Research Article

Effect of phosphorus and zinc levels on maize (Zea mays L.) forage production grown in calcareous soil in Peshawar valley

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Citation

Abstract
Lack of macro and micro-nutrients limits the growth and development of exhaustive crops like maize especially in calcareous soil. The present study was carried out in fall 2021 at the Agriculture Research Institute, Tarnab (ARI-Tarnab), Peshawar, Khyber Pakhtunkhwa, Pakistan. Maize variety Kaptan was treated with treatments T1 (Control), T2 (P2O5 @ 80 kg ha⁻¹), T3 (P2O5 @ 100 kg ha⁻¹), T4 (Zn @ 10 kg ha⁻¹), T5, (P2O5 @ 80 kg ha⁻¹ + Zn @ 10 kg ha⁻¹), T6 (P2O5 @ 100 kg ha⁻¹ + Zn @ 10 kg ha⁻¹), T7 (Zn @ 20 kg ha⁻¹), T8 (P2O5 @ 80 kg ha⁻¹ + Zn @ 20 kg ha⁻¹) and T9 (P2O5 @ 100 kg ha⁻¹ + Zn @ 20 kg ha⁻¹). Our findings revealed that various levels of phosphorus (P) and zinc (Zn) had significantly (P≤0.05) affected days to tasseling, days to silking, leaf area (cm²), leaf area index and biological yield (kg ha⁻¹) while their effect on harvest index (%) was recorded non-significant. Results of the study revealed maximum leaf area (454.68 cm²), leaf area index (3.79), and biological yield (17831 kg ha⁻¹) for T9 (P2O5 @ 100 kg ha⁻¹ + Zn @ 20 kg ha⁻¹). While maximum days to tasseling (63.00) and silking (68.33) were observed in treatment T7 (Zn @ 20 kg ha⁻¹). Thus it is recommended that if maize crop is grown for fodder purpose under said conditions then the treatment T9 (P2O5@ 100 kg ha⁻¹ + Zn @ 20 kg ha⁻¹) is the best option.

Keywords: Biological yield; Fodder; Leaf area; Maize; Phosphorus; Zinc

Introduction
Maize (Zea mays L.) is a multipurpose crop that belongs to the poaceae family. It is grown in both irrigated and rain-fed locations throughout Pakistan’s provinces. Maize crops are typically farmed in temperate, tropic, and warm subtropical regions across the world [1]. Following wheat and rice, maize is Pakistan's third most significant cereal crop. It contributed 3.4 percent to agricultural value added and 0.6 percent to GDP. Maize is used as a multifunctional crop for food, feed, and fodder. In 2020-21, maize was grown on 1,418 thousand hectares, a 1.0 percent increase over the previous year's total of...
1,404 thousand hectares. Its output increased by 7.4 as compared to the previous year. Increased area, the availability of improved seed types, and larger economic returns all contributed to the increase in yield [2].

Phosphorus (P) serves numerous critical activities in plant life, the most important of which is storing energy and distributing it. It is considered as a key factor for increasing economic yield, after nitrogen [3]. Plants of intense and short-cycle development, such as maize, require greater amounts of phosphorus than perennial crops. The flowering, grain development, ripening, and reproductive portions of the maize plant require phosphorus. It is required for cell division, growth, nucleus development, photosynthesis, sugar, fats and starch utilization [4]. Sufficient amount of phosphorus is required for quick growth and vegetative quality. Small ears in maize are due phosphate deficiency, which causes irregular and incomplete rows as a result of kernel twist. It boosts root system development and enables plants to resist moisture deficiencies in soil. Phosphorus insufficiency is particularly common in low-moisture soils or arid regions [5], and alternatively it may be claimed that 90% of Pakistan is covered by dry to semi-arid regions, resulting in P deficiency [6].

Among micronutrients zinc is considered as the most important one for vigorous growth and development of plants [8]. Zinc is the co-factor or structural component of several enzymes involved in various biochemical processes. The importance of zinc in plants is due to its role in photosynthesis, protein and carbohydrate metabolism, formation of pollens, and maintenance of membrane integrity and tolerance induction against biotic and abiotic stresses [9]. Alkaline soil pH significantly decreases the bioavailability of zinc. Due to high soil pH and CaCO3 concentration, Pakistani soils are facing deficiency of zinc [10]. Young leaves are more susceptible to zinc deficiency as its shortage reduces its mobility in phloem. Zinc deficiency causes reduced tillering, brown spots on leaves, delayed maturity and stunted growth. Cup-shaped leaves and interveinal discoloration are further signs of its deficiency [6].

