

Original Research Article

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Evaluation of Different Levels of Phosphorus, Zinc and Arbuscular Mycorrhizae on Growth and Soil Parameters in Bell Pepper

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ABSTRACT

The present investigation was conducted as a pot experiment to evaluate different levels of Phosphorus, Zinc and Mycorrhizae on growth and soil parameters in bell pepper during 2017. This experiment was carried out in the net house of Department of Soil Science and Water Management, Dr YSPUHF Nauni, Solan, Himachal Pradesh, India. The pot experiment comprised of 24 treatment combinations with 4 levels of Phosphorus i.e. P_i-0, P_{ii}- 237.5 kg ha⁻¹ Single Super Phosphate, P_{iii}- 355.5 kg ha⁻¹ Single Super Phosphate, P_{iv}- 475 kg ha⁻¹ Single Super Phosphate; 3 levels of Zinc, Zn_i-5 kg ha⁻¹ Zinc Sulphate, Zn_{ii}- 7.5 kg ha⁻¹ Zinc Sulphate Zn_{iii}- 10 kg ha⁻¹ Zinc Sulphate and 2 levels of mycorrhizal inoculation, I_i – 0 and I_{ii}- 15 g Arbuscular Mycorrhizal Fungi per pot. The results obtained from this investigation was that with increase in application of Phosphorus, Zinc and Arbuscular Mycorrhizae, plant height, root length, total nutrient uptake increased. Along with this mycorrhizae also enhanced the total nutrient uptake by counteracting P-Zn deficiency in the plant.

Keywords

P-Zn Interaction, AM fungi, Antagonistic interaction, capsicum

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Introduction

Capsicum is cultivated over an area of about 29,800 ha in India with an annual production of 1,71,370 tonnes. This crop is extensively grown in the hills of Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Andhra Pradesh and Nilgiris during summer months and as an autumn crop in Karnataka, Maharashtra, Tamil Nadu, Bihar, West

Bengal and Madhya Pradesh. In Himachal Pradesh it is grown as an off season crop during summer and rainy season and bulk of bell pepper is transported to nearby and distant markets in Punjab, Haryana, Delhi and U.P bringing handsome monetary returns to the small and marginal farmers. Thus it is a remunerative crop to the farmers of the state having a great economic importance and cultivated over an area of about 2,260 ha with

an annual production of 35,900 tonnes (Anonymous, 2013). 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. However, suitable and balanced combination of macro and micro nutrients are not only essential for plant growth and production, but also good for the environment (Chen, 2006).

Moreover, quality and yield potential of plants can be enhanced by maintaining an adequate level of nutrients by soil or foliar application. Zinc and Phosphorus are two essential nutrients governing to a large extent the normal plant growth. Nutrient deficiencies in plant tissue usually occur when a nutrient is not available in adequate amount. In some cases, a nutrient is available in marginal to normal amount, but the excessive rates of antagonizing ions can cause the deficiency of the other nutrient ion in the plant tissue. High available P can induce visual Zn deficiency symptoms in plants.

This is called P- induced Zn deficiency. Zn-induced P deficiency is very rare, because growers commonly apply large amounts of P fertilizer as compared to Zinc fertilizer (Edwards and Kamprath, 1974). The plant growth and Phosphorus uptake increases when Vesicular Arbuscular Mycorrhizal (VAM) Fungi applied to the soils. AM fungi provide various benefits to the plant by increasing plant nutrient acquisition, improvement in quality of soil and offers resistance to plant from environment stress (Bhardwaj *et al.*, 2019).

Mycorrhizal benefits were greatest when plants were grown under low soil P and Zn. Furthermore, the effect of soil Zn supply on plant growth, nutrition and AM colonization was strongly influenced by the concentration

of P in the soil. AM also plays an important role in the acquisition of Zn, N, Cu, K and other nutrients (Frey and Schuepp, 1993). While AM can improve plant Zn acquisition in Zn-deficient soils, they can also “protect” plants against excessive Zn uptake when in Zn-contaminated soils (Li and Christie, 2001).

The plant colonized by arbuscular mycorrhizal fungi (AMF) have been found to have lower tissue Zn concentrations when grown under toxic soil Zn concentrations, as compared to their non-mycorrhizal counterparts (Dueck *et al.*, 1986). Under moderately high P regimes, where tissue P was non-growth-limiting in non mycorrhizal plants, the water status of VAM plants has been reported to be enhanced compared with non-VAM plants (Sweatt and Davies, 1984). The concentration of Phosphorus in soil strongly affects the soil Zinc supply in plant.

