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Research Article

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EXPLORING THE IMPACT OF SOIL AMENDMENTS ON FOOD SAFETY AND CROP PRODUCTIVITY FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

Aflatoxins impact the entire food supply chain, from agricultural fields to processing facilities, markets, and consumer tables. In peanut cultivation, this threat poses a constant challenge throughout the cultivation, processing, and consumption stages. To confront this challenge, an exhaustive study was undertaken with the aim of investigating the effects of targeted soil amendments; namely, Vermicompost, Lentil crop residue, and Sulphate of Potash applied during the pivotal sowing phase at two distinct locations, Chakwal and Attock. The research includes meticulous groundnut sample analysis to quantify aflatoxin levels, revealing a significant reduction across all soil amendments compared to the control group. Vermicompost stands out as the most effective, achieving a remarkable 64.8% reduction, followed closely by Sulphate of Potash at 62.4%. Statistical analysis highlights non-significant differences among amendments. Beyond aflatoxin mitigation, the study underscores the dual benefit of these soil amendments, contributing not only to mycotoxin control but also enhancing overall crop productivity. Percent increase in number of grains per plant ranged between 58.82% to 43.53% whereas in hundred grain weight it ranged between 17.10% and 10.55%. In summary, the study emphasizes the importance of strategic soil amendments, particularly Vermicompost and Sulphate of Potash, in mitigating aflatoxin contamination in peanuts. The dual benefit of improved crop productivity adds significance to the findings, offering a holistic approach to address the multifaceted dimensions of aflatoxin challenges in peanut cultivation.

KEYWORDS: Food Safety; Food Security; Aflatoxin Contamination; Soil Amendments

INTRODUCTION

In the global agricultural landscape, Groundnut (*Arachis hypogaea* L.) stands as a widely cultivated crop, spanning over 100 countries and occupying 26 million hectares, with a substantial global production of approximately 44 million metric tons. Noteworthy contributors to this cultivation are Asia and Africa, with China, India, and Nigeria taking the lead in production volumes. The average global yield hovers around 1,655 kg/ha, emphasizing its economic significance (FAO, 2020). Pakistan, cultivating Groundnut on 91.1 thousand hectares, contributes 74.8 thousand tons annually, reflecting an average yield of 821.1 kg/ha (Nawaz *et al.*, 2022). Beyond its economic value, Groundnut is esteemed for its nutritional benefits, particularly in Ghana and India, where it serves as a nutritious staple supporting both income generation for producers and improved health for consumers (Anim-Somuah, Henson, Humphrey, & Robinson, 2013; Doley, Dudhane, Borde, & Jite, 2014).

However, the formidable challenge of aflatoxin contamination looms large over Groundnut crops produced by fungi like *Aspergillus flavus* and *A. parasiticus*, aflatoxins pose severe health risks, including carcinogenicity linked to liver cancer, immune suppression, and growth impairment, especially in children (Afzal, Syed, Ahmad, Zeeshan, & Nabi, 2023; Ijaz *et al.*, 2022). The intricate connection between food security and food safety is evident as a safe food supply, considering safety, nutrition, and accessibility, directly impacts the ability to achieve and sustain food security (King *et al.*, 2017). Global concerns about food safety, especially contamination outbreaks, can affect international trade and the stability of the global food system (Tauxe, O'Brien, & Kirk, 2008). International trade further underscores the importance of compliance with regulatory standards, as exceeding permissible aflatoxin levels may lead to shipment rejection (Agyekum & Jolly, 2017). Aflatoxins, potent metabolites from *Aspergillus* fungi, pose a significant threat to global food safety, infiltrating crops at various supply chain stages (Lima, Oliveira, Pimenta, & Uchôa, 2019).

Effectively addressing aflatoxin contamination requires a comprehensive approach for establishing a resilient and sustainable food system that addresses immediate health risks and broader socio-economic aspects, ensuring the nourishment of populations worldwide. Mitigating this risk demands adherence to good agricultural practices, encompassing timely harvesting, proper drying, and suitable storage. Swift drying post-harvest and controlled storage effectively counteract the growth of aflatoxin-producing fungi (Ashiq, 2015). A multifaceted approach involving proactive measures like biological control agents and non-toxic compounds is imperative (Aslam, Irshad, Naz, Aslam, & Ahmed, 2015; Peles *et al.*, 2021).

