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RESEARCH ARTICLE

# Effect of Silicon and Boron Foliar Application on Yield and Quality of Rice

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**ABSTRACT**

A field study was carried out to investigate the effect of foliar application of silicon and boron on yield and quality of rice (*Oryza sativa* L.).. Randomized complete block design with factorial arrangement comprising three replications was planed and 4m × 2.25m net plot size was maintained. The treatments were comprised of silicon i.e. no additive, 0.50%, 1.00%, 1.50% aqueous solutions and boron i.e. no additive, 0.50%, 1.00%, 1.50% aqueous solutions for foliar application. Nursery of 30 days old seedling was transplanted and 22.5cm hill to hill distance was maintained. Sodium silicate (20.35% Si) and boric acid (11.17% B) were used as the source of silicon and boron, respectively. Combine application of both the nutrients at 1.5% silicon and 1.0% boron performed well. The interactive effect of silicon at 1.5% and boron at 1% has significantly improved 1000 kernels weight (19.65 g), biological yield (20.09 t ha$^{-1}$), kernel yield (5.63 t ha$^{-1}$), protein content (7.23 %), starch content (79.71 %) and economical to use. Silicon (1.0% silicon level) produced the maximum plant height and grain starch where in all others parameters silicon at 1.5% silicon solution resulted best. Individual application of boron had not shown any increase in plant height, whereas 1000-grain weight, paddy yield harvest index and all quality parameters were significantly affected by boron at 1.0% boron solution.

## INTRODUCTION

Micronutrients such as silicon and boron are the most important for sustainable production of Basmati rice. Silica is known as the second most abundant element in earth crust. Silicon concentrations in plants range from 0.1% (similar to Phosphorous and Sulfur) to more than 10% of whole plant dry matter (Epstein, 1999). Rice plant accumulates about 10% silicon in shoot which helps rice plant to fight against biotic and abiotic stresses. Silicon has been found accumulating in shoots in the form of monosilicic acid ($H_4SiO_4$). 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 (Akhtar et al., 2003 and Massey and Hartley, 2006). It is general consideration among the growers that role of Si in plant growth is non-obligatory. Silicon effects on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, production of phenols which stimulates phytoalexin production, reduces lodging, decreases transpiration losses and increases photosynthesis capacity of crop plants. Plant tissue analysis has revealed the optimum amount of silicon is necessary for plant development (Liang et al*.,* 2006).

Boron is needed in small amount but proved essential micronutrient for plant growth. Its deficiency symptoms and nutritional disorder characteristics appear when plant faces reduced supplies of boron. It is under consideration of many scientists for last many years. Its role in plant growth has been extensively studied in as many as 20 agricultural crops. Boron impacts transport of carbohydrates, cell division, cell wall strength and development, onset of fruits and seed development and hormonal production (Gunes et al., 2003). Its severe deficiency causes abnormal development of reproductive organs (Huang et al., 2000) and ultimately results in reduction of plant yield (Nabi et al., 2006).

Although most of the broad leave plants as well as cereals including maize, sorghum, wheat, rice and barley are generally less sensitive to boron deficiency however its deficiency appeared in several parts of the world (Rashid et al., 2004). Boron application improve the plant functioning at cellular level including cell division, flower and fruit formation and development, carbohydrate and nitrogen metabolism, water retention and disease resistance. Application of boron gave 41.8% yield increase. Different levels of B application have been reported and different levels in yield increase have been observed (Korndörfera and Lepsch, 2001). Boron can be used as soil application as well as foliar application on growing crop. Foliar application of boron is believed to retain significant carbohydrate phloem mobility to flowering meristemistic cell from either senescing leaves and/or bark. Thus foliar spray of boron not only a source to apply boron at a particular growth stage but also permits a rapidly-acting action to mitigate the problem soon after the deficiency diagnosis (Rashid et al*.,* 2004). The objective of the current study was to evaluate the effect of different silicon and boron levels and their interactive effect on growth, yield and quality of rice.

