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Effect of phosphorus, Zinc and Mycorrhizae application on growth and nutrient uptake in capsicum under protected conditions

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Abstract
The present pot culture experiment was conducted to see the effect of Phosphorus, Zinc and Mycorrhizae on capsicum in net house, Department of Soil Science and Water Management, Dr YSPUHF Nauni-Solan during the year 2016. The experiment consists of twenty four treatment combinations with four levels of phosphorus (P_A, P_B, P_C and P_D) equivalent to 0, 237.5, 355.5 and 475 kg ha^{-1} Single Super Phosphate, three levels of Zinc (Zn_A, Zn_B and Zn_C) equivalent to 5, 7.5 and 10 kg ha^{-1} Zinc Sulphate and two levels of Arbuscular Mycorrhizal Fungi Inoculation (I_A and I_B i.e. 0 and 15 g per pot). The results revealed that the plant height, root length, above ground nutrient total uptake as well as below ground nutrient total uptake by plant increases with increase in dose of Phosphorus (from 0 to 475 kg ha^{-1}), Zinc (from 5 to 10 kg ha^{-1}) and Mycorrhizal Inoculation (from 0 to 15 g per pot). Along with this total Nitrogen content in aboveground portion and below ground portion also increases with increase in application of P, Zn and Mycorrhizae. The distribution of total Phosphorus content however remained variable in above ground portion but in below ground portion, it increases with increase in application of P, Zn and AM inoculation. The potassium content remains variable in both above ground and below ground portion of the plant.

Keywords: Phosphorus, zinc, arbuscular mycorrhizae, antagonistic interaction, capsicum

Introduction
Capsicum annuum L. commonly known as capsicum or bell pepper is a domesticated species of the plant genus Capsicum of family Solanaceae. Capsicum is an important crop in mid hills of India. It is an economically beneficial crop to the farmers of the state which is cultivated over area of about 2,260 ha with an annual production of 3,900 tonnes (Anonymous, 2013) [3]. Macronutrients as well as micronutrients plays a significant role in whole development process of the plant, the root development, formation of ATP and various functions are carried out by Phosphorus (Shaheen *et al.* 2007) [22]. Whereas micronutrients like Zinc is involved in carbohydrates protein metabolism and sexual fertilization (Cakmak *et al.* 1989) [7] Phosphorus and Zinc are the two most essential nutrients which are responsible for the growth and development of plant. Both of these nutrients are antagonistic mutually in some cases, further leads to reduction in yield as well as nutrient uptake in many crops mainly due to Phosphorus or Zinc deficiencies (Bhardwaj *et al.* 2019) [4]. In plants, the interactions which are widely investigated is Phosphorus-Zinc interactions (Marschner, 1995) [18]. These interactions may be of two types whether increasing P application decreases/does not decrease Zinc concentration in the plant (Floneragan and Webb, 1993) [9]. Increase in application of P is likely to reduce Zn concentration in grains and inplant (Buekert *et al.* 1998) [5]. The higher P application and lower Zinc application increases P concentration in plant, which leads to P toxicity contributing to the symptoms resembling Zn deficiency (Loneragan *et al.* 1982) [15]. Translocation of Zinc from roots to the upper parts of plant can be impaired by enhanced level of P supply. In the roots of plant, high P concentration may causes Zinc to be bind within the root cell and thus remains unavailable for the plant. Whereas in case of high concentration of zinc in the roots results in formation of soluble Zn phosphates which is further responsible for unequal distribution of zinc between roots and upper parts of the plant (Cakmak and Marschner, 1987) [6].

In order to alleviating Zn deficiencies or any other nutrient deficiency, mycorrhizae can be used which not only improves the nutritional status of the plant but also promotes P or Zn nutrition of the plant independently (Bhardwaj *et al*. 2019) [4]. Similarly it has also been reported that benefits of mycorrhizal association were more when plants grow under P/Zn deficiency. Also soils in mid hills conditions of the state are high in phosphorus which can affect the uptake of zinc in the plant. AM colonization in such conditions is expected to improve the availability of micronutrients. Keeping this in view the present study was carried out to see the effect of phosphorus and zinc in plant nutrition and mycorrhizae on growth and nutrient uptake in capsicum.

