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Effect of fertility levels on growth, yield and soil fertility status of maize (*Zea mays* L.) in vertisol of Maharashtra

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Abstract: A field experiment was conducted at the experimental farm, AICRP on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during 2014-15 to assess the nitrogen, phosphorus and zinc requirement for maize crop. The experiment was laid out in a split plot design using eight treatments with three replications. The main plot consists of three levels of Nitrogen i.e., 100 kg ha^{-1}(N_1), 125 kg ha^{-1}(N_2),150 kg ha^{-1}(N_3) with two Zinc levels *viz.*,25 kg ha^{-1}(Z_1), 35 kg ha^{-1}(Z_2) and sub plot comprised of three levels of 50 kg ha^{-1}(P_1), 75 kg ha^{-1}(P_2)and 100 kg ha^{-1}(P_3). Application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 35 kg Zn ha^{-1} recorded significantly higher growth at 5% level of significance attributes *viz.,* plant height (218.64), no. of functional leaves (11.30), leaf area $plant^{-1}$ (65.07 cm^2), total dry matter $plant^{-1}$ (269.08) and grain yield (6705.8 kg ha^{-1}), husk yield (1378.2 ha^{-1}), spindle yield (1642.6 ha^{-1}), stover yield (7161.0 ha^{-1}) and biological yield (13866.8 ha^{-1}). The nutrient status after harvest of maize was highest in the treatment combination of $N_3P_3Z_2$ receiving 150 kg N ha^{-1}, 75 kg P ha^{-1} and 35 kg $ZnSO_4$ ha^{-1}. But the result were at par with the treatment combination $N_2P_2Z_1$ which received 125 kg N ha^{-1}, 75 kg P ha^{-1} and 25 kg $ZnSO_4$ ha^{-1}. From the results, it was concluded that the maximum growth, yield, & post harvest nutrient status could be achieved by judicious application of chemical fertilizers (N, P & Zn).

Keywords: Growth, Maize, Vertisols, Yield, Zinc

INTRODUCTION

Maize plays a vital role in ensuring food security as well as nutritional security through quality protein. In Maharashtra, the area and production of maize is about 1.21 million hectares and 3.98 million tonnes productions with the productivity of 2544 kg ha^{-1} (Anonymous, 2014). The main challenge before India is to increase the production of quality food in a sustainable manner and feeding the country's large population and ultimately in increasing the income of the farmer. The requirements of fertilizers in maize are important for the early growth and total production of yield. Maize requires heavy feeding for its potential production of yield. Indiscriminate use of inorganic fertilizers leads to nutrient imbalance in soil causing ill effect on soil health and micro flora (Choudhary *et al.,* 2015). Unfortunately, continuous application of higher amount of fertilizer may pose deleterious effects which leads to decline in productivity, deteriorates the physical, chemical and biological properties of soil. Land being marginal and farmers poorer, it is important to prevent the unnecessary over use of fertilizer to minimize the effect on the soil and most importantly, reduce the production cost.

Nitrogen is universally deficient in majority of Indian soil and experiment which are conducted at various places in different agro climatic zones of India indicated that nitrogen has beneficial effect on growth, yield attributing characters and yield of maize. The importance of phosphorus has been emphasized by many workers (Arya and Singh, 2001). After Nitrogen and phosphorus, Zinc has been reported as the third most important limiting nutrient elements in crop production. Manan *et al.* (2013) concluded that significant increase in grain yield was found with application of increased level of Nitrogen and Phosphorus up to 60% higher than the control. Therefore, application of ample quantities of plant nutrients is a key aspect of increasing overall maize productivity. Further increase in maize production will require the transfer of better technology particularly in fertilizer application at farmer's level. Therefore, the knowledge of nitrogen, phosphorus and zinc, their dose, method and application rate must be properly evaluated for maize crop as information on the influence of these nutrients levels on yield components and yield of maize is lacking in Marathwada region. In view of the above, a study into the effect of fertility levels on growth, yield and soil fertility status of maize (*Zea mays* l.) was undertaken.