As soil in mid hills condition of the state is very rich in Phosphorus, which ultimately affects the Zinc uptake by the plant. In those circumstances, AM colonization is expected to enhance the availability of nutrients and provide necessary nutrition to the plants. Keeping this in view, the present investigation was carried out to evaluate different levels of Phosphorus, Zinc and mycorrhizae on plant and soil parameters in bell pepper.

Materials and Methods

The experimental site was situated in mid hills of Himachal Pradesh and pot experimented was conducted in the net house of Department of Soil Science and Water Management, Dr YSPUHF Nauni, Solan. The climate of the area in summer is moderately hot during May-June while winter months from December-January are the coldest ones. The average annual rainfall of the area is about 1100 mm and 75% of it is received during the monsoon period (mid June-mid

September). The properties of the soil of study area are given as follow:

Initial soil properties	
pH (1:2)	6.98
EC (dS m ⁻¹)	0.439
Organic Carbon (%)	1.41
Available N (mg kg ⁻¹)	192.36
Available P (mg kg ⁻¹)	31.62
Available K (mg kg ⁻¹)	89.72
Available Fe (mg kg ⁻¹)	3.84
Available Mn (mg kg ⁻¹)	1.22
Available Zn (mg kg ⁻¹)	1.89
Available Cu (mg kg ⁻¹)	0.78

Treatment details

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

Treatment combinations without mycorrhiza	Treatment combinations with mycorrhiza
Treatment ₁ : P _i Zn _i I _i	Treatment ₁₃ : P _i Zn _{ii} I _{ii}
Treatment ₂ : P _i Zn _{ii} I _i	Treatment ₁₄ : P _i Zn _{ii} I _{ii}
Treatment ₃ : P _i Zn _{iii} I _i	Treatment ₁₅ : P _i Zn _{iii} I _{ii}
Treatment ₄ : P _{ii} Zn _i I _i	Treatment ₁₆ : P _{ii} Zn _i I _{ii}
Treatment ₅ : P _{ii} Zn _{ii} I _i	Treatment ₁₇ : P _{ii} Zn _{ii} I _{ii}
Treatment ₆ : P _{ii} Zn _{iii} I _i	Treatment ₁₈ : P _{ii} Zn _{iii} I _{ii}
Treatment ₇ : P _{iii} Zn _i I _i	Treatment ₁₉ : P _{iii} Zn _i I _{ii}
Treatment ₈ : P _{iii} Zn _{ii} I _i	Treatment ₂₀ : P _{iii} Zn _{ii} I _{ii}
Treatment ₉ : P _{iii} Zn _{iii} I _i	Treatment ₂₁ : P _{iii} Zn _{iii} I _{ii}
Treatment ₁₀ : P _{iv} Zn _i I _i	Treatment ₂₂ : P _{iv} Zn _i I _{ii}
Treatment ₁₁ : P _{iv} Zn _{ii} I _i	Treatment ₂₃ : P _{iv} Zn _{ii} I _{ii}
Treatment ₁₂ : P _{iv} Zn _{iii} I _i	Treatment ₂₄ : P _{iv} Zn _{iii} I _{ii}

Plant growth analysis

Plant growth parameters like plant height;

root length was measured in centimeters. In plant analysis, Nitrogen of plant samples was determined by micro-kjeldahl method (A.O.A.C, 1980), total Phosphorus content was determined by method given by Jackson (1973) and by flame photometric method, total potassium content was determined. Also in Atomic Absorption Spectrophotometer, micronutrient cations (Fe, Mn, Zn and Cu) were estimated.

Soil analysis

Soil samples from the pot were collected and analyzed. Analysis of soil was carried out by estimating Organic Carbon by rapid titration method given by Wakley and Black (1934). The available Nitrogen in the soil was estimated by Alkaline Potassium permanganate method given by Subbiah and Asija (1956); available Phosphorus in the soil was determined by method given by Olsen *et al.*, (1972) and available potassium content in the soil was estimated by Ammonium Acetate method given by Merwin and Peech (1951). The DTPA extractable Fe, Mn, Zn and Cu were estimated on Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978).

