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RESEARCH PAPER

Exploring the effect of nitrogen levels on yield and yield attributes of diverse open-pollinated varieties (OPVs) of maize (*Zea mays*)

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Key Message: The study evaluated the effects of different nitrogen levels on maize yield and attributes across various open-pollinated varieties. Results indicate that applying 200 kg ha^{-1} of nitrogen significantly enhances plant growth, yield, and yield components, with the Jalal variety showing the best overall performance.

Abstract

A field trial was carried out during the Kharif season of 2022 at the Agronomy Research Farm, University of Swabi. The trial was designed as a 3×3 factorial experiment, involving three varieties (CIMMYT FATA, DSW, and Kaptan) which were allocated to the main plots. Three levels of nitrogen (200, 150, and 100 kg ha−1) were applied to the subplots. A plot size of 22.5 m^2, having 6 rows 75 cm apart with plant-to-plant distance of 25 cm was maintained. The concerned maize varieties were sown at the first week of July 2022. The required amount of N was applied at the time of second irrigation using urea fertilizer. Similarly, the recommended dose of phosphorus (TSP) and potassium (KCl) were applied at a rate of 60 kg ha^{-1} prior to the final ploughing. The field was cultivated twice with a cultivator and rotavator, and then leveled with a back leveler. Irrigation was managed according to weather conditions, and the water needs of the crop. Among the different maize varieties, Jalal variety significantly ($p<0.05$) delayed tasseling (54 days) and silking (61days), Plant height (193 cm), ear length (18.9 cm), 1000 grain weight (31 g), grains per ear (422), grain yield (5030 kg ha^{-1}) and biological yield (12337 kg ha^{-1}) were all improved when compared to DSW and CIMMYT FATA cultivars. However, the harvest index (43.7%) was highest for the DSW variety. The application of 200 kg ha^{-1} delayed silking (60 days) and tasseling (53 days), as well as enhanced plant height (192 cm), ear length (18.8 cm), grains per ear (411), thousand seed weight (305 g), biological yield (12036 kg ha^{-1}), and grain yield (4995 kg ha^{-1}) as compared to 100 and 150 kg N ha^{-1}. Based on the study's findings, it is recommended that nitrogen be supplied at a rate of 200 kg ha^{-1}and the Jalal variety be used to boost maize yield as well as yield components in the study area.

Keywords: Crop nutrition, Maize, Nitrogen fertilization, Open-pollinated varieties (OPVs), Yield attributes

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Introduction

Maize (*Zea mays* L.) is a member of the Poaceae family. It has a fibrous root system, short-lived and cross-pollinated. It provides raw materials for industries as well as animal feed for animals (Tasneem et al., 2004; Batool et al., 2019; Noor et al., 2021). It is the world's most frequently farmed cereal, ranking third among major cereal crops (Carruthers et al, 2000; Aslam et al., 2021; Raza et al., 2023). It is primarily cultivated in industrialized countries for industrial products (dextrose, glucose and starch) as well as animal feed (Malvar et al., 2008; Iqbal et al., 2022). Its average yield of 4815 kg ha^{-1} was recorded (FAOSTAT, 2008). In Pakistan it is cultivated in 1.04 million hectares areas, yielding 3.1 million tons of grain per year with an average yield of 2984 kg ha^{-1} (MINFAL, 2007). As the most significant summer cereal crop, it takes up almost 27% of all cultivated area in Pakistan's Northwest Frontier Province (NWFP) each year (Khan et al., 2004). In the NWFP region, maize is grown on about 0.49 million hectares, producing approximately 0.78 million tons annually, with an average yield of 1590 kg ha^{-1} (MINFAL, 2007).

