zeeshan et al., 2023b). These changes give biochar quite different physicochemical properties from those of a material that is responsible for photocatalytic and oxidation/reduction reactions (Zeeshan et al., 2023c). It could improve further the immobilization process. This resulted in an increased surface area and abundant functional groups, providing numerous binding sites for heavy metal ions. For example, the combined use of biochar with phosphate-solubilizing bacteria (PSB) showed a marked increase in stable mineral phase formation over the surface of biochar, thereby assisting immobilization of heavy metals (Zeeshan et al., 2023d). Furthermore, biochar added to soil enhanced soil enzyme activity, which again helps in the immobilization of heavy metals in contaminated soils. Therefore, the work with changing biochar structure and its interaction with soil constituents underlines it as a promising technique of heavy metal remediation in diverse environmental conditions (Zaib et al., 2023e).

Regional Variations in Biochar Effectiveness

Differential effects of biochar on heavy metal immobilization are applied into soil because soil types have very direct interactions with what biochar is. For example, high moisture content in the soils will facilitate better interactions between biochar and heavy metals because most of these interactions are within the soil solution phase (Zeeshan et al., 2023e). This has pronounced effects in most cases of acidic soils that usually coarse texture and low in organic matter where biochar would express much of its effects on stabilization of cationic heavy metals. Soil pH plays a fundamental role; the higher the pH values, the higher cation exchange capacity (CEC), and ash content inside biochar, the more it will stabilize heavy metals. All of them enhance the general efficiency of stabilization attained by biochar in diverse classes of soil (Zaib et al., 2023f). Nevertheless, the long-term efficacy of biochar amendments can reduce, implying that the soil condition needs regular monitoring and other management practices to maintain high levels of heavy metal immobilization (Zeeshan et al., 2023g). Thus, an insight into the interaction between soil type and biochar characteristics is paramount for the enhanced immobilization of heavy metals with concomitant sustainable soil health (Zeeshan et al., 2023h; Zaib et al., 2023g).

The efficiency of biochar in improving soil organic carbon (SOC) is diverse with several organics and soil textures (Zeeshan et al., 2023i; Zaib et al., 2023h). Variability also is reported to occur with feedstock used in the production of biochar in their efficiencies of sequestering SOC, where plant and wood-based biochars usually are better than those from animal excreta. This has been attributed to their higher C/N ratios, which were much higher for plant and wood-based biochars than animal excreta biochar and that positively affects SOC (Zaib et al., 2023i). Besides, in some cases, applications with organic fertilizers can also increase SOC levels, further showing the synergistic effects of combining biochar with other organic amendments (Zeeshan et al., 2024a). Soil texture also played an important role, with medium to fine grain textures proving to selectively accumulate more SOC following the application of biochar than the coarser textured, demonstrating probably that finer textured soils give better physical protection and stability to SOC (Zaib et al., 2023j). The above interaction between the organic content of biochar, the type of feedstock, and soil texture clearly stresses that, to maximize SOC sequestration and any other potential effects on soils, all biochar applications should be tailored based on specific soil characteristics (Zaib et al., 2023k).

Case Studies from European Agricultural Practices

The interactions between treatments with biochar and Italian and Polish soils to alter dynamics of organic carbon and other soil properties are testament to the intricate relations among biochar treatment levels and soil attributes. At the end of the day, mean values of Corg increased after biochar application, yet the specific dynamics during the 2017–2018 vegetation period differed from treatment to treatment. Especially, for the treatments B10N0 and B20N0, the Corg showed a clear trend to decrease with time during these vegetation seasons. Such disparate results mean that although biochar might have the potential to

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

improve carbon levels in the soil, how much and for how long a period this benefit may be accrued could depend on the very particular rates of biochar application and on the presence of nitrogen fertilization. From the results obtained, it means that there is the greatest increase in Corg in treatment B20N1 compared to that in control treatment B0N1 (Zaib et al., 2023l). This re-emphasizes the role of high biochar application, especially combined with nitrogen fertilization, in the enhancement of total soil carbon. Apart from total soil carbon, the effects that biochar imposed on soil fertility and physical properties were immense, such as better soil water holding capacity and reduced soil bulk density, which both have impacts on drought resilience and plant growth. The sustainability of these benefits in the long run forms an interesting area of further research with caution that the benefits might start reducing over time. In the whole, though promising in terms of improved soil properties and carbon sequestration, biochar application has to be handled with special attention to rates of application, supplementations with nitrogen, and their long-term effects to maximize its agricultural benefits (Zaib et al., 2023m).