Materials and Methods

Site description

The study was carried out in mid hills of Himachal Pradesh and the experimental site was situated in net house of Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh. It is located at 30˚52′ North latitude and 77˚11′ East longitude and elevation of 1175 m above mean sea level.

Climate and Soil

The climate in which experiment was carried out lies in the sub- tropical zone but is slightly biased towards temperate climate. The soil of the experimental area falls in order Inceptisols (USDA Soil taxonomy), near neutral in reaction, medium in available N, K and high in available P, Zn, Cu, Mn, but deficient in Fe.

Plant material and potting mixture

One month old capsicum seedlings were selected for conducting the present studies. The seedlings were grown in pots filled with soil taken from field.

Treatment details

There were 24 treatment combination and details of treatments are given as follow:

1. P- LEVELS (Four levels)

- P_A: No application of P
- P_B: 237.5 kg ha^{-1} SSP (50% of P)
- P_C: 355.5kg ha^{-1} SSP (75% of P)
- P_D: 475 kg ha^{-1} SSP (100% of P)

2. Zn - LEVELS (Three levels)

- Zn_A: 5 kg $ZnSO_4$ ha^{-1}(50% of Zn)
- Zn_B: 7.5 kg $ZnSO_4$ ha^{-1}(75% of Zn)
- Zn_C: 10 kg $ZnSO_4$ ha^{-1}(100% of Zn)

3. Inoculation with AM- Fungal Consortia: I_A: Inoculated and I_B: Uninoculated

AM fungal consortia were applied @15 grams pot^{-1} by layering method (Jackson *et al*. 1972) [12]. N and K application along with FYM to be applied uniformly at the recommended rates to all the treatments were applied by calculating the dozes per 10 kg of soil in the pots.

Table 1: Treatment Combinations: 4×3×2 = 24

Treatment combinations without mycorrhiza	Treatment combinations with mycorrhiza
$Treatment_1$: $P_AZn_AI_A$	$Treatment_{13}$: $P_AZn_AI_B$
$Treatment_2$: $P_AZn_BI_A$	$Treatment_{14}$: $P_AZn_BI_B$
$Treatment_3$: $P_AZn_CI_A$	$Treatment_{15}$: $P_AZn_CI_B$
$Treatment_4$: $P_BZn_AI_A$	$Treatment_{16}$: $P_BZn_AI_B$
$Treatment_5$: $P_BZn_BI_A$	$Treatment_{17}$: $P_BZn_BI_B$
$Treatment_6$: $P_BZn_CI_A$	$Treatment_{18}$: $P_BZn_CI_B$
$Treatment_7$: $P_CZn_AI_A$	$Treatment_{19}$: $P_CZn_AI_B$
$Treatment_8$: $P_CZn_BI_A$	$Treatment_{20}$: $P_CZn_BI_B$
$Treatment_9$: $P_CZn_CI_A$	$Treatment_{21}$: $P_CZn_CI_B$
$Treatment_{10}$: $P_DZn_AI_A$	$Treatment_{22}$: $P_DZn_AI_B$
$Treatment_{11}$: $P_DZn_BI_A$	$Treatment_{23}$: $P_DZn_BI_B$
$Treatment_{12}$: $P_DZn_CI_A$	$Treatment_{24}$: $P_DZn_CI_B$

Plant growth analysis

The plant growth parameters like plant height, root length was measured at the end of crop season and measured in centimeters. Total Nitrogen of plant samples (above ground portion and below ground portion) was determined by micro-kjeldahl method as described in A.O.A.C (1980) [1], total Phosphorus content was determined by vanado-molybdo yellow colour method (Jackson, 1973) [11]. Total Potassium content was determined by flame photometric method. Micronutrients like Fe, Mn, Zn and Cu were determined in the extract using Atomic Absorption Spectrophotometer.

