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EFFECT OF MINERAL AND FARM YARD MANURE NITROGEN ON GROWTH AND YIELD COMPONENT OF MAIZE UNDER VARIOUS TILLAGE IMPLEMENTS

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Article Info

Abstract

Nitrogen is vital and primary nutrient for plant growth and major constituent of chlorophyll, the compound by which plants utilize sunlight energy to produce starch from water and carbon dioxide (i.e. photosynthesis), protein formation, and influences plant development. The research was conducted to assess the effect of nitrogen levels and tillage implements on the maize growth and yield at Agronomy Research Farm, The University of Agriculture Peshawar during 2024. The experiment was designed in randomized complete block design (RCBD) with split plot arrangement in four replications. The experiment was consisted of two-factors in which one factor was tillage implements. The tillage implements were operated in main plots i.e. Mouldboard plough as (Deep tillage, DT), field cultivator (Shallow tillage, FC) and Rotavator (minimum tillage, RT). The second factor was nitrogen levels in the sub plots i.e. the application of urea (120 and 180 kg ha^{-1}) as well as farmyard manure (FYM) i.e. 12 and 18 tons ha^{-1} incorporated before sowing as well as control. Maize variety (Azam) was sowing on ridges in the month of July 2024. Based on experimental results DT increased numbers of leaves $plant^{-1}$ (13), leaf area (476.4 cm^2), plant height (203 cm), number of ears (6.1 m^{-2}), grains ear^{-1} (349), thousand grain weight (256 g), biological yield (10429 kg ha^{-1}) and grain yield (3518 kg ha^{-1}) than the either FC or RT. High mineral nitrogen applied at the rate of 180 kg ha^{-1} delayed tasseling (55 days), silking (62 days), physiological maturity (113 days), increased numbers of leaves $plant^{-1}$ (14 leaves), leaf area (492.1 cm^2), plant height (212 cm), ear length (17 cm), number of rows ear^{-1} (14 rows), number of ears (6.5 m^{-2}), grain ear^{-1} (390 grains), thousand grain weight (273 g), biological yield (11110 kg ha^{-1}) and grain yield (3983 kg ha^{-1}) as compared to control plot. From the results it was concluded that the deep tillage i.e. mould board plough and high mineral nitrogen (urea – N) application at rate of 180 kg ha^{-1} is suitable for increasing the grain yield and yield components of maize crop in experimental location.

Keywords:
Maize, Farm Yard Manure, Mineral Nitrogen, Tillage Implements.

Introduction

Maize (*Zea mays* L.) is an essential cereal crop globally and is widely grown in Pakistan in both irrigated and rainfed areas (Rizwan *et al.*, 2017). Maize is a critical source of food, feed and industrial raw materials, playing a vital role in food security and providing food and livelihoods for millions of people in Pakistan (Rizwanullah *et al.*, 2023). The crop has significant economic, social and cultural importance in Pakistan and it has been recognized as a vital component of the country's agriculture sector (Azam and Shafique, 2017). It is the third widely cultivated crop after wheat and rice in many countries. It is widely grown in temperate, subtropical and tropical climatic regions (Soto-Gómez and Pérez-Rodríguez, 2022). It can be grown on all types of soils varying from sandy to clayey, however, soil with pH 6.5 to 7.5 is most ideal for maize (Adiaha, 2016). Maize yield in the Khyber Pakhtunkhwa is very less as compared to the provinces of Pakistan due to low fertility of soil, and less organic matter (Shah *et al.*, 2020). The arable land of Pakistan is deficient in organic matter and in primary nutrients such as nitrogen (N) (Ahmad *et al.*, 2019). Less crop production is the most challenging factor for agriculture scientist in Pakistan due to very less organic matter and exhausted soil with the deficiency of nutrients. Nitrogen fertilization is one of the most crucial factors for crop growth and development (Khan *et al.*, 2022).

Nitrogen is a vital element required for plant growth, development and productivity (Leghari *et al.*, 2016). It is a key component in the synthesis of proteins, nucleic acids, chlorophyll, also played a vital role in the photosynthesis and respiration processes of plants (Fathi, 2022). The nitrogen deficiency in soils lead to stunted plant growth and less productivity (Abbas *et al.*, 2021). Thus, the application of nitrogen fertilizers had become an influencing practice in modern agriculture to enhance crop production and yield (Giordano *et al.*, 2021). Nitrogen fertilizers are chemical compounds that provide plants with a concentrated source of nitrogen (Ohyama, 2010). They are commonly used in agricultural production in the form of ammonium nitrate, urea and ammonium sulfate (Chien *et al.*, 2011). Synthetic application of Nitrogenous fertilizers may enhance plant growth and development but it is not long-term solution; therefore, combining it with organic sources is necessary to acquire long term fertility, improve soil health and crop productivity (Gurmu, 2019).

The application of farmyard manure is another important factor that can affect soil enzymatic activities, microbial symbiosis and soil health (Brar *et al.*, 2017). The farmyard manure fertilizers played a vital role in the growth of plants (Negassa *et al.*, 2005). The abundance of well-decomposed farmyard manure favored the activity of enzymes in the soil (Kumar *et al.*, 2021). The farmyard manure application for soil conditioner dates back to ancient times and its benefits are still being explored as large quantities are needed to fulfil the nutritional requirements of crops (Yilman and Alagöz, 2010). The use of organic manure has regained popularity worldwide because to the need for renewable forms of energy and reduced fertilization costs (Smith *et al.*, 2015). Increased use of organic matters promotes soil health in the long term of farming practices, sustainable farming and environmental health conditions. (Tahat *et al.*, 2020).

Among the all agricultural practices, Tillage is one of the important agricultural practice that has been used for thousands of years to prepare the soil for planting and increase crop yields (Lal, 1991). Over time new techniques and technologies have been developed to improve tillage practices and approached for sustainability and health of soil (Shahane and Shivay, 2021). In recent years there has been a growing body of research on the influence of tillage on health of soil, growth of plants and environmental sustainability (Busari *et al.*, 2015). Mouldboard plough tillage implement significant increase plant height, due to fine seed bed preparation, increased field capacity and provided optimum condition for root development also increase the mass flow of nutrients towards plant among tillage implements (Parvin *et al.*, 2014). The use of the Rotavatour can improve soil structure such as soil aggregate stability, bulk density and water infiltration leading to increased crop yields (Zhang *et al.*, 2024). The use of the field cultivator can improve soil physical properties, such as soil aggregate, stability and water infiltration leading to increased crop yields (Indoria *et al.*, 2016)

Keeping the above facts, the current study was conducted to explore the impact of mineral nitrogen and farm yard manure (FYM) on growth and yield attributes of maize crop under various tillage implements.

