



Check for updates

Research Article

Fodder yield performance of maize (*Zea mays* L.) variety Akbar under diverse soil applied nitrogen levels

Shabir Hashim¹, Zulfiqar Ali Abbasi², Muhammad Mahamood-ur-Rahman Jamro³, Pir Ahmed Naqi Shah¹, Muhammad Nawaz Kandhro¹, Shahjahan Rajput⁴

¹Department of Agronomy, Faculty of Crop Production, Sindh Agriculture University Tandojam, Sindh, Pakistan.

²Department of Agronomy, Faculty of Agriculture Science, The University of Larkano, Sindh, Pakistan.

³Khairpur College of Agriculture and Management Sciences Khairpur Mir's, Sindh, Pakistan.

⁴Department of Entomology, Faculty of Agriculture Science, The University of Larkano, Sindh, Pakistan.

ABSTRACT

The optimum nutrient management offers a pathway to resource-efficient and sustainable crop production. Usually, the farmers frequently misunderstand the association between crop growth and N application. Thus, the exploration of most favorable nitrogen level is the dire need of Maize growers. Therefore, a field experiment consisting of seven nitrogen application rates viz; T1= No nitrogen (control), T2= Nitrogen @ 75 kg ha⁻¹, T3= Nitrogen @ 100 kg ha⁻¹, T4= Nitrogen @ 125 kg ha⁻¹ (recommended), T5= Nitrogen @ 150 kg ha⁻¹, T6= Nitrogen @ 175 kg ha⁻¹ and T7= Nitrogen @ 200 kg ha⁻¹ were tested under randomized complete block design (RCBD). The highest plant height (cm), leaves plant⁻¹, nodes plant⁻¹, stem girth (cm), fodder weight (g plant⁻¹) and fodder yield (t ha⁻¹) were noted @ 200 kg ha⁻¹. However, nitrogen at 200 kg ha⁻¹ did not vary notably by 175 kg ha⁻¹ for all studied traits. The lowest performance of yield and yield components were noted in control plots. Thus, it is advised to achieve the maximum fodder production of Maize variety Akbar, the crop must be supplied with nitrogen @ 175 kg ha⁻¹ under agro-climatic conditions of Tandojam.

Keywords: Growth; maize; nitrogen; yield.



Correspondence

Muhammad Mahamood-ur-Rahman Jamro

mmrehman@sau.edu.pk

Article History

Received: February 19, 2025

Accepted: April 18, 2025

Published: April 30, 2025



Copyright: © 2025 by the authors.

Licensee: Roots Press, Rawalpindi, Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license: <https://creativecommons.org/licenses/by/4.0>

INTRODUCTION

As a green fodder, Maize (*Zea mays* L.) serves as nutritious food source for livestock. Due to its ability of climate resilience and impressive productivity, it is recognized as the "The Queen of Cereals" (Singh et al., 2021). The maize fodder and grain holds pivotal position in livestock production system (Suganya et al., 2020). In Pakistan, the maize was cultivated on approximately 1.7 million ha yielding around 10.9 million tons annually with contribution of 0.7 percent in GDP (MNFSR, 2023). The maize yield is regulated not only by its photosynthetic ability and dry matter accumulation, but also by agronomic management practices. Among agronomic practices, balance use of nitrogen fertilizer is critical to harvest its maximum quality fodder and grain yield (Lu et al., 2019). As a key nutrient, nitrogen plays a vital role for photosynthesis, nucleic acids, protein production, and overall metabolism (Sharma & Bali, 2017; Tariq et al., 2023). Balanced nitrogen application leads to significant improvement in maize growth and fodder yield (Scavo, 2022) by promoting vegetative growth, influencing various physiological processes such as respiration and transpiration (Rahman et al., 2019). Moreover, nitrogen application in the soil can positively influence Maize root development which increases the surface area for nutrient and water absorption (Al-Kaisi, 2016). However, the excessive nitrogen use can inhibit root growth (Leghari et al., 2016). With the application of nitrogenous fertilizers at the

appropriate time, Maize plant have more leaves, which produce high fodder yield (Hisse et al., 2019). Hence, it is an essential to optimize nitrogen management practices to maximize Maize productivity while minimizing adverse environmental impacts (Smith & Johnson., 2018). Proper nitrogen management practices can enhance Maize productivity and contribute to sustainable agriculture (Jiang et al., 2018). The application of nitrogen, contributes the complementary approaches to nutrient management in Maize cultivation. However, achieving optimal outcomes requires careful consideration of various factors, including nutrient interactions, environmental implications, and agronomic practices (Sainju et al., 2023). Considering the importance of soil applied nitrogen for achieving maximum fodder output in Maize, different nitrogen levels were evaluated to assess the suitable level for achieving better fodder yield of Maize variety “Akbar”.

MATERIALS AND METHODS

Experiment was executed in the departmental farm of Agronomy at S. A. U. Tandojam, Pakistan. Experimental details are listed below:

Experimental design= Randomized complete block design

Replications = 03

Plot size = 6 m x 5 m (30 m²)

Variety = Akbar

(Nitrogen levelskg ha⁻¹) = 7

T₁ = No nitrogen (control)

T₂ = Nitrogen@ 75

T₃ = Nitrogen @ 100

T₄ = Nitrogen @ 125 (recommended)

T₅ = Nitrogen @ 150

T₆ = Nitrogen @ 175

T₇ = Nitrogen @ 200

Land Preparation

Primarily two dry ploughings using mould board plough, followed by leveling with land leveler were used. Then soaking dose of irrigation was applied. As soil reached in the right condition again it was ploughed with cultivator and experimental layout was designed.

Sowing Time and Method

Seed of the maize variety Akbar, was obtained from the Maize and Millet Research Station Dadu, Sindh, Pakistan. According to recommendations 125 kg ha⁻¹, the required quantity of seed was calculated for the experimental plots and sown with single coulter hand drill on 25-07-2023.

Fertilizer and Irrigation Application

The phosphatic fertilizer was applied in the form of Single Super Phosphate (SSP) and potash was also used completely in the form of Sulphate of Potash (SOP) during the land preparation. Nitrogen was applied in two equal doses in the form of urea: the first half of the dose was applied at the time of first irrigation and the remaining half was used at the time of third irrigation.

Crop Harvesting

The experimental units were harvested by cutting, at the soil surface using the sickle on 10-10-2023 and remaining data was collected.

Procedure for Data Recording

Plant height (cm)

Using a measuring tape, the height of five randomly selected plants by each plot was recorded from the bottom to the top of the plant and mean value was calculated.

Leaves plant⁻¹

At the time of harvesting, the numbers of leaves from five randomly selected plants were counted and average was calculated.

