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Full Length Research Paper

Interactive effects of nitrogen, phosphorus and zinc on growth and yield of Tomato (*Solanum lycopersicum*)

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An experiment "interactive effects of nitrogen (N), phosphorus (P) and zinc (Zn) on growth and yield of tomato" was carried out at North Mingora Agriculture Research Station, Pakistan. The experiment was laid out by three factors factorial in a randomized complete block design (RCBD) and all treatments were replicated three times. Four levels of nitrogen (0, 100, 150 and 200 kg/ha), four levels of phosphorus (0, 60, 80 and 100 kg/ ha) and three levels of zinc (0, 5 and 10 ppm) were applied. The results pertaining to various growth and yield parameters showed that early flowerings were observed when plots received phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. In contrast, flowerings were significantly delayed when plots received nitrogen alone at 200 kg/ha. The minimum disease incidence (3.67%) was recorded in plots applied with phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. Maximum number of fruit per plant (41.67) was observed when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. Total yield (28.43 t/ha) was 100% increased as compared to control (13.44 t/ha) when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm.

Key words: Nitrogen (N) - phosphorus (P) – zinc (Zn) interactions, tomato, growth, yield.

INTRODUCTION

Tomato (*Solanum lycopersicum)* is one of the most popular, important and widely used vegetable crops as ranked number two vegetable of the world after potato (Dorais et al., 2008; Olaniyi et al., 2010). It is considered a perennial crop, but for commercial productions it is cultivated as an annual crop (Mohamed et al., 2010). In Pakistan, two crops of tomato are produced annually. For spring crops, the seed is sown in November and seedlings are ready for transplantation in February (Khattak et al., 2007). The second crop is sown in June and seedlings are ready for transplantation in August. However, due to difference in climate condition, changes occur in sowing times such as in Swat (Mingora) spring crop nursery is grown in March and transplanted in April.

Food security for the rapid expanding population is a big challenge and can only be achieved by increasing crop productions and healthy foods. However, the objectives of food security cannot be attained without availability of essential plant nutrients (Chen, 2006; Ali et al., 2008). Therefore, plant nutrients are the essential component of sustainable agriculture. Undoubtedly, for optimum plant growth and production, the essential nutrients must be readily available in sufficient and balanced quantities. The readily available sources, which provide essential nutrients and maintain a favorable balance, are chemical fertilizers. However, suitable and balance combination of macro and micro nutrients are not only essential for plant growth and production, but also good for the environment (Chen, 2006).

Macro nutrients play an important role in growth and development process of the plant such as nitrogen

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Table 1. Physical and chemical properties of the experimental field.

Textural class	Sandy loam
Organic matter	1.21%
Lime	12.2%
Electrical conductivity	0.28 dSm^{-1}
Soil pH	6.2
Nitrogen	0.025%
Phosphorus	3.1 $mgkg^{-1}$
Potash	37.5 $mgkg^{-1}$
Zinc	0.75 $mgkg^{-1}$

encourages vegetative growth (Ali et al., 2003; Wajid et al., 2010) and phosphorus encourages root development and also providing energy by forming ATP (Shaheen et al., 2007). Similarly, micro nutrients are essential as macro nutrients because important growth processes depend on them (Ali et al., 2008). For example, zinc is essential for normal plant growth and development as carbohydrates, protein metabolism and sexual fertilization depend on zinc (Cakmak et al., 1989; Hall, 2002; Imtiaz et al., 2003; Vasconcelos et al., 2011). However, the zinc deficiency in agriculture soil caused by removal of zinc by crops is not fully replenished by fertilizer applications (Akay and Koleli, 2007). In contrast, high concentration and unbalance ratios of both macro and micro nutrients lead to undesirable plant growth and development (Hall, 2002). As reported by Cakmak et al. (1989) that plant growth is severely depressed by zinc deficiency, but high concentration of zinc also reduces dry weight of crop (Imtiaz et al., 2003). It was found that balance fertilization of macro and micro nutrients is essential for the production of high yield and quality products (Swan et al., 2001; Ali et al., 2008), while foliar application of micronutrients to plant is the most effective and safest way (Aghtape et al., 2011). However, little information is available to show interactive effects of macro and micro nutrients on growth and yield parameters of crops (May and Pritts, 1993; Zhu et al., 2001; Islam et al., 2009). Although, tomato is the second major crop of the world after potato, but there is lack of research, particularly under field conditions, to show interactive effects of nitrogen, phosphorus and zinc on tomato. Therefore, the current experiment was conducted to study the effects of nitrogen, phosphorus and zinc to find out suitable interaction for growth and yield of tomato.

