Research Article

Nitrogen, phosphorus and zinc enhance Maize hybrid productivity and build up soil phosphorus and zinc in Maize faba bean cropping system in semiarid region

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Abstract

It is assumed that all of the applied nitrogen, phosphorus and zinc are not utilized by the current crop and may remain in the soil that could be used by succeeding crops. Aim of this study to evaluate the effect of nitrogen (N) phosphorus (P) and zinc (Zn) on maize hybrid 3305 and soil P and Zn. A two years experiment was conducted at The University of Agriculture Peshawar, Pakistan in 2013-2014 to evaluate the impact of N, P and Zn on maize and soil P and Zn accumulation. Three levels of N (150, 200 and 250 kg ha⁻¹), P (75, 125 and 175 kg ha⁻¹) and Zn (5, 10, 15 kg ha⁻¹) along with control were applied to maize. N, P and Zn significantly increased grains ear⁻¹(GE), thousand grains weight (TGW) and delayed days to silking (DS) compared with control. Grains ear⁻¹(GE), thousand grains weight (TGW) was significantly higher as compared to control. Each increment of N, P and Zn increased GE and TGW. Maximum GE and TGW were recorded at 250 kg N ha⁻¹, 175 kg P ha⁻¹ and 15 kg Zn ha⁻¹ across both years. The DS was higher with 250 kg N ha⁻¹, 75 kg P ha⁻¹ and 15 kg Zn ha⁻¹. Soil P content increased from 0.96 mg kg⁻¹ in control to 2.9 mg kg⁻¹ in P and Zn fertilized plots, whereas Zn increased from 3.68 mg kg⁻¹ in control to 6.58 mg kg⁻¹ in P and Zn fertilized plots over 2 years. It is concluded that 250 kg N ha⁻¹, 175 kg P ha⁻¹ and 15 kg Zn ha⁻¹ resulted in better production of maize and increased soil P and Zn that could be utilized by succeeding crop.

Keywords: Nitrogen; Phosphorus; Zinc; Maize; Soil P and Zn

Introduction

Maize (*Zea mays* L) is used as food and feed for cattle [1]. It is utilized as raw material for starch, corn soup and corn flakes [2]. Maize grains composed of 70% starch, 4.8% oil, 10% protein, 13.2% fiber and 2% ash [3]. Among other factors, indiscriminate

applications of fertilizers including nitrogen, P and Zn are responsible for low yield [4].

Nitrogen (N) is an essential element for plant growth and development, and is considered one of the main factors controlling productivity of cereal crops [5, 6]. N deficiency results in poor plant

development and severe reduction in harvestable yield.

Phosphorus (P) is another essential macro nutrient present in the inorganic as well as organic forms in soil. It is a component of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), nucleus, cell division and heredity transmission. Plants absorb most of the P during vegetative growth, which is remobilized into the grains during grain filling stage [7]. It enhances early growth and root development [8, 9]. However Phosphorus (P) availability is low in soil due to high concentration of CaCO_3 in the soil. P is the least available macronutrient in soil [10]. The application of P to the P deficit soil could increase maize production with superior quality [11]. Zinc (Zn) is the 3rd yield limiting nutrient after nitrogen and phosphorus [12]. Zn is the main component of the different enzymes which are responsible for the metabolism of carbohydrate, protein, and increases disease resistance in plant [13, 14]. Zn enhances the synthesis of the enzyme which promotes chlorophyll formation [15]. Photosynthetic productions in crops are also Zn dependent [16, 17]. Zn deficiency causes stunted growth, slow cell division, susceptibility to disease [18], results in less number of seeds set and reduces crops yield [19]. In soil as well as plants, P combines with Zn form phosphate complexes, which prevent absorption of P and movement of P in the plant. The current study was conducted to determine the effect of nitrogen and phosphorus in combination with Zn on maize yield and yield components.

