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Application of Nitrogen and Silicon Rates on Morphological and Chemical Lodging Related Characteristics in Rice (*Oryza sativa* L.) at North of Iran

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Abstract

Rice-based irrigated lowlands are the major cropping system in north of Iran. This experiment was carried out in split plot in basis of randomized complete block design with three replications at north of Iran in 2010. Main plot was nitrogen rates including (0, 50, 100 and 150 kg N ha^{-1}) applied as urea and sub plot was silicon rates (0, 300 and 600 kg ha^{-1}) applied as calcium silicate. Results showed that minimum of the plant height, flag leaf length, fourth inter-node bending moment and grain yield (4350 kg ha^{-1}) were obtained at N_0, as well as the maximum of the plant height, panicle length, flag leaf length, third inter-node length were observed at N_{100} and N_{150}, respectively. But the highest of bending moment obtained for fourth inter-node and maximum grain yield (6063 kg ha^{-1}) was observed in N_{150}. Treatment Si_{600} had increased significantly over control in plant height, stem length, panicle length, third inter-node length, third inter-node bending moment, cellulose, hemi-cellulose and lignin in relation to 7.76, 9.91, 30.18, 31.03, 18.71, 7.60, 34.50 and 26.26 %, respectively. Therefore treatment with N_{150} and Si_{600} had shown best results for agronomical indices and grain yield.

Keywords: Bending moment, Cellulose, Lignin, Nitrogen, Rice, Silicon

1. Introduction

Rice is one the most important crops in developing countries and a main food stuff for about 35% of the whole world population (Becker and Asch, 2005). Rice plants require large amounts of mineral nutrients including N for their growth, development and grain production (Ma, 2004). Rice continuous cultivation in the north of Iran has recently decreased rice production and farmers for increasing yield used nitrogen application resulting in coast increasing and production decreasing duo to highland sensitive to disease especially blast and lodging, where disease and lodging have caused major yield losses. Rice production in much of the world increasingly focuses on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment (Koutroubas and Ntanos, 2003). Nitrogen nutrition is critical in yield realization of irrigated rice ecosystems. Nitrogen is clearly the most limiting element; we proposed a set of basic guidelines for improved nutrient management, which after further efforts of all stakeholders involved, could contribute to increased system productivity (Haefel *et al.,* 2006). Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelets, reflecting on grain productivity. Excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of fertile tiller, filled spikelet percentage and grain mass (Mauad *et al.,* 2003). N application significantly increased grain yield largely through an increased biomass and grain number (Belder *et al.,* 2005). Nitrogen rates of 138 and 0 kg ha^{-1} produced maximum and minimum grain yield, biological yield and straw yield, respectively. Si at 500 and 0 kg ha^{-1} produced maximum and minimum biological yield with 11874 and 10538 kg ha^{-1}, and straw yield, respectively (Ghanbari-Malidarreh *et al.,* 2008).

Silicon is one of the most abundant elements in Earth's crust and plants ash (Jones and Handereck, 1976). It is necessary element for rice because of positive effaces on rice planting (Mengel and Kirkby, 1987). Silicon uptake is activated in rice and wheat, so it's not be affected by the rate of transpiration and this element is located in leaf, sclerenchyma, vascular tissues and vascular sheaths, old leaves have more silicon than the young leaves (Tanaka and Park, 1996). Silicon caused to be vertical in leaves (Elwad and Green, 1979), increase to resistance in fungal diseases (Datnoff *et al*., 1997) and caused to increase filled spikelets percentage and grain yield (Datnoff *et al*., 2001). Silicon caused to increase total number of spikelets per panicle, filled spikelets percentage, 1000-seed weight, grain yield and to decrease lodging (Chaoming *et al.,* 1999). Silicon increase vegetative growth, dry matter and decrease transpiration and affects on qualitative and grain yield (Agarie *et al.,* 1993). Silicon is necessary for grain yield stability in rice (Mauod *et al.,* 2003). Silicon application showed direct growth in leaves, stems and plants sheaths specially in rice consequently silicon application improved light contributing inside of canopy (Savant *et al.,* 1997). Silicon uptake is different in varieties and parts of plants (Windslow *et al.,* 1997). Optimal silicon application increase tolerance of plants to salinity and drought (Bocharnikova and Matichenkov, 2008). Silicon improved plant height, inter-node length, fresh weight, bending moment, breaking resistance, lodging index, and increase tolerance of lodging in rice (Fallah, 2008). So according to silicon and potassium importance on growth and yield an experiment was carried out intitled: **"**Application of Nitrogen and Silicon Rates on Morphological and Chemical Lodging Related Characteristics in rice (*Oryza sativa* L.)."

