Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 6 (8): 1256-1260, 2007
ISSN 1682-3974

Effect of Zinc and Manganese Foliar Application on Yield, Quality and Enrichment on Potato (*Solanum tuberosum* L.)

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Abstract: In order to study effect of foliar application of Zinc and Manganese on yield and quality of potato crop, an experiment was conducted at Aligoudarz Agriculture research station, Lorestan, Iran. The experiment was a randomized complete block design whit 4 replication. All combinations of 4 levels of both elements (including 0, 2, 4 and 8 ppt solution as sulfate compound $ZnSO_4$, $MnSO_4$), Which formed 16 different treatments, were distributed randomly in each block. Solutions were sprayed 10 days before and 20 days after flowering. Plants were harvested after ripened and plant characteristics including tuber weight, number of tuber per plant, tuber yield, percent of dry matter, specific weight, protein and starch percent on tuber were measured. Results showed that Zn and Mn application increased all plant characteristics relating to yield and quality of potato crop. These were tuber yield per plant, dry matter percentage, specific weight, protein and starch contents of the tuber. Application of Zn at 8 ppt increased yield to 34170 kg ha^{-1} which, was 25% higher compare with control, meanwhile application of Mn at 4 ppt level increased yield to 33866 kg ha^{-1} which was only 15% higher than control. However application of Mn at 8 ppt decreased both quality and yield of potato tuber compare with 2 and 4 ppt. maximum yield (38950 kg ha^{-1}) was obtained at 8 ppt of Zn and 4 ppt of Mn foliar application. Fertilizers were significantly affected on elements percentage in tuber. Zinc increased Zn percentage and decrease phosphorus percentage in tuber. Manganese increased Mn percentage of tuber, but no significantly effected on Zn, P and K in tuber. Zinc and manganese Fertilizers together increased Zn and Mn percentage and decrease P percentage in tubers, that they no significant.

Key words: Zinc sulfate, manganese sulfate, potato, yield, quality, enrichment

INTRODUCTION

Potato is one of the main tubers and nutritious crops, which also is very important due to nutritive value and economical. This crop with high performance in unit level is containing abundant carbohydrate and also biological value of protein is high. Studies have shown that utilization of microelements cause development of performance and quality of crops. Enrichment of agriculture crops for increasing of healthy level of society, production of seeds with high growth rate and sprout rate is very beneficial (Mohamadi, 2000).

Zn is playing main metabolically role in plants. This element partially interferes in most of the enzymes structure like, dehydrogenises, aldolase and isomerases. In production of energy and crebs cycle Zn also is effective (Alloway, 2004). Mn is one of the main components in structure of enzymes and these enzymes are effective in photosynthesis and other reactions and shortage of Mn cause efficiency of photosynthesis to be decreased extremely (Heckman, 2000).

Utilization of Zn and Mn in potato production cause, increase in number of potato, tubers, mean tubers weight and finally high performance and by applying ascorbic acid, Zn, Mn and other micronutrients, quality of potato tubers is increasing (Iqbal *et al*., 1995; Mohamadi, 2000). Studies has shown that utilization of Zn and Mn in other agriculture crops as, wheat, barley, maize and rapeseed, caused quality and quantity of theses crops to be increased (Bybordy and Malakoty, 2003). In most of the Iranian soils pH is high and they are also calcareous (Alloway, 2004). In this type of soils solvability of microelements is less and cause decline absorbency these elements and finally requirement of plants to this elements is increasing (Uygur and Rimmer, 2000). In Iranian soils situation, foliar application of elements viz: Zn, Mn, Cu

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and Mg is better than direct application them in soil due to: removing shortage very fast, easily utilization, decrease poisonous ness due to gathering and prevention from stabilization of these elements in soil. Generally, foliar application is very fast method for providing requires elements in plants because nutrients are absorbing quickly in compare with absorption that through plant roots (Hashemy majd *et al*., 1998). In this study utilization of microelements such as Zn and Mn, through foliar application on potato tubers performance and qualitative particulars has been studied.

MATERIALS AND METHODS

The study area is located in Aligoudarz Agriculture research station, Lorestan, Iran. Annual average temperature in research area was 13.6°C and average rainfall was 407 mm and also it was 2024 m higher than sea level. The experiment was a randomized complete block design with 4 replication. All combinations of 4 levels of both elements (increasing 0, 2, 4 and 8 ppt solution as sulfate compound Zn sou and Mn sou) which formed 16 different treatments, were distributed randomly in each block, solutions were sprayed 10 days before and 20 days after flowering.

