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EFFECT OF FOLIAR APPLICATION OF SILICON ON YIELD AND QUALITY OF RICE (*ORYZA SATIVA* L)

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ABSTRACT. A field experiment was conducted at University of Agriculture, Faisalabad, Pakistan, to investigate the effect of foliar application of silicon on yield and quality of fine rice (*Oryza sativa* L.). The research was designed as randomized complete block design (RCBD) having three replications and 6m x 4.5m net plot size was maintained. Foliar applications of silicon's aqueous solution were used as treatments comprised of control, 0.25%, 0.50%, 1.00% silicon solutions. Nursery of 30 days old seedling nursery was transplanted to the plots under aerobic condition and 22.5cm hill to hill distance was maintained. Sodium silicate (20.35% Si) as the source of silicon (soluble in warm water) was used. Fertilizer inputs as nitrogen, phosphorus and potassium were uniformly applied at the rate of 100, 67, 67 kg ha^{-1} while all other agronomic practices were kept constant for all the treatments. The data from the field (yield components) as well as lab analysis (quality parameters) was recorded according to the standard procedures. Fisher's analysis of the variance technique was used for statistical analysis and treatment's mean differences were compared using least significant difference (LSD) test at 5% probability level. Silicon showed no significant effect on plant height, harvest index, number of kernels and opaque kernels percentage. Silicon (0.50% silicon solution) produced maximum grain diameter and grain protein while silicon @ 1.00% silicon solution resulted maximum in number of productive tillers, straw yield, spike per panicle, 1000 grain weight, paddy yield and grain starch. All others parameters have overlapping results of different silicon levels.

Key words: Rice; Micro nutrient; Silicon; Yield: Quality.

INTRODUCTION

Rice is the second most important food crop after wheat in Pakistan (Nazeer *et al.,* 2012). In last few years rice yield has been found diminishing and nutritional imbalance has been reported as one of major reasons. In a more specific study of nutrients; the micronutrients have now have been found equally important as macronutrients although they are required in a minute quantity. Balancing the micronutrients for rice cultivation enhanced the quality and

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yield Ma *et al. (*2007). Micronutrients such as silicon are the most important for sustainable production of Basmati rice. Though the solubility of silicate minerals vary under different soil and environmental conditions however its concentrations in soil solutions range from 0.1 to 0.6 mM usually (Joseph, 2009).

Among all the micronutrients assimilated by plants, silicon alone is consistently present at concentrations similar to those of the macro nutrients. Its concentrations in different plants range from 0.1% (similar to P and S) to more than 10% of whole plant dry matter (Epstein, 1999). Hydrated amorphous silicon compounds are likely to be deposited in different cellular parts such as cell lumens, cell walls and intercellular spaces, its deposition below and above of the cuticle layer has also been reported.

Silicon is an important micronutrient for healthy and competitive growth of all cereals including rice in Asia (Brunings *et al.,* 2009). Role of silicon in plant health and growth has been investigated in silicon accumulating crops and it seemed significantly effecting (Jinab *et al.,* 2008). Research evidences proved that adequate uptake of silicon (Si) can increase the tolerance of agronomic crops especially rice to both abiotic and biotic stress (Ma and Takahashi, 2002).

Silicon up take by plants reduces the susceptibility to chewing insects such as stem borer; it might be by rendering plant tissue less digestible or by damaging greatly to the mandibles of feeding insects (Massey and Hartley, 2006). Silicon deficiency in plants makes them more susceptible to insect feeding, fungal diseases, germs attack and abiotic stresses that adversely affect crop yield and quality. Low silicon uptake has been proved to increase the susceptibility of rice to diseases such as rice blast, leaf blight of rice, brown spot, stem rot and grain discoloration (Kobayashi *et al.*, 2001; Rodrigues *et al.*, 2001; Massey and Hartley, 2006).

Effects of silicon on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses (Korndörfer *et al.*, 2004). The ability of silicon solution to reduce the impact of plant diseases has been clearly described in the case of rice blast (Kim *et al.*, 2002). Recently, silicon considers as a primary contributor to cause “Localized Decline” (Breitenbeck *et al*. 2006). Silicon uptake has been reported to mitigate the aluminum (Al) and iron (Fe) toxicity and a wide range of stresses in rice and other crops (Ma and Takahashi, 2002).

Many scientists working on role of silicon in plant growth have concluded that reduced amount of silicon in plant develops necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduces grain yield in cereals (Shashidhar *et al.*, 2008). Although silicon has not been considered important for vegetative growth but it aids the plant in healthy development under stresses in different grasses especially in rice. Plant tissue analysis has revealed the optimum amount of silicon is necessary for cell development and differentiation (Liang *et al.,* 2005).