Effectively managing aflatoxin contamination requires a multifaceted strategy that addresses both pre-harvest and postharvest stages. By integrating technical knowledge, advanced agricultural practices, and ongoing education, stakeholders can work together to safeguard the food supply from the harmful effects of aflatoxins, ultimately ensuring food safety and public health. Considering the aforesaid circumstances, this study was undertaken to address pre-harvest management by utilizing Vermicompost, CCR and Potash of Sulphate (K_2SO_4). The objective was to diminish aflatoxin B1 levels in groundnut to a level below the permissible limit.

MATERIAL AND METHODS

This study seeks to investigate the efficacy of specific soil amendments; namely, the Application of Vermicompost (VC), Lentil Crop Residue (LCR), and Sulphate of Potash (K_2SO_4) applied at the sowing stage to mitigate aflatoxin contamination in rain-fed groundnut cultivation. The research, conducted across two distinct locations, Chakwal and Attock, provides a comprehensive understanding of the impact of soil amendments on aflatoxin levels. The research methodology employed in this study was characterized by a rigorous and systematic approach, designed to provide a comprehensive assessment of the influence of distinct soil amendments on aflatoxin levels in groundnut cultivation.

Site selection: Two distinct geographical locations, Chakwal and Attock, were chosen for the study to capture potential variations in soil conditions. The selection considered factors such as climate, soil type, and prevalent agricultural practices to ensure representative samples.

Pre-planting soil analysis: Before initiating the planting process, a thorough analysis of relevant soil properties was conducted at both locations. This involved collecting soil samples from multiple points across each site. Parameters assessed included soil pH, nutrient levels, organic matter content, and any existing contaminants that could influence aflatoxin production (Qazi, 2021).

Soil amendments: Three specific soil amendments were selected for the study: Vermicompost (VC), Lentil Crop Residue (LCR), and Sulphate of Potash (K_2SO_4). These amendments were applied at the time of sowing, and the quantity applied was carefully measured to ensure consistency and accuracy.

Planting and crop management: Groundnut cultivation was initiated following the application of soil amendments. Standard agricultural practices were employed for planting, including seed spacing, weed eradication and pest control (Ijaz *et al.*, 2021). Crop management practices were kept consistent across all experimental plots to isolate the impact of soil amendments on aflatoxin levels.

Sample collection: As the groundnuts reached maturity, samples were systematically collected from each experimental plot. The sampling process involved random collection from multiple points within each plot to ensure representativeness.

Aflatoxin quantification: Aflatoxin levels in the groundnut samples were quantified through enzymatic analyses. This involved extracting aflatoxins from the samples and employing specific enzymes to measure their concentrations accurately (Leszczyńska, Masłowska, Owczarek, & Kucharska, 2001). The use of enzymatic analyses provided a precise and quantitative assessment of aflatoxin levels, allowing for a detailed comparison between the control group and plots with different soil amendments.

Data analysis: The collected data, including applied amendments, and aflatoxin levels, were subjected to rigorous statistical analysis by using Linear Model Statistics package (Version 8.1). Statistical tests were conducted to determine the significance of differences in aflatoxin levels among the experimental groups, ensuring the reliability of the study's findings.

RESULTS AND DISCUSSION

The study aimed to identify the most effective soil amendment in reducing aflatoxin levels while also considering the impact on crop productivity. By meticulously following this methodology, the study aimed to provide valuable insights into the role of soil amendments in mitigating aflatoxin contamination in groundnut cultivation, offering practical implications for sustainable agricultural practices. While all amendments demonstrated a significant reduction in aflatoxin levels compared to the control group, intriguingly, the distinctions among the various amendments were not statistically significant. The study emphasizes the significance of soil amendments in mitigating aflatoxin contamination in groundnut before harvesting.

These findings underscore the potential of strategic soil management not only in curbing aflatoxin contamination but also in promoting sustainable agricultural practices that boost crop yields. Globally, aflatoxins are acknowledged as the most crucial mycotoxins concerning the safeguarding of human and animal health (Marshall *et al.*, 2020). Discovered in the

1960s, aflatoxin holds the distinction of being the first identified mycotoxin (Bennett & Klich, 2003; Richard, 2008) and is extensively researched. Aflatoxins exhibit carcinogenic, immunogenic, and teratogenic properties in both humans and animals (Marshall *et al.*, 2020). Additionally, they have been associated with compromised immunity, diminished fertility, and potential stunting in children (Pitt *et al.*, 2012). Against the backdrop of 821 million individuals globally grappling with chronic undernourishment (UN, 2019), coupled with documented instances of aflatoxins contributing to child stunting in Africa (Matacic, 2016), the substantial losses in food and feed due to mycotoxin contamination compound the challenges, particularly in developing countries and notably in Sub-Saharan Africa.

