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Nitrogen and Silicon Application Facts on Rice Growth Parameters at Alborz Mountain Range

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Abstract

Rice is the main staple food of around half of the world's population. This experiment was carried out in split plot in basis of randomized complete block design with three replications at the north of Iran in 2012. Main plot was nitrogen rates including (0, 50, 100 and 150 kg/ha) applied as urea and sub plot was silicon rates (0, 300 and 600 kg/ha) applied as calcium silicate. Results showed that minimum number of panicle per m^2, number of blank spikelet per panicle, grain yield and harvest index were obtained in control treatment. The maximum number of panicle per m^2, number of spikelet per panicle, grain yield and harvest index were observed at N_{150}. Number of blank spikelet was significantly decreased at Si_{600} compare to control treatment. Number of total and fertile tillers per hill, number of total spikelet per panicle and filled spikelet percentage were increased. Therefore, grain yield and agronomical parameters had shown increase in N_{150} and Si_{600}.

Keywords: HI, Nitrogen, Rice, Silicon, Yield

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 [1]. Rice require large amounts of mineral nutrients including N for their growth, development and production [2]. Rice continuous cultivation in the north of Iran has recently decreased 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 [3]. Nitrogen 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 [4]. Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelet, reflecting on grain productivity. Excessive tillering caused by inadequate nitrogen fertilization reduced the fertile tiller; filled spikelet percentage and grain mass [5]. N application significantly increased grain yield largely through an increased biomass and grain number [6]. Nitrogen rates of 138 and 0 kg ha^{-1} produced maximum and minimum grain yield, biological 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 [7,8].

Silicon is not considered an essential element for plant development and growth, but its absorption brings several benefits to some crops, especially rice, by increasing cellular wall thickness, providing mechanical resistance to the penetration of fungi, improving the opening angle of leaves and making them more erect, decreasing self-shading and increasing resistance to lodging, especially under high nitrogen rates, silicon fertilization reduced the number of blank spikelet per panicles and increased grain yield, but did not affect grain productivity [5]. An increase in Si concentration in rice plant parts, and deposits of Si in the form of silica gel, are expected to stiffen the stems. Therefore, using Si fertilizer will increase the lodging resistance of rice plants [9]. Grain yield increased by as much as 22% with Si applied at 500 kg ha^{-1} [7,8]. In yield components, silicon increases the number of spikelet per panicle [10,11], spikelet fertility [11], and the grain yield [12]. Therefore, Si alone could improve grain yield of rice cultivars without further genetic improvements. Silicon helps plants to overcome multiple stresses including biotic and a biotic stresses [2]. For example, Si plays an important role in increasing the resistance of plants to pathogens such as blast on rice [13]. Silicon also alleviates the effects of other a biotic stresses including salt stress, metal toxicity, drought stress, radiation damage, nutrient imbalance, high temperature, and freezing [2,14,15]. The search for new technologies that will enable the expansion of the producing area as well as productivity has featured the use of silicon fertilization in rice crops as a promising alternative. However, when nitrogen applied in excess it may limit to produce grain yield because of lodging, especially for cultivars of the traditional and intermediate groups, and promote shading and disease problems. These effects could be minimized by the use of silicon. Therefore, this article aims to evaluate the effect of nitrogen and silicon rates on rice growth parameters.

2. Materials and Methods

The field experiment was conducted at Sari region at the north of Iran (Latitude 36° 46 N, Longitude 53° 13 E and altitude 4 m above sea level) in 2012. The soil was clay loamy. The soil chemical analysis indicates (Table 1). The minimum and maximum daily temperatures were obtained from the Dashte Naz airport at Sari near to farm (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.

Table 1. Selected soil properties for composite samples at experimental site in 2012.

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	pH	EC (μmohs/cm)	Depth (cm)
Clay-loam	165	9.8	0.18	1.2	7.3	0.22	0-30

Table 2. Weather condition in experiment site in rice growth stages at Sari in 2012

Variable	Jan.	Feb.	March	April	May	June	July	August
Minimum tem.	2.5	4.2	9.3	7.5	14	18.8	23.1	23.7
Maximum tem.	10.2	12.1	15.2	16.4	24	27.8	32.6	33.2
Evaporation (mm)	52	52	43	58.1	75.8	135.1	128.2	152.6
Precipitation (mm)	65	136	38	124.9	26.9	29.4	8.1	11.9

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 one 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 yield components**.** Yield component**s** were analyzed base on different samples of plant to determine the spikelet per panicle, filled spikelet percentage per panicle, and harvest index (i.e., grain yield per plant/biological yield per plant). Grain yield from panicle in each plot was scaled as final grain yield (g m^2). All the data were subjected to statistical analysis (one-way ANOVA) using SAS software [16]. Differences between the treatments were performed by Duncan's Multiple Range Test (DMRT) at 5% confidence interval.