Soil analysis

Composite soil samples were collected from pots and analyzed by standard methods. The organic carbon was estimated by rapid titration method (Wakley and Black, 1934) [26]. Available N, P and K in soil were determined by Alkaline Potassium permanganate method (Subbiah and Asija, 1956) [24]; Ammonium molybdate method using olsen’s extractant (Olsen *et al*. 1972) [20] and Ammonium Acetate method (Merwin and Peech, 1951) [19] respectively. The DTPA extractable Fe, Mn, Zn and Cu were estimated on Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978) [14].

Results and Discussions

Above ground parameters

As depicted in Table 2, the two-way interaction shows that P×Zn and I×Zn interaction was non-significant however the I_BP_D interaction recorded significantly higher plant height (72.5cm). These results are in accordance with the results of Cwala *et al*. (2010) [8] who observed that growth and development of capsicum plant was affected by commercial mycorrhizal inoculants. Among macronutrient content in above ground portion, in case of total nitrogen content, the P×Zn interaction was non-significant. The interaction I×Zn and I×P was significant with maximum value of total nitrogen content was observed in I_BZn_C and I_BP_D. These results are in line with the results obtained by Abbott and Robson (1984) who concluded that uptake and translocation of nitrogen increases with the application of AM fungi. The effect of P, Zn and Mycorrhizae on total phosphorus content was observed significant only for I×Zn and I×P interactions with maximum value recorded in I_BZn_A and I_BP_D treatment. These results are similar with those obtained by Tanwar and Aggarwal (2013) [25], who demonstrated that the dual inoculation and multi inoculation of bell pepper plants with *Glomus mosseae* had increased the phosphorus content. Also the in case of total potassium content, two way interaction P×Zn and I×P was significant with maximum value in P_AZn_C and I_BP_A treatment and the interaction I×Zn was non-significant. These results are similar with the results found by Maksoud *et al*. (1994) [6] who observed that AM mycelium increases the potassium content in plants.

Among micronutrient content, all three interactions (P×Zn, I×P and I×Zn) were significantly affected with maximum value of total K content in P_AZn_A, I_BP_A and I_BZn_A treatments. These observations are similar with the findings of Halder and Mandal (1981) [10], who reported that application of phosphorus causes a decrease in concentration of iron in the shoots. The two factor interaction was also significant with P_AZn_C recorded higher total Mn content. On the other hand, I_BZn_C and I_BP_A were maximum and significantly higher. The results are in line with those obtained by Halder and Mandal (1981) [10], who reported that application of phosphorus caused a decrease in the concentration of manganese in shoots also the application of zinc, increases the concentration of manganese in shoots (Cakmak and Marshner, 1987) [6] in a synergistic manner with Fe. In case of total Zn content in above ground parts of the plant, all three interactions were

Table 2: Effect of P, Zn and Mycorrhizae application on above ground parameters.