Nodes plant⁻¹

From each treatment, the total nodes of five randomly selected plants were counted at the time of harvesting, and then the sum was divided by the total number of plants.

Stem girth (cm)

Stem girth (cm) was measured at harvest using a vernier caliper on five randomly selected plants from each plot.

Fodder weight (g plant⁻¹)

At the maturity stage, randomly selected five plants were cut at ground level then weighed and averaged.

Fodder yield (t ha⁻¹)

It was calculated for each treatment, according the formula given below:

$$\text{Fodder yield (t ha}^{-1}\text{)} = \frac{\text{Fodder yield plot}^{-1}\text{ (kg)} \times 10000 \div 1000}{\text{Net plot size (m}^2\text{)}}$$

Physico-Chemical Properties of Experimental Soil

The analysis showed that the soil was silty clay loam in texture with Sand 19.4%, Silt 41.9% and Clay 38.4%. The recorded chemical properties were, EC (dS m⁻¹) 0.22, pH 8.10, Organic matter 0.73%, Total Nitrogen 0.09 %, available P (mg kg⁻¹) 8.78 and extractable K (mg kg⁻¹) 0.86.

Statistical Analysis

The collected data were analyzed using the software Statistix Ver. 1.0 (Statistix, 2006). The Least Significant Difference (LSD) test at the 0.05 level was used to compare the treatments.

RESULTS AND DISCUSSION

Meteorological Data

During the experimental season of year (2023), the meteorological data of Tandojam was obtained from Meteorological Station Tandojam, Sindh Pakistan. The details of weather data on weekly basis for min and max: temperature (C), humidity (% rh) and Rainfall (mm) are shown in Figure 1.

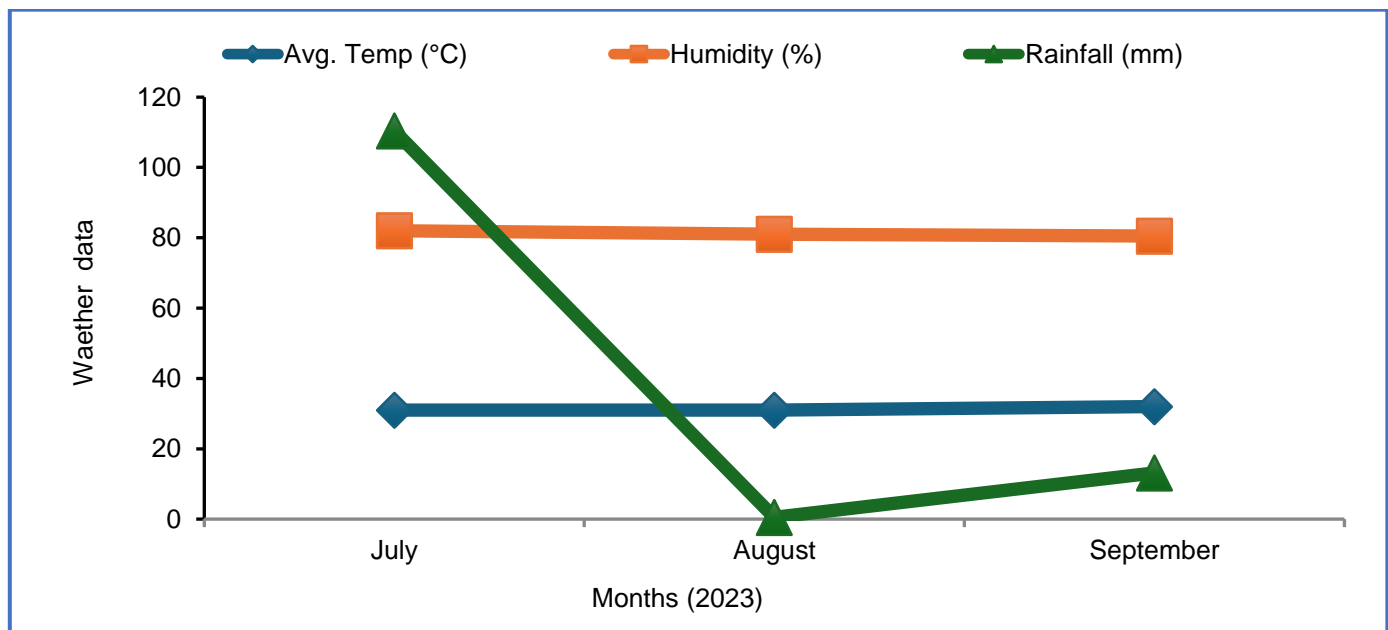


Figure 1. Weather data of Tandojam during maize growing season (2023).

The data pertaining to plant height (cm) is shown in Figure 2. The results illustrated that the maximum plant height 186.0 cm was noted in T7 (Nitrogen @ 200 kg ha⁻¹), followed by T6 (Nitrogen @ 175 kg ha⁻¹) with plant height of 180.7 cm. While, the T5 and T4 ranked 3rd and 4th in efficacy having plant height of 165.0 cm and 157.8 cm, respectively. Furthermore, declining trend was observed in T2 and T3 where plant height of 121.0 and 132.0 cm was recorded. Nevertheless, minimum plant height 116.4 cm was noticed in T1 (Untreated). It is worth mentioning that the plant height between T7 and T6 was found non-significant with each other on the basis of LSD 0.05 value 14.618. The increase in plant height with increased nitrogen levels could be ascribed to the sufficient availability of nitrogen which leads to boost the Maize plant by enhancing protein synthesis, chlorophyll production and root development, which all contributed to more vigorous and taller growth (Yousaf et al., 2021). These results are in line with the study of Hanifullah et al. (2023) and Tirfi (2023), who reported the tallest plants (196 cm) with the application of 180 kg N ha⁻¹. Parallel results also reported by Mahesh, (2020) who noted the highest plant height (140.40 cm) in plots where 120 kg N ha⁻¹ was applied.

