Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 8, 2025

INTEGRATED USE OF BIOFERTILIZERS AND ZINC SULPHATE FOR ENHANCED GROWTH AND PRODUCTIVITY OF WHEAT (*TRITICUM AESTIVUM* L.)

Shakir Ullah[*1], Lubna Shakir[2], Mohammad Sohail[3], Iqbal Hussain[4], Ghani Subhan[5]

*[*1]State Key Laboratory of Systematic and Evolutionary Botany (LSEB), Institute of Botany, Chinese Academy of Science, Beijing, China, 100000*
[2]Department of Botany, Government Post Graduate College Mardan, Mardan 23200, Pakistan
[3,4]Department of Botany, Garden Campus, Abdul Wali Khan University Mardan, Mardan 23200, Pakistan
[5]College of Life Sciences, University of Chinese Academy of Sciences, Beijing, China 100049

[*1]Shakirawkum321@gmail.com

DOI: https://doi.org/10.5281/zenodo.16779560

Keywords
Wheat, Bio-fertilizers, Zinc Sulphate, Growth Parameters, Yield Attributes

Article History
Received: 29 April, 2025
Accepted: 20 July, 2025
Published: 08 August, 2025

Corresponding Author: *
Shakir Ullah

Abstract
A field experiment was conducted during the Rabi season of 2024 at the Govt Post College, Timergara District, Dir Lower Khyber Pakhtunkhwa, Pakistan, to evaluate the response of biofertilizers and zinc sulphate on the growth and yield of maize (Triticum aestivum). The experiment included treatments with phosphate-solubilising bacteria (PSB), Azotobacter, their combination (PSB + Azotobacter), and zinc sulphate at rates of 20, 25, and 30 kg/ha. The experimental soil was sandy loam in texture, nearly neutral in pH (7.8), and low in organic carbon (0.35%). The results indicated that the combined application of PSB, Azotobacter, and zinc sulphate at 30 kg/ha significantly enhanced the growth and yield parameters of maize. Specifically, it recorded the highest plant height (159.03 cm), plant dry weight (162.70 g/plant), crop growth rate (26.25 g/m²/day), number of cobs per plant (1.8), number of rows per cob (16.8), number of seeds per cob (553.4), 100-seed weight (29.3 g), grain yield (6.5 t/ha), straw yield (12.9 t/ha), and harvest index (33.8%). These improvements may be attributed to the synergistic effect of biofertilizers and micronutrient supplementation. Biofertilizers enhance nutrient availability and uptake, particularly phosphorus and nitrogen, by promoting microbial activity in the rhizosphere. Zinc sulphate contributes to various physiological and enzymatic functions essential for crop development. The findings confirm that integrated nutrient management, using biofertilizers in conjunction with zinc supplementation, is an effective strategy for improving maize productivity while potentially reducing dependency on chemical fertilizers.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a globally cultivated cereal crop and serves as one of the cornerstones of global food security, providing nearly 20% of the total dietary calories and protein intake for the human population (Irshad et al., 2025). In India, wheat occupies a prominent place in the agricultural landscape, ranking second after rice in both area and production (Ullah et al., 2025a). However, the continuous intensification of wheat cultivation, coupled with declining soil fertility, has led to stagnation in yield levels in many regions (Ullah et al., 2025b). This necessitates the adoption of improved and sustainable agronomic practices to ensure optimal productivity without compromising environmental health (Divakar Reddy et al., 2023).

One of the key challenges in wheat production is the imbalance in soil nutrient availability, particularly the widespread deficiency of micronutrients such as zinc (Zn) Ullah et al., 2025c). Zinc plays a pivotal role in various physiological and biochemical functions in plants, including enzyme activity, protein and nucleic acid synthesis, photosynthesis, and membrane integrity (Khan et al., 2018a). Zinc deficiency is especially prevalent in sandy loam and alkaline soils, common in wheat-growing regions of northern India. This micronutrient deficiency is often linked with stunted plant growth, chlorosis, poor grain filling, and ultimately, yield losses (Reddy et al., 2023).

Zinc sulphate ($ZnSO_4$) is widely recommended to correct zinc deficiency due to its high solubility and effectiveness in supplying bioavailable zinc to crops (Manan et al., 2025). However, reliance solely on inorganic fertilizers is often economically unsustainable for smallholder farmers and may lead to environmental degradation through nutrient leaching and accumulation. This has led to increased interest in integrated nutrient management (INM) strategies that combine chemical fertilizers with biofertilizers, which are natural, living microorganisms that improve soil fertility and plant nutrition through biological processes (Kumar et al., 2021; Shakir et al., 2023a and 2023b).

Biofertilizers such as Azotobacter (a free-living nitrogen-fixing bacterium) and Phosphate Solubilizing Bacteria (PSB) play significant roles in improving nutrient uptake efficiency in non-leguminous crops like wheat. Azotobacter not only fixes atmospheric nitrogen but also synthesizes growth-promoting substances like indole acetic acid (IAA), gibberellins, and Cytokinins, enhancing root development and plant vigor (Shakir et al., 2023b). PSB enhances the availability of phosphorus by converting insoluble phosphate forms into soluble ones that are readily absorbed by plants. When used in combination, these biofertilizers promote a more robust and efficient root system, which further facilitates the uptake of macro and micronutrients, including zinc (Ssemugenze et al., 2025).

The integrated application of biofertilizers and zinc sulphate has shown promising results in improving not only the growth parameters such as plant height, dry matter accumulation, and tillering ability but also important yield attributes including spike length, number of grains per spike, 1000-grain weight, grain yield, and harvest index (Khan et al., 2028b; Lubna et al., 2025). The synergistic interaction between beneficial microbes and micronutrients creates a favorable rhizosphere environment, enhances nutrient use efficiency, and supports long-term soil health (Samantaray et al,, 2024).

Despite growing evidence on the individual roles of biofertilizers and zinc in crop production, studies focusing on their combined influence on wheat performance are relatively scarce, especially under field conditions specific to the Indo-Gangetic plains (Khan et al., 2018). Therefore, the present study was undertaken to evaluate the integrated use of biofertilizers (PSB and Azotobacter) along with zinc sulphate at graded levels (20, 25, and 30 kg/ha) for their effects on the growth, yield, and overall productivity of wheat (*Triticum aestivum* L.) (Khosravi et al., 2024). The study aims to contribute to the development of sustainable and cost-effective nutrient management practices for improving wheat cultivation in zinc-deficient soils.

Materials and Methods

The field experiment was conducted in 2024 at the Govt Post College, Timergara District, Dir Lower Khyber Pakhtunkhwa, Pakistan. The experimental site is geographically located at 25°24′42″ N latitude, 81°50′56″ E longitude, and at an altitude of 98 meters above mean sea level (Asif et al., 2025).