A standout result of the study was the substantial decrease in aflatoxin concentration observed in the presence of Vermicompost (64.8%), closely followed by Sulphate of Potash (62.4%) (Figure 1). Importantly, beyond their role in aflatoxin mitigation, the soil amendments exhibited an additional benefit, they concurrently enhanced crop productivity (Figure 2, Table 1). It was observed treatments were more effective in Attock as compared to Chakwal.

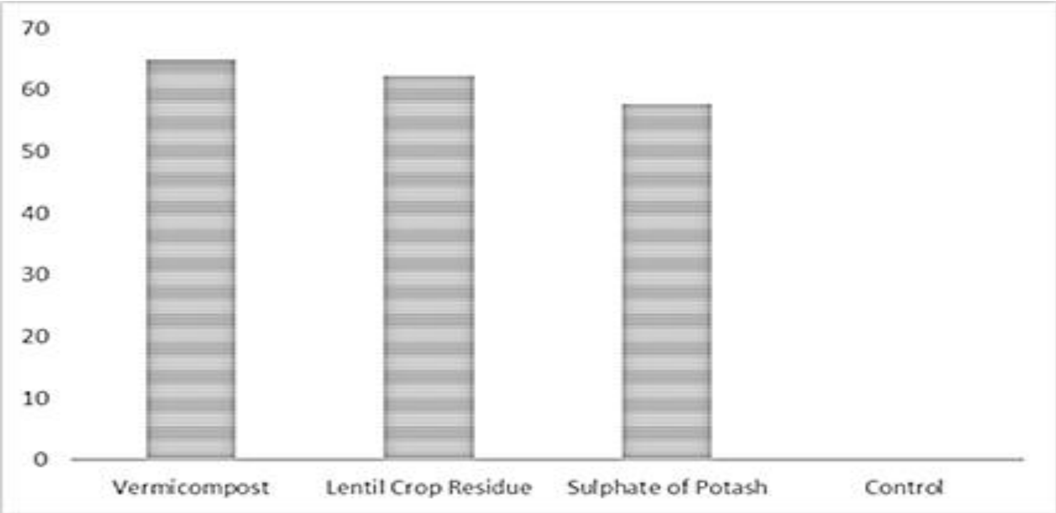

Figure 1: Mitigating Impact in Percentage of Diverse Soil Amendments on Aflatoxin Contamination in Peanut.

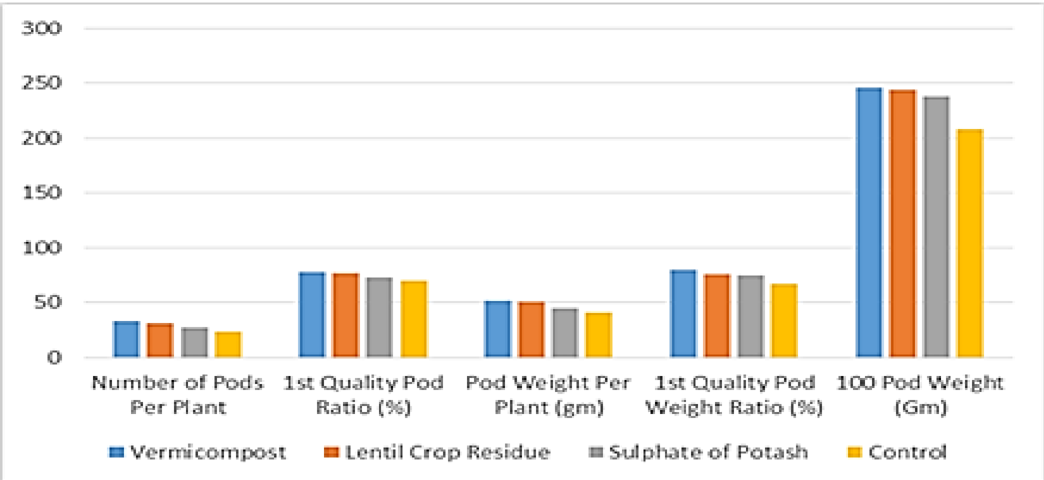

Figure 2: Effect of soil amendment on yield components of Peanut.

