STUDY OF SILICON AND NITROGEN EFFECTS ON YIELD COMPONENTS AND SHOOT IONS NUTRIENT COMPOSITION IN RICE

MAHYAR GERAMI¹, VALIOLLAH RAMEEH^{2*}

¹Sana Institute of Higher Education, Mazandran, Sari

²Agriculture and Natural Resources Research Center of Mazandran, Sari

GERAMI, M. – RAMEEH, V.: Study of silicon and nitrogen effects on yield components and shoot ions nutrient composition in rice. *Agriculture (Poľnohospodárstvo)*, vol. 58, 2012, no. 3, pp. 93–98.

Rice (*Oryza sativa* L.) is an important crop in Iran and other parts of the world and it is also a staple food of nearly one-half of world's population contributing high calorie intake. Silicon is considered as a beneficial and nitrogen as an essential element for rice production. In order to study the effects of silicon and nitrogen on some yield components and shoot nutrition ion compositions in rice, a hydroponic culture experiment was conducted under the greenhouse condition. Two factors, including silicon and nitrogen, each one with three levels (0, 50, and 100 ppm) were studied in a completely randomized design in factorial arrangement with 3 replications. The traits including panicle length, unfilled grains, 1000-grain weight and shoot ions including silicon, potassium, and

nitrogen were significantly affected by applied silicon levels. All the traits were affected by nitrogen levels except unfilled grains and shoot potassium concentration. The highest grain yield was detected at 100 ppm of silicon application. Shoot silicon ranged from 5.01 to 6.92 ppm in 0 and 100 ppm silicon application. Shoot potassium was increased in high levels of silicon treatment. Significant negative correlation of unfilled grain with shoot silicon and potassium indicated that increasing these shoot ions had reduction effects on unfilled grains. Significant positive correlation was determined between shoot potassium and 1000-grain weight, implied that this trait was affected by indirect effect of silicon via shoot potassium increasing.

Key words: grain yield, hydroponics culture, potassium, silicon, rice

Silicon (Si) is a beneficial element for growth of rice (*Oryza sativa* L.) and other monocotyledon species (Savant *et al.* 1997; Ma 2003). The rice shoot contains Si at a several-fold higher concentration than the other necessary macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Agarie *et al.* 1996; Epstein 1999; Ma & Takahashi 2002). Without Si, the growth of rice is considerably decreased and the productivity is markedly reduced mainly due to reduced fertility (Ma 2003). Rice exhibits the greatest uptake of silicic acid in the grass family. With the application of large quantity of Si fertilizers, rice can accumulate Si in the stem and leaves up to 10–15% of its dry weight. A growing body of confirmation indicates that adequate uptake

of Si can substantially increase the tolerance of rice and other crops to both abiotic and biotic stresses (Agarie *et al.* 1993; Matsuo *et al.* 1995; Datnoff *et al.* 2001; Ma & Takahashi 2002). While all plants accumulate Si to some degree, the amounts accumulated vary greatly among species. When accumulated Si typically represents more than 1% of dry mass, the species is considered an Si-accumulator (Epstein 1999). Many species of wetland grasses, notably rice, accumulate 5% Si or more in their leaf tissue. Rice requires large amounts of Si for growth and is considered as a beneficial element for rice production (Deren 1997; Ma 2004). There are several reports of beneficial effects of Si in rice crop (Marschner 1995; Takahashi 1995). Agarie *et al.*

Ing. Mahyar Gerami, Sana Institute of Higher Education, Mazandran, Sari, Iran, E-mail: mahyar.gerami@yahoo.com
Dr. Valiollah Rameeh, Agriculture and Natural Resources Research Center of Mazandran, Sari, Iran. E-mail: vrameeh@yahoo.com (*Corresponding author)