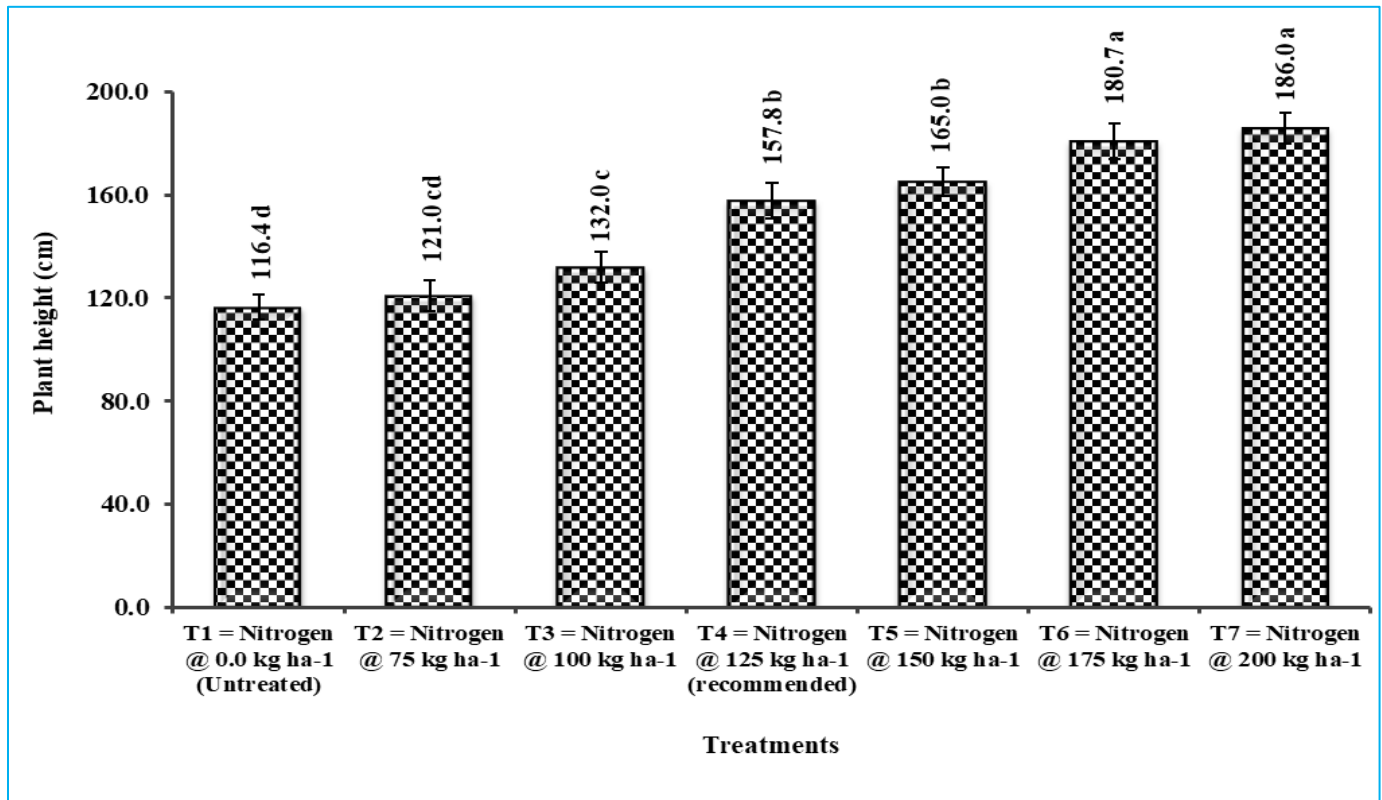


Figure 2. Effect of nitrogen on plant height (cm) of maize variety Akbar. P-value=0.0000; SE=6.7092; LSD0.05=14.618

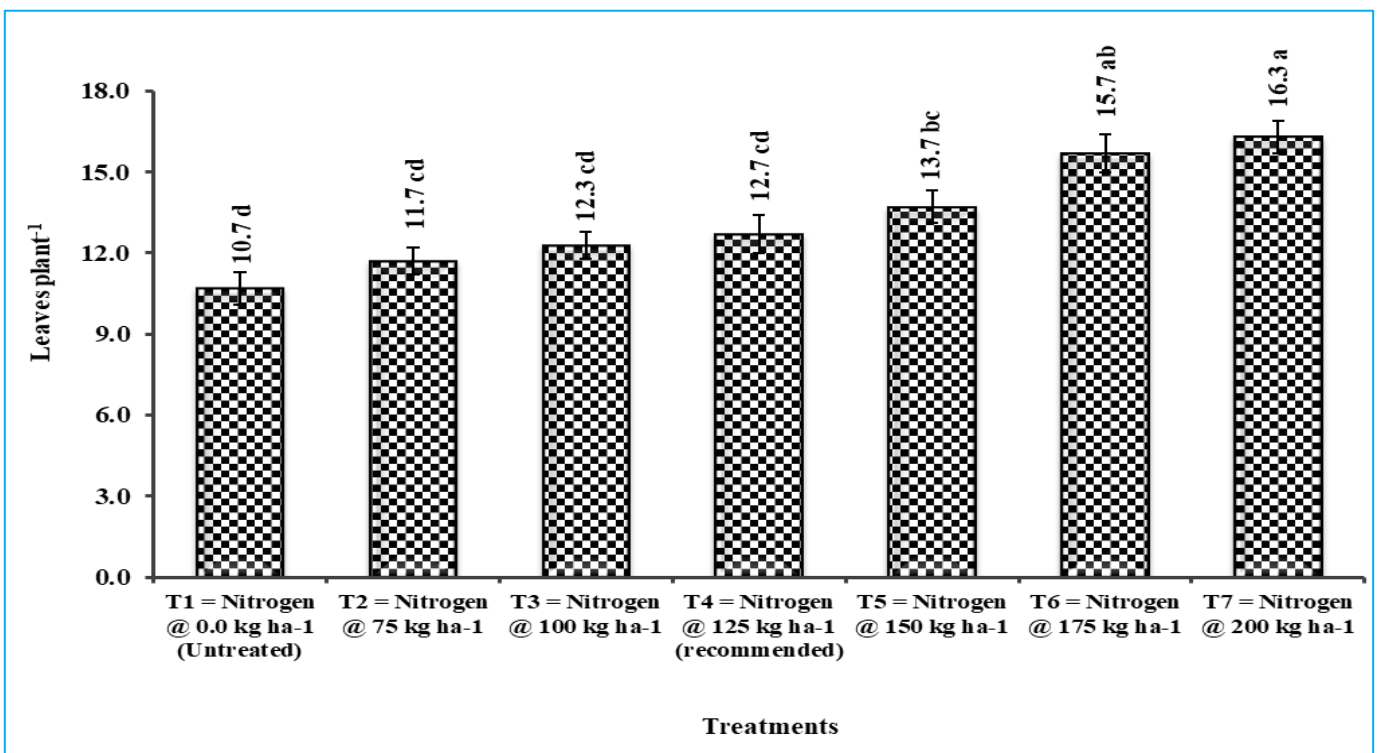


Figure 3. Effect of nitrogen on leaves plant⁻¹ of maize variety Akbar. P-value=0.0017; SE=1.0789; LSD0.05=2.3507.