2. Materials and Methods

The field experiment was conducted at Neka region in the north of Iran (Latitude 36° 46 N, Longitude 53° 13 E and altitude 4 m above sea level) in 2010. The minimum and maximum daily temperatures were obtained from the Dashte-Naz airport at Sari near to farm (Table 1). The soil was a loamy, with a sand, silt, and clay composition of 39, 39, and 22%, respectively. The soil chemical analysis indicates (Table 2). The experiment was carried out as split-plot in randomized complete block design with four replications. The rice cultivar was Tarom Hashemi that is one of medium grain yield, early-maturing, tall and sensitive cultivar to blast. Main plots were nitrogen rates in four levels including (0, 50, 100 and 150 kg ha^{-1} N) applied as urea and sub plots were three silicon rates (0, 300 and 600 kg ha^{-1}) applied as calcium silicate (total silicon oxide (SiO_2)=62%), pH in water = 7.1 to 7.4, solubility in water negligible, 91% calcium silicate. Seeds were soaked for 12 to 24 h and emergence date was considered to be five days after sowing, when 90% of the seedlings showed coleoptile. Seeds spread with hands into an area of 10 m^2 (2 × 5). Sowing arrangement was 20 × 20 cm^2. The water depth was controlled at 3 to 5 cm. Nitrogen, phosphorous and potassium fertilizers were used at the rates of N 150 kg ha^{-1} urea, P_2O_5 100 kg ha^{-1} triple superphosphate and K_2O 100 kg ha^{-1} potassium sulphate. Basal fertilizers were applied in all plots 1 day before transplanting. Nitrogen was applied by designing map arrangement. Nitrogen was applied three times (first at planting time, second at tillering time and third panicle imitation, using 33.3%, 33.3% and 33.3% in each stage in plot. Calcium silicate was used in the field 10 days before sowing. Phosphate and potassium fertilizers weren't used during of growth stages. Weeding was made 22 days after sowing by hand. 10 hills were randomly collected at harvesting time from each plot to measure grain yield and morphological characteristics. 12 samples were used for measuring of plant height, stem length and panicle length. Grain dry weight from panicle in each plot was measured as final grain yield (g m^{-2}). Lodging characteristic was observed when the flowering of the plant just started. Stem characters related to lodging were determined at 10 days after flowering. 12 samples were measured in each plot for lodging characteristics. Stem length (length between plant base and panicle neck node), and the lengths of the third inter-node (N_3), and fourth inter-node (N_4) from the top were measured. Bending moment (BM) at N_3 or N_4 inter-node was calculated using the following formula (Islam *et al.,* 2007).

BMN_3= Length from the lowest node of N_3 to the top of panicle × weight of this portion

BMN_4= Length from the lowest node of N_4 to the top of panicle × weight of this portion

The data were analyzed with SAS software. Mean comparison calculated by method of Duncan's multiple range tests at the 0.05 significance level.