MATERIALS AND METHODS

The experiment was conducted, using commercial tomato variety ROMA, at Mingora Research Station during 2002 to 2003. Soil analyses were carried out before experiment to find out physical and chemical compositions of soil and presented in Table 1. The seed of tomato was sown in March and seed bed was made 10 cm above the surface to avoid over irrigation. The experiment was laid out by three factors factorial in a randomized complete block design (RCBD) and all treatments were replicated three times. The experimental plots were ploughed three times before transplantations and size of each plot was kept 3 × 2.25 m. There were three rows in each plot, containing 10 plants per row, in which plant to plant distance was maintained at 30 cm and row to row distance at 75 cm.

Fertilizer application plan

Nitrogen, phosphorus and zinc were applied as Urea, Triple Super Phosphate and Zinc Sulfate. For the experiment, half nitrogen and full phosphorus doses were applied in the preparation of land while half nitrogen was applied in the earthling up stage. The foliar spray of zinc ($ZnSO_4$) was conducted after 15 days of transplantation which was before flowering stage. During experiment, uniform culture practices were maintained from the time of sowing till harvest.

Data recorded

Number of days to flowering and plant height

Five randomly chosen plants, selected from central rows of each plot, were used to determine the total number of days from transplanting to first flowering (40%of the plants) and to measure average plant height at flowering.

Disease incidence percentage: The disease incidence percentage was calculated after twenty days of zinc application.

Number of fruits per plant

Average number of fruits per plant was calculated by labeling five plants in central row and counted number of fruits picked.

Total yield (t/ha)

The yield from first harvest to last harvest was determined for each treatment in all replications and was converted into yield per hectare.

Statistical analysis

The data were analyzed through SPSS software 16 by using analysis of variance techniques (Three ways ANOVA) at 5% significance level, while significant differences between means were further analyzed by using post hoc test. The ANOVA for growth and yield parameters of tomato is presented in Table 2.

RESULTS AND DISCUSSION

Number of days to flowerings

There was a significant interaction effect of nitrogen, phosphorus and zinc on days to first flowering, F (18. 96) = 2.23, p<.05 (Table 2). The post hoc test revealed that plants flowered significantly earlier (M = 30.67, SD = 1.6)

Table 2. Analysis of variance (ANOVA) for growth and yield parameters of tomato.

Sources	D.F	Days to flowering	Plant height at flowering	Disease incidence	Number of fruits per plant	Total yield (ton/ha)
		MS	MS	MS	MS	MS
Nitrogen (N)	3	357.470**	2165.647**	622.544**	278.167**	104.738**
Phosphorus (P)	3	363.414**	107.845**	395.859**	569.907**	297.377**
Zinc (Zn)	2	709.771**	24.486**	375.132**	1551.444**	86.661**
N × P	9	13.785**	26.690**	26.248**	34.667**	6.149**
N × Zn	6	19.345**	12.687**	3.336NS	28.222**	0.433 NS
P × Zn	6	1.289NS	3.340NS	23.262**	23.380*	0.560NS
N × P × Zn	18	2.900**	5.716NS	5.873**	23.231**	4.567**
Error	96	1.299	3.662	1.785	8.167	0.655

MS = Mean Square,*, ** = Significant at 5 and 1% respectively, NS = Non Significant.