Results and Discussion

Above ground parameters

As shown in Table 1, for plant height P×Zn, I×Zn and I×P interaction was non-significant however maximum plant height was recorded in P_{iv}Zn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_{iv}. These findings are in accordance with studies carried out by Mun *et al.*, (1990) who observed that inoculated bell pepper plants were found to be more developed and taller compared to non-inoculated plants. Similarly among macronutrient content, maximum total N content in plant (above ground portion) was observed in P_{iv}Zn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_{iv}.

treatments. The inoculation of AM fungi resulted in maximum Nitrogen content in pepper plant as compare to uninoculated plants was also reported by Kim *et al.*, (2010). In case of total Phosphorus content interaction I×P and I×Zn were found to be significant with maximum value of total Phosphorus content in I_{ii}P_{iv} and I_{ii}Zn_i treatments. Barben *et al.*, (2007) in their studies also reported the similar results. They observed that Phosphorus concentrations in the top leaves and middle leaves and stems (middle) are depressed with increasing Zn activity in solution which is found in our studies also. However the effect of different levels of Phosphorus, Zinc and arbuscular mycorrhizae on total potassium content was significant with maximum value recorded in P_iZn_{iii}, I_{ii}Zn_i and I_{ii}P_i treatments. Maksoud *et al.*, (1954) also observed similar results who observed that potassium content in plants was increased with the application of AM mycelium.

For micronutrient content in plants, the effect of levels of P, Zn and Mycorrhizae was significant on total Fe content in plant with maximum value in P_iZn_i, I_{ii}Zn_i and I_{ii}P_i treatments. Similar results were also observed by Halder and mandal (1981). Similarly total Mn content was observed maximum in P_iZn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_i treatments. Cakmak and Marshner (1987) also observed similar results; they reported that with increase in application of Zn, there is increment in concentration of manganese in shoots.

In case of total Zn content, different levels of P, Zn and mycorrhizal inoculation affected significantly with maximum value in P_iZn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_i. Halder and Mandal (1981) also reported that application of Phosphorus caused a decrease in the concentration of Zinc in shoot. Also maximum value of total Cu content was found in P_iZn_i, I_{ii}Zn_i and I_{ii}P_i treatments which were statistically significant. These results are in accordance with the

findings of Halder and Mandal (1981) they reported that application of Phosphorus caused a decrease in the concentration of copper in the shoots. Also total nutrient uptake was statistically significant and maximum value was obtained in P_{iv}Zn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_{iv}. These results are in conformity with the results obtained by Abbott and Robson (1982). They found that AM fungi are associated with increased growth of many plant species

Below ground parameters

Among below ground parameters, root length was non-significantly affected by different levels of P, Zn and Arbuscular Mycorrhiza as given in Table 2. The maximum value of root length was observed in P_{iv}Zn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_{iv}. Kim *et al.*, (2010) also observed similar results in their study that inoculation with *Methylobacterium oryzae* strains resulted in increase in root length as well as fresh weight. Among macronutrient content in root, maximum value of total N was observed in P_{iv}Zn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_{iv}. Interaction I×P and I×Zn had non-significant effect on total P content. These results are also similar with those obtained by Barben *et al.*, (2007), who concluded that root P concentration increased with increasing Zn activity in solution possibly due to binding of these two elements within the root tissue and preventing P transport to tops. The maximum total K content in root was observed in P_iZn_{iii}, I_{ii}Zn_{iii} and I_{ii}P_i. Maksoud *et al.*, (1994) also observed similar findings who concluded that AM mycelium affects the potassium content in plants.

Among micronutrient content in root, P_iZn_i, I_{ii}Zn_i and I_{ii}P_i interaction exhibited maximum Fe content in roots. Similar results are also observed by Halder and mandal (1981), who reported that supply of Phosphorus decrease the concentration of iron in roots.

