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EVALUATING THE INFLUENCE OF MINERAL FERTILIZERS IN THE GROWTH AND YIELD OF YANTAR DURUM WHEAT CULTIVAR IN CENTRAL KAZAKHSTAN'S KARAGANDA REGION

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Abstract: **A field experiment was conducted to evaluate the effectiveness of mineral fertilizers on the growth, yield and yield parameters for durum wheat in the Karaganda region of central Kazakhstan. The experiment was a 10×3 factorial fitted into a complete randomized design, and treatments replicated three times. The treatments consisted of a control plot, with sole and combined Nitrogen (ammonium nitrate) and phosphorus (Ammophos) fertilizers (N_{30}, N_{60}), (P_{90}, P_{120}, P_{150}, P_{180}) and ($P_{90}N_{30}$, $P_{120}N_{60}$, $P_{120}N_{90}$) respectively. Analysis of variance (ANOVA) was carried out on soil and plant data, and their means separated using turkey t-test, while a spearman rho correlation analysis was done to show the relationship between growth, yield and yield. The results obtained showed that mineral fertilizers had significant impact on growth and yield of durum wheat. Though sole application of P and combined N x P had an impact on growth of durum wheat, this effect was not significant ($p>0.05$). similarly, mean yield attributes were not significantly affected by mineral fertilizers except for grain yield. The highest grain yield was found for P_{120} (8.86 c/ha), followed by $P_{90}N_{30}$ (8.76 c/ha) and P_{90} (8.63 c/ha) while for N-N_{60} (8.06 c/ha). Spike length strongly correlated with plant height (0.952***), grain yield significantly correlated with root length (0.689*) and 1000-weight grain (0.709*), number of grains positively correlated with plant height (0.806*) and spike length (0.806*) while grain weight significantly correlated with plant weight (0.640*) and spike weight (0.706*). Harvest index however was highest for N_{60} (9.14%) and P_{90} (8.30%) indicating higher proportion conversion of plant total biomass into grain. Thus, the sole application of these fertilizers is recommended.**

Keywords: **Durum Wheat, Grain yield, Harvest index, Mineral Fertilizers, Nitrogen, Phosphorus.**

1. INTRODUCTION

Kazakhstan holds a significant position within the global wheat production landscape, with wheat cultivation serving as a vital component of the country's agricultural industry (Fehér et al, 2017). Durum wheat, is a prominent crop in Kazakhstan, which contributes approximately 20% to the nation's overall wheat production. The country's diverse climate and geography also makes it a suitable region for Durum wheat cultivation, where various regions within the country offer conditions conducive to this crop. The use of mineral fertilizers is common trend in Kazakhstan's agriculture, this is due the fact that soils of Kazakhstan, with the exception of the northern regions, have a low level of natural fertility in terms of optimum nutrient availability for cultivation of some crops, and are subject to degradation, risk of desertification, manifestation of wind and water erosion (Kenenbaev et al, 2018). Most of arable land is characterized by a low concentration of humus and mobile forms of nitrogen, more than half of which are not provided with mobile forms of phosphorus, that is, they need addition of nitrogen and phosphorus fertilizers. Furthermore, several research studies have highlighted the efficiency of mineral fertilizers in all natural and climatic zones of Kazakhstan. These findings suggest a strong correlation between the application of fertilizers, the provision of essential nutrients to the soil, and the yield potential of agricultural crops. It has been established that a judicious and scientifically grounded use of fertilizers plays a significant role in maintaining and enhancing key indicators of soil fertility. This, in turn, leads to higher crop yields and an overall improvement in the quality of agricultural production.