Materials and methods

Experimental site, design and treatments

The experiment was conducted at University of Agriculture Peshawar,

Pakistan. It is located at 34° N and 71.3° E at 350 meter above sea level. Daily maximum mean temperature ranges from 40 to 44 °C summer, while winter minimum temperature ranges from 4 to 5 °C [20]. Annual rainfall ranges from 450 to 750 mm with more than 60% rainfall occur in July and August [20]. Experimental plots were established in June 2013 at Agronomy Research Farms, University of Agriculture Peshawar Pakistan. Maize hybrid- 3305 was planted on the established plots on 14th June, 2013 and harvested on 10th October 2013. Maize was planted on the same plots on 14th June, 2014 and harvested in October 2014. Cultural practices, such as weeding, earthing up and thinning was done, canal water was the source of irrigation. Experiment was conducted according to randomized complete block (RCB) design having three replications. Three nitrogen levels (150, 200 and 250 kg N ha⁻¹), three phosphorus levels (75, 125 and 175 kg P ha⁻¹) and three zinc levels (5, 10 and 15 kg Zn ha⁻¹) along with control were applied to maize. A plot size of 3 m x 3.75 m having 5 rows 3 meter long, 75 cm apart was used. A plant to plant distance of 25 cm was maintained by thinning. Nitrogen was applied in three splits: 1st at time of sowing, 2nd at V5 (five leaf stage) and 3rd at VT stage, while full doses of P and Zn were applied at sowing to maize hybrid 3305 each year. Faba bean was planted each year after harvest of maize with no N, P or Zn application. The meteorological data was obtained from the regional centre (Peshawar) of Pakistan Meteorological Department (Figure 1).

Figure 1. Days to silking of maize as affected by N x P interaction.

Soil Analysis

A composite soil sample was taken from 0-30cm depth before the start of the experiment and was analysed for N, P and Zn content and other physical properties. Sampling from each experimental unit was done after each crop harvest and was analysed for different traits studied in the research. The soil was silty clay loam having 31.23 % clay, 51.5 % low P, N and Zn content silt, 17.23 % sand and low in N (0.04 %), P (1.15 mg kg⁻¹) and Zn (0.7 mg kg⁻¹).

Results and discussion

Days to silking

Statistical analysis of the data revealed that year (Y), nitrogen (N), phosphorus (P), zinc (Zn), control vs fertilizer and N x P interaction significantly affected days to silking (DS) of maize (Table 1). More DS (60.2) were recorded in 2014 compared with 2013. Generally higher DS (62) was observed for plots that received fertilizer compared with control. Mean values for N revealed that DS increased with each increment of N and maximum DS (65.3) were recorded at 250 kg N ha⁻¹. Similar increases in DS were noted with each increment of Zn up to 15 kg Zn ha⁻¹. DS

were higher (62.9) in plots where P was applied at the rate of 75 kg ha⁻¹, whereas higher level of P significantly reduced DS. Increase in DS was also noted with each increment of Zn up to 15 kg Zn ha⁻¹ which resulted 63.1 days to silking. N x P interaction indicated that more days to silking were taken with 250 kg N and 75 kg P ha⁻¹. DS were delayed with each increment of N at all levels of P (Figure 1). Delay in DS due to increase in N level may be due to the fact that N enhances vegetative growth thus delaying the development of reproductive parts. Our results are in line with Dawadi and Shah [21] who reported that N delayed DS. Decrease in DS at higher level of P may be due to the fact that P is involved in root growth and the nutrients are efficiently utilized and the crop accelerates its growth. These results are in line with Amanullah et al. [22] who concluded that P application accelerate DS of maize. Zinc also delayed DS, which may be due to the fact that Zn control various physiological processes during vegetative growth and thus extended the vegetative growth. These results contradict with Asif et al. [23], who reported earlier DS with addition of zinc.

Table 1. Days to silking of maize as affected by year, nitrogen, phosphorus and zinc levels

Nitrogen (kg ha ⁻¹)	Year		Mean
	2013	2014	
150	58.9	60.0	59.5 c
200	61.3	62.7	62.0 b
250	64.9	65.6	65.3 a
Phosphorus (kg ha⁻¹)			
75	62.7	63.1	62.9 a
125	61.2	62.8	62.0 b
175	61.1	62.4	61.8 c
Zinc (kg ha⁻¹)			
5	60.9	62.1	61.5 c
10	61.6	62.6	62.1 b
15	62.6	63.7	63.1 a
Control	58	58	58 b
Fertilizer	62	63	62 a
Mean	60.0 b	60.2 a	

LSD (0.05) for N = 0.5, LSD (0.05) for P = 0.5, LSD (0.05) for Zn = 0.5

Means followed by different letters in each category are significantly different at 5% level of probability using LSD test.

