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Response of Maize *(Zea mays L.)* to Nitrogen and Phosphorus Fertilizers under semi-arid condition of Hamelmalo, Eritrea.

By

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Abstract

Changes in climate, development of new hybrids and soil fertility status has influenced nutrient application rates worldwide. A field experiment was conducted at the Agronomic Research Area of Hamelmalo Agricultural College's experimental farm to determine the optimal levels of nitrogen (N) and phosphorus (P) for enhancing maize productivity in the semi-arid conditions of Hamelmalo, Eritrea. The study, replicated three times, employed a randomized complete block design with nine treatments, covering an area of 404 square meters. Observations on various parameters such as growth, development, yield, and yield attributes were meticulously monitored throughout the experimental period. The results showed that increasing nitrogen levels from no application to 100 kg/ha significantly impacted plant height, with values ranging from 209.6 cm to 224.8 cm. Similarly, phosphorus application from no application to 50 kg/ha led to an increase in plant height (207.6 cm to 230 cm) and leaf area (449 cm² to 571 cm²). While nitrogen and phosphorus applications did not significantly affect the time taken for tasseling and silking, they did influence the time to maturity. The yield parameters indicated that grain yield was not significantly affected by either nitrogen or phosphorus levels, although biomass yield was significantly influenced by higher nitrogen levels (150 kg/ha), resulting in a biomass yield of 7.4 t/ha. Additionally, cob length, a critical yield attribute, was significantly influenced by the application of 150 kg/ha of nitrogen, resulting in a cob length of 11.6 cm, while phosphorus application did not significantly impact cob length. In conclusion, the study found that applying 150 kg/ha of nitrogen through urea and 50 kg/ha of phosphorus through di-ammonium phosphate (DAP) resulted in significant improvements in most of the parameters studied. These findings provide valuable insights into optimizing maize productivity in semi-arid regions, highlighting the importance of nutrient management in enhancing crop performance under challenging environmental conditions.

Keywords*: Maize, Nitrogen and Phosphorus levels, Semi-arid conditions, Crop response, Growth, Development, Yield, Nutrient management*

1. Introduction

Maize (Zea mays L.) is a crucial cereal crop, ranking third globally in importance after wheat and rice [1, 2]. It is cultivated extensively in numerous countries around the world, with the United States, Brazil, France, India, and Italy being among the major producers. In Africa, the majority of maize produced is consumed as human food, although its use as livestock feed is also becoming more prevalent. According to available data, the area dedicated to maize cultivation in

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West and Central Africa experienced significant growth, increasing from 3.2 million hectares in 1961 to 8.9 million hectares in 2001. This substantial expansion led to a marked increase in maize production, rising from 2.4 million metric tons in 1961 to 10.6 million metric tons in 2001.This growth underscores the increasing importance of maize as a staple crop in these regions [2].

Despite the expansion of land areas dedicated to maize production, yields remain suboptimal. Several key factors contribute to this low yield, including declining soil fertility and the inadequate use of fertilizers, which lead to severe nutrient depletion in the soil [3]. Maize requires an adequate supply of nutrients, particularly nitrogen, phosphorus, and potassium, to achieve good growth and high yields. Nitrogen and phosphorus are crucial for robust vegetative growth and grain development in maize production. The specific quantities of these nutrients, especially nitrogen, are influenced by factors such as the pre-clearing vegetation, organic matter content, tillage methods, and light intensity.

Increasing the levels of nitrogen and phosphorus in the soil, particularly under various soil and management conditions, has been shown to enhance several aspects of maize growth. This includes increases in grain yield, above-ground biomass, the number of kernels per ear, and plant height [3, 4]. However, phosphorus utilization in soils is complicated by its tendency to be fixed in the soil, making much of the inherent phosphorus unavailable. In soils deficient or marginally sufficient in available phosphorus, applying higher doses of phosphorus fertilizer can improve seedling emergence, root development, and ultimately, days to flowering and maturity, leading to increased grain yield [5, 6.].

