Indian Journal of Agricultural Sciences **80** (12): 1054–7, December 2010

Differential response of vegetable crops to zinc fertilization in Alluvial soils

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Received: 30 January 2010; Revised accepted: 30 September 2010

ABSTRACT

An experiment was conducted during winter (r*abi)* season of 2005–07 to study the effect of zinc fertilization on carrot (*Daucus caroto* L.), cauliflower (*Brassica oleracea* L.) and onion (*Allium cepa* L.) on Alluvial soil. Application of zinc sulphate up to 30 kg/ha significantly increased the yields and dry matter production of vegetable crops, whereas at higher zinc level (60 kg $ZnSO_4.7H_2O$/ha) the yield tended to decrease. The magnitude of response to zinc application differed from crop to crop and were recorded as carrot > cauliflower > onion. Zinc application progressively increased their concentrations and uptake in vegetable crops. The maximum zinc removal was recorded with cauliflower curd and minimum in carrot roots. Zinc application also improved the content and yield of protein of all the vegetable crops. All the 3 vegetable crops gave maximum net returns and B:C ratio with 30 kg $ZnSO_4.7H_2O$/ha. The apparent recovery of zinc was influenced by zinc levels with maximum at 30 kg $ZnSO_4.7H_2O$/ha except onion where maximum (0.40%) apparent recovery was recorded with 15 kg $ZnSO_4.7H_2O$/ha. Better zinc use-efficiency was obtained with application of 15 kg $ZnSO_4.7H_2O$/ha. The zinc use-efficiency decreased with its increasing levels and minimum use-efficiency was recorded with 60 kg $ZnSO_4.7H_2O$/ha application.

Key words: Apparent recovery, Protein yield, Response, Vegetable crops, Zinc concentration

Zinc deficiency in soils is prevalent world wide, especially in high *p*H calcareous soils (Cakmak 2002, Norman *et al.* 2003, Prasad 2006, Cakmak 2008). A recent analysis of 2.4 lakh soil samples in India showed that 49% soils are deficient in zinc (Behera *et al.* 2009) and zinc deficiency is widespread in Indo-Gangatic plains of India (Prasad 2005). Zinc is an important and essential limiting micronutrient for proper growth of plants. Major portion of agricultural lands in Uttar Pradesh has been found to be deficient in available zinc. Zinc deficiency, in varying degrees of intensity has been noted on vegetable crops being grown on alluvial soils in the state. Response to applied zinc for better growth and yield of several important field crops has been reported from almost all corners of the country (Shivay *et al.* 2007, Shivay *et al.* 2008), including Uttar Pradesh. The information on beneficial effect of zinc on economic yield and quality of field-grown vegetable is rather meager. The information regarding the differential behaviour of vegetable crops to zinc application under identical soil and weather conditions was considered to be of interest. The present investigation was, therefore, undertaken to study the variability in the response of the vegetable crops to zinc application in alluvial soil of Agra.

MATERIALS AND METHODS

A field experiment was conducted during winter (r*abi)* seasons of 2005–07 on a sandy loam soil at the research farm of the Raja Balwant Singh College, Bichpuri, Agra in Uttar Pradesh. The *p*H, EC, organic carbon and DTPA extractable zinc of the soil at the initial stage (before sowing/ transplanting) were 8.0, 0.20 dS/m, 4.2 g/kg and 0.53 mg/ kg, respectively. The soil was low in available nitrogen (176 kg/ha), phosphorus (9.5 kg/ha) and medium in potassium (210 kg/ha). Zinc Sulphate was applied to soil @ 0, 15, 30, 45, and 60 kg/ha. The experiment was laid out in randomized block design with 4 replications. Three vegetable crops, namely 'Pusa Kesar' carrot (*Daucus carota* var. *sativus* L.), 'Pusa Snowball 16' cauliflower (*Brassica oleracea* var. *botrytis* L.) and the 'Nasik Red' onion (*Allium cepa* L.) were sown/transplanted on 20 November and 3 December in 2005 and 2006, respectively. A basal fertilizer dosage of 60 kg nitrogen, 60 kg P_2O_5 and 100 kg K_2O/ha to carrot, 200 kg nitrogen, 100 kg P_2O_5 and 100 kg K_2O/ha to onion and 120 kg N, 80 kg P_2O_5 and 60 kg K_2O/ha to cauliflower was

Based on complete information of Ph D thesis of the first author submitted to Dr B R Ambedkar University, Agra during 2007

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applied through prilled urea, di-ammonium phosphate and muriate of potash, respectively. Full dose of phosphorus and potassium along with half nitrogen were applied at sowing/ transplanting and the remaining half dose of nitrogen was applied after 45 days of sowing/transplanting. The vegetable crops were harvested at their maturity and the yields were recorded. Plant samples were drawn and processed for chemical analysis taking utmost care against zinc contamination. The samples were digested in di-acid mixture and zinc concentration was determined using an atomic absorption spectrophotometer (Prasad *et al.* 2006). The economics was calculated on the basis of prevailing market prices of different inputs and outputs.