3. Results and Discussion

Stem length had significant effect under nitrogen treatment in 5 % probability level and under silicon treatment 1 % probability level (Table 3). Maximum stem length (137.1 cm) was observed for 100 kg h^{-1} nitrogen and minimum of that (122.7 cm) was for control (no nitrogen application). Stem length decreased 9.1 % by silicon application. Maximum stem length (135.3 cm) was obtained for control (no silicon application) and minimum of that (123.1 cm) was for 600 kg h^{-1} silicon application (Table 4). Saadati and Fallah (1995) stated stem length had significant effect in tillering time by nitrogen contributing treatments in 1 % probability level.

Panicle length had significant effect under nitrogen treatment in 5 % probability level and under silicon treatment 1 % probability level (Table 3). Maximum panicle length (34.9 cm) was observed for 100 kg h^{-1} nitrogen and minimum of that (28.2 cm) was for control (no nitrogen application). Panicle length decreased 30.18 % by silicon application. Maximum panicle length (35.8 cm) was obtained for control (no silicon application) and minimum of that (27.5 cm) was for 600 kg h^{-1} silicon application (Table 4). Panicle length affects in grain yield by more transport of photosynthesis material (Dobermann *et al.,* 2002). Saadati and Fallah (1995) stated panicle length had significant effect in tillering time by nitrogen contributing treatments in 1 % probability level. Mobasser (2004) found that panicle length had significant effect by interaction year × nitrogen amounts × nitrogen contributing in 5 % probability level.

Plant height had significant effect under nitrogen treatment in 5 % probability level and under silicon treatment 1 % probability level (Table 3). Minimum plant height (154.6 cm) was noted for control (no nitrogen application) and maximum of that (168.7 cm) was for 100 kg h^{-1} nitrogen. Plant height decreased 7.2 % by silicon application. Maximum plant height (168 cm) was obtained for control (no silicon application) and minimum of that (155.9 cm) was for 600 kg h^{-1} silicon application (Table 4). Absorbed silicon is located on leaf area in rice and by this, decreased cuticle transpiration and it decreases plant elongation (Datnoff *et al.,* 2001). Silicon improved plant height, inter-node length and fresh weight in rice (Fallah, 2008). Yoshida *et al*. (1962) stated that plant height increased by increase of sodium silicate levels because of silicon effect on straight stature of leaves. Agarie *et al.* (1993) showed silicate fertilizers increased vegetative growth, dry matter and grain yield. Saadati and Fallah (1995) stated plant height had significant effect in tillering time by nitrogen contributing treatments in 1 % probability level.

Flag leaf length had significant effect under nitrogen treatment in 5 % probability level (Table 3). Maximum flag leaf length (37.00 cm) was observed for 150 kg h^{-1} nitrogen and minimum of that (29.9 cm) was for control (no nitrogen application) (Table 4). Sedghi *et al.* (2007) reported that silicon had no significant effect on flag leaf length and this result supported our experiment. Pantuwan *et al.* (2002) stated that grain yield had a positive correlation and significant with flag leaf length.

3rd inter-node length had significant effect under nitrogen and silicon treatments in 1 % probability level (Table 3). Maximum 3rd inter-node length (36.7 cm) was observed for 150 kg h^{-1} nitrogen and minimum of that (27.1 cm) was for control (no nitrogen application). 3rd inter-node length decreased 23.7 % by silicon application. Maximum 3rd inter-node length (38 cm) was obtained for control (no silicon application) and minimum of that (29 cm) was for 600 kg h^{-1} silicon application (Table 4). Silicon improved inter-node length in rice (Fallah, 2008).

4th inter-node length had significant effect under silicon treatment in 1 % probability level and under interaction nitrogen × silicon in 5 % probability level (Table 3). 4th inter-node length decreased 10.1 % by silicon application. Maximum 4th inter-node length (27.7 cm) was obtained for control (no silicon application) and minimum of that (24.9 cm) was for 600 kg h^{-1} silicon application (Table 4). Minimum 4th inter-node length (23.3

cm) was obtained under interaction control (0 kg h^{-1} nitrogen) × silicon (600 kg h^{-1}) and maximum of that (29 cm) was for interaction 100 kg h^{-1} nitrogen × control (0 kg h^{-1} silicon) (Figure 1). Yoshida (1981) stated that inter-node length decreased by less than 40 kg h^{-1} nitrogen application. 3rd and 4th inter-nodes length are important for morphological characteristics related to lodging, because the most lodging were happened in this two areas, on the other hand 3rd and 4th inter-nodes length have positive correlation with lodging index (Islam *et al*., 2007).