The application of increasing levels of phosphorus (P) fertilizer has been found to enhance the aboveground biomass and grain yields of maize. This is because higher P application rates also improve the uptake of soil nitrate and potassium by maize plants [7]. Additionally, it has been observed that the use of nitrogen (N) fertilizer can enhance phosphorus uptake from the soil, reinforcing the idea that the response to one nutrient is influenced by the sufficiency of other nutrients [8]. Nitrogen fertilization can increase phosphorus concentrations in plants by promoting root growth, enhancing the roots' ability to absorb and translocate phosphorus, and reducing soil pH through the absorption of ammonium ion ($NH4^+$), which increases the solubility of fertilizer phosphorus [9,10].

Maize, as the world's most significant cereal crop, is highly valued for its high yields, ease of processing, digestibility, and relatively lower cost compared to other cereals. However, in Eritrea, the average maize production under rain-fed conditions is only 0.99 t/ha [11], which is substantially lower than the global average yield of 8.0 t/ha. Several key factors contribute to this disparity, including declining soil fertility and the inadequate use of fertilizers, leading to severe nutrient depletion in the soils [12]. Nitrogen and phosphorus are crucial for the healthy vegetative growth and grain development of maize. The judicious application of these nutrients, particularly nitrogen and phosphorous, can significantly enhance maize production and productivity.

Given the imperative to enhance maize production, it is clear that future gains must be driven by increased productivity per unit area and time. This necessitates the meticulous management of scarce fertilizer nutrients at the farm level. The efficient use of nitrogen (N) and phosphorus (P) fertilizers is crucial, as these nutrients are essential for the healthy vegetative growth and grain development of maize. This study is designed to identify the optimal levels of N and P fertilizers required for maximizing maize production and productivity under Eritrean growing conditions. It also seeks to elucidate the interactions between different levels of these fertilizers on maize growth and yield. By understanding these dynamics, farmers and agricultural practitioners can adopt more effective strategies to optimize fertilizer application, thereby bridging the yield gap and ensuring sustainable maize production. In light of these considerations, this investigation aims to provide definitive insights into the optimal nitrogen and phosphorus levels necessary to achieve higher maize production and productivity, ultimately contributing to improved food security and economic benefits for Eritrean farmers.

2. Material and Methods

The field experiment was conducted at the experimental farm of Hamelmalo Agricultural College during the summer of 2022. The site is situated in the Zoba Anseba region of Eritrea, with coordinates 15° 52’ 18’’ N latitude and 38° 27’ 55’’ E longitude, and an elevation of 1280 meters above mean sea level. This area is characterized by a semi-arid mid-land climate, receiving an average annual rainfall of 513.5 mm. The temperature ranges from a maximum of 34.7°C to a minimum of 11.1°C. The soil at the experimental site is classified as sandy loam, with a moderately alkaline pH of 8.07. The soil analysis revealed low levels of total nitrogen (0.05%), very low levels of phosphorus (2.04 ppm), and low levels of potassium (0.18 cmol/kg), along with an electrical conductivity of 0.13 dS/m. The variety of maize used for this experiment was 04 Sadve, which is highly suitable for both rain-fed and irrigated conditions. Developed and released by the National Agricultural Research Institution (NARI) in 2013, this variety thrives in a range of soil types, including well-drained heavy clay, light clay, and sandy loam soils, even at altitudes up to 2500 meters above sea level. The recommended seeding rate is 25-30 kg/ha. For optimal growth, the crop requires rainfall between 500-800 mm. It matures approximately 130 days after fertilization and features white-colored seeds with compact, shaped cobs. The yield potential of this variety is 2.5-3.0 tons per hectare. The 04 Sadve variety is moderately drought-tolerant and exhibits good disease resistance in the field, although it may not retain this resistance in storage. The experiment was laid out in randomized complete design with three replications. It comprised of three Nitrogen levels (0, 100, 150 kg ha^{-1}) and three Phosphorus levels (0, 50, 100 kg ha^{-1}). There were 9 treatments and treatments were assigned in the whole experimental area at random. Each treatment was allocated

