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EFFECT OF DIFFERENT DOSES OF PHOSPHORUS AND POTASH ON THE GROWTH AND YIELD OF MAIZE

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ABSTRACT

Maize is the most important cereal crop globally, following rice and wheat. It is a highly-yielding cereal crop and is of considerable significance to countries such as Pakistan. Phosphorus and potash fertilizers are regarded as essential nutrients affecting the phenology and grain production of maize. Therefore, the effect of different doses of phosphors and potash on the phenology and grain yield of maize was assessed in this study. For this purpose, a field experiment was conducted at the research area of Vital Green Pvt. Ltd. Lahore during the spring season of 2023 using a randomized complete block design with a plot size of 4.0 m × 1.6 m having three replications. There were five treatments in total including a control (T_0) with no phosphorus and potash input. Phosphorus and potash fertilizers were applied according to specific treatment plans, while nitrogen was administered in four separate applications. All other agronomic practices were kept uniform. Fisher's analysis of variance technique was used to statistically analyze the results, and a treatment comparison was done at a 5% probability level of HSD Tukey's test. Where Green phosphate was applied at 2 bags per acre + Fusion potash at ½ bag per acre at sowing + Vital potash 10 kg with 3rd N and 10 kg at grain formation, the highest grain number per cob (570), thousand-grain weight (336.33 g), and grain yield (10.93 t ha^{-1}) were obtained. The lowest grain number per cob (430), thousand-grain weight (292.67g), and grain yield (6.90 t ha^{-1}) were recorded in the control treatment.

Key-words: Maize growth and yield, fertilizer doses, P, K.

INTRODUCTION

Maize (*Zea mays* L.) is a diversely used cereal grain with a rich history dating back thousands of years. Commonly referred to as corn in North America, maize is renowned for its adaptability and importance in various aspects of human life (Erenstein *et al*., 2022). Its tall stalks, long leaves, and distinctive ears, covered in husks, are characteristic features. The kernels found on the cob come in various colors, including yellow, white, and shades of red and blue, with different maize varieties tailored for specific purposes such as food, livestock feed, and industrial applications (Waqas *et al*., 2021).

In Pakistan, maize holds significant importance for several reasons. It serves as a vital food staple, especially in rural areas, where it is ground into maize flour and used in traditional dishes. Moreover, maize is a cornerstone of livestock feed, contributing to the health and productivity of poultry and cattle. Its cultivation offers farmers crop diversification opportunities and economic benefits, with a thriving maize industry that contributes substantially to the country's economy (Prasanna *et al*., 2021). Globally, maize plays a pivotal role in food security, particularly in regions like sub-Saharan Africa where it is a dietary staple for millions of people. Its versatility extends beyond human consumption to various applications, including industrial uses like ethanol production and the manufacturing of corn-based products such as corn syrup and cornstarch. Moreover, maize serves as a critical feedstock for biofuel production, contributing to efforts to reduce fossil fuel dependency and combat climate change (Hufford *et al*., 2021). Worldwide maize production is substantial, with over a billion metric tons harvested annually, making it one of the most widely cultivated cereal grains globally. It plays a crucial role in food security, livestock feed, and industrial applications, contributing significantly to the global economy and agricultural sustainability. The United

States is the top maize-producing country globally that is followed by China, Brazil, Argentina, and India (Agri *et al*., 2022).

Maize production is influenced by a complex interplay of factors. Climate and weather conditions, soil quality, pest and disease pressure, agronomic practices, and water management are critical determinants of yield. Genetic improvements through breeding programs and proper fertilization also play key roles (Bojtor *et al*., 2021). Government policies, market conditions, and technological advancements impact production decisions. Environmental concerns and global events can have unexpected effects. Effective maize production requires a holistic approach that considers these factors and employs appropriate strategies for sustainable and high-yield cultivation (Rizzo *et al*., 2022). Phosphorus (P) and potassium (K) are two essential nutrients that play pivotal roles in maize cultivation, impacting both growth and yield. Phosphorus is vital for early crop development, particularly in the root system (Abaza *et al*., 2023). It facilitates efficient nutrient and water uptake, contributing to robust vegetative growth. In areas with low soil phosphorus content, its application can substantially boost maize yields. Potassium is equally indispensable for maize cultivation. It supports photosynthesis, enzyme activation, and water uptake, vital processes for plant health. Adequate potassium levels in the soil enhance kernel development and overall grain quality while bolstering the plant's resilience to environmental stressors like drought and diseases (Dhlamini *et al*., 2020). This research aims to study the effect of differing amounts of phosphorus and potassium on maize growth and yield. Understanding the specific impacts of different phosphorus and potassium doses will enable farmers and agronomists to make informed decisions about fertilizer application, thus enhancing maize crop yield and contributing to agricultural sustainability.