Table.1 Effect of different levels P, Zn and Arbuscular Mycorrhizae 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 _i Zn _i	55.4	8.04	0.86	10.74	448.80	239.62	80.33	52.60	3.52
P _i Zn _{ii}	54.8	8.43	0.81	10.84	431.00	247.44	87.19	50.62	3.81
P _i Zn _{iii}	56.0	8.92	0.76	10.96	396.50	254.15	90.93	43.26	4.02
P _{ii} Zn _i	56.5	8.56	0.92	10.60	397.47	231.57	72.30	51.55	3.79
P _{ii} Zn _{ii}	60.0	8.79	0.87	10.70	381.75	245.37	80.63	45.17	4.12
P _{ii} Zn _{iii}	60.3	9.05	0.83	10.74	355.10	247.69	84.42	41.81	4.24
P _{iii} Zn _i	57.0	8.89	1.01	10.06	377.75	223.02	68.88	44.12	4.00
P _{iii} Zn _{ii}	59.6	9.05	0.94	10.60	364.00	230.57	74.30	39.41	4.39
P _{iii} Zn _{iii}	59.7	9.18	0.88	10.66	331.50	238.02	81.61	35.41	4.53
P _{iv} Zn _i	58.7	9.06	1.07	9.91	343.24	216.81	65.28	38.56	4.09
P _{iv} Zn _{ii}	60.4	9.16	1.01	10.46	331.52	223.96	72.69	37.53	4.56
P _{iv} Zn _{iii}	62.3	9.30	0.98	10.56	314.50	228.27	75.77	37.03	4.71
Mean	58.4	8.87	0.91	10.57	372.76	235.54	77.86	43.09	4.15
CD _{0.05}	NS	0.04	NS	0.14	7.17	2.84	1.35	0.69	0.08
I _i Zn _i	52.3	8.05	0.85	9.84	355.59	224.35	67.65	44.38	3.25
I _i Zn _{ii}	54.5	8.18	0.80	10.08	336.51	232.42	74.72	41.14	3.40
I _i Zn _{iii}	55.4	8.50	0.78	10.16	306.30	234.20	81.11	38.63	3.55
I _{ii} Zn _i	61.5	9.22	1.08	10.81	428.04	231.16	75.75	49.03	4.45
I _{ii} Zn _{ii}	62.9	9.53	1.01	11.21	417.63	241.25	82.68	45.22	5.04
I _{ii} Zn _{iii}	63.7	9.72	0.95	11.30	392.50	249.87	85.26	40.12	5.21
Mean	58.4	8.87	0.91	10.57	372.76	235.54	77.86	43.09	4.15
CD _{0.05}	NS	0.03	0.02	0.10	5.07	2.01	0.95	0.49	0.06
I _i P _i	51.0	7.68	0.72	10.25	377.82	243.44	82.48	47.93	3.14
I _i P _{ii}	55.1	8.20	0.79	10.12	339.54	235.66	75.51	44.92	3.36
I _i P _{iii}	54.9	8.48	0.82	9.96	323.33	225.15	70.85	36.86	3.49
I _i P _{iv}	55.4	8.62	0.91	9.78	290.50	217.04	69.12	35.82	3.60
I _{ii} P _i	59.9	9.24	0.90	11.44	473.05	250.70	89.82	49.72	4.42
I _{ii} P _{ii}	62.8	9.39	0.96	11.24	416.67	247.42	82.73	47.43	4.74
I _{ii} P _{iii}	62.6	9.61	1.06	10.92	392.17	235.92	79.00	42.42	5.12
I _{ii} P _{iv}	65.4	9.72	1.12	10.83	369.00	228.99	73.37	39.59	5.30
Mean	58.4	8.87	0.91	10.57	372.76	235.54	77.86	43.09	4.15
CD _{0.05}	NS	0.03	0.02	0.11	5.85	2.32	1.10	0.56	0.06