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randomly in a gross plot size of 4m × 2.7m in each three replication. Distance between replication and unit plots was 1.0 m and 0.5 m respectively. All treatments were assigned at random to a group of plots called the block in such a way that each treatment occurs only once in each block and replicated over all blocks. All traits that assisted in bringing higher yields of maize were recorded sequentially. Crop was sown manually in the 7th of July 2022 keeping the inter row spacing 75cm and intra row spacing of 30cm. Nitrogen and phosphorus was applied as treatments using Urea and Di-ammonium phosphate respectively. The quantity of urea was deducted from the nitrogen available in Di-ammonium phosphate to avoid overdose application. Thinning was done at 14 days after sowing (DAS) to maintain the recommended plant density per plot. First weeding was done at the time before thinning and second weeding was done at 28 days after sowing. Five plants in each plot were randomly selected to record the data on different growth, development and yield attributes. Crops were harvested when husks and cobs became dry and physiologically matured from the net plot area of $6m^2$, by keeping one border row and 25 cm from each side of the plot as non-experimental area. Gran yield and biological yield were recorded from the net plot area and converted to tons per hectare. The harvest index was calculated by dividing the seed yield by biological yield per plot. The data obtained were statistically analysed in RCBD design using Analysis of Variance (ANOVA) with the help of GENSTAT 14 statistical computer package software at 5% level of significance.

3. Results and Discussion

3.1. Morphological and Phenological Parameters

The study presents and discusses the data on several morphological parameters, including plant height, number of leaves, and leaf area, as well as phenological parameters such as days to emergence, days to tasseling, days to silking, and days to maturity and yield and yield attributes. This information is summarized in Table 1 and is elaborated upon in the following section.

3.1.1 Plant height:

The statistical analysis reveals that there was no significant difference in plant height among the various N and P levels. However, the highest plant height was numerically observed with the application of 100 kg/ha of nitrogen, reaching a value of 224.8 cm. In the case of phosphorus application, the maximum plant height was recorded at 50 kg/ha of P2O5, with a value of 230.7 cm, as shown in Table 1. This finding contrasts with previous studies [12, 13, 8], which reported a significant impact of nitrogen and phosphorus (NP) application on plant height; increasing the application of N and P significantly increased plant height.

Furthermore, these findings were dissimilar with [24] who reported that significant increase in plant height was observed in both N and P levels**.**

3.1.2 Number of leaves:

The statistical analysis discloses that there was no significant difference in the number of leaves among the various treatments. However, the highest numerical value for the number of leaves was observed at the 150 kg ha^{-1} treatment, with a count of 14. Similarly, in the case of phosphorus application, the maximum number of leaves, also 14, was recorded at the 50 kg ha^{-1} treatment. These findings are presented in Table 1. This outcome contradicts the findings of [8], which reported a significant impact of phosphorus application on dry matter yield and individual plant characteristics, including the number of leaves and leaf area.

Furthermore, these results were dissimilar with [24] who reported that Nitrogen played role in increasing No. of leaves in maize where N level 200 kg/ha produced 12.95% more leaves.

3.1.3 Leaf area:

The statistical analysis indicates that there was no significant difference in leaf area among the nitrogen treatments. However, the numerically highest leaf area was observed at the 150 kg/ha nitrogen treatment, with a value of 552 cm², as shown in Table 1. This finding aligns with the observations of [15], and, [16] who reported that nitrogen significantly enhances leaf area by promoting leaf elongation and maintaining functional leaf area during the vegetative development and growth periods.

In the case of phosphorus application, a significant difference was noted among the treatments, with the highest leaf area recorded at the 150 kg/ha treatment. This result is consistent with [8], which found that phosphorus application had a significant impact on dry matter yield and individual plant characteristics such as height, number of leaves, and leaf area.

