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Effects of phosphorus-zinc interactions on the yield of potato cultivars

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Abstract: *It seems that the synergy between adding P and Zn together can substantially increase potato-tuber-yield and quality in situations where this phenomenon occurs. Previous research indicates negative effects on potato when excess phosphorus (P) fertilizer is applied. The standard grower practice is to uniformly apply P to an entire field, which results in 30%-45% of the field receiving excess P fertilizer. One possible approach is based on a physiological coupling of excess P inducing a zinc (Zn) deficiency. The objectives of this project were to evaluation the interaction effects of P and Zn fertilization on the yield of three potato cultivars. A two years field project was excuted. Treatments arranged in a split-plot randomized complete block design with three replications. Treatments were factorial combinations of three P2O5 rates (0, 75 and 100 kg ha-1) and three rates of ZnSO4 (0, 50 and 100 kg ha-1) as a sub-plot and three potato cultivars (Marfoona, Santee and Maradona, Early, middle and late season respectively) as a main-plot. Two years combined analysis of variances, resulted that Mara-dona cultivar had significantly maximum tuber yield. In Marfoona and Santee cultivars, tuber yield differences didn't significant. Significant responses were observed both for P and Zn fertilization, as well as a significant interaction between the two. The most tuber yield resulted from 75 kg ha-1 (as P2O5) and 50 kg ha-1 (as ZnSO4). It was concluted if the soil test showed the critical soil available P and Zn, in Maradona cultivar, application of 150 kg ha-1 triple super-phosphate and 50 kg ha-1 ZnSO4 recommended as soil application in tillage stage. Phosphorus application without consideration Zn nutrition is potentially a serious management problem for potatoes grown in Zn-limiting soils. Further research is needed to confirm this effect and to explore rate and ratio effects of adding P and Zn fertilizers.*

key words: *P, Zn, potato cultivars, tuber yield,*

INTRODUCTION

Zinc and phosphorus are among the most important nutrients needed for potato growth (Solanum tuberosum). Zinc is a relatively static element in soil that is mostly concentrated in organic matters and in the surface soil. Phosphorus and zinc have a lot of mutual impacts on each other. Adding too much phosphorus to the soil, can cause a reaction with zinc and finally leads to the zinc non-absorption in the soil (2,3). Calcareous soils and low organic matters of soil, low solubility of micronutrients, especially elements such as zinc and manganese can be seen on most farms. Also, cold, wet weather causes the reduction of the mobility of the phloem and it can lead to its deficiency in the plant. With increasing soil pH higher than7, the solubility of elements such as zinc logarithmically reduces. The surveys show that the potato crop continuously absorbs zinc from the soil till the harvest time. Zinc deficiency first will appear in young leaves. Zinc deficiency causes leaves chlorosis and rosttes on most crops (4,5).

Hopkins et al (2004) showed that 30-45 percent of Idaho farms in America have used a lot of phosphate fertilizers. And the application of phosphorus fertilizers in potatoes irrespective of zinc element can cause serious problems on growth, yield and quality of potatoes. In addition, the simultaneous application of zinc and phosphorus can have a synergistic effect in increasing the yield and quality of potatoes (6). Bowan et al

(2002) reported that increasing the density of phosphorus of the plant causes an increase in the ratio of P/Zn and incidence of metabolic abnormalities. And the proportion density of P/Zn is a proper criterion for determining the mutual impacts of phosphorus and zinc in potato; in healthy plant P/Zn is usually less than 400 and in the plants deficient in ratio this were more than 400(3).

Munday et al (1993) noted the application of zinc caused the density of calcium, manganese, copper, aluminum, cobalt and ascorbic acid (vitamin C) and lack of change in cadmium density in potato tubers. Also, potato leaves with Zinc deficiency contained 2.22% of phosphorus higher than others. And the phosphorus toxicity symptoms including, burning tip, margins necrosis and complexity of potato leaf was observed (8). McLaughlin et al (2004) reported surveying the effect of fertilizer sources and amounts of zinc, phosphorus and potassium, as well as cadmium in fertilizers, on the absorption of cadmium in farms with potatoes' tubers exceeding cadmium (0.05 mg kg-1 fresh weight), that the application of 100 kg hectare-1, on net zinc, causes the reduction in the level of tuber cadmium in four places of the five locations of the experiment (7). Barben et al (2007) reported that consumption of 120 kg zinc sulfate per hectare along with twice folair application of Zinc sulfate(5 per thousand) a week before and a week after flowering, lead to a significant increase in yield of potato tubers (yield of control plots was 32.1 and yield of treated plots was 42.6 tons per hectare) (2). The objectives of this research was to investigate the mutual impact of zinc and phosphorus on yield of three varieties of common and commercial potato crops in Esfahan province (Frieden region), respectively.

Materials and methods

The current study was implemented based on a completely randomized block design in the format of one-time split plots within two years in Freydan region (Rezveh agricultural research station). The region is in a-2330-meter altitude from the sea level. It is located at longitude 50°, 26′and 38′′ east and at latitude 32°, 59′ and 45′′ north. The station is in a 120 km distance from Isfahan and it is situated in the north west of Isfahan Province. The climate typology of the region is steppe and cold. And there is frost for about 7 months of the year. The annual evapotranspiration potential is 520.4 mm. The average annual precipitation rate is 400 mm. Precipitations begin in November and in December it usually snows and it rarely rains in the summers. The annual average temperature is 10.4 °C. In the present study, three potato cultivars, naming, early-ripening Sante, mid-ripening Marfonna and late-ripening Maradonna were designed to be cultivated in the primary plots.