MATERIALS AND METHODS

The experiment was conducted at Experimental farm, All India Coordinated Research Project on Integrated

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Farming Systems, VNMKV, Parbhani. Geographically Parbhani is situated 409m above the mean sea level, 19º16¹ North latitude and 76º 47¹ East longitude in Marathwada region of Maharashtra state and has sub tropical climate. The soil of the experimental area was clayey in texture, low in Nitrogen, medium in Phosphorus, high in Potassium, low in available Zn and slightly alkaline in reaction. The experiment was laid out in split plot design with three replications. Treatments were eighteen (18) comprising of a combination of nitrogen (3), zinc (2) and phosphorus (3) levels. Treatment allocation to plots in each replication was done randomly. The levels of nitrogen are 100,125 and 150 kg ha^{-1} and zinc levels are 25 and 35 kg ha^{-1} in main plot and three phosphorus levels (50, 75 and 100 kg ha^{-1}) in sub-plots. The trial was conducted in Kharif 2014. Nitrogen was applied through neem coated urea - 46% as per treatments in two equal splits at sowing (basal) and knee height stage (top dress). The full dose of phosphorus and zinc were applied through single super phosphate (SSP-16%) and Zinc sulphate ($ZnSO_4$ – 23%) as per treatment at the time of sowing respectively. A common dose of potassium was applied through muriate of potash at the rate of 75 kg ha^{-1} to all treatment plots at sowing. Maize hybrid, RASI-3022 was dibbled along a row spacing of 60 cm x 30cm, with a seed rate of 18 kg ha^{-1}. The physiological studies on growth parameters like leaf area index (LAI), absolute growth rate (AGR), relative growth rate (RGR) were computed from growth characters namely: height, dry matter and leaf area $plant^{-1}$ to study the growth and development of plants as influenced by treatments. AGR of two growth characters *viz.* plant height and total dry matter accumulated was calculated using the formula given by Richards (1969), RGR was calculated using the formula as per Fisher (1921) and LAI as given by Watson (1952).The soil samples after harvest of the crop was analyzed for status of available N, P and Zn. The available N was analyzed by Kjeldhal method (Piper, 1966), available P (Olsen *et al.* 1954), available K by flame photometer (Hanway and Heidal, 1967) and available Zn (ppm) by Atomic Absorption spectrophotometer.

AGR (cm plant $\frac{H_2 - H_1}{t_2 \quad - t_1}$ ……..for plant height

AGR (g $\frac{W_2 - W_1}{t_2 \quad - t_1}$ plant …….. for dry matter

H
RGR (g g $\frac{(logeW_2 - logeW_1)}{t_2 \quad - t_1}$

LAI = $\frac{Leafareaperplant}{Groundareaperplant}$ $\frac{Leafareaperplant(dm^2)}{Groundareaperplant(dm^2)}$

RESULTS AND DISCUSSION

Effect on growth attributes: In present investigation plant height increased with a rise in nitrogen level, application of 150 kg N ha^{-1} was superior compared to 125 kg and 100 kg N ha^{-1}. AGR for plant height was also higher with increased N level. This effect may be attributed to the fact that N causes cell elongation, acts as a principal constituent of protein, enzymes, hormones, vitamins, chlorophyll and thus accelerates the meristematic activity of plant that led to progressive increase in internodes length. This result is in conformity with works of Sepat and Kumar (2007) in respect to growth attributes of maize crop.