Regarding the interaction of nitrogen and phosphorus (NP), there was a significant difference among the treatments, with the highest leaf area observed at the 150*100 NP treatment, reaching a value of 590 cm². This outcome is in agreement with [9], which reported that increased application rates of NP enhance growth and grain yield in maize production in Nigeria.

3.1.4 Days to emergence:

The statistical analysis revealed a highly significant difference among the nitrogen and phosphorus treatments. The mean data values showed that the earliest emergence days were observed at 150 kg/ha of nitrogen (with a value of 5.0 days) and 100 kg/ha of P2O5 (with a value of 5.4 days). These findings are consistent with the report of [5], which stated that in soils with deficient or marginal available phosphorus, applying higher doses of phosphorus enhances seedling emergence by promoting root development, subsequently accelerating days to flowering and maturity, and increasing maize grain yield. Additionally, the interaction between nitrogen and phosphorus treatments also exhibited significant differences. This aligns with the observation [9] that the application of nitrogen fertilizer increases phosphorus uptake from the soil, supporting the general principle that the response to one nutrient is influenced by the sufficiency level of other nutrients, although the specific reference mentioned is not provided in the sources listed.

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3.1.5 Days to tasseling:
As the data indicated in (Table.1) there was no significant difference among treatments in the case of days to tasseling even though there was a slight difference numerically. Earliest days taken to tasseling was recorded on no application of nitrogen with the value of 62.3 days. In case of application of phosphorus earliest days taken to tasseling was recorded on no application phosphorus with the value of 62.4 days. This result was in agreement with **[7]** reported that an important problem associated with phosphorus whether it is derived from the soil or applied as fertilizers is its fixation in the soil and the amount of inherent P is very low in the soils, most of which present in the soil in unavailable form, and added soluble forms of P are quickly fixed by many soils. Moreover, these results were in conformity with [24] who reported Application of both N and P resulted non-significant on days to 50% tasseling regardless of the levels used.

3.16 Days to silking:
The statistical analysis showed that there was no significant difference among treatment in case of days to silking. But numerically earliest days taken to silking was recorded on 150kg ha^{-1} of nitrogen with value of 73.9 days. These results were in contrast with [24] who reported that application of both nutrients in higher levels significantly increased the No. of days to reach 50% silking stage. In case of phosphorus the earliest days taken to silking was recorded on no application of phosphorus with value of 73.8days, this result was in disagreement with [17] who reported that among the essential nutrients, phosphorus is one of the most important nutrients for higher yield in larger quantity and controls mainly the reproductive growth of plants.

3.1.7 Days to maturity:
As the data presented in (Table.1) there was no significant difference among treatment by different level of nitrogen and phosphorus levels. But numerically earliest days taken to maturity was recorded on 150kg ha^{-1} of nitrogen with the value 95.1days. In case of application of phosphorus earliest days taken to maturity was recorded on 100kg ha^{-1} of P which is 95.0 days. These results were in agreement with [5] who reported that in soils which are deficient or marginal in available P, application of higher dose of P enhances emergence of seedlings through its effect on development of root, and thereby enhances days to flowering and maturity and also increases the grain yield of maize [18] also reported that adequate P results in rapid growth and earlier maturity and improves the quality of vegetative growth. In addition, these results were in disagreement with [24] who reported the shortest duration, with values of 84.22 and 84.33 days, in both N and P applied at the rates of 100 kg ha-1 and 50 kg ha-1, respectively.

Table 1. Effect of treatments on Morphological and phonological parameters

Treatments	Plant height (cm)	Number of leaves (No. m^{-2})	Leaf area (cm^{-2})	Days to emergence	Days to tasseling	Days to silking	Days to maturity
			Nitrogen levels in kg ha^{-1}				
0	209.6	12.89	455	6.7	62.3	74.2	98.2
100	224.8	13.0	543	5.7	62.6	74.0	95.3
150	223.7	13.33	552	5.0	63.2	73.9	95.1
LSD	NS	NS	60.3	0.263**	NS	NS	0.707
			Phosphorus levels (kg ha^{-1})				
0	207.6	12.33	449	6.0	62.4	73.8	97.3
50	230.7	13.56	571	5.9	62.6	74.2	96.3
100	219.9	13.33	529	5.4	63.1	74.1	95.0
LSD (0.05)	NS	NS	60.3	0.263**	NS	NS	0.707
CV (%)	8.1	5.5	10.6	2.7	0.9	1.0	0.4
N*P	NS	NS	*	*	NS	NS	NS

