

Integrated Impact of Phosphorus and Zinc on Maize (*Zea Mays* L.) Production under Calcareous Soil

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Abstract

Maize (*Zea mays* L.) is an exhaustive crop and its yield is often limited by the deficiency of phosphorus (P) and Zinc (Zn) particularly in calcareous soil. Therefore, this experiment was conducted to examine the integrated effect of P and Zn [control (T1), 35 kg P ha⁻¹ (T2), 44 kg P ha⁻¹ (T3), 10 kg Zn ha⁻¹ (T4), 35 kg P and 10 kg Zn ha⁻¹ (T5), 44 kg P and 10 kg Zn ha⁻¹ (T6), 20 kg Zn ha⁻¹ (T7), 35 kg P and 20 kg Zn ha⁻¹ (T8), and 44 kg P and 20 kg Zn ha⁻¹ (T9)] on maize productivity in calcareous soil. Their application significantly affected plant height, cob length, cob weight, grains per cob, 1000-grain weight, and grain yield, however, shelling percentage and emergence didn't show any response to their application. The highest cob length (16.97 cm), grains per cob (430.53), 1000-grain weight (289.15 g), shelling percentage (77.66%) and grain yield (5674 kg ha⁻¹), were observed at 35 kg P ha⁻¹ applied with 20 kg Zn ha⁻¹. In contrast, the tallest plants (200.33 cm) and maximum cob weight (161.03 g) were recorded under 44 kg P ha⁻¹ applied with 20 kg Zn ha⁻¹. Therefore, 35 kg P ha⁻¹ along with 20 kg Zn ha⁻¹ is suggested for the better yield of maize crop in calcareous soil.

KEYWORDS

Calcareous soil, Grain yield, Maize, Phosphorus, Zinc

1.0 INTRODUCTION

Maize is one of the main cereal crops having high lucrative importance. It belongs to family Poaceae and is one of the major cereals following rice and wheat. It is abundantly available in the market, and its oil is used for cooking purpose [1]. Maize crop contributes 2.9% to Pakistan's value agriculture and 0.6% to GDP. Punjab and Khyber Pakhtunkhwa are Pakistan's leading maize producers. Both provinces produce over 97 percent of the country's total maize production. Maize production in In Khyber Pakhtunkhwa was 0.9045 million tons over an area of 0.468 million hectare having an average yield of 1933 kg ha⁻¹ [2].

Phosphorus (P) has vital role in both biochemical and physiological reactions in plants such as photosynthesis and respiration [3]. It is estimated that phosphorus-deficient soil accounts for approximately 67 percent of all

cropland on the planet [4]. In Pakistan, about 90% of soil is phosphorus deficient and its application is considered crucial for crop production [5, 6]. It is necessary for plant growth, photosynthesis, consumption of starch and sugar, formation of nucleus, and cell division [7]. Phosphorus translocates in plants, and moves to young tissues from older tissues [8]. High levels of phosphorus results in faster growth and high yield. According to Amanullah *et al*, [9], phosphorus application @ 90 kg ha⁻¹ resulted maximum economic yield.

Zinc (Zn) is an important plant micro nutrient, although it has received less attention in comparison to nitrogen (N), phosphorus (P), and potassium (K) [8]. For plants, humans, and animals, zinc is among the most important micronutrients and in the world's poorer countries; zinc deficiency is becoming increasingly common. Almost half of the world's cereal-growing areas have low plant-available Zn and thus its supplementation is required in such locations to ensure proper Zn concentrations in cereal grains [10, 11].

Many studies have shown that application of Zn fertilizer to Zn-deficient soils had increased maize grain production considerably [12].

Excessive P application to soil may induce Zn deficiency due to the formation of insoluble complex zinc-phosphate [13]. The results propose that excessive use of P fertilizers can cause P toxicity and also induce Zn deficiency, therefore, phosphorus application rate must be chosen carefully. Maralian [14] and Arshad et al. [15] also reported that higher P supplementation improved its uptake by plant but induced Zn-deficiency while their integrated application improved plant yield and P and Zn uptake.

Most of the area of Khyber Pakhtunkhwa (90%) is calcareous and in calcareous soils deficiency of P and Zn are widespread micronutrient disorders due to high CaCO₃ concentration that affect crop growth and development. That why, the present study was proposed to optimize phosphorous and zinc fertilization for improving yield under calcareous soil.