The experiment was laid out in a Randomized Block Design (RBD) with ten treatments, each replicated three times. The individual plot size was 3 m × 3 m. The study aimed to investigate the integrated effect of biofertilizers and zinc sulphate on the growth and yield of wheat (*Triticum aestivum* L.) (Kumar, 2022).

Experimental Factors

- **Biofertilizer Treatments:**
  - Phosphate Solubilizing Bacteria (PSB) @ 10 ml/kg seed
  - Azotobacter @ 10 ml/kg seed
  - PSB + Azotobacter @ 10 ml each/kg seed
- **Zinc Sulphate ($ZnSO_4$) Levels:**

- o 20 kg/ha
- o 25 kg/ha
- o 30 kg/ha

Treatment Combinations

- T_1 – PSB + $ZnSO_4$ @ 20 kg/ha
- T_2 – PSB + $ZnSO_4$ @ 25 kg/ha
- T_3 – PSB + $ZnSO_4$ @ 30 kg/ha
- T_4 – Azotobacter + $ZnSO_4$ @ 20 kg/ha
- T_5 – Azotobacter + $ZnSO_4$ @ 25 kg/ha
- T_6 – Azotobacter + $ZnSO_4$ @ 30 kg/ha
- T_7 – PSB + Azotobacter + $ZnSO_4$ @ 20 kg/ha
- T_8 – PSB + Azotobacter + $ZnSO_4$ @ 25 kg/ha
- T_9 – PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha
- T_{10} – Control (no biofertilizer or $ZnSO_4$)

Crop Management

Wheat was sown on 17th November 2022 using recommended agronomic practices. Zinc sulphate was applied as a basal dose and thoroughly mixed in the soil before sowing (Ullah et al., 2024). The biofertilizers were applied as seed inoculants before sowing. At maturity, the crop was harvested by collecting samples from a 1 m² area in the center of each plot to minimize border effects. From each sample plot, five representative plants were randomly selected for recording biometric and yield-related parameters (Chaudhary, 2022).

Parameters Recorded

The following growth and yield parameters were observed:

- Plant height (cm)
- Dry weight (g/plant)
- Crop growth rate (g/m²/day)
- Number of cobs per plant
- Number of seed rows per cob
- Number of seeds per cob
- Seed index (100-seed weight in grams)
- Grain yield (t/ha)
- Stover yield (t/ha)

Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA) as per the procedure described by Gomez and Gomez (1976) to test the significance of treatment effects. Where applicable, the critical difference (CD) at a 5% level of significance was used for comparing the means.

Growth Parameters

Plant Height (cm)

At harvest, a significantly higher plant height (159.03 cm) was recorded in Treatment T_9 (PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha), followed closely by Treatment T_8 (PSB + Azotobacter + $ZnSO_4$ @ 25 kg/ha), which was found to be statistically at par with T_9. The results indicate that the integrated application of biofertilizers as seed inoculants, along with zinc sulphate, positively influenced plant height. The increase in plant height may be attributed to the timely and balanced availability of essential nutrients, particularly nitrogen and phosphorus from biofertilizers and zinc from $ZnSO_4$, which play a pivotal role in cell elongation, division, and internodal growth. Additionally, zinc is known to enhance the synthesis of indole acetic acid (IAA), a plant hormone that promotes shoot elongation. The bacterization of wheat with Azotobacter likely stimulated root proliferation and nutrient uptake, which in turn supported shoot development. These findings are consistent with the observations reported by Garima Joshi and Aaradhana Chilwal (2018) and Alka Jyoti Sharma et al. (2020), who also found that the integration of biofertilizers and micronutrients significantly increased plant height in cereal crops.

Crop Growth Rate (g/m²/day)

At the 60–80 days after sowing (DAS) interval, the highest crop growth rate (64.12 g/m²/day) was recorded in Treatment T_9 (PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha), while Treatment T_8 (PSB + Azotobacter + $ZnSO_4$ @ 25 kg/ha) was statistically at par with T_9. The results demonstrate that the combined application of biofertilizers and a higher zinc dose significantly enhanced the crop growth rate during this critical growth stage. The improved crop growth rate can be attributed to the enhanced nitrogen availability resulting from the biological nitrogen fixation capacity of Azotobacter, which supports vigorous vegetative development (Ullah et al., 2018g). This finding aligns with the study of Monib et al. (1979), who reported that Azotobacter inoculation increased soil nitrogen content, thereby contributing to higher biomass accumulation and growth rate. Additionally, Fallik et al. (1988) observed a noticeable enhancement in both root and shoot growth of Zea mays under controlled conditions when biofertilizers were applied. Enhanced root systems facilitate greater nutrient and water uptake, directly supporting higher photosynthetic activity and dry matter production. According to Ritchie et al. (1993), although plants require relatively small amounts of nutrients during their early developmental stages, a high concentration of available nutrients in the root zone during these stages is critical for promoting robust early growth, which in turn influences subsequent crop performance (Ullah et al 2023). The combined presence of PSB and Azotobacter, along with adequate zinc from $ZnSO_4$, likely created a favorable rhizosphere environment, improving nutrient solubilization and uptake. This contributed to greater leaf area expansion, higher chlorophyll content, and longer duration of active photosynthesis, all of which supported higher crop growth rate during the 60–80 DAS interval (Ullah et al., 2024).

Dry Weight per Plant (g)

At harvest, the highest plant dry weight (162.70 g) was recorded under Treatment T_9 (PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha), which was significantly superior over all other treatments. However, Treatment T_8 (PSB + Azotobacter + $ZnSO_4$ @ 25 kg/ha) was statistically at par with T_9, indicating that the combined application of biofertilizers and zinc sulphate had a substantial impact on dry matter accumulation (Ullah et al., 2018g).

The increase in plant dry weight may be attributed to the inoculation of Azotobacter, which not only fixes atmospheric nitrogen, but also plays a vital role in modifying microbial communities, suppressing soil-borne pathogens, and enhancing the bioavailability of phosphorus (Ullah et al., 2018h). Moreover, Azotobacter produces growth-promoting substances such as auxins, cytokinins, and gibberellins, which stimulate early plant development and contribute to enhanced vegetative growth. These findings align with the observations reported by Meshram and Shende (1982), who noted that Azotobacter improves plant growth through multiple physiological mechanisms.

The beneficial effects of Azotobacter on plant dry weight are further supported by Jarak et al. (2012), who reported similar results in maize. In addition, Ghodpage et al. (2008) emphasized the importance of adequate zinc supply throughout the crop life cycle, which enhances photosynthetic activity, prolongs leaf area duration, and supports metabolic processes essential for dry matter production. The observed increase in dry biomass under integrated treatments reflects the synergistic role of biofertilizers and zinc in optimizing plant metabolic efficiency and overall growth performance (Ullah et al., 2018).