P and Zn have antagonist behavior in plant nutrition, which may reduce the yield and quality of crops [11]. Excessive Phosphorous fertilization improved plant P uptake but directly affects Zn availability to plant and resulted in Zn deficiency. The antagonistic effect of phosphorus and zinc results in one nutritional shortage as phosphorus and zinc binds together forming an insoluble complex zinc-phosphate while the combine application of both the nutrients enhances plant growth and yield parameters [12].

The current study was designed to evaluate the impact of phosphorus and zinc on maize fodder production in calcareous soil under the agro-climatic conditions of Peshawar valley.

**Materials and Methods**

The research was conducted at Agriculture Research Institute Tarnab, Peshawar Khyber Pakhtunkhwa in fall 2021, to examine the influence of phosphorus and zinc fertilization on maize (Zea mays L.) productivity in calcareous soil. The experiment was set up with three replications under randomized complete block design. The experiment was comprised of 27 plots with sub plot size of 4m × 3m. The plants to plant and row to row spacing were 30 cm and 75 cm consistently. In the experiment Kaptan variety was used, whereas experiment was consisted for the following treatments: T1 (Control), T2 (P2O5 @ 80 kg ha⁻¹), T3 (P2O5 @ 100 kg ha⁻¹), T4 (Zn @ 10 kg ha⁻¹), T5, (P2O5 @ 80 kg ha⁻¹ + Zn @ 10 kg ha⁻¹), T6 (P2O5 @ 100 kg ha⁻¹ + Zn @ 10 kg ha⁻¹), T7 (Zn @ 20 kg ha⁻¹), T8 (P2O5 @ 80 kg ha⁻¹ +
Zn @ 20 kg ha\(^{-1}\)) and T9 (P\(_2\)O\(_5\) @ 100 kg ha\(^{-1}\) + Zn @ 20 kg ha\(^{-1}\)).

Before seeding, the experimental plots were ploughed thoroughly and leveled to ensure even distribution of fertilizers.

**Pre-sowing analysis of soil**

![Table of soil properties]

The preliminary soil (pre-sowing) analysis was as follows:

- Soil textural class: Silt loam
- Sand % = 20, Silt % = 62, Clay % = 18

**Soil properties**

- pH: 8.4
- EC: 0.03 dSm\(^{-1}\)
- TSS: 0.009 %
- CaCO\(_3\): 5 %
- Organic matter: 0.48 %
- N: 0.024 mg kg\(^{-1}\)
- P: 8.6 mg kg\(^{-1}\)
- K: 194 mg kg\(^{-1}\)
- Zn: 3.46 mg kg\(^{-1}\)

Data were recorded on days to 60% tasseling, days to 60% silking, leaf area (cm\(^2\)), leaf area index (LAI), biological yield (kg ha\(^{-1}\)) and harvest index (%).

For data regarding days to 60% tasseling were recorded by calculating days from sowing date till 60% tassels production in each plot. Similarly, data on days to 60% silking were finalized by counting of days from the date when plants were sown till the completion of 60% silk production.

Leaf area was counted using the following formula:

\[
\text{Leaf area} = \text{Leaf length} \times \text{leaf width} \times \text{correction factor (0.75)}
\]

Leaf areas of three randomly selected plants were calculated in m\(^2\) in each plot then averaged. Then following formula was used for getting the data regarding the leaf area index:

\[
\text{LAI} = \frac{\text{Leaf area plant}^{-1}(m^2) \times \text{No. of plants}}{\text{Ground area (m}^2)}
\]

For biological yield (Kg ha\(^{-1}\)), at the time of physiological maturity, harvesting of three central rows was done in each treatment followed by sun-drying of the samples. Their weights were taken using spring balance. Then the data were finalized according to the following equation:

\[
\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological yield (kg)}}{\text{Row length} \times R - R \text{ distance} \times \text{No. of Rows}} \times 10,000
\]

For recording data regarding Harvest index (%) the following equation was used:

\[
\text{Harvest index} = \frac{\text{Grains yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100
\]
Statistical analysis
Using Statistix 8.1 software, the data were gathered and statistically evaluated using the analysis of variance (ANOVA) technique and the LSD test at the 5% level of probability.