The maximum number of functional leaves, leaf area and leaf area index were recorded by 150 kg N ha^{-1}. The increase in leaf number, leaf area as well as leaf area index with increase dose of N could be related to the increases in photosynthetic activity due to balance N nutrition which resulted in more leaf growth. Meena *et al*. (2011) reported similar findings. They conducted field experiment at New Delhi to assess the growth, yield and nutrient uptake behavior of maize–wheat cropping system under different bio-sources and nitrogen levels. Six combinations of organic sources [control, farmyard manure (FYM) and vermicompost (VC)] with and without *Azotobacter* application in main-plots and four N fertilizer treatments (0, 40, 80 and 120 kg N/ha) in sub-plots were tested. Dry matter accumulation $plant^{-1}$, AGR and RGR were higher with increased N rate up to 150 kg N ha^{-1} in the present investigation with respect to maize crop. Similar findings were also reported by Akmal *et al*. (2010) in an experiment which was conducted at NWFP Agriculture University, Peshawar, to study performance of different maize varieties and Nitrogen rates (90, 120, 150 kg ha^{-1}) for growth, yield and yield components. They revealed that heavier grains in number and weight were due to higher LAI and application of 150kg N ha^{-1} recorded taller plants maximum biological and seed yield which corroborate my results.

The increased levels of P accomplished the requirement of P nutrition and caused rapid root development that resulted in improved plant growth which consequently showed significant translocation and storage of photosynthates from source to sink. A similar trend was reported by Masood *et al.* (2011) at the Agricultural Research Institute, Tarnab (Peshawar) for the maize crop. The value of plant height, AGR for plant height, as well as dry matter increased with a rise in P level up to 100 kg ha^{-1} at all growth stages. It might be due to the beneficial effect of higher level of P on growth and development. Same kind of trend is observed with higher values of LAI and leaf area with higher level of P. Rapid plant growth and development with the highest rate of P was also earlier reported by Amanullah and Muhammad Zakirullah (2010). They conducted an experiment on maize crop with timing and rate of phosphorus (30, 60 and 90 kg P ha^{-1}) application at Tamilnadu Agricultural University, Coimbatore Growth parameters of maize increased with a rise

Table 1. Plant height (cm), No. of functional leaves, leaf area plant^{-1}(dm^2), total dry matter plant^{-1}(g) of maize as influenced by different treatments.

Treatments	Plant height		No. of functional leaves		Leaf area plant^{-1}		Total dry matter plant^{-1}	
	75DAS	90DAS	75 DAS	90 DAS	75 DAS	90 DAS	75 DAS	90 DAS
N levels (kg ha^{-1}) - Main plot								
N_1 - 100	187.58	188.65	12.49	9.44	83.26	47.71	184.11	220.41
N_2 - 125	207.55	208.67	13.73	10.51	94.73	59.59	203.86	255.19
N_3 - 150	217.59	218.64	14.19	11.30	102.76	65.07	228.06	269.08
S.E. ±	3.58	4.14	0.30	0.27	3.08	2.15	2.58	4.44
C.D. at 5%	11.2	13.0	0.95	0.84	9.69	6.76	8.11	13.9
Z levels (kg ha^{-1}) - Main plot								
Z_1 - 25	204.21	205.31	12.47	9.39	89.08	54.96	198.56	246.71
Z_2 - 35	206.29	205.32	14.87	10.97	95.01	59.09	212.13	255.74
S.E. ±	2.92	3.38	0.25	0.22	2.51	1.76	2.10	3.63
C.D. at 5%	NS	NS	0.78	0.68	NS	NS	6.62	NS
P levels (kg ha^{-1}) – Sub plot								
P_1 - 50	183.89	185.01	12.25	9.24	92.01	53.52	194.08	233.72
P_2 - 75	204.28	205.35	14.62	10.40	94.09	57.60	209.91	249.12
P_3 - 100	207.58	208.60	15.14	10.90	94.41	57.86	215.95	262.84
S.E. ±	5.86	5.90	0.26	0.32	0.82	0.49	2.16	4.76
C.D. at 5%	17.1	17.2	0.77	0.92	2.39	1.42	6.28	13.9
Interaction								
N x Z								
S.E. ±	5.06	5.86	0.43	0.38	4.36	3.04	3.64	6.28
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
N x P								
S.E. ±	10.16	10.22	0.46	0.55	1.42	0.85	3.73	8.24
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
Z x P								
S.E. ±	8.29	8.35	0.37	0.45	1.16	0.69	3.05	6.73
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
N x Z x P								
S.E. ±	14.37	14.46	0.64	0.78	2.01	1.20	5.28	11.7
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
General mean	202.37	203.19	13.72	10.18	93.17	56.93	205.83	249.10

in zinc application but not in all growth stages. Plant height, number of functional leaves, leaf area and dry matter plant^{-1} varied significantly to difference in zinc levels at 5% level of significance. Zinc enhances root development leading to improve N uptake and rapid vegetative growth. Hence the improve gains up to 35 kg $ZnSO_4$ ha^{-1}. Shafea and Saffari (2007) observed similar results; they conducted a field experiment to evaluate the effect of zinc and nitrogen at the experimental farm of Shiraz University, Kerman (Iran).