Table.2 Effect of different levels P, Zn and Arbuscular Mycorrhizae 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_iZn_i	8.3	3.96	0.29	3.20	136.35	133.25	34.11	26.32	0.82
P_iZn_{ii}	9.4	4.14	0.33	3.53	127.78	134.40	34.74	20.52	0.95
P_iZn_{iii}	9.7	4.25	0.37	3.59	122.90	136.73	38.67	16.64	0.96
P_{ii}Zn_i	8.8	3.99	0.32	3.15	128.33	131.93	37.56	16.33	0.98
P_{ii}Zn_{ii}	9.6	4.23	0.35	3.22	122.75	133.20	39.26	15.74	1.05
P_{ii}Zn_{iii}	10.2	4.35	0.41	3.49	119.48	136.45	40.93	14.95	1.09
P_{iii}Zn_i	8.7	4.03	0.39	3.00	120.05	130.30	38.75	13.97	1.05
P_{iii}Zn_{ii}	10.1	4.25	0.41	3.11	118.18	133.00	43.16	12.35	1.07
P_{iii}Zn_{iii}	10.6	4.37	0.43	3.46	115.68	135.08	44.61	11.79	1.13
P_{iv}Zn_i	9.4	4.22	0.40	2.98	116.08	128.93	43.79	12.52	1.11
P_{iv}Zn_{ii}	10.9	4.28	0.43	3.09	113.53	132.22	44.84	12.05	1.13
P_{iv}Zn_{iii}	11.5	4.41	0.55	3.33	112.10	134.83	45.41	11.82	1.17
Mean	9.8	4.21	0.39	3.26	121.10	133.36	40.48	15.42	1.04
CD_{0.05}	NS	0.06	NS	0.14	2.68	0.70	1.03	0.87	0.04
I_iZn_i	7.7	3.80	0.33	3.03	122.16	127.84	36.06	14.94	0.71
I_iZn_{ii}	8.4	4.13	0.35	3.12	115.56	128.44	38.39	14.43	0.78
I_iZn_{iii}	8.8	4.36	0.40	3.27	112.26	130.66	39.64	12.81	0.84
I_{ii}Zn_i	9.9	4.30	0.37	3.13	128.24	134.36	41.04	19.63	1.27
I_{ii}Zn_{ii}	11.6	4.32	0.40	3.35	125.55	137.98	42.61	15.90	1.33
I_{ii}Zn_{iii}	12.2	4.33	0.48	3.66	122.81	140.88	45.17	14.79	1.34
Mean	9.8	4.21	0.39	3.26	121.10	133.36	40.48	15.42	1.04
CD_{0.05}	NS	0.04	NS	0.10	1.89	0.49	0.73	0.62	0.03
I_iP_i	7.7	3.98	0.30	3.21	120.65	130.22	33.17	19.43	0.68
I_iP_{ii}	8.2	4.07	0.34	3.15	118.40	129.27	35.45	13.37	0.76
I_iP_{iii}	8.4	4.10	0.39	3.09	115.58	128.65	39.69	11.77	0.79
I_iP_{iv}	9.1	4.23	0.41	3.11	112.02	127.78	43.80	11.67	0.86
I_{ii}P_i	10.6	4.25	0.37	3.67	137.37	139.37	38.51	22.89	1.14
I_{ii}P_{ii}	10.9	4.31	0.38	3.42	128.63	138.45	43.05	17.98	1.32
I_{ii}P_{iii}	11.3	4.33	0.42	3.28	120.35	136.93	44.66	13.64	1.38
I_{ii}P_{iv}	12.1	4.37	0.51	3.15	115.78	136.20	45.55	12.59	1.42
Mean	9.8	4.21	0.39	3.26	121.10	133.36	40.48	15.42	1.04
CD_{0.05}	NS	0.05	NS	0.11	2.19	0.57	0.84	0.71	0.04