Long term studies conducted by Amantaev et al, (2023) in Naidorovskoye, Karaganda region of central Kazakhstan aimed at evaluating the influence of agrotechnical factors on the production of summer wheat varieties noted increase in yield of soft spring wheat on application of mineral fertilizers. Maximum yield of 5.5t/ha equivalent to 55c/ha was achieved with application of ammophos at 176kg/ha (a.i), and nitrogen fertilizer in form of ammonium sulphate at 80kg/ha (a.i). However, several factors such as sowing date/period and rate, as well as variety of wheat was noted as important indicators which limits grain yield. Furthermore, in a study conducted by Zavalin et al. (2018) and Kassipkhan et al. (2023), stable isotope of nitrogen (^{15}N) was employed to investigate the utilization of fertilizer nitrogen by spring triticale and spring wheat cultivated on dark-chestnut soils within the arid steppe region of Kazakhstan. Their observations revealed that the highest wheat grain yield (GY) was achieved when an N_{60} dosage was applied before sowing. Furthermore, the application of the same quantity of nitrogen fertilizer resulted in a two-fold increase in the grain yield of spring triticale. This discrepancy in performance was attributed to the superior nitrogen-use efficiency exhibited by spring triticale in comparison to spring wheat.

A notable factor which doubles as a limiting factor of crop production and grain yield in Kazakhstan is its harsh and unfavorable climate conditions. Similarly, low crop yields can be attributed to adverse climate conditions characterized by a short growing season, high temperatures, and limited water availability which in turn limits nutrient use as well as fertilizer use efficiency (NUE and FUE). The fluctuating and unpredictable climate conditions are a primary driver for the low input use, resulting in significant variations in yields and total production from one year to another, as noted by various studies (Sommer et al., 2013; Bobojonov and Aw Hassan, 2014; Meyfroidt et al., 2016).

In the agricultural landscape of the Karaganda region in Central Kazakhstan, introducing a new variety of durum wheat holds significant promise for enhancing productivity and resilience in arid climates. However, a major challenge is the lack of comprehensive data on the optimal doses of mineral fertilizers necessary for its growth and productivity. This knowledge gap hinders the full realization of the crop's potential. Successful cultivation of these varieties depends on precise management of mineral nutrients, particularly nitrogen and phosphorus, which are crucial for crop performance. Thus, the primary objective of this study is to examine the effects of nitrogen and phosphorus mineral fertilizers on the productivity of various durum wheat varieties in the Karaganda region and their impact on soil properties. By addressing these factors, the study aims to provide valuable insights for optimizing wheat production in this region.

2. MATERIALS AND METHODS

Study Area and climate data

The study was conducted at the limited liability company "Naidorovskoye," situated in Akpan village, Osakarovsky district, Karaganda region, which lies between longitude 50°08'13"N and latitude 72°09'11"E, with an elevation of 502 meters above sea level. The experimental field features a 4-field crop rotation system, with fallow as the final rotation before crop cultivation.

The climate of the region is sharply continental and dry, coupled with a high degree of continentality, manifested in large annual and daily temperature amplitudes followed by an instability of climatic indicators over time. Annual precipitation in the region varies from 130 mm or less to 310 mm or more. Precipitation during the warm period in the northeast of the region averages 200-270 mm, and in the desert zone only 65-80 mm. The average annual temperature throughout the region ranges from 1.4 to 7.3°C, with its highest values typical for the southernmost regions. Summer in the region is typically hot with summer temperatures sometimes rising to 40-48°C; winter, on the contrary, is cold. On average, the duration of the warm period varies throughout the region from 200 to 240 days.

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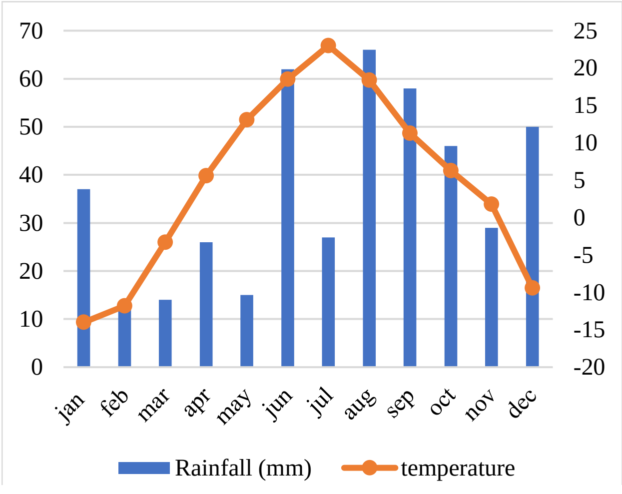

Fig 1.