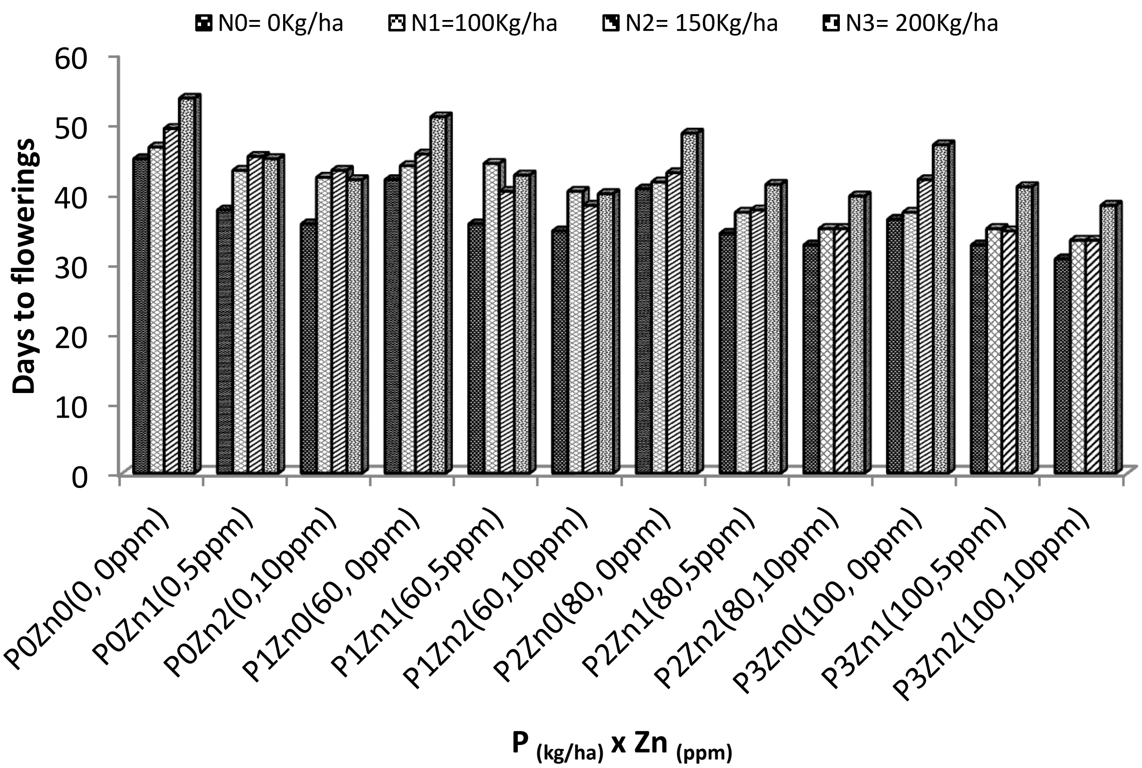

Figure 1. Interaction effects of N, P and Zn on number of days to flowerings.

than control (M= 45.3, SD = 1.2) when received phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. Similarly, early flowerings were also observed in those plots which had received phosphorus at 80 kg/ha and zinc at 10 ppm (M= 32.43, SD= 1.52) or phosphorus at 100 kg/ha and zinc at 5 ppm (M= 32.43, SD= 0.67) without nitrogen. In contrast, flowerings were significantly delayed (M= 53.7, SD= 1.2) when plots received nitrogen at 200 kg/ha without phosphorus and zinc. Additionally, flowerings were also significantly delayed in those plots which had received nitrogen at 200 kg/ha with phosphorus at 60 kg/ha (M= 51.00, SD= 1.1) without zinc or nitrogen alone at 150 kg/ha (M= 49.33 and SD= 0.56). The results clearly showed that early flowerings were encouraged by phosphorus and zinc, but delayed by nitrogen (Figure 1). Noticeably, early flowerings were observed when plots received low level of phosphorus (80 kg/ha) with high level of zinc (10ppm) or high level of phosphorus (100 kg/ha) with low level of zinc (5 ppm). This showed that there were some antagonistic effect of