## MATERIALS AND METHODS

A field experiment was conducted to study the effect of foliar application of silicon and boron on rice yield and quality, at Agronomic Research Area, University of Agriculture, Faisalabad, on a sandy clay loam soil during 2010. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement having three replications. The treatments were comprised of silicon i.e. no additive, 0.50%, 1.00%, 1.50% aqueous solutions (Factor A) and boron i.e. no additive, 0.50%, 1.00%, 1.50% aqueous solutions for foliar application (Factor B). Soil analysis for boron and silicon was performed according to standard procedure. Nitrogen, phosphorous and potash

**Table 1: Effect of Foliar Application of Silicon and Boron on Yield and Quality of Rice**

| Treatments | Plant Height | Panicle Length | 1000 kernels Wt. | Biological Yield | Kernel Yield | Harvest Index | Protein Contents | Starch Contents |
|---|---|---|---|---|---|---|---|---|
| Boron levels | cm | | g | Mg ha$^{-1}$ | | | % | |
| $B_0$=0.0% | 103.65b | 26.12c | 17.02d | 18.92b | 4.64d | 26.25d | 6.20d | 77.41d |
| $B_1$=0.5% | 105.58a | 27.77b | 18.11c | 19.06ab | 5.16c | 27.25c | 6.41c | 78.00c |
| $B_2$=1.0% | 103.13b | 28.56a | 19.24a | 19.20ab | 5.45a | 28.35a | 7.09a | 79.54a |
| $B_3$=1.5% | 103.67b | 28.23a | 18.69b | 19.37a | 5.26b | 27.59b | 6.87b | 79.15b |
| *LSD at 5%* | *0.8728* | *0.3889* | *0.3208* | *0.3139* | *0.0823* | *0.3089* | *0.0558* | *0.0288* |
| Silicon level | | | | | | | | |
| $Si_0$=0.0% | 103.63 | 27.32b | 17.68c | 18.37d | 4.97d | 27.29 | 6.50c | 78.38d |
| $Si_1$=0.5% | 105.10 | 27.72a | 18.23b | 18.99c | 5.07c | 27.32 | 6.62b | 74.48c |
| $Si_2$=1.0% | 103.62 | 27.80a | 18.37b | 19.36b | 5.16b | 27.27 | 6.74a | 78.56b |
| $Si_3$=1.5% | 103.70 | 27.83a | 18.77a | 19.84a | 5.30b | 27.37 | 6.70a | 78.68a |
| *LSD at 5%* | *N.S* | *0.3889* | *0.3208* | *0.6279* | *0.0823* | *N.S* | *0.0558* | *0.0288* |
| Interaction (Si × B) | | | | | | | | |
| $Si_0B_0$ | 104.47c | 25.14h | 15.74j | 17.66i | 4.18h | 26.25 | 6.11j | 77.31n |
| $Si_0B_1$ | 104.15c | 27.62de | 17.56hi | 18.23hi | 5.1e | 27 | 6.28ghi | 77.88k |
| $Si_0B_2$ | 103.90cd | 28.53abc | 18.79bcde | 18.68gh | 5.42b | 28.46 | 6.89c | 79.39d |
| $Si_0B_3$ | 101.99ef | 28bcd | 18.64cdef | 18.89fg | 5.18cde | 27.43 | 6.74d | 78.95g |
| $Si_1B_0$ | 10360cde | 25.87gh | 17i | 18.68gh | 4.71g | 26.33 | 6.21hij | 77.34n |
| $Si_1B_1$ | 106.29ab | 27.77cd | 18.08fgh | 19.29cdef | 5.10g | 27.01 | 6.34fg | 77.95 j |
| $Si_1B_2$ | 105.22bc | 28.80a | 19.22abc | 19.10defg | 5.35bc | 28.39 | 7.08b | 79.47c |
| $Si_1B_3$ | 105.28bc | 28.45abc | 18.61cdefg | 18.89fg | 5.14de | 27.54 | 6.87c | 79.15f |
| $Si_2B_0$ | 104.69bc | 26.57fg | 17.34i | 19.89abc | 4.78fg | 26.95 | 6.31gh | 77.4m |
| $Si_2B_1$ | 104.72bc | 27.89bcd | 18.29efg | 19.02efg | 5.18de | 27.41 | 6.60e | 78.04i |
| $Si_2B_2$ | 101.23f | 28.32abcd | 19.29ab | 18.93fg | 5.42b | 28.15 | 7.16ab | 79.61b |
| $Si_2B_3$ | 103.82cd | 28.41abc | 18.56defg | 19.61abcd | 5.27bcd | 27.56 | 6.92c | 79.19f |
| $Si_3B_0$ | 101.85f | 26.88ef | 17.98gh | 19.46b-f | 4.88f | 25.65 | 6.19ij | 77.57l |
| $Si_3B_1$ | 107.17a | 27.79cd | 18.50defg | 19.70acd | 5.25cde | 27.59 | 6.43f | 78.13h |
| $Si_3B_2$ | 102.17def | 28.59ab | 19.65a | 20.09a | 5.63a | 28.40 | 7.23a | 79.71a |
| $Si_3B_3$ | 103.60cde | 28.05abcd | 18.94bcd | 20.06ab | 5.43 | 27.81 | 6.96c | 79.31e |
| LSD at 5% | 1.7457 | 0.7777 | 0.6416 | 0.6279 | 0.1645 | N.S | 0.1115 | 0.0576 |