MATERIALS AND METHODS

Experimental Procedure

The impact of various nitrogen, farm yard manure under different tillage implements on maize growth and yield was evaluated at the Agronomy Research Farm, The University of Agriculture Peshawar, during the Kharif season of 2024. Maize variety (Azam) was sown in July on a prepared field. The experiment was performed in a randomized complete block design with split-plot arrangement, each treatment was replicated four times. The three tillage implements, Rotavator, field cultivator and Mouldboard plough, were used. In contrast, nitrogen source urea fertilizer (120 and 180 kg ha^{-1}), and farmyard manure (12 and 18 tons ha^{-1}), with control included in the experiment. The tillage implements were allotted to main plots and the fertilizer treatments to subplots. The sub-plot size was kept at 5×4 m^{2,} containing six rows having meters in length. The row-to-row and plant-to-plant distances were maintained 75 cm and 25 cm, respectively. Maize variety (Azam) was sown on ridges. Weeds were controlled through roughing.

Experimental Factors

The experiment consisted of two factors, which included tillage implements and fertilizer treatments. Factor A, tillage implements, consisted of three levels: Rotavator, Field Cultivator and Mouldboard plough. Factor B, fertilizer treatments, included five levels: F1-control (no fertilizer applied); F2-optimum mineral nitrogen at 120 kg ha^{-1}; F3-high mineral nitrogen at 180 kg ha^{-1}; F4-optimum farmyard manure at 12 tons ha^{-1}; and F5-high farmyard manure at 18 tons ha^{-1}.

Data Parameters

Data on various phenological and growth parameters of maize were collected during the growing season. Days to emergence were recorded as the number of days from sowing until 80% seedling emergence occurred. Days to tasseling and silking were counted when 80% of the plants in a plot produced tassels and silk, respectively. Similarly, days to physiological maturity were noted when 80% of the plants reached maturity. The number of leaves $plant^{-1}$ was recorded from five randomly selected plants per plot at physiological maturity, and averaged to determine the leaf count. For leaf area (cm^2), ten plants were sampled at random for each treatment, and leaf length and width were calculated using a measuring tape, and the average leaf area was calculated using a standard formula. Plant height (cm) was measured at physiological maturity from the base to the last leaf with a measuring rod on five randomly selected plants $plot^{-1}$ and averaged. Ear length (cm) was assessed using a measuring tape on five randomly selected ears per plot and the average values were calculated. The number of ears m^2 was estimated by counting ears in a one-meter row at three randomly selected places within each plot and converting the data to ears m^{-2} using a standard formula. For the number of grains per ear, 10 ears were selected at random from each plot, counted individually, and averaged. Thousand grain weight (g) was finally determined after threshing and drying by weighing a sample of 1,000 grains from each experimental unit and averaging for analysis.

Grain yield (kg ha^{-1})

The harvested three central rows of grain yield were used for grain yield after sun drying threshed and grains weighed with an electronic balance and then data were converted into kg ha^{-1} by following formula.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield in three central rows}}{\text{Row length} \times \text{R} - \text{R distance} \times \text{Number of rows}} \times 10000\ m^2$$

Biological yield (kg ha^{-1})

At maturity, three central rows in each experimental unit were harvested, dried in the sun for five days and weighed to record the biological yield. The data were converted into kg ha^{-1} by following formula.

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological yield in three central rows}}{\text{Row length} \times \text{R} - \text{R distance} \times \text{Number of rows}} \times 10000\ m^2$$

Harvest index (%)

The ratio of grain yield to biological yield was calculated as the harvest index. Then the data multiplied by one hundred to express the values in percentages.

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

Statistical Analysis

The data were statistically analyzed using analysis of variance techniques applicable for randomized complete split block design. When the F-values are significant, a LSD test at the 0.05 level of probability was applied for comparing means (Steel and Torrie, 1996).

Results

Days to emergence

Data pertaining days to emergence across different treatments is present in Figure 1 (a). The resulting data shows that the shortest days to emergence were recorded 6.8 days with FYM at 18 t ha^{-1} under the Rotavatour, indicating a strong positive influence of organic amendments towards early seedling establishment. On the other hand, the longest maize emergence was recorded 8.5 days with N application at 120 kg ha^{-1} under the Field Cultivator. The Intermediate maize emergence values were recorded 7.5 days with FYM at 12 t ha^{-1} under Mouldboard Plough implement and 7.6 days N application at 180 kg/ha under Rotavator conditions, suggesting some moderate influence on the emergence. Overall, FYM treatments have encouraged higher emergence rates faster than mineral nitrogen or control treatments; however, Field Cultivator does tend to delay emergence in all fertilizer conditions.

Emergence m^2

The impact of different fertilization and tillage implements on emergence m^2 is demonstrated in Figure 1 (b). depicting the highest emergence was recorded 12.5 plants m^{-2} with FYM at 18 t ha^{-1} under Rotavator, closely followed by the same treatment under Mouldboard Plough and Field Cultivator, indicating an optimum response to such high organic matter application. Control treatment had shown the minimum number of emergence, 10.5 plants m^2 in response to the overall tillage implement, showing the prominent effect of nutrient application. The average emergence level was obtained 11.5 plants m^2 from the mean N 180 kg ha^{-1} treatment, particularly under Mouldboard Plough and Rotavator, representing an improvement compared with the control.

Days to Tasseling

Figure 1 (c) depicts the effect of different tillage implements and fertilizer treatments on the days to tasseling in the maize crop. For the control treatment, days to tasseling were recorded 52.3, 52.6, and 52.9 for Mouldboard Plough, Field Cultivator, and Rotavator, respectively. Under the application of N 120 kg ha^{-1}, tasseling took place at 54.2, 54.6, and 54.9 days for the same implements, with N 180 kg ha^{-1} resulting in tasseling at 55.3, 55.7, and 56.1 days for the respective implements. The application of FYM at 12 t ha^{-1} caused tasseling at 53.7, 54.1, and 54.3, while with FYM at 18 t ha^{-1}, it was 54.8, 55.0, and 55.2. These results suggest that increasing nitrogen application or FYM application generally delays tasseling, while the Rotavator slightly prolongs the tasseling period compared with other implements, but the difference in tillage methods was relatively small.

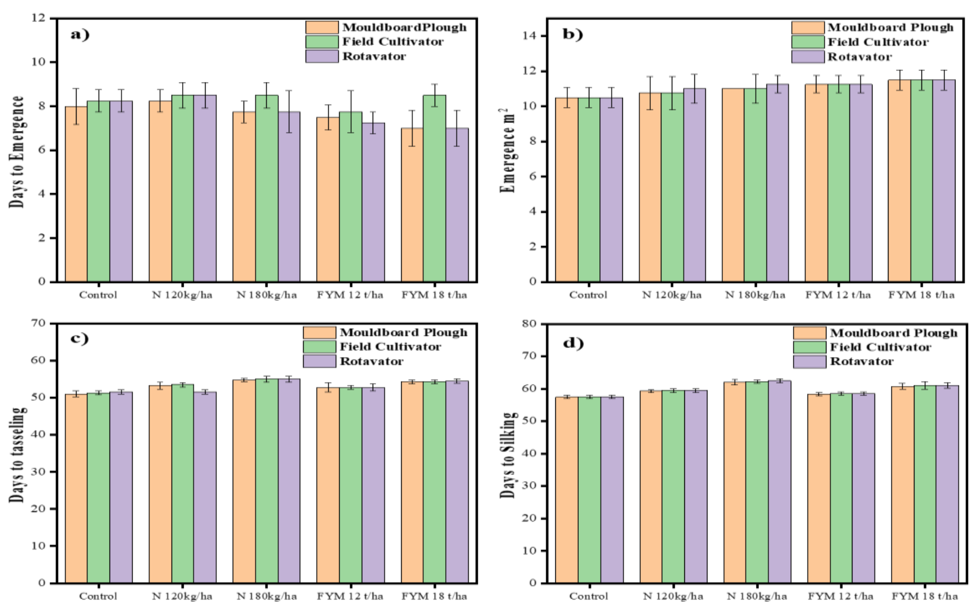

Figure 1: The bar charts presents the response of maize growth attributes in response to various treatments. Furthermore, figure (a) shows days to emergence, (b) emergence m², (c) days to tasseling and (c) days to silking (y-axis) in response to different nitrogen and Farm yard manure under various tillage implements (x-axis).