Before preparing seed bed in 0-30 cm deep soil, sampling was conducted than by soil analyzing, amount of absorbable elements in soil was measured (Table 1). Main elements such as N, P and K on the basis of soil analysis, agriculture research center recommendations and natural resources was provided from urea super phosphate tripe and sulphate potassium resources which were 350, 50 and 15 kg ha^{-1}, respectively. Whole amount of super phosphate tripe and sulfate potassium and half of the urea at the time of preparing seed bed was used and other half of urea was applied at the time of giving soil to collar plant.

Seed cultivation with density 5.3 plants per m^2 at first of Jun 2004, was done, plants distance on the rows were 25 cm. Control of weed was done through mechanical and in tow times manually. At the end of September 2004 by harvesting 2.5 m^2 from each plot, tuber yield and number of tuber per plant was determined and by weighting tubers in each plant, mean weight of tuber was calculated. From each plot around 3 kg potato tuber for determining qualitative particulars of tubers including specific weight, percent of dry matter, protein and starch percent was used. Specific weight of tubers was determined with the half of 2 L graduated cylinder. For determining dry matter percent, tubers after weighting was cut with the help of knife to laminates 4-5 mm and then located inside of oven at 75°C for 24 h. Percent of protein was obtained by following formula after determining amount of nitrogen.

Pr = 6.25 × Nt × DM.
Pr = Percent of protein.
Nt = Percent of total N.
DM = Percent of dry matter.

Starch percentage was obtained with the help of polarimeter method. Concentration of elements such as; Zn, Mn and K was measured by atomic absorption and concentration of phosphate was obtained by spectrophotometer method. The data were analyzed with the help of MSTAT-C software and treatment means were compared by Duncan's new Multiple Range Test (DMRT). Excel software was used for drawing graphs.

RESULTS AND DISCUSSION

Effect of fertilizer treatments on number of tuber in plant: On the basis of results obtained was increased with increasing Zn and Mn utilization, because in forth level of Zn_8 (foliar application Zn at 8 ppt) and in third level of Mn_4 (foliar application Mn at 4 ppt). Maximum numbers, i.e., 0.99 and 11.22 was obtained, respectively and in compare with control it was increased 16 and 9.5%, respectively (Table 2, 3). Interaction of studied factors on number of tuber per plant was significant. Maximum tubers per plant was obtained by applying Zn and Mn together at 8 and 4 ppt in which compare with control 31% increased (Table 4). Foliar application of Mn at 8 ppt caused decrease in number of tubers as compared with second and third levels (Table 3).

Effect of Zn and Mn foliar application on mean weight of potato tubers: With considering Table 2-4, utilization of Zn and Mn causes on increase in mean weight potato tubers. Foliar application of Zn at 8 ppt was increased mean weight potato tubers to 75.59 g which in compare with control 7.2% increased, also utilization of Mn at 4 ppt by foliar application increased mean weight. Potato tuber up to 73.48 g which it was shown 5.2% increases in compare with control. Maximum mean

Table 1: Soil analyses result for physical and chemical characteristic

			Micro and macro nutrient (mg kg^{-1} soil)									
Characteristic	EC (dS m^{-1})	OC	P	K	Fe	Mn	Zn	Cu	B	TDS	Soil tissue	pH
Value	0.49	0.69	10.4	220	2.2	5.1	0.48	0.9	0.43	224	Clay-loam	7.8

Table 2: Effect of zinc ($ZnSO_4$) on tuber yield and quality of potato

Treatments (ppt)	No. of tuber per plant	Mean tuber weight (g)	Total yield (kg ha^{-1})	Dry matter (%)	Specific weight (g cm^{-3})	Protein (%)	Starch (%)
Zn_0	9.47^{b1}	70.52^{b}	27340^{c}	21.02^{b}	1.053^{b}	9.03^{b}	20.67^{b}
Zn_2	10.48^{a}	70.82^{b}	29390^{b}	21.63^{ab}	1.062^{bc}	9.10^{b}	21.12^{ab}
Zn_4	10.95^{a}	72.38^{b}	32500^{a}	22.05^{a}	1.065^{ab}	9.87^{ab}	21.75^{ab}
Zn_8	10.99^{a}	75.59^{a}	34170^{a}	22.06^{a}	1.073^{a}	10.34^{a}	22.14^{a}
Result	**	**	**	*	**	**	*

** = p<0.01, * = p<0.05; Column means followed by the same letter are not significantly different at the 0.05 and 0.01 probability level