Growth functions viz. AGR, RGR and LAI were not markedly influenced by different zinc levels, though 35 kg $ZnSO_4$ ha^{-1} produced maximum rate in most instances over 25 kg $ZnSO_4$ ha^{-1}. Increase in maize growth due to zinc application was reported by Mahdi *et al*., 2012 at Shalimar, Srinagar.

Effect on yield: A significant difference at 5% level of significance in maize grain yield, husk yield, spindle yield and biological yield ha^{-1} were observed due to different N levels. Application of 125 kg N ha^{-1} being on par with 150 kg N ha^{-1} significantly improved grain and stover yield over 100 kg N ha^{-1}. The nitrogen application at 125 kg and 150 kg ha^{-1} recorded (6705.8, 6428.4 and 7161, 6811.2 kg ha^{-1}) grain and stover yield respectively. Maximum husk, spindle and biological yield of (1378.2, 1642.6 and 13866.8 kg ha^{-1}) were obtained by N application at 150 kg ha^{-1} and were significantly superior at 5% level of significance over 125 kg and 100 kg ha^{-1}.

The increment in grain and biological yield with a rise in N level might be attributed to the optimum utilization of solar light, higher assimilates production due to higher growth character and it conversion to starches resulted in higher yield attributes, biomass and seed yield. Lower N fertilization decreased the grain and stover yield because it affects the number of endospermatic cell and starch granules in the early post flowering period and also causes the reduction of source assimilation during grain filling period. These results agree with those reported by Manan *et al*. (2013). They conducted a field experiment at Punjab Agricultural University, Ludhiana, to study the effect of preceding rainy-season (*Kharif*) crops, via. Soybean [Glycine *max* (L.) Merr.], maize (*Zea mays* L.) and rice (*Oryza*

Table 2. Absolute growth rate (cm plant^{-1} day^{-1}) for plant height, AGR for dry matter (g plant^{-1} day^{-1}), RGR for dry matter accumulation (g g^{-1} day^{-1}) and leaf area index as influenced by different treatments in maize.

Treatments	AGR for plant height		AGR for dry matter		RGR for dry matter accumulation		Leaf area index	
	61-75 DAS	76-90 DAS	61-75 DAS	76-90 DAS	61-75 DAS	76-90 DAS	75 DAS	90 DAS
N levels (kg ha^{-1}) - Main plot								
N_1 - 100	0.93	0.071	5.29	2.41	0.038	0.012	4.799	2.835
N_2 - 125	1.59	0.074	5.98	3.42	0.039	0.015	5.262	3.122
N_3 – 150	1.82	0.070	7.01	2.73	0.041	0.012	5.429	3.430
Z levels (kg ha^{-1}) - Main plot Z_1 - 25	1.46	0.073	5.59	3.21	0.038	0.014	5.151	3.125
Z_2 - 35	1.44	0.070	6.40	2.91	0.040	0.012	5.176	3.133
P levels (kg ha^{-1}) – Sub plot								
P_1 - 50	1.46	0.075	6.03	2.64	0.040	0.012	5.061	2.974
P_2 - 75	1.47	0.071	6.12	2.61	0.038	0.012	5.205	3.199
P_3 - 100	1.43	0.070	6.05	3.12	0.039	0.013	5.224	3.214
General mean	**1.45**	**0.072**	**6.06**	**2.88**	**0.039**	**0.014**	**5.163**	**3.129**

Table 3. Grain yield, husk yield, spindle yield, Stover yield and biological yield (kg ha^{-1})as influenced by different treatments in maize.