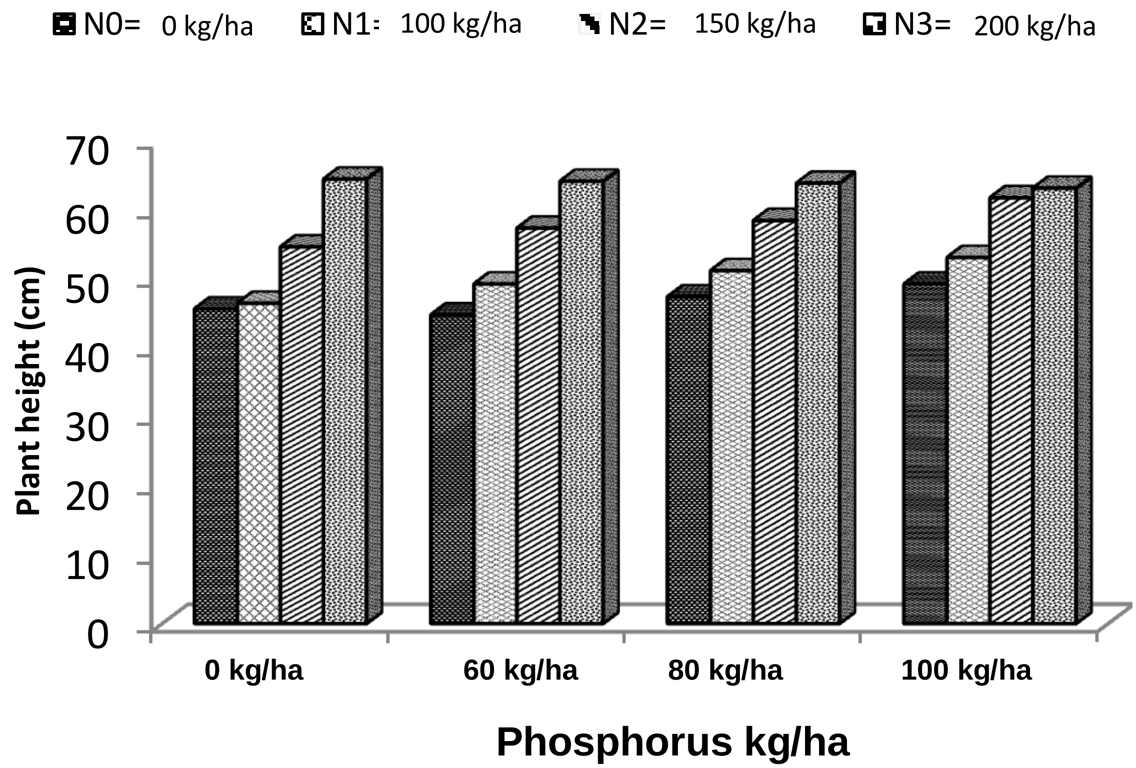

Figure 2a. Interaction effects of N and P on plant height.

phosphorus on zinc which was also observed by Islam et al. (2009) when he studied the effect of phosphorus on micronutrients availability to plants.