The research findings presented in Figure 3 reveal a substantial reduction in aflatoxin contamination recorded in Chakwal compared to Attock. This notable disparity is ascribed to variations in the chemical composition of the soil in these two locations. The intricate interplay between soil chemistry and aflatoxin levels underscores the importance of understanding local environmental factors in agricultural practices. Chakwal, with its distinctive soil characteristics, appears to provide a less conducive environment for aflatoxin development compared to Attock. The specific soil properties, such as pH, organic matter content, and mineral composition, could be influential factors affecting the growth of aflatoxin-producing molds. A percent variance of 42.03% indicates a relatively significant difference between the two locations, highlighting the importance of considering regional or geographical variations in the study's findings. Researchers and practitioners in agriculture often need to account for such differences when developing region-specific strategies or recommendations. It also underscores the need for a nuanced understanding of the local ecological context for effective agricultural management and mitigation of issues like aflatoxin contamination.

Table 1: Percent increase in yield components affected by soil amendments.

Yield Components	Vermicompost	LCR	SOP	Least Significant Difference (0.05%)
No. of Pods^{-Plant}	58.82	52.16	43.53	10.3
Pod Weight $^{-Plant}$	26.26	26.26	19.19	6.5
100 Pod Weight	17.10	14.25	10.55	4.8

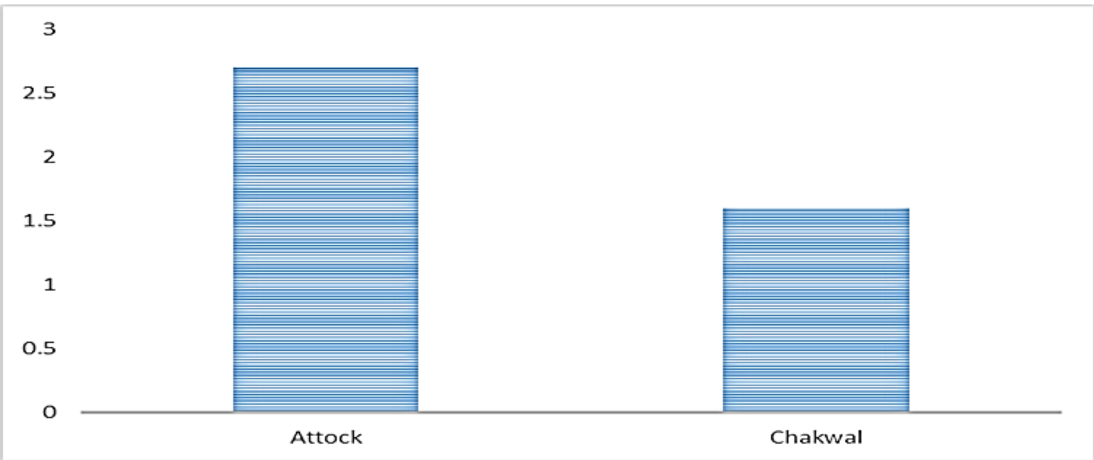

Figure 3: Variation in aflatoxin contamination in Peanut influenced by location.

The incorporation of specific soil amendments serves to optimize soil conditions (Antonious, 2016). Vermicompost, renowned for its richness in organic matter and beneficial microorganisms, plays a pivotal role in enhancing soil structure, elevating nutrient content, and fostering increased microbial activity. These cumulative effects synergistically contribute to the creation of a more robust and wholesome soil environment (Rehman, De Castro, Aprile, Benedetti, & Fanizzi, 2023). Similarly, Lentil Crop Residue (LCR) emerges as a valuable contributor to soil health by introducing organic material. This addition not only influences the physical structure of the soil but also enhances nutrient availability (Venugopalan *et al.*, 2021). Moreover, the organic matter from legume residues has the potential to modulate the soil micro biome, exerting a positive influence on its composition and function (Singh, Choudhary, & Sharma, 2021). This intricate interplay may, in turn, impact aflatoxin-producing molds, potentially reducing their prevalence. In parallel, the introduction of Sulphate of Potash (K_2SO_4) addresses the essential nutrient needs of plants, particularly focusing on potassium. As a soluble form of potassium, this amendment becomes instrumental in augmenting plant stress resistance and overall health (Alenyorege, 2015). By fortifying the physiological well-being of the crops, Sulphate of Potash contributes to a less hospitable environment for aflatoxin-producing microbes (Shabeer, Asad, Jamal, & Ali, 2022). Within this context, the shift in soil pH induced by these amendments becomes a crucial factor. The alterations in pH levels render the soil less conducive for the proliferation of microbes associated with aflatoxin contamination. This transformation in soil pH disrupts the optimal conditions required by aflatoxin-producing molds, thereby acting as a preventive measure against their growth (Bhatnagar-Mathur, Sunkara, Bhatnagar-Panwar, Waliyar, & Sharma, 2015). In essence, the comprehensive approach of utilizing Vermicompost, Lentil Crop Residue, and Sulphate of Potash not only enhances soil fertility and plant health but also strategically modifies the soil environment to deter the microbial factors contributing to aflatoxin contamination.