Grains ear⁻¹

Y, N, P, Zn, control vs fertilizer and the N x P and N x Zn interaction significantly affected grains ear⁻¹ (GE) of maize (Table 2). More GE (442.1) was recorded in the 2014 as compared to 2013. Generally higher GE (497) was recorded for plots that received fertilizer compared with control. Mean values for N revealed that GE increased with each increment of N and maximum GE (582.6) were recorded at 250 kg N ha⁻¹. Similar increases in GE were noted with each increment of P up to 175 kg p ha⁻¹. GE increased with each increment of Zn and higher GE (511.6) was recorded with 15 kg Zn ha⁻¹. N x P interaction indicated that higher GE was recorded with 250 kg N and 175 kg P ha⁻¹. GE was increased with each increment of N at all levels of P (Figure 2). N x Zn interaction indicated that more GE was recorded at 250 kg N and 15 kg Zn ha⁻¹. GE increased with each increment of N at each level of Zn (Figure 3). Nitrogen play an important role in growth of pants and increasing nitrogen

increased growth which produced more dry matter and ultimately resulting in higher GE. Our results are in line with Akhtar [24], who reported that N increase GE. Increase in GE in case of higher level of P may be due to the fact that P is involved in many physiological processes and enhances the nutrient uptake of the plant by proliferating the roots and thus increasing total dry matter production which enhanced GE. These results are in line with Bereaz [25] who reported that GE increases with each increment of P. Zinc also increased GE which may be due to the fact that Zn produces more fertile pollens which results in more seed sets. Moreover, zinc also play important role in pollen tube formation which resulted in fertilization of more number of eggs and lead to higher number of grains ear⁻¹. These results are supported by the findings of Kenbaev and Sade [26], Gul et al. [27] and Harris et al. [28] who concluded that GE increases with each increment of Zn.

Table 2. Number of grains ear⁻¹ of maize as affected by year, nitrogen, phosphorus and zinc levels

Nitrogen (kg ha ⁻¹)	Year		Mean
	2013	2014	
150	377.1	424.0	400.6 c
200	487.9	529.5	508.7 b
250	560.9	604.3	582.6 a
Phosphorus (kg ha⁻¹)			
75	447.2	491.1	469.1 c
125	473.1	514.7	493.9 b
175	505.6	551.9	528.8 a
Zinc (kg ha⁻¹)			
5	459.3	503.6	481.4 c
10	477.2	520.5	498.8 b
15	489.5	533.7	511.6 a
Control	318	365	342 b
Fertilizer	475	519	497 a
Mean	396.7 b	442.1 a	

LSD (0.05) for N = 4.96, LSD (0.05) for P = 4.96, LSD (0.05) for Zn = 4.96

Means followed by different letters in each category are significantly different at 5% level of probability using LSD test.

Figure 2. Number of grains ear⁻¹ of maize as affected by N x P interaction

Figure 3. Number of grains ear⁻¹ of maize as affected by N x Zn interaction

Thousand grains weight (g)

Y, N, P, Zn, control vs fertilizer and the N x P interaction significantly affected thousand grains weight (TGW) of maize (Table 3). Heavier TGW (319.8 g) were recorded in the year 2014 as compared to 2013. Generally higher TGW (338 g) was recorded for plots that received fertilizer compared with control. Mean values for N revealed that TGW increased with each increment of N and maximum TGW (379.9 g) were recorded at 250 kg N ha⁻¹. Similar increase in TGW was noted with each increment of P up to 175 kg P ha⁻¹. TGW was increased with each increment of Zn and higher TGW (343.3 g) was noted with 15 kg Zn ha⁻¹. N x P interaction revealed that TGW was higher with 250 kg N and 175 kg P ha⁻¹. TGW was increased each increment of N at all three levels of P (Figure 4). Increase in TGW in case of N might be due to the fact that nitrogen enhanced the rate of photosynthesis and more dry matter accumulation which