RESULTS AND DISCUSSION

Economic yield

The results on economic yield distinctly indicated that all the test crops responded markedly to zinc application (Table 1). In general, each additional dose of zinc application up to 30 kg $ZnSO_4.7H_2O$/ha increased significantly the yields and thereafter a decreasing trend was observed. Application of 30 kg $ZnSO_4.7H_2O$/ha appeared to be the optimum dose under this experimental conditions. Meena and Singh (1998) and Dubey *et al.* (2003) also reported significant response of onion and tomato to zinc application. It was also apparent that vegetable crops differed significantly amongst themselves in their magnitude of response to zinc application. The maximum yield response of carrot, onion and cauliflower were 38.8, 31.9 and 35.7 tonnes/ha, respectively. In terms of yields the vegetable crops responded in the order carrot > cauliflower > onion. Singh *et al.* (1983) reported similar results in vegetables crops to zinc application. Increasing levels of zinc significantly increased dry matter production in carrot roots from 4.2 to 5.2 tonnes/ha, onion bulb from 4.1 to 5.1 tonnes/ha and in cauliflower curd from 12.1 to 15.3 tonnes/ha up to 30 kg $ZnSO_4$/ha. The average dry matter yields of vegetable crops exhibited practically no difference at 30 or 45 kg $ZnSO_4.7H_2O$/ha level. Hence, 30 kg $ZnSO_4.7H_2O$/ha can be regarded as suitable dose for all vegetable crops. Dry matter yield of these vegetable crops tends to reduce at 60 kg $ZnSO_4.7H_2O$/ha. Dubey *et al.* (2003) also reported significant response of tomato crop to zinc application.

Protein content and protein yield

Increasing levels of zinc significantly increased the protein content in roots of carrot, bulb of onion and curd of cauliflower from 3.8 to 4.5, 6.1 to 7.0 and 5.9 to 6.7% respectively, with 45 kg $ZnSO_4.7H_2O$/ha application (Table 1). Among these crops, the minimum value of protein content was recorded in carrot roots. Cauliflower curd and the onion bulbs contained more or less similar amounts of protein in their productive parts. The protein yield increased up to the level of 45 kg $ZnSO_4.7H_2O$/ha over control. The

Table 1 Effect of zinc fertilization on economic and dry matter yield and protein content and protein yield of vegetable crops (mean of 2 years)

Zn level (kg/ha)	Carrot root		Onion bulb		Cauliflower curd							
	Economic and dry matter yield						Protein content and protein yield					
	Economic yield (tonnes/ha)	Dry matter yield (tonnes/ha)	Economic yield (tonnes/ha) (tonnes/ha)	Dry matter yield (tonnes/ha)	Economic yield (tonnes/ha)	Dry matter yield	Protein content (%)	Protein yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
0	31.60	4.20	25.60	4.08	28.33	12.14	3.81	160	6.09	245	5.93	720
15	35.73	4.75	29.15	4.64	31.38	13.45	4.00	190	6.50	300	6.21	835
30	38.75	5.16	31.87	5.08	35.62	15.26	4.18	215	6.93	335	6.65	1015
45	37.72	5.02	30.65	4.88	35.71	15.30	4.49	220	7.03	350	6.68	1020
60	35.95	4.79	28.95	4.67	32.50	13.93	4.40	210	6.87	315	6.59	915
SEm±	0.55	0.07	0.38	0.06	0.42	0.18	0.12	8	0.15	11	0.14	22
CD (P=0.05)	1.20	0.16	0.82	0.13	0.91	0.39	0.27	17	0.34	25	0.29	49

Protein content and protein yield

maximum value of protein yield was recorded in cauliflower (1 020 kg/ha), followed by onion (350 kg/ha) and carrot (220 kg/ha) at 45 kg $ZnSO_4.7H_2O$/ha level. This increase in protein yield may be attributed to higher production of vegetable crops and an improvement in protein content. The highest level of 60 kg $ZnSO_4.7H_2O$/ha could not improve significantly the protein production in all the vegetables crops over 45 kg $ZnSO_4.7H_2O$/ha. The increase in protein yield with zinc application has been also reported by Dubey *et al.* (2003).