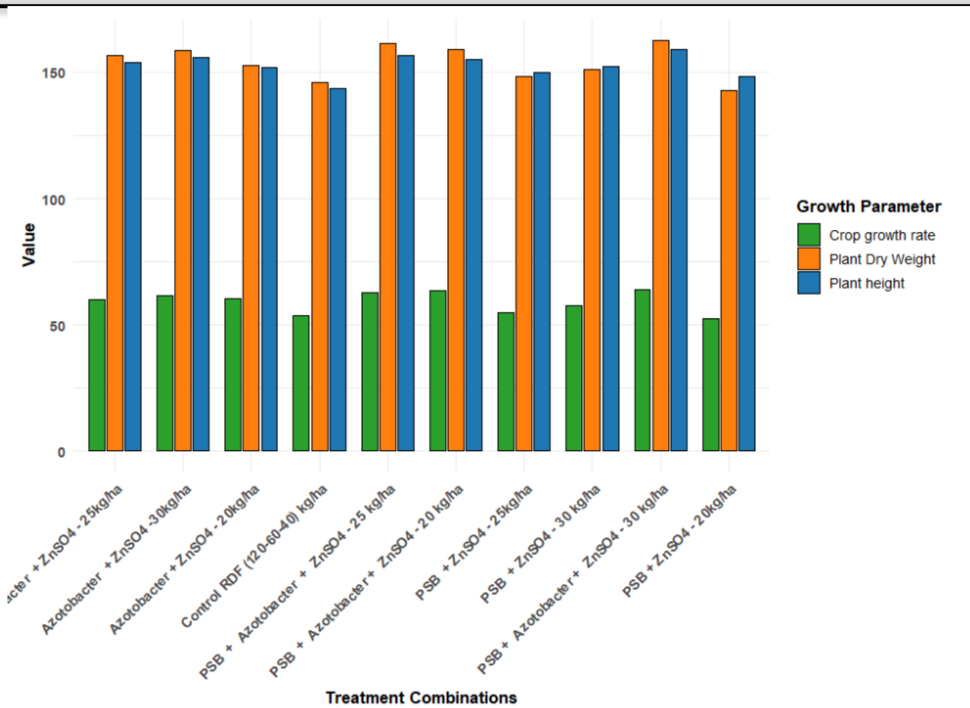

Figure 1 represents the crop growth rate, plant dry weight, and plant height

Yield Attributes

Number of Cobs per Plant

A significantly higher number of cobs per plant (1.8) was recorded in Treatment T_9 (PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha), which was significantly superior over all other treatments. However, Treatment T_8 (PSB + Azotobacter + $ZnSO_4$ @ 25 kg/ha) was statistically at par with T_9.

The increased number of cobs per plant may be attributed to improved soil nutrient status due to biofertilizer inoculation, which created a favorable rhizosphere environment for root proliferation and nutrient uptake (Ullah et al., 2018c). Azotobacter and PSB are known to produce growth-promoting substances such as gibberellins, Cytokinins, and auxins, while also contributing to nitrogen fixation. These microbial activities collectively enhance plant vigor and reproductive potential. These results are from Singh and Totawat (2002).

Number of Seeds per Cob

The maximum number of seeds per cob (553.4) was also observed in Treatment T_9, followed by T_8, which was statistically similar. The combined application of biofertilizers and zinc enhanced reproductive development and seed setting in wheat (Shakir et al., 2023a).

The improvement in grain number may also be linked to the presence of magnesium, which plays a role in pollen viability and fruit set. As noted by Mahgoub et al. (2010) and Siam et al. (2008), magnesium positively influences pollen formation and viability, contributing to a higher grain count per cob. While the increase in grain number was not drastic, it was significant enough to reflect the effectiveness of integrated nutrient management (Ullah et al., 2018; 2025).

Number of Rows per Cob

A significantly higher number of rows per cob (16.85) was recorded in Treatment T_9, with T_8 again being statistically at par. The improved number of rows may result from enhanced zinc availability, which supports reproductive growth, grain setting, and development of reproductive structures.

The positive response of maize yield components to zinc application may be attributed to its essential role in enzyme activation, protein synthesis, and hormone regulation, all of which are critical during the flowering and grain filling stages. These results are in agreement with findings reported by Gupta et al. (2018).

Seed Index (100-Seed Weight in g)
Treatment T_9 exhibited the highest 100-seed weight (29.35 g), indicating better seed development. Treatment T_8 was statistically equal to T_9. The increased nitrogen availability from Azotobacter inoculation likely contributed to enhanced leaf area and photosynthetic efficiency, leading to greater assimilate accumulation in developing grains. These findings align with Kader et al. (2002), who reported that Azotobacter improved nitrogen use efficiency and increased seed size and weight in cereal crops (Ullah et al., 2019c).

Grain Yield (t/ha)
The highest grain yield (6.5 t/ha) was recorded in Treatment T_9, significantly outperforming all other treatments, with T_8 being statistically at par. The improvement in grain yield can be linked to the positive effects of biofertilizers on nutrient availability and root development, as well as the role of zinc in chlorophyll formation and enzymatic activity (Ullah et al., 2019b).
Biofertilizer-treated plants exhibited enhanced photosynthetic activity, improved metabolic functions, and better synthesis of growth regulators, which together contributed to increased reproductive efficiency and grain filling. These findings are consistent with those of (Shaikh Wasim Chand et al. 2017) and Chandra Naik et al. (2020).

Stover Yield (t/ha)
The maximum stover yield (12.9 t/ha) was also recorded under Treatment T_9, indicating the significant role of integrated nutrient application in promoting total biomass production. Treatment T_8 was again statistically at par (Ullah et al., 2018e). Zinc fertilization is known to promote plant metabolism and vegetative growth, which leads to increased straw yield. Similar results have been reported by Tariq et al. (2014) and Palai et al. (2018), who highlighted the beneficial effects of zinc and biofertilizers on overall plant vigor and fodder production (Ullah et al., 2019a; Ullah et al., 2018f).

Harvest Index (%)
The highest harvest index (33.8%) was observed in Treatment T_9, which was significantly higher than the other treatments, with $\mathbf{T_8}$ again being statistically at par (Ullah et al., 2018b). The increased harvest index indicates improved partitioning of assimilates toward grain production relative to total biomass (Ullah et al., 2021). This improvement may be attributed to the enhanced availability of phosphorus and other nutrients facilitated by biofertilizers, especially in calcareous soils, where nutrient availability is typically constrained. These results are supported by Afzal et al., who demonstrated the beneficial role of biofertilizers in nutrient uptake and efficient biomass utilization (Ullah et al., 2018d).