*N.B: LSD (Least significant difference); CV (Coefficient of variation) and N*P (Interaction of nitrogen and phosphorus), * (Significant), ** (highly Significant).*

Table 2. Interaction effect of nitrogen and phosphorus levels on leaf area (cm^{2})

	Phosphorus levels (kg ha^{-1})		
Nitrogen Levels (kg ha^{-1})	0	50	100
0	321	550	493

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100	537	588	506
150	490	574	590
LSD (0.05)	104.4		
CV (%)	10.6		

N.B: LSD (Least significant difference); CV (Coefficient of Variation) and N*P (Interaction of nitrogen and phosphorus)

The data presented in Table 2 show that the combination of 150 kg/ha of nitrogen and 100 kg/ha of phosphorus resulted in a significant increase in leaf area, reaching 590 cm^2. It is noteworthy that other combinations also showed numerical increases in leaf area, although not all were statistically significant. Specifically, the combination of 100 kg/ha of nitrogen and 50 kg/ha of phosphorus, which yielded a leaf area of 588 cm^2, was statistically equivalent to the combination of 150 kg/ha of nitrogen and 100 kg/ha of phosphorus.

Table 3. Interaction Effect of Nitrogen and Phosphorus levels on days taken to emergence

	Phosphorus levels (kg ha^{-1})		
Nitrogen Levels kg ha^{-1}	0	50	100
0	7.0	7.0	6.0
100	6.0	5.7	5.3
150	5.0	5.0	5.0
LSD (0.05)	0.46		
CV (%)	2.7		

NB: LSD (Least significant difference); CV (Coefficient of variation) and N*P (Interaction of Nitrogen and Phosphorus

The data in Table 3 indicate that the combinations of 150 kg/ha of nitrogen with no phosphorus (P2O5), 150 kg/ha of nitrogen with 50 kg/ha of phosphorus, and 150 kg/ha of nitrogen with 100 kg/ha of phosphorus all resulted in a significant reduction in the days to emergence, with a value of 5.0 days. It is noteworthy that other combinations also showed numerical reductions in days to emergence, although not all were statistically significant. However, the combination with no nitrogen and no phosphorus application (7.0 days) was statistically equivalent to the combination with no nitrogen application but 50 kg/ha of phosphorus application also (7.0 days).

3.2 Effect of treatments on yield and yield related parameters:

3.2.1 Grain yield:

The statistical analysis revealed that there was no significant difference in grain yield among the various treatments. However, the highest grain yield was observed numerically at 100 kg/ha of nitrogen, with a yield of 1.5 t/ha. For phosphorus, the highest grain yield was recorded at 50 kg/ha of P2O5, with a yield of 16.2 kg/ha. As indicated in Table 4, the increase in grain yield due to the application of nitrogen and phosphorus is consistent with previous findings that report enhanced grain yields resulting from NP application. [13]. However, this finding was in contrast with [18] who reported significant effect of P application on grain yield. [19] Also stated that phosphorus fertilizer affected plant growth, yield and also increased plant height, leaf area, grain weight, number of grains ear-^{1,} grain and Stover yields, shelling percentage and harvest index of maize as compared with control.

3.2.1 Biological yield:

The statistical analysis shows that there was significant difference among treatments in case of biological yield by different levels of nitrogen but in case of phosphorus there was no significant difference among treatments but numerically highest biological yield was recorded on 50kg ha^{-1} P2O5 with the value 74.6 t ha^{-1}. Moreover, the interaction N and P shows significant difference among the treatments. This result is indicated in (Table.4); and it is in agreement with the statement that says nitrogen and phosphorus are very essential for good vegetative growth and grain and development in maize production [9].