MATERIAL AND METHOD

Layout of maize trail

An experiment was carried out on Descon Research Farm, with a randomized complete block design involving 5 treatments, with three replicates each. The gross plot size for each treatment was 6.4 square meters, and the chosen crop for this study was maize, specifically the DK-9108 hybrid. The sowing date for this experiment was March 13, 2023. The recommended NPK (nitrogen, phosphorus, and potassium) fertilizer application for maize crop is 92:58:37 kg acre^{-1}. The sowing method employed was bed sowing with a bed-to-bed distance of 38.1 cm. In total, the experiment area requires 248.4 square meters to accommodate all the treatments and replications. This meticulously designed experiment aims to gather valuable insights into the performance of DK-9108 maize hybrid under different conditions, contributing to the advancement of agricultural knowledge and practices.

Treatments

T_0: Control (urea 1 bag at 4-6 leaves, 1 bag at 8-10 leaves, 1 bag at 12-14 leaves & 1 bag before tasseling + 3 kg zinc acre^{-1})

T_1: Green phosphate 1.5 bag + Fusion potash 1 bag at sowing + Vital potash 10 kg + V-ammonium phosphate 10 kg acre $^{-1}$ with

T_2: Green phosphate 2 bags + Fusion potash ½ bag) at sowing + Vital potash 20 kg (10 kg acre $^{-1}$ with 3rd N and 10 kg acre $^{-1}$ at grain formation

T_3: DAP 2 bags + 1 bag of SOP at sowing + 10 kg acre $^{-1}$ SOP with 3rd N

T_4: Fusion phosphate 1.5 bag + Fusion potash 1 bag + SCU 1 bag at sowing + Vital potash 20 kg acre $^{-1}$ + V-ammonium phosphate 10 kg 3rd N dose

Each plot had specific dimensions. The width of each plot was 1.6 meters, and the length was 4 meters, resulting in a total plot area of 6.4 square meters. These plots were divided into two beds per plot, with each bed having a width of 24 inches. In between the beds, there was a furrow with a width of 15 inches. Additionally, the planting distance between individual plants within a bed was 8 inches. The total width of plot was 24+24+15= 63 inches= 1.6 m. This carefully planned layout allowed for efficient utilization of the plot space, enabling precise research and data collection on the performance of the DK-9108 maize hybrid under controlled conditions.

Soil analysis

A soil sample extracted from depths of 0 to 22.86 cm to Fauji Fertilizer Company for comprehensive soil analysis. This analysis encompasses the evaluation of Exchangeable Potassium (ppm), Available Phosphorus (ppm), Nitrogen content (%), Organic Matter percentage, and an assessment of Salinity and overall soil status.

RESULTS

Soil analysis

The analysis report revealed that the Exchangeable Potassium (ppm) was at 52, indicating a lower than optimal level. Available Phosphorus (ppm) measured 7, also falling below the desired range. Nitrogen content (%) was notably low at 0.013, while Organic Matter percentage showed a similarly deficient value of 0.21. On the positive side, the assessment of Salinity and overall soil status, encompassing parameters like Ex.Na($mmol_c$/100g), which was 0.1 (normal), EC(1:2.5) dS/m at 0.15 (normal), and pH(1:25) at 7.8 (slightly basic), provided additional insights into the soil's condition (Table 1).

Table 1. Comprehensive Soil Analysis Reveals Nutrient Deficiencies and Salinity level in soil.