Plant height at flowerings

Plant height at flowerings was not significantly affected by the interaction of nitrogen, phosphorus and zinc, F (18, 96) =1.56, p>.05 (Table 2). Similarly, phosphorus and zinc interaction had no significant effect on plant height at flowering, F (6, 96) =0.91, p>0.05 (Table 2). On the other hand, plant height was significantly affected by the interaction of nitrogen and phosphorus, F (9, 96) =7.28, p<0.05, as well as nitrogen and zinc, F (6, 96) =3.64, p<0.05 (Table 2). Post hoc analysis of N-P interaction showed that plant height was maximum (M= 64.36, SD= 1.94) than control (M= 45.6, SD= 6.37) in those plots which were treated with nitrogen at 200 kg/ha without phosphorus followed by those plots which had received nitrogen at 200 kg/ha with phosphorus at 60 kg/ha (M= 64.2), 80 kg/ha (M= 63.76) and 100 kg/ha (M= 63.04). Similar pattern was also observed for N-Zn interaction in which plant height was maximum when plots received nitrogen at 200 kg/ha with or without zinc (Figure 2b). As observed in Figure 2a and b, plant height was increased more by nitrogen than phosphorus and zinc. The reason may be that nitrogen encourages vegetative growth while phosphorus and zinc encourages reproductive growth. This was also reflected in the data collected for days to flowerings where flowerings were encouraged by P and Zn but was depressed by N. These findings could give further support to observations made by Ali et al. (2003), Manzoor et al. (2006) and Wajid et al. (2010) reported that nitrogen shifts the balance from reproductive to vegetative growth as a result excessive vegetative growth but minimum flowerings.

Disease incidence percentage

A single disease early blight was observed which is caused by *Alternaria solani* in tomato. The analysis of the data related to disease incidence (%) showed that it was significantly affected by the interaction of nitrogen, phosphorus and zinc, F (18, 96) =3.29, p<0.05 (Table 2).

Further analysis of the data by post hoc test showed that significantly minimum disease incidence (3.67%) than control (17.2%) was recorded in those plots which had treated with phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. Similarly, other plots which showed great resistance towards disease were those which had received phosphorus at 80 kg/ha and zinc at 10 ppm (4.33%) or phosphorus alone at 100 kg/ha (4.67%). In

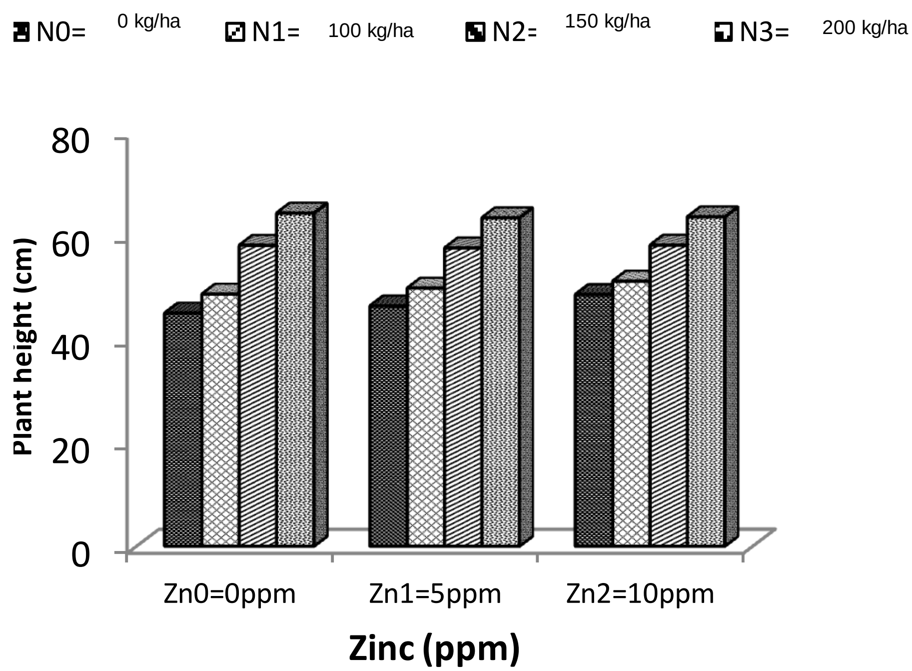

Figure 2b. Interaction effects of N and Zn on plant height.