Fig 1: Mean Annual Temperature and Precipitation data, 2023, Akpan district, Karaganda

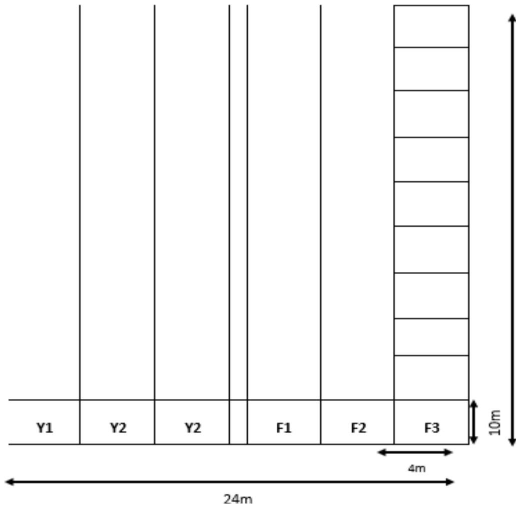

Fig 2.

Fig 2: Schematic representation of the experimental plot

Experimental design and Treatments

The experiment consists of three factors; Fertilizer levels for N and P (Ammonium Nitrate and Ammophos) and durum wheat varieties (yantar and floradur) replicated three times. The experiment followed a 10×3 factorial fitted into a complete randomized design (CRD). The experimental plot measured a total 2400sqm (0.24ha) with a total of 10 sub-plots measuring 40sqm.

Table 1: Experimental design and Treatments

Durum wheat Variety	Nitrogen fertilizer	Phosphorus fertilizer	N x P
	control	P_{90}	$P_{90}N_{30}$
Yantar	N_{30}	P_{120}	$P_{120}N_{60}$
	N_{60}	P_{150}	$P_{120}N_{90}$
		P_{180}	

Soil and Plant Analysis

The pH of the soil was determined in a soil-water (H_2O) solution (1:5 w/v). Phosphorus and exchangeable potassium in the soil was determined using the Machigin method. Organic matter was determined using the Tyurin method modified by TsINAO. Nitrate nitrogen N-NO_3 was determined by ionometric method. Data on plant parameters; plant height and weight, Spike length and weight, yield and yield parameters; Grain yield (c/ha), Thousand-grain weight, Harvest index, was taken to record growth and yield attributes.

Data Analysis

Data from plant and soil collected were subjected to statistical Two-Way Analysis of Variance (ANOVA) using Minitab v17 software. The treatment means were separated for significant differences using Fisher Pairwise comparison at a 5% probability level. Simple correlation of coefficients was also used to show the relationship between growth, yield and yield components parameters was evaluated using spearman rho's correlation.

3. RESULTS AND DISCUSSION

Characterization of the soil and organic materials used in the experiment.

From laboratory analysis, the soil pH was 8.40, indicating an alkaline soil medium. Humus content in the upper 0-40cm horizon of dark chestnut soils before cultivation/sowing was 2.53%, the nitrate nitrogen content of the soil 13.5mg/kg which was optimum for wheat growth. The availability of mobile forms of phosphorus was low (12 mg/kg), while the mean potassium level was high (677 mg/kg).

Effect of fertilizer application on soil chemical properties

Prior to application of mineral fertilizers, soil pH for control plots were 8.40, indicating an alkaline soil medium. However, on application of mineral fertilizers, decreased slightly from 8.40 to 8.20. it was observed that these decreases were associated with increase in mineral fertilizers. Increased P fertilizers also led to decrease in soil pH. This is due to the fact that the fertilizer used contains 10% of nitrogen. The use of nitrogenous fertilizers has been known to a primary source of soil acidification hence leading to decreases in soil pH.

