Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2322-3227 (Online)
Vol. 1, No. 2, 2015
http://JCNS.iauahvaz.ac.ir
OPEN ACCESS

Assessment of Foliar Application of Iron and Silicon on Some Agronomic, Quantitative and Qualitative Parameters of Potato (*Solanum tuberosum* L.)

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RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *23 Mar. 2015*
Received in revised form: *25 Apr. 2015*
Accepted Date: *24 May. 2015*
Available online: *1 Jul. 2015*

To Cite This Article: Ahmad Estaji, Hamid Reza Rousta, Mohammad Reza Mir Kahnooj. Assessment of Foliar Application of Iron and Silicon on Some Agronomic and Quantitative and Qualitative Parameters of Potato (*Solanum tuberosum* L.). ***J. Crop. Nut. Sci., 1(2),*** *18-25, 2015.*

ABSTRACT

This study aimed at evaluating some quantitative and qualitative properties of potato as one of the main commercial products in Iran. To this end, a split plot experiment on the basis of randomized complete bloke design with silicone and iron was carried out in jiroft as one of the commercial area of planting potatoes. The main factor included different levels of silicon (0, 10, 20, 30 $mM.l^{-1}$) and sub plot included different levels of Iron (0, 1, 2, 3 $g.l^{-1}$). The results showed that the highest and the lowest dry and fresh weight of plant, stem diameter, number of tubers per plant, number of tubers above 100 g, and the yield of tuber per hectare were observed in treatments with the interactive effect of iron and silicon at a concentration of 2 g per liter and control treatment, respectively. Tuber yield due to foliar application of 2 $g.l^{-1}$ iron and 2 $g.l^{-1}$ silicon was 15-35% more than control treatment. However, the interactive effect of the fertilizers on plant height, number of stems, number of tubers and tuber weight was not significant. In general, iron and silicon fertilizers with concentration of 2 $g.l^{-1}$ is recommended for producing potato with higher quality and quantity.

Keywords: *Agronomic traits, Fertilizer, Micronutrient, Potato, Yield.*

INTRODUCTION

Potato is one of the strategic foods in world which is considered as fourth food crop for human being after wheat, maize, and rice. Rate of the potato production in Iran is 176000 hectares with about 4.5 million tons product which is relatively low in comparison with average production in developed countries (Iran Agriculture Statistics, 2009). So to increase yield and quality of potato it is necessary to take a variety of factors into consideration such as balanced nutrition, to this end and supplying the micronutrients along with application of macronutrients are highly important (Briat *et al*., 2007).

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Since the potato demand for nutrients is high, the yield and the quality of the product severely reduce if the nutrients particularly iron and manganese is deficient (Panahi Kord Laghari *et al*., 2010). Moreover, since the soils in Iran particularly in Jiroft region are calcareous the soils, there is the micronutrients deficiency and difficulty in the nutrients uptake, nutritional management of the micronutrients can significantly increase the potato yield. Iron is one of the essential elements for the plant and plays an important role in the many plant processes such as photosynthesis, respiration, nitrogen uptake and construction, and also in construction and development of chloroplasts in plants. It ultimately influences plant growth, and yield and quality of product (Briat *et al*., 2007). Iron fertilizer treatment improves the some vegetative properties, dry and the fresh weight, and yield of tomato (Shenker *et al*., 2004), pepper (Roosta and Mohsenian, 2012), sweet potato (Adamski *et al*., 2012). Silicon is one of the mineral elements that play a fundamental role for plants (Richmond and Sussman, 2003). Research shows that the silicon increases growth, yield, and the freshness of plant (Fawe *et al*., 2001), bacterial and the fungal resistance (Balakhnina and Borkowska, 2013), resistance to heavy the metal toxicity (Liang *et al*., 2005), salt stress tolerance (Lee *et al*., 2010), water use efficiency (Gao *et al*., 2006) and nitrogen and phosphorus uptake by plant (Epstein and Bloom, 2005). Although there is the limited information about the effect of silicon, an investigation showed that by adding the silicon to nutrient solution the rate of the iron in apoplast space increased and the effects of iron deficiency in the soybean and cucumber reduced (Gonzalo *et al*., 2013, Bityutskii *et al*., 2014). Moreover, application of the silicon and iron increased the vegetative growth properties and yield of rice (Ashrafi Esfahani *et al*., 2014). Given the calcareous soils of Iran and the nutritional problems, especially the micronutrients and also due to the importance of cultivation and off-season production of the potato and implementation and continuation of its production in Iran. This research was conducted to investigate the effect of silicon and iron on the growth indices and qualitative and quantitative yield of potato in Jiroft.