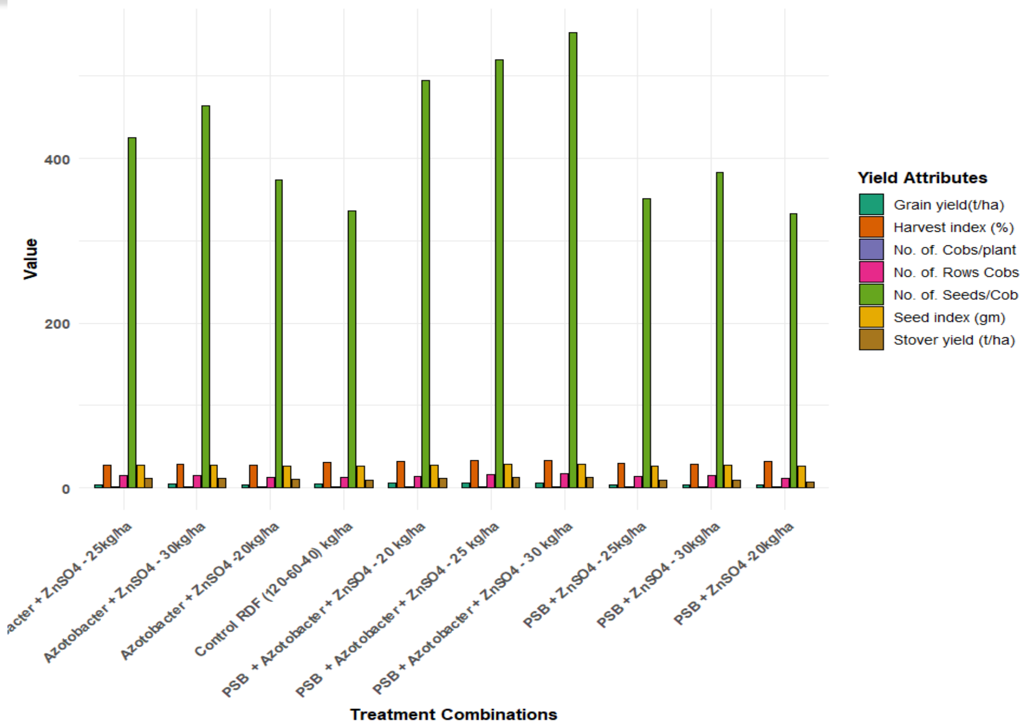

Figure 2. Resented no of cobs/plan, no of rows of cobs, no of seeds/cob, seed index (gm), grain yield(t/ha), stover yield (t/ha), harvest index (%)

Conclusion

The present investigation demonstrated that the integrated application of biofertilizers (PSB + Azotobacter) and zinc sulphate, particularly at 30 kg/ha, significantly improved the growth parameters and yield attributes of wheat (*Triticum aestivum* L.) under field conditions. Among all treatments, Treatment T_9 (PSB + Azotobacter + $ZnSO_4$ @ 30 kg/ha) consistently recorded the highest values in plant height, dry weight, crop growth rate, number of cobs per plant, rows and seeds per cob, seed index, grain yield (6.5 t/ha), stover yield (12.9 t/ha), and harvest index (33.8%).

The positive effects observed are likely due to the synergistic interaction between beneficial microbes and zinc, which enhanced nutrient solubilization, nitrogen fixation, root development, and physiological activity, ultimately leading to better growth and higher productivity. Biofertilizers improved nutrient use efficiency and soil health, while zinc played a vital role in hormonal regulation and reproductive development. Therefore, it can be concluded that the integrated use of PSB + Azotobacter + $ZnSO_4$ at 30 kg/ha is a viable and eco-friendly strategy for enhancing wheat growth, yield, and sustainability in nutrient-deficient soils. Adoption of such integrated nutrient management practices can reduce the dependency on chemical fertilizers and support sustainable agriculture.

Novelty Statement

This study provides novel insights into the synergistic effects of biofertilizers (PSB and Azotobacter) and zinc sulphate on the growth and yield performance of wheat (*Triticum aestivum* L.) under field conditions. Unlike previous research focusing on either biofertilizers or micronutrients alone, this work uniquely demonstrates that their combined application, particularly at 30 kg/ha of $ZnSO_4$, significantly enhances crop productivity. The findings contribute to the development of sustainable nutrient management strategies, offering a practical alternative to excessive chemical fertilizer use while improving soil health and crop performance in zinc-deficient soils.

REFERENCES

Afzal, A., Ashraf, M., Asad, S.A. and Farooq, M. (2005). Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of wheat (*Triticum aestivum* L.) in rainfed area. International journal of Agriculture and Biology.,. **7:** 207–9.

Alka Jyoti Sharma, Singh MK, Sanjay Kumar, Shweta Shambhavi, Sneha (2020). Effect of plant geometry, graded fertility and zinc level on growth characters, yield and quality of baby corn (Zea mays L.) fodder in Bihar. International Journal of Chemical Studies; **8**(3):816- 821.

Alley, M.M., Martens, D.C., Schnappinger, M.G. and Hawkins, G.W. 1972. Field calibration of soil tests for available zinc. Soil Science Society of America Journal, **36**: 621-624.

Alloway, B.J. 2009. Soil factors associated with zinc deficiency in crops and humans. Environmental Geochemistry and Health, **31**: 538-548.

Azeem Tariq, Shakeel A, Anjum, Mahmood A, Randhawa, Ehsan Ullah et al (2014). Influence of zinc nutrition on growth and yield behaviour of maize (Zea mays L.) hybrids. American Journal of Plant Sciences;**5**:2646-2654.

Asif, S., Nisar, M., Ullah, S., & Naeem, M. (2025). Reviewing the Impact of Seed-Borne Mycoflora on Mycotoxin Accumulation: A Threat to Lentil Genetic Resources. Toxicon, 108290.DOI: 10.1016/j.toxicon.2025.108290

Chandra Naik, Meena MK, Ramesha YM, Amaregouda A, Ravi MV, Dhanoji MM (2020). Morpho-physiological impact of growth indices to Biofortification on growth and yield of sweet corn (Zea mays L. Saccharata). Bulletin of Environment, Pharmacology and Life Sciences;**9**(3):37-43.

Chaudhary, P. (2022). Overview of biofertilizers in crop productivity and stress resilience. Frontiers in Plant Science, 13, 930340.

Divakar Reddy, K., Singh, R., & Pradhan, A. (2023). Influence of Biofertilizers and Zinc Sulphate on Growth and Yield of Maize (Zea mays L.). International Journal of Environmental & Climate Change, 11(7), 61–67.

Fageria, N.K. 2010. Nitrogen use efficiency in upland rice genotype. Journal of Plant Nutrition, **33**(11): 1696-1711.

Fallik E., Okon Y., Fischer, M., 1988. Growth response of maize roots to Azospirillum inoculation: effect of soil organic matter content, number of rhizosphere bacteria and timing of inoculation. Soil Biol Biochem **20**, 45-49.

Garima Joshi, Aaradhana Chilwal (2018). Effect of integrated nutrient management on growth parameters of baby corn (Zea mays L.). International Journal of Advances in Agricultural Science and Technology;**5**(7):216-225.