CONCLUSION

The article studied into the significance of soil amendments as a practical and holistic approach to ensure food safety, safeguard crop yields, and foster resilience in peanut cultivation against the persistent threat of aflatoxins. The research contributes valuable insights into sustainable agricultural practices, emphasizing the pivotal role of soil management in mitigating aflatoxin contamination in peanuts. As global concerns regarding food safety continue to escalate, the implementation of strategic soil amendments emerges as a crucial component of a comprehensive strategy for ensuring the integrity of the food supply chain. This comprehensive study embarks on an exploration of the profound impact wrought by distinctive soil amendments-specifically, the Application of Vermicompost (VC), Lentil crop residue (LCR), and Sulphate of Potash (K_2SO_4)-applied at the critical juncture of sowing. The ambit of experimentation extends across two geographically distinct locations, Chakwal and Attock, where the intricacies of pertinent soil properties were rigorously documented prior to the inaugural act of planting. The quantification of aflatoxin levels, a critical pursuit in this endeavor, unfolded through meticulous enzymatic analyses of groundnut samples. Remarkably, the collective findings of this study reveal a significant reduction in aflatoxin levels across all soil amendments when juxtaposed against the control group. Yet, intriguingly, statistical scrutiny unveils subtle disparities among the various amendments, with Vermicompost emerging as the star performer, effecting a remarkable 64.8% reduction, closely trailed by Sulphate of Potash at 62.4%. Beyond the realm of aflatoxin mitigation, it is noteworthy that these soil amendments transcend their primary purpose, concurrently fostering a discernible enhancement in crop productivity. Variance in findings under different sites underscores the significance of considering the broader ecological context in agricultural research and management strategies. Future studies may delve deeper into the precise soil components influencing aflatoxin contamination, enabling more targeted and effective mitigation measures. Additionally, a comprehensive understanding of these soil-related dynamics could contribute to the development of region-specific agricultural practices aimed at minimizing aflatoxin risks and ensuring food safety.

References

Afzal, A., Syed, S., Ahmad, R., Zeeshan, M., & Nabi, G. (2023). The Menace of Aflatoxin. In *Understanding the Effects of Contamination by Aspergillus Species on Crops and Human Health and Advancements in Managing These Toxic Metabolites*: Intech Open.

Agyekum, M., & Jolly, C. M. (2017). Peanut trade and aflatoxin standards in Europe: Economic effects on trading countries. *Journal of Policy Modeling, **39***(1), 114-128.

Alenyorege, E. A. (2015). *Effect of fertilizer and storage on aflatoxin concentration and nutrient composition of groundnut (Arachis hypogaea L.).* (Masters). University for Development Studies,

Anim-Somuah, H., Henson, S., Humphrey, J., & Robinson, E. (2013). *Strengthening agri-food value chains for nutrition: Mapping value chains for nutrient-dense foods in ghana*. Retrieved from

Antonious, G. F. (2016). Soil amendments for agricultural production. In *Organic fertilizers-from basic concepts to applied outcomes* (pp. 157-187): InTech Open.

Ashiq, S. (2015). Natural occurrence of mycotoxins in food and feed: Pakistan perspective. *Comprehensive reviews in food science and food safety, **14***(2), 159-175.

Aslam, M. F., Irshad, G., Naz, F., Aslam, M. N., & Ahmed, R. (2015). Effect of seed-borne mycoflora on germination and fatty acid profile of peanuts. *Pakistan Journal of Phytopathology, **27***(2), 131-138.

Bennett, J., & Klich, M. (2003). Clinical microbiology reviews. *Mycotoxins, **16***(1), 497-516.

Bhatnagar-Mathur, P., Sunkara, S., Bhatnagar-Panwar, M., Waliyar, F., & Sharma, K. K. (2015). Biotechnological advances for combating *Aspergillus flavus* and aflatoxin contamination in crops. *Plant Science, **234***, 119-132.

Doley, K., Dudhane, M., Borde, M., & Jite, P. K. (2014). Effects of *Glomus fasciculatum* and *Trichoderma asperelloides* in roots of groundnut (cv. Western-51) against pathogen *Sclerotium rolfsii*. *International Journal of Phytopathology, **3***(2), 89-100.