3. Results

Results of this experiment in Table 3 showed that panicle number per m^2 and total spikelet number per panicle ($p \leq 0.01$) and filled spikelet percentage per panicle, blank spikelet number per panicle and 1000 grain weight ($p \leq 0.05$) were significant effect by at the nitrogen rates. Also, total tiller number per hill and total spikelet number per panicle ($p \leq 0.05$), and filled spikelet percentage per panicle, blank spikelet number per panicle and 1000 grain weight ($p \leq 0.01$) significant at the silicon rates. In between of yield components, only filled spikelet percentage per panicle ($p \leq 0.01$) and blank spikelet number per panicle ($p \leq 0.05$) were significant difference at interaction of nitrogen× silicon rates (Table 3).

Rate of the 150 kg ha^{-1} N had been most of total spikelet number per panicle (131 spikelet), blank spikelet number per panicle (29.1 number) and panicle number per m^2 (469.7 panicle), but the maximum of filled spikelet percentage (89 %) and 1000 grain weight (28.6 g) were obtained at control treatment. Si_{600} had the maximum of total tiller number per hill (24.3 tillers), fertile tiller number per hill (20.7 numbers), total spikelet number per panicle (117.8 numbers), filled spikelet percentage per panicle (86.9 %) and blank spikelet number per panicle (15.5 numbers). Si_{600} in comparison Si_0, were increased the total tiller number per hill, fertile tiller number per hill, total spikelet number per panicle, filled spikelet percentage per panicle and blank spikelet number per panicle in ratio 14.1, 15.6, 11.9, 12.4 and 23.5 %, respectively (Table 4).

Table 3. Mean square of nitrogen and silicon rates on yield components in rice.

S.O.V.	DF	Number of total tiller per hill	Number of fertile tiller per hill	Number of unfertile tiller per hill	Number of panicle per m^2	Number of spikelet per panicle	Filled spikelet percentage per panicle	Number of blank spikelet per panicle
Replication	2	26.69	60.25	6.86	969.33	236.86	5.66	13.53
Nitrogen(N)	3	8.67	14.92	14.18	29253.66**	2633.52**	366.32*	493.44*
Error	6	8.92	28.36	7.12	2056.30	211.27	74.42	71.60
Silicon (S)	2	28.86*	22.75	1.03	2700.33	543.86*	273.73**	181.36**
N × S	6	16.75	13.86	2.07	322.19	188.49	64.08**	47.99*
E	16	10.15	8.79	1.31	1084.85	150.58	7.81	21.00
C.V. (%)	-	13.92	15.40	31.40	8.31	11.15	3.93	23.87

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

Table 4. Mean comparison of nitrogen and silicon rates on yield components in rice.

Treatments	Number of total tiller per hill	Number of fertile tiller per hill	Number of unfertile tiller per hill	Number of panicle per m^2	Number of spikelet per panicle	Filled spikelet percentage per panicle	Number of blank spikelet per panicle
Nitrogen rates							
control	21.7 a	19.6 a	2.1 a	340.6 c	110.6 b	89.0 a	12.6 b
50 kg ha^{-1}	22.7 a	17.6 a	5.1 a	364.3 bc	109.6 b	88.5 ab	14.7 b
100 kg ha^{-1}	23.2 a	19.2 a	4.0 a	411.8 b	89.1 c	76.3 b	20.4 ab
150 kg ha^{-1}	24.0 a	20.7 a	3.3 a	469.7 a	131.0 a	77.5 b	29.1 a
Silicon rates							
control	21.25 b	17.9 b	3.3 a	382.6 a	105.3 b	77.3 c	23.3 a
300 kg ha^{-1}	23.1 ab	19.2 ab	3.9 a	394.8 a	107.2 ab	82.8 b	18.8 b
600 kg ha^{-1}	24.3 a	20.7 a	3.7 a	412.4 a	117.8 a	86.9 a	15.5 b

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

The highest of filled spikelet percentage were obtained at interaction of $N_0 \times Si_0$ (90.1 %), $N_0 \times Si_{600}$ (90.5 %) and $N_{50} \times Si_{600}$ (90.1 %), and the lowest of filled spikelet percentage (64.5 %), were produced at interaction of $N_{100} \times Si_0$ (Figure 1). The most of hollow spikelet number per panicle (34.3 numbers) had observed at interaction of $N_{150} \times Si_0$ (Figure 2).