The particular outcomes that can be observed in Belgium's agricultural soils resolutely express a blend of good and bad environmental aspects (Zaib, 2024a). Among these outcomes is one of the most essential: the absence of a real loss of soil or maintenance of soil mass as an essential indicator of ecosystem integrity. Basically, these outcomes have been reported due to noninversion tillage practices being very extensively applied in Belgium agriculture, which improves soil management relative to the more traditional approaches. These fit in with the outcomes of several meta-analyses that situate agricultural practices as those practices having a direct impact on soil structure amid the very diversified agro-environmental conditions of Europe. This, however, does not turn into adequate positive results, as the actions of the policy measures against soil erosion generally remain rather inconsistent and underestimated by policymakers concerning the potential these agronomic techniques have. This causes a much more coherent policy proposal for optimum generalization and effectiveness of soil conservation practices across Belgium (Zaib et al., 2023n).

Practical Insights for Biochar Application

The interactions between treatments with biochar and Italian and Polish soils to alter dynamics of organic carbon and other soil properties are testament to the intricate relations among biochar treatment levels and soil attributes. At the end of the day, mean values of Corg increased after biochar application, yet the specific dynamics during the 2017–2018 vegetation period differed from treatment to treatment. Especially, for the treatments B10N0 and B20N0, the Corg showed a clear trend to decrease with time during these vegetation seasons (Afzal et al., 2023). Such disparate results mean that although biochar might have the potential to improve carbon levels in the soil, how much and for how long a period this benefit may be accrued could depend on the very particular rates of biochar application and on the presence of nitrogen fertilization (Zaib, 2024b). From the results obtained, it means that there is the greatest increase in Corg in treatment B20N1 compared to that in control treatment B0N1 (Zaib et al., 2023o). This re-emphasizes the role of high biochar application, especially combined with nitrogen fertilization, in the enhancement of total soil carbon (Zaib et al., 2024a). Apart from total soil carbon, the effects that biochar imposed

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

on soil fertility and physical properties were immense, such as better soil water holding capacity and reduced soil bulk density, which both have impacts on drought resilience and plant growth [38]. The sustainability of these benefits in the long run forms an interesting area of further research with caution that the benefits might start reducing over time (Ge et al., 2024). In the whole, though promising in terms of improved soil properties and carbon sequestration, biochar application has to be handled with special attention to rates of application, supplementations with nitrogen, and their long-term effects to maximize its agricultural benefits (Zaib et al., 2023p).
In Norway and Germany, both countries have extensively assessed biochar for its effectiveness in soil remediation. However, results are highly variable between specific environmental conditions and biochar origin (Aslam et al., 2023). Indeed, wheat straw biochar from Norway proved promising regarding reductions in contamination of soils as well as improving soil fertility (Zubair et al., 2024a). Correspondingly, in Germany, the efficiency of carbon sequestration and its retention by kiln-type biochar, like that from Carbon Terra, was very high, which means soil remediation and climate change can be tackled with one stone. Such comparative studies across the countries reiterate the necessity of local adaptation of biochar types and methods of its application to soil conditions and agricultural practices (Bayar et al., 2024). Such site-specific technologies are indeed needed, as technological application effectiveness for the creation of biochar in the case of Germany and Norway is several times higher, where developed technology for biochar production from kilns addressed specific soil contamination problems much better (Iftikhar et al., 2023). The next task of the scientific community is to optimize these place-specific technologies to enhance the efficiency of biochar for soil remediation while designing biochar application methodologies that will also enhance sustainable agricultural practices and environmental health (Zaib et al., 2023r).
The particular outcomes that can be observed in Belgium agricultural soils resolutely express a blend of good and bad environmental aspects. Among these outcomes is one of the most essential: the absence of a real loss of soil or maintenance of soil mass as an essential indicator of ecosystem integrity (Zubair et al., 2024b). Basically, these outcomes have been reported due to noninversion tillage practices being very extensively applied in Belgium agriculture, which improves soil management relative to the more traditional approaches (Zeeshan et al., 2024b). These fit in with the outcomes of several meta-analyses that situate agricultural practices as those practices having a direct impact on soil structure amid the very diversified agro-environmental conditions of Europ. This, however, does not turn into adequate positive results, as the actions of the policy measures against soil erosion generally remain rather inconsistent and underestimated by policymakers concerning the potential these agronomic techniques have. This causes a much more coherent policy proposal for optimum generalization and effectiveness of soil conservation practices across Belgium (Zeeshan et al., 2024c).