Days to Silking

Days to silking response vary in response to various tillage implements and fertilizer treatments, as shown in Figure 1 (d). Findings of the current study show that the maximum days to silking were recorded 56.8 under Rotavator with 180 kg N ha^{-1} application, while the minimum days were observed 53.1 in the control treatment with Mouldboard Plough. A Mid-range value of days was recorded 54.7 under Field Cultivator with FYM 12 t ha^{-1}. The inference drawn is that higher doses of nitrogen influence the delay in silking, while the absence of fertilizers application reduces days till silking, and organic amendments give an intermediate response depending on the tillage method used.

Days to Physiological Maturity

Different tillage implements and fertilizer treatments variously affect the number of days to physiological maturity in maize, as shown in Figure 2 (e). Resulting data show that the maximum days to physiological maturity were recorded at 125.7 days under 180 kg N ha^{-1} application with Mouldboard Plough, whereas the lowest days count was observed 105.3 from the control treatment with Rotavator. The average value was recorded 115.2 days using the Field Cultivator with FYM 12 t ha^{-1}. The deduction derived is that greater nitrogen levels delay physiological maturity, while no fertilizer treatments stimulate it, and application of organic amendments like FYM has shown an intermediate response conditioned by the types of tillage implements used. Therefore, optimum fertilization is necessary to get optimum physiological maturity duration and ensure better production.

Leaf area cm^2

Figure 2 (f) illustrates the influence of various tillage implements and fertilizer treatments on the leaf area (cm^2) $plant^{-1}$ in maize. Data from the experiment shows that the highest leaf area was recorded 520.6 cm^2 under Mouldboard Plough with the application of 180 kg N ha^{-1}, while the lowest leaf area recorded was under the control treatment with Rotavator (310.4 cm^2). the optimum leaf area was recorded 450.3 cm^2 following the Field Cultivator implement with FYM 12 t ha^{-1}. The results suggest that higher nitrogen application significantly increases the leaf area in maize, whereas without fertilizers, canopy development is restricted, and organic amendments such as FYM give average results, which depend on the tillage implement in use.

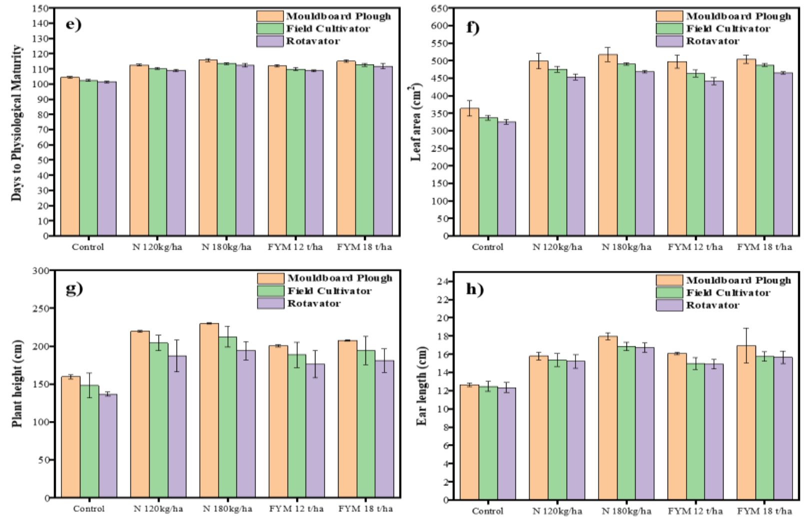

Figure 2: The bar charts presents the response of maize growth attributes in response to various treatments. Furthermore, figure (e) shows days to physiological maturity, (f) Leaf area, (g) Plant height and (h) Ear length (y-axis) in response to different nitrogen and Farm yard manure levels under various tillage implements (x-axis).

Plant height cm

The average value of plant height was remarkably affected by various tillage implements, farm yard levels and nitrogen levels, as demonstrated in Figure 2 (g). The plant height shows a response differently across various treatments, moreover Mouldboard Plough treatment of 180 kg N ha^{-1} resulted maximum plant height of 233.7 cm, respectively, while under the application of Rotavator, a minimal height of 143.3 cm has been recorded for the control treatment. Field Cultivator and FYM at 12 t ha^{-1} recorded an optimum plant height of 199.5 cm. The data indicate that higher nitrogen level applications significantly enhance growth during active tillage with implements like the Mouldboard Plough, but growth is reduced in the absence of fertilizer applications, the least amount with the Rotavator. Organic amendments like FYM thus give a response of growth in the moderate range, which varies with the tillage system.

Ear length cm

Data regarding the Ear length of maize plants across various treatments is present in the Figure. The figure 2 (h) shows that the ear length was notably affected by different nitrogen, farm yard manure levels under various tillage practices. Furthermore, resulted data found a maximum of up to 18.4 cm using the Mouldboard Plough with 180 kg N ha^{-1} application, while the minimum ear length (12.6 cm) was recorded under control treatment with Rotavator implement. The optimum ear length was observed 16.1 cm under the Field Cultivator with FYM at 12 t ha^{-1}. Results show that ear development is greatly improved by increased nitrogen fertilization, particularly under deep tillage methods like the Mouldboard Plough. Without fertilizer, ear length would be shorter, with very low performance. Organic manure application produced moderate improvement because it releases nutrients slowly and has a long-term effect, leading a sustainable production.

Number of Rows ear^{-1}

The Figure 3 (i) the number of rows ear^{-1} in maize with different tillage implements in combination with different fertilizer treatments. Results show that the maximum rows per ear were recorded 15.6 under Mouldboard Plough with 180 kg N ha^{-1}, followed by 13.1 rows under Field Cultivator with FYM at 12 t ha^{-1}. In contrast, the minimum was found 8.2 under the control treatment with the Rotavator. These results suggest that intensive tillage with a moderately high level of nitrogen makes a significant improvement in the reproductive development of maize, as reflected in the higher number of rows per ear.

Ear m^2

The Response of ear m^2 under different tillage implements and fertilizer treatments of maize is represented in the Figure 3 (j). The ear m^2 of maize plants was found to be maximum in response to an increase in fertilization levels under Mouldboard ploughed tillage application. Furthermore, results from the study show that the maximum ear area was recorded 7.3 m² with the application of N @ of 180 kg ha^{-1} under Mouldboard Plough, and the minimum 4.2 m² was recorded on the control treatment with Rotavator. An intermediate ear m^2 of 6.0 m² was recorded under Field Cultivator with FYM at 12 t ha^{-1}. The results suggest that deeper tillage practices such as the Mouldboard Plough, combined with higher nitrogen application rates.