2.0 MATERIALS AND METHODS

The study was performed at ARI Tarnab to evaluate the integrated effect of P and Zn on maize yield under alkaline calcareous soil. The N, P, K and organic matter content in soil were 24 mg kg⁻¹, 8.6 mg kg⁻¹, 194 mg kg⁻¹ and 0.48% respectively.

Maize variety Kaptan was exposed to various levels of phosphorus and Zn including control (T1), 35 kg P ha⁻¹ equivalent to 80 kg P₂O₅ ha⁻¹ (T2), 44 kg P ha⁻¹ equivalent to 100 kg P₂O₅ ha⁻¹ (T3), 10 kg Zn ha⁻¹ (T4), 35 kg P and 10 kg Zn ha⁻¹ (T5), 44 kg P and 10 kg Zn ha⁻¹ (T6), 20 kg Zn ha⁻¹ (T7), 35 kg P and 20 kg Zn ha⁻¹ (T8), and 44 kg P and 20 kg Zn ha⁻¹ (T9). Recommended dose of N (120 kg ha⁻¹) and potassium (60 kg ha⁻¹) were also evenly applied to all plots. These treatments were assigned into 4m × 3m plots by adopting randomized complete block design (RCBD) having three (3) replications.

Data were recorded on plant height (cm), emergence m⁻², grains cob⁻¹, cob length (cm), cob weight (g), 1000-grain weight (g), shelling percentage (%) and yield (kg ha⁻¹). For emergence m⁻² the data were recorded in three randomly selected rows of 1 meter length in each plot. Emerged plants were counted in these rows and the value was then converted to emergence m⁻². For plant height (cm) in each plot three plants were selected randomly followed by measuring their heights. After that their means were worked out. After that five of cobs were chosen in each treatment randomly and their lengths were measured with a ruler. Then the mean values were worked out to finalize the data. After recording cob length data, the cobs were weighed using an electronic balance followed by working out of the mean values to get data for cob weight. To record the grains ear⁻¹ data, grains of the five randomly

chosen cobs in each treatment were counted and then their means were worked out. For obtaining the data on 1000-grain weight, a representative selection of 1000-grains was made in each treatment and was weighed using an electronic balance (g). For shelling percentage data, five randomly selected ears in each plot were weighed, and then the grains of the selected ears were also weighed. Then the following equation was used to calculate the shelling percentage:

$$\text{Shelling\%} = \frac{\text{Weight of grains}}{\text{Ear weight}} \times 100$$

For recording grain yield (kg ha⁻¹) data, ears were separated from the harvested plants in each plot followed by threshing, and weighing of grains using an electronic balance. The data were finalized as follow:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grains weight (kg)}}{\text{Row length} \times \text{R} - \text{R distance} \times \text{No. of Rows}} \times 10,000$$

3.0 RESULTS AND DISCUSSION

Emergence m⁻²

Analysis of variance for the data concerning emergence m⁻² showed a non-significant effect P and Zn (Table 1.). The data revealed maximum emergence m⁻² of 23.33 for T6 (44 kg P ha⁻¹ + 10 kg Zn ha⁻¹) when matched with T2 (35 kg P ha⁻¹) and control with emergence m⁻² of 20.33 and 21.33 respectively. This might be due to the fact that in early phases, the seedling obtained its nourishment from the seed's storage tissues, with little benefit from the addition of external nutrients. Furthermore, the seed rate used controls emergence m⁻², and a homogeneous seed rate had no effect on emergence m⁻². Hafidi *et al.* [16] concluded that during germination period the seed did not rely on nutrients from external source (s) and consumed food reserves from its own endosperm. Azeem *et al.* [17], found that fertilizer, had no effect on the emergence m⁻². Faisal *et al.* [18] also discovered non-significant influence of different inorganic and organic fertilization on emergence m⁻² of maize. Our findings regarding the trait are in line with the conclusions of Khan *et al.* [19] and Ibrahim et al. [20].

Plant height (cm)

Analysis of the values conformed that P and Zn application had markedly (P≤0.05) influenced the said parameter (Table 1). According to the results obtained tallest plant (200.33 cm) were noted in T9 (44 kg P ha⁻¹ + 20 kg Zn ha⁻¹) when matched with control (171.78 cm). Phosphorus with addition of zinc enhanced root growth, which has a significant impact on total plant growth and positive consequences of rising P and Zn levels on plant height is

most likely attributed to enhanced root system growth. Zhang *et al* [21] documented that plant height of maize was enhanced with increased P level. Our conclusions are also matching with results of Arshad *et al.* [22] who reported taller plants at higher levels of P. Sánchez-Rodríguez *et al.* [23] found that higher Zn levels resulted in maximum plant height.