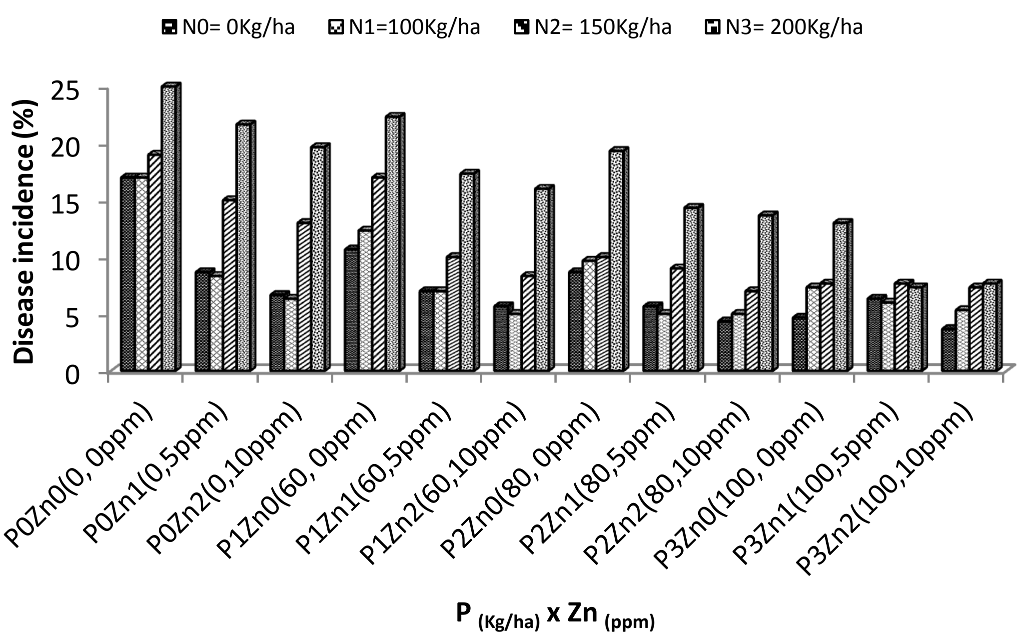

Figure 3. Interaction effects of N, P and Zn on disease incidence (%).

contrast, maximum disease incidence was recorded in those plots which were applied nitrogen at 200 kg/ha alone (25%) or with low level of phosphorus (22.32%) or zinc (21.67%). From Figure 3, it can be seen that plant resistance towards fungal disease was increased by P and Zn but decreased by N. The reason may be that nitrogen encouraged tender vegetative growth which was more susceptible to fungal disease. These findings could further validate the claim made by Snoeijers et al. (2000) that high concentration of nitrogen increases plant susceptibility towards diseases, and Shaheen et al. (2007) that phosphorus increases plant resistance