Treatments	Grain yield	Husk yield	Spindle yield	Stover yield	Biological yield
N levels (kg ha^{-1}) - Main plot					
N_1 - 100	5509.7	766.9	1092.2	6477.8	11987.5
N_2 - 125	6428.4	1127.1	1454.2	6811.2	13299.6
N_3 - 150	6705.8	1378.2	1642.6	7161.0	13866.8
S.E. ±	215.9	29.0	28.4	111.1	26.2
C.D. at 5%	679.3	91.2	89.5	323.8	82.3
Z levels (kg ha^{-1}) - Main plot					
Z_1 - 25	5652.2	1027.9	1375.6	6692.8	12345.0
Z_2 - 35	6105.6	1153.6	1417.1	6940.6	13046.2
S.E. ±	176.3	23.7	23.2	67.3	21.4
C.D. at 5%	NS	74.4	NS	211.6	67.2
P levels (kg ha^{-1}) – Sub plot					
P_1 - 50	5716.6	966.3	1299.4	6504.7	12221.3
P_2 - 75	6003.2	1094.7	1413.5	6782.2	12785.4
P_3 - 100	6126.0	1211.2	1476.2	6843.0	12969.0
S.E. ±	88.19	35.8	41.2	82.4	27.1
C.D. at 5%	257.0	104.3	120.1	291.2	84.0
Interaction					
N x Z					
S.E. ±	305.4	41.0	40.2	157.1	37.0
C.D. 5%	NS	NS	126.5	NS	NS
N x P					
S.E. ±	152.8	62.0	71.4	192.5	65.9
C.D. 5%	NS	NS	NS	NS	NS
Z x P					
S.E. ±	124.7	50.6	58.3	116.5	53.8
C.D. 5%	NS	NS	NS	NS	NS
N x Z x P					
S.E. ±	216.0	87.6	100.9	272.2	81.2
C.D. 5%	NS	NS	NS	NS	NS
General mean	6009.7	1090.7	1396.4	6776.7	12800.1

sativa L.), farmyard manure 0 and 20 t ha^{-1} and nitrogen 0, 100, 140, 180, 220 kg ha^{-1} on winter maize. Harvest index was highest at 150 kg N ha^{-1} (48.4%). It was significantly higher with application of 255 kg N ha^{-1} over 75 kg and 150 kg N ha^{-1} as reported by Tyagi *et al*. 1998.

Maize grain yield did not differ significantly with different zinc fertility levels. The zinc application at the rate 35 kg $ZnSO_4$ ha^{-1} recorded a grain yield of (6105.6 kg ha^{-1}) and was at par with (5652.2 kg ha^{-1}) that of 25 kg $ZnSO_4$ ha^{-1}. Increasing the amount of Zn applied

Table 4. Post harvest Available N, P and Z content in soil as influenced by different treatments.

Treatments	kg ha^{-1}		ppm
	N	P	Z
N levels (kg ha^{-1}) - Main plot			
N_1 - 100	131.65	20.92	1.81
N_2 - 125	133.61	21.22	1.87
N_3 - 150	141.80	21.81	1.88
S.E. ±	1.08	0.24	0.04
C.D. at 5%	3.40	0.76	NS
Z levels (kg ha^{-1}) - Main plot			
Z_1 - 25	131.90	21.06	1.77
Z_2 - 35	133.08	21.57	1.93
S.E. ±	1.01	0.19	0.03
C.D. at 5%	NS	NS	0.11
P levels (kg ha^{-1}) – Sub plot			
P_1 - 50	133.95	20.15	1.84
P_2 - 75	135.71	21.05	1.85
P_3 - 100	137.40	21.74	1.86
S.E. ±	1.13	0.24	0.04
C.D. at 5%	3.29	0.69	NS
Interaction			
N x Z			
S.E. ±	1.52	0.34	0.06
C.D. 5%	NS	NS	NS
N x P			
S.E. ±	1.96	0.41	0.07
C.D. 5%	NS	NS	NS
Z x P			
S.E. ±	1.60	0.34	0.06
C.D. 5%	NS	NS	NS
N x Z x P			
S.E. ±	2.77	0.58	0.10
C.D. 5%	NS	NS	NS
General mean	134.8	21.19	1.85
Initial content	186.42	17.18	1.42