Maize (*Zea mays* L.), commonly known as corn, is a significant cereal crop globally. Maize is commonly called corn which has many types or names such as flint corn, dent corn, flour corn, waxy corn, popcorn and sweet corn. All of these have unique nutritional properties (Gibson & Benson, 2002). It is usually used in three industries e.g. wet milling, dry milling and nixtamalization. The raw material from these further changed into snacks bakery items, breakfast cereals, beer, tortillas and distilled spirits (Serna-Saldivar, 2016). These nutritional values have a great impact on the status of civilizations throughout the world. It has also phytochemical compounds. These compounds have an important role in controlling chronic diseases. Phytochemicals include phenolic compounds, phytosterols and carotenoids. It has also Galanthus nivalis agglutinin (GNA) or lectin (Shah et al., 2016). Maize oils have essential fatty acid which has beneficial effect on children and adults (Dupont et al., 1990). Decoctions made from the roots, silk, leaves, and stems of the plant are used to treat nausea, bladder issues, stomach problems, and vomiting. It also has potential anti-HIV activity. Zein in maize endosperm has application in pharmaceutical and biomedical fields (Li & Song, 2020). Resistant starch of maize used in cecal cancer treatment and obesity related problem (Keenan et al., 2015).

However, there are other reasons that contribute to maize's low yield and productivity. The most important parameters contributing to low maize production are wrong crop nutrition management, poor soil fertility, and acceptable genotype (Shah et al., 2009). Nutrient insufficiency is a fundamental barrier to the establishment of an economically effective farm (Fageria & Baligar, 2005). Farmers in developing countries often face challenges in accessing an adequate supply of N fertilizer. This can be attributed to various factors, including limited access to fertilizers due to high prices or insufficient availability. Additionally, there may be issues related to the timing and application rates of fertilizers, as highlighted by Bellete (2014). This has to do with the depletion of physical soil properties, erosion of topsoil, loss of organic matter, and macro- and micronutrients in the soil (Zeleke et al., 2010). Consequently, a consistent and optimum supply of nutrients is vital for optimal crop development and growth (Ali & Anjum, 2017).

In fact, the response of maize on application of nitrogen fertilizer is based on cultivars, location of cultivation, and nutrient availability (Ahmad et al., 2018). Maize varieties respond better to fertilizers than local cultivars (Taye, 2009). When provided with favorable environmental conditions and better management practices, maize varieties respond well to fertilizer application, especially nitrogen and phosphorus, producing better and more consistent yields than local types. The hybrids' yield of maize is low when planted with less than optimal management approaches. Use better nitrogen fertilizer variety. Maize's high-yielding potential is being realized thanks to improved application procedures. The key to better and maintained crop production is supplying necessary plant nutrients in the right amount and proportion, as well as using precise procedures and timing. As a result, applying properly balanced fertilizer amounts based on site and type of crop is one of the most successful agronomic methods for increasing productivity. However, much of the research has concentrated on crop nitrogen requirements, with limited information available on other essential nutrients such as sulfur (S) potassium (K), boron (B), zinc (Zn) and other micronutrients. The primary objective of this experiment was to determine the impact of varying nitrogen fertilizer rates on the growth and yield characteristics of different maize varieties.

Materials and Methods

This research was conducted during Kharif season 2022 at the University of Swabi in Agronomy Research Farm, University of Swabi. The experiment was designed using a Randomized Complete Block Design (RCBD) with split plots and three replications. Each replication included 9 treatments, with three maize varieties (CIMMYT FATA, DSW, and Kaptan) in the main plots and three nitrogen levels (100, 150, and 200 kg ha^{-1}) in the subplots. Plots were 22.5 m², consisting of 6 rows spaced 75 cm apart and a plant-to-plant distance of 25 cm. The maize varieties were sown in the first week of July 2022, and the designated nitrogen levels were applied with urea fertilizer during the second watering. Similarly, the essential phosphorus (TSP) and potassium (KCl) doses were used at rates of 60 kg ha^{-1} before the final ploughing. The field was plowed two times using a rotavator and cultivator, followed by leveling with a back leveler. Irrigation was applied based on atmospheric conditions and the specific water requirements of the crop. All other agronomic methods were kept consistent across all experimental plots. Following are the factors and their levels:

Factor A:		**Varieties (Main plot)**
V_1	=	CIMMYT FATA
V_2	=	DSW
V_3	=	Jalal
Factor B:		**Nitrogen (kg ha^{-1}) (Sub plot)**
N_1	=	100
N_2	=	150
N_3	=	200

The following parameters were studied:

Days to tasseling

The data for this parameter was recorded for each treatment from date of planting till 80% of the tassels emerged to collect data regarding days to tasseling.

Days to silking

Data on days to silking were recorded by counting the number of days from planting until 80% of the silks were visible.