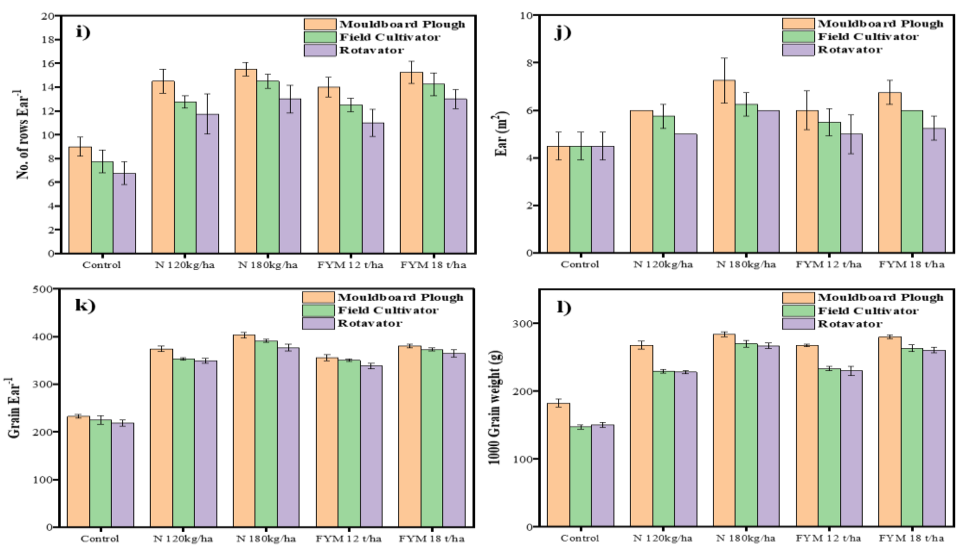

Figure 3: The bar charts presents the response of maize yield attributes in response to various treatments. Furthermore, figure (i) Number of rows ear^{-1}, (j) ear^{-} m^2 (k) Grains ear^{-2} and (l) 1000 grain weight (y-axis) in response to different nitrogen and Farm yard manure levels under various tillage implements (x-axis).

Grains ear^{-1}

The Figure 3 (k) shows the number of grains ear^{-1} in maize concerning the application of tillage implements and fertilizers. The resulting data shows the maximum grain count was observed 406 under Mouldboard Plough with 180 kg N ha^{-1} application, whereas the minimum grain count was recorded 235 under Rotavator in the control treatment. the optimum grain ear^{-1} was recorded 360 using the Field Cultivator under FYM at 12 t ha^{-1}. These results illustrate that maximum nitrogen level combined with high tillage practices like the Mouldboard Plough significantly improves grain formation in maize.

1000-Grains weight

The Figure 3 (l) shows the 1000-grain weight (g) of maize obtained under different tillage implements and fertilizer treatments. Findings show that the Mouldboard Plough with 180 kg N ha^{-1} resulted in the maximum grain weight of 290 g, followed by 260 g grain weight obtained from the Field Cultivator with FYM at 12 t ha^{-1}. In contrast, the lowest grain weight was recorded 145 g in the control treatment with Rotavator. The high nitrogen application combined with deep tillage enhances grain filling and weight, while low soil disturbance and lack of fertilizers have detrimental effects on grain weight.

Grain Yield kg ha^{-1}

Figure 4 (m) compares yield of maize in response to different treatments. There is a remarkable effect of different tillage implements and fertilization levels. Moreover, it was observed that the maximum grain yield was produced 4280 kg ha^{-1} by using the Mouldboard Plough with a rate of 180 kg N ha^{-1}, while the minimum yield recorded was 1820 kg ha^{-1} under the Rotavator in the control treatment. Field Cultivator combined with FYM at 12 t ha^{-1} resulted in the optimum yield of 3670 kg ha^{-1}. Results indicate that the deep tillage operation and high nitrogen application have a prominent effect on maximizing maize productivity.

Biological Yield kg ha^{-1}

Biological yield (kg ha^{-1}) of maize as affected by different tillage implements and fertilizer treatments is illustrated in the Figure 4 (n). Data from the experiment shows the highest biological yield 12,120 kg ha^{-1} under Mouldboard Plough with 180 kg N ha^{-1}, followed by 10,580 kg ha^{-1} under Field Cultivator with FYM at 12 t ha^{-1}. The lowest biological yield was observed 7, 380 kg ha^{-1} in the control treatment with the Rotavator. The results showed that deep tillage as well as higher nitrogen input resulted in maximum total biomass production in maize. In contrast, poor tillage implements and minimum fertilizer application restrict vegetative and reproductive growth.

Harvest Index %

Figure 4 (o) depicting the harvest index (%) of maize under different tillage implements and different fertilizer treatments. The maximum harvest index, which is 38.2%, was observed under Rotavator using 180 kg N ha^{-1} application, while the minimum was noted 24.5% in the control treatment and Rotavator tillage implement. The optimal harvest index was noted 33.7% under Field Cultivator with FYM at 12 t ha^{-1}. The results show that the harvest index is highest for the deeper tillage operations, such as the Mouldboard Plough, but such operations may compromise the conservation tillage practices, such as the Rotavator. Under higher nitrogen input, the increase in the efficiency of biomass partitioning to grain is assisted by deeper tillage; under low nitrogen input, the harvest is less efficient. The organic treatments seem to react more uniformly in terms of productivity, depending on the intensity of tillage adopted.

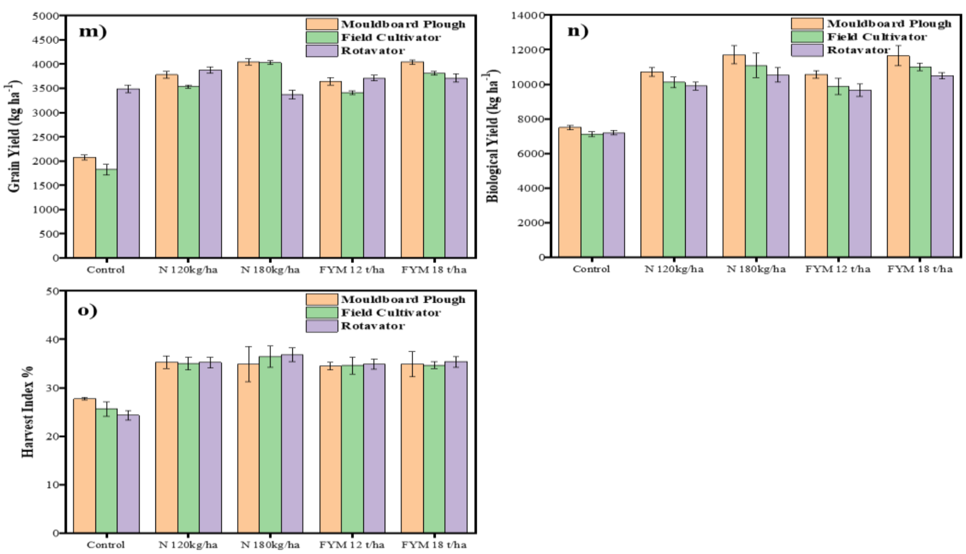

Figure 4: The bar charts presents the response of maize yield attributes in response to various treatments. Furthermore, figure (m) 1000 grain yield, (n) Biological yield and (o) Harvest index % (y-axis) in response to different nitrogen and Farm yard manure levels under various tillage implements (x-axis).