MATERIALS AND METHODS

Specifications of Experiment Site

The experiment was carried out in 2012 in Jiroft Town (Kerman Province) at longitude 56̊ 55̍ E and latitude 28̊ 15̍ N and 950 m above the sea level. The average annual rainfall in this location is 182 mm, average temperature is 25.41̊c and the relative humidity is 44%. Characteristics of the soil of experiment site are displayed in table (1).

Table 1. Results of Physicochemical analysis of the experiment soil of the site (Soil depth: 0-30 cm)

Characteristic	Rate	Characteristic	Rate
EC ($ds.m^{-1}$)	1.69	Potassium ($mg.kg^{-1}$)	660
pH	8.3	Phosphorus ($mg.kg^{-1}$)	12.5
Sand (%)	35	Manganese ($mg.kg^{-1}$)	18.5
Clay (%)	40	Iron ($mg.kg^{-1}$)	15.6
Silt (%)	25	Zinc ($mg.kg^{-1}$)	17.6
Total nitrogen (%)	0.18	Copper ($mg.kg^{-1}$)	1.35
SAR	1.81	Sodium ($mg.kg^{-1}$)	4.33

Crop management

In order to investigate the effects of iron and silicon on quantitative and qualitative yield of potato in Jiroft, a split plot experiment in on the basis of randomized complete block design was carried out. The main plots included four levels of silicon (0, 10, 20, 30 $mM.l^{-1}$) and the sub plots included four levels of Iron (0, 1, 2, 3 $g.l^{-1}$). Amino chelate and salicylic acid compounds were respectively used as the sources of iron and silicon. Size of each experimental plot was 10×3. Fertilizers of nitrogen (150 $kg.ha^{-1}$ in three stages) phosphorus (100 $kg.ha^{-1}$) and potassium (130 $kg.ha^{-1}$) were added to all plots and finally, potato with the density of 75×25 cm (53000 plants per hectare) were planted. Foliar application of treatments was done during 6-7 leaf stage and continued in three steps (biweekly). All agricultural operations including weeds, pests, and diseases control were done.

Traits measure

Factors such as plant height, number of branches, number of tuber per plant, weight of light tubers (below 50 g), average tubers (50-100 g), and heavy tubers (above 100 g), average weight of tuber per plant, total weight of tuber per plant, total weight of tuber per square meter, and the number of nodes per tuber were determined.

Data analysis

The data were analyzed by SAS software (Ver. 8) and the means of treatments were compared by Duncan's test at 5% probability levels.

RESULTS AND DISCUSSION

Plant height, number of stems, stem diameter, plant fresh weight and plant dry weight

The ANOVA results in Table (2) showed that plant height was affected by simple effects of fertilizer treatment of silicon and iron, but the number was only affected by iron fertilizer. Moreover, the simple effects and the interactive effects of silicon and iron on stem diameter were significant. Mean comparison showed that the maximum plant height belonged to the Iron fertilizer (2 per1000) by 76.28 cm and silicon (3 per 1000) by 75.46 cm.

Table 2. The ANOVA results of effect of silicon and iron effect on measured traits

S.O.V	df	Plant height	Number of stems	Stem diameter	Plant fresh weight	Plant dry weight
Replication	2	28.36	0.856	2.356	735.851	36.45
Iron	3	485.363**	4.365**	19.485*	4321.26*	585.536**
Error 1	6	47.445	0.36	2.671	691.955	55.42
Silicon	3	266.752**	0.327^{ns}	27.097**	8223.543**	442.485**
Iron × silicon	9	98.331^{ns}	0.298^{ns}	12.91*	4961.159**	462.28**
Error 2	24	50.86	0.322	5.432	923.852	85.86
CV (%)	-	11.42	7.6	14.6	8.9	12.12

ns, *.**, non-significant, and significant at 5% and 1% probability levels, respectively.