3.3 Harvest Index:

As indicated in (Table.4) the statistical analysis shows that there was no significant difference among treatments in case of harvest index. But numerically highest harvest index was recorded on no application of nitrogen with the value of 24.7%. In case of application of phosphorus highest harvest index was recorded on 100kg ha^{-1} P_2O_5 with the value of 22.4%. This result is in coincided with [8] who reported above ground biomass and grain yields of maize increased with the application of increasing levels of phosphorus fertilization [20] stated that phosphorus fertilizer affected plant growth, yield and also increased plant height, leaf area, grain weight, number of grains ear-^{1,} grain and stover yields, shelling percentage and harvest index of maize as compared with control.

3.3.1 Cob length (cm)

The statistical analysis in (Table.4) shows that there was significant difference among treatments in the cob length in case of application of nitrogen, but in case of phosphorus there was no significant difference among treatments, but numerically the highest cob length was recorded on 50kg/ha of P2O5 with the value 10.47 cm. This result was in agreement with [5] who reported that ear length decrease with decrease in nitrogen levels. High ear length was recorded in the higher treatments and minimum ear length was recorded in the control plots.

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3.3.2 Number of cobs per plant:

As indicated in (Table.4) there was no significant difference among the treatments in case of number cobs per plant even though there was slight difference numerically. The highest number of cobs per plant recorded on 150kg ha^{-1} of N with the value of 1.8. In case application of phosphorus the highest number of cobs per plant was recorded on 50kg ha^{-1} P_2O_5 with the value of 2.2. This result is in agreement with [20] who reported that the number of cobs per plant of maize increased with increase of phosphorus application. They argued that less number of cobs per plant in control plots resulted in less number of grains per plant that finally resulted in minimum grain yield.

3.3.3 Weight of kernels per cob:

The statistical analysis shows that there was no significant difference among treatments in case of weight of kernel per cob by applying different level of nitrogen and phosphorus, but numerically highest weight of kernel per cob was recorded on 150kg ha^{-1} of N with the value of 72.9 grams. In case of application phosphorus the highest weight of kernel per cob was recorded on 50kg ha^{-1} of P_2O_5 with the value of 74.6 grams. This result is indicated in (Table.4) and was line with [21] who reported that the increase in grain weight was due to more grains per ear and ear length. Increase in number of grains per ear and grain weight per ear with increasing nitrogen rate has also been observed.

3.3.4 Number of rows per cob:

The statistical analysis (Table.4) shows that there was significant difference among the treatments in case of phosphorus application in the number of rows per cob. But in case of application of nitrogen there was no significant difference. But numerically the highest number of rows per cob was recorded on 150kg ha^{-1} level of nitrogen with the value of 13.3. This result is indicated in (Table.4) was in agreement with [22] who reported that Increasing P levels up to 60 kg P_2O_5 ha^{-1} significantly increased the yield attributes, grain and Stover yield of maize.

3.3.5 Number of kernel per cob:

The data analysis of (Table.4) showed that there was significant difference among treatment in the number of kernel per cob in application of both nitrogen and phosphorus levels. This result were similar with that of [14] who reported that number of grains per cob were influenced with nitrogen and phosphorus application [21] Also reported increase in number of grains per ear and grain weight per ear with increasing nitrogen rate.

3.3.6 Number of kernels per row:

As the data analysis in (Table.4) showed that there was significant difference among the treatments in case of application of nitrogen on number of seeds per row but in case of phosphorus level there was no significant difference among the treatments. But numerically the highest number of rows per cob was obtained from 50kg/ha of P_2O_5 with the value of 28.1. This result indicates that the higher number of seeds per row the higher would be the number of grains ear. This result is in conformity with [5] who reported that high number of grains ear was recorded in the plots treatment with 150kg ha^{-1} and180kg ha^{-1} Nitrogen. Minimum number of grains ear was recorded on control.