(1993) indicates that silicon application was effective in increasing dry matter production in the rice crop. In general, Si increases leaf area and keeps leaves erect, which improve crop photosynthesis. Nitrogen is also the most important macro nutrient for rice production (Yoshida 1981). As a whole, nutrient supply influences plant growth by affecting dry matter production. The 90 percentage of dry matter production is producing by photosynthesis process in which it affects various resources such as light, CO₂, water, and mineral nutrients. Increasing the supply of these inputs from the deficiency range increases the plant growth rate (Marschner 1995). In green leaf cells, up to 75% of total organic N is located in the chloroplasts, mainly as enzyme protein. A deficiency of N that is directly involved in synthesis of protein or chloroplast pigments or electron transfer, however, lowers the photosynthetic efficiency (Takahashi 1995). Nitrogen is one of the most important plant nutrients and plays a vital role in plant photosynthesis and biomass production. Several studies showed that when N is slightly deficit within plants, the demand for NO₃⁻, free amino acid, and free amino N increases quickly, without necessarily bringing a simultaneous marked change in total nitrogen (Wang *et al.* 2005). Increasing panicle numbers in per unit area is the main factor of yield increment, as the result of N application (Bindra *et al.* 2000). Zhou and Wang (2003) indicated that in the tillering stage, the ratio of protein-N to non-protein-N were not considerably different between the upper leaf and the lower leaf. Sulok *et al.* (2007) reported that urea and potassium chloride application significantly increased soil N, K, magnesium (Mg), and sodium (Na) concentrations. Potassium concentration in stems and N in roots were significantly higher under fertilized condition than under unfertilized condition. Due to N and K fertilization, there was significant increase in plant height and number of panicles under fertilized condition compared to under unfertilized condition. Nitrogen, K, Na, and Mg uptake in stem were significantly higher for fertilized condition than under unfertilized condition (Bahmanyar & Soodaee Mashae 2010).

The objectives of the present study were to investigate the effect of Si and N and their interaction effects on yield components and shoot ions nutrient compositions and their relationship in rice.

MATERIALS AND METHODS

In order to study the effect of Si and N on yield components and shoot ions nutrient compositions in rice, a hydroponics culture experiment was conducted at the greenhouse of the Rice Research Institute of Iran-Deputy of Mazandaran (Amol) in 2009. Treatments were studied in a completely randomized design (CRD) in factorial arrangement that included two factors (Si and N fertilizer) with three replications. Each factor had three levels including 0, 50, and 100 ppm. The variety under study was Iranian local high quality variety, Tarom. The nutrient solution was prepared according to Yoshida *et al.* (1976). For every 4 liters of culture solution to be prepared, 5 ml of each stock solution was added to 1 liter of water in plastic bucket. For N treatments, ammonium nitrate (NH₄NO₃) corresponding treatments were calculated. For Si treatments, potassium silicate solution (26% SiO₂) was used for preparation of stock solutions. Seeds were sterilized by soaking them in Benomyl fungicide for 15 minutes. Then they were washed thoroughly by several changes of distilled water. The seeds were soaked for 24 hours and then spread on nylon net stretched over a styropore frame and floated in a tray containing complete culture solution at pH 5. Seedlings were transplanted in each pot. Water was added to each pot at least once a day to supplement water lost by evapotranspiration. The traits including panicle length, unfilled grain, 1000-grain weight, and seed yield were recorded for each plot. For ion extractions, plant samples were ground by mill and then dried in a furnace at 500°C for 2 hours. After that, plant samples were added 5 ml of 2M HCl for digestion and then filtered and diluted by distilled water. The final volume of each sample was 100 ml. Amount of K and Na of each final sample was measured by flame photometer (Isaac & Kerber 1971). Silicon determination was made as described by Elliot and Snyder (1991). For analysis of N content, 100 mg of dried shoot was digested with sulfuric acid and o-phosphoric acid in Kjeldahl digestion unit estimated by the method of Lemaire and Meynard (1997).

The data were subjected to analysis of variance and mean separation by Duncan multiple range test using SAS program version 9 (SAS Institute Inc. 2004).

RESULTS AND DISCUSSION

Significant mean square of Si levels was determined for panicle length, unfilled grains, 1000-grain weight; and shoot ions including Si, K, and N indicated that these traits were significantly affected by treatment of Si levels (Table 1). All traits were affected by N levels except unfilled grains and K, indicating the importance of the effects of N levels for these traits except unfilled grains and shoot K. Significant interaction effect of Si $\times$ N mean square was detected for panicle length, grain yield; and all shoot ions including Si, K, and N, implied that the trend of variations of these traits in levels of each factor depend on to another factor levels. There are several reports of valuable effects of Si in rice crop (Marschner 1995; Takahashi 1995). Agarie *et al.* (1993) indicates that Si application was effective

in increasing of dry matter production and yield components in the rice crop.