The highest number of stems belonged to the treatment with iron (2 per 1000) (Table 3). The highest stem diameter belonged to the treatment with interactive effect of Iron 2 × silicon 2 per 1000 (Fig. 1). Iron is an essential element for growth particularly for potato. If this element is insufficient chlorophyll synthesis is disrupted which leads to the leaves chlorosis and the leaf death. Consequently, the plant photosynthetic area decreases (Xie *et al*., 2014). Furthermore, the iron deficiency inhibits the formation of new leaves and stops the plant growth (Chen *et al*., 2010).

Table 3. Mean comparison of foliar application of silicon and iron on plant height and number of stem

Element	Concentration (g.l^{-1})	Plant height (cm)	Number of stem
Silicon	0	51.54^{c}	1.93^{a}
	1	63.31^{b}	2.36^{a}
	2	75.46^{a}	2.48^{a}
	3	77.82^{a}	2.63^{a}
Iron	0	68.45^{b}	1.854^{c}
	1	69.67^{b}	2.306^{b}
	2	76.28^{a}	3.11^{a}
	3	68.33^{b}	3.00^{a}

Similar Letters in each column show non-significant difference according to 5% level in Duncan Test.

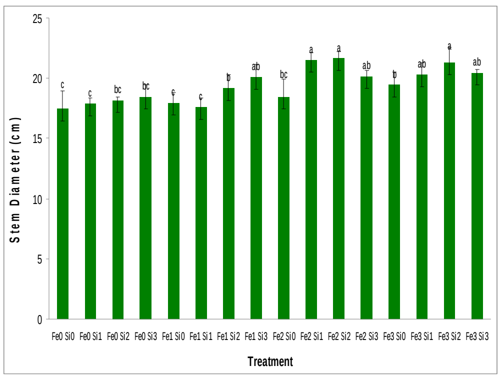

Fig. 1. The interactive effect of silicon and iron on stem diameter of potato, via Duncan test at 5% probability level. Fe_0, Fe_1, Fe_2, and Fe_3 are iron treatments with concentrations of 0, 1, 2, and 3 g.l^{-1}, respectively. Si_0, Si_1, Si_2, and Si_3 are silicon treatments with concentrations of 0, 1, 2, and 3 g.l^{-1}, respectively.

There are many reports on the effect of application of different iron fertilizers on plant growth properties, so that the number of leaves and branches of pepper treated with iron chelate significantly increased compared with the control treatment (Roosta and Mohsenian, 2012). Similar results were the obtained on the effect of application of the different iron fertilizers on strawberry (Zaiter and Saad, 1993) and tomato (Roosta and Hamidpour, 2011). This is probably due to the increase of chlorophyll synthesis and activity of the enzymes engaged in electron transfer that lead to the increase of the photosynthesis and plant growth and development (Ghasemi *et al*., 2014). Silicon is an unnecessary element for plants. It causes a series of physiochemical properties in soil and affects nutrients uptake by plant, on one hand, and indirectly influences structural and physiological processes of plant and enhances plant growth, on the other hand (Balakhnina and Borkowska, 2013). Silicon enhances cucumber growth and prevents necrosis of leaf tissues under the stress conditions of iron, zinc, and manganese (Bityutskii *et al*., 2014). The same results were found on cucumber, pumpkin, and soybean under iron deficiency conditions (Gonzalo *et al*., 2013).

Dry and Fresh Plant Weight

The interactive effect of silicon and iron on dry and fresh weight was significant at 1% level (Table 2). Highest fresh weight and dry weight of plant belonged with iron 2 g.l^{-1} ×silicon 2 g.l^{-1} and lowest fresh weight and dry weight belonged to iron 0×silicon 0 g.l^{-1} and iron 0 × silicon 3 g.l^{-1} (Fig. 2). It has been reported that treatment of nano chelate and chelated iron in comparison to control treatment increased fresh and dry weight of basil (Peivandi *et al*., 2011). Strawberries treated with silicon had highest dry matter of root and stem compared with control treatment (Miyake and Takahashi, 1986). Silicon treatment had no effect on fresh and dry weight of rice under field conditions (Ando *et al*., 2002).