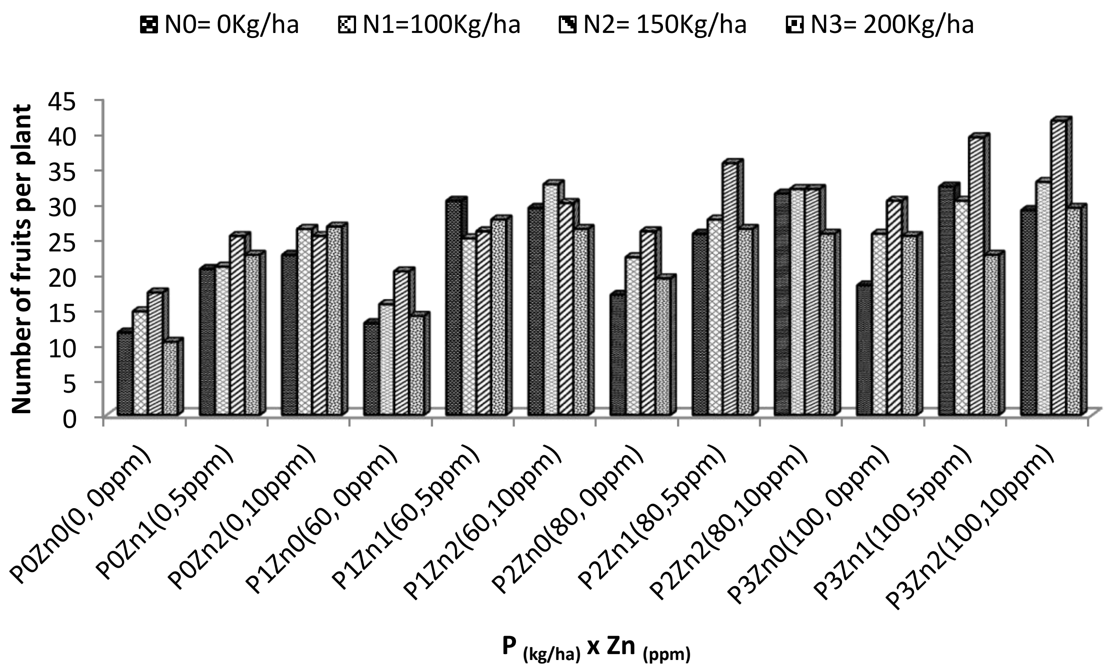

Figure 4. Interaction effects of N, P and Zn on number of fruits per plant.

diseases.

Number of fruits per plant

The analysis of the data showed that number of fruits per plant was significantly affected by the interaction of nitrogen, phosphorus and zinc, F (18, 96) =2.845, p<0.05 (Table 2). To find out exact differences, further analysis was performed by using post hoc test. The test showed that maximum number of fruits per plant (M=41.67, SD= 6.65) than control (M=11.67, SD= 1.53) was observed in those plots which had received nitrogen at 150 Kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. Similarly, second highest number of fruits per plant (M=39.33, SD= 3.05) was recorded in those plots which had given nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 5ppm. In contrast, minimum number of fruits per plant (M=10.33, SD= 1.53) was found in those plots which had received nitrogen at 200 kg/ha without phosphorus and zinc. As noticed in Figure 4, number of fruits per plant was higher in those plots which had received suitable combinations of N, P and Zn, which showed that these nutrients played important role in fruits set. The close observations of the data showed that number of fruits per plant and fruit set were mainly depended upon P and Zn. For example, without P and Zn, the number of fruits per plant was significantly decreased by nitrogen. Similar observations were also made by Mohamed et al. (2011) that both P and Zn improve flower formation, while Wajid et al. (2010) reported that high concentration of N depressed reproductive growth.

Total yield (t/ha)

The yield data, originally collected in kg, was converted to t/ha before analysis. The analysis of the data showed that total yield was significantly affected by the interaction of nitrogen, phosphorus and zinc, F (18, 96) =6.97 p<0.05 (Table 2). Post hoc analysis of the data showed that highest yield (M=28.43, SD = 0.45) as compared to control (M= 13.44, SD= 0.16) was observed in those plots which had received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. On the other hand, total yield was slightly reduced (M=11.8, SD=1.1) than control when plots received nitrogen at 200 kg/ha without phosphorus and zinc. From Figure 5, it can be observed that total yield was positively increased (except for N at 200 kg/ha) by the application of nitrogen, phosphorus and zinc alone and their interactions. Noticeably, highest yield of tomato is strongly related to suitable combinations of nitrogen, phosphorus and zinc. For example, total yield (28.43 t/ha) was hundred percent increased as compared to control (13.44 t/ha) when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. However, it is important to mention that yield was also adversely affected by high concentration of nitrogen in the absence of phosphorus and zinc. This might be due to the fact that nitrogen encourages vegetative growth over reproductive growth which decreases yield (Ali et al., 2003; Wajid et al., 2010).