Discussion

Tillage implements and nitrogenous fertilizers had non-significant effects on days to emergence on the maize crop. This effect is due to endospermic food present inside seed which is primary source of food for the seedling. The seedling utilized endosperm to manage all its physiological processes during germination and seedling growth (Iqbal *et al.*, 2021). However, the application of manure had improved the soil structure in term of optimal atmospheric temperature (Ahmed *et al.,* 2022), and sufficient moisture storage (Abbas *et al.,* 2023). There-fore influenced the days to emergence on the application of manure fertilizer.

Tillage implements and nitrogenous treatments did not affect emergence per square meter. These findings also line with findings of Ibrahim and khan (2020) from the findings it is confirmed that nitrogen levels did not affect the emergence per square meter of maize because of the reason that germination of seed and seedling mainly depend upon on endospermic food rather on nitrogen at very early physiological processes (Qadeer *et al.*, 2021). The food is mostly available to seed and seedling in the form of endosperm or in cotyledons, which provide all the necessary food for viable seed germination.

Maize days to tasseling were non-significant affected by tillage implements, while nitrogen treatments significantly affected days to tasseling. Nitrogen an increased level (180 kg ha^{-1}) delayed days to tasseling because it increases maize vegetative growth, by chlorophyll formation continuously in leaves of the plant and thus leaf senescence (Ashenafi *et al.,* 2023). These results are also confirmed by the findings of (Gheith *et al.,* 2022), which stated that nitrogen increased maize physiological parameters and increased its vegetative growth phase and thus delayed maize tasseling.

Tillage implements had a non-significant effect on maize days to silking and maturity; however nitrogenous fertilizers had a significantly effect on days to silking and physiological maturity. Maize crop took more to silking and maturity on application of nitrogen at level of 180 kg ha^{-1} as compared to control plot which took more days to silking and maturity because of nitrogen which increases maize plant vegetative growth and chlorophyll synthesis formation thus delay senescence and plant tend to continue grow and delayed phenological parameters (Liang *et al.,* 2023). These results were also confirmed by (Anwar *et al.,* 2020) that increasing nitrogen levels in maize plants tend to delay tasseling, silking and maturity. Higher levels of nitrogen resulted prolonged vegetative growth phase.

Tillage implements and nitrogenous treatments had significant effects on the number of leaves per plant. These findings are also in line with the findings of (Majide *et al.,* 2020) which showed that deep tillage improves the soil's properties, such as nitrogen availability and soil organic matter. These results were also confirmed by researchers (Adhikari *et al.,* 2021), the increase in the number of leaves due to a decrease in the soil bulk density and lower nutrient volatization rates by 20–30%, helped in uniformly distributing nutrients in soil and increased growth and yield. Deep fertilizer application is an effective strategy for minimizing gaseous losses and improving the nutrient use efficiency (Wu at al. 2022), high nitrogen application would be conducive to higher canopy photosynthetic capacity (Li *et al.,* 2021).

The leaf area of maize was significantly influenced by tillage implements and the application of nitrogenous fertilizers. The deep tillage increased the loss of soil, better root interception, aeration and gaseous exchange and enhanced the mobility of nutrients. The results also match the available literature **(**Lamidi *et al.,* 2021**)**. The results are also supported by the finding of (Ali *et al.,* 2020) stated that deep tillage had a strong impact on maize root initiation and root growth of maize plants, which favours higher nutrient uptake. Nitrogen applied at the rate of 180 kg ha^{-1} recorded maximum leaf area of maize as increased levels of nitrogen is crucial to increased maize growth as a result of sufficient availability of nitrogen the growth cells tend to expend and thus helped in longer the leaf area and increased leaves number (Akmal *et al.,* 2020). The higher nitrogen concentration in the leaves of plants as well as in the roots increased the cell number and expanded the leaf area greater than plants gown in non-fertilized plots (Shahid *et al.,* 2021). Another possible cause is that the nitrogen increased the formation of chlorophyll, which is the primary constituent of the photosynthetic machinery of plants (Akram *et al.,* 2020).

Plant height was significantly influenced by tillage implements and nitrogenous fertilizers. Deep tillage implements a significant increase in plant height due to the fine seed bed preparation, increased field capacity and provides favourable conditions for root development, also increasing the mass flow of nutrients towards the plant among tillage implements (Khan *et al.,* 2023; Wasaya *et al.,* 2021). Nitrogen influences the production of growth hormones such as auxins and gibberellins, and hence increases plant height. These hormones are responsible for maize plant height, increased cell elongation and cell division (Zulfiqar *et al.,* 2023; Ali *et al.,* 2022). Higher nitrogen availability can increase these hormones, which increase stem elongation and maize plant height. The results are also supported by the results of (Shahzad *et al.,* 2020), which stated that an increase in nitrogen levels from 90 kg ha^{-1} to 160 kg ha^{-1} significantly increased maize plant height.

Nitrogen treatments had a significant effect on ear length and the number of rows per ear. Nitrogen treatments increase both ear length and the number of rows per ear. The results are similar to the findings of earlier researchers (Ahmad *et al.,* 2022), an increase in ear length, due to nitrogen sufficiency and other essential nutrients, which increased ear length and number of rows ear^{-1}. The application of nitrogen increased the protein percentage, an increase in ear length, number of rows ear^{-1} (Azam *et al.,* 2023). Similar results were reported by (Anjum *et al.,* 2022), reported that the adequate amount of nitrogen to the plant highly increase in vegetative growth which increased length of ear and number of rows ear^{-1}, (Ghasemi *et al.,* 2021) reported that highest ear length was observed in nitrogen application plots and smallest ear length in the plots where nitrogen was not applied.

Tillage implements and nitrogenous treatments had significantly effect on number of ears m^{-2}. These results are supported by (Oyeranmi *et al.*, 2021) observed that tillage implements, and nitrogen levels had significant effect on number of ears m^{-2}. Similar findings were also documented by (Saeed *et al.*, 2023), stated that the effects of nitrogen statistically differ among the treatments.

Grain ear^{-1} was affected by both tillage implements and nitrogen treatments. Deep tillage helps improve soil aeration and root penetration. By loosening the compacted soil, tillage allows plant roots to reach nutrients and absorb adequate moisture, which is essential for both healthy root development and better crop growth (Fahad *et al.,* 2024). The results are also supported by (Mehran*et al.*, 2023) who observed that deep tillage implements like Mouldboard plough significantly increased grain ear^{-1} due to uniform and fine seed bed preparation in response to improved water holding capacity. The nitrogen levels also increased in the number of grains ear^{-1} (Anjum *et al.*, 2022) and it was reported that 180 kg N ha^{-1} gives higher number of grain ear^{-1}. Other researchers (Nawaz *et al.*, 2023) also reported that higher nitrogen levels allowing the plants to increase photosynthetic processes to accumulate more biomass with higher capacity to convert more photosynthates into sinks help in increase more grains ear^{-1}. These results are also in agreement with the finding of (Ahmad *et al.*, 2022) reported that grain number per cob was highest at the highest nitrogen level.