Table 5 showed that the grain yield and harvest index significant differences ($p \leq 0.05$) by nitrogen rates. Also, biological yield were significant at the silicon rates. The maximum of the grain yield (6063 kg ha^{-1}) and harvest index (40.6 %) were obtained for rate of 150 kg ha^{-1} N, because most of the total spikelet numbers per panicle, panicle number per m^2 were observed in this rate. The lowest of grain yield (4350 kg ha^{-1}) and harvest index (34.5 %) were produced by control. The maximum and minimum of biological yield (15040 and 13680 kg ha^{-1}) were obtained for rates of Si_{300} and Si_0, respectively (Table 6).

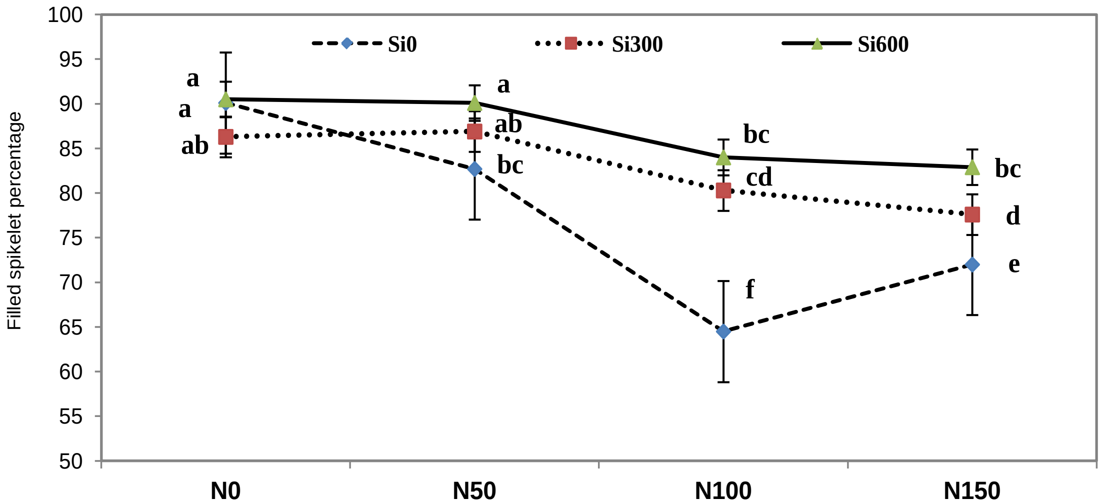

Figure 1. Interaction of nitrogen and silicon rates on filled spikelet percentage per panicle.

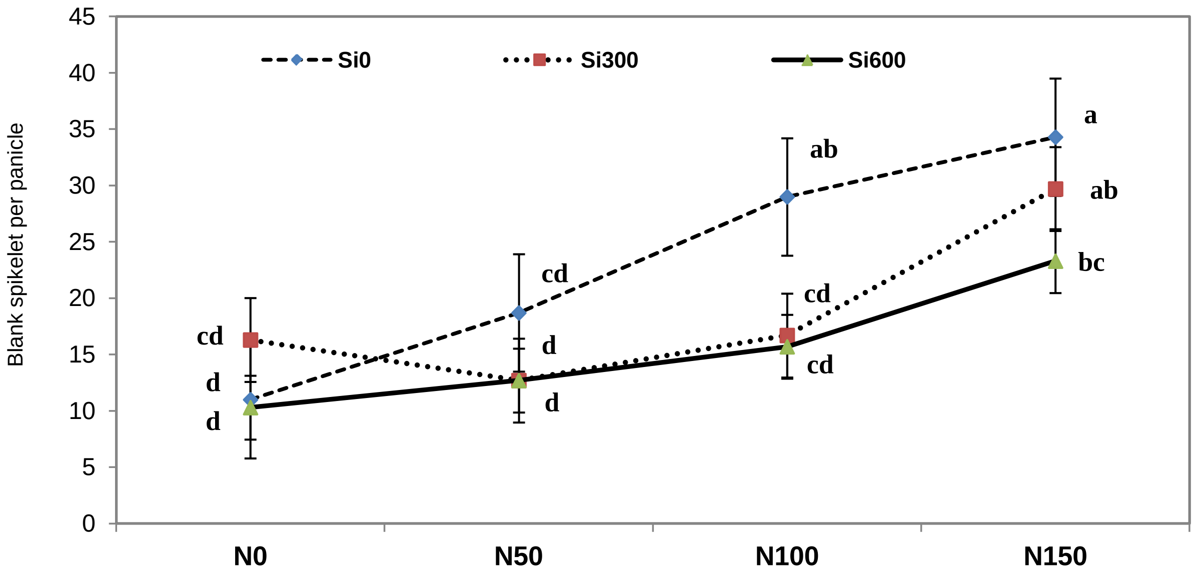

Figure 2. Interaction of nitrogen and silicon rates on blank spikelet number per panicle.