Plant height (cm)

Plant height was measured at physiological maturity by selecting five random plants from each experimental unit. The total vertical height, from the base to the tassel tip, was recorded using a measuring rod. The average of all measured plants was used to calculate a single mean.

Ear length (cm)

Five ears were chosen at random, and their lengths were measured using a measuring tape before being averaged to yield a single mean.

Number of grains ear^{-1}

We counted the grains in each ear by first randomly selecting five ears from each subplot, shelling, drying, and counting the grains separately.

1000 grains weight (g)

Thousand grains were collected from each plot. They were threshed, dry and clean. Their weights will be measured in gram (g) using an electric balance.

Biological yield (kg ha^{-1})

To calculate this parameter, four central rows were harvested from each plot. After five days of sun drying and weighing the obtained material, the biological yield was measured by using following formula to kg ha^{-1}:

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological weight of four central rows}}{\text{R} - \text{R distance} \times \text{row length} \times \text{No. of rows}} \times 10{,}000$$

Grain yield (kg ha^{-1})

Grain yield was measured after shelling the dried ears from the four central rows of each plot. Then it was converted into kg ha^{-1}:

$$\text{Garin yield (kg ha}^{-1}) = \frac{\text{Grain weight of four central rows}}{\text{R} - \text{R distance} \times \text{row length} \times \text{No of rows}} \times 10{,}000$$

Harvest index (%)

Following formula was used to calculate the harvest index of each plot:

$$\text{Harvest index(\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The data was statistically evaluated using methods outlined by Steel et al. (1996). To assess the differences between group means, the Least Significant Difference (LSD) test was employed. In this analysis, a significance level of p<0.05 was used, indicating that differences with a p-value less than 0.05 were considered statistically significant.

Results and Discussion

Number of days to tasseling

Table 1 shows data regarding the No. of days required for tasseling. The results showed that the No. of days till maize tasseling was considerably influenced by nitrogen levels and maize varieties, according to the analysis of the data, but the interaction between nitrogen and varieties was not significant. Jalal variety required additional days to tassel (54), compared to CIMMYT (53) and DSW (51). The various nitrogen levels showed that tasseling took longer (53) in the plots treated with 200 kg N ha^{-1}, which was statistically similar to N administered at a rate of 150 kg ha^{-1} (53), while the plots treated with 100 kg N ha^{-1} had the shortest days to tasseling. The variation in days to tasseling of the different varieties may be due to the genetic variation of the plant. The most plausible explanation for this observation is that organic and inorganic fertilizers have high nutrient content, which increases leaf area duration and delays tasseling and silking (Mehmood et al., 2005). Ali et al. (2019) also found that applying fertilizer enhanced or lowered the number of days to tasseling.

No. of days to silking

Table 2 presented data regarding days to silking of maize. The influence of different types and nitrogen on days before silking was substantial, while the interaction between the varieties and nitrogen was not significant. Mean data regarding varieties showed that Jalal variety took more days to silking (61), as compared to CIMMYT (59) and DSW (57). Silking was delayed (60) in plots treated with 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (59), whereas the plots that received N at a rate of 100 kg N ha^{-1} had the shortest days to silking (58). Amanullah et al. (2009) reported that days to silking decreased or increased with the application of fertilizers. The variation in days to silking of the different varieties may be due to the genetic variation of the plant.

Table 1 Effect of various levels of nitrogen on the days to tasseling of maize varieties

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	52	50	53	52^{b}
150	53	51	54	53^{a}
200	53	52	55	53^{a}
Mean	53^{b}	51^{c}	54^{a}	

LSD (p<0.05) for varieties (V) = 0.80; LSD (p<0.05) for nitrogen (N) = 0.83; LSD (p<0.05) for V × N = NS

Table 2 Effect of varying nitrogen levels on the number of days until maize varieties silk

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	58	56	60	58^{c}
150	59	57	61	59^{b}
200	60	58	63	60^{a}
Mean	59^{b}	57^{c}	61^{a}	

LSD (p<0.05) for varieties (V) = 1.44; LSD (p<0.05) for nitrogen (N) = 0.86; LSD (p<0.05) for V × N = NS; The LSD test indicates that the mean levels of each factor are significantly different at p values equal to or less than 0.05, as indicated by distinct letters (a, b, c).