Means not sharing the same letters differ significantly at 5% probability level. Non significant = N.S.

were applied at the rate of 100, 67 and 67 kg $ha^{-1}$, respectively. Data on various parameter like plant height (cm), panicle length (cm), 1000 kernels weight (g), biological yield (Mg $ha^{-1}$), kernel yield (Mg $ha^{-1}$), harvest index (%), protein content (%), starch content (%) were collected using standard procedures and analyzed by using Fisher's analysis of Variance technique. LSD test at 5% probability was used to compare the differences among treatments means (Steel et al., 1997).

## RESULTS AND DISCUSSION

Regarding plant height data presented in table-1 shown that the individual effect of silicon and boron found highly significant. The combined application of boron and silicon was also found highly significant. The maximum plant height (107.17cm) was obtained when combine treatment of silicon and boron at 1.5% silicon ($Si_3$) and 0.5% boron ($B_1$) was applied. This was followed by the combination of 0.5% silicon ($Si_1$) and 0.5% boron ($B_1$) solution which was also statistically at par to the above treatment. The maximum plant height (104.69cm) was recorded with alone application of 1.0% silicon ($Si_2$) solution. It was also statistically similar to plant height 104.47 cm and 103.69 cm obtained by no additive ($Si_0$) and 1.0% silicon ($Si_2$) solution respectively however 1.5% silicon ($Si_3$) application has reduced the plant height (101.85cm). Maximum plant height (104.47cm) was found in rice where no boron was applied. Results presented that the gradual increase in boron concentration of the applied solution caused the reduction in plant height and minimum plant height (101.99cm) was found in rice treated with 1.5% boron ($B_3$). These findings were contradicted to the results of Aziz et al. (2002); Mauad et al. (2003). They had reported that the application of silicon to rice might increase the growth rate and plant height. It might be due to the fertility status of the soil or some environmental factors. The findings of current study were in contradiction to the results of Khan et al. (2006) and Shah et al. (2011). They reported that boron application to rice might increase the plant height by enhancing the growth rate and development of root and shoot.

Data regarding panicle length had been presented in table-1 shown that the affect of silicon alone on panicle length was significant whereas of boron application was highly significant. Various combinations of the silicon and boron were also found significantly differing. Combine application of both the nutrients at 0.5% silicon ($Si_1$) and 1.0% boron ($B_2$) produced highest panicle length (28.80cm). Minimum panicle length (25.14cm) was achieved in no additive treatment ($Si_0$ and $B_0$). Effect of silicon alone application on rice was studied and maximum panicle length (26.83cm) was found in rice with 1.5% silicon ($Si_3$) followed by 1.0% silicon ($Si_2$) application with 26.57cm panicle length which was also statistically at par. Minimum panicle length (25.14cm) was achieved in no additive. Maximum panicle length (28.53cm) was recorded in rice treated with 1.0% boron solution ($B_2$). It was followed by 1.5% boron ($B_3$) application with 28.00 cm panicle length which was also statistically similar. Minimum panicle length (24.14cm) was found in no additive ($B_0$). These results were similar to the findings of Singh et al. (2007) while contradicted to the results of Abro et al. (2009) who reported that silicon application had no significant affect on panicle length in rice.