Ghodpage, R.M., Balpanda, S.S., Babhulkar, V.P., Pongade, S., 2008. Effect of phosphorus and zinc fertilization on nutrient content in root, yield and nutritional quality of maize. Journal of Soils and Crops **18**, 458–461

Gomez, K. A and Gomez, A. A (1976). Three or more factor experiment. In: Statistical Procedure for Agricultural Research **2**nd edition, p. 139 -141.

Guntoro, D., B.S. Purwoko, and R.G. Hurriyah. 2007. Growth, nutrient uptake, and quality of turfgrass at some dosages of mycorrhiza application. Bul. Agron. **35**:142-147.

Gupta, S., Swaroop, N., Thomas, T., Dawson, J. and Rao, S.P. 2018. Efeect of different levels of Phosphorus and Zinc on physico-chemical properties of soil, growth and yield of maize (Zea may L.) var. Shivani. International Joural of Chemical Studies, **6**(6): 2105-2108.

Irshad, A., Noreen, S., Sajid, U., Jamal, M., Iqbal, M. A., Ullah, S., Sabtain, T., Ullah, S., Ibañez-Arancibia, E., De Los Ríos-Escalante, P. R., Belkahia, H., Ben Said, M., & Swelum, A. A. (2025). *Molecular identification, risk factors' assessment and phylogenetic analysis of Toxoplasma gondii in goats from Malakand Division, Khyber Pakhtunkhwa, Pakistan*. (2025) 49:21, https://doi.org/10.1007/s11259-025-10783-

Hossain, M., et al. (2024). Effect of biofertilizer and $ZnSO_4$ on wheat growth and physiology under drought. AgroScience Today, 8(1), 112–120.

Jarak, M., N. Mrkovacki, D. Bjelic, D. Josic, T.H. Jafari and D. Stamenov. 2012. Effects of plant growth promoting rhizobacteria on maize in greenhouse and field trial. Afr. J. Microb. Res. **6**(27): 5683-5690.

Kader M.A, Mian M.H, Hoque M.S 2002; Effect of Azotobacter inoculants on the yield and nitrogen uptake by wheat. Journal of Biological science; **4**: 259-261.

Khosravi, H., et al. (2024). Indigenous Azotobacter chroococcum improves wheat root growth and yield under field conditions. Microbial Ecology Reports, 15(4), 210–222.

Kumar, P., Dubey, S. D., & Pandey, R. K. et al. (2021). Effect of VC, FYM, S, Zn, Azotobacter and PSB on Growth and Yield Attributes of Maize and Wheat. International Journal of Current Microbiology & Applied Sciences, 10(6), 764–773.

Kumar, S. (2022). Biofertilizers: An ecofriendly technology for nutrient sustainability in cropping systems. Journal of Sustainable Agriculture, 12(1), 45–58.

Lubna S, Sohail M, Naz F, Ali S, Khan H, Noreen A, Subhan G, Naveen D, Ullah S. Phytochemical profiling and antibacterial potential of Morus alba L. leaf extracts against Salmonella typhi. Frontier in Medical and Health Research. 2025;3(5):1482–1492. Available from: https://fmhr.org/index.php/fmhr/article/vie w /692

M, Khan., M, Haris., M, Riaz Khan., I, Ali., N, Nasreen., M, Sohail2., S, Ullah, Acaricidal efficacy of Melia azedarach, *Olea ferruginea*, and *Zanthoxylum armatum* against *Rhipicephalus microplus* from Khyber Pakhtunkhwa, Pakistan. 3, No. 1 (January-December), 2024, pp. 99-114. DOI: 10.47264/idea.ajset/3.1.75:

Khan, S., Jan, G., Bibi, H., Sher, J., Ullah, S., & Abidullah, S. (2018). Phytochemical screening and antimicrobial activity of *Cichorium intybus* (Family: Asteraceae) and *Medicago sativa* (Family: Fabaceae), Peshawar, Pakistan. Journal of Pharmacognosy and Phytochemistry, 7(3), 603–616.

Khan, S., Jan, G., Bibi, H., Ullah, K., Gul, F., & Ullah, S. (2018a). Plants traditional medication in the arid and semi-arid zone of Tehsil Domal, District Bannu, Khyber Pakhtunkhwa, Pakistan. Journal of Applied Environmental and Biological Sciences, 8(8), 14–21.

Khan, S., Jan, G., Bibi, H., Ullah, K., & Ullah, S. (2018b). Antimicrobial, phytochemical, and traditional studies of selected medicinal plants in Bajaur Agency, Pakistan. International Journal of Research in Pharmacy and Science, 8(2), 4–21.

Manan, F., I. Ahmad, F. Asad, L. Shakir and S. Ullah. 2025. Pharmacognosy, phytochemistry, and antimicrobial potential of Pteris cretica L. collected from Dir (Lower), Khyber Pakhtunkhwa. Pakistan Journal of Weed Science Research, 31(2): 117-131. DOI | https://dx.doi.org/10.17582/journal.PJWS.

Mahgoub, M., H., El-Quesni, Fatima E. M. and Kandil M.M. 2010. "Response of Vegetative Growth and Chemical Constituents of Schefflera arboricola L. Plant to Foliar Application of Inorganic Fertilizer (Grow-More) and Ammonium Nitrate at Nubaria." Ozean Journal of Applied Science, Vol. **3**, pp. 177-184.

Mengal, K. and Kirkby, E. A. 1982. Principal of plant Nutrition 5th education Kluwer Academic Publishers, Dordrech.

Meshram, S.U. and S.T. Shende. 1982. Response of maize to Azotobacter chroococcum. Plant Soil. **69**(1-3): 265- 273.

Monib, M., Abd-el-Malek, Y., Hosny, I. and Fayez, M. 1979. Effect of Azotobacter inoculation on plant growth and soil nitrogen. Zentralbi Bakteriol Naturwiss, **134**: 140-148.

Paramasivam, M., Kumaresan, K.R., Malarvizhi, P., Mahimairaja, S. and Velayudham, K. 2010. Effect of different levels of NPK and Zn on yield and nutrient uptake of hybrid maize (COHM 5) (Zea mays L.) in Madhukkur (Mdk) series of soils of Tamil Nadu. Asian Journal of Soil Science, **5**: 236-240.

Reddy, K. D., Singh, R., & Pradhan, A. (2023). Field study at SHUATS on PSB, Azotobacter, and zinc sulphate in maize. International Journal of Environmental & Climate Change, Article IJECC-101926.

Ritchie, W.S., John, J. Hanway, Garreno, B., 1993. How a corn plant develop. Special report No. 48, Iowa State Univ. of Science and Technology, Cooperative Extension Service.

Samantaray, A. (2024). Advances in microbial-based bio-inoculum for amelioration of abiotic stress and nutrient uptake in cereals. Agricultural Sciences Review, 19(2), 78–92.