Nitrate nitrogen (N-NO3) had significant increase ($p<0.05$) on application of mineral N and P fertilizers. For both control plots, successive increase in mineral fertilizers increased NO3 from 13.56 – 27.13mg/kg, and 8.86 – 22.36mg/kg NO3. The highest soil NO3 was observed on application of $P_{120}N_{90}$ in both plots. Similarly, both soil phosphorus and potassium were significantly affected by application of mineral fertilizers with notable increases from 12.0 – 29.8 mg/kg and 560 – 677mg/kg respectively for both plots.

Table 2. Effect of fertilizer application on soil nutrient content in the soil under yantar durum wheat cultivar

Fertilizers	Soil Depth (cm)	**pH (H_2O)**	**N-NO_3 (mg/kg)**	**P_2O_5 (mg/kg)**	**K_2O**
control	0-40	8.4 ± 0.3a	13.56 ± 0.3k	12 ± 0.3g	677 ± 0.5b
N30	0-40	8.3 ± 0.2a	17.43 ± 0.2e	12.2 ± 0.1g	668 ± 0.5c
N60	0-40	8.2 ± 0.2a	21.33 ± 0.2c	15.8 ± 0.2f	590 ± 0.6L
P90	0-40	8.3 ± 0.2a	13.53 ± 0.3k	21.5 ± 0.3de	632 ± 0.6gh
P120	0-40	8.3 ± 0.2a	14.53 ± 0.2i	24.2 ± 0.1b	649 ± 0.0e
P150	0-40	8.3 ± 0.2a	15.40 ± 0.3h	27.6 ± 1.9b	636 ± 1.5f
P180	0-40	8.2 ± 0.2a	15.90 ± 0.2g	30.2 ± 1.3a	658 ± 1.0d
P90N30	0-40	8.2 ± 0.2a	16.06 ± 0.3g	21.2 ± 0.2de	695 ±0.6a
P120N60	0-40	8.2 ± 0.3a	22.36 ± 0.3b	24.2 ± 0.2b	670 ± 0.0c
P120N90	0-40	8.2 ± 0.3a	27.13 ± 0.3a	24.2 ± 0.2b	606 ± 0.6k

Means±SD with different alphabets are significantly different ($p<0.05$).

Effect of fertilizer application on growth properties of Durum wheat

Plant height and weight

The influence of the application of mineral fertilizers on the morphological structure of durum wheat varieties were investigated, and the results are presented in Table 6. Generally, the application of mineral fertilizers had notable effect on plant height and differed significantly ($p<0.05$) from control plot for both varieties of durum wheat. Plant height for yantar variety ranged from 70.00 to 88.83cm. However, it could be observed that although the highest mean plant (88.83 cm) height for yantar variety was gotten on application of mineral-P fertilizer at P-90kg/ha (a.i), there was no significant difference ($p>0.05$) between sole and combined applications of mineral fertilizers at P-120, 150, 180 kg/ha and $P_{90}N_{30}$, $P_{120}N_{60}$, $P_{120}N_{90}$ respectively. Moreover, sole applications of mineral-P at 90, 120, and 150 kg/ha (a.i) showed promising increase in plant height compared to control other treatments, while the least plant mean plant (70.00 cm) was observed at N_{30}.

Decreases in plant height on application of fertilizers especially N-fertilizers seem counterintuitive however, this was observed when nitrogen fertilizers were applied. There was a sharp decrease in plant height when mineral-N was applied at N_{30}, N-60 kg/ha (a.i) as well as the combined application $P_{90}N_{30}$, $P_{120}N_{60}$ and $P_{120}N_{90}$ and the decrease followed the order $N_{60} < N_{30}$ for sole application and $P_{120}N_{90} < P_{120}N_{60} < P_{90}N_{30}$. According to Chernenok (2011), the optimal amount of N-NO_3 required for wheat falls between 12-15mg/kg. However, the application of mineral-N was seen to have increased soil N-NO_3 from 13.56mg/kg to 17.43, 21.33, 16.06, 22.37, and 27.16mg/kg for control, N_{30}, N_{60}, $P_{90}N_{30}$, $P_{120}N_{60}$ and $P_{120}N_{90}$ respectively. Therefore, it can be inferred that the addition of excess amount of mineral-N resulted in less N-utilization and less growth when compared to control treatment as observed in N_{30} and N_{60}. Though in comparison with control, combined N x P fertilization increased plant height but the same decreasing trend was observed although not significant.