1000-kernel weight presented had shown significant differences among the various silicon and boron concentrations as foliar application (Table 1). Interaction between silicon and boron was obtained significant. Highest 1000-kernel weight (19.65g) was found when combination of both micronutrients was applied at 1.5% silicon ($Si_3$) and 1.0% boron ($B_2$). This was followed by the kernel weight obtained by the combined application of 1.0% silicon and 1.0% boron (19.29g) and 0.5% silicon ($Si_3$) and 1.0% boron ($B_2$) (19.22g) respectively. All above combinations were also statistically similar. Similar findings have been stated by Datnoff et al., 1997). However minimum 1000-kernels weight (15.74g) was obtained when neither silicon nor boron was applied. Silicon application alone significantly increased the1000-kernel weight in rice. The maximum kernel weight (17.98g) was obtained at 1.5% silicon solution ($Si_3$) followed by 1.0% silicon ($Si_2$) which was statistically similar to 0.5% silicon ($Si_1$) foliar applications but greater than no additive ($Si_0$). These results are similar to the findings of Huang et al. (2000). The maximum 1000-kernels weight (18.79g) was recorded in 1.0% boron ($B_2$) application alone followed by 1.5% boron ($B_3$) (18.64g) which was also statistically at par to 1.0% boron ($B_2$) application but significantly different from other boron levels.

Effect of silicon on biological yield was obtained highly significant while of boron foliar application was significant. Difference among the various combination of both the nutrients (silicon and boron) was also significant (table 1). The maximum biological yield (20.09 Mg $ha^{-1}$) was obtained when silicon and boron combination at 1.5% silicon ($Si_3$) and 1.0% boron ($B_2$) was applied while minimum biological yield (17.66 Mg $ha^{-1}$) was found in no additive ($Si_0$ and $B_0$). Silicon alone application regarding biological yield was found maximum (19.89 Mg $ha^{-1}$) when silicon at 1.0% silicon ($Si_2$) was applied. It was followed by 1.5% silicon ($Si_3$) application (19.46 Mg $ha^{-1}$). Minimum biological yield (17.66 Mg $ha^{-1}$) was recorded in no additive ($Si_2$). Researches (Mubeen et al., 2011 and Nabi et al., 2006) had also reported the similar findings. They reported that the silicon application either basel or foliar treatment in rice might significantly enhance the biological yield. Data regarding the effect of boron on biological yield of rice shown that maximum biological yield (18.89 Mg $ha^{-1}$) was found in rice treated with 1.5% boron ($B_3$). It was followed by 1.0% boron solution ($B_2$) application with 18.68 Mg $ha^{-1}$ biological yield which was also statistically similar to the above treatment. Minimum biological yield (17.66 Mg $ha^{-1}$) was obtained in rice treated with no additive ($B_0$).

Paddy yield has a highly significant difference among the foliar applications of various silicon and boron levels has been observed. Interaction between both nutrients (silicon and boron) at their various combinations was also found highly significant. The maximum paddy yield (5.62 Mg $ha^{-1}$) was achieved in rice treated with the combine application of both silicon and boron at 1.5% silicon ($Si_3$) and 1.0% boron ($B_2$). Alone application of silicon (Si) significantly enhanced the paddy yield. Highest paddy yield (4.88 Mg $ha^{-1}$) was found when silicon foliar application at 1.5% silicon solution ($Si_3$) was applied. This is statistically at par to the paddy yield (4.78 Mg $ha^{-1}$) produced by 1.0% silicon ($Si_2$) application. However minimum paddy yield (4.18 Mg $ha^{-1}$) was obtained with no additive silicon ($Si_0$). Paddy yield in response to the boron alone application had obtained highly significant. The maximum paddy yield (5.42 Mg $ha^{-1}$) was observed in rice treated 1.0% boron ($B_2$) spray. This was followed by foliar application 1.5% boron solution ($B_3$) with 5.18 Mg $ha^{-1}$ paddy yield. While the minimum paddy yield (4.18 Mg $ha^{-1}$) was obtained in rice having no boron application. These results were closely related with the findings of Tahir et al. (2008)