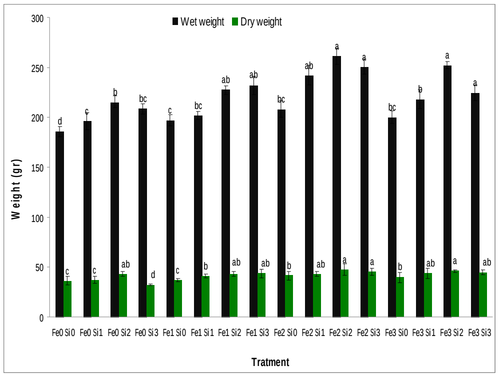

Fig. 2. The interactive effect of silicon and iron on dry and fresh weight of potato. Fe_0, Fe_1, Fe_2, and Fe_3 are iron treatments with concentrations of 0, 1, 2, and 3 $g.l^{-1}$, respectively. Si_0, Si_1, Si_2, and Si_3 are silicon treatments with concentrations of 0, 1, 2, and 3 $g.l^{-1}$, respectively.

Dry and fresh weight of stem and root in tomato plant under salt stress improved by silicon treatment (Romero-Aranda *et al*., 2006). The highest rate of dry weight of root, leaf, and stem in soybean and cucumber belonged to iron and silicon (Gonzalo *et al*., 2013). Dry and fresh weight of rice, under the high and low rate of iron significantly decreased compared with the optimal concentration of iron, but application of silicon increased dry matter in such conditions (Ashrafi Esfahani *et al*., 2014). On application of silicon in stress condition of micronutrients including iron, zinc, manganese, the adverse effects caused by the lack of elements particularly iron on dry weight of cucumber plant were reduced by silicon (Bityutskii *et al*., 2014). Since the results of this experiment are consistent with the findings of previous researches, it can be concluded that the increase of fresh weight and dry matter is probably due to the role of iron in the synthesis of chlorophyll and enzymes involved in photosynthesis. Silicon also plays a role in iron uptake by plant and prevention of chlorophyll degradation which prevents the degradation of chlorophyll and chloroplast membrane (Feng *et al*., 2010). Furthermore, silicon increases water potential in plant tissue and consequently leads to the increase of leaf tissue freshness and photosynthesis enhancement and thus increases carbohydrate accumulation in plant tissue (Romero-Aranda *et al*., 2006).

Yield and Yield Components

The ANOVA results indicated that the effect of silicon, iron, and their interactive effect on yield and yield components (number of turbines between 50-100 g) were significant at 1% level (Table 4). The interactive effect on the number of tuber per plant was significant at 5% level; however, the effect of treatments on the number of tubers (less than 50 g) was not significant. Mean comparison results showed that the maximum number of tubers between 50-100 g, total weight of tuber per plant, number of tubers per plant and tuber yield belonged to the treatment with iron 2 × silicon 2 $g.l^{-1}$, but the highest number of tubers more than 100 g belonged to the treatment with iron 2 × silicon 3 $g.l^{-1}$ (Table 5). It has been reported that the treatment with different iron fertilizers increased the number of fruits and the fruit weight of pepper plant (Roosta and Mohsenian, 2012). As the iron concentration increased in nutrient solution, the yield of potato tuber increased compared with control treatment and in high concentrations of iron the yield of tuber decreased (Chatterjee *et al*., 2005). Tuber yield, number of tuber, and weight of each tuber increased significantly compared with the control treatment in potato plants treated with iron and zinc (Reshma *et al*., 2007). This is probably due to the synergistic effect of iron with absorbable nitrogen and phosphorus which increases photosynthetic activity and IAA hormone, and consequently enhances vegetative growth and more stolon is produced and tuber yield rises (Sahota and Virk, 1986). Silicon is also an unnecessary element that can affect the yield, so that the treatment with silicon increased the number of tuber, weight of each tuber, and tuber yield compared with control treatment (Crusciol *et al*., 2009). Moreover, the highest rate of tuber weight, tuber diameter, and the number of tubers belonged to the potato plants treated by lignosilicon (Lebedeva *et al*., 2011). Silicon application increased yield and quality of cucumber particularly under salt stress conditions (Stamatakis *et al*., 2003). This is probably due to the increase of vegetative growth and photosynthesis level, so that more photosynthetic materials are produced and consequently a product with greater quality and quantity is produced (Hattori *et al*., 2005).