The data on the number of leaves plant⁻¹ are shown in Figure 3. It is apparent from the data that T7 with nitrogen applied @ 200 kg ha⁻¹, recorded the highest figure (16.3) whereas T6 (Nitrogen @ 175 kg ha⁻¹) followed in performance with 15.7 leaves plant⁻¹. The results regarding the T5 and T4 were noted 13.7 and 12.7 leaves plant⁻¹. Additionally, the leaves plant⁻¹ decreased to 11.7 in T2 and 12.3 in T3. However, least (10.7) leaves plant⁻¹ was

recorded in T1 (Untreated). It is pertinent to mention here that on the basis of LSD0.05 value (2.3507) non-significant difference for leaves plant⁻¹ was noted between T7 and T6. The increased number of leaves plant⁻¹, especially with the use of nitrogen, was observed @ 200 kg ha⁻¹ was due to the reason that, more nitrogen promotes cell division (Landrein et al., 2018), consequently producing new tissues and encourages the vegetative growth of plant parts like stems and leaves. The increased metabolic activity promotes the formation of new leaves throughout the vegetative phase. Our results are also supported by (Haraga & Ion, 2023) who reported the utmost number of leaves with the use of higher nitrogen doses. Similarly, Hammad et al. (2018) confirmed that, the use of nitrogen improves the node and length of internode. Additionally, Shrestha et al. (2018) observed that nitrogen promotes leaf multiplication significantly.

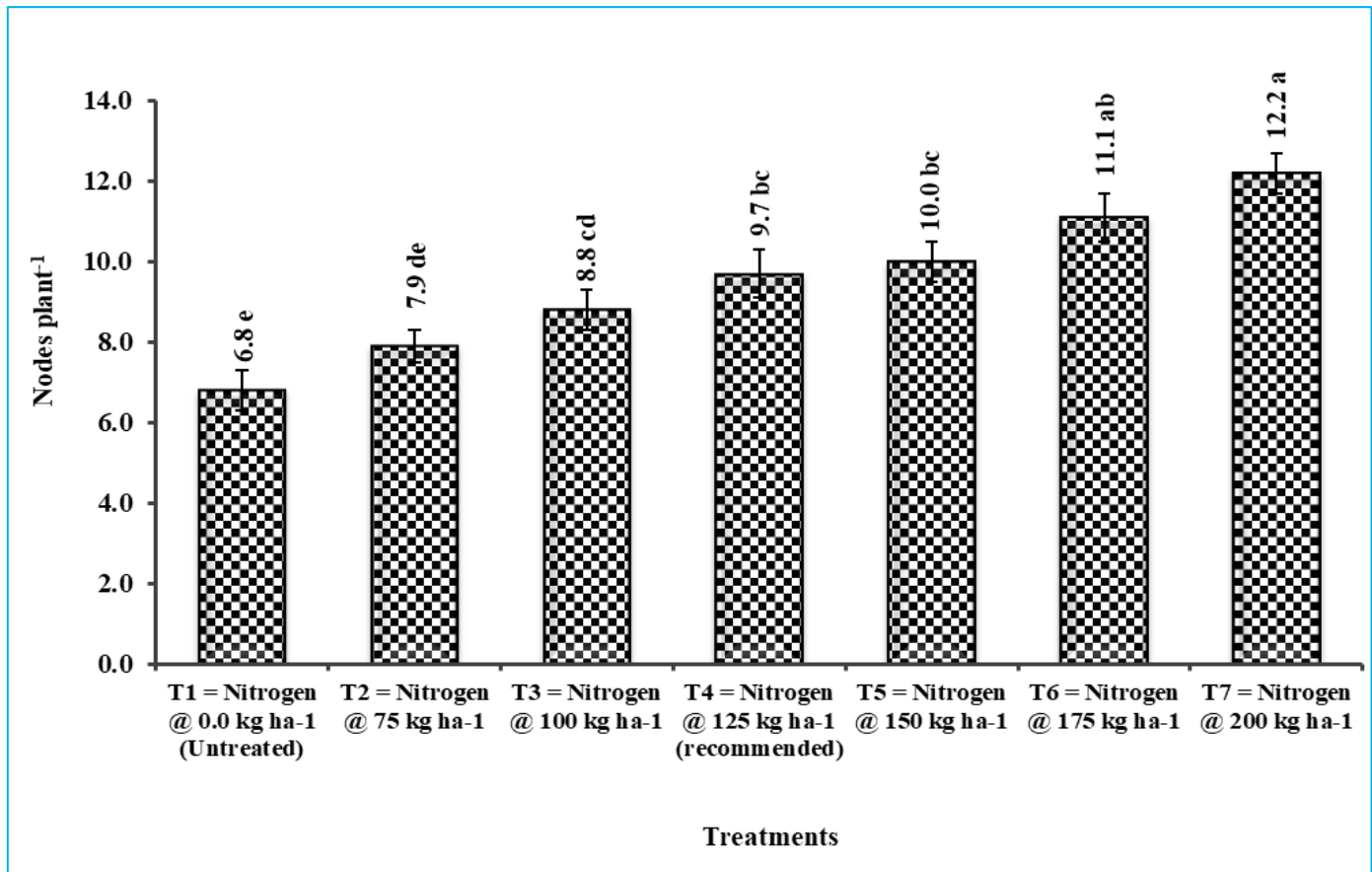


Figure 4. Effect of nitrogen on nodes plant⁻¹ of maize variety Akbar. P-value=0.0001; SE=0.6716; LSD_{0.05}=1.463.

The data pertaining to nodes plant⁻¹ is shown in Figure 4. The results illustrated that the maximum nodes plant⁻¹ (12.2) were noted in T7 (Nitrogen @ 200 kg ha⁻¹), followed by T6 (Nitrogen @ 175 kg ha⁻¹) with nodes plant⁻¹ (11.1). While T5 and T4 were recorded nodes plant⁻¹ 10.0, 9.7 respectively. Furthermore, declining trend was observed in T3 and T2 where nodes plant⁻¹ 8.8 and 7.9 were noted. Nevertheless, minimum (6.8) nodes plant⁻¹ was noticed in T1 (Untreated). However T7 and T6 were found non-significant with each other on the basis of LSD 0.05 value (1.4634). These findings emphasize the nitrogen effect on the formation of nodes in Maize plant and suggesting that, the optimizing nitrogen use can contribute to superior node initiation. Because adequate nitrogen increases the rate of cell division, particularly in meristematic tissues such as the stem tips (Mahdi, 2011). This leads to more nodes being formed along the stem as the plant can continue to grow. Furthermore, Nitrogen influences the production and activity of plant hormones (Wang et al., 2018) such as cytokinins and auxins (Teale et al., 2006) which regulate various aspects of growth, including the formation of nodes. These findings are in collaboration with the results of (Kulwinder & Karan., 2023) who reported that, an application of the nitrogen @ 100 kg ha⁻¹ observed 14.88 nodes plant⁻¹ in the Maize variety J-1006. Similarly, (Ivanka & Veselina, 2024) concluded that, the Maize variety Saccharate recorded nodes plant⁻¹ (8.25) with the use of 200 kg ha⁻¹ nitrogen.