Mean comparison of Si levels for the traits is presented in Table 2. Panicle length mean value ranged from 22.85 to 23.72 cm for 0 and 100 ppm of Si levels, respectively. Due to increasing Si level, panicle length was increased and also 50 and 100 ppm of Si level had no significant difference effects on panicle length. Unfilled grains were reduced at high levels of Si application levels but there was no significant difference of the trait in 0 and 50 ppm of Si application. The trait 1000-grain weight was increased at high levels of Si. This trait ranged from 23.45 to 24.15 g in 0 and 100 ppm of Si levels, respectively. Due to increase of most yield components at high levels of Si application, grain yield was subsequently increased, and its mean values in three Si levels were classified into two statistical

T a b l e 1

Factorial analysis of variance for yield components and shoot ions compositions in rice

Source of variability	df	MS						
		Panicle length [cm]	Unfilled grains	1000-grain weight	Grain yield [g/hill]	Shoot silicon	Shoot potassium	Shoot nitrogen
Treatment	8	3.83 ⁺⁺	3.70	2.25 ⁺⁺	148.68 ⁺⁺	0.481 ⁺⁺	0.373 ⁺⁺	0.106 ⁺⁺
Silicon (Si)	2	1.74 ⁺	12.96 ⁺⁺	1.11 ⁺	5.33	0.572 ⁺⁺	1.31 ⁺⁺	0.136 ⁺⁺
Nitrogen (N)	2	11.01 ⁺⁺	1.32	3.68 ⁺⁺	449.47 ⁺⁺	0.477 ⁺⁺	0.0452	0.156 ⁺⁺
Si $\times$ N	4	4.28 ⁺	0.27	2.10	69.97 ⁺	0.437 ⁺⁺	0.656 ⁺⁺	0.066 ⁺⁺
Error	18	0.40	1.67	0.30	21.17	0.022	0.013	0.004

⁺, ⁺⁺ Significant at $P = 0.05$ and 0.01 , respectively

T a b l e 2

Mean comparison of silicon levels effects on yield components and shoot ions compositions in rice

Characters Silicon(ppm)	Panicle length [cm]	Unfilled grains	1000-grain weight [g]	Grain yield [g/hill]	Shoot silicon [ppm]	Shoot potassium [ppm]	Shoot nitrogen [ppm]
0	22.85 ^b	9.86 ^a	23.45 ^b	21.76 ^b	5.01 ^c	2.26 ^c	1.00 ^a
50	23.18 ^a	9.21 ^a	23.73 ^b	22.76 ^b	6.37 ^b	2.30 ^b	0.98 ^b
100	23.72 ^a	7.54 ^b	24.15 ^a	25.09 ^a	6.92 ^a	2.42 ^a	0.95 ^b

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability using Duncan's test

groups (Table 2). The highest grain yield was detected at 100 ppm of Si application. Shoot Si ranged from 5.01 to 6.92 ppm in 0 and 100 ppm of Si of treatment. Shoot K was increased in high levels of Si but shoot N was decreased at high levels of Si application. Shoot K varied from 2.26 to 2.42 ppm in 0 and 100 ppm Si application, respectively.

Interaction effects of Si $\times$ N means on the traits are present in Table 3. Panicle length for three nitrogen levels were increased in each Si level but its highest increment was detected at 0 ppm of Si level. Unfilled

grain was not affected by N levels but its lower mean values were related to 100 ppm of Si level. The trait 1000-grain weight was increased in high levels of Si application specially at 0 ppm of Si level. Due to increasing N application in each level of Si, grain yield was increased but its highest range was related to 100 ppm of Si level. Bindra *et al.* (2000) reported that increasing panicle numbers in per unit area is the main factor of yield increment as result of N application. Significant positive correlation was detected between panicle length and grain yield (Table 4); therefore,

T a b l e 3

Mean comparison of silicon $\times$ nitrogen interaction effects for yield components and shoot ions compositions in rice

Treatments		Panicle length [cm]	Unfilled grains	1000-grain weight [g]	Grain yield [g/hill]	Shoot silicon [ppm]	Shoot potassium [ppm]	Shoot nitrogen [ppm]
Silicon	Nitrogen							
0	0	21.13 ^d	10.66 ^a	21.66 ^c	13.12 ^c	4.96 ^{de}	2.12 ^g	0.92 ^c
0	50	23.87 ^{ab}	9.24 ^{ab}	24.33 ^{ab}	20.79 ^{bc}	5.18 ^d	2.25 ^{ef}	0.96 ^{bc}
0	100	24.53 ^a	9.69 ^{ab}	24.36 ^{ab}	34.37 ^a	4.89 ^e	2.41 ^{bc}	1.13 ^a
50	0	21.98 ^{cd}	9.49 ^{ab}	23.53 ^b	17.41 ^{bc}	5.93 ^c	2.20 ^{fg}	0.94 ^c
50	50	22.74 ^{bc}	9.06 ^{ab}	24.06 ^{ab}	19.05 ^{bc}	6.19 ^c	2.33 ^{cd}	1.03 ^b
50	100	23.82 ^{ab}	9.08 ^{ab}	23.60 ^{ab}	33.36 ^a	6.99 ^b	2.38 ^{bcd}	0.97 ^{bc}
100	0	23.00 ^{bc}	7.76 ^b	23.93 ^{ab}	19.82 ^{bc}	6.18 ^c	2.32 ^{de}	1.00 ^{bc}
100	50	23.89 ^{ab}	7.42 ^b	23.93 ^{ab}	21.80 ^{bc}	7.52 ^a	2.43 ^{ab}	0.94 ^c
100	100	24.27 ^a	7.43 ^b	24.60 ^a	33.66 ^a	7.06 ^b	2.50 ^a	0.92 ^c