Bending moment of 3rd inter-node had significant effect under silicon treatment in 5 % probability level (Table 3). Silicon application had decreasing trend in bending moment of 3rd inter-node because of decrease in stem length, panicle length, plant height, 3rd and 4th inter-nodes length. Maximum bending moment of 3rd inter-node (2588 g cm) was obtained for control (no silicon application) and minimum of that (2180 g cm) was for 600 kg h^{-1} silicon application (Table 4).

Bending moment of 4th inter-node had significant effect under nitrogen treatment in 5 % probability level (Table 3). Maximum bending moment of 4th inter-node (4585 g cm) was obtained for control (no nitrogen application) and minimum of that (3652 g cm) was for 100 kg h^{-1} nitrogen application. Maximum and minimum of plant height and stem length were observed by 100 kg h^{-1} nitrogen and control (no nitrogen application) respectively, so most bending moment was also for these treatments (Table 4). Silicon contents in rice stem had a direct relation with lodging resistance (Ma and Yamaji, 2006). Mobasser *et al.* (2008) found that bending moment of 4th inter-node decreased by 500 kg h^{-1} silicon, but it didn't support our results.

Cellulose had significant effect under silicon treatment in 1 % probability level (Table 5). Cellulose increased 7.6 % by silicon application. Maximum cellulose (46.7 %) was noted for 600 kg h^{-1} silicon application and minimum of that (43.4 %) was for control (0 kg h^{-1} silicon application) (Table 6).

Hemicellulose had significant effect under nitrogen treatment in 5 % probability level and under silicon treatment 1 % probability level (Table 5). Maximum hemicellulose (15.1 %) was noted for control (0 kg h^{-1} nitrogen application) and minimum of that (12.8 %) was for 150 kg h^{-1} nitrogen application (Table 6). Hemicellulose increased 34.5 % by silicon application. Maximum hemicellulose (15.2 %) was obtained for 600 kg h^{-1} silicon application and minimum of that (11.3 %) was for control (0 kg h^{-1} silicon application) (Table 6).

Lignin had significant effect under silicon treatment in 1 % probability level (Table 5). Lignin increased 26.3 % by silicon application. Maximum lignin (12.5 %) was obtained for 600 kg h^{-1} silicon application and minimum of that (9.9 %) was for control (0 kg h^{-1} silicon application) (Table 6).

Grain yield had significant effect under nitrogen treatment in 5 % probability level (Table 5). Maximum grain yield (6063 kg h^{-1}) was observed for 150 kg h^{-1} nitrogen application and minimum of that (4350 kg h^{-1}) was for control (0 kg h^{-1} nitrogen application) (Table 6). Pantuwan *et al.* (2002) reported that grain yield had positive correlation with flag leaf length. Chaoming *et al.* (1999) stated that silicon application increased grain yield by increase of spikelet number, filled spikelet percentage and 1000-seed weight. Mauod *et al.* (2003); Ma and Takashi, (1990); Mobasser *et al*. (2008) reported that grain yield increased by silicon application. Maximum grain yield was obtained by 69 kg h^{-1} nitrogen and nitrogen contributing in three times (transplanting time, panicle initiation and heading time) (Mobasser *et al.,* 2005). Grain yield increased by 120 kg h^{-1} nitrogen contributing in three times (transplanting time, tillering time and panicle initiation) (Singh *et al.,* 2002).

