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EFFECT OF NITROGEN AND SILICON FERTILIZATION ON GROWTH, YIELD AND YIELD ATTRIBUTES OF RICE (*Oryza sativa* L.) UNDER LOWLAND CONDITIONS

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ABSTRACT

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. To evaluate the effects of nitrogen and silicon fertilization on yield components and yield of rice cultivar GAR 13, an experiment was carried out combining four nitrogen rates (0, 75, 100 and 125 kg N ha^{-1}) applied as ammonium sulphate, and four silicon rates (0, 200, 400 and 600 kg ha^{-1}) applied as calcium silicate. Trial was set up in a randomized block design with factorial concept and tree replications. Results showed that minimum of the plant height (91.5 cm), tillers (6.06), panicle length (21.18 cm), test weight (17.54 g), grain (5241 kg ha^{-1}) and straw (6961 kg ha^{-1}) yields were obtained at N0, as well as the maximum of the plant height, panicle length, tillers, test weight were observed at N_{125} kg N ha^{-1}, respectively.

KEY WORDS
Rice
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Growth and yield attributes

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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 Scrivner, 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 India has recently decreased rice production and farmers for increasing yield used nitrogen application, resulting in coast increasing and production decreasing due to high land 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. Nitrogen nutrition is critical to 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.

Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelet's, 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). Nitrogen application significantly increased grain yield largely through an increased biomass and grain number (Mauad *et al.,* 2003). Application of nitrogenous fertilizers is an important practice for increasing rice yields. However, when applied in excess may limit, yield because of lodging and promote shading and susceptibility to insects and diseases. These effects could be minimized by the use of Si (Ma *et al.,* 1989; Munir *et al.,* 2003). Due to a synergistic effect, the application of Si has the potential to raise the optimum N rate, thus enhancing productivity of existing lowland rice fields (Ho *et al.,* 1980). Silicon has been reported to raise the optimum level of N in rice. However, information on Si and N interaction in aerobic/upland/rain fed rice is very limited. In this context the present study was undertaken to evaluate the effect of Si and N on yield, yield components and NUE of lowland rice.

Silicon is considered an agronomically essential element for sustainable rice production (Savant *et al.,* 1997) and recognized as such in Japan (Ma 2004). Silicon is believed to play the following roles in rice plants: i) Rice as a Si accumulator; Si is absorbed as PAS by rice plants in far larger quantities than the macronutrients. For example, Si uptake is 108% greater than Nitrogen (N) uptake. A rice crop producing a yield of 5000 kg ha^{-1} removes 230-470 kg Si ha^{-1}. ii). Increases a rice plant growth. Savant *et al.* (1997) reports that an adequate supply of Si increases the number of panicles, the number of grains per panicle, the percentage ripening and the light-receiving posture of rice plants, thereby improving photosynthesis. iii) Increase fertilizer efficiency: Elawad and Green (1979) reported that Si has the potential to raise the optimum rate of N. The Si also improves the availability and utilization of P by rice plants (Savant *et al.,* 1997). iv) Develops resistance and/or tolerance to abiotic stresses: Si supplied rice plants can tolerate Fe, Al and Mn toxicities and the increased mechanical strength of the culm helps reduce crop lodging (Savant *et al.,* 1997; Takahashi, 1995). There is also increased resistance to salt stress.

Nitrogen is essential for plant growth and development, and is often a limiting factor for high productivities. However, when applied in excess it may limit 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 paper aims to evaluate the effect of silicon and nitrogen rates on lowland rice and their interaction with yield components and grain productivity.

MATERIALS AND METHODS

In order to achieve the pre-set objectives behind the present investigation, a field experiment was conducted during the *Kharif* season for two years 2014 and 2015 at the Agriculture Research Station, Anand Agricultural University, Jabugam, Gujarat. Geographically, Jabugam is situated at 22⁰17