Results and discussion
Days to tasseling
The (Table 1). Shows data regarding days to tasseling. The tabulated data reveals that days to tasseling showed significant variations to various levels of phosphorus (P) and zinc (Zn). Maximum days to tasseling (63.00) were noted in treatments fertilized with Zn @ of 20 kg ha\(^{-1}\) followed by T4 and T6 treatments that took 62.33 days to tasseling as compared to control (55.33). This might be due to the rapid vegetative growth, boosted by fertilizer effects, which slowed down reproductive growth. [5] Observed late tassel emergence with increased levels of P. The findings are consistent with discoveries of [13, 14]

Days to silking
Mean values regarding days to silking as shown in (Table 1) confirmed marked (P ≤ 0.05) influence of various levels of phosphorus (P) and zinc (Zn) on the said trait.
More (68.33) were noted in treatments which were fertilized with Zn @ of 20 kg ha\(^{-1}\) when compared with control (62.00 days). This might be due to the fact that zinc and phosphorus regulates numerous processes during early growth and delays maturity. [5] Found that increasing the amount of P in the soil decreased maize silking. Our findings are in contrast with those of [15], who found that silking was expedited with Zn supply.

Leaf area (cm\(^2\))
Analysis of means conformed a significant (P ≤ 0.05) variation in leaf area to various levels P and Zn (Table 1).
Maximum value (454.68 cm\(^2\)) was observed in T9 treatment that was at par with leaf area of 450.33 cm\(^2\) from T3 (P\(_2\)O\(_5\) @ 100 kg ha\(^{-1}\)) when matched with control (347.88 cm\(^2\)). Plants with high leaf area in P-applied plots could have better absorption of nutrients such as N, P and Fe [12]. Application of P and Zn together improved enzymes and ATP production that concurrently enhanced photosynthetic rate [16]. Same conclusions were concluded by [17], and [18]. Results of our study are also matched with conclusions of [19], who stated that Zn fertilization boosted Zn concentration in leaves that resulted in increment of leaf area.

Leaf area index (LAI)
Values of the trait are tabulated in (Table 2). Mean values of the data shows marked effects P and Zn on leaf area index. Highest value (3.79) was observed in T9 treatment when compared with control (2.90). Greater LAI for more P and Zn might be related to the fact that P speeds up root growth and expansion and Zn boosted enzymes and ATP generation. These results are supported by [20] who concluded that maize leaf area index increased as phosphorus levels increased. [7] Concluded that Zn treatment led to a higher LAI. Same conclusions were documented by [18, 21].

Biological yield (kg ha\(^{-1}\))
The tabulated means regarding biological yield showed significant variations to P and Zn application (Table 2).
The results confirms maximum biological of 17831 kg for T9 treatment when matched with control (12750 kg ha\(^{-1}\)). The yield boosted with increase of P levels. When P fertilizer was provided just before sowing, it was more efficiently utilized [22]. Similar findings were also concluded by [23]. [24]
Were of the view that enhancement in biological yield was due to the crucial role of zinc in the production of corn. Results of the study are also consistent with results obtained by [22] who found that addition of micronutrients boosted biological yield.

Harvest Index (%)
Data concerning harvest index (%) revealed a non-significant influence of P and Zn fertilization on harvest index (%) (Table 2).
However maximum harvest index of 37.05% was noted for T5 treatment as compared to harvest index of 30.53% from
T9 (P$_2$O$_5$ @ 100 kg ha$^{-1}$ + Zn @ 20 kg ha$^{-1}$). This might be due to increased growth rate of vegetative traits [23]. Maize vegetative organs respond to Zn application more strongly than reproductive organs [25].

Table 1. Influence of P and Zn levels on days to tasseling and days to silking and leaf area (cm$^2$) of maize crop grown on calcareous soil in Peshawar valley