Under changing socio-economic conditions all around the world, reduction in paddy yield is not affordable by the agricultural system. Major nutrients (N,P,K) are already in practice at optimum level but yield gap is still present so following the recent research it is needed to enter micronutrients like silicon (Si) rice production system. In the light of above discussions, present study was designed to investigate the effect of foliar application of different concentrations of silicon on fine rice under the agro climatic conditions of Faisalabad, Pakistan. The main objective was to evaluate the effect of foliar application of silicon on yield and quality of rice.

MATERIALS AND METHODS

Experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, on loamy soil during 2010-’11. Super Basmati (fine rice) was the crop to investigate the effect of foliar application of silicon on yield and quality of rice. Randomized complete block design having three replications was used and net plot size 6m x 4.5 m was maintained. The replications were considered as blocks. Before cultivation soil analysis according to standard procedure was performed. Treatments included in the experiment were as following, Si_0 = 0.00, Si_1 = 0.25, Si_2 = 0.50, Si_3 = 1.00 in percentage (%) silicon aqueous solutions. Nursery of 30 days old seedlings was transplanted to the puddle field; two seedlings per hill at 22.5 cm distance. Silicon was applied after 4 weeks of transplantation as foliar spray. Fertilizers as N, P and K were applied at the rate of 100, 67 and 67 kg ha^{-1}, respectively. Whole of phosphorous (di-ammonium phosphate) and potassium (sulphate of potash) were applied before transplantation while nitrogen (urea) was applied in three splits, half of urea was applied during transplanting whereas 1/4 was applied at tillering stage and 1/4 was applied at the time of panicle initiation. Irrigation was applied one week prior to nursery transplantation.

The data on different agronomic traits and quality parameters were collected and subjected to one way analysis of variance according to Steel *et al.* (1997) to sort out significant differences among treatments. Differences among means were compared using LSD at 5% probability level.

RESULTS AND DISCUSSION

Physico-chemical characteristics of the soil given in *Table 1* showed a clear picture of the total nutrients status of the soil. Analysis of variance table for number of tiller $plant^{-1}$ and sterile kernel presented in *Tables 3* and *4*, respectively. Effect of silicon on plant height (*Table 2*), panicle length and grain length (*Table 3*) harvest index, number of kernels and opaque kernels was non-significant as mentioned in *Table 4*.

Table 1 - Physico-chemical characteristics of soil

Soil properties	Values
pH	8.05
E.C dsm^{-1}	0.54
$CaCo_3$ Eq. (%)	10.30
Organic matter (%)	0.78
Nitrogen (%)	0.051
Sod bicarbonate extractable P (mg kg^{-1})	3.90
Amm acetate extractable K (mg kg^{-1})	83.00
Si (ppm)	0.47
Sand (%)	23.00
Silt (%)	45.50
Clay (%)	31.50
Textural class	Loamy

Table 2 - Mean values of some traits of rice as affected by different silicon levels.

Treatments	Plant height (cm)	Number of tiller $plant^{-1}$	Number of productive tiller	Straw yield (t/ha)	Branches $panicle^{-1}$	Spike $panicle^{-1}$
Si_0	5.77 A	268.96 a	248.01 A	10.49 c	10.41 b	113.22 d
Si_1	103.60	244.28 d	225.76 d	10.96 b	10.74 a	115.37 c
Si_2	104.69	259.58 b	240.33 b	11.93 a	10.74 a	116.73 b
Si_3	101.85	248.77 c	233.10 c	11.93 a	10.41 a	121.46 a
LSD (0.05)	NS	0.538	6.32	0.016	0.184	1.32

Si_0 =0.0% Si_1= 0.25% Si_2 =0.50% Si_3 =1.0%
Means not sharing a letter differ significantly using LSD at 5% probability level.

Table 3 - Mean values of some traits of rice as affected by different silicon levels.

Treatments	Panicle length (cm)	1000 grain weight (g)	Paddy yield (t/ha)	Abortive kernels (%)	Grain diameter (mm)	Grain length (mm)
Si_0	25.13	15.74 d	4.16 b	5.77 a	1.90 c	9.24
Si_1	25.87	17.66 c	4.71 a	5.28 b	1.92 b	9.29
Si_2	26.57	17.35 b	4.78 a	5.32 b	1.93 a	9.31
Si_3	26.88	17.98 a	4.88 a	5.20 b	1.85 d	9.52
LSD (0.05)	NS	0.33	0.214	0.29	1.15	NS

Si_0 =0.0% Si_1= 0.25% Si_2 =0.50% Si_3 =1.0%
Means not sharing a letter differ significantly using LSD at 5% probability level.