Plant height (cm)

Data are displayed in Table 3 regarding plant height in cm. Data analysis showed that different types and quantities of nitrogen showed significant impact on maize plant height. Plant height of the Jalal variety was maximum (193cm), followed by CIMMYT FATA (189cm), while shorter plants (182cm) were recorded in the plot sown with DSW variety. Mean data regarding the different levels of N showed that plant height increased as N rates increases. The plots (plants) treated with 200 kg N ha^{-1} had the highest plant height (192 cm), followed by 150 kg N ha^{-1} (187 cm), and shorter plants (185 cm) were seen in the plots treated with 100 kg N ha^{-1}. The interactive effect was also found to be significant. This finding aligns with Kandil (2013), who observed considerable variability in plant height attributed to different hybrid maize types. Furthermore, Radma and Dagash (2013) found that plant heights varied significantly between types. This is most likely related to genetic variance in plant height. Similarly, Mahmood et al. (2001) found that nitrogen significantly influenced the number of grains per cob, plant height and 1000 grain weight when studying maize components.

Ear length (cm)

Table 4 presents data on ear length. The data showed that variety and nitrogen considerably affected ear length, but the interactive effect was not significant. Jalal variety produced maximum ear length (18.9 cm); followed by DSW (18.6 cm), while CIMMYT FATA produced minimum ear length (17.7 cm). Mean data regarding the different levels of nitrogen showed that ear length decreased from 18.1 cm to 18.8 cm as N rates reduced from 100 kg ha^{-1} to 200 kg N ha^{-1}. Farshad and Mojtaba (2014) stated that the variation in the yield components and plant growth could be due the genetic variation of the varieties. Cob weight, length, and diameter all increased significantly after application of nitrogen, which could be attributable to nitrogen's good influence on the leaf size, length, number of leaves per plant, and number of ears per plant. These results are similar with Carlone and Russell's (1987) results that nitrogen application has a considerable effect on maize yield components.

Table 3 Effect of varying nitrogen concentrations on maize variety plant height (cm)

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	187	177	190	185^{c}
150	189	181	193	187^{b}
200	191	189	197	192^{a}
Mean	189^{b}	182^{c}	193^{a}	

LSD ($p<0.05$) for varieties (V) = 4.04; LSD ($p<0.05$) for nitrogen (N) = 1.90; LSD ($p<0.05$) for V × N = *

Table 4 Effect of varying nitrogen concentrations on maize variety ear length (cm)

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	17.3	18.3	18.6	18.1^{b}
150	17.7	18.5	18.9	18.4^{b}
200	18.2	19.0	19.2	18.8^{a}
Mean	17.7^{c}	18.6^{b}	18.9^{a}	

LSD ($p<0.05$) for varieties (V) = 0.32; LSD ($p<0.05$) for nitrogen (N) = 0.30; LSD ($p<0.05$) for V × N = NS;
The means of the levels within each factor are significantly different at a significance level of 0.05, denoted by different letters (a, b, c) based on the LSD test

Number of grains ear^{-1}

Table 5 showed that data regarding this parameter and data analysis discovered that nitrogen had a substantial effect on the number of grains ear-1 of maize varieties, however the interaction between varieties and nitrogen was not significant. Data regarding varieties showed that Jalal variety produced maximum grains ear^{-1} (422), followed by CIMMYT FATA variety (402), while DSW variety produced minimum grains ear^{-1} (383). Mean data regarding the different levels of N showed that number of grains ear^{-1} increased from 396 to 411 as Nitrogen fertilizer rates increased from 100 kg ha^{-1} to 200 kg ha^{-1}. Farshad and Mojtaba (2014) stated that the variation in the plant growth and yield components could be due to the genetic variation of the varieties. The largest quantity of grains per ear was found using 180 kg N ha^{-1} (Izadi & Imam, 2010). Other research has shown that increasing the amount of grains per ear leads to high fertilizer use (Sadeghi et al., 2021).