Straw yield had significant effect under silicon treatment in 5 % probability level (Table 5). Maximum straw yield (9846 kg h^{-1}) was observed for 300 kg h^{-1} silicon application and minimum of that (8558 kg h^{-1}) was for control (0 kg h^{-1} silicon application) (Table 6). Agarie *et al.* (1993) showed that silicate fertilizers increased dry matters by effect on vegetation growth consequently increase grain yield. Matsuo *et al.* (1995) stated that silicon increased vegetation growth and dry matter. Sedghi *et al.* (2007) reported that grain yield increased by silicon application.

4. Conclusions

According to results of this study, plant height, stem length, panicle length and third inter-node length were increased by increasing the nitrogen fertilizer. With increase of nitrogen, the fourth inter-node length had increased and it caused more lodging. Application of silicon increased lodging-related traits such as plant height, panicle length, third inter-node length and stem length, but the fourth inter-node length was reduced which is so important to breaking resistant. So there was no significant difference in the bending moment of fourth inter-node, although the bending moment of the third inter-node was significant and the use of silicon was increased the bending moment and it seems that use of silicon can be distributed between the third and fourth inter-node and had increased resistance to lodging.

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Table 1. Weather condition in experiment site in rice growth stages at Neka in 2010

Variable	Jan.	Feb.	March	April	May	June	July	August
Minimum tem.	2.2	4.1	8.2	1.3	14.2	19.5	25	28
Maximum tem.	12.1	14.1	12.1	16.3	23.1	31.7	33	36
Evaporation (mm)	46	45	48	52	96	152	192	212
Precipitation (mm)	55	124	31	108	28	16	18	14

Table 2. Selected soil properties for composite samples at experimental site in 2010

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	pH	EC (μm/cm)	Depth (cm)
Loamy	285	18.2	0.12	1.6	7.2	0.74	0-30

Table 3. Mean square of nitrogen and silicon rates on lodging related characteristics in rice

Sours Of Variation	DF	Plant height	Stem length	Panicle length	Flag leaf length	Third Inter-node length	Fourth Inter-node length	Third Inter-node diameter	Fourth Inter-node diameter	Inter-node number	Third inter-node bending moment	Fourth inter-node bending moment
Replication	2	395.36	297.80	11.96	35.44	52.69	51.38**	1.72*	1.02	0.10	639630.33	942386.78
N rates (A)	3	426.39*	437.53*	97.67*	100.31*	187.83**	2.39	0.11	0.94	0.04	306432.99	1375119.00*
E (A)	6	123.50	129.90	13.05	16.22	15.64	4.08	0.25	0.83	0.03	266497.69	337915.22
Si rates (B)	2	442.72**	444.26**	205.03**	22.65	257.22**	25.26**	0.06	0.14	0.06	609847.00*	409321.19
A×B	6	24.38	18.86	4.72	45.92	16.72	6.06*	0.09	0.14	0.02	214078.96	333757.97
E	16	13.41	13.82	9.51	30.90	9.65	2.42	0.22	0.22	0.03	205495.47	830201.90
C.V. (%)	-	2.26	2.88	9.70	16.23	9.43	5.96	8.74	8.03	3.75	19.46	22.46

** and * respectively significant in 1% and 5% level.

Table 4. Mean comparison of nitrogen and silicon rates on lodging related characteristics in rice