from (10 to 40 kg ha^{-1}) did not affect grain yield statistically (Olusegun and Chirwa, 2014). However, stover yield and biological yield of maize were significantly superior at 5% level of significance with 35 kg $ZnSO_4$ ha^{-1}. The highest value of harvest index i.e. 46.7% was noted with 35 kg $ZnSO_4$ ha^{-1}. The result of this research confirms the previous works of Sharma *et al.* (1992). They have conducted a field experiment during *Kharif* season at Agriculture Research Station, Rajasthan Agriculture University, Banswara and reported that mean grain and stover yield of maize increased by 1.51 kg ha^{-1} and 30.39 kg ha^{-1} with increasing zinc levels from 0 to 25 kg ha^{-1} respectively. Zinc is reported to enhance the absorption of native as well as added major nutrients such as Nitrogen and Phosphorus, thereby increased yield attributes and production of maize (Bhattacharaya *et al.*, 2008).

Phosphorus levels had significant effect at 5% level of significance on grain, stover and biological yield of maize. Phosphorus application at 100 and 75 kg ha^{-1} recorded at par higher grain yield of 6126 kg and 6003.2 kg ha^{-1} respectively and were significantly superior at 5% level of significance over 50 kg ha^{-1} (5716.6 kg ha^{-1}). Further increase in phosphorus from 75 to 100 kg ha^{-1} though increased the grain yield but failed to record statistical significance. In case of stover and biological yield same kind of trend is observed. Harvest index of maize increased up to 100 kg P ha^{-1} (47.2%). The increase in maize yield at higher phosphorus level probably, may be ascribed to the increase in cob number, number of grains row and number of grains cob^{-1} as well as heaviest grain weight. A good and optimum supply of phosphorus is associated with increase root growth due to which the plants explore more soil nutrients and water. The increase in grain yield due to increase Phosphorus application was also reported by Nsanzabaganwa *et al.* (2014). Nitrogen and Phosphorus play vital role in different metabolic activities and in improving nutritional status of plants. Application of 150 kg Nitrogen + 100 kg Phosphorus ha^{-1} might have supplied Nitrogen and Phosphorus to the plants to the level of sufficiency that was able to improve yield attributes and finally the yield. The present findings are in close agreement with that of Suthar *et al.* (2014) and Owla *et al.* (2015) with respect to maize crop. The increase grain yield of maize might be due to the increased availability of essential nutrients from the enhanced level of nutrients applied to the crop. Choudhary *et al.* (2012) observed that increasing phosphorus level enhance maize yield when they conducted the experiment consisting of 24 treatments having combination of 3 levels of phosphorus (20, 30 and 40 kg P2O5/ha), 2 levels of FYM (0 and 10 t/ha) and 4 combination of biofertilizer (control, PSB, VAM and PSB + VAM).

Table 5. Spindle yield ha^{-1} as influenced by N x Z interaction in maize.

Treatment	Spindle yield kg ha^{-1}	
	Z_1	Z_2
N_1	1024.6	1159.9
N_2	1393.1	1515.3
N_3	1573.8	1711.4
S.E. ±	40.2	
C.D. 5%	126.5	

Effect of soil fertility status: Soil fertility is a measure of the available nutrient status in soil. It helps to detect the efficiency of fertilizers applied and used by the crop. The soil fertility status after the harvest of maize indicated that there were significant differences in the availability of major nutrient (N, P) and Micronutrient (Zn) in soil. The data revealed that available N, P and Zn were highest in N_3 than that of N_2 and N_1. The nutrient status of the experimental soil after harvest of maize crop indicated a higher available N, P and Zn with higher levels of N. Available N was highest and significant at 5% level of significance with application of 150 kg N ha^{-1} compared to other N levels. P content in soil was shown high up to 75 kg ha^{-1}. Available Zn in soil was not affected significantly by N levels. Paramasivan *et al.* (2011) carried an experiment to study the effect of inorganic fertilizers on yield and nutrient uptake of maize (*Zea mays* L.) in Peelamedu soil series at Tamil Nadu Agricultural University, Coimbatore also showed the similar kind of findings in relation with the post harvest status of soil in relation with the Nitrogen, Phosphorus, Potassium and Zinc.