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Application of mineral-P fertilizers at high levels with mineral-N also had a positive influence on plant height compared to sole application of mineral N. This result corroborates findings by Zubillaga et al, (2002) that higher P levels increases both plant height and nitrogen use efficiency. Generally, several research has reported increases in plant height of wheat on application of mineral regardless of its variety. Gyanendra et al, (2020) reported similar increase in plant height of wheat when applied with increasing dosage of mineral fertilizers.

Plant weight significantly differed from control and ranged from 2.64 – 4.03g. Though the influence of fertilizer application at different rates was not significant, mean plant weight increased on application of both sole and combined mineral fertilizers. Sole applications of mineral-N, N-60kg/ha had a plant weight of 2.76g, compared to N-30kg/ha (2.64g). Between all sole applications of mineral-P, P-90kg/ha gave highest plant weight (3.47g), while the combined application of N and P fertilizers gave highest plant weight ($P_{120}N_{90}$, 3.79g). However, plant weight for control group was significantly higher than all fertilized group.

Root length and weight

The root length and weight were significantly affected by both the individual and combined application of mineral fertilizers. Notably, mineral phosphorus (P) greatly enhanced root growth, resulting in the highest average root lengths of 8.00 cm for the application rate of 120 kg/ha of phosphorus alone, and 9.17 cm for the combined application of 120 kg/ha of phosphorus with either 30 kg/ha or 60 kg/ha of nitrogen. This is due to the fact that phosphorus as a plant nutrient is recognized as a crucial nutrient for plant root development (Tanwar and Skatawat, 2003).

Table 3: Effect of fertilizer application on growth of yantar durum wheat cultivar

Treatment	Plant height (cm)	Plant weight (g)	Root length (cm)	Root weight (g)
control	76.03 ± 8.3bcd	2.23 ± 2.3c	6.00 ± 2.0a	5.67 ± 3.8a
N30	71.67 ± 2.2cde	2.64 ± 0.2bc	6.00 ± 1.3abc	3.35 ± 0.6bc
N60	70.00 ± 0.8 def	2.76 ± 0.3abc	5.50 ± 1.3abc	3.32 ± 0.4bc
P90	88.83 ± 4.3a	3.47 ± 0.6abc	6.83 ± 1.8abc	2.94 ± 0.3bc
P120	83.27 ± 6.2ab	2.86 ± 0.5abc	8.00 ± 3.5ab	3.62 ± 0.7bc
P150	86.33 ± 3.8a	3.12 ± 0.6abc	7.16 ± 0.7abcd	3.43 ± 0.6bc
P180	80.10 ± 7.0abc	2.79 ± 0.4abc	7.67 ± 2.0abc	3.15 ± 0.4bc
P90N30	81.23 ± 10.7abc	2.79 ± 0.8abc	9.17 ± 2.3a	4.16 ± 1.2abc
P120N60	80.83 ± 9.8abc	3.03 ± 0.4abc	9.17 ± 1.8a	3.92 ± 0.5abc
P120N90	80.08 ± 10.8abc	3.79 ± 1.3a	5.17 ± 1.7abc	2.74 ± 1.0bc

Means±SD with different alphabets are significantly different ($p < 0.05$)

Effect of fertilizer application on yield and yield properties of Durum wheat Varieties