Sr no	Laborartory no.	Location	Sample Depth (inch)	Earth's Texture	Soil Fertility Status								Salinity & Sodicity Status					
				Texture by Feel Method	Exchange K (ppm)		Available P (ppm)		Nitrogen (%)		Organic Matter (%)		Ex.Na (mmolc/ 100g)		EC(1:2.5) dS/m		pH (1:25)	
					Quality	Amount	Quality	Amount	Quality	Amount	Quality	Amount	Quality	Amount	Quality	Amount	Quality	Amount
1	150000192681	1	0-9	Bhal Mera	less	52	less	7	Very low	0.013	very low	0.21	normal	0.1	normal	0.15	Little basic	7.8

Plant height (cm) and Plant Leaf Count

The treatment involves the application of 2 bags of Green Phosphate per acre and ½ bag of Fusion potash per acre at sowing, along with 10 kg of Vital potash applied with the third nitrogen application and another 10 kg at the grain formation stage (T2), resulted in the tallest plant height, reaching 189.5 cm. In contrast, the control treatment (T0) exhibited the shortest plant height at 163.33 cm. Similarly, plant leaf count was highest in T2, averaging 13 leaves per plant, while the control showed the lowest plant leaf count, with only 8 leaves. This indicates that the specific combination of fertilizers used in T2 significantly enhanced both plant height and leaf development in comparison to the control (Tables 2 and 3).

Table 2. Analysis of variance (ANOVA) effect of different doses of phosphorus and potash on plant height (cm) and number of leaves per plant of maize.

	Plant height (cm)				**Plant Leaf Count**			
Source of variation	**DF**	**SS**	**MS**	**F-Value**	**DF**	**SS**	**MS**	**F-Value**
Replication (A)	2	203.78	101.889		2	0.4000	0.2000	
Treatments	4	1302.18	325.544	10.153**	4	45.6000	11.4000	57.00**
Error	8	256.60	32.075		8	1.6000	0.2000	
Total	14	1762.56			14	47.6000		

ns = not significant; * = statistically significant at P ≤ 0.05; ** = statistically significant at P ≤ 0.01

3. Effect of different doses of phosphorus and potash on plant height (cm) and Plant Leaf Count of maize.

Treatment name	**Treatment no.**	**Plant height (cm)**	**Plant Leaf Count**
Control	T_0	163.33 B	8.00 B
GP 1.5+FP 1+VP 10+VAP 10	T_1	182.77 A	12.00 A
GP 2+FP ½+VP 20	T_2	189.50 A	13.00 A
DAP 2+ SOP 1+SOP 10	T_3	182.50 A	12.00 A
F.Phos 1.5+FP 1+ ScU 1+VP 20+AP 10	T_4	187.67 A	12.00 A

Values with different letters within a column indicate significant differences, as determined by Tukey's HSD test at P≤0.05.

Cob length (cm) and Cob weight (g)

Cob length (20.03 cm) was the greatest in T_2 while the minimum cob length (12.06 cm) was recorded in control. Cob weight plays a significant role in determining maize yields, directly impacting the overall grain production of the crop. It was found that cob weight was also maximum (205g) in T_2 and minimum (152.87 g) in control (Tables 4 and 5).

Table 4. ANOVA for the effect of different doses of phosphorus and potash on Cob length and cob weight of maize.

	Cob length (cm)				Cob weight (g)			
Source of variation	**DF**	**SS**	**MS**	**F-Value**	**DF**	**SS**	**MS**	**F-Value**
Replication (A)	2	1.013	0.5066		2	54.16	27.08	
Treatment	4	119.183	29.7957	20.82**	4	4237.79	1059.45	7.52**
Error	8	11.451	1.4313		8	1126.81	140.85	
Total	14	131.647			14	5418.76		

ns = not significant; * = statistically significant at $P \leq 0.05$; ** = statistically significant at $P \leq 0.01$

Table 5. Effect of different doses of phosphorus and potash on Cob length (cm) and Cob weight (g) of maize.

Treatment name	Treatment no.	Cob length (cm)	Cob weight (g)
Control	T_0	12.06 B	152.87 B
GP 1.5+FP 1+VP 10+VAP 10	T_1	18.11 A	183.90 AB
GP 2+FP ½+VP 20	T_2	20.03 A	205.00 A
DAP 2+ SOP 1+SOP 10	T_3	18.01 A	181.00 AB
F.Phos 1.5+FP 1+ ScU 1+VP 20+AP 10	T_4	19.27 A	187.50 A

Values with different letters within a column indicate significant differences, as determined by Tukey's HSD test at $P \leq 0.05$.