resulted in heavier grains. Our results are in line with Alam and Jan [29] and Hussain et al. [30] who concluded that TGW increases with each increment of N. Similarly P levels also increased TGW which might be attributed to the P role as energy formation and constituent of the plant parts as well as its effect in increasing growth of the crop which resulted in more assimilates formation. These results are in agreement with Sahoo and Panda [31] who reported maximum grain weight with higher P application. In case of Zn thousand grains weight increased due to the involvement of the Zn in enzyme activation, membrane integrity, chlorophyll formation, stomatal regulation and starch utilization at early stages, while enhanced accumulation of assimilate in the grains, which resulted in heavier grains. These results are supported by Harris et al. [28] and Karim et al. [32] who observed increase in TGW with each increment of Zn.

Table 3. Thousand grains weight (g) of maize as affected by year, nitrogen, phosphorus and zinc levels.

Nitrogen (kg ha ⁻¹)	Year		Mean
	2013	2014	
150	282.1	315.1	298.6 c
200	320.1	351.2	335.7 b
250	365.2	394.6	379.9 a
Phosphorus (kg ha⁻¹)			
75	309.4	340.3	324.9 c
125	321.0	353.3	337.2 b
175	337.0	367.3	352.2 a
Zinc (kg ha⁻¹)			
5	316.3	348.0	332.1 c
10	323.3	354.3	338.8 b
15	327.9	358.6	343.3 a
Control	253	286	269 b
Fertilizer	322	354	338 a
Mean	287.6 b	319.8 a	

LSD (0.05) for N = 2.6, LSD (0.05) for P = 2.6, LSD (0.05) for Zn = 2.6

Means followed by different letters in each category are significantly different at 5% level of probability using LSD test

Figure 4. Thousand grains weight (g) of maize as affected by N x P interaction

Soil P (mg kg⁻¹)

Soil P content was significantly affected by years (S), N, P, Zn, control vs fertilizer, N x P x Zn, S x N, S x P, S x Zn and S x Control vs fertilizer interactions (Table 4). Mean values of the data indicated that soil P was higher in the first season after maize harvest and lower soil P was recorded in the 2nd

season. Soil P of unfertilized plots was lower as compared with fertilized plots. Soil P was increased with each increment of N and higher soil P was recorded with application of 250 kg N ha⁻¹ which was statistically at par with N applied at the rate of 200 kg ha⁻¹. Soil P was also increased with each increment of P and higher soil P

was recorded with 175 kg P ha⁻¹. Zn decreased soil P with each increment of Zn and higher soil P was found with application of 5 kg Zn ha⁻¹. N x P x Zn interaction revealed that higher P was recorded with application of 15 kg Zn, 175 kg P and 200 kg N ha⁻¹. Soil P was decreased with increasing Zn level at 75 and 125 kg P irrespective of N, however soil P increased with increase in P, P content were increased with increase in Zn level at 200 kg N ha⁻¹ (Figure 5). S x N interaction indicated that soil P was higher with 200 kg N ha⁻¹ in first season after maize and decreased in 2nd season. S x P interaction revealed that soil P was higher with 175 kg P ha⁻¹ in the first season where as it was decreased after 2nd season. S x Zn interaction revealed soil P was higher with 5 kg Zn ha⁻¹ in the first season, however increasing Zn decreased the soil P in both years. S x control vs fertilizer interaction revealed that higher soil P was recorded in the fertilized plots in first season, whereas the soil P decreased in each season in unfertilized plots. Increase in soil P due to nitrogen application might be attributed to the property of N to decrease

the P uptake which resulted in low use of P. Contradictory results were found by Shehu et al. [33] who reported higher P uptake with increasing N. In case of P fertilizer soil P content increased, which might be attributed to more accumulation of P in soil and the crop take some part of it and the rest remain in soil. Similar results were reported earlier by Shehu et al. [33]. After the first experiment faba bean was grown on the same established plots in rabi season which is a P loving crop, due to which soil P decreased in the 2nd year as compared to the first year. The increase in Zn content decreased the soil P content which might be attributed to the Zn property that P uptake was reduced with increasing Zn which resulted in more P accumulation in soil. These results are in contrast with those of Abbas et al. [34]. The increase in N content with the application of N might be due to the fact that all applied nitrogen was not utilized by the crop, remained in the soil and thus increased the soil N content. These results are in line with Sebilo et al. [35] who reported that increasing N dose also increased soil N.