Table 3: Effect of Manganese ($MnSO_4$) on tuber yield and quality of potato

Treatments (ppt)	No. of tuber per plant	Mean tuber weight (g)	Total yield (kg ha^{-1})	Dry matter (%)	Specific weight (g cm^{-3})	Protein (%)	Starch (%)
Mn_0	10.20^{b1}	69.80^{b}	29360^{c}	21.30^{b}	1.050^{b}	8.95^{b}	21.02^{b}
Mn_2	10.46^{ab}	72.97^{a}	31350^{b}	21.94^{ab}	1.070^{a}	9.72^{a}	21.79^{ab}
Mn_4	11.22^{a}	73.48^{a}	33866^{a}	22.32^{a}	1.075^{a}	10.19^{a}	22.21^{a}
Mn_8	9.96^{b}	70.70^{ab}	28380^{c}	21.17^{b}	1.058^{b}	9.47^{ab}	20.66^{b}
Result	**	**	**	*	**	*	*

** = p<0.01, * = p<0.05; 1-Column means followed by the same letter are not significantly different at the 0.05 and 0.01 probability level

Table 4: Effect of Zinc and Manganese on tuber yield and quality of potato

Treatments (ppt)	No. of tuber per plant	Mean tuber weight (g)	Total yield (kg ha^{-1})	Dry matter (%)	Specific weight (g cm^{-3})	Protein (%)	Starch (%)
Zn_0,Mn_0	9.13^{cd1}	67.49^{de}	25290^{g}	20.36^{d}	1.034^{f}	8.10^{d}	20.18^{c}
Zn_0,Mn_2	9.36^{bcd}	71.59^{bcde}	27450^{fg}	20.92^{bcd}	1.050^{ef}	8.84^{bcd}	20.92^{abc}
Zn_0,Mn_4	10.36^{abcd}	70.70^{cde}	29980^{def}	22.10^{abcd}	1.066^{bcde}	9.84^{abc}	21.34^{abc}
Zn_0,Mn_8	9.04^{d}	72.29^{bcde}	26650^{fg}	20.70^{cd}	1.063^{bcde}	^{d}9.35^{abc}	20.23^{bc}
Zn_2,Mn_0	10.26^{abcd}	67.00^{e}	28170^{efg}	21.31^{abcd}	1.051^{ef}	8.40^{cd}	21.10^{abc}
Zn_2,Mn_2	10.23^{abcd}	68.88^{cde}	29160^{efg}	21.68^{abcd}	1.068^{bcde}	9.06^{bcd}	21.05^{abc}
Zn_2,Mn_4	11.00^{ab}	69.82^{cde}	31430^{cde}	22.13^{abcd}	1.078^{abcd}	^{d}9.56^{abc}	21.83^{abc}
Zn_2,Mn_8	10.34^{abcd}	68.19^{cde}	28800^{efg}	21.39^{abcd}	1.051^{ef}	9.38^{abcd}	20.51^{bc}
Zn_4,Mn_0	10.75^{abcd}	67.65^{de}	29800^{def}	21.85^{abcd}	1.054^{def}	9.60^{abcd}	21.17^{abc}
Zn_4,Mn_2	10.56^{abcd}	74.11^{abc}	32010^{cde}	22.37^{abc}	1.078^{abc}	10.06^{abc}	22.34^{abc}
Zn_4,Mn_4	11.52^{a}	74.25^{abc}	35070^{bc}	22.22^{abcd}	1.065^{bcde}	10.32^{ab}	22.48^{abc}
Zn_4,Mn_8	10.99^{ab}	73.50^{abcd}	33110^{bcd}	21.76^{abcd}	1.062^{cde}	9.52^{abcd}	21.03^{abc}
Zn_8,Mn_0	10.85^{abc}	77.08^{ab}	34180^{bc}	21.77^{abcd}	1.062^{cde}	9.71^{abcd}	21.64^{abc}
Zn_8,Mn_2	11.60^{a}	77.30^{ab}	36780^{ab}	22.79^{ab}	1.048^{ab}	10.93^{a}	22.85^{ab}
Zn_8,Mn_4	12.00^{a}	79.16^{a}	38950^{a}	22.85^{a}	1.091^{a}	11.06^{a}	23.19^{a}
Zn_8,Mn_8	9.50^{bcd}	68.83^{cde}	26750^{fg}	20.83^{cd}	1.056^{de}	9.66^{abcd}	20.86^{abc}
Result	**	**	**	*	**	*	*

** = p<0.01, * = p<0.05; Column means followed by the same letter are not significantly different at the 0.05 and 0.01 probability level

production has been by foliar application of Zn and Mn together at 8 and 4 ppt respectively up to 79.16 g which has shown 17% increase in compare with control.