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability – using Duncan's test

T a b l e 4

Correlation analysis among the yield components and shoot ions compositions in rice

Traits	Panicle length [cm]	Unfilled grains	1000-grain weight [g]	Grain yield [g/hill]	Shoot silicon [ppm]	Shoot potassium [ppm]	Shoot nitrogen [ppm]
Panicle length [cm]	1						
Unfilled grains	-0.54	1					
1000-grain weight [g]	0.83 ⁺⁺	-0.62	1				
Grain yield [g/hill]	0.78 ⁺	-0.11	0.50	1			
Shoot silicon [ppm]	0.33	-0.79 ⁺	0.31	0.15	1		
Shoot potassium [ppm]	0.85 ⁺⁺	-0.73 ⁺	0.75 ⁺	0.65 ⁺	0.64 ⁺	1	
Shoot nitrogen [ppm]	0.39	0.18	0.38	0.58	-0.39	0.25	1

⁺, ⁺⁺ Significant at P = 0.05 and 0.01, respectively

panicle length is good criterion for selection of high yield rice genotypes. Negative correlation between unfilled grains and grain yield, indicating this trait, had reduction effect on grain yield. Shoot Si was statistically affected by nitrogen levels, but the high mean value of this trait was detected in high Si levels. Increasing of N levels in each Si level increases shoot K. Significant negative correlation of unfilled grains with shoot Si and K indicated that increasing these shoot ions had reduction effect on unfilled grains. Significant positive correlation was determined between shoot K and 1000-grain weight, which implied that this trait was affected by indirect effect of silicon via shoot K increasing. Shoot N was increased in high levels of N at 0 ppm of Si level and was decreased in high levels of N at 100 ppm of Si level. Sulok *et al.* (2007) reported that urea and potassium chloride application significantly increased soil N, K, magnesium (Mg), and sodium (Na) concentrations. Potassium concentration in stems and N in roots were significantly higher under fertilized condition than under unfertilized condition. Bahmanyar and Soodaee Mashaee (2010) were noted due to N and K fertilization, there was significant increase in plant height and number of panicles under fertilized condition compared to under unfertilized condition. Nitrogen, K, Na, and Mg uptake in stem were significantly higher for fertilized condition than under unfertilized condition.

CONCLUSION

In general, N had more considerable effect than Si on grain yield because of its more important effects on yield components. The highest Si level (100 ppm) had significant effects on yield components and consequently significant effect on grain yield. Significant negative correlation of unfilled grains with shoot Si and K indicated that increasing these shoot ions had amendment effect on unfilled grain. Among yield components, panicle length had significant correlation with grain yield; therefore the trait can be considered as selection criterion for improving grain yield.

Acknowledgments. The authors wish to thank the Rice Research Institute of Iran-Deputy of Mazandaran (Amol) for providing genetic materials and facility for conducting the experiment.