Table 4. The ANOVA results of effect of silicon and iron on yield and yield components of potato

S.O.V	df	Number of tubers below 50 g	Number of tubers between 50-100 g	Number of tubers above 100 g	Total weight of tuber per plant	Number of tubers per plant	Tuber yield
Replication	2	3.256	4.322	2.273	4.35	2.724	6.443
Iron	3	18.132^{ns}	15.603**	8.485**	7.265^{ns}	6.513*	189.375**
Error a	6	5.96	1.04	0.753	3.36	1.11	13.917
Silicon	3	16.27^{ns}	8.73*	6.725**	306.27**	7.218**	160.282**
Iron × silicon	9	9.43^{ns}	9.48**	3.693**	78.453**	4.436*	73.442**
Error b	24	13.4	2.326	0.973	3.242	1.45	13.29
CV (%)	-	9.7	13.1	3.65	5.78	6.6	18.4

ns, *, ** non-significant difference and significant difference at probability levels of 5% and 1%, respectively.

Table 5. Mean Comparison Interactive effect of foliar application of silicon and iron on yield and yield components of potato

Iron treatment ($g.l^{-1}$)	Silicon treatment ($g.l^{-1}$)	Number of tubers between 100-500 g	Number of tubers above 100 g	Total weight of tuber per plant (g)	Number of tubers per plant	Tuber yield (T)
0	0	2.95^{d}	1.4^{e}	640.92^{f}	7.63^{c}	42.724^{d}
0	1	3.4^{c}	1.81^{d}	666.4^{e}	7.84^{bc}	44.426c
0	2	3.17^{c}	2.53^{c}	702.74^{d}	8.57^{bc}	46.849^{bc}
0	3	3.26^{c}	3.17^{bc}	750.06^{c}	9.26^{b}	49.998^{bc}
1	0	3.56^{c}	3.43^{b}	687.24^{e}	8.28^{bc}	45.853^{c}
1	1	3.63^{c}	3.57^{b}	792.995^{c}	9.73^{b}	52.768^{b}
1	2	4.87^{ab}	3.52^{b}	840.84^{b}	10.78^{ab}	56.050^{ab}
1	3	4.78^{ab}	3.65^{b}	908.85^{ab}	10.95^{ab}	60.583^{a}
2	0	4.23^{b}	3.04^{bc}	792.184^{c}	9.78^{b}	52.806^{b}
2	1	4.54^{b}	3.6^{b}	890.52^{b}	10.86^{ab}	59.362^{ab}
2	2	5.19^{a}	3.24^{bc}	1000.912^{a}	12.36^{a}	66.726^{a}
2	3	4.37^{b}	4.3^{a}	911.078^{ab}	11.03^{ab}	60.738^{a}
3	0	3.96^{bc}	2.45^{c}	701.92^{d}	8.56^{bc}	46.794^{bc}
3	1	3.75^{bc}	3.45^{b}	782.4^{c}	9.78^{b}	52.799^{b}
3	2	4.29^{b}	3.93^{ab}	939.72^{a}	11.46^{ab}	62.641^{a}
3	3	3.76^{bc}	3.59^{b}	848.45^{bc}	10.21^{ab}	56.563^{ab}

Similar Letters in each column show non-significant difference according to 5% level in Duncan Test.

Although a limited number of research has been reported on the effect of application of silicon and iron on plants yield, it can be said that treatment of silicon and iron can indirectly influence the yield, so that silicon improves some processes such as photosynthesis (Xie *et al*., 2014), nitrate assimilation (Isuwan *et al.*, 2007). It also increases potential of leaf water (Romero-Aranda *et al.*, 2006), and uptake of iron by plant root. Results of this research are consistent with findings of previous researches. Rice plants treated with ferrous sulfate and salicylic acid had highest yield in comparison with control treatment (Ashrafi Esfahani *et al*., 2014).

CONCLUSION

The results of experiment indicate that the fertilizer treatment of silicon and iron had a significant effect on growth properties and yield of tomato, so application of each fertilizer alone had less effect than their interactive effect on growth properties and yield of potato. The treatment with interactive effect of Iron 2 $g.l^{-1}$ and silicon 2 $g.l^{-1}$ is recommended for potato in Jiroft.

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