Treatments combinations	Plant Height (cm)	N (%)	P (%)	K (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Total uptake (g plant^{-1})
P_AZn_A	51.3	7.60	0.85	10.49	390.96	240.80	72.63	47.15	3.21
P_AZn_B	53.0	7.72	0.81	10.64	376.00	249.64	79.36	45.17	3.36
P_AZn_C	53.2	7.88	0.76	10.71	351.50	256.12	81.95	37.10	3.43
P_BZn_A	52.8	7.69	0.91	10.35	349.22	225.85	66.12	46.10	3.29
P_BZn_B	55.3	7.85	0.85	10.45	331.00	238.80	71.38	39.72	3.45
P_BZn_C	57.3	8.08	0.82	10.49	310.31	249.35	77.09	36.55	3.57
P_CZn_A	57.5	8.74	0.99	9.98	328.50	219.77	61.05	43.20	3.66
P_CZn_B	58.5	8.96	0.93	10.35	313.50	224.74	66.47	37.00	4.06
P_CZn_C	60.5	9.18	0.88	10.41	281.25	237.53	74.08	32.18	4.16
P_DZn_A	60.0	8.93	1.11	9.66	286.95	214.47	57.28	35.45	3.73
P_DZn_B	60.5	9.04	1.07	10.18	282.76	218.85	61.73	34.29	4.16
P_DZn_C	63.3	9.25	1.03	10.31	267.75	231.92	67.67	32.08	4.28
Mean	56.9	8.41	0.92	10.33	322.47	233.98	69.73	38.83	3.70
CD 0.05	*NS*	*NS*	*NS*	*0.13*	*8.21*	*1.52*	*1.46*	*0.50*	*0.09*
I_AZn_A	44.4	7.50	0.86	9.59	298.42	221.98	59.58	41.98	3.13
I_AZn_B	45.8	7.65	0.82	9.85	281.63	227.87	64.74	38.08	3.28
I_AZn_C	47.2	7.90	0.80	9.90	250.40	238.31	72.30	33.95	3.40
I_BZn_A	66.4	8.98	1.07	10.64	379.39	228.46	68.96	43.98	3.81
I_BZn_B	67.9	9.13	1.01	10.96	370.00	238.14	74.72	40.01	4.24
I_BZn_C	69.9	9.29	0.94	11.06	355.00	249.15	78.09	35.00	4.33
Mean	56.9	8.41	0.92	10.33	322.47	233.98	69.73	38.83	3.70
CD 0.05	*NS*	*0.06*	*0.02*	*NS*	*5.81*	*1.07*	*1.04*	*0.36*	*0.06*
I_AP_A	42.5	7.20	0.72	10.03	319.79	243.10	73.81	42.01	3.00
I_AP_B	43.3	7.30	0.78	9.87	284.68	234.49	66.73	39.47	3.06
I_AP_C	47.3	8.04	0.81	9.71	268.33	222.53	63.02	37.47	3.48
I_AP_D	50.0	8.19	1.01	9.51	234.47	217.42	58.59	33.07	3.54
I_BP_A	62.5	8.26	0.89	11.19	425.86	254.60	82.14	44.27	3.67
I_BP_B	66.8	8.45	0.95	10.99	375.67	241.51	76.33	42.11	3.81
I_BP_C	70.3	9.87	1.06	10.78	347.17	232.16	71.37	37.45	4.44
I_BP_D	72.5	9.95	1.13	10.59	323.83	226.07	65.85	34.81	4.58
Mean	56.9	8.41	0.92	10.33	322.47	233.98	69.73	38.83	3.70
CD 0.05	*1.5*	*0.07*	*0.02*	*0.11*	*6.71*	*1.24*	*NS*	*0.41*	*0.07*

Significantly affected with maximum value of total Zn content observed in P_AZn_C, I_BZn_C and I_BP_A. These results are in line with the results of Ortas *et al*. (2011) who showed that plants inoculated with *Glomusmosseae*, *G. intraradices*,,*G. etunicatum*, *G. clarum*, *G. caledonium* and the mixture of these fungi had increased Zn content compared to control plants. The total Cu content in plants also recorded significant higher values in P_AZn_A, I_BP_A and I_BZn_A. Similar results were also recorded by Halder and Mandal (1981) [10] who found that P application decrease concentration of Cu in the shoots. The total nutrient uptake by plant in above ground portion also affected significantly with maximum value of total nutrient uptake recorded in P_DZn_C, I_BZn_C and I_BP_D. These results are in conformity with those of Srinivasan *et al*. (2012) who concluded that in crop plants, with inoculation of mycorrhizae there is increase in uptake of macro and micronutrients.