Conclusions

The interactive effects of nitrogen, phosphorus and zinc

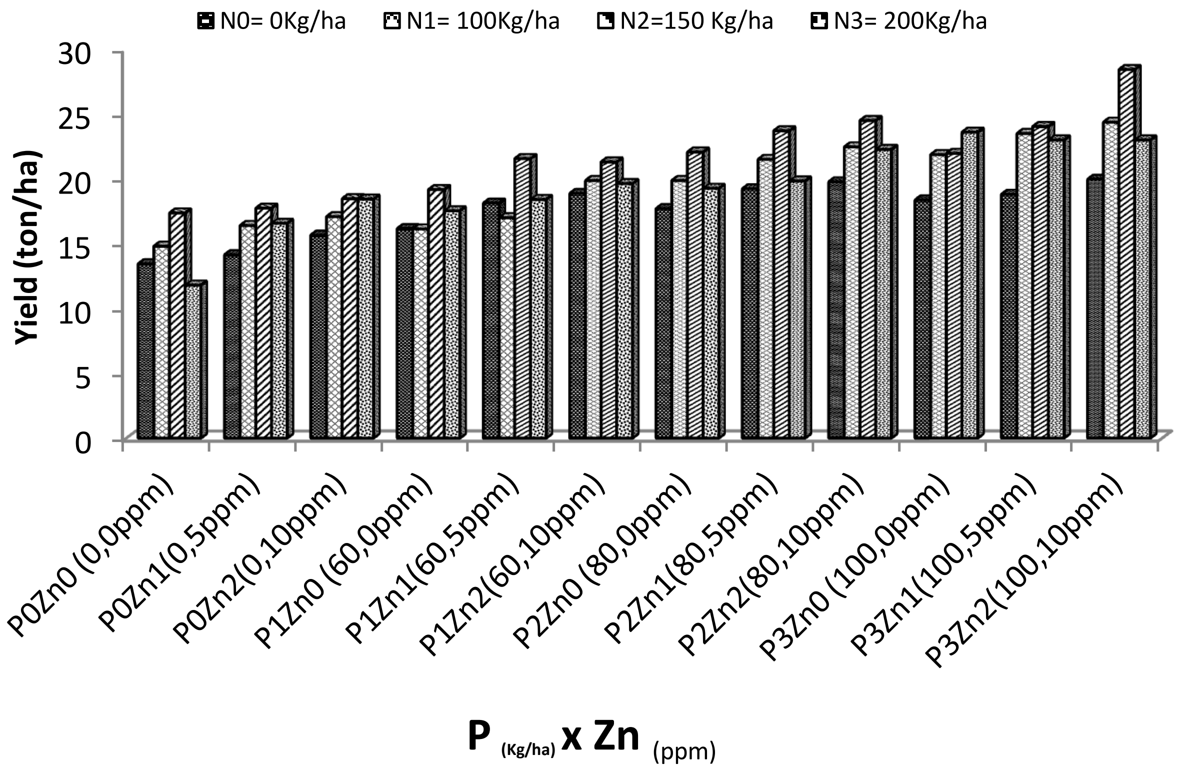

Figure 5. Interaction effects of N, P and Zn on total yield.

on growth and yield parameters of tomato were investigated. The results indicated that growth and yield parameters of tomato were significantly related to suitable combinations of nitrogen, phosphorus and zinc. Flowerings and fruit set were increased by combinations of P and Zn but was decreased by high levels of N. In contrast, plant height was increased by N more than P and Zn, but resistance towards fungal disease was significantly decreased. Interestingly, number of fruits perplant and total yield were hundred percent increased by combinations of N, P and Zn when plots received N at 150 kg/ha, P at 100 kg/ha and zinc at 10 ppm. However, yield started to decline from peak when P and Zn were kept constant (P at 100 kg and Zn at 10 ppm), but nitrogen was increased from 150 to 200 kg/ha. Therefore, to make recommendation and generalization about these combinations of N, P and Zn (150 and 100 kg/ha and 10 ppm) for highest yield, further research needs to be carried out to check combinations of N at 200 kg/ha with higher levels of P (above 100 kg/ha) and Zn (above 10 ppm). However, cost of fertilizers and water pollutions through high fertilizations should also be kept in mind when making recommendations for highest yield through high levels of fertilizations. In general, it can be concluded that compared to control best growth, disease resistance and yield of tomato for this experiment were obtained when plots received N at 150 kg/ha, P at 100 kg/ha and zinc at 10 ppm.

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