Saraswati, R. and Sumarno. (2008). Application of soil microorganisms as component of agriculture technology. Iptek. Tan. Pangan 3:41.

Shaikh Wasim Chand, Susheela R, Sreelatha D, Shanti M, Hussain SA (2017). Effect of zinc fertilization on yield and economics of baby corn (Zea mays L.). Journal of Pharmacognosy and Phytochemistry;**6**(5):989-992.

Shakir, L., Ullah, S., Suhail, M., & Ullah, R. (2023). Phytochemical analysis, antipyretic and antifungal activities of *Solanum nigrum* L. National Journal of Pharmaceutical Sciences, 3(2), 6–12.

Shakir, L., Asif, S., Haq, A., Haq, S., Zada, K., Said, M., Sajid, M., Ullah*, S., & Ullah, R. (2023b). Phytochemical detection and medicinal studies of selected plants from war-affected areas of Khyber Pakhtunkhwa, Pakistan., Journal of Agriculture & Forestry Research, 2(5).

Shekh, B.A. (2006). Biotechnology and biofertilization: Key to sustainable agriculture. Scientific issue, (1) Das, K., R.Dang, T. N.

Shevananda. (2008). Influence of bio-fertilizers on the availability of nutrients (N, P and K) in soil in relation to growth and yield of Stevia rebaudiana grown in South India. International Journal of Applied Research in Natural Products, Vol. **1**(1), pp. 20-24.

Singh, R., and K.L. Totawat. 2002. Effect of integrated use of nitrogen on the performance of maize (Zea mays L.) on haplustalfs of sub-humid southern plains of Rajasthan. Indian Journal of Agriculture and Research. **36**(2): 102-107.

Singh, S., Singh, V. and Mishra, P. 2017. Effect of NPK, boron and Zinc on productivity and profitability of late sown kharif maize (Zea mays L.) in western Uttar Pradesh, India. Annals of Agricultural New Series, **38**(3): 310-313.

Ssemugenze, B., Ocwa, A., Kuunya, R., et al. (2025). Enhancing Maize Production Through Timely Nutrient Supply: The Role of Foliar Fertiliser Application. Agronomy, 15(1), 176.

Abidemi, J., Akindele, J., Awulika, O.-S., & Usuwah, B. A. (2015). *Antinociceptive and Anti-Inflammatory Activities of Morus albaHydroethanolic Leaf Extract (Cucurbitaceae)*. https://doi.org/10.1089/jmf.2014.0146

Adeniyi, S. A., Orjiekwe, C. L., Ehiagbonare, J. E., & Arimah, B. D. (2010). Preliminary phytochemical analysis and insecticidal activity of ethanolic extracts of four tropical plants (Vernonia amygdalina, Sida acuta, Ocimum gratissimum and Telfaria occidentalis) against beans weevil (Acanthscelides obtectus). *International Journal of Physical Sciences*, *5*(6), 753–792.

Akindele, A., Oladimeji-Salami, J., Oyetola, R., & Osiagwu, D. (2018). Sub-Chronic Toxicity of the Hydroethanolic Leaf Extract of Morus albaHook. f. (Cucurbitaceae) in Male Rats. *Medicines*, *5*(1), 4. https://doi.org/10.3390/medicines5010004

Akoroda, M. O. (1990). Ethnobotany of Morus alba(cucurbitaceae) among Igbos of Nigeria. *Economic Botany*, *44*(1), 29–39. https://doi.org/10.1007/BF02861064

Alada, A. (2000). *THE HAEMATOLOGICAL EFFECT OF TELFERIA OCCIDENTALS DIET PREPARATION*. *3*, 185–186.

Andrews, J. M. (2001). Determination of minimum inhibitory concentrations. *Journal of Antimicrobial Chemotherapy*, *48*(suppl_1), 5–16. https://doi.org/10.1093/jac/48.suppl_1.5

Aneja, K.R., (2007). Experiments in Microbiology, Plant Pathology and Biotechnology. (IV Ed.) New Age International (P) Limited, Publishers. New Delhi. p145-156

Asif, S., Nisar, M., Ullah, S., & Naeem, M. (2025). Reviewing the Impact of Seed-Borne Mycoflora on Mycotoxin Accumulation: A Threat to Lentil Genetic Resources. Toxicon, 108290.DOI: 10.1016/j.toxicon.2025.108290

Badifu, G. I. O., & Ogunsua, A. O. (1991). Chemical composition of kernels from some species of Cucurbitaceae grown in Nigeria. *Plant Foods for Human Nutrition*, *41*(1), 35–44. https://doi.org/10.1007/BF02196380

David, N. J., & Craig, G. M. (2020). Natural Products as Sources of New Drugs over the Nearly Four Decades from 01/1981 to 09/2019. *Journal of Natural Products*, *83*(3), 770–803. https://doi.org/10.1021/acs.jnatprod.9b01285

Egharevba, E. M. (2014). *PHYTOCHEMICAL ANALYSIS, PROXIMATE AND MINERAL COMPOSITION AND IN VITRO ANTIOXIDANT ACTIVITIES IN Morus albaAQUEOUS LEAF EXTRACT*. https://www.researchgate.net/publication/279529603

Eseyin, O. A., Ebong, P., Ekpo, A., Igboasoiyi, A., & Oforah, E. (2007). Hypoglycemic effect of the seed extract of Morus albain rat. *Pakistan Journal of Biological Sciences*, *10*(3), 498–501. https://doi.org/10.3923/pjbs.2007.498.501

Eseyin, O. A., Sattar, M. A., & Rathore, H. A. (2014). A review of the pharmacological and biological activities of the aerial parts of Morus albaHook.f. (Cucurbitaceae). *Tropical Journal of Pharmaceutical Research*, *13*(10), 1761–1769. https://doi.org/10.4314/tjpr.v13i10.28

Fabricant, D. S., & Farnsworth, N. R. (2001). The value of plants used in traditional medicine for drug discovery. *Environmental Health Perspectives*, *109*(SUPPL. 1), 69–75. https://doi.org/10.1289/EHP.01109S169

Inoue, H., Yamazaki, S., Shimizu, M., Uozaki, H., Goto, T., Ohnishi, S., & Koike, K. (2011). Liver injury induced by the Japanese herbal drug Kamishoyosan. *Gastroenterology and Hepatology*, *7*(10), 692–695.