Table 4. Soil Phosphorus (mg kg⁻¹) as affected by year, nitrogen, phosphorus and zinc levels

Nitrogen (kg ha ⁻¹)	Year		Mean
	2013	2014	
150	2.89	2.66	2.77 b
200	3.11	2.91	3.01 a
250	2.90	2.92	2.91 a
Phosphorus (kg ha⁻¹)			
75	2.89	2.74	2.8 b
125	2.88	2.82	2.85 ab
175	3.13	2.93	3.03a
Zinc (kg ha⁻¹)			
5	3.22	3.14	3.18 a
10	2.84	2.79	2.81 b
15	2.83	2.56	2.69 b
Control	1.63	0.30	0.96 b
Fertilizer	2.97	2.83	2.9 a
Mean	2.30 a	1.57 b	

LSD (0.05) for Years = 0.15, Nitrogen = 0.13, Phosphorus = 0.13, Zinc = 0.13.

Means followed by different letters in each category are significantly different at 5% level of probability using LSD test.

Figure 5. Soil P content as affected by N x P x Zn interaction. Standard error = (T)

Soil Zn (mg kg⁻¹)

Soil Zn was significantly affected by S, P, Zn, control vs fertilizer, N x P, N x P x Zn and S x Control vs fertilizer (Table 5). Mean values of the data indicated that soil Zn was higher in the 3rd season. The soil Zn of unfertilized plots was lower as compared with fertilized plots. Soil Zn was increased with each increment of P and higher soil Zn was recorded with 175 kg P ha⁻¹. Applied Zn also increased the soil Zn with each increment of Zn and higher soil Zn was recorded with application of 15 kg Zn ha⁻¹. N x P interaction indicated that higher soil Zn was recorded with addition of 250 kg N and 175 kg P ha⁻¹, the soil Zn increased with increasing P level and at 250 and 150 kg N ha⁻¹, while the soil Zn decreased with

increasing P at 200 kg N ha⁻¹ (Figure .6). N x P x Zn interactions indicated that higher soil Zn was recorded with 150 kg N, 15 kg Zn and 175 kg P ha⁻¹, soil Zn increased with increasing Zn and P at all levels of N, however the increase was higher at 150 kg N ha⁻¹ (Figure 7). S x control vs fertilizer interaction indicated that Zn content of the soil was higher in fertilized plots in 3rd season after maize and decreased each season in unfertilized plots. Higher soil Zn in case of higher Zn application might be the reason that as micronutrient Zn is required in low quantity by crop, thus crop utilizes some the applied Zn and the rest is leftover in the soil. Similar results were reported by Asad and Rafique [36] and Khan et al. [37].

Table 5. Soil Zn (mg kg⁻¹) after harvest of maize as affected by year, nitrogen, phosphorus and zinc

Nitrogen (kg ha ⁻¹)	Year		Mean
	2014	2015	
150	6.22	6.91	6.56
200	6.43	6.65	6.54
250	6.46	6.81	6.63
Phosphorus (kg ha⁻¹)			
75	6.22	6.69	6.56 b
125	6.32	6.88	6.66 b
175	6.57	6.79	6.68 a
Zinc (kg ha⁻¹)			
5	6.23	6.58	6.40 b
10	6.18	6.83	6.50 b
15	6.70	6.95	6.82 a
Control	2.93	4.40	3.68 b
Fertilizer	6.37	6.79	6.58 a
Mean	4.65 b	5.59 a	

LSD (0.05) for Years = 0.78, Phosphorus = 0.12, Zinc = 0.12

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test.

Figure 6. Soil Zn content as affected by N x P interaction.

Figure 7. Soil Zn content as affected by N x P x Zn interaction ($\bar{x}$ = Standard error).

Conclusion

N, P and Zn applied at the rate of 250, 175 and 15 kg ha⁻¹ respectively increased soil fertility and productivity of hybrid maize 3305.

Authors' contributions

Conceived and designed the experiments: SK Khalil, Performed the experiments: Imranuddin. Analyzed the data: SK Khalil, Contributed reagents/ materials/ analysis tools and wrote the paper: Imranuddin

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