Thousand grains weight (g)

Table 6 shows data for 1000 grain weight. The data analysis revealed that nitrogen had a substantial effect on the 1000 grain weight of maize varieties, but there was no significant interaction between varieties and nitrogen. Data regarding varieties showed that Jalal variety produced maximum 1000 grain weight (316 g), followed by CIMMYT FATA variety (299 g), while DSW variety produced minimum 1000 grain weight (278 g). Mean data regarding the different levels of N showed that 1000 grain weight increased from 305g to 291g as N rates increased from 100 kg ha^{-1} to 200 kg ha^{-1}. Farshad and Mojtaba (2014) stated that the variation in the plant growth and yield components could be due the genetic variation of the varieties. Similarly, Mahmood et al. (2001) observed significant effects of nitrogen on maize components such as plant height, number of grains per cob, and 1,000 grain weight. According to Blumenthal et al. (2003), adding nitrogen dramatically increases grain weight in maize. Izadi and Imam (2010) observed that adding nitrogen from 90 to 180 kg ha^{-1} caused a considerable increase in maize seed weight. Khan et al. (1999) and Sharar et al. (2003) observed similar findings.

Table 5 Effect of nitrogen on the number of grains ear^{-1} of maize varieties

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	394	378	416	396^{b}
150	399	378	421	399^{b}
200	412	393	429	411^{a}
Mean	402^{b}	383^{c}	422^{a}	

LSD (p<0.05) for varieties (V) = 2.87; LSD (p<0.05) for nitrogen (N) = 6.69; LSD (p<0.05) for V × N = NS

Table 6 Effect of different levels of nitrogen on 1000 grains weight (g) of maize

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	289	274	310	291^{c}
150	298	277	317	297^{b}
200	311	283	322	305^{a}
Mean	299^{b}	278^{c}	316^{a}	

LSD (p<0.05) for varieties (V) = 5.23; LSD (p<0.05) for nitrogen (N) = 6.12; LSD (p<0.05) for V × N = NS; Using the LSD test, distinct letters (a, b, and c) represent the mean levels of each factor that are significantly different at a p value of 0.05 or less.

Biological yield (kg ha^{-1})

Table 7 presents data on biological yield. The data analysis demonstrated that nitrogen had a substantial effect on the biological yield of maize varieties, but there was no significant interaction between the nitrogen and varieties. Data regarding varieties showed that Jalal variety produced maximum biological yield (12337 kg ha^{-1}), followed by CIMMYT FATA variety (11898 kg ha^{-1}), while DSW variety produced minimum biological yield (11170 kg ha^{-1}). The mean data for the various levels of N demonstrated that biological yield increased from 11581 kg ha^{-1} to 12036 kg ha^{-1} as N rates climbed from 100 kg ha^{-1} to 200 kg ha^{-1}. Maize yields may be low when produced using less-than-optimum management approaches. The use of enhanced cultivars and optimal nitrogen fertilizer application practices allow for maize's high-yielding potential (Abera et al., 2017). The above-ground biomass yield increased with higher fertilizer levels. This finding is consistent with Ahmad et al. (2003).

Grain yield (kg ha^{-1})

The data of this parameter is summarized in Table 8. Analysis indicated that nitrogen has a significant effect on the grain yield of maize varieties, whereas the interaction between varieties and nitrogen was not significant. Among the varieties, Jalal produced the highest grain yield at 5030 kg ha^{-1}, followed by CIMMYT FATA variety at 4973 kg ha^{-1}, while DSW variety had the lowest grain yield at 4877 kg ha^{-1}. Mean data across different nitrogen levels showed an increase in grain yield from 4924 kg ha^{-1} to 4995 kg ha^{-1} as nitrogen rates increased from 100 kg ha^{-1} to 200 kg ha^{-1}.

Table 7 Effect of different levels of nitrogen on biological yield (kg ha^{-1}) of maize varieties

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	11760	10965	12017	11581^{c}
150	11878	11257	12231	11789^{b}
200	12055	11289	12763	12036^{a}
Mean	11898^{b}	11170^{c}	12337^{a}	

LSD (p<0.05) for varieties (V) = 184; LSD (p<0.05) for nitrogen (N) = 200 LSD (p<0.05) for V × N = NS

Table 8 Grain yield (kg ha^{-1}) of maize varieties as affected by different levels of nitrogen

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	4943	4831	4997	4924^{c}
150	4975	4885	5024	4962^{b}
200	5001	4916	5068	4995^{a}
Mean	4973^{b}	4877^{c}	5030^{a}	

LSD (p<0.05) for varieties (V) = 24; LSD (p<0.05) for nitrogen (N) = 14; LSD (p<0.05) for V × N = NS; the means of the levels within each factor are significantly different at a significance level of 0.05, denoted by different letters (a, b, c) based on the LSD test.