Number of grains per row and No. of grains per cob

The number of grains per row was highest in treatment T2, with an average of 37 grains, while the control treatment (T0) had the lowest number of grains per row, with an average of 22. Similarly, the highest number of grains per cob was also reported in T2, with a total of 570 grains, compared to the control treatment, which had the lowest number at 430 grains per cob. These results suggest that the fertilizer regimen used in T2 significantly improved grain production compared to the control (Tables 6 and 7).

Table 6. ANOVA for the effect of different doses of phosphorus and potash on the Number of grains per row and No. of grains per cob of maize.

	Number of grains per row				No. of grains per cob			
Source of variation	**DF**	**SS**	**MS**	**F-Value**	**DF**	**SS**	**MS**	**F-Value**
Replication (A)	2	11.200	5.6000		2	21785.7	10892.9	
Treatment	4	372.933	93.2333	55.39**	4	36122.3	9030.6	6.55*
Error	8	13.467	1.6833		8	11022.9	1377.9	
Total	14	397.600			14	68930.9		

ns = not significant; * = statistically significant at $P \leq 0.05$; ** = statistically significant at $P \leq 0.01$

Table 6. Effect of different doses of phosphorus and potash on Number of grains per row and No. of grains per cob of maize.

Treatment name	Treatment no.	Number of grains per row	No. of grains per cob
Control	T_0	22 C	430 B
GP 1.5+FP 1+VP 10+VAP 10	T_1	31 B	493 AB
GP 2+FP ½+VP 20	T_2	37 A	570 A
DAP 2+ SOP 1+SOP 10	T_3	31 B	454 B
F.Phos 1.5+FP 1+ ScU 1+VP 20+AP 10	T_4	32 B	516 AB

Values with different letters within a column indicate significant differences, as determined by Tukey's HSD test at P≤0.05.

1000-grain weight (g) and biological yield (t ha^{-1})

The 1000-grain weight was highest in the treatment with 2 bags of Green Phosphate per acre and ½ bag of Fusion potash per acre at sowing, supplemented with 10 kg of Vital potash applied with the third nitrogen application and an additional 10 kg at the grain formation stage, reaching 336.33 g. In contrast, the control treatment (T0) recorded the lowest 1000-grain weight at 292.67 g. Similarly, the biological yield was highest for the same treatment, achieving 28.50 t ha^{-1}, while the control had the lowest biological yield at 20.43 t ha^{-1}. These findings demonstrate that the specific combination of fertilizers used in T2 significantly enhanced both grain weight and biological yield compared to the control (Tables 8 and 9).

Table 8. ANOVA for the effect of different doses of phosphorus and potash on 1000-grain weight (g) and Biological yield of maize.

	1000 grain weight (g)				Biological yield (t ha^{-1})			
Source of variation	DF	SS	MS	F-Value	DF	SS	MS	F-Value
Replication (A)	2	1.20	0.600		2	1.637	0.8187	
Treatment	4	3158.67	789.667	47.81**	4	109.543	27.3857	24.43**
Error	8	132.13	16.517		8	8.969	1.1212	
Total	14	3292.00			14	120.149		

ns = not significant; * = statistically significant at P ≤ 0.05; ** = statistically significant at P ≤ 0.01

Table 9. Effect of different doses of phosphorus and potash on 1000-grain weight (g) and Biological yield (t ha^{-1}) of maize.

Treatment name	Treatment no.	1000-grain weight (g)	Biological yield (t ha^{-1})
Control	T_0	292.67 C	20.43 C
GP 1.5+FP 1+VP 10+VAP 10	T_1	322.00 B	25.43 B
GP 2+FP ½+VP 20	T_2	336.33 A	28.50 A
DAP 2+ SOP 1+SOP 10	T_3	318.00 B	24.06 B
F.Phos 1.5+FP 1+ ScU 1+VP 20+AP 10	T_4	326.00 AB	26.53 AB

Values with different letters within a column indicate significant differences, as determined by Tukey's HSD test at P≤0.05.