Zinc concentration and uptake

Application of zinc significantly increased zinc concentration in carrot roots, onion bulbs and cauliflower curds from 34.0 to 62.5, 39.0 to 65.5 and 49.5 to 76.5 mg/kg, respectively with 60 kg $ZnSO_4.7H_2O$/ha (Table 2). This increase in zinc concentration may be attributed to increased zinc concentration in soil solution with its application. Application of zinc tended to increase its uptake by vegetable crops. The average zinc uptake increased from 145.0 to 295.0 g/ha in carrot roots, 155.0 to 305.0 g/ha in onion bulbs and 605.0 to 1 135.0 g/ha in cauliflower curd at 60 kg $ZnSO_4.7H_2O$/ha. This increase in zinc uptake may be

Table 2 Effect of zinc fertilization on zinc concentration and its uptake in vegetable crops (mean of 2 years)

	0	15	30	45	60	SEM±	CD (P=0.05)
Carrot root							
Zinc concentration (mg/kg DM)	34.0	42.0	49.5	56.0	62.5	1.51	3.30
Zinc uptake (g/ha)	145.0	200.0	255.0	280.0	295.0	0.015	0.030
Onion bulb							
Zinc concentration (mg/kg DM)	39.0	46.0	53.0	62.0	65.5	1.09	2.36
Zinc uptake (g/ha)	155.0	215.0	265.0	305.0	30.50	0.010	0.020
Cauliflower curd							
Zinc concentration (mg/kg DM)	49.5	57.0	66.0	74.5	76.5	1.02	2.24
Zinc uptake (g/ha)	605.0	765.0	1005.0	1025.0	1135.0	0.020	0.040

Table 3 Effect of zinc fertilization on net returns, B:C ratio, zinc apparent recovery and agronomic zinc- use efficiency of vegetable crops (mean of 2 years)

Zn level (kg/ha)	Economics: Carrot root		Economics: Onion bulb		Economics: Cauliflower curd		Zinc-use indices					
	Net returns (Rs/ha)	B:C ratio	Net returns (Rs/ha)	B:C ratio	Net returns (Rs/ha)	B:C ratio	Zinc apparent recovery (%)	Agronomic zinc-use efficiency (kg vegetable produce increase/ kg zinc applied)	Zinc apparent recovery (%)	Agronomic zinc- use efficiency (kg vegetable produce increase/ kg zinc applied)	Zinc apparent recovery (%)	Agronomic zinc- use efficiency (kg vegetable produce increase/kg zinc applied)
0	71 603	1.30	46 047	0.81	84 850	1.49						
15	85 683	1.49	58 097	0.99	98 178	1.67	0.36	275.33	0.40	236.67	1.07	242.95
30	95 861	1.62	67 242	1.08	116 905	1.91	0.37	238.16	0.37	209.00	1.33	203.00
45	91 881	1.56	62 597	1.01	110 913	1.89	0.30	137.89	0.33	112.22	1.18	163.89
60	85 311	1.46	57 480	0.96	102 115	1.69	0.25	72.41	0.25	61.58	0.70	69.50

attributed to increase in zinc concentration in vegetable crops and dry matter yield due to rising zinc levels.

Apparent recovery and zinc-use efficiency

The maximum values of apparent recovery of zinc by carrot and cauliflower were 0.37 and 1.33%, respectively, at 30 kg $ZnSO_4.7H_2O$/ha except onion where maximum (0.40%) apparent recovery of zinc was noted at 15 kg $ZnSO_4.7H_2O$/ha (Table 3). The minimum values of apparent recovery of zinc in all the vegetable crops were noted at 60 kg $ZnSO_4.7H_2O$/ha level. Zinc utilization efficiency (kg produce increase/kg $ZnSO_4$) declined with the increase in the rates of zinc sulphate application. The response in kg produce increase/kg zinc sulphate showed an increase up to the level of 15 kg $ZnSO_4.7H_2O$/ha in all the vegetable crops. Further increase in the level of $ZnSO_4.7H_2O$ tended to decrease the zinc utilization efficiency. Better zinc-use efficiency was obtained with application of 15 kg $ZnSO_4.7H_2O$/ha and recorded 275.3 kg in carrot root, 236.7 kg in onion bulb and 242.9 kg produce increase in cauliflower curd per kg $ZnSO_4.7H_2O$ applied.

Economics

All the vegetable crops gave higher net returns with zinc application (Table 3). The maximum net returns (Rs 116 905/ha) was obtained by cauliflower, followed by carrot (Rs 95 861/ha) and onion (Rs 67 242/ha) with 30 kg $ZnSO_4.7H_2O$/ha. Similarly the maximum values of B:C ratio in carrot (1.62), onion (1.08) and cauliflower (1.91) were obtained with 30 kg $ZnSO_4.7H_2O$/ha. Singh and Balyan (1994) also showed that the B:C ratio was significantly superior with the application of zinc sulphate in cauliflower.

Based on 2 years of field study it may be concluded that application of zinc sulphate @30 kg/ha to the winter (*rabi*) season vegetables, viz carrot, onion and cauliflower is sufficient dose for increased productivity and quality of vegetable produce under zinc-deficient conditions.

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