Lattice Models in Biochar Research

Lattice models have emerged as vital instruments for comprehending the intricate interactions between biochar and heavy metals, providing microscale simulations that illustrate how the adsorption efficiency of biochar is influenced

Dialogue Social Science Review (DSSR)
www.journalforeducationalresearch.online

ISSN Online: 3007-3154
ISSN Print: 3007-3146

DIALOGUE SOCIAL SCIENCE REVIEW

Vol. 2 No. 3 (October) (2024)

by its physical characteristics and production conditions (Zeeshan et al., 2024d). These models enable researchers to investigate the crystal lattice structure of biochar, pinpointing interaction sites and mechanisms, including the stretching behavior of the graphite lattice, which is crucial for the immobilization of heavy metals. Findings from experiments utilizing ternary and quaternary solutions further clarify the complex dynamics present within the biochar lattice, revealing how structural modifications can enhance its adsorption capabilities (Zeeshan et al., 2024e). Furthermore, the examination of biochar's molecular structure, including its polyaromatic layers and lattice fringes, through methodologies such as Electron Spin Resonance (ESR), yields essential insights regarding its reactivity and stability. Mesoscale modeling, particularly through the Lattice Discrete Particle Model, has uncovered the impact of structural damage on the functionality of biochar, while enhancements made with functional agents, such as magnetic precursors and alkalis, have markedly increased its adsorption capacity (Zaib & Adnan, 2024). Additionally, the role of biochar in soil remediation is closely associated with its physicochemical properties, which can be improved through modifications such as the addition of magnesium or activation techniques involving metallic potassium (Shaukat et al., 2023). The enhancements made to biochar not only enhance its capacity to immobilize heavy metals but also facilitate improvements in soil health, including heightened fertility and diminished pollution levels. The study underscores the necessity for additional investigation into the long-term effects of biochar on soil ecosystems, particularly concentrating on the development of biochar-based nanocomposites and the optimization of application rates across various agricultural practices (Zaib et al., 2024b).

References

Afzal, A., Zubair, H., Abid, S., Shahzaib, M., Hassan, M., Khalid, S., Ahmad, A. & Zaib, M. (2023). Impacts of Water Logging on Soil Microbial Intentions and Mung Bean (*Vigna radiata L.)* Physiology. Indian Journal of Pure & Applied Biosciences. 11(6), 68-79. DOI: http://dx.doi.org/10.18782/2582-2845.9036

Aslam, Saira & Mansoor, Mubeena & Bano, Sadaf & Zeeshan, Ali & Ilyas, Aqsa & Eman, Anam & Javed, Fatima & Baksh, Muhammad. (2024a). Ethnoveterinary Study of Medicinal Plants of District Okara, Pakistan. Journal of Health and Rehabilitation Research, 4(2),963-970.

Iftikhar, Anwaar & Aijaz, Nazish & Farooq, Rida & Aslam, Sadaf & Zeeshan, Ali & Munir, Mariyam & Irfan, Muhammad & Mehmood, Tahir & Atif, Muhammad & Ali, Muhammad & Shiraz, Anabia. (2023). Beneficial Role of Phosphate Solubilizing Bacteria (PSB) In Enhancing Soil Fertility Through A Variety Of Actions On Plants Growth And Ecological Perspective: An Updated Review. Xi'an Shiyou Xueyuan Xuebao/Journal of Xi'an Petroleum Institute (Natural Science Edition). 19.(9) 520-547.

Shaukat, Shama & Zeeshan, Ali. (2023). APPLICATION OF FLOATING WETLAND FOR TREATMENT OF PAPER MILL WASTEWATER. J. Plantarum.5.(1) 69-86.

Zaib, M., Abbas, Q., Hussain, M., Mumtaz, S., Khalid, M., Raza, I., Abbas, S., Danish, M., Abbas, R., Muhammad, N. & Bano, S. (2023a). Micronutrients and Their significance in Agriculture: A Mini Review with Future

Prospects Corresponding Author address. International Research Journal of Education and Technology. 05(04), 234-252.

Zaib, M., Aryan, M. & Ullah, H. (2023b). Innovative Inorganic Pollutant Bioremediation Approaches for Industrial Wastewater Treatment: A Review. International Journal of Scientific Research and Engineering Development. 6(4), 1294-1304

Zaib, M., Farooq, U., Adnan, M., Abbas, Z., Haider, K., Khan, N., Abbas, R., Nasir, A., Sidra., Muhay-Ul-Din, M., Farooq, T., & Muhammad, A. (2023c). Optimization water stress in crop plants, implications for sustainable agriculture: current and future prospects. Journal of Environmental & Agricultural Sciences. 25 (1&2): 37-50.