Tillage implements and nitrogenous treatments had a significant effect on thousand-grain weight. The weight of the thousand grains was higher in the deep tillage tilth plot as compared to other tilth plots. These findings are also supported by (Arshad *et al.*, 2020), who reported that deep tillage increases water holding capacity than shallow tillage, and hence crop growth. The plant absorbed better moisture and more nutrients and performed optimal physiological processes, which increased the yield and yield components of maize (Faheem *et al.,* 2022). Similarly, nitrogen also played a crucial role in increased thousand grain weight (Saeed *et al.,* 2023), The results are in agreement with Ahmad *et al.,* 2021) stated that increasing nitrogen levels increased thousand grain weight. The results are also in line with the results of (Azam *et al.,* 2024). It may be due to high photosynthetic and enzymatic processes, which increase the crop growth and hence the grain weight.

Biological yield was affected by tillage implements and nitrogen treatments. Among tillage implements the deep tilth plot increased biological yield of maize crop, may be soil loosing, better water infiltration and nutrients cycle (Ramadhan, 2021) the results are also confirmed by (Asenso *et al.*, 2022) Based on statistical analysis the deeper tillage increased biological yield as a result of better nutrients and water availability to plants during growth and reproductive stages, to meet their requirements. Nitrogen at higher doses also increased biological yield as compared to control and lower nitrogenous sources (Adhikari *et al.*, 2021). The results are supported by the finding of (Asibi *et al.*, 2021) stated that increased levels of nitrogen showed higher biological yield than non-nitrogenous plots.

The grain yield of maize was significantly affected by tillage implements and nitrogen source. It was noted that the mould board plough had increased maize grain yield as compared to other tillage implements by improving soil structure and nutrient availability, root penetration and nutrient uptake in deeply tilled soils (Haseeb *et al.*, 2021). Deep tillage increased porosity, aeration, effective gaseous exchange and allows roots to absorb water and nutrients, resulting in increased maize grain yield (Zhai *et al.*, 2021). The results are confirmed by previous literature (Yang *et al.*, 2020), which stated that deep tillage improved soil physical properties such as decreased bulk density and water retention, resulting in increased maize grain yield. The deep tilled reduced soil compaction and nitrate leaching, enhanced nutrients, led to increased maize grain yield (Mingotte *et al.*, 2020). The results are also supported by the findings of earlier researchers (Khan *et al.*, 2021), who reported that high nitrogen levels had increased maize grain yield, as nitrogen played a key role in vegetative growth, resulting in an increase in maize yield. Similarly, (Khan *et al.*, 2024) also reported that increased nitrogen levels led to a highly improvement in maize yield, nitrogen levels increase plant vigour as a result of N addition, resulting in better cob formation, ultimately increasing maize grain yield. The nitrogen application played a vital as it is a main constituent of chlorophyll production, which is the primary source of photosynthesis to convert light energy into chemical energy in the form of starch, which ultimately increased maize yield (Ahmad *et al.*, 2021).

The harvest index was affected by the nitrogenous source. Higher levels of nitrogen showed increased harvest index as compared to the control. The results are confirmed by the previous findings of (Hammad *et al.*, 2020) stated that an increased level of nitrogen significantly increases grain yield and harvest index. The results are supported by Shah *et al.*, 2020) reported that nitrogen is vital for photosynthesis to accumulate more assimilate, which helps in increased maize grain yield. The results are also confirmed by (Mahmood *et al.*, 2022) stated that increased levels of nitrogen significantly increased production, ultimately a higher harvest index.

Conclusion and Recommendation

The current study concluded that the Mouldboard plough being a deep-tillage implement, significantly improved overall growth and yield components such as leaf number plant^{-1}, leaf area, plant height, number of ears m^2, grains ear^{-1}, thousand grain weight, grain and biological Yield. However, emergence days, tasseling, and silking were not influenced much by the tillage type. Nitrogen at 180 kg ha^{-1} considerably delayed phenological stages such as tasseling, silking, and physiological maturity, but it indeed had a positive effect on all major growth and yield parameters that ultimately contributed to a 10.5% increase in grain yield concerning 120 kg ha^{-1} N and a 3.3% increase concerning 18 tons FYM ha^{-1}. Thus, it was concluded that among various tillage implements, the Mouldboard plough can be rated quite high for maize cultivation, while 180 kg ha^{-1} mineral nitrogen is the most suitable application for optimizing maize growth and yield. It is thereby suggested that farmers practice deep tillage with Mouldboard ploughs supplemented with mineral nitrogen to derive maximum maize yield. Further research may deal with the joint long-term effects of deep tillage and integrated nutrient management upon the health of soil and stability of maize yield.

References

Abbas, S., Javed, M.T., Ali, Q., Azeem, M. and Ali, S., 2021. Nutrient deficiency stress and relation with plant growth and development. In Engineering tolerance in crop plants against abiotic stress (pp. 239-262). CRC Press.

Adhikari, K., S. Bhandari, K. Aryal, M. Mahato and J. Shrestha. 2021. Effect of different levels of nitrogen on growth and yield of hybrid maize (Zea mays L.) varieties. Journal of Agriculture and Natural Resources. 4(2): 48-62.

Adiaha, M.S., 2016. Influence of Different Soil types and Mineral Fertilizer on Maize (Zea mays L.) growth for effective Production, Soil fertility improvement and Food Security. World Scientific News, 55, pp.137-167.

Ahmad, F., S.A. Siddiqui, R.S. Sundari, J. Ahmad, S.M. Ali, M.R. Khan and S.A. Ibrahim. 2021. Assessing integrated nitrogen and planting density on growth, yield component and financial analysis of maize crops (Zea mays. Journal of Hygienic Engineering and Design. 37(4): 1-12

Ahmad, S., A. Khan, M. Kamran, I. Ahmad, S. Ali and S. Fahad. 2022. Response of maize cultivars to various nitrogen levels. Eur. Exp. Biol. 8(1): 1-4.

Ahmad, W., Khan, F., Sharif, M. and Khan, M.J., 2019. Agricultural land management of eroded soil to restore productivity, organic matter (OM) stock and physical properties. Sarhad Journal of Agriculture, 35(4), pp.1144-1154.

Akmal, M., A. Shah, R. Zaman, M. Afzal and N.U. Amin. 2020. Carryover response of tillage depth, legume residue and nitrogen-rates on maize yield and yield contributing traits. International Journal Agriculture Biology. 17(5): 961-968.

Akram, M. 2020. Effects of nitrogen application on chlorophyll content, water relations, and

Alam, M.S., R.K. Naresh, K.S. Vivek and H.L. Singh. 2022. Effect of Sowing Methods and Irrigation Scheduling on Production and Productivity of Wheat Crop. Int. J. Biol. Forum. 14(2): 445-452.