Table 5. Mean square of nitrogen and silicon rates on yield quantity and harvest index in rice.

S.O.V.	DF	1000 grain weight	Grain yield	Biological yield	Harvest index
Replication	2	10.11	1352368.44	72561005.03*	162.72*
N rates (N)	3	16.67*	4685057.07*	9501624.62	63.83*
E (A)	6	4.89	653297.19	7814245.07	16.13
Si rates (S)	2	38.36**	57204.78	5565308.78*	16.68
N × S	6	3.69	66275.07	1841114.59	15.32
E	16	4.57	65926.67	1586652.10	12.48
C.V. (%)	-	7.95	4.96	8.79	9.60

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

Table 6. Mean comparison of nitrogen and silicon rates on quantity yield and harvest index in rice.

Treatments	1000 grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Nitrogen rates				
control	28.6 a	4350 c	13170 a	34.5 b
50 kg ha^{-1}	25.2 b	4941 bc	13770 a	36.5 ab
100 kg ha^{-1}	26.9 ab	5370 ab	15220 a	35.7 b
150 kg ha^{-1}	26.9 ab	6063 a	15170 a	40.6 a
Silicon rates				
control	28.1 a	5118 a	13680 b	39.0 a
300 kg ha^{-1}	24.8 b	5255 a	15040 a	35.7 a
600 kg ha^{-1}	27.8 a	5170 a	14290 ab	36.7 a

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

4. Discussions and Conclusions

This result is agreement with findings obtained by [17], who observed increasing plant height with increasing nitrogen fertilization level. The reduction in fertile tillers could be related to the greatest number of stem produced as nitrogen fertilization increased, which could have caused a smaller number of vegetative buds to become reproductive, High nitrogen rates induce the formation of large number of stem and leaves, creating unfavourable conditions to yielding, such as shading and lodging [18]. Nitrogen fertilization induced an increase of this variable, and the result is associated to a greater availability of nitrogen. This behaviour is a consequence of the participation of N in structural functions of the plant, such as cell multiplication and differentiation, genetic inheritance and formation of tissues [19]. Since no organic molecule is known to be associated to silicon in plants [20], however, in opposition to results [5,12], did not observe any influence of silicon fertilization on this yield component. We measured spikelet per hill that there is no significant difference between two silicon treatments. However, tiller number and dry matter accumulation is the most important in spikelet formation in ear and hill and probably there is a correlation between two traits. Therefore, the total number of spikelet is determined during the reproductive stage. Silicon fertilizer application decreased blank spikelet number in rice and that caused plants not to have enough carbohydrates to fill up all spikelet produced as the silicon fertilization level increased, contributing to decrease the number of blank spikelet and to increase filled spikelet percentage [7,8]. Fallah *et al.* (2004) indicated that silicon significantly increases percent spikelet filling, resulting in improved grain yield, silicon deposition was on rice grain hulls [9], and the increase in grain mass would be the greatest deposition of silicon on the paleae and lemmas. Mauad *et al.* (2003) indicated the grain mass is a quite stable variety trait, and depends on hull size, and on caryopsis development after flowering [5].

Application of nitrogen significantly increased grain yield by an increase in biomass and grain number [6]. 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 [7,8]. According to results of this study application of nitrogen fertilizer had increased the number of panicles per square meter, the total number of spikelet per panicle and number of blank spikelet per panicle, but number of filled spikelet per panicle had decreased. This effect was important because there were effect of the sink-source that in the yield components. Silicon have shown increase in total number of tiller per hill, the total number of spikelet per panicle and the number of filled spikelet per panicle, but number of blank spikelet per panicle had decreased. Interaction of silicon application with high levels of nitrogen fertilizer had increased percentage of filled spikelet per panicle which can be due to the influence of silicon on the reduction of blast disease and drought. By increase of nitrogen application number of blank spikelet per panicle was increased but by application of silicon it was decreased.

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