Zaib, M., Ibrahim, M., Aryan, M., Mustafa, R., Zubair, M., Mumtaz, S. & Hussain, T. (2023d). Long-Term Efficacy of Biochar- Based Immobilization for Remediation of Heavy Metal-Contaminated Soil and Environmental Factors Impacting Remediation Performance. International Journal of Scientific Research and Engineering Development. 06(05), 58-72

Zaib, M., Raza, I., Zubair, M., Arif, Z., Mumtaz, M., Abbas, M.Q., Javed, A., Salman, S., Sikandar, A., Kashif, M., Muneeb, M. & Uzair, M. (2023e). Nano-Enabled Soil Amendments for Improved Soil Structure and Water Holding Capacity: An In-depth Review. International Research Journal of Education and Technology. 05(08), 344-357.

Zaib, M., Sandhu, M., Zar, M., Ghani, U., Rehman, A., Musharraf, M., Zubair, M., Abbas, R. & Raza, I. (2023f). A Brief Review on Plant Growth Promoting Rhizobacteria (PGPR): A Key Role in Plant Growth. International Research Journal of Education and Technology. 05(07), 104-126.

Zaib, M., U. Farooq, M. Adnan1, S. Sajjad, Z. Abbas, K. Haider, N. Khan, R. Abbas, A.S. Nasir, M.F. Muhay-Ul-Din. (2023g). Remediation of Saline Soils by Application of Biochar: A Review. Journal of Agriculture and Environmental Sciences. 24(3&4): 29-36

Zaib, M., Zeeshan, A., Akram, H., Amjad, W., Aslam, S. & Qasim, S. (2023h). Impact of Climate Change on Crop Physiology and Adaptation Strategies: A Review. International Research Journal of Education and Technology. 05(08), 15-38.

Zaib, M., Zubair, H., Afzal, A., Naseem, M., Maryam, D., Batool, S., Raza, S., Umar, M., Marium, A. & Tariq, H. (2023i). Biofortification for Enhancement of Micronutrient Contents in Cereals. Indian Journal of Pure & Applied Biosciences. 11(6), 53-67. DOI:http://dx.doi.org/10.18782/2582-2845.9035

Zaib, M., Zubair, H., Akbar, H., Zahra, M., Ali, U., Afzal, A., & Marium, A. (2023j). Emerging Trends in Biofortification for Microelement Enrichment in Crop Edibles: Implications for Health. Curr. Rese. Agri. Far. 4(4), 15- 24. DOI: http://dx.doi.org/10.18782/2582-7146.204

Zaib, M., Zubair, M., Aryan, M., Abdullah, M., Manzoor, S., Masood, F. & Saeed, S. (2023k). A Review on Challenges and Opportunities of Fertilizer Use Efficiency and Their Role in Sustainable Agriculture with Future Prospects and Recommendations. Curr. Rese. Agri. Far. 4(4), 1-14. doi: http://dx.doi.org/10.18782/2582-7146.201

Zaib, M., Zubair, M., Mumtaz, S., Shaheen, C., Muqaddas, A., Sarwar, R., Noman, M., Irfan, M., Aman, Z., Hanan, A. & Sajid, S. (2023l). Trace Elements

Behavior in Salt- Affected Soils: A Review. International Journal of Scientific Research and Engineering Development. 06(05), 73-81.

Zaib, M., Zubair, M., Nawaz, S., Haider, W., Shafiq, M., Cheema, Q., Shabbir, U., Nawaz, H., & Noor, M. (2023m). In-Situ Remediation Strategies to Treat Polluted Water: A Review. International Research Journal of Education and Technology. 05(08), 331-343.

Zaib, Muhammad & Aryan, Muhammad & Khaliq, Adnan & Haider, Kamran & Ahmad, Safwan & Zeeshan, Ali & Haq, Ul & Ahmad, Umair & Rajuwa, Hussain & Zubair, Hassan. (2023n). Essential Insights for Effective Environmental Management and Human Well-being: Strategies for Remediation in Soil-Plant- Environment Systems. Journal of Asian Development Studies, 12(3), 1453-1469.