Results regarding the stem girth (cm) are presented in figure (5). It is depicted from the data that T7 (Nitrogen @ 200 kg ha⁻¹) resulted in highest (6.7 cm) stem girth whereas T6 (Nitrogen @ 175 kg ha⁻¹) followed in performance with

stem girth (6.0 cm). The results further suggested that T5 and T4 obtained 3rd and 4th position with stem girth 4.6 and 3.6 cm respectively. Moreover, stem girth reduced to 3.4 and 2.9 cm in T3 and T2 respectively. However, least (2.2 cm) stem girth was recorded in T1 (Untreated). It is pertinent to mention here that on the basis of LSD 0.05 value (1.1037) non-significant difference for stem girth (cm) was noted between T7 and T6. The increase in stem girth (cm) due to increased nitrogen application @ 200 kg ha⁻¹ is in harmony with the study of (Szabo et al., 2022) who also concluded that Nitrogen enhances the diameter of stem. According to Bojtor et al. (2022) due to the effect of nitrogen the stem diameter was noted at higher level in Maize crop. Generally, the nitrogen boosts overall vegetative growth of the maize plant, which increases the biomass of the stem (Oluoch et al., 2022). However, in the contrast to our study (Chanchal et al., 2023) reported the stem girth 3.5 cm of fodder maize variety African tall with the use of nitrogen @ 160 kg ha⁻¹. Ahmad et al., 2024 concluded that with the use of 200 kg ha⁻¹N, maize variety Jumbo recorded (3.40 cm) stem diameter.

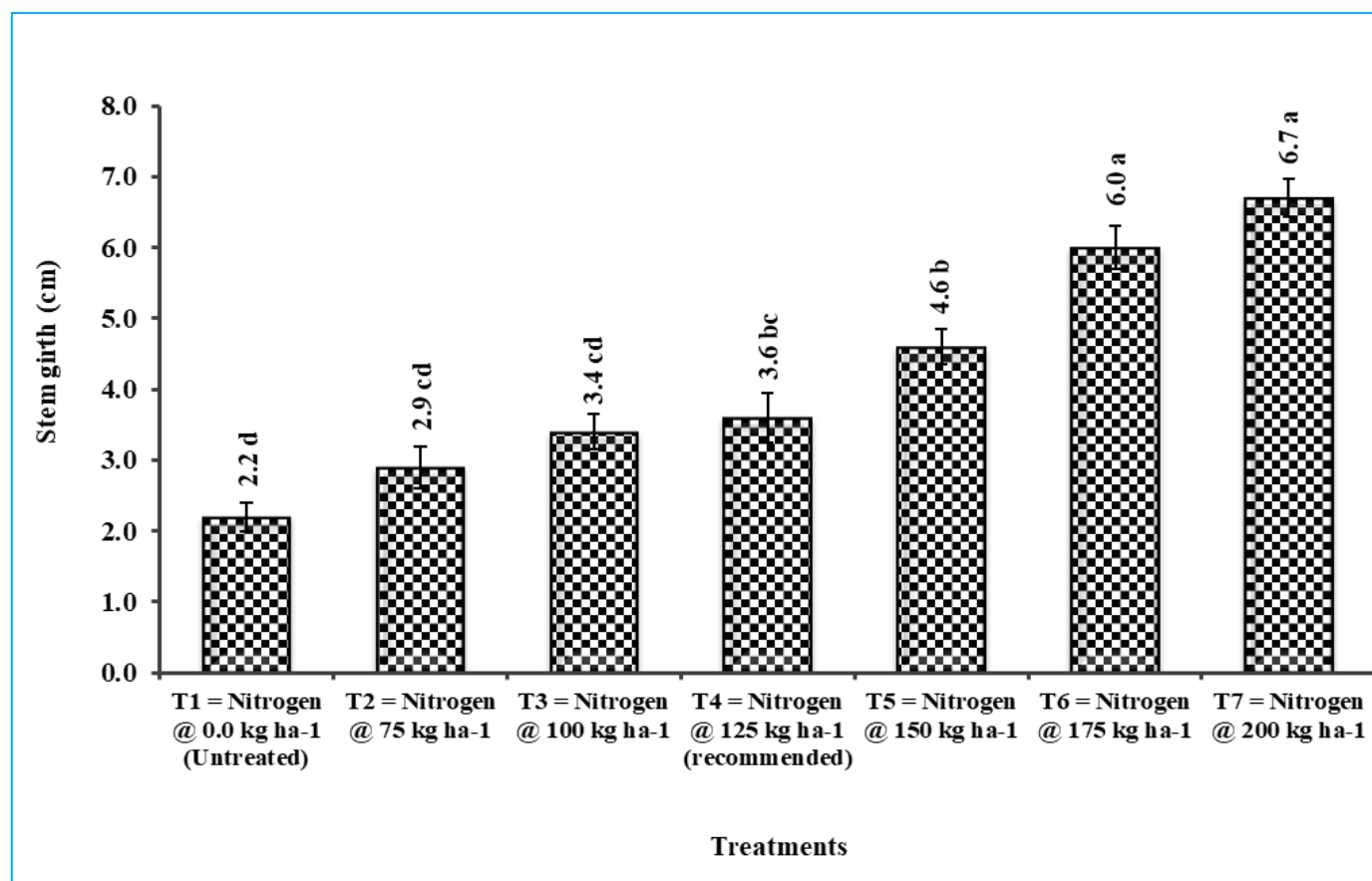


Figure 5. Effect of nitrogen on stem girth (cm) of maize variety Akbar. P-value=0.0000; SE=0.5066; LSD_{0.05}=1.1037.