Harvest index (%)

Table 9 shows data on the harvest index (%). Analysis of the results showed that maize varieties greatly influenced harvest index, whereas varied levels of nitrogen had no significant effect on harvest index since there was not a substantial variance between the mean values of harvest index. The interaction between the different plant population and nitrogen was also not significant. Higher harvest index (43.7%) was recorded by DSW variety, followed by CIMMYT FATA variety (41.8%), while least harvest index (40.8%) was recorded by Jalal variety. The harvest index represents the ratio of grain yield to biological yield, which increases with a higher proportion of grain yield. The greater harvest index could be attributed to a higher grain-to-stove ratio as a result of the combination of organic and inorganic P applications. Similar findings were previously published by Luo et al. (2018); Mukhtiar et al. (2018). This may be due to the allocation of additional photosynthetic resources towards grain yield rather than vegetative growth, which can vary by variety. Similarly, Ahmad et al. (2003) reported significant variability in harvest index associated with different maize varieties.

Table 9 Effect of nitrogen on harvest index (%) of maize

Nitrogen (kg ha^{-1})	Varieties (V)			Mean
	CIMMYT FATA	DSW	Jalal	
100	42.0	44.1	41.6	42.6
150	41.9	43.4	41.1	42.1
200	41.5	43.6	39.7	41.6
Mean	41.8^{b}	43.7^{a}	40.8^{c}	

LSD ($p<0.05$) for varieties (V) = 0.70; LSD ($p<0.05$) for nitrogen (N) = NS; LSD ($p<0.05$) for V × N = NS; Means of the levels within each factor are significantly different at a significance level of 0.05, indicated by different letters (a, b, c) using the LSD test.

Conclusion

Based on results it was concluded that applications of nitrogen at rate of 200 kg ha^{-1} significantly ($p<0.05$) delayed days to silking, ear length, increased plant height, days of tasseling, grains per ear, 1000 grain weight, biological and grain yield of maize as compared to 100 and 150 kg N- ha^{-1}. Ear length, plant height, grains per ear, 1000 grain weight, biological and grain yield of the Jalal variety was superior to DSW and CIMMYT FATA varieties. Jalal variety treated at rate of 200 kg N ha^{-1} improved plant growth and development. The present study's conclusions suggest that planting the Jalal variety and applying nitrogen at a rate of 200 kg ha^{-1} can improve the yield and yield components of maize in the studied area.

References

Abera, T., Debele, T., & Wegary, D. (2017). Effects of varieties and nitrogen fertilizer on yield and yield components of maize on farmers' fields in mid-altitude areas of Western Ethiopia. *International Journal of Agronomy*, *2017*, Article ID 4253917, 13 pages. https://doi.org/10.1155/2017/4253917

Ahmad, A., Usman, M., Ullah, E., & Warraich, E. A. (2003). Effects of different phosphorus levels on the growth and yield of two cultivars of maize (*Zea mays* L.). *International Journal of Agriculture and Biology*, *5*(4), 632-634.

Ahmad, S., Khan, A. A., Kamran, M., Ahmad, I., Ali, S., & Fahad, S. (2018). Response of maize cultivars to various nitrogen levels. *European Journal of Experimental Biology*, *8*(1), Article 2. https://doi.org/10.21767/2248-9215.100043

Ali, N. A., & Anjum, M. M. (2017). Effect of different nitrogen rates on growth, yield and quality of maize. *Middle East Journal of Agriculture Research*, *6*, 107-112.

Ali, W., Ali, M., Kamal, A. M., Uzair, & Ullah, N. (2019). Maize yield response under various phosphorus sources and their ratios. *European Journal of Experimental Biology*, *9*(1), 5. doi:10.21767/2248-9215.100082

Amanullah, Marwat, K. B., Shah, P., Maula, N., & Arifullah, S. (2009). Nitrogen levels and its time of application influence leaf area, height, and biomass of maize planted at low and high density. *Pakistan Journal of Botany*, *41*(2), 761-768.