Zaib, Muhammad & Muneeb Hassan, Muhammad & Hassan, Muhammad Haseeb & Zeeshan, Ali. (2024a). Soil Microbes and Human Health: A Comprehensive Review. Int J Contemp Issues Soc Sci, 3(1), pp.939-951

Zaib, Muhammad & Zeeshan, Ali & Akram, Humaira & Amjad, Waheed & Bano, Sadaf & Aslam, Saira & Qasim, Samreen & Faiz, Sidra & Nazar, Aquib & Nazim, Farah. (2023p). Innovative Approaches Utilizing Plant-Based Techniques for Soil Conservation: An In-depth Review. Int Res J Educ Technol, 5(08), 319-330.

Zaib, Muhammad & Zeeshan, Ali & Akram, Humaira & Hameed, Sunila & Wakeel, Ammara & Qasim, Samreen & Aslam, Saira. (2023q). Soil Contamination and Human Health: Exploring the Heavy Metal Landscape: A Comprehensive Review. Journal of Health and Rehabilitation Research. 3(2), 351-356.10.61919/jhrr.v3i2.123.

Zaib, Muhammad & Zeeshan, Ali & Akram, Humaira & Nazim, Farah & Nawaz, Sidra & Abdullah, Zain & Baksh, Muhammad. (2024b). Navigating Food Security Challenges in Emerging Populations. Emerging trends in sustainable agriculture. 69-94

Bayar, Jalal & Ali, Nawab & Dong, Younsuk & Ahmed, Uzair & mehran anjum, Muhammad & Khan, Gul & Zaib, Muhammad & Jalal, Arshad & Ali, Rovaid & Ali, Liaqat. (2024). Biochar-based adsorption for heavy metal removal in water: a sustainable and cost-effective approach. Environmental Geochemistry and Health. 46. 428. 10.1007/s10653-024-02214-w.

Ge, Shiji & Zhiqiang, Jiao & Gao, Chenyang & Zaib, Muhammad & Ruan, Xinling & Wang, Yangyang. (2024). Potential Health Risks for Long-Term Stays in Underground Parking Garages: Implications of Polycyclic Aromatic Hydrocarbons in Surface Dust. Indoor Air. 2024. 5527710. 10.1155/2024/5527710.

Zaib, Muhammad. (2024a). Biofortification: Bridging the Nutrient Gap in Chinese Agricultural Practices. International Journal of Contemporary Issues in Social Sciences. 3. 902-911.

Zaib, Muhammad. (2024b). Boron Nutrient for Sustainability of Plant Growth and Soil Health: A Review with Future Prospects. International Journal of Contemporary Issues in Social Sciences. 3. 912-931.

Zaib, Muhammad & Adnan, Muhammad. (2024). Phytoremediation: A Comprehensive Look at Soil Decontamination Techniques. International Journal of Contemporary Issues in Social Sciences. 3. 998-1029.

Zaib, Muhammad & Zeeshan, Ali & Aslam, Saira & Bano, Sadaf & Ilyas, Aqsa & Abbas, Zeeshan & Nazar, Aquib & Mumtaz, Sana. (2023r). Drought Stress and Plants Production: A Review with Future Prospects. International Journal of Scientific Research and Engineering Development 6.(4) 1278-1293

Zeeshan, A., & Zaib, M., Ahmad, S., Akram, H. & Qasim, S. (2023a). Diversity of Weeds in Rose Field in District Kasur Punjab Pakistan. Int. J. Adv. Res. Sci. Technol. 12(09), 1122-1132.

Zeeshan, A., Nazar, A., Akram, H., Hafeez, I., Tariq, A., Ali, G., ... & Ahmed, Z. (2023b). PARTHENIUM HYSTEROPHORUS L: A REVIEW OF ITS PHYTOCHEMICAL, BIOLOGICAL AND THERAPEUTICAL APPLICATIONS. Lahore Garrison University Journal of Life Sciences, 7(03), 281-302.