REFERENCES

- AGARIE, S. – AGATA, W. – UCHIDA, H. – KUBOTA, F. – KAUFMAN, P.B. 1996. Function of silica bodies in the epidermal system of rice (*Oryza sativa* L.): Testing the window hypothesis. In *Journal of Experimental Botany*, vol. 47, 1996, no. 299, pp. 655–660. DOI:10.1093/jxb/47.5.655
- AGARIE, S. – UCHIDA, H. – AGATA, W. – KUBOTA, F. – KAUFMAN, P.B. 1993. Effect of silicon on growth, dry matter production and photosynthesis in rice plant (*Oryza sativa* L.). CPITA KSCS, Korea, 1993, pp. 225–234.
- BAHMANYAR, M.A. – SOODAE MASHAE, S. 2010. Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa* L.). In *African Journal of Biotechnology*, vol. 9, 2010, no. 18, pp. 2648–2653. DOI: 10.5897/AJB10.1750
- BINDRA, A.D. – KALIA, B.D. – KUMAR, S. 2000. Effect of nitrogen levels and dates of transplanting on growth, yield and yield attributes of scented rice. In *Advances in Agricultural Research in Indian*, vol. 10, 2000, no. 1, pp. 45–48.
- DATNOFF, L.E. – SNYDER, G.H. – KORNDORFER, G.H. 2001. *Silicon in agriculture*. Amsterdam: Elsevier Science B. V., 2001, pp. 171–199.
- DEREN, C.W. 1997. Changes in nitrogen and phosphorus concentrations of silicon- fertilized rice grown on organic soil. In *Journal of Plant Nutrition*, vol. 20, 1997, no. 6, pp. 765–771. DOI:10.1080/01904169709365292
- ELLIOTT, C.L. – SNYDER, G.H. 1991. Autoclave-induced digestion for the colorimetric determination of silicon in rice straw. In *Journal of Agricultural and Food Chemistry*, vol. 39, 1991, no. 6, pp. 1118–1119. DOI: 10.1021/jf00006a024
- EPSTEIN, E. 1999. Silicon. In *Annual Review of Plant Physiology and Plant Molecular Biology*, vol. 50, 1999, pp. 641–664. DOI: 10.1146/annurev.arplant.50.1.641
- ISAAC, R.A. – KERBER, J.D. 1971. Atomic absorption and flame photometry: Techniques and uses in soil, plant and water analysis. In WALSH, L.M. (Ed.): *Instrumental Methods for Analysis of Soil and Plant Tissue*. Soil Science Society of America. Madison, WI, 1971, pp. 17–37.
- LEMAIRE, G. – MEYNARD, J.M. 1997. Use of the nitrogen nutrition index for the analysis of agronomical data. In LEMAIER, G. (Ed.): *Diagnosis of the nitrogen status in crops*. Berlin : Heidelberg: Springer-Verlag, 1997, pp. 45–55.
- MA, J.F. – TAKAHASHI, E. 2002. *Soil, Fertilizer, and Plant Silicon Research in Japan*. Amsterdam : Elsevier Science, 2002, pp. 83–84.
- MA, J.F. 2003. *Functions of silicon in higher plants*. In MULLER, W.E.G. (Ed.): *Silicon Biomineralization*. Berlin : Springer, 2003, pp. 127–147.
- MA, J.F. 2004. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. In *Soil Science and Plant Nutrition*, vol. 50, 2004, no. 1, pp. 11–18. DOI:10.1080/00380768.2004.10408447
- MARSCHNER, H. 1995. *Mineral nutrition of higher plants. Second Edition*. Academic Press., 1995, p. 899

- MATSUO, T. – KUMAZAWA, K. – ISHII, R. – ISHIHARA, K. – HIRATA, H. (eds) 1995. *Science of the rice plant*. Volume 2: Physiology. Tokyo : Food and Agricultural Policy Research Center, 1995. 1240 pp. ISBN 4-540-94051-1
- SAS INSTITUTE INC. 2004. SAS/STAT user's guide. Version 6. Fourth Edition. Statistical Analysis Institute Inc., Cary North Carolina.
- SAVANT, N.K. – SNYDER, G.H. – DATNOFF, L.E. 1997. Silicon management and sustainable rice production. In *Advances in Agronomy*, vol. 58, 1996, pp.151–199.
- SULOK KEVIN, M.T. – AHMAD, O.H. – ASRIN, W. – RAJAN, A. – AHZAM, M. 2007. Towards growing Bario rice on low land soils: A preliminary nitrogen and potassium fertilization trial. In *American Journal of Agricultural and Biological Science*, vol. 2, 2007, no. 2 pp. 99–105.
- TAKAHASHI, E. 1995. Uptake mode and physiological functions of silica. In *Science Rice Plant*, vol. 2, 1995, no. 1, pp. 58–71.
- WANG, S. – ZHU, Y. – JIANG, H. – CAO, W. 2005. Positional differences in nitrogen and sugar concentration of upper leave relate to plant nitrogen status in rice under different nitrogen rated. In *Field Crops Research*, vol. 96, 2005, no. 2–3, pp. 224–234.
- YOSHIDA, S. – FORNO, D.A. – COCK, J.H. – GOMEZ, K.A. 1976. *Laboratory manual for physiological studies of rice*. International rice research Institute (IRRI) : Manila, Philippines. 1976, pp. 7–13.
- YOSHIDA, S. 1981. *Fundamentals of rice crop science*. Los Banos, Laguna Philippines : International Rice Research Institute (IRRI). 1981, p. 291.
- ZHOU, Q. – WANG, J. 2003. Comparison of upper leaf and lower leaf of rice plants in response to supplemental nitrogen levels. In *Journal of Plant Nutrition*, vol. 26, 2003, no. 3, pp. 607–617.

Received: June, 25th, 2012