The data pertaining to fodder weight (g plant⁻¹) shown in Figure 6. The results illustrated that the maximum fodder weight plant⁻¹ (489.5 g) noted in T7 (Nitrogen @ 200 kg ha⁻¹) followed by T6 = (Nitrogen @ 175 kg ha⁻¹) with (486.6 g) fodder weight plant⁻¹. While T5 and T4 were observed lower 472.5, 449.0 fodder weight (g plant⁻¹) respectively. Furthermore, declining trend was observed in T3 and T2 where fodder weight plant⁻¹ of 354.5 and 265.2g was recorded. Nevertheless, minimum (230.5g) fodder weight plant⁻¹ was noticed in T1 (Untreated). However, the fodder weight plant⁻¹ between T7 and T6 was recorded non-significant with each other on the basis of LSD 0.05 value (10.885). It is observed from this study that sufficient nitrogen promotes the development of healthier leaves that tend to a larger leaf area. More leaves resulted in the larger surface area for nutrient and water absorption, allowing the plant to produce more biomass. These results are not in association with previous research of (Iranna et al., 2022) who noted the fodder weight (229.7 g) plant⁻¹ by the use of 150 kg N ha⁻¹ in the 'African Tall' Maize variety. Our study establishes the results of (Andrzej et al., 2020) who noted the fodder yield plant⁻¹ ranging from 427-566 g under 80-115- 120 kg K ha⁻¹ of the two varieties of Maize, Kosmo 230 and RGT Kixxo. Results regarding the fodder yield (t ha⁻¹) are presented in Figure 7. The data showed that T7 (Nitrogen @ 200 kg ha⁻¹) resulted in highest fodder production

(20.6t ha⁻¹) which was followed by T6 (Nitrogen @ 175 kg ha⁻¹) with fodder yield of 19.4 t ha⁻¹. The results further suggested that, T5 and T4 ranked 3rd and 4th with respective fodder yield of 16.2 t ha⁻¹ and 13.3 t ha⁻¹. Moreover,

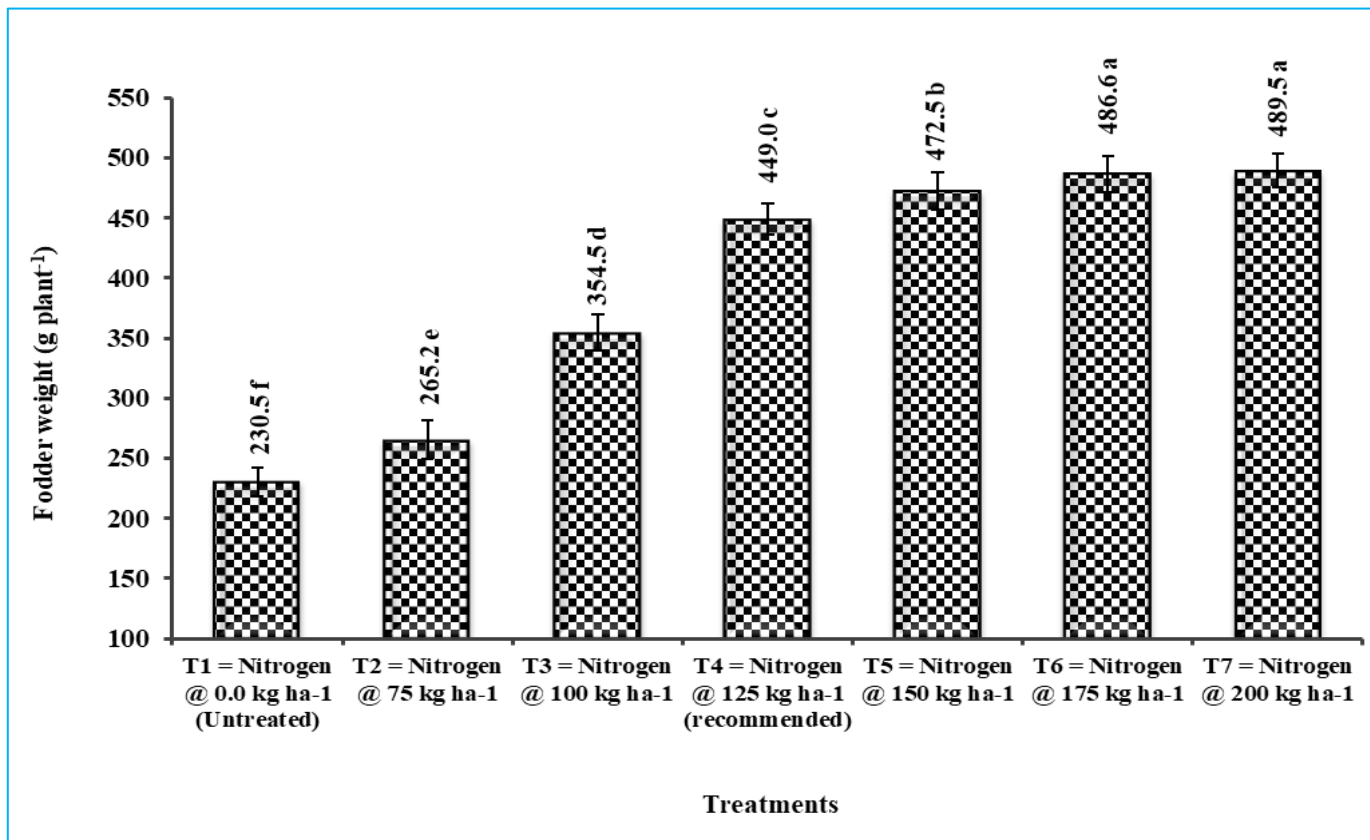


Figure 6. Effect of nitrogen on fodder weight (g plant⁻¹) of maize variety Akbar. P-value=0.0000; SE=4.9960; LSD_{0.05}=10.885