Effect of fertilizer treatments on performance of potato crop: By considering present results in Table 2 and 4, maximum production level has referred to simple effect of Zn in forth level of Zn (foliar application Zn at 8 ppt) that was 34170 kg ha^{-1} and in compare with control 25% increased. Maximum production level about Mn has been third level (foliar application of Mn at 4 ppt) and it was equal to 33866 kg ha^{-1} and in compare with control it is increased up to 15%. Maximum performance concerned to Zn_8, Mn_4 treatment (foliar application of Zn and Mn together at 8 and 4 ppt, respectively) that total performance in this treatment 38950 kg ha^{-1} obtained that in compare with simple effect of fertilizer treatment increased. Above results have been significant.

Effect of foliar application of Zn and Mn specific weight of potato tubers: Results obtained from ANOVA has shown that increase in specific weight of potato tubers (Table 2, 4) utilization of Zn at 2, 4 and 8 ppt increase specific weight of potato tubers in compare with control up to 0.8, 1.1 and 1.9%, respectively and also application of Mn at 2, 4 and 8 ppt is increased specific weight of potato tubers as compared with control up to 1.9, 2.3 and 0.7%. Utilization of Zn along with Mn at 8 and 4 ppt, 5 increased specific weight in potato tubers in compare with control. Effect of different level of Zn, Mn and their interaction on specific weight of potato tubers statistically was significant (p<0.01).

Effect of fertilizer treatments on dry matter of potato tubers: Utilization of Zn and Mn increased dry matter percentage in potato tubers and this increase statistically was significant. Application of Zn at 8 ppt increased percent of dry matter up to 5% in compare with control and also Zn at 4 ppt increased dry matter up to 4.7% in compare with control (Table 2, 3). Application of Zn along with Mn also increased percent of dry matter, because by utilization of them together at 8 and 4 ppt percent of dry matter 12.2% increased (Table 4).Whatever, application of Mn at 8 ppt decreased percent of dry matter (Table 3).

Table 5: ANOVA data about concentration of elements in potato tubers

		MS			
SOV	df	Zn (mg kg^{-1})	Mn (mg kg^{-1})	P (%)	K (%)
Replication	3	2.83ns	1.02ns	0.0003ns	0.0003ns
Zn	3	21.60**	0.03ns	0.0090**	0.0003ns
Mn	3	2.15ns	3.56*	0.0003ns	0.0003ns
Interaction Zn*Mn	9	1.07ns	0.03ns	0.0001ns	0.0002ns
Error	45	1.48	1.05	1.0010	0.0003
CV (%)		10.50	22.38	25.6200	3.1600

ns = Non significant, ** = p<0.01, * = p<0.05

Effect of foliar application Zn and Mn on protein percent of potato tubers: On the basis of present result in Table 2, utilization of Zn at 8 ppt increased 14.5% amount of protein in potato tubers in compare with control, which this change statistically was significant. Application of Mn at 2, 4 and 8 ppt increased protein percent in potato tubers at 8.6, 13.8 and 5.8% in compare with control respectively and this increase statistically was significant (Table 3). Utilization of Zn and Mn together at 8 and 4 ppt increased protein percent of potato tubers up to 36.5% as compared with control (Table 4).

Effect of fertilizer treatments on starch percent of potato tubers: Increase in Zn and Mn utilization caused increase in starch percent in potato tubers. Application of Zn at 2, 4 and 8 ppt increased starch percent in potato tubers 2.1, 5.2 and 7.1% in compare with control, respectively (Table 2). Utilization of Mn at 2 and 4 ppt also increased starch percent in potato tubers 3.6 and 5.6% as compared with control, however application of Mn at 8 ppt caused decrease in starch percent in compare with 2 and 4 ppt (Table 3). Application of Zn and Mn together also increased starch percent in potato tubers. Utilization of Zn along with Mn at 4 and 8 ppt also increased 14.9% amount starch in potato tubers in compare with control. Above results were statistically significant (Table 4).

Effect of foliar application Zn and Mn on concentration of elements like; Zn, Mn, P and K available in tubers: On the basis of results in Table 5, effect of foliar application Zn and Mn on concentration of elements like, Zn, Mn and P percent in potato tubers they were significant. Foliar application of Zn caused increase concentration of Zn in potato tubers and utilization of Zn at 2, 4 and 8 ppt increased concentration of Zn in potato tubers 8, 22 and 23% in compare with control respectively (Fig. 1). Results statistically were significant. There was no effect of Mn treatments on Zn concentration in potato tubers (Table 5).