Below ground parameters

As given in Table 3, among below ground parameters, the maximum root length was observed in P_3Zn_2, I_1Zn_2 and I_1P_3. These results are same with those of Kim *et al*. (2010) [13] who found that red pepper plants inoculated with *Methylobacterium oryzae* strains resulted in a significant increase in root length and root fresh weight compared to untreated control plants. Among macronutrient content of below ground portion (root), the total Nitrogen content was significantly affected with maximum value of total Nitrogen content in treatments P_DZn_C, I_AZn_C and I_BP_D. These are similar results with findings obtained by Kim *et al*. (2010) [13] who observed that mycorrhizal inoculation addition resulted in significantly higher nitrogen accumulation in the roots of red pepper plants as compare to control. In case of total phosphorus content, I×P and I×Zn interaction had non-significant effect on total P content. However P×Zn interaction had significantly affect with maximum value total P content in P_DZn_C treatment. These results are in accordance with studies carried out by Kim *et al*. (2010) [13] who showed that the addition of AM fungi increased the phosphorus (P) content by 23.3% compared to untreated control. The total K content in below ground portion was significantly affected by application of P, Zn and mycorrhizae with maximum value of total K observed in P_AZn_C, I_BZn_C and I_BP_A. These results are in accordance with results of Maksoud *et al*. (1994) [16] who found that arbuscular mycorrhizal mycelium influences the potassium content in plants. Among micronutrient content in roots, P_AZn_A, I_BZn_A and I_BP_A interaction shows significantly higher Fe content in roots. Similar results were also

Table 3: Effect of P, Zn and Mycorrhizae application on below ground parameters

Treatments combinations	Root length (cm)	N (%)	P (%)	K (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Total uptake (g plant^{-1})
P_AZn_A	9.5	3.49	0.26	2.53	129.50	124.90	30.65	24.63	0.62
P_AZn_B	10.4	3.64	0.30	2.82	124.00	125.48	30.79	18.83	0.72
P_AZn_C	11.2	3.75	0.34	2.89	119.70	127.73	35.20	14.95	0.78
P_BZn_A	10.0	3.49	0.29	2.49	121.48	124.10	34.60	14.64	0.72
P_BZn_B	11.1	3.73	0.32	2.74	118.95	124.10	35.79	14.05	0.78
P_BZn_C	11.7	3.85	0.38	2.80	115.13	127.45	37.46	14.20	0.90
P_CZn_A	10.3	3.53	0.35	2.36	113.65	121.30	35.84	12.28	0.76
P_CZn_B	11.6	3.76	0.38	2.61	112.28	124.50	39.70	10.66	0.84
P_CZn_C	12.1	3.87	0.40	2.77	110.70	126.18	41.14	10.10	0.95
P_DZn_A	10.9	3.72	0.36	2.28	110.18	119.93	40.32	10.83	0.80
P_DZn_B	12.4	3.78	0.40	2.46	107.63	123.22	41.34	10.35	0.89
P_DZn_C	12.8	3.91	0.46	2.68	106.20	125.83	41.94	10.13	1.09
Mean	11.2	3.71	0.35	2.62	115.78	124.56	37.06	13.80	0.82
CD 0.05	*NS*	*0.06*	*0.02*	*0.03*	*1.79*	*0.80*	*1.07*	*0.24*	*0.06*
I_AZn_A	9.1	3.30	0.30	2.27	115.79	119.03	33.12	13.24	0.69
I_AZn_B	9.7	3.63	0.32	2.30	111.78	119.85	34.91	12.73	0.77
I_AZn_C	10.2	3.86	0.37	2.36	108.95	121.66	36.17	11.59	0.83
I_BZn_A	11.2	3.81	0.33	2.56	121.61	126.09	37.58	17.94	0.76
I_BZn_B	13.1	3.82	0.37	3.02	119.65	128.80	38.90	14.21	0.85
I_BZn_C	13.7	3.83	0.42	3.20	116.91	131.93	41.70	13.10	1.03
Mean	11.2	3.71	0.35	2.62	115.78	124.56	37.06	13.80	0.82
CD 0.05	*NS*	*0.04*	*NS*	*0.02*	*1.27*	*0.56*	*0.76*	*0.19*	*0.04*
I_AP_A	8.8	3.48	0.27	2.36	117.97	121.27	29.70	17.73	0.61
I_AP_B	9.4	3.57	0.31	2.34	114.30	120.52	32.32	12.31	0.74
I_AP_C	9.9	3.60	0.36	2.30	110.30	120.15	36.59	10.07	0.82
I_AP_D	10.5	3.73	0.38	2.24	106.12	118.78	40.32	9.97	0.88
I_BP_A	11.9	3.77	0.33	3.14	130.83	130.80	34.72	21.20	0.81
I_BP_B	12.4	3.81	0.35	3.01	122.73	129.92	39.58	16.28	0.86
I_BP_C	12.8	3.84	0.38	2.85	114.12	127.83	41.19	11.95	0.88
I_BP_D	13.6	3.87	0.43	2.70	109.88	127.20	42.08	10.90	0.97
Mean	11.2	3.71	0.35	2.62	115.78	124.56	37.06	13.80	0.82
CD 0.05	*NS*	*0.05*	*NS*	*0.02*	*1.46*	*0.65*	*0.88*	*0.22*	*0.05*