Ali, K., F. Munsif, I. Uddin, A. Khan and N. Khan. 2020. Maize penology as affected by tillage practices and nitrogen sources. Agric. Sci. Res. 2(8): 453-458.

Ali, K., S.K. Khalil, F. Munsif, A. Rab, K. Nawab, A.Z. Khan and Z.H. Khan. 2022. Response

Anjum, M.M., M. Shafi, H. Ahmad, N. Ali, M.O. Iqbal, S. Ullah, and W. Liaqat. 2022. Influence of split nitrogen application on yield and yield components of various maize varieties. Pure and Applied Biology. 7(2): 721-726.

Anwar, S., W. Ullah, M. Islam, M. Shafi, A. Iqbal and M. Alamzeb. 2020. Effect of nitrogen rates and application times on growth and yield of maize (Zea mays L) Pure Appl. Biol. 6(3): 908-916

Asenso, E., L. Hu, F. Issaka, K. Tian, L. Zhang, L and J. Li. 2022. Four tillage method assessments on soil organic carbon, total nitrogen, biological activities, and maize grain yield in Southern China. Food and Energy Security. 8(4): 118-132.

Ashenafi, M., Y. Selassie, G. Alemayehu and Z. Berhani. 2023. Growth, Yield Components, and Yield Parameters of Maize (Zea mays L) as Influenced by Unified Use of NPSZnB Blended Fertilizer and Farmyard Manure. International Journal of Agronomy. 3(1): 13-21.

Asibi, A.E., Q. Chai and A.J. Coulter. 2021. Mechanisms of nitrogen use in maize. Saudi Journal of Biological Sciences. 9(12): 775-842.

Azam, A. and Shafique, M., 2017. Agriculture in Pakistan and its Impact on Economy. A Review. Inter. J. Adv. Sci. Technol, 103, pp.47-60.

Azam, M.F., J. Bayar, B. Iqbal, U. Ahmad, M.K. Okla, N. Ali and A. Jalal. 2024. Planting pattern and nitrogen management strategies: positive effect on yield and quality attributes of Triticum aestivum L. Crop. BMC Plant Biology. 24(1): 845.

Brar, A., Gosal, S.K. and Walia, S.S., 2017. Effect of biofertilizer and farmyard manure on microbial dynamics and soil health in maize (Zea mays L.) rhizosphere. Chem. Sci. Rev. Lett, 6, pp.1524-1529.

Busari, M.A., Kukal, S.S., Kaur, A., Bhatt, R. and Dulazi, A.A., 2015. Conservation tillage impacts on soil, crop and the environment. International soil and water conservation research, 3(2), pp.119-129.

Chien, S.H., Gearhart, M.M. and Villagarcía, S., 2011. Comparison of ammonium sulfate with other nitrogen and sulfur fertilizers in increasing crop production and minimizing environmental impact: a review. Soil

Fahad, S., I. Ali, I. Hussain, D. Ahmad, S. Saud, K. Dawar and K. El-Kahtany. 2024. Modulation of maize growth, yield and soil enzymes activities by introducing wheat straw mulching and tillage practices. Plant and Soil. 496(1): 699-719.

Faheem, M., M. Altaf, J. Liu, M. Yamin, M. Akram, M. W. Iqbal and M.U. Khan. 2022. Design, development and performance evaluation of zone disc tiller drill for maize crop production in Pakistan. Agricultural Engineering International: CIGR Journal. 24(4): 1-12

Fathi, A., 2022. Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A. Agrisost, 28, pp.1-8.

Ghasemi, A., A. Ghanbari, B. Fakheri and H.R. Fanaie. 2021. Effect of different fertilizer resources on yield and yield components of grain maize (Zea mays L.) affected by tillage managements. Journal of Agroecology. 7(4): 499-512.

Gheith, E.M.S., O.Z. El-Badry, S.F. Lamlom, H.M. Ali, M.H. Siddiqui, R.Y. Ghareeb and E.E. Kandil. 2022. Maize (Zea mays L.) productivity and nitrogen use efficiency in response to nitrogen application levels and time. Frontiers in Plant Science. 1: 9-13.

Giordano, M., Petropoulos, S.A. and Rouphael, Y., 2021. The fate of nitrogen from soil to plants: Influence of agricultural practices in modern agriculture. Agriculture, 11(10), p.944.

Gurmu, G., 2019. Soil organic matter and its role in soil health and crop productivity improvement. Forest Ecology and Management, 7(7), pp.475-483.

Hammad, H.M., F. Abbas, A. Ahmad, H.F. Bakhat, W. Farhad, C.J. Wilkerson and G. Hoogenboom. 2020. Predicting kernel growth of maize under controlled water and nitrogen applications. International Journal of Plant Production. 14(3): 609-620.

Indoria, A.K., Sharma, K.L., Reddy, K.S. and Rao, C.S., 2016. Role of soil physical properties in soil health management and crop productivity in rainfed systems–II. Management technologies and crop productivity. Current science, pp.320-328.levels. Journal of Global Innovation Agricultural Science. 5: 159-164.

Khan, A., S. Fahad, A. Khan, S. Saud, M. Adnan, F. Wahid and O. Sonmez. 2021. Managing

Khan, H., A. Khan, S. Khan, A. Anjum and H. Akbar. 2024. Maize productivity and nutrient status in response to crop residue mineralization with beneficial microbes under various tillage practices. Soil and Tillage Research. 239: 106057.

Khan, I., Akram, A., Fatima, S., Ahmad, B., Rehman, Z., Arshad, N., Sattar, A. and Ahmad, Z., 2022. Problems of agriculture in Pakistan: an insight into their solution. Pakistan Journal of Biotechnology, 19(02), pp.73-83.

Khan, M.H., H. Liu, A. Zhu, M.H. Khan, S. Hussain and H. Cao. 2023. Conservation tillage practices affect soil microbial diversity and composition in experimental fields. Frontiers in Micro Biology. 14(3): 122-139.

Kumar, S., Dhar, S., Barthakur, S., Rajawat, M.V.S., Kochewad, S.A., Kumar, S., Kumar, D. and Meena, L.R., 2021. Farmyard manure as K-fertilizer modulates soil biological activities and yield of wheat using the integrated fertilization approach. Frontiers in Environmental Science, 9, p.764489.

Lal, R., 1991. Tillage and agricultural sustainability. Soil and tillage research, 20(2-4), pp.133-146.

Lamidi, W.A., M.A. Murtadha, M.S. Afolabi and A.E. Olawum. 2021. Effect of depths of tillage on the performances of open-pollinated yellow Maize (Zea Mays) varieties. Polish J Natural Sci. 36(3): 215-228.

Leghari, S.J., Wahocho, N.A., Laghari, G.M., Hafeez Laghari, A., MustafaBhabhan, G., Hussain Talpur, K., Bhutto, T.A., Wahocho, S.A. and Lashari, A.A., 2016. Role of nitrogen for plant growth and development: A review. Advances in Environmental Biology, 10(9), pp.209-219.

Li, R., P. Liu, S. Dong, J. Zhang and B. Zhao. 2021. Increased maize plant population induced leaf senescence, suppressed root growth, nitrogen uptake, and grain yield. Agronomy Journal. 111(4): 1581-1591.