Grain yield

Fig 1. below shows the grain yield as a result of fertilization with Nitrogen and Phosphorus fertilizers, and the results further indicates an increase in grain yield. Grain yield ranged from 7.10 – 8.86 c/ha. The control plot gave the least the grain yield 7.10c/ha, followed by P_{150} (7.40c/ha), N_{30} (7.63c/ha), and P_{180} (7.90 c/ha). Whereas, higher grain yields were observed in N_{60} (8.06 c/ha), P_{90} (8.63 c/ha) and P_{120} (8.86 c/ha). Although all treatments had a mean increase in grain yields, this did not significantly differ from control treatment. The influence of mineral N nutrition on grain yield could be seen to have been affected by increase in successive N levels. Mineral-N fertilizer at 60kg/ha gave the highest grain yield compared to N-30kg/ha (a.i). Both fertilizer rate influenced and increased grain yields, but did not significantly differ ($p < 0.05$) from control.

Sole application of mineral-P on the hand had similar grain yield with mineral-N. There was no linear increase in grain yield with respect to increase in P-levels. Grain yield ranged from 7.40 – 8.86 c/ha, where the application of mineral-P at

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120kg/ha obtained the highest yield (8.86 c/ha), followed by P_{90} (8.86 c/ha) both of which differed significantly ($p > 0.05$) from grain yield of control plot whereas, P_{150} had the least grain yield (7.40 c/ha). The interaction between N and P (N x P) was seen to have lesser effect on grain yield. Application of $P_{90}N_{30}$ produced grain yield of 8.76 c/ha, $P_{120}N_{30}$ 8.13 c/ha, and $P_{120}N_{30}$ with least grain yield 6.03c/ha which was significantly lower than control plot.

With respect to nutrient utilization on grain yield, the application of mineral-P at 120kg resulted in highest grain yield followed closely by $P_{90}N_{30}$ combined fertilizer. Mineral-N x P interaction did not significantly contribute to a substantial increase in grain yield. Moreover, the grain yield accounted for was low, in comparison with average yield results for wheat plant. The low yield accumulated could be directly linked to changes in weather condition which is one of the limiting factors in Kazakhstan's agricultural sector. The 2023 growing season was characterized minimum rainfall during the period of cultivation of both varieties of durum wheat, with a mean monthly maximum rainfall of 66mm with a mean maximum temperature 23^{o}C. With less precipitation during the growing season accompanied by high temperatures, which on the other hand facilitates water loss from agricultural soils, there is less utilization of applied solid mineral fertilizers, since plants will require them in liquid form for utilization.

Spike Length and Spike Weight

Spike length responded differently and significantly to fertilization. The mean spike length ranged from 5.61 – 7.66 cm. Sole application of mineral-P however significantly influenced spike length. P_{150} and P_{90}; 7.66cm, 7.50cm respectively had the highest spike length in comparison with control. This result corroborates the research finding reported by (Debnath et al., 2011; and Fayera et al., 2014), who reported that the spike length of wheat significantly increases on application of mineral fertilizers. Spike weight also varied significantly ranged from 1.44 - 2.02g.

Number of Grains and Thousand weight grains

Number of grains as influenced by fertilizer application was not significantly different from control plot except from P_{90} which had the highest mean number of grains per spike head (31.33). The mean number of grains ranged from 21.73 – 31.33. The number of grains was rather positively influenced by sole applications of Mineral fertilizer, this might be due to the fact that phosphorus is essential in the development of grains. Though the interaction of N x P fertilizers had a mean increase in comparison with unfertilized plot, these changes statistically were not significant.

Thousand weigh grains (TWG) in response to sole and combined application of mineral-N and P fertilizers did not vary significantly ($p > 0.05$). The mean 1000-weight grains ranged from 36.77 – 41.37g. Though the application of mineral fertilizers N_{60}, P_{90}, and $P_{90}N_{30}$ was observed to have increased TWG from control plot, this interaction was not significant, while further increase in combined application of N and P fertilizer ($P_{120}N_{90}$) led to decrease in TWG. The effect of fertilizer application showed that the application of N_{60}, P_{90}, and $P_{90}N_{30}$ had significant influence on TWG. Similar results were reported by Gooding and Davies (1997), and Woyema et al. (2012) for increase in TWG on successive increase especially for nitrogen fertilization. In contrast, successive increase in phosphorus fertilization had little effect on TWG.