Table 1. Integrated effect of P and Zn on emergence m², plant height of maize under calcareous soil.

Treatments	Emergence m ²	Plant height (cm)
T1 (Control)	21.33	171.78 d
T2 (35 kg P ha ⁻¹)	20.33	189.00 bc
T3 (44 kg P ha ⁻¹)	23.00	190.26 bc
T4 (10 kg Zn ha ⁻¹)	21.67	187.55 c
T5 (35 kg P and 10 kg Zn ha ⁻¹)	21.33	187.37 c
T6 (44 kg P and 10 kg Zn ha ⁻¹)	23.33	188.26 c
T7 (20 kg Zn ha ⁻¹)	21.00	191.54 bc
T8 (35 kg P and 20 kg Zn ha ⁻¹)	22.00	197.25 ab
T9 (44 kg P and 20 kg Zn ha ⁻¹)	21.00	200.33 a
LSD(0.05)	NS	8.61

Values with sharing letters in each category are statistically similar at $\alpha=0.05$ while the NS represent non-significance.

Cob length (cm)

Mean values pertaining cob length (cm) shown in Table 2. Confirms marked effects of P and Zn fertilization on the said trait of maize crop. T8 treatment resulted in greatest cob length (16.97 cm) followed by T3 (44 kg P ha⁻¹) and T9 (44 kg P ha⁻¹+ Zn @ 20 kg ha⁻¹) treatments with cob lengths of 15.85 and 15.84 cm consistently. Since P and Zn have essential roles in enzymatic activity and improves specific plant performance in terms of vegetative and reproductive growth that leads to increase in cob length [24-26]. Liu *et al.* [27] also documented similar results.

Cob weight (g)

Mean values regarding cob weight (g) showed significant response to the treatments (Table 2). Our findings confirm maximum cob weight of 161.03 g at 44 kg P applied with 20 kg Zn ha⁻¹ (T9) over control (111.54 g). Zhang *et al.* [21] revealed that No. of grains cob⁻¹ improved as the P levels were increased. The kernels cob⁻¹ of maize increased with greater rate that led to increase ear weight [28-30]. Results of the research are matching with results of Akmal *et al.* [31].

Table 2. Impact of P and Zn on cob length and cob weight of maize in calcareous soil.

Treatments	Cob length (cm)	Cob weight (g)
T1 (Control)	11.48 d	111.54 b
T2 (35 kg P ha ⁻¹)	14.27 bc	145.02 a
T3 (44 kg P ha ⁻¹)	15.85 ab	146.23 a
T4 (10 kg Zn ha ⁻¹)	13.81 c	134.15 ab
T5 (35 kg P and 10 kg Zn ha ⁻¹)	14.57 bc	155.91 a
T6 (44 kg P and 10 kg Zn ha ⁻¹)	15.33 abc	138.41 ab
T7 (20 kg Zn ha ⁻¹)	15.63 ab	147.53 a
T8 (35 kg P and 20 kg Zn ha ⁻¹)	16.97 a	155.57 a
T9 (44 kg P and 20 kg Zn ha ⁻¹)	15.84 ab	161.03 a
LSD(0.05)	1.77	26.95

Values with sharing letters in each category are statistically similar at $\alpha=0.05$ while the NS represent non-significance.

Grains cob⁻¹

The effect of P and Zn was significant for grains cob⁻¹ (Table 3). The maximum grains cob⁻¹ was recorded for T8 (35 kg P and 20 Zn kg ha⁻¹) which was at par to T9, T7, T6 and T3. According to Zeidan *et al.*, [24], increase in grain cob⁻¹ following P fertilization could be attributed to improved photosynthetic activity due to optimal phosphorus availability. The increase in number of kernels of maize was due to increased levels of Zn [1].

1000-grains weight (g)

Mean values pertaining 1000-grains weight (gm) are tabulated in Table 3. The means reveals that both P and Zn fertilization had marked effects on thousand grains weight (g). T8 (35 kg P ha⁻¹ + Zn @ 20 kg ha⁻¹) exhibited maximum 1000-grains weight of 289.15 g over control. These findings of higher thousand grain weights in the P applied plots are similar with the conclusions of Amanullah *et al.*, [32], who found that P fertilization had a favorable influence on grain weight. The microelements' influence on leaf area development and higher assimilate production might explain the greater 1000-grains weight in Zn-treated plots [33]. Higher P levels resulted in heavier 1000-grains weight [23]. The highest value for 1000-grain weight was vetted in treatments having 20 kg Zn ha⁻¹ when matched with the lowest in Zn control plots. The weight of thousands of grains increased

as Zn levels increased [1].

by increasing energy availability for enzymatic activities [37].