Zeeshan, Ali & Abbas, Muhammad & Qasim, Samreen & Nawaz, Laiba & Najam, Mahnoor & Waqas, Muhammad & Zubair, Muhammad & Haider, Zawar. (2024a). Addressing Nutrient Deficiencies through Zinc Biofortification. Emerging trends in sustainable agriculture. 95-146

Zeeshan, Ali & Akram, Humaira & Ilyas, Aqsa & Niaz, Shereen & Nazar, Aquib & Shakeel, Yasha. (2023c). Solanum nigrum Linn: An analysis of the therapeutic properties of plant. Journal of Pure and Applied Agriculture, 8(4): 1-10

Zeeshan, Ali & Akram, Humaira & Nasir, Awon & Manzoor, Saba. (2023d). Historical Significance and Modern Applications of Turmeric (Curcuma longa) in Traditional Medicine and Beyond. int. Res. J. Educ. Technol 5 (11): 113-123

Zeeshan, Ali & Akram, Humaira & Nazar, Aquib & Shoukat, Adnan & Pearl, Carmel & Nazim, Farah & Faiz, Sidra. (2024b). Medicinal Importance of Ginger (Zingiber officinale): A Systematic Review. GU JOURNAL OF PHYTOSCIENCES .4(1)331-342.

Zeeshan, Ali & Akram, Humaira & Qasim, Samreen & Naseer, Abeera & Nazar, Fatima & Rafique, Oniza. (2023e). The Healing Touch of Foeniculum vulgare Mill. (Fennel): A Review on Its Medicinal Value and Health Benefits. Journal of Health and Rehabilitation Research, 3(2), 793-800.

Zeeshan, Ali & Amjad, Waheed & Akram, Humaira & Mobeen, Nimra & Qasim, Samreen & Naseer, Abeera & Fatima, Ayesha & Fatima, Zoha. (2023f). Assessment of Nursery Administration and Identification of Ornamental Plant Species: A Case Study of Tehsil Pattoki (Pakistan) Journal of Asian Development Studies, 12(4), 468-480

Zeeshan, Ali & Amjad, Waheed & Faiz, Sidra & Noor, Mohsin & Akram, Waseem & Yameen, Iqra & Hassan, Horia & Majeed, Kainat. (2023g). Medicinal Importance of Solanum nigrum Linn; A Review. Journal of Plant and Environment. 5(2),181-189.

Zeeshan, Ali & Amjad, Waheed & Masood, Mohsin & Akram, Waseem & Yameen, Iqra & Mansoor, Mubeena & Hassan, Horia & Majeed, Kainat. (2024c). Neem's Bioactive Marvels: A Therapeutic Review. Journal of Health and Rehabilitation Research, 4(1), .185-195

Zeeshan, Ali & Aslam, Saira & Shaukat, Shama & Nazar, Aquib & Akram, Humaira & Riaz, Amtal. (2023h). GU JOURNAL OF PHYTOSCIENCES

Ethnobotanical Study of Medicinal Plants of Tehsil Ethnobotanical Study of Medicinal Plants of Tehsil Pattoki, Pakistan. 3(1)14-21.

Zeeshan, Ali & Hafeez, Umer Bin & Abdullah, Muhammad & Saeed, Sana & Tariq, Muhammad Hassam & Abbas, Muhammad & Parvez, Arbab. (2023i). The Controversy Surrounding Water Use and Its Implications for Crop Production: A Review with Current and Future Directions. int. Res. J. Educ. Technol 5. (10)336-351.

Zeeshan, Ali & Waqas, Muhammad & Ramzan, Muhammad & Ghafoor, Fatima & Usama, & Ibrahim, Muhammad & Fatima, Noor & Rauf, Abdul & Hussain, Ayesha & Abbas, Mustansar & Zahid, Noman & Hanif, Sana & Baksh, Muhammad. (2024d). Narrative Review From Fields to Families: Understanding the Health Impacts of Excessive Soil Fertilization. Journal of Health and Rehabilitation Research, 4(2), 990-995

Zeeshan, Ali. Munir,M A Sadia, S (2024e). Unlocking the Promise of the "Miracle Tree: A Review on Therapeutic Applications and Phytochemistry of Moringa Oleifera L. ournal of Bioresource Management, 11(1) 102-122.

Zubair, H., Afzal, A., Shahid, M., Ali, U., Iftikhar, H., Abuzar, A., Zaib, M. & Marium, A. (2023a). Historical Overview of the Chinese Agricultural Sciences and Technological Development. 4. 35-45. DOI: http://dx.doi.org/10.18782/2582-7146.206

Zubair, M., Raza, I., Batool, Y., Arif, Z., Muneeb, M., Uzair, M., Haidar, A., Zaib, M., Ashfaq, M., Akbar, H., Abbas, Q. & Ali, A. (2023b). A Review of Remediation Strategies against Arsenic (As) Removal from Groundwater by Using Different Filtration Techniques. Current Research in Agriculture and Farming. 4(3), 1-14. doi: http://dx.doi.org/10.18782/2582-7146.192