Available N, P and Zn status of soil increased with increasing dose and higher available N, P and Zn was found with Z_2. But the N and P was found to be non-significant. Higher N availability at higher doses and responsiveness of crop increased meristematic activities in different plant parts which also required more P for fulfilling their energy and tissues requirement. It is inferred from the above that increase in available status of soil was due to increase in fertilizer dose with declining response at higher levels. These results are in conformity with the work done by Stalin *et al.* (2011). They conducted Field experiments at Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India in the Zn deficient light textured red soils with Millets (maize, sorghum), Pulses (green gram, black gram) and Oilseeds (groundnut and sesame) crops as test crops to study their response to graded levels of Zn alone and in combination with FYM @12.5 t ha-1 along with foliar spray of 0.5 % ZnSO4 twice.

Interaction effect: The interaction effect between nitrogen and zinc was significant on maize spindle yield at 5% level of significance. The highest maize spindle yield was registered with 150 kg N ha^{-1} (1573.8 kg ha^{-1}) and 35 kg $ZnSO_4$ (1711.4 kg ha^{-1}). The least yield was registered with 100 kg N ha^{-1} (1024.6 kg ha^{-1}) and among Zinc fertility levels with 25 kg $ZnSO_4$ (1159.9 kg ha^{-1}). Srikanth *et al.* (2009) conducted a field experiment at Tamil Nadu Agricultural University, Coimbatore to study the effect of plant density and fertilizer levels on the yield and quality of hybrid maize under irrigated condition. They also found significant interaction effect among the fertility levels (Three fertilizer levels viz., 150:75:75, 200:100:100 and 250:125:125 NPK kg ha^{-1}). Owla *et al.* (2015) conducted a field experiment which was laid out at Udaipur, Rajasthan, to evaluate effect of fertility levels, nutrient sources and weed control on productivity of quality protein maize (*Zea mays* L.). Twenty seven treatment combinations comprising 3 fertility levels (90 kg N + 40 kg P2O5, 120 kg N + 50 kg P2O5 and 150 kg N + 60 kg P2O5/ha), 3 nutrient sources (100% NP through fertilizers, 75% NP through fertilizers + 25% through vermicompost and 50% NP through fertilizers + 50% through vermicompost) and 3 weed-control measures (weedy check, metribuzin 0.4 kg/ha followed by (fb) hoeing and weeding and atrazine 0.4 kg + alachlor 2.0 kg/ha fb hoeing and weeding) were tested in split-plot block design They reported that interaction effect was significant among the fertility levels. This increase in yield was probably due to effective utilization of applied nutrients, increased sink capacity and nutrient uptake by the crop. Since Nitrogen is the major structural constitute of cells, as Nitrogen level increased the rate of vegetative and reproductive growth also increased in plants due to increase in assimilating surface of plants as well as total photosynthesis. In physiological terms, the grain yield of maize is largely governed by source (Photosynthesis) and sinks (grain) relationship which is directly related to Nitrogen. These resulted in more interactive significant effect among fertility levels of Nitrogen and Zinc. The findings of Srikanth *et al.* (2009) and Owla *et al.* (2015) corroborate results of the present study with respect to significant fertility levels interaction.

Conclusion

The study led to a conclusion that the maximum growth parameters like highest yield and soil fertility status could be achieved by judicious application of Nitrogen, Phosphorus and Zinc. Therefore, it was concluded that increasing dose of nitrogen, phosphorus and zinc from 25 % to 50 % may result in the better performance of maize crop.

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