Table 3. Effect of P and Zn on grains cob⁻¹ and thousand grains weight of maize crop under calcareous soil.

Treatments	Grains cob ⁻¹	1000 grains weight (g)
T1 (Control)	313.47 c	237.21 e
T2 (35 kg P ha ⁻¹)	395.47 ab	267.26 bcd
T3 (44 kg P ha ⁻¹)	349.35 bc	268.26 bcd
T4 (10 kg Zn ha ⁻¹)	390.00 ab	253.42 de
T5 (35 kg P ha ⁻¹ +10 kg Zn ha ⁻¹)	408.07 a	283.67 ab
T6 (44 kg P ha ⁻¹ +10 kg Zn ha ⁻¹)	414.20 a	263.84 cd
T7 (20 kg Zn ha ⁻¹)	404.93 a	275.27 abc
T8 (35 kg P ha ⁻¹ +20 kg Zn ha ⁻¹)	430.53 a	289.15 a
T9 (44 kg P ha ⁻¹ +20 kg Zn ha ⁻¹)	398.53 ab	272.85 abcd
LSD _(0.05)	53.75	19.78

Values with sharing letters in each category are statistically similar at $\alpha= 0.05$.

Grain yield (kg ha⁻¹)

Grains yield of maize was significantly affected by application of P and Zn as shown in table 4. Mean values conformed marked effects of P and Zn on grain yield (kg ha⁻¹). The higher value of 5674 kg ha⁻¹ was observed under 35 kg P and 20 kg Zn ha⁻¹ that was followed by T5 (35 kg P with 10 kg Zn ha⁻¹) producing 5651 kg ha⁻¹ grain yield while the lowest was recorded under control (4103 kg ha⁻¹). Bindraban *et al.* [34] found boost in maize grain production with rising levels of phosphorus. Similarly, Liu *et al.*, [13] discovered that higher Zn levels increased grain yield. According to their observations higher fertilizer levels boosted grain yield due to increased vegetative growth time, leaf area duration, and LAI. Khan *et al.*, [35] found that adding Zn and macronutrients to maize boosted yield related traits.

Shelling percentage (%):

The effect P and Zn application on shelling percentage (%) was found non-significant (Table 4). Though, highest shelling percentage (77.66%) was confirmed for T8 (35 kg P and 20 kg Zn ha⁻¹) over control (55.79%). Hussain *et al.*, [36] documented that as the level of P was raised, maize yield and yield components increased dramatically. Zn availability might had triggered pyrophosphate activity that boosted carbon fixation

Table 4. Effect of P and Zn on grain yield and shelling percentage of maize crop grown under calcareous soil.

Treatments	Grain yield (kg ha ⁻¹)	Shelling (%)
T1 (Control)	4103 d	55.79
T2 (35 kg P ha ⁻¹)	4550 cd	55.98
T3 (44 kg P ha ⁻¹)	5133 abc	59.72
T4 (10 kg Zn ha ⁻¹)	4797 bc	60.92
T5 (35 kg P ha ⁻¹ +10 kg Zn ha ⁻¹)	5651 a	60.88
T6 (44 kg P ha ⁻¹ +10 kg Zn ha ⁻¹)	5648 a	60.03
T7 (20 kg Zn ha ⁻¹)	5514 a	61.77
T8 (35 kg P ha ⁻¹ +20 kg Zn ha ⁻¹)	5674 a	77.66
T9 (44 kg P ha ⁻¹ +20 kg Zn ha ⁻¹)	5446 ab	64.77
LSD _(0.05)	648.70	NS

Values with sharing letters in each category are statistically similar at $\alpha= 0.05$ while the NS represent non-significance differences.

4.0 CONCLUSION

Our findings demonstrated a significant effect of P and Zn application over all studied traits except plant height and cob weight. Among the treatments 35 kg P applied with 20 kg Zn ha⁻¹ performed better than the rest of treatment combinations with respected to all tested traits. Therefore, the application of 35 kg P ha⁻¹ (equivalent to 80 kg P₂O₅ ha⁻¹) along with 20 kg Zn ha⁻¹ is suggested as the optimum nutrient combination for improving maize productivity in calcareous soils.



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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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