Treatments	Plant height (cm)	Stem length (cm)	Panicle length (cm)	Flag leaf length (cm)	Third Inter-node length (cm)	Fourth Inter-node length (cm)	Third Inter-node diameter (mm)	Fourth Inter-node diameter (mm)	Inter-node number	Third inter-node bending moment (g cm)	Fourth inter-node bending moment (g cm)
Nitrogen rates											
control	154.6 b	122.7 b	28.2 b	29.9 b	27.1 b	25.6 a	5.4 a	6.0 a	4.9 a	2082 a	3652 b
50 kg ha^{-1}	157.1 ab	123.9 b	29.8 b	33.4 ab	31.5 b	25.7 a	5.5 a	6.0 a	4.9 a	2294 a	3922 ab
100 kg ha^{-1}	168.7 a	137.1 a	34.2 a	36.7 a	36.5 a	26.6 a	5.2 a	6.0 a	5.0 a	2467 a	4062 ab
150 kg ha^{-1}	166.4 a	132.7 ab	34.9 a	37.0 a	36.7 a	26.6 a	5.4 a	5.4 a	4.8 a	2474 a	4585 a
Silicon rates											
control	155.9 c	123.1 c	27.5 c	32.7 a	29.0 c	27.7 a	5.3 a	5.9 a	4.9 a	2180 b	3913 a
300 kg ha^{-1}	161.3 b	129.0 b	32.1 b	35.1 a	31.8 b	25.8 b	5.4 a	5.7 a	4.8 a	2219 ab	3995 a
600 kg ha^{-1}	168.0 a	135.3 a	35.8 a	35.0 a	38.0 a	24.9 b	5.4 a	6.0 a	5.0 a	2588 a	4266 a

Values within each column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).

Table 5. Mean square of nitrogen and silicon rates on chemical traits and grain yield and straw yield in rice

Sours Of Variation	DF	Cellulose	Hemi-cellulose	Lignin	Grain yield	Straw yield
Replication	2	17.69	3.53	0.25	1352368.44	53156653.69**
N rates (A)	3	90.56	8.33*	5.85	4685057.07*	2090775.81
E (A)	6	9.25	2.19	4.77	653297.19	4260062.14
Si rates (B)	2	34.19**	11.44**	21.58**	57204.78	5156484.78*
A×B	6	1.42	1.44	0.88	66275.07	1925948.56
E	16	4.11	0.82	1.18	65926.67	1369617.42
C.V. (%)	-	4.53	6.44	9.88	4.96	12.75

** and * respectively significant in 1% and 5% level.

Table 6. Mean comparison of nitrogen and silicon rates on chemical traits and grain yield and straw yield in rice

Treatments	Cellulose	Hemi-cellulose	Lignin	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Nitrogen rates					
control	45.7 a	15.1 a	9.9 a	4350 c	8820 a
50 kg ha^{-1}	43.8 a	14.1 ab	11.0 a	4941 bc	8842 a
100 kg ha^{-1}	45.7 a	14.2 ab	11.3 a	5370 ab	9853 a
150 kg ha^{-1}	44.0 a	12.8 b	11.8 a	6063 a	9202 a
Silicon rates					
0 kg ha^{-1}	43.4 b	11.3 b	9.9 b	5118 a	8558 b
300 kg ha^{-1}	44.3 b	13.7 b	10.6 b	5255 a	9864 a
600 kg ha^{-1}	46.7 a	15.2 a	12.5 a	5170 a	9116 ab

Values within each column followed by same letter are not significantly different at Duncan ($P \leq 0.05$).

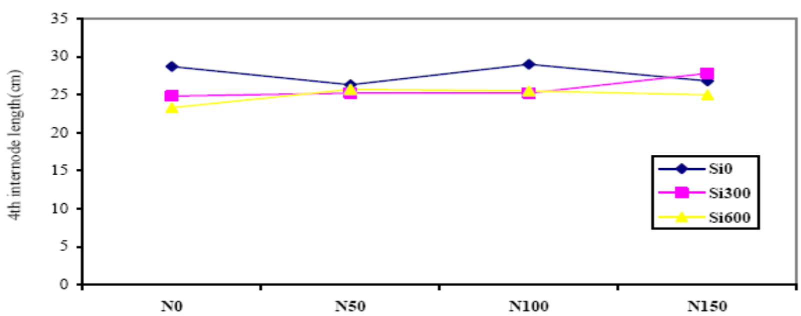

Figure 1. Interaction effects of nitrogen silicon rates on fourth interned length