Irshad, A., Noreen, S., Sajid, U., Jamal, M., Iqbal, M. A., Ullah, S., Sabtain, T., Ullah, S., Ibañez-Arancibia, E., De Los Ríos-Escalante, P. R., Belkahia, H., Ben Said, M., & Swelum, A. A. (2025). *Molecular identification, risk factors' assessment and phylogenetic analysis of Toxoplasma gondii in goats from Malakand Division, Khyber Pakhtunkhwa, Pakistan*. (2025) 49:21, https://doi.org/10.1007/s11259-025-10783-z

Krause, J., & Tobi, G. (2013). Discovery, Development, and Regulation of Natural Products. In *Using Old Solutions to New Problems - Natural Drug Discovery in the 21st Century*. InTech. https://doi.org/10.5772/56424

Kuete, V., Efferth, T., & Gunatilaka, L. (2010). Cameroonian medicinal plants: pharmacology and derived natural products. *Article*, *1*(1). https://doi.org/10.3389/fphar.2010.00123

M, Khan., M, Haris., M, Riaz Khan., I, Ali., N, Nasreen., M, Sohail2., S, Ullah, Acaricidal efficacy of Melia azedarach, *Olea ferruginea*, and *Zanthoxylum armatum* against *Rhipicephalus microplus* from Khyber Pakhtunkhwa, Pakistan. 3, No. 1 (January-December), 2024, pp. 99-114. DOI: 10.47264/idea.ajset/3.1.75:

Khan, S., Jan, G., Bibi, H., Sher, J., Ullah, S., & Abidullah, S. (2018). Phytochemical screening and antimicrobial activity of *Cichorium intybus* (Family: Asteraceae) and *Medicago sativa* (Family: Fabaceae), Peshawar, Pakistan. Journal of Pharmacognosy and Phytochemistry, 7(3), 603–616.

Khan, S., Jan, G., Bibi, H., Ullah, K., Gul, F., & Ullah, S. (2018a). Plants traditional medication in the arid and semi-arid zone of Tehsil Domal, District Bannu, Khyber Pakhtunkhwa, Pakistan. Journal of Applied Environmental and Biological Sciences, 8(8), 14–21.

Khan, S., Jan, G., Bibi, H., Ullah, K., & Ullah, S. (2018b). Antimicrobial, phytochemical, and traditional studies of selected medicinal plants in Bajaur Agency, Pakistan. International Journal of Research in Pharmacy and Science, 8(2), 4–21.

Leonard B, S., Karen L, L., Bruce R, B., Thomas F, K., & Jay H, H. (2001). Complementary and alternative medicine in chronic liver disease. *Hepatology (Baltimore, Md.)*, *34*(3), 595–603. https://doi.org/10.1053/JHEP.2001.27445

Manan, F., I. Ahmad, F. Asad, L. Shakir and S. Ullah. 2025. Pharmacognosy, phytochemistry, and antimicrobial potential of Pteris cretica L. collected from Dir (Lower), Khyber Pakhtunkhwa. Pakistan Journal of Weed Science Research, 31(2): 117-131. DOI | https://dx.doi.org/10.17582/journal.PJWSR/2025/31.2.117.131

Nwozo, S., Adaramoye, O., & Ajaiyeoba, E. (2005). Anti-Diabetic And Hypolipidemic Studies Of <I>Telifairia occidentali</i>s On Alloxan Induced Diabetic Rabbits. *Nigerian Journal of Natural Products and Medicine*, *8*(1). https://doi.org/10.4314/NJNPM.V8I1.11814

Oboh, G., Nwanna, E. E., & Elusiyan, C. A. (2006). Antioxidant and Antimicrobial Properties of Morus alba(Fluted pumpkin) Leaf Extracts. *Journal of Pharmacology and Toxicology*, *1*(2), 167–175. https://doi.org/10.3923/jpt.2006.167.175

Odebiyi, A. and Sofowora, A.E. (1978). Phytochemical screening of Nigeria medicinal plant part III Lioydia 4: 234-246.

Okokon, J. E., Ekpo, A. J., & Eseyin, O. A. (2009). Evaluation of in vivo antimalarial activities of ethanolic leaf and seed extracts of telfairia occidentalis. *Journal of Medicinal Food*, *12*(3), 649–653. https://doi.org/10.1089/jmf.2008.0099

Oladele, J. O., M.O, B., Olowookere, B. D., Oyeleke, M. O., J.C, A., K.S, O., I.O, O., & Olaleye, J. (2020). *Identification of Bioactive Chemical Constituents Presents in the Aqueous Extract of Morus albaand Its in vitro Antioxidant Activities. Nat Ayurvedic Med 2020, 4(2): 000237.* https://doi.org/10.23880/jonam-16000237

Olaniyan, M. F., & Adeleke, A. (2005). Short Communication: A study of the effect of pumpkin (ugu - *Telfaira occidentals*) milk and raw egg mixture in the treatment of anaemic pregnant women in a rural area. *African Journal of Traditional, Complementary and Alternative Medicines*, *2*(3). https://doi.org/10.4314/AJTCAM.V2I3.31126

Oyewole, O., & Abalaka, M. (2012). Antimicrobial Activities of Morus alba(fluted pumpkins) Leaf Extract against Selected Intestinal Pathogens. *International JOURNAL OF HEALTH SCIENCE*, *2*(2), 1–4. https://doi.org/10.5923/j.health.20120202.01

Robinson, M. M., & Zhang, X. (2011). the World Medicines Situation 2011 Traditional Medicines : Global Situation , Issues and Challenges. *World Health Organization, 3rd Edition*, 1–14.

Stevels, J. M. C. (1990). *Legumes traditionnels du Cameroun, une etude agro-botanique*. Agricultural University.

Shakir, L., Ullah, S., Suhail, M., & Ullah, R. (2023). Phytochemical analysis, antipyretic and antifungal activities of *Solanum nigrum* L. National Journal of Pharmaceutical Sciences, 3(2), 6–12.

Shakir, L., Asif, S., Haq, A., Haq, S., Zada, K., Said, M., Sajid, M., Ullah*, S., & Ullah, R. (2023b). Phytochemical detection and medicinal studies of selected plants from war-affected areas of Khyber Pakhtunkhwa, Pakistan., Journal of Agriculture & Forestry Research, 2(5).

Teke, G. N., Elisée, K. N., & Roger, K. J. (2013). Chemical composition, antimicrobial properties and toxicity evaluation of the essential oil of Cupressus lusitanica Mill. leaves from Cameroon. *BMC Complementary and Alternative Medicine*, *13*. https://doi.org/10.1186/1472-6882-13-130

Teke, G. N., & Fokunang, C. (2020). *Antimicrobial Activity of Combined Plant Extracts of Ageratum conyzoides and Bidens pilosa*. *1*.

Tsafack, N., Yameen, A., Njateng, G., Fokunang, C., Nyemb, J., Nighat, F., & Gatsing, D. (2017). GC/MS analysis, antisalmonellal potential of methanol leaf extracts of Tristemma mauritianum and effects on hematological parameters on Wistar rats infected with Salmonella typhi. *International Journal of Pharmacy*, 7(2), 120–131.

Ullah, S., Ullah, I., Naz, R., Sohil, M., Ihsan, M., & Abasi, F. (2019b). Phytochemical's screening and chromatographic separation of bio-active compound from the roots of Berberis lyceum. Journal of Biotechnology & Bioinformatics Research, 1(1).