Data regarding harvest index in response to foliar application of silicon and boron has been presented in Table 1 Silicon alone application had no significant difference among the treatments. Effect of the foliar application of different boron (B) concentrations however found highly significant in regard to harvest index. Maximum harvest index (28.35%) was found in rice with 1.0% boron ($B_2$). This was followed by 1.5% boron ($B_3$) with 27.59% harvest index value and 0.5% boron ($B_1$) solution (27.25%) respectively. Minimum harvest index (26.05%) was obtained in no additive ($B_0$). The interaction of both the nutrients silicon and boron was found non-significant. Similar results had also been reported by Malidareh et al. (2011) but contradicted to Faraz et al. (2007) and Singh et al. (2007) who reported that silicon application significantly affect the harvest index.

Grain protein contents of the rice had been presented in table-1 showed that silicon and boron independent applications were found highly significant. Various combinations of these two nutrients (silicon and boron) were also found significantly differing. Highest grain protein (7.23%) was found in rice treated with the combine application of 1.5% silicon ($Si_3$) and 1.0% boron ($B_2$) solutions. It was followed by the combination at 1.0% silicon ($Si_2$) and 1.0% boron ($B_2$) with 7.16% protein contents while minimum (6.11%) grain protein was recorded in complete no additive ($Si_0$ and $B_0$). Maximum grain protein (6.31%) was found in rice plants treated with 1% silicon ($Si_2$) followed by 0.5% silicon ($Si_1$) solution application with 6.21% grain protein contents. However minimum grain protein (6.11%) was recorded when no silicon ($Si_0$) was applied. Boron at 1.0% boron ($B_2$) solution produced maximum grain protein (6.89%). It was followed by 1.5% boron ($B_3$) application with 6.74% grain protein contents. Minimum percentage of grain protein (6.11%) was obtained in no additive ($B_0$) application. Saha et al. (2010) had also reported the similar findings and they reported that boron application in rice significantly contributed to the grain weight and grain protein contents.

Grain starch percentage had shown that both silicon and boron applications was found highly significant. Various combinations of silicon and boron were also obtained highly significant as shown in table-1. Combined application of silicon and boron at 1.5% silicon ($Si_3$) and 1.0% boron ($B_2$) was found maximum with 79.71% grain starch contents. It was followed by 79.61% grain starch contents obtained by the combine application 1.0% silicon ($Si_2$) and 1.0% boron ($B_2$) application. Minimum grain starch percentage (77.31%) was obtained in complete no additive. Maximum grain starch (77.57%) was recorded in rice treated with 1.5% silicon ($Si_3$) alone application. It was followed by 1.0% silicon ($Si_2$) application with 77.40% starch contents. Minimum starch percentage (77.31%) was found in no additive ($Si_0$). Baron application at 1.0% boron ($B_2$) solution produced maximum grain starch (79.39%). It was followed by 1.5% boron ($B_3$) solution application with 78.95% grain starch. Minimum percentage of grain starch (77.31%) was obtained in no additive. These results were inline wtih the findings reported by Wang and Galletta, (1998). Similar results had also been reported by Gunes et al. (2003) and Grag et al. (2005). They reported that the amount of boron applied significantly enhanced the carbohydrates of the rice grains.

**Conclusion**

On the basis of results it was suggested that higher and sustainable rice production can be attained by the application of boron (B) at the rate of 1.0% boron aqueous solution as foliar application. However the combine application of both silicon (Si) and boron (B) at the rate of 1.5% silicon and 1.0% boron can produce better yield.

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