Table 4 - Mean values of some traits of rice as affected by different silicon levels.

Treatments	Grain protein content (%)	Grain starch (%)	Normal kernel (%)	Sterile kernels (%)	Opaque kernels (%)	Harvest index (%)
Si_0	6.10 b	77.30 c	70.54	10.95 a	12.72	26.25
Si_1	6.20 ab	77.34 c	71.37	10.82 b	12.52	26.35
Si_2	6.30 a	77.40 b	72.02	10.24 c	12.41	25.95
Si_3	6.19 ab	77.57 a	73.09	10.24 c	11.45	25.65
LSD (0.05)	0.15	0.042	NS	0.077	NS	NS

Si_0 =0.0% Si_1= 0.25% Si_2 =0.50% Si_3 =1.0%
Means not sharing a letter differ significantly using LSD at 5% probability level.

Maximum number to productive tillers (248.01) was found in control which is followed by 0.05% silicon application (240.03) while minimum in 0.025% silicon solution application as shown in *Table 2*. These findings are in line to Li *et al.* (2002), Rodrigues *et al.* (2003) and Mobasser *et al.* (2008) while contradicted to Pereira *et al.* (2004). They reported that increase in applied silicon amount enhanced the number of productive tillers and total number of tillers/m^2. Number of branches presenting in *Table 2* showed that all three applications of silicon are statistically similar but significantly higher than control. These results are similar to that of Ahmad *et al.* (2007) and Shahidhar *et al*. (2008).

Data regarding spikes/panicle showed significant effect. The maximum number of spike/panicle present in (Si_3) at the rate 1.00% have 121.48 number of spike/panicle followed by Si_2 having (116.73). Silicon application significantly affects the 1000 kernel weight. Silicon at the rate 1.00% (Si_3) produced maximum kernel weight (17.98 g) followed by 0.50% silicon solution and 0.25% silicon while control (Si_0) resulted minimum as 15.74 g (*Table 3*). These findings are similar to Malidareh (2011) but against the results of Mobasser *et al.* (2008) who reported that silicon application does not affect 1000 kernel weight in rice.

Foliar application of 1.00% silicon solution produced highest paddy yield (4.88 t ha^{-1}) but all three silicon applications are statistically similar while differing from control (Si_0) (*Table 3*). These results resembled to the findings reported by Mobasser *et al.* (2008) and Malidareh *et al.* (2011) but against to the finding of Mauad *et al.* (2003), who reported that silicon application does not affect the paddy yield.

Maximum straw yield (12.61 t ha^{-1}) was produced when 1.00% silicon was applied it was followed by 0.50% silicon and 0.25%, respectively, while minimum (10.49 t ha^{-1}) was found in control (Si_0) *(Table 2*). Similar were reported by Ahmad *et al.* (2007), Surapornpiboom *et al.*

(2008) and Elzbieta (2009). They reported that silicon is responsible to control stomatal activity, photosynthesis and water use efficiency which ultimately results in better vegetative growth and straw yield.

Sterile kernels percentage was found maximum (10.95%) in control (Si_0) where as this percentage is significantly reduced by silicon application as shown in *Table 4*. This reduction in kernel sterility is might be due to balanced nutrition, optimum metabolic activities or nullification of stresses by silicon application. These findings are near to the Mauad *et al.* (2003) and Wang *et al*. (2010), who reported that silicon is not directly evolved in quality enhancement but it control diseases and stresses to maximize the quality.

Abortive kernels percentage presented in *Table 3* proved that silicon application to rice was found significant regarding this parameter as all three silicon applications although statistically similar but differing from control (Si_0). Similar findings had also reported by Li *et al.* (2002), Buck *et al.* (2008) and Elzbieta (2009).

Maximum grain protein (6.30%) was found in 0.50% silicon (Si_2), followed by 0.25% silicon (Si_1) solutions application with 6.20% grain protein contents significantly higher than control. Grain starch regarding silicon application found maximum (77.57%) in with 1.00% silicon (Si_3) application while control (Si_0) produce minimum starch percentage (77.31%).

Silicon application regarding grain diameter (1.93) at 0.5% silicon (Si_2) followed by (Si_1) 0.25% silicon having 1.92 grain diameter presented in *Table 3*. These results resembled to the findings, that application of silicon improve the crop quality reported by Shashidhar *et al.* (2008).

CONCLUSIONS

From above the results the following conclusion was observed during the experiment. Plant height, number of tillers per plant, number of productive tiller, abortive kernal performed better where control silicon was applied, while straw yield, branches per panicle, spike per panicle, 1000 grain weight, paddy yield, grain starch were performed better where 1% silicon was applied by foliar application.

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