M. Tahat, M., M. Alananbeh, K., A. Othman, Y. and I. Leskovar, D., 2020. Soil health and sustainable agriculture. Sustainability, 12(12), p.4859.

Mahmood, H., j. Cai, Q. Zhou, X. Wang, A. Samo, M. Huang and D. Jiang. 2022. Optimizing nitrogen and seed rate combination for improving grain yield and nitrogen uptake efficiency in winter wheat. International Journal of Plant Production. 11(13): 17-31.

Majid, M.A., M.S. Islam, A. El-Sabagh, M.K. Hasan, M.O. Saddam, C. Barutcular and M.S. Islam. 2017. Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (Zea mays. Journal of Agriculture and Natural Resources. 3(4): 44-57.

Mehran, M.A., I. Inamullah, S.A. Ahmad and K. Arsalan. 2018. Nitrogen sources incorporation with different tillage implements affects maize productivity and soil organic matter. Pure and Applied Biology. 9(1): 5-14.

Mingotte, F.L.C., C.A. Jardim, M.M. Yada, C.B. Amaral, T.P.L.C. Chiamolera, A.P. Coelho and F.D. Fornasieri 2020. Impact of crop management and no-tillage system on grain and straw yield of maize crop. Cereal Research Communications. 48: 399-407.

Nawaz, H., H. Akbar, A. Khan, M. Arif, M. Riaz, M. Zuhair and B. Khan. 2023. Pigeon Pea green manuring and nitrogen fertilization increase agronomic efficiency by improving

Negassa, W., Gebrekidan, H. and Friesen, D.K., 2005. Integrated use of farmyard manure and NP fertilizers for maize on farmers' fields. Journal of Agriculture and Rural development in the Tropics and Subtropics (JARTS), 106(2), pp.131-141.

Ohyama, T., 2010. Nitrogen as a major essential element of plants. Nitrogen Assim. Plants, 37, pp.1-17.

Oyeranmi, A.T and W.A. Lamidi, 2021. Effect of depths of tillage on selected morphological characteristics, yield and yield components of yellow maize (Zea mays) hybrids. Ethiopian Journal of Environmental Studies and Management. 14(2): 35-46

Parvin, N., Parvage, M.M. and Etana, A., 2014. Effect of mouldboard ploughing and shallow tillage on sub-soil physical properties and crop performance. Soil science and plant nutrition, 60(1), pp.38-44.

Qadeer, U., M. Ahmed, F.U. Hassan and Akmal. M. 2021. Impact of nitrogen addition on physiological, crop total nitrogen, efficiencies and agronomic traits of the wheat crop under rainfed conditions.

Ramadhan, M.N. 2021. Yield and yield components of maize and soil physical properties as affected by tillage practices and organic mulching. Saudi Journal of Biological Sciences. 28(12): 7152-7159.

Rizwanullah, M., Yang, A., Nasrullah, M., Zhou, X. and Rahim, A., 2023. Resilience in maize production for food security: Evaluating the role of climate-related abiotic stress in Pakistan. Heliyon, 9(11).

Saeed, B., M. Azam, S. Khan and D. Zafar. 2023. Exploring the effect of nitrogen levels on yield and yield attributes of diverse open-pollinated varieties (OPVs) of maize (Zea mays L). Advances in Agriculture and Biology. 6(1): 445-457

Science, 176(7), pp.327-335.

Shah, M.N., D.L. Wright, S. Hussain, S.D. Koutroubas, R. Seepaul, S. George and R. Eswaramoorthy. 2023. Organic fertilizer sources improve the yield and quality attributes of maize (Zea mays L.) hybrids by improving soil properties and nutrient uptake under drought stress. Journal of King Saud University-Science. 35(4): 10-25.

Shah, S.A., Ali, S., Ali, A. and Baig, A., 2020. Economic Analysis of Maize Production in Central Khyber Pakhtunkhwa, Pakistan. Sarhad Journal of Agriculture, 36(3).

Shahane, A.A. and Shivay, Y.S., 2021. Soil health and its improvement through novel agronomic and innovative approaches. Frontiers in Agronomy, 3, p.680456.

Shahzad, K., A. Khan, J. Smith, M. Saeed and S.A. Khan. 2020. Response of maize to different nitrogen sources and tillage systems under humid subtropical conditions. JAPS: Journal of Animal and Plant Sciences. 25(1): 1-4.

Smith, L.G., Williams, A.G. and Pearce, B.D., 2015. The energy efficiency of organic agriculture: A review. Renewable agriculture and Food systems, 30(3), pp.280-301.

Soto-Gómez, D. and Pérez-Rodríguez, P., 2022. Sustainable agriculture through perennial grains: Wheat, rice, maize, and other species. A review. Agriculture, Ecosystems & Environment, 325, p.107747.

system. Agronomy Journal. 111(5): 2600-2609.

tillage operation and manure to restore soil carbon stocks in wheat–maize cropping

Wasaya, A., M. Tahir, H. Ali, M. Hussain, T.A. Yasir, A. Sher and M. Ijaz. 2021. Influence of varying tillage systems and nitrogen application on crop allometry, chlorophyll contents, biomass production and net returns of maize (Zea mays L). Soil and Tillage Research. 170: 18-26.

Wu, P., F. Liu, G. Chen, J. Wang, F. Huang, T. Cai and Z. Jia. 2022. Can deep fertilizer application enhance maize productivity by delaying leaf senescence and decreasing nitrate residue levels. Field Crops Research. 27(7): 108-117.

Yang, H., G. Wu, P. Mo, S. Chen, S. Wang, Y. Xiao and G. Fan. 2020. The combined effects of maize straw mulch and no-tillage on grain yield and water and nitrogen use efficiency of dry-land winter wheat (Triticum aestivum L). Soil and Tillage Research. 19(7): 10-44.

Yilmaz, E. and Alagöz, Z., 2010. Effects of short-term amendments of farmyard manure on some soil properties in the Mediterranean region-Turkey. Journal of Food Agriculture & Environment, 8, pp.859-862.

Zhai, L., P. Xu, Z. Zhang, B. Wei, X. Jia and L. Zhang. 2021. Improvements in grain yield and nitrogen use efficiency of summer maize by optimizing tillage practice and nitrogen application rate. Agronomy Journal. 111(2): 666-676.

Zhang, W., Shao, J., Huang, K., Chen, L., Niu, G., Wei, B. and Huang, G., 2024. Deep vertical rotary tillage: A sustainable agricultural practice to improve soil quality and crop yields in China. Agronomy, 14(9), p.2060.

Zulfiqar, U., M. Ishfaq, M.U. Yasin, N. Ali, M. Ahmad, A. Ullah and W. Hameed. 2023. Performance of maize yield and quality under different irrigation regimes and nitrogen Rizwan, M., Ali, S., Qayyum, M.F., Ok, Y.S., Zia-ur-Rehman, M., Abbas, Z. and Hannan, F., 2017. Use of maize (Zea mays L.) for phytomanagement of Cd-contaminated soils: a critical review. Environmental Geochemistry and Health, 39, pp.259-277.