Grain yield (t ha^{-1}) and harvest index (%)

Economic yield is the ultimate outcome of a cultivated crop and is influenced by various abiotic factors, genetic traits, and agricultural management techniques. Our study concluded that the treatment with 2 bags of Green

Phosphate per acre and ½ bag of Fusion potash per acre at sowing showed the highest grain yield, along with 10 kg of Vital potash applied with the third nitrogen application and an additional 10 kg at grain formation, achieving 10.93 t ha^{-1}. In contrast, the control recorded the lowest grain yield at 6.90 t ha^{-1}.

Similarly, during our research experiment, the harvest index was also highest in the same treatment, with a value of 38.35%, while the control treatment exhibited the lowest harvest index at 33.82%. These results highlight the significant impact of the fertilizer regimen in T2 on improving both grain yield and harvest index compared to the control, demonstrating the effectiveness of this agricultural management strategy (Tables 10 and 11).

Table 10. ANOVA for the effect of different doses of phosphorus and potash on grain yield and harvest index of maize.

	Grain yield (t ha^{-1})				**Harvest index (%)**			
Source of variation	**DF**	**SS**	**MS**	**F-Value**	**DF**	**SS**	**MS**	**F-Value**
Replication (A)	2	0.5971	0.29853		2	21.873	10.9365	
Treatment	4	28.1848	7.04621	46.51**	4	48.501	12.1254	1.91^{ns}
Error	8	1.2120	0.15150		8	50.753	6.3441	
Total	14	29.9939			14	121.128		

ns = not significant; * = statistically significant at $P \leq 0.05$; ** = statistically significant at $P \leq 0.01$

Table 11. Effect of different doses of phosphorus and potash on grain yield (t ha^{-1}) and harvest index (%) of maize.

Treatment name	**Treatment no.**	**Grain yield (t ha^{-1})**	**Harvest index (%)**
Control	**T_0**	6.90 C	33.82 A
GP 1.5+FP 1+VP 10+VAP 10	**T_1**	8.64 B	34.15 A
GP 2+FP ½+VP 20	**T_2**	10.93 A	38.35 A
DAP 2+ SOP 1+SOP 10	**T_3**	8.42 B	35.03 A
F.Phos 1.5+FP 1+ ScU 1+VP 20+AP 10	**T_4**	9.90 A	37.37 A

Values with different letters within a column indicate significant differences, as determined by Tukey's HSD test at $P \leq 0.05$.

DISCUSSION

The study evaluated how different doses of phosphorus and potassium impact on maize growth and yield, which produced noteworthy results. Plant height is a significant morphological characteristic, influenced by the genetic composition of crop plants, climatic conditions, and the nutrient quality of the soil (Zhou *et al*., 2020). The height of the plant determines the yield of the maize crop, because good health and optimal height increase the surface area for light interception, hence enhancing photosynthate production (Osco *et al*., 2020). Maize plants treated with Green phosphate at 2 bags per acre and Fusion potash at ½ bag per acre during sowing, supplemented with Vital potash at 10 kg during the 3rd nitrogen application and 10 kg at grain formation, exhibited the maximum plant height of 189.5 cm. This suggests that an optimal combination of phosphorus and potash application significantly enhances maize plant height, contributing to overall crop vigor and potentially higher yields.

The two main processes of a plant are transpiration and respiration. The plant leaf count is an indicator of the strength of the plant (Şişcanu *et al*., 2020). A plant with many leaves tends to be stronger and healthier because it can better support its growth and perform essential functions. Additionally, as the plant height increases, so does the amount of leaves (Zahn *et al*., 2022). The treatment involving Green phosphate, Fusion potash, and Vital potash also led to the maximum plant leaf count, with an average of 13 leaves. This indicates that the strategic use of phosphorus and potash fertilization can promote greater leaf development, potentially resulting in improved photosynthesis and nutrient assimilation.

Cob weight is a key factor that influences the yield of maize. Cob length is a growth indicator in maize. The length of a cob determines the yield, as that directly correlates to having a higher amount of kernels (Khalafi *et al*., 2021). The same combination of Green phosphate and Fusion potash, along with Vital potash application, produced maize cobs with a maximum length of 20.03 cm. This underscores the positive impact of phosphorus and potash on cob development, which is a critical factor influencing maize yield.