Table 4: Effect of fertilizer application on yield and yield of yantar durum wheat cultivar

Treatment	Grain yield (c/ha)	Spike length (cm)	Spike weight (g)	Number of grains	Grain weight (g)	1000-seeds (g)	Harvest index (%)
control	7.10 ± 0.1e	6.30 ± 0.4bcde	1.44 ± 0.5b	25.08 ± 5.1cd	1.12 ± 0.4ab	38.63 ± 5.7a	6.95 ± 0.4c
N30	7.63 ± 0.2de	6.26 ± 0.0bcde	1.64 ± 0.1ab	26.06 ± 0.3bcd	1.12 ± 0.0ab	38.40 ± 2.3a	6.35 ± 0.3c
N60	8.06 ± 0.3c	5.61 ± 0.5e	1.49 ± 0.2b	21.73 ± 2.1d	0.97 ± 0.1ab	41.37 ± 2.6a	9.14 ± 0.3a
P90	8.63 ± 0.1ab	7.50 ± 0.7a	2.02 ± 0.3a	31.33 ± 1.0a	1.50 ± 0.2a	41.33 ± 3.6a	8.80 ± 0.4a
P120	8.86 ± 0.2a	7.31 ± 0.5a	1.56 ± 0.3ab	27.03 ± 0.7abc	1.12 ± 0.2ab	39.60 ± 4.5a	7.44 ± 0.3b
P150	7.40 ± 0.2de	7.66 ± 0.5a	1.54 ± 0.4ab	27.73 ± 2.8abc	1.17 ± 0.3ab	38.73 ± 1.3a	4.27 ± 0.3ef
P180	7.90 ± 0.3d	7.10 ± 0.4ab	1.57 ± 0.4ab	27.17 ± 2.0abc	1.09 ± 0.2ab	39.93 ± 2.6a	4.63 ± 0.2ef
P90N30	8.76 ± 0.1ab	7.00 ± 0.6abc	1.50 ± 0.4ab	26.37 ± 4.4abc	1.11 ± 0.3ab	40.30 ± 2.6a	5.73 ± 0.3d
P120N60	8.13 ± 0.2c	7.13 ± 0.8ab	1.67 ± 0.3ab	26.00 ± 4.6bcd	1.23 ± 0.2ab	39.43 ± 3.0a	4.81 ± 0.3ef
P120N90	6.03 ± 0.1f	6.85 ± 0.3abcd	1.68 ± 0.2ab	26.80 ± 2.2abc	1.20 ± 0.1ab	36.77 ± 1.9a	3.94 ± 0.2g

Means±SD with different alphabets are significantly different ($p < 0.05$)

Plant Biomass

Plant biomass at the different stage of growth significantly increased in comparison to control plot. There was a linear increase from 40.5 – 84.10g during the tillering stage, and 88 – 173.2g during the heading stage. $P_{90}N_{30}$ had the most significant effect on plant biomass during the tillering stage followed by sole applications of phosphorus fertilizers. Sole applications of nitrogen fertilizers had the least effect on plant biomass during tillering stage, and was not ($p>0.05$) significantly different from control though there were increases in its mean values. During the heading stage, the highest plant biomass was recorded where mineral-P was applied at 150kg/ha and 180kg/ha.