Table.3 Effect of different levels P, Zn and Arbuscular Mycorrhizae 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 _i Zn _i	1.17	174.00	36.87	109.43	5.63	1.84	2.37	0.77
P _i Zn _{ii}	1.18	176.62	38.21	112.15	5.71	1.86	2.55	0.87
P _i Zn _{iii}	1.21	178.40	38.50	111.38	5.72	1.88	2.56	0.91
P _{ii} Zn _i	1.21	178.03	39.98	112.90	5.78	1.89	2.40	1.00
P _{ii} Zn _{ii}	1.24	182.90	40.01	116.10	5.88	1.91	2.70	1.09
P _{ii} Zn _{iii}	1.24	187.60	42.53	117.15	5.89	1.96	2.70	1.13
P _{iii} Zn _i	1.36	200.60	43.85	125.25	6.20	2.03	2.97	1.21
P _{iii} Zn _{ii}	1.40	201.25	44.35	127.33	6.27	2.05	3.09	1.25
P _{iii} Zn _{iii}	1.43	206.83	47.78	129.00	6.37	2.15	3.20	1.27
P _{iv} Zn _i	1.30	189.55	48.90	120.25	5.95	1.99	2.52	1.13
P _{iv} Zn _{ii}	1.33	192.58	49.93	121.00	6.04	2.01	2.88	1.17
P _{iv} Zn _{iii}	1.35	195.75	50.90	124.73	6.12	2.03	2.88	1.18
Mean	1.28	188.67	43.48	118.89	5.96	1.97	2.73	1.08
CD _{0.05}	NS	1.70	1.18	1.58	0.03	0.02	0.11	0.04
I _i Zn _i	1.22	174.21	38.00	111.40	5.52	1.80	2.42	1.00
I _i Zn _{ii}	1.26	178.12	38.45	115.13	5.60	1.82	2.46	1.07
I _i Zn _{iii}	1.27	181.86	39.67	116.69	5.64	1.86	2.51	1.09
I _{ii} Zn _i	1.30	196.88	46.79	122.51	6.25	2.08	2.71	1.06
I _{ii} Zn _{ii}	1.32	198.55	47.80	123.16	6.35	2.09	3.14	1.12
I _{ii} Zn _{iii}	1.34	202.43	50.18	124.44	6.41	2.15	3.16	1.16
Mean	1.28	188.67	43.48	118.89	5.96	1.97	2.73	1.08
CD _{0.05}	NS	1.20	0.83	1.11	0.02	NS	0.08	0.03
I _i P _i	1.15	160.58	34.53	102.87	5.35	1.70	2.25	0.86
I _i P _{ii}	1.18	171.37	36.03	110.00	5.45	1.76	2.35	1.04
I _i P _{iii}	1.36	197.88	39.87	124.67	5.90	1.94	2.74	1.19
I _i P _{iv}	1.29	182.43	44.40	120.08	5.65	1.90	2.51	1.12
I _{ii} P _i	1.21	192.10	41.19	119.10	6.02	2.01	2.73	0.84
I _{ii} P _{ii}	1.28	194.32	45.64	120.77	6.25	2.08	2.85	1.10
I _{ii} P _{iii}	1.42	207.90	50.78	129.72	6.66	2.22	3.43	1.30
I _{ii} P _{iv}	1.37	202.82	55.42	123.90	6.42	2.11	3.01	1.20
Mean	1.28	188.67	43.48	118.89	5.96	1.97	2.73	1.08
CD _{0.05}	NS	1.39	0.96	1.29	0.03	NS	0.09	0.03

Statistically significant and higher values of Mn in roots were observed in P_iZn_{iii} , $I_{ii}Zn_{iii}$ and $I_{ii}P_i$ treatments. However 2 way interactions, $P \times Zn$, $I \times Zn$ and $I \times P$ was statistically significant in case of total Zn content with maximum value was recorded in $P_{iv}Zn_{iii}$, $I_{ii}Zn_{iii}$ and $I_{ii}P_{iv}$ treatments.

The two way interaction as represented in table 2 shows that P_iZn_i , $I_{ii}Zn_i$ and $I_{ii}P_i$ interaction had significantly higher Cu content in the roots and the results fall in line with the reports of Halder and Mandal (1981).

Along with this, total nutrient uptake by root was recorded maximum in $P_{iv}Zn_{iii}$, $I_{ii}Zn_{iii}$ and $I_{ii}P_{iv}$. These results are in accordance with the results carried out by Marscher and Dell (1994) who reported that the mycorrhizal infection enhances plant growth and inoculation increases the concentration of some nutrients particularly micronutrients both in the roots and shoots.

Soil parameters

The organic carbon contents of soil increased significantly with maximum values under mycorrhizae treated soils as compared to mycorrhizal uninoculated soils. Similarly the two factor interactions were significant with maximum soil N being in $P_{iii}Zn_{iii}$ 206.83 mg kg^{-1} . Also the $I_{ii}Zn_{iii}$ recorded maximum soil N with values of 202.43 mg kg^{-1} .

The $I_{ii}P_{iii}$ interaction shows maximum available N in soil. Interaction also exhibit high soil P in $P_{iv}Zn_{ii}$, $P_{iv}Zn_{iii}$, $I_{ii}Zn_{iii}$ and $I_{ii}P_{iv}$ interactions.. The results are in line with the findings of Yusnizar and Rahmawati (2014) who also reported that a combination of Phosphorus and mycorrhizae resulted in increase of available P. The trend of available K in soil was similar to that obtained in available N in soils. Similar findings were reported by Medina *et al.*, (2004). Among

micronutrient content in soil, maximum DTPA-Fe, Mn, Zn and Cu was found in $P_{iii}Zn_{iii}$, $I_{ii}Zn_{iii}$ and $I_{ii}P_{iii}$.

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