The fertilizer treatments including a composition of Phosphorus and Zinc were as follow: three Phosphorus (P_2O_5) levels were applied in 0, 75 and 100 kg ha-1 and three Zinc levels($ZnSO_4$) including 0, 50 and 100 kg ha-1 were incorporated in the secondary plots as stated as: 0 P× 0 Zn, 2. 0 P × 50 Zn, 3.0 P × 100 Zn, 4.75 P× 0 Zn, 5.75 P × 50 Zn, 6.75 P × 100 Zn, 7. 100 P× 0 Zn, 8. 100 P × 50 Zn, 9. 100 P × 100 Zn. Phosphorus and Potassium fertilizers were applied manually pre-planting and they were buried under the soil surface with the use of plowing methods. Nitrogen fertilizers were applied in a 200 kg ha-1 rate in the form of urea three times, including 100 kg ha-1 when planting, the first top dressing with a 50 kg ha-1 when going muddy and the second top dressing with an amount of 50 kg ha-1, 15 days after going mudding. Zinc fertilizer in the form of zinc sulphate was manually applied when planting and it was buried under the soil surface with the use of plowing methods.

The planting method was forrow with a distance of 75 cm and the potato tubers were planted in a row, each 25 cm apart and in a 15 cm depth (the distance between the beds). Every secondary treatment included 4 planting lines and it was stretched up to 6 meter in length. The tuber yield was evaluated according to the potato cultivars and different phosphorus: zinc treatments. The information obtained was statistically analyzed and there were conclusions drawn based on the results attained.

Results and Discussion

Soil and water properties

Quality of irrigation water was good and is located in class C1S1 (without limitation to crops irrigation). Remember soil temperature regime is mesic and its moisture regime is xeric. The soil category is Inceptisols and its series is Loamy skeletal carbonatic, mesic, typic calcixerepts. The soil type has been classified as Frieden series. The soil properties of Frieden series includes the restrictions of soil depth, heavy surface texture, with 15 to 35 percent gravel, 30 to 40 percent lime and its increase in the layer beneath, petrocalcic

layer of soil at one meter depth and prevention of the of root penetration to the deep soil, 7.5 to 8 pH and are with no soil salinity problem (tables 1 and 2).

Table1: Some of soil physicochemical properties *

EC dS m^{-1}	pH	OC (%)	P	K	Zn	Fe	Mn	Cu	texture
			mg kg^{-1}						
0.95	7.7	0.55	25.9	410	5	6.4	12	1.8	SiC

*P, K, Zn, Fe, Mn and Cu are in the available form

Table2: Some of irrigation water chemical properties

$Ca^{2+}+Mg^{2+}$	Na^{+}	SO_4^{2-}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	pH	EC dSm^{-1}
meq l^{-1}							
2.8	0.1	0.1	0.2	0.4	2.2	7.3	0.3

Tuber yield: The comparison of two years compound mean yield of potato showed the highest tuber yield (statistically significant at the 5% level) is in the Maradona kind. Marfona and Sante gland yield respectively are located in the next ranks (both in a statistical group). The highest tuber yield recorded in Maradona shows the potential of this kind in the mentioned region as well as its good response to nutrient treatment of the phosphorus and zinc fertilizer supply and in other words, the above mentioned kind accepts the fertilizing.

Table 3: Mean values of potato cultivar yield *

Sante	Marfona	Maradona	cultivars
23.6B	**25.0**B	**28.0**A	Yield(t ha^{-1})

* numbers followed by the same letter are not significantly different($P<0.05$)

The interaction of Zn and P on tuber yield

Among the positive synergistic effects of phosphorus and zinc is the improvement of the yield and quality of potatoes. Records over two years show that in total, the two years of the most significant increase in potato tuber yield of users 75kg per hectare triple super phosphate source and 50 kg of zinc per hectare was obtained on the source sulfate). The lowest yield is the ratio of 24 tons per hectare related to the highest level of phosphorus and zinc sulfate treatment which can be a sign of the importance of zinc use along with the adequate phosphorus (Table 4). A recent subject indicates the necessity of application of zinc and phosphorus and positive and progressive effects of these elements together on the growth and yield of potato tubers. Hopkins et al (2004) and Motalebi et al (2013) evaluated the mutual impact between zinc and phosphorus in potato tuber yield increase as positive.

Table 4: Mean values of Zn and P effects on potato yield (t ha-1) *

9	8	7	6	5	4	3	2	1	treatment
26.3AB	**25.4**B	**24.0**B	**26.0**AB	**27.6**A	**26.6**AB	**24.3**B	**25.1**B	**25.3**B	yield

* numbers followed by the same letter are not significantly different($P<0.05$)

Conclusion

Finally, it can be concluded that if a soil test indicates the soil available phosphorus and zinc is located below the critical level, in the regional Daran city(Isfahan) the Maradona kind with 150 kg per hectare triple super phosphate plus 50 kg of zinc per hectare and the kinds of Sante and Agria with 75 kg per hectare triple super phosphate plus 50 kg of zinc sulfate per hectare in preparation of the substrate, phosphorus and zinc needed for the plants to grow to achieve optimal growth and yield of gland to be fulfilled. Ofcourse, in the soil that has higher levels of available phosphorus and zinc, according to the soil test should be used with lower amounts of phosphorus and zinc fertilizers. In the case that in the previous cultivation high phosphorus has been used and the soil test showed that the remained absorbable phosphorus of soil is above 12 mg per kg soil, should only suffice to the use of zinc sulfate. In the fields that the soil residual phosphorus is too high with the application of 100 kg zinc sulfate per hectare and several times zinc spray during the growing season, the adverse phosphorus effects on the absorption of micronutrients, particularly zinc can be prevented and cause the yield and quality of potato tubers increase in calcareous soils.

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