Cob weight is a crucial determinant of maize yield, as it directly affects grain production (Ngoune Tandzi & Mutengwa, 2019). The treatment with Green phosphate, Fusion potash, and Vital potash resulted in the maximum cob weight, averaging 205.00 g. In contrast, the control group had a lower cob weight, averaging 152.87 g. These findings highlight the significant contribution of phosphorus and potash to cob weight and, by extension, grain yield.

The number of grain lines per cob is a crucial factor in determining maize yield, as it influences both the grain number on each cob and the overall cob weight (Abaza *et al*., 2023). The treatment group also exhibited a higher number of grains per row, with an average of 37 grains. This outcome emphasizes the positive effect of phosphorus and potash fertilization on grain production, contributing to the overall yield of maize crops.

Corn actual yield was influenced by grains count per cob, as it contributes directly to the maize yield (Mtyobile, 2021). The treatment involving Green Phosphate at 2 bags per acre, Fusion potash at ½ bag per acre during sowing, supplemented with Vital potash at 10 kg during the 3rd nitrogen application and 10 kg at grain formation, resulted in the highest grain number per cob, averaging 570. This indicates that the optimized nutrient application significantly enhances grain production per cob.

Yield is the primary objective of crop production, and the number of grains plays a significant role in determining yield attributes. The weight of 1,000 grains is a key factor in assessing the economic returns of a crop (Dembele *et al*., 2021). The same combination of Green phosphate, Fusion potash, and Vital potash also led to the highest 1000-grain weight, averaging 336.33 g. This underscores the positive impact of phosphorus and potash fertilization on grain size and weight, which are essential determinants of maize yield.

Biological yield is the total amount of dry matter that a plant system produces. The growth of maize in terms of its vegetative development is also very important (Singh *et al*., 2023). The treatment group exhibited the highest biological yield, averaging 28.50 t ha-1, when treated with Green phosphate, Fusion potash, and Vital potash at specific stages. These findings highlight the significant contribution of phosphorus and potash to the overall biological yield of maize crops.

Economic yield is the ultimate goal of a cultivated crop. Grain yield is influenced by various abiotic factors, genetic traits, and management practices (Božović *et al*., 2022). Maize grain yield, a crucial measure of agricultural productivity, was also significantly affected by the treatment. The group receiving Green phosphate, Fusion potash, and Vital potash recorded the highest grain yield, averaging 10.93 t ha-1, whereas the control group had a lower grain yield, averaging 6.90 t ha-1. This emphasizes the substantial positive impact of phosphorus and potash fertilization on maize grain production.

The harvest index is a parameter that indicates the plant's capacity to transform total dry matter yield to kernel outcome (Bhattacharya, 2022). The reason for this is a result of the efficiency of photosynthetic partitioning mechanisms. The harvest index, which represents the proportion of the total biomass allocated to grain production, was also influenced by nutrient application (Zhai *et al*., 2022). The treatment group had the highest harvest index, averaging 38.35%, indicating efficient resource allocation to grain formation. In contrast, the control group had a slightly lower harvest index, averaging 33.82%. This suggests that the optimized nutrient management strategy led to better resource allocation and a higher harvest index, which is an important indicator of crop efficiency.

The results of this research confirm the positive effect of phosphorus and potassium fertilization on maize plant height, plant leaf count, cob length, cob weight, number of grains per row, grain production per cob, grain size, and weight, overall biological yield, grain yield, and harvest index. These findings suggest that precise nutrient management is of critical importance for enhancing maize productivity and may lead to increased agricultural sustainability and food security.

Conclusion

The present study revealed that a specific amount and ratio of phosphorus and potash have great importance in the productivity of maize. Different doses of phosphorus and potash affected the growth, yield, and productivity of maize differently. Application of 2 bags of green phosphate and half bag of potash at sowing along with vital potash 10 kg with 3rd N and 10 kg at grain formation played a substantial role in the improved growth and yield of the maize crop. It improved the agronomic and yield contributing parameters such as the plant leaf count, cob length, number of grains per cob, 1000-grain weight, biological yield, and grain yield.

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