FAO. (2020). *Food and agriculture organization of the United Nations*. Retrieved from Rome, Italy:

Ijaz, M., Afzal, A., Ali, S. R., Nawaz, H. H., Altaf, R., Jannat, F. T., & Syed, S. (2022). Aflatoxin: Can be managed by soil amendments in groundnut? *Pakistan Journal of Phytopathology, **34***(1), 65-70.

Ijaz, M., Nawaz, A., Ul-Allah, S., Sher, A., Sattar, A., Sarwar, M., . . . Ansari, M. J. (2021). Optimizing sowing date for peanut genotypes in arid and semi-arid subtropical regions. *PLoS One, **16***(6), e0252393.

King, T., Cole, M., Farber, J. M., Eisenbrand, G., Zabaras, D., Fox, E. M., & Hill, J. P. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. *Trends in Food Science and Technology, **68***, 160-175.

Leszczyńska, J., Masłowska, J., Owczarek, A., & Kucharska, U. (2001). Determination of aflatoxins in food products by the ELISA method. *Czech Journal of Food Science, **19***(1), 8-12.

Lima, M. A. S., Oliveira, M. d. C. F. d., Pimenta, A. T., & Uchôa, P. K. (2019). *Aspergillus niger*: A hundred years of contribution to the natural products chemistry. *Journal of the Brazilian Chemical Society*, ***30***, 2029-2059.

Marshall, H., Meneely, J. P., Quinn, B., Zhao, Y., Bourke, P., Gilmore, B. F., . . . Elliott, C. T. (2020). Novel decontamination approaches and their potential application for post-harvest aflatoxin control. *Trends in Food Science and Technology, **106***, 489-496.

Matacic, C. (2016). Fungal toxins are poisoning Africa's children, says new report. *Science*.

Nawaz, N., Cheema, N. M., Yousaf, M. M., Jahanzaib, M., Khan, M. A., & Munir, M.

(2022). NARC-2019; A high yielding medium duration groundnut variety suitable for commercial cultivation in Pakistan. *Pakistan Journal of Agricultural Research*, ***35***(1), 172-186.

Peles, F., Sipos, P., Kovács, S., Győri, Z., Pócsi, I., & Pusztahelyi, T. (2021). Biological control and mitigation of aflatoxin contamination in commodities. *Toxins*, ***13***(2), 104-115Qazi, M.A. 2021. Soil and Water Analysis Manual. Soil Fertility Research Institute Punjab, Lahore. Agriculture Department, Government of the Punjab.

Pitt, J. I., Wild, C. P., Baan, R. A., Gelderblom, W. C., Miller, J., Riley, R., & Wu, F. (2012). *Improving public health through mycotoxin control*. Lyon, France: International Agency for Research on Cancer.

Qazi, M. A. (2021). *Soil and Water Analysis Manual*. Lahore, Pakistan: Soil Fertility Research Institute Punjab.

Rehman, S. u., De Castro, F., Aprile, A., Benedetti, M., & Fanizzi, F. P. (2023). Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. *Agronomy*, ***13***(4), 1134-1143.

Richard, J. L. (2008). Discovery of aflatoxins and significant historical features. *Toxin Reviews*, ***27***(3-4), 171-201.

Shabeer, S., Asad, S., Jamal, A., & Ali, A. (2022). Aflatoxin contamination, its impact and management strategies: An updated review. *Toxins*, ***14***(5), 307-314.

Singh, U., Choudhary, A. K., & Sharma, S. (2021). Agricultural practices modulate the bacterial communities, and nitrogen cycling bacterial guild in rhizosphere: Field experiment with soybean. *Journal of the Science of Food and Agriculture*, ***101***(7), 2687-2695.

Tauxe, R. V., O'Brien, S. J., & Kirk, M. (2008). Outbreaks of food-borne diseases related to the international food trade. In *Imported Foods: Microbiological Issues and Challenges* (pp. 69-112): Wiley Online.

UN. (2019). *UN News global perspective human stories: Can we feed the world and ensure no one goes hungry?* Retrieved from

Venugopalan, V. K., Nath, R., Sengupta, K., Nalia, A., Banerjee, S., Chandran, M. A. S., . . . Hassan, M. M. (2021). The response of lentil (*Lens culinaris* Medik.) to soil moisture and heat stress under different dates of sowing and foliar application of micronutrients. *Frontiers in plant science*, ***12***, 679469.