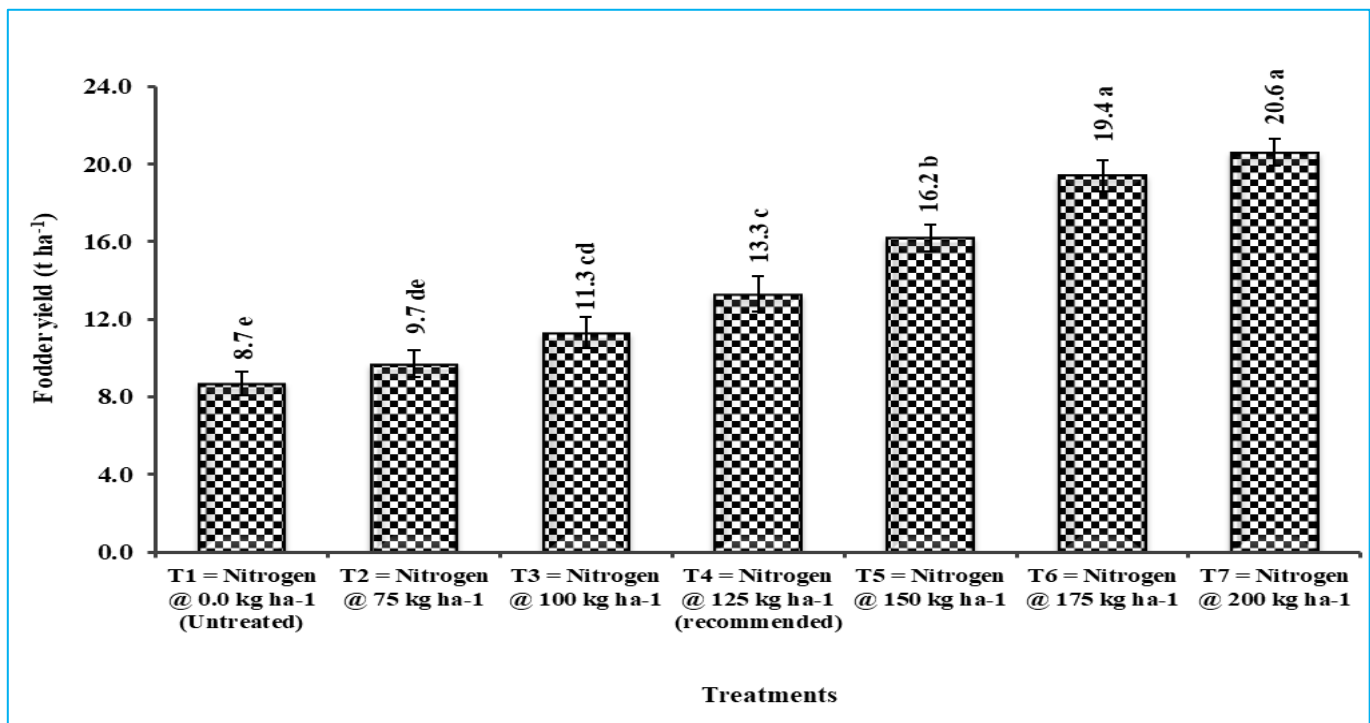


Figure 7. Effect of nitrogen on fodder yield (t ha⁻¹) of maize variety Akbar. P-value=0.0000; SE=1.0759; LSD_{0.05}=2.3442

fodder yield was lower for T₃ and T₂. However, least (8.7t ha⁻¹) fodder yield was recorded in T₁ (Untreated). It is pertinent to mention that non-significant difference for fodder yield was noted between T₇ and T₆. The reason of higher fodder yield may be attributed to the maximum consumption of nitrogen because it is an essential element of plant tissue. Therefore, its constructive effect on yield components resulted in superior fodder production. These findings are concord with Panwar et al. (2020) who revealed that, the sufficient N increases the green fodder production significantly. The increase in Maize fodder, with amplified nitrogen also reported by (Varma et al., 2022 and Kamsu et al., 2022).

CONCLUSION

The experimental results showed that, the increasing levels of nitrogen boosted the crop growth and yield parameters. It is concluded that the superior growth and fodder yield (t ha⁻¹) can be achieved by application of nitrogen at 200 and 175 kg ha⁻¹. However, both levels of the N were non-significant statistically. It is recommended that nitrogen application at 175 kg ha⁻¹ must be used so as to obtain maximum fodder production of Maize variety Akbar.

AUTHOR'S CONTRIBUTION

Performed the experiment: Shabir Hashim, Analyzed the data: ZA Abbasi, Wrote the paper: MMR Jamro and Shahjahan Rajput, contributed in material: Pir Ahmed Naqi Shah, conceived and designed the experiment: MN Kandhro.

FUNDING

None.

AVAILABILITY OF DATA AND MATERIAL

All the data and material available at the concerned department.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the relevant forums.

CONSENT FOR PUBLICATION

All the authors are agreeing on the publication.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGEMENT

This study is a part of M.Sc. thesis. The first Author is deeply grateful to his supervisory committee and other esteemed teachers for their guidance.

REFERENCES

- Ahmad, H., Arif, M., Khan, Z.A., Rehman, S., ullah, I., Khan, R.A., Ahmed, U., & Iqbal, W. (2024). Comparative Performance of Modern Jumbo Maize Variety and Local Varieties in Fodder Production under Different Nitrogen Levels, *Journal of Bioresource Management*, 11(2): 110-121.
- Al-Kaisi, M. (2016). Nitrogen management for improved use efficiency. *Journal of Plant Protection*, 84(4), 868-875.
- Andrzej, A., Piotr, M., Stanislaw, K., Zdzislaw, K., Adam, J.L., & Dariusz, J.C. (2020). Effect of seeding rate on selected physical parameters and biomass yield of maize *Chilean Journal of Agriculture Research*, 80(2) 171-180.
- Bojtor, C., Illés, Á., Nasir, S.M., Széles, A., Tóth, B., Nagy, J., & Marton, C.L. (2022). Nutrient Composition Analysis of Maize Hybrids Affected by Different Nitrogen Fertilization Systems, *Plants* 11(12) 1-14.
- Chanchal, P., Jha, S.K., Dwivedi, S.K., & Purna, J. (2023). Effect of different nitrogen levels and planting geometry on growth parameters and seed yield of African tall fodder maize (*Zea mays* L.). *The Pharma Innovation Journal*, 12(12): 3570-3574.
- Hammad, H.M., Abbas, F., Saeed, S., Fahad, S., Cerdà, A., Farhad, W., & Bakhat, H.F. (2018). Offsetting land degradation through nitrogen and water management during Maize cultivation under arid conditions. *Land Degradation and Development*, 29(5), 1366-1375.