reported by Halder and Mandal (1981) [10] who reported decrease in Fe concentration with increase in P application. Similarly the two factor interaction shows statistically higher values of Mn in roots of P_AZn_C, I_BZn_C and I_BP_A plants. These findings are in consonance with the findings of Halder and Mandal (1981) [10] who found a decrease in the concentration of manganese in roots with increasing P and Zn application. The two factor interactions were also found significant for P_DZn_C, I_BZn_C and I_BP_D interactions. These results are similar to those obtained by Olsen (1972) [20] who reported that high level of soil available P or with high Phosphorus application, Zinc in roots may accumulate and metabolic disorder at cellular level may occur due to Phosphorus and Zinc imbalance. The two factor interactions were also found significant for P_DZn_C, I_BZn_C and I_BP_D interactions. These results are similar to those obtained by Olsen *et al*. (1972) [20] who reported that high level of soil available P or with high Phosphorus application, Zinc in roots may accumulate and metabolic disorder at cellular level. In case of total Cu content in roots, two way interaction show P_AZn_A, I_BZn_A and I_BP_A interaction had significantly higher Cu content in the roots. The total Nutrient uptake by root in two factor interaction reveals that total nutrient uptake by root was recorded maximum in P_DZn_C, I_BZn_C and I_BP_D. These results are in accordance with the results carried out by Marscher and Dell (1994) [17] who reported that the mycorrhizal infection enhances plant growth by increasing nutrient uptake.

Soil parameters

As represented in Table 4, I×P interaction and P×Zn interaction shows significant effect on OC whereas I×Zn interaction was non-significant. The organic carbon contents of soil increased significantly in with maximum values under mycorrhizae treated soils as compared to mycorrhizal uninoculated soils. Overall the results show that the Phosphorus and Zinc levels in association with inoculation with AM fungi show higher levels of organic carbon in the soils. Among macronutrient content in soil, two way interactions were significant with maximum soil N in P_CZn_C, I_BZn_C and I_BP_C. The results are in line with the values obtained for organic carbon status of these soils indicating better soil health at medium levels of application in combination with inoculation. In case of available P in soil, two factor interaction also exhibit high soil P in P_DZn_B, I_BZn_C and I_BP_D interactions. The results are in line with the findings of Yusnizar and Rahmawati (2014) [27] who also reported that a combination of mycorrhizae and phosphate can

Table 4: Effect of P, Zn and Mycorrhizae application on soil parameters.