Aslam, M. A., Aziz, I., Shah, S. H., Muhammad, S., Latif, M., & Khalid, A. (2021). Effects of biochar and zeolite integrated with nitrogen on soil characteristics, yield, and quality of maize (*Zea mays* L.). *Pakistan Journal of Botany*, *53*(6), 2047-2057.

Batool, A., Wahid, A., Abbas, G., Shah, S. H., Akhtar, M. N., Perveen, N., & Hassnain, Z. (2019). Application of Moringa oleifera plant extracts for enhancing the concentration of photosynthetic pigments leading to stable photosynthesis under heat stress in maize (*Zea mays* L.). *Pakistan Journal of Botany*, *51*(6), 2031-2036.

Bellete, T. (2014). Fertility mapping of soils of AbayChomen District, Western Oromia, Ethiopia (Master's thesis). Haramaya University.

Blumenthal, M., Lyon, J., & Stroup, W. (2003). Optimal plant population and nitrogen for dry land corn in Western Nebraska. *Agronomy Journal*, *95*, 878-883.

Carlone, M. R., & Russell, W. A. (1987). Response to plant densities and nitrogen level for four maize cultivars. *Crop Science*, *27*(3), 165-470.

Carruthers, K., Prithiviraj, B., Cloutier, F. D., Martin, Q. R. C., & Smith, D. L. (2000). Intercropping corn with soybean, lupin, and forages: Yield component responses. *European Journal of Agronomy*, *12*(2), 103-115.

Dupont, J., White, P. J., Carpenter, M. P., Schaefer, E. J., Meydani, S. N., Elson, C. E., Woods, M., & Gorbach, S. L. (1990). Food uses and health effects of corn oil.

Journal of the American College of Nutrition, 9(5), 438-470. https://doi.org/10.1080/07315724.1990.10720403

Fageria, N. K., & Baligar, V. C. (2005). Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy, 88*, 97-185.

FAOSTAT. (2008). Retrieved from http://faostat.fao.org (Accessed: August 30, 2008).

Farshad, S., & Mojtaba, F. (2014). Effect of nitrogen fertilizer on yield components of maize. *International Journal of Biosciences*, *5*(6), 16-20.

Gibson, L. & G. Benson. (2002). Origin, History, and Uses of Corn (Zea mays). Iowa State University, Department of Agronomy. Accessed October 14, 2013. http://agronwww.agron.iastate.edu/Courses

Iqbal, J., Sarwar, G., Shah, S. H., Sabah, N. U., Tahir, M. A., Muhammad, S., Manzoor, M. Z., Zafar, A., & Shehzad, I. (2022). Evaluating the combined effect of compost and mineral fertilizers on soil health, and growth and mineral acquisition in maize (*Zea mays* L.). *Pakistan Journal of Botany, 54*(5), 1793-1801.

Izadi H, Imam U. (2010). Effect of planting pattern, plant density and nitrogen levels on yield and yield components of maize single cross 704. *Iranian Journal of Crop Science 12*(3), 251-239.

Kandil, E. E. (2013). Response of some maize hybrids (*Zea mays* L.) to different levels of nitrogenous fertilization. *Journal of Applied Sciences Research, 9*(3), 1902–1908.

Keenan, M. J., Zhou, J., Hegsted, M., Pelkman, C., Durham, H. A., Coulon, D. B., & Martin, R. J. (2015). Role of resistant starch in improving gut health, adiposity, and insulin resistance. *Advances in Nutrition, 6*(2), 198–205.

Khan, K., Karim, F., Iqbal, M., Sher, H., & Ahmad, B. (2004). Response of maize varieties to environments in two agroecological zones of NWFP: Effects on morphological traits. *Sarhad Journal of Agriculture, 20*(3), 395-399.

Khan, M. A., Khan, N. U., Ahmad, K., Baloch, M. S., & Sadiq, M. (1999). Yield of maize hybrid-3335 as affected by NP levels. *Pakistan Journal of Biological Sciences, 2*(3), 857-859.

Li, C., & Song, R. (2020). The regulation of zein biosynthesis in maize endosperm. *Theoretical and Applied Genetics, 133*(6), 1443–1453.