3.3.7 Weight of kernel per cob:

The statistical analysis in (Table.4) shows that there was no significant difference among treatments in case of weight of kernel per cob by applying different level of nitrogen and phosphorus, but numerically highest weight of kernel per cob was recorded on 150kg ha^{-1} of N with value of 72.9 grams. In case of application of application phosphorus the highest weight of kernel per cob was recorded on 50kg ha^{-1} of P_2O_5 with the value of 74.6 grams. This result is indicated in (Table.4) and was line with [21] reported that the increase in grain weight was due to more grains per ear and ear length. Increase in number of grains per ear and grain weight per ear with increasing nitrogen rate has also been observed.

3.3.8 Number of rows per cob:

The statistical analysis shows that there was significant difference among the treatments in the number of rows per cob in case of phosphorus application. But in case of application of nitrogen there was no significant difference among the treatments. But numerically the highest number of rows per cob was recorded on 150kg ha^{-1} level of nitrogen with the value of 13.3. This result is indicated in (Table.4) was in agreement with [22] who reported that increasing P levels up to 60 kg of P_2O_5 ha^{-1} significantly increased the yield attributes, grain and Stover yield of maize. Moreover, [24] reported that, changes in nutrient levels, particularly nitrogen and phosphorus, did not lead to statistically significant alterations in the number of grain rows per cob.

3.3.9 Number of kernels per cob:

The data analysis of in (Table.4) showed that there was significant difference among treatment in number of kernels per cob with respect to application of both nitrogen and phosphorus. These results were similar with that of [24] who reported that when nitrogen and phosphorus were applied individually, there was a significant increase in the number of grains per cob. [21] Also reported increase in number of grains per ear and grain weight per ear with increasing nitrogen rate.

3.3.10 Number of kernels per row:

As the data analysis in (Table.4) showed that there was significant difference among the treatments in case of application of nitrogen on number of seeds per row but in case of phosphorus level there was no significant difference. However, numerically the highest number of rows per cob was obtained from 50kg ha^{-1} of P_2O_5 with the value of 28.1. This result indicates that the higher number of seeds per row the higher would be the number of grains ear. This result is in conformity with [5] who reported that high number of grains ear was recorded in the plots treatment with150kg and180kg ha^{-1} Nitrogen. Minimum number of grains ear was recorded in control.

3.3.11 1000 grain weight:

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The statistical analysis in (Table.4) showed that there was significant difference among treatments in case of 1000 grain weight by applying different levels of phosphorus, but in case of application of nitrogen there was no significant difference among the treatments. But numerically the highest 1000 grain weight was obtained from 150kg ha^{-1} of nitrogen with the value of 209.8grams. Moreover the interaction effect shows significant difference among treatments. These results are in agreement with [23] who observed an increase in 1000 grain weight with an increase in nitrogen and phosphorus application. Similarly, phosphorus being responsible for good root growth directly affected the 1000 grain weight. Maximum 1000-grain weight (430.00 g) was obtained in 250-125 kg NP level against minimum (141.8 g) in case of control plot according to [14]. Furthermore, [24] suggests that these nutrient levels resulted in grains of greater weight and potentially higher quality. Farmers aiming for higher-quality maize may consider optimizing nitrogen and phosphorus levels accordingly.