Harvest index

Harvest index (H.I) is an indicator which shows the plant ability to utilize and convert applied nutrients into appreciable grain yields. Harvest index for both varieties ranged from 3.94 – 10.95%. However, the harvest indexed recorded is low compared to values reported from different authors. Bekena (2019) reported harvest index for bread wheat ranging from 21.0 - 31.2%, similar result was reported by woyema (2012). Yantar cultivar had harvest index ranging from 3.94 – 9.14%. N_{60} had the highest harvest index (9.14%) for yantar cultivar with a corresponding grain yield of 8.00c/ha. Though the highest grain yield was recorded on application of P_{120} (8.86 c/ha), the higher harvest index suggests that a higher proportion of the plant's total biomass is being converted into grain. This is typical because nitrogen often boosts both vegetative and reproductive growth, but with a slightly higher emphasis on reproductive parts (grain), while the lower harvest index when on successive increase in mineral-P fertilizer indicates that while the grain yield is higher, a significant portion of the biomass is allocated to roots and other non-grain parts. Phosphorus promotes overall plant health, including root development, which might not directly translate into a proportional increase in grain yield relative to the total biomass though crucial for long-term plant health but less efficient in terms of grain production.

Correlation Between Plant and Yield Properties

Table 4 shows a spearman's rho correlation between growth and yield components of durum wheat. Plant height had a very strong and significant positive correlation with spike length (0.952***), and number of grains (0.806*), but negatively correlated with harvest index (-0.115) indicating that harvest index is independent of plant height. Similar relationship was reported by Bekena (2019). Plant weight positively and significantly correlated with grain weight (0.640*), root length weakly but positively correlated with grain yield (0.689*), while root weight weakly and negatively correlated with spike weight (-0.636*). Spike length strongly and positively correlated with number grains per spike (0.806*) while spike weight had a strong positive correlation with grain weight (0.706*) which suggests that increases in spike weight leads to increases in grain weight, while 1000-weight grain strongly correlated with grain yield (0.709*).

Table 5: Spearman rho's coefficient of correlation for the relationship between growth and yield variables

	PH	PW	RL	RW	SL	SW	NG	TWG	GY	GW
PW	0.347									
RL	0.579	-0.174								
RW	0.018	0.030	0.530							
SL	0.952***	0.365	0.561	-0.018						
SW	0.333	0.146	-0.012	-0.636*						
NG	0.806*	0.231	0.226	-0.442	0.806*					
TWG	0.236	-0.353	0.311	-0.055	0.127	-0.176				
GY	0.467	-0.383	0.689*	0.224	0.333	0.042	0.152	0.709*		
GW	0.534	0.640*	0.032	-0.166	0.558	0.706*	0.399	-0.350	-0.092	
HI	-0.115	-0.237	-0.104	0.127	-0.236	-0.261	-0.285	0.600	0.515	-0.227

* $p<0.05$; ** $p<0.01$; *** $p<0.001$. **PH**; *plant height*, **PW**; *plant weight*, **RL**; *root length*, **SL**; *spike length*, **SW**; *spike weight*, **NG**; *number of grains*, **TWG**; *1000-grain weight*, **GY**; *grain yield*, **GW**; *grain weight*, **HI**; *harvest index*.

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The use of mineral fertilizers, particularly nitrogen and phosphorus, has been shown in numerous studies to significantly increase the grain yield of crops. However, the extent of this increase is typically dependent on the level of application, soil chemical properties, and climatic conditions. The results of this study indicate that variations in climatic conditions influenced the grain yield of the Yantar durum wheat cultivar. The combined application of phosphorus and nitrogen fertilizers at higher rates significantly enhanced wheat growth. In contrast, the sole application of 60 kg/ha of nitrogen (N_{60}) and 90 kg/ha of phosphorus (P_{90}) resulted in the highest harvest index, though not the highest grain yield. A high harvest index indicates that a larger proportion of the plant's biomass is allocated to the grain rather than to other plant parts, this suggests that while the overall grain yield might not be the highest, the efficiency of converting the available nutrients into harvestable grain is optimized. Additionally, a high harvest index can imply better resource use efficiency and potentially greater resilience to environmental stresses. Therefore, the sole application of these fertilizers is recommended. Further investigation into their combined application and its subsequent effect on the yield of the Yantar cultivar is also suggested.

CONFLICT OF INTEREST

The authors declare no conflict of interest in this article.

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