Treatments combinations	Organic Carbon (%)	N $(mg\ kg^{-1})$	P $(mg\ kg^{-1})$	K $(mg\ kg^{-1})$	Fe $(mg\ kg^{-1})$	Mn $(mg\ kg^{-1})$	Zn $(mg\ kg^{-1})$	Cu $(mg\ kg^{-1})$
P_AZn_A	1.13	152.00	38.96	106.48	5.11	1.62	2.29	0.60
P_AZn_B	1.18	155.18	39.83	110.00	5.13	1.64	2.54	0.74
P_AZn_C	1.18	162.58	40.53	112.00	5.25	1.68	2.67	0.83
P_BZn_A	1.19	163.23	39.99	109.50	5.13	1.70	2.53	0.68
P_BZn_B	1.22	167.07	42.20	111.75	5.16	1.72	2.86	0.81
P_BZn_C	1.28	175.50	44.34	111.75	5.19	1.78	3.06	0.84
P_CZn_A	1.36	200.05	42.53	122.25	5.37	2.01	3.33	0.92
P_CZn_B	1.39	200.47	42.93	125.00	5.50	2.03	3.39	1.01
P_CZn_C	1.40	207.88	44.23	126.90	5.57	2.08	3.83	1.13
P_DZn_A	1.28	171.87	44.70	112.18	5.27	1.88	3.07	0.81
P_DZn_B	1.29	184.25	45.75	117.21	5.38	1.93	3.09	0.95
P_DZn_C	1.31	186.78	45.70	121.00	5.42	1.99	3.34	0.98
Mean	1.27	177.24	42.64	115.50	5.29	1.84	3.00	0.86
$CD_{0.05}$	*0.02*	*3.46*	*1.28*	*2.01*	*0.03*	*0.02*	*0.13*	*0.05*
I_AZn_A	1.16	165.86	40.45	105.14	5.07	1.56	2.85	0.77
I_AZn_B	1.18	169.03	41.48	110.73	5.09	1.61	2.91	0.85
I_AZn_C	1.20	172.42	43.31	113.38	5.15	1.68	3.10	0.88
I_BZn_A	1.32	177.72	42.64	120.06	5.37	2.04	2.76	0.74
I_BZn_B	1.36	184.45	43.88	121.25	5.50	2.05	3.03	0.90
I_BZn_C	1.39	193.96	44.08	122.45	5.56	2.08	3.34	1.00
Mean	1.27	177.24	42.64	115.50	5.29	1.84	3.00	0.86
$CD_{0.05}$	*NS*	*2.45*	*0.90*	*1.42*	*0.02*	*0.02*	*0.09*	*0.04*
I_AP_A	1.11	148.42	39.26	103.73	4.93	1.34	2.37	0.72
I_AP_B	1.15	157.67	40.76	102.67	4.97	1.47	2.83	0.79
I_AP_C	1.27	199.49	42.00	122.17	5.32	1.90	3.51	0.98
I_AP_D	1.18	170.83	44.97	110.42	5.19	1.75	3.11	0.85
I_BP_A	1.22	164.76	40.29	115.25	5.39	1.95	2.63	0.73
I_BP_B	1.31	179.53	43.59	119.33	5.35	1.99	2.81	0.76
I_BP_C	1.50	206.11	44.45	127.27	5.64	2.18	3.52	1.06
I_BP_D	1.41	191.10	45.80	123.17	5.52	2.11	3.22	0.98
Mean	1.27	177.24	42.64	115.50	5.29	1.84	3.00	0.86
$CD_{0.05}$	*0.02*	*2.83*	*1.04*	*1.64*	*0.02*	*0.02*	*0.11*	*0.04*

increase available P on growing media. Also I×P and P×Zn interaction had significant effect on available potassium. The trend was similar to that obtained in available N in soils. Similarly, among micronutrient content in soils, the two way interactions P×Zn, I×Zn and I×P were significantly affected by the application of P, Zn, mycorrhizae. The maximum value of available Fe, Mn, Zn and Cu were reported in P_CZn_C, I_BZn_C and I_BP_D.

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