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Days to tasseling</th>
<th>Days to silking</th>
<th>Leaf area (cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (Control)</td>
<td>55.33 d</td>
<td>62.00 c</td>
<td>347.88 b</td>
</tr>
<tr>
<td>T2 (P$_2$O$_5$ @ 80 kg ha$^{-1}$)</td>
<td>57.00 cd</td>
<td>64.00 bc</td>
<td>445.12 a</td>
</tr>
<tr>
<td>T3 (P$_2$O$_5$ @ 100 kg ha$^{-1}$)</td>
<td>56.67 d</td>
<td>62.33 c</td>
<td>450.33 a</td>
</tr>
<tr>
<td>T4 (Zn @ 10 kg ha$^{-1}$)</td>
<td>62.33 ab</td>
<td>67.33 ab</td>
<td>412.91 a</td>
</tr>
<tr>
<td>T5 (P$_2$O$_5$ @ 80 kg ha$^{-1}$+ Zn @ 10 kg ha$^{-1}$)</td>
<td>61.33 ab</td>
<td>65.67 abc</td>
<td>434.82 a</td>
</tr>
<tr>
<td>T6 (P$_2$O$_5$ @ 100 kg ha$^{-1}$+ Zn@ 10 kg ha$^{-1}$)</td>
<td>62.33 ab</td>
<td>67.67 ab</td>
<td>398.74 a</td>
</tr>
<tr>
<td>T7 (Zn @ 20 kg ha$^{-1}$)</td>
<td>63.00 a</td>
<td>68.33 a</td>
<td>424.57 a</td>
</tr>
<tr>
<td>T8 (P$_2$O$_5$ @ 80 kg ha$^{-1}$+ Zn @ 20 kg ha$^{-1}$)</td>
<td>59.00 bcd</td>
<td>64.00 bc</td>
<td>417.55 a</td>
</tr>
<tr>
<td>T9 (P$_2$O$_5$ @ 100 kg ha$^{-1}$+ Zn @ 20 kg ha$^{-1}$)</td>
<td>60.67 abc</td>
<td>67.33 ab</td>
<td>454.68 a</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>3.92</td>
<td>4.257</td>
<td>59.83</td>
</tr>
</tbody>
</table>

Table 2. Influence of P and Zn fertilization on leaf area index (LAI), Biological yield (kg ha$^{-1}$), and Harvest Index (%) of maize crop grown on calcareous soil in Peshawar valley

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Leaf area index (LAI)</th>
<th>Biological yield (kg ha$^{-1}$)</th>
<th>Harvest Index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (Control)</td>
<td>2.90 b</td>
<td>12750 c</td>
<td>32.12</td>
</tr>
<tr>
<td>T2 (P$_2$O$_5$ @ 80 kg ha$^{-1}$)</td>
<td>3.71 a</td>
<td>14888 bc</td>
<td>30.57</td>
</tr>
<tr>
<td>T3 (P$_2$O$_5$ @ 100 kg ha$^{-1}$)</td>
<td>3.75 a</td>
<td>16556 ab</td>
<td>31.00</td>
</tr>
<tr>
<td>T4 (Zn @ 10 kg ha$^{-1}$)</td>
<td>3.44 a</td>
<td>15448 b</td>
<td>31.52</td>
</tr>
<tr>
<td>T5 (P$_2$O$_5$ @ 80 kg ha$^{-1}$+ Zn @ 10 kg ha$^{-1}$)</td>
<td>3.62 a</td>
<td>15356 b</td>
<td>37.05</td>
</tr>
<tr>
<td>T6 (P$_2$O$_5$ @ 100 kg ha$^{-1}$+ Zn@ 10 kg ha$^{-1}$)</td>
<td>3.32 ab</td>
<td>16275 ab</td>
<td>34.78</td>
</tr>
<tr>
<td>T7 (Zn @ 20 kg ha$^{-1}$)</td>
<td>3.54 a</td>
<td>15431 b</td>
<td>36.33</td>
</tr>
<tr>
<td>T8 (P$_2$O$_5$ @ 80 kg ha$^{-1}$+ Zn @ 20 kg ha$^{-1}$)</td>
<td>3.48 a</td>
<td>16763 ab</td>
<td>34.02</td>
</tr>
<tr>
<td>T9 (P$_2$O$_5$ @ 100 kg ha$^{-1}$+ Zn @ 20 kg ha$^{-1}$)</td>
<td>3.79 a</td>
<td>17831 a</td>
<td>30.53</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>0.49</td>
<td>2285.7</td>
<td>NS</td>
</tr>
</tbody>
</table>

Conclusion and Recommendation

Results of the study revealed significant (P≤0.05) influence of various levels of P and Zn on days to tasseling, days to silking, leaf area (cm$^2$), leaf area index, and biological yield (kg ha$^{-1}$). The results showed maximum leaf area (cm$^2$), leaf area index and biological yield (kg ha$^{-1}$) for T9 (P$_2$O$_5$@ 100 kg ha$^{-1}$ + Zn @ 20 kg ha$^{-1}$). Keeping in view the above conclusions, treatment T9 (P2O5@ 100 kg ha$^{-1}$ + Zn @ 20 kg ha$^{-1}$) is the best option for the maize crop for fodder purposes in the calcareous soil under the agro climatic conditions of Peshawar valley.
Authors’ contributions
Conceived and designed the experiments: Y Jamal & IU Haq. Performed the experiments: S Fahad. Analyzed the data: S Fahad. Contributed reagents/ materials/ analysis tools: NE Jan, M Haroon & B Iqbal. Wrote the paper: S Fahad & M Ibrahim.

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References