Foliar application of Zn and Mn together caused increase Zn concentration in tubers, more ever maximum Zn concentration (13.34) obtained by foliar application of Zn along with Mn at 8 and 2 ppt, but this increase was not significant (Table 5).

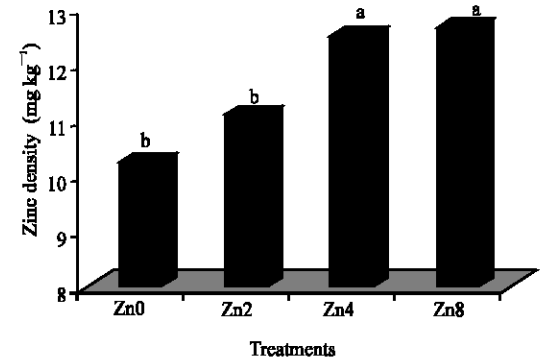

Fig. 1: Effect of zinc on tuber zinc density

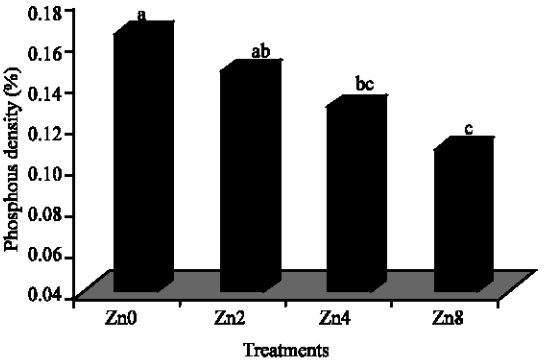

Fig. 2: Effect of zinc on tuber phosphorus density

Results showed that foliar application of Mn is increasing Mn concentration in potato tubers, so that foliar application of Mn at 8 ppt increased 26% concentration of Mn in potato tubers in compare with control. This results statistically were significant. Zn foliar application alone and or its utilization along with Mn did not show any significant effect on Mn concentration in potato tubers (Table 5). By increasing Zn utilization, decreased concentration of available P in potato tubers. Results were significant (Fig. 2). Foliar application of Mn had not any effect on P concentration in potato tubers. Utilization of Zn and Mn together decreased concentration of P in potato tubers, whatever this decrease was not significant (Table 5). By foliar

application of elements such as, Zn and Mn observed texture cells and potato performance developed but by increasing performance, concentration of P decreased in potato tubers.

Results are in agreement with finding most of the workers like (Bybordy and Malakoty, 2001; Ranjbar Malakoty, 2000; Hashemy *et al*., 1998).

CONCLUSIONS

Due to metabolic role of Zn in synthesis of proteins, enzyme activation and metabolism of carbohydrate, utilization of fertilizers containing this element increase qualitative and quantitative performance of potato tubers. Due to shortage of Zn, performance and quality of potato will be decreased (Alloway, 2004). Numerous studies separately have reported that utilization of Zn is increasing performance and quality of potato tubers (Ranjbar and Malakoty, 2000; Iqbal *et al*., 1995; Mondy *et al*., 1993).

Foliar application of elements like Zn and Mn with high concentration is poisonous and with decreasing level of photosynthesis in plants performance will be less. It was observed in forth level of Mn. Foliar application of elements like Zn and Mn caused enrichment and addition concentration of elements like Zn and Mn and decline P concentration in potato tubers (Bybordy and Malakoty, 2001; Ranjbar and Malakoty, 2000). Bybordy and Malakoty (2003) indicate that Mn element from sulfate Mn resource in increased quality and efficiency of rapeseed crop.

In general, Zn and Mn elements have main role in synthesis of proteins, enzyme activating, oxidation and revival reactions and metabolism of carbohydrates. By utilizing of fertilizers contain above elements, performance on quality of crops is increasing and with shortage of this elements due to decline in plant photosynthesis and destroy RNA, amount of solution carbohydrates and synthesis of protein decreased and then performance and quality of crop will be decreased. Kelling and Speth (2001) reported that utilization of elements like Zn and Mn together from resource sulfate Zn and Mn increased efficiency and quality of potato crop. Mohamadi (2000) found that application of Zn along with Mn to from foliar application caused increase in efficiency and quality of potato crop.

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