- Hanifullah., Muhammad, T., Muhammad, O.K., Tahir, S., Nawab, A.K., Abid, H., Gul, B., Muhammad, I., & Shabir, M. (2023). Influence of Nitrogen and Phosphorus on Yield of Maize. *International Journal of Agricultural and Statistical Sciences*, 19(1) 381-388.
- Haraga, L.C., & Ion, V. (2023). The effects of side-dressing different rates and release types of Nitrogen fertilizer on hybrid seed Maize production. *Romanian Agricultural Research*, 40, 429–438.
- Hisse, I.R., Andrea, K.E., & Otegui, M.E. (2019). Source-sink relations and kernel weight in Maize inbred lines and hybrids: Responses to contrasting nitrogen supply levels. *Field Crops Research*, 230: 151-159.
- Iranna, S., Shivakumar, B.G., Kubasad, V.S., & Kulkarni, N.S. (2022). Evaluation of precision nitrogen management practices on growth, yield and economics of fodder maize. *Journal of Farm Sciences*, 35(1): (80-84).
- Ivanka, M., & Veselina, V. (2024). Growth and yield response of maize (*Zea mays* var. *saccharata*) to different nitrogen fertilization sources and rates. *Journal of Central European Agriculture*, 25(1)137-145.
- Jiang, L.L., Zhang, Z.X., & Zheng, E.N. (2018). Effects of different fertilizations on chlorophyll fluorescence characteristics and the yield of Maize in black soils in cold region. *Journal of Irrigation Drainage*, 37(3), 75–80.
- Kamsu, A., Kalasare, R.S., Maitra, S., Adhikary, R., & Mahapatro, S. (2022). Response of summer maize (*Zea mays* L.) to different doses of nitrogen and potassium. *Crop Research*, 57(3):145-150.
- Kulwinder, S., & Karan, V. (2023). Effect of different levels of nitrogen and phosphorus on growth of fodder Maize (*Zea mays* L.) Forage Research, 49(1) 99-102.
- Landrein, B., Formosa, J.P., Malivert, A., Schuster, C., Melnyk, C.W., Yang, W., Turnbull, C., Meyerowitz, E.M., Locke, J.C.W., Jönsson, H. (2018). Nitrate modulates stem cell dynamics in Arabidopsis shoot meristems through cytokinins. *Proceedings of the National Academy of Science USA*, 115, 1382–1387.
- Leghari, S.J., Wahocho, N.A., Laghari, G.M., Hafeez, L.A., Mustafa, G.B., Hussain, K.T., Bhutto, A.T., Wahocho, S.A., Lashari, A.A. (2016). Role of nitrogen for plant growth and development: A review. *Advances in Environmental Biology*, 10, 209–219.
- Lu, Z., Qiu, X., Zhang, M., Zhang, Y., Qin, H., & He, G. (2019). Effect of drought stress on leaf photosynthetic characteristics and yield of Maize. *Water Saving Irrigation*, 2, 34-42.
- Mahdi, S.S. (2011). Response of fodder Maize (*Zea mays* L.) to levels of nitrogen, zinc and seed rate under temperate conditions. Ph.D Dissertation, Division of Agronomy, Sher-e-Kashmir University of Agricultural Science and Technology.
- Mahesh, K., Bishnu, P.P., Pritee, S., Aarty, G.C., Rajendra, R. (2020). Effect of different doses of Nitrogen on production of spring Maize (*Zea mays* L.) in Gulmi, Nepal. *Sustainable Food and Agriculture* 1(1): 01-05.
- Ministry of National Food Security & Research (2023). Crops area & production (district wise) economic wing Islamabad, Government of Pakistan. pp 6.
- Oluoch, K.O.A., Groote, De., Gitonga, Z.M., Jin, Z., Davis, K.F. (2022). A suite of agronomic factors can offset the effects of climate variability on rain fed maize production in Kenya. *Scientific Reports*, 12(1), 16043.
- Panwar, D., Chouhan, D., Singh, D., Singh, R.P., Nepalia, V. (2020). Performance of fodder maize (*Zea mays* L.) under varying plant densities and fertility levels. *International Journal of Current Micro and Applied Sciences*, 11, 255–260.
- Rahman, M.A., Haque, M.E., & Ali, M.S. (2019). Nitrogen management for enhancing fodder yield and nutritional quality of Maize variety "Akbar." *International Journal of Agriculture Research*, 6(4), 312-324.
- Sainju, U., Irika, R., Crista, R., & Lopez, J. (2023). Sustainable nitrogen management practices for Maize cultivation. *Journal of Sustainable Agriculture*, 45(3), 987-1001.
- Scavo, A., Fontanazza, S., Restuccia, A., Pesce, G.R., Abbate, C., & Mauromicale, G. (2022). The role of cover crops in improving soil fertility and plant nutritional status in temperate climates: A Review. *Agronomy for Sustainable Development*, 42(5), 93-104.
- Sharma, L.K., & Bali, S.K. (2017). A review of methods to improve nitrogen use efficiency in agriculture. *Journal of Sustainable Agriculture*, 10(1), 51-64.
- Shrestha, J., Nath, Y.D., Prasad, A.L., & Prasad, S.J. (2018). Effects of Nitrogen and plant density on Maize (*Zea mays* L.) Phenology and Grain Yield. *Current Agriculture Research Journal*, 6(2), 175–182.
- Singh, J., Partap, R., Singh, A., & Kumar, N. (2021). Effect of Nitrogen and Zinc on Growth and Yield of Maize (*Zea mays* L.). *International Journal of Biological Research and Stress Management*, 12(3), 179–185.
- Smith, J.K., & Johnson, A.B. (2018). Effects of nitrogen fertilization on growth and yield of Maize. *Journal of Crop Science*, 45(3), 215-226.
- Statistix, (2006). Statistix 8 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright © 2006 by Analytical Software.
- Suganya, A., Saravanan, A., & Manivannan, N. (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of Maize grains: An overview. *Journal of Soil and Plant Science*, 51(5), 201-214.
- Szabo, A., Széles, Á., Illés, C., Bojtor, S.M.N., Mousavi, L., Radócz & Nagy, J. (2022). Effect of Different Nitrogen Supply on Maize Emergence Dynamics, Evaluation of Yield Parameters of Different Hybrids in Long-Term Field Experiments. *Agronomy* 12(2) 1-13.

- Tariq, A., Zeng, F., Graciano, C., Ullah, A., Sadia, S., Ahmed, Z., & Zhang, Z. (2023). Regulation of Metabolites by nitrogen in Maize. *Journal of Plant Science*, 70(4), 195-208.
- Teale, W.D., Paponov, I.A., Palme, K. (2006). Auxin in action: signalling, transport and the control of plant growth and development. *Nature reviews. Molecular cell biology* 7, 847– 859.
- Tirfi, A.G. (2023). Effect of different nitrogen dose on growth and yield characteristics of hybrid maize (*Zea mays* L.) Varieties at Sundar bazar, Lamjung. *Malaysian Journal of Sustainable Agriculture*, 7(2), 65-71.
- Varma, D.J., Adhikary, R., Reddy, M.D., Maitra, S. (2022). Influence of nitrogen and phosphorus on growth and yield of summer maize (*Zea mays* L.). *Crop Research*, 57(3):141-144.
- Wang, J., Lu, K., Nie, H., Zeng, Q., Wu, B., Qian, J., Fang, Z. (2018). Rice nitratetransporter OsNPF7.2 positively regulates tiller number and grain yield. *Rice*, 11-12.
- Yousaf, M., Bashir, S., Raza, H., Shah, A.N., Iqbal, J., Arif, M., Hu, C. (2021). Role of nitrogen and magnesium for growth, yield and nutritional quality of radish. *Saudi Journal of Biological Sciences*, 28: 3021-3030.