Ullah, S., Ullah, I., Khan, M., Zamir, M., Khan, B. T., Naz, R., Sohil, M., Ihsan, M., & Abasi, F. (2019c). Phytochemical analysis and antibacterial activity of *Ajuga bracteosa*, *Bergenia ciliata*, and *Amaranthus viridis* from District Lower Dir, Village Maidan Banda of Khyber Pakhtunkhwa, Pakistan. International Journal of Biosciences, 14(5), 403–412.

Ullah, S. and L. Shakir. 2023. The Effects of Plant Age on Phytochemical and Geographical Distribution of Euphorbia helioscopia, (sunspurge or madwoman's milk) Euphorbiaceae from Arrang District Bajaur Pakistan Journal of Weed Science Research, 29(4): 206-212.DOI: 10.17582/journal.PJWSR/2023/29.4.206.2 127:

Ullah, R., Rahim, F., Sajid, M., Ullah, S., Ali, S., Shakir, L. & Subhan, G. (2024). Ethnobotanical study of Munda Khazana, District Dir Lower, Khyber Pakhtunkhwa. Pakistan Journal of Weed Science Research, 30(3), 105-120.DOI: 10.17582/journal.PJWSR/2024/30.3.105.1 20

Ullah, S., Shakir, L., Sohail, M., Noreen, A., & Aziz, L. (2025). Controlling of Cotton Leaf Worm in Solanum nigrum L. at District Swat (Switzerland of Pakistan) Under Semi-Field Conditions. Pakistan Journal of Weed Science Research, 31(1) https://.10.17582/journal.PJWSR/2025/31 .1.56.65

Ullah, S., Saeed, M., Sohail, M., Sajid, A., Aziz, L., Noreen, A., & Shakir, L. (2025b). Indigenous knowledge of medicinal plants used by the tribal communities of Hasham Valley, District Dir Lower, Khyber Pakhtunkhwa, Pakistan. Pakistan Journal of Weed Science Research, 31(1), 37, 10.17582/journal.PJWSR/2025/31.1.56.65

Ullah*, S., Shakir, L., Ali, S., Subhan, G., Sohail, M., Khan, I., & Ali, S. (2025c). The Nutritional Analysis, Phytochemical and Antifungal Study of Equisetum arvense L. From Village Kharkay Pak Afghan Border District Dir Lower, Pakistan. Kashmir Journal of Science, 4(01). https://DOI: 10.63147/jey5re67.

Ullah S., Shakir, L., Subhan, G., Sohail, M., Bilqees, R., Khan, F., Gulzar, U., Ali, S., Ullah, Z., & Ali, S. (2024). Phytodiversity and conservation assessment of ethnobotanically significant flora in Khall Hagram Dara, Lower Dir, Khyber-Pakhtunkhwa, Pakistan. Plant Protection, 8(1), 143–162, DOI: 10.33804/pp.008.01.5084.

Ullah, S., Shakir, L., & Ullah, R. (2023a). Morphological and phytochemical study of Cirsium arvense from District Mardan, Pakistan. Journal of Bioinformatics and Biotechnology Research, 1(1), 1–7.

Ullah*, S., Ullah, R., Ullah, F., Khan, G. Z., Shakir, L., Sardar, F., & Ullah, R. (2021). Traditional uses of plants and their role in the community development of Sheen Ghar Valley, District Lower, Khyber Pakhtunkhwa, Pakistan. International Journal of Agriculture and Nutrition, 1(1).

Ullah, S., Khattak, M., Abasi, F., Sohil, M., Ihsan, M., & Ullah, R. (2019a). Antifungal, nutritional and phytochemical investigation of Actiniopteris radiata of District Dir Lower, Pakistan. International Journal of Horticulture and Food Science, 1(1), 1–8.

Ullah, S., Sohail, M., Niaz, K., Khan, S., & Khattak, M. (2018). Phytochemistry and antibacterial activity of Convolvulus arvensis Linn against Escherichia coli. Journal of Chemical, Biological and Physical Sciences, 8(4), 2249–1929.

Ullah*, S., Jan, G., Jan, F. G., Khan, S., Khattak, M., Bibi, H., & Ihsan, M. (2018). Phytochemical analysis, antipyretic and antifungal activities of *Cyrtomium caryotideum*. *Biosciences Biotechnology Research Asia*, *15*(3), 577–589.

Ullah, S., Jan, G., Jan, F. G., Khan, S., Khattak, M., Bibi, H., & Ihsan, M. (2018). Phytochemical analysis, analgesic, anti-inflammatory, and anti-bacterial activities of *Berberis lycium*. *International Journal of Advanced Research*, 6(7), 1150–1166.

Ullah*, S., Jan, G., Gul, F., Khan, S., Husna, Sher, J., & Abidullah, S. (2018c). Phytochemistry and antibacterial activities of some selected plants of war-affected area Bajaur Agency, Pakistan. *Journal of Pharmacognosy and Phytochemistry*, 7(3), 415–422.

Ullah, S., Jan, G., Gul, F., Khan, S., Khattak, M., Ihsan, M., & Bibi, H. (2018d). Phytochemical and nutritional analysis of selected plants of District Buner, Pakistan. *International Journal of Fauna and Biological Studies*, *5*(3), 111–117.

Ullah, S., Jan, G., Gul, F., Israr, M., Khan, S., Khattak, M., Bibi, H., & Sher, J. (2018e). Phytochemical analysis, antipyretic, analgesic, anti-inflammatory, and antifungal activities of *Pteris quadriaurita* Retz. World Journal of Pharmacy and Pharmaceutical Sciences, 7(1), 857–876.

Ullah, S., Jan, G., Gul, F., Khan, S., & Sheer, J. (2018f). Antifungal, nutritional, and phytochemical investigation of *Asplenium dalhousiae* of District Dir Lower, Pakistan. *Journal of Pharmacognosy and Phytochemistry*, 7(2), 3281–3288.

Ullah, S., Jan, G., Gul, F., Khan, S., Khattak, M., Sher, J., & Bibi, H. (2018g). Antifungal and phytochemical screening of selected medicinal plants of Malamjaba, Swat, Pakistan. *The Pharma Innovation Journal*, 7(5), 176–180.

Ullah, S., Jan, G., Gul, F., Khan, S., Khattak, M., Bibi, H., & Sher, J. (2018g). Phytochemistry, anti-inflammatory and antipyretic activities of *Adiantum capillus-veneris* in Swiss albino mice. *International Journal of Fauna and Biological Studies*, *5*(3), 19–25.

Ullah, S., Ali, S., Shakir, L., Asif, S., Subhan, G., Sohail, M., Ali, S., Khan, Y. (2025). Ecological studies of different plant communities of Malasaid Hills, District Bajour, Khyber Pakhtoonkhwa. International Journal of Applied and Experimental Biology4(4):249-264.