Table 4. Effect of treatments on Yield and yield related parameters

Treatments	Grain Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)	Cob Length (cm)	No. of cobs (No. Plant^{-1})	Wt. of kernels (No. cob^{-1})	No. rows (No. cob^{-1})	No.of kernels (No. cob^{-1})	No. seeds (No. row^{-1})	1000 Grain weight (g)
					Nitrogen levels kg ha^{-1}					
0	1.4	5.6	24.7	9.1	1.8	50.3	11.7	273.0	22.4	204.4
100	1.5	7.0	20.9	8.2	1.7	59.3	11.2	271.0	23.8	206.4
150	1.39	7.4	18.6	11.6	1.8	72.9	13.3	391.0	28.8	209.8
LSD (%)	NS	13.35	NS	2.138	NS	NS	NS	102	4.89	NS
					P_2O_5 levels kg ha^{-1}					
0	1.4	6.7	20.8	9.3	1.4	53.8	11.3	277.0	23.6	213.4
50	1.6	7.4	21.6	10.5	2.2	74.6	14.0	398.0	28.1	221.4
100	1.3	5.8	22.4	9.0	1.6	54.1	10.9	259.0	22.3	185.8
LSD (0.05)	NS	NS	NS	NS	NS	NS	2.401	102.0	NS	23.69
CV (%)	25.1	14.3	14.8	6.7	24.3	12.8	12.2	14.6	4.6	4.9
N*P	NS	*	NS	NS	NS	NS	NS	NS	NS	*

NB: LSD (least significant difference); CV (coefficient of variation) and N*P (interaction of nitrogen and phosphorus),*(Significant

Table 5. Effect of nitrogen and phosphorus interaction on biological yield (t/ha)

	Phosphorus levels (kg ha^{-1})		
Nitrogen Levels kgha^{-1}	0	50	100
0	3.9	7.7	5.3
100	7.7	7.1	6.2
150	8.6	7.6	6.0
LSD (0.05)	23.13		
CV (%)	14.3		

NB: LSD (least significant difference); CV (coefficient of variation) and N*P (interaction of nitrogen and phosphorus)

A critical perusal of nitrogen and phosphorus interaction in Table. 5 revealed that increase in nitrogen levels increase biological yield significantly. However, increase in phosphorus levels decreases biological yield numerically. Therefore, interaction of 150kg/ha nitrogen and no application phosphorus (8.6kg ha^{-1}) gives better results as compared to the individual treatments. At the same time combination of 100kg/ha of nitrogen and no application phosphorus (7.7 kg/ha$^{-1)}$ was statistically at par with combination of no application of nitrogen and 50kg ha^{-1} of phosphorus (7.7kg ha^{-1}).

Table 6. Interaction Effect of nitrogen and phosphorus on 1000 grain weight

Phosphorus levels (kg ha^{-1})

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Nitrogen Levels kg ha^{-1}	0	50	100
0	179	238	196.3
100	209.3	216.7	193.3
150	252	209.7	167.7
LSD (0.05)	41.02		
CV (%)	4.9		

NB: LSD (Least significant difference); CV (coefficient of variation) and N*P (Interaction of nitrogen and phosphorus)

A data in Table 6. Indicated that interaction of 150 kg/ha nitrogen and no phosphorus (252g) increases 100seed weight significantly. However, combination of 100kg/ha of nitrogen and 100kg/ha of phosphorus (193.3 g) were statistically at par with combination of no application of nitrogen and 100kg/ha of phosphorus (196.3).

4. CONCLUSION

The study on the response of maize to nitrogen and phosphorus fertilizers in semi-arid conditions of Hamelmalo, Eritrea, underscores the critical role of optimal fertilizer application in enhancing maize productivity. The optimal application of 150 kg ha^{-1} of nitrogen and 50 kg ha^{-1} of phosphorus significantly improves leaf area, and biological yield, while also influencing emergence, maturity, and grain yield. Although nitrogen and phosphorus did not significantly affect days to tasseling, maturity and silking but they impacted significantly days to emergence. The interaction of these nutrients resulted in the highest biological yield and 1000-grain weight at 150 kg/ha of nitrogen and 100 kg/ha of phosphorus. Specifically, the application of 150 kg/ha of nitrogen through urea and 50 kg/ha of phosphorus through di-ammonium phosphate (DAP) was found to significantly increase the majority of the parameters under study. These findings provide valuable insights into optimizing maize productivity in semi-arid regions, emphasizing the importance of nutrient management in enhancing crop performance under challenging environmental conditions. The study highlights the need for balanced and judicious use of these fertilizers for sustainable maize production, stressing the importance of integrated nutrient management to enhance crop performance and mitigate environmental impacts.

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