Luo, B., Ma, P., Nie, Z., Zhang, X., He, X., Ding, X., ... & Gao, S. (2019). Metabolite profiling and genome-wide association studies reveal response mechanisms of phosphorus deficiency in maize seedling. *The Plant Journal, 97*(5), 947-969.

Mahmood, M. T., Maqsood, M., Awan, T. H., Rashid, S., & Sarwar, R. (2001). Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. *Pakistan Journal of Agricultural Sciences, 38*, 48-49.

Malvar, R. A., Revilla, P., Moreno-González, J., Butrón, A., Sotelo, J., & Ordás, A. (2008). White and maize: Genetics of quality and agronomic performance. *Journal of Crop Science*, *48*(4), 1373-1381.

Mehmood, K., Ahmad, Z. I., & Khan, K. S. (2005). Maize growth as influenced by different manures in Pothwar tract (Pakistan). *International Journal of Agriculture and Biology, 7*(3), 521-523.

MINFAL. (2007). Government of Pakistan. Ministry of Food and Livestock, Economic Wing. Islamabad.

Mukhtiar, A., Waqar, A., Khalil, M. K., Tariq, M., Muhammad, S., Hussain, A., & Kamal A. (2018). Evaluating the potential organic manure for improving wheat yield and quality under agro-climatic conditions of Pakistan. *Advances in Crop Science and Technology, 6*, 349. https://doi.org/10.4172/2329-8863.1000349

Noor, K., Sarwar, G., Shah, S. H., Muhammad, S., Zafar, A., Manzoor, M. Z., & Murtaza, G. (2021). Formulation of phosphorus-rich organic manure from rock phosphate and its dose optimization for the improvement of maize (*Zea mays* L.). *Journal of Plant Nutrition, 44*(1), 96-119.

Radma, I. A. M., & Dagash, Y. M. I. (2013). Effect of nitrogen and phosphorus fertilizers on yield and yield components of three cultivars of maize (*Zea mays* L.). *Universal Journal of Agricultural Research, 1*(4), 119–128.

Raza, A., Tahir, M. A., Sabah, N.-u.-S., Shah, S. H., Sarwar, G., & Manzoor, M. Z. (2023). Seed priming with zinc ion on growth performance and nutrient acquisition of maize in aridisols. *Pakistan Journal of Botany, 55*(4), 1365-1374.

Sadeghi, F., Rezeizad, A., & Rahimi, M. (2021). Effect of zinc and magnesium fertilizers on the yield and some characteristics of wheat (*Triticum aestivum* L.) seeds in two years. *International Journal of Agronomy, 2021*, Article 8857222, 6 pages. https://doi.org/10.1155/2021/8857222

Serna-Saldivar, S. O. (2016). Maize: Foods from maize. In Reference module in food science. Elsevier. Amsterdam, The Netherlands.

Shah, S., Talat, H., Zamir, M., Shahid, I., Waseem, M., Ali, A., & Khalid, W. B. (2009). Growth and yield response of maize (*Zea mays* L.) to organic and inorganic sources of nitrogen. *Pakistan Journal of Life and Social Sciences, 7*(2), 108–111.

Shah, T. R., Prasad, K., & Kumar, P. (2016). Maize—A potential source of human nutrition and health: A review. *Cogent Food & Agriculture, 2*, 1166995. http://dx.doi.org/10.1080/23311932.2016.1166995

Sharar, M., Ayub, S. M., Nadeem, M., & Ahmad, N. (2003). Effect of different rates of nitrogen and phosphorus on growth and grain yield of maize (*Zea mays* L.). *Asian Journal of Plant Sciences, 2*(3), 347-349.

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). Principles and procedures of statistics: A biometrical approach (3rd ed.). McGraw-Hill.

Tasneem, K., Tariq, M., Kamal, J., & Masood, A. J. (2004). Effectiveness of farmyard manure, poultry manure, and nitrogen for corn productivity. *International Journal of Agriculture & Biology, 6*(2), 260-263.

Taye, G. (2009). Effects of nitrogen and phosphorus fertilizers on the growth, yield, and yield components of maize (*Zea mays* L.) at Nedjo, West Wollega, Ethiopia (Master's thesis). Haramaya University.

Zelleke, G., Agegnehu, G., Abera, D., & Rashid, S. (2010). Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system (Working paper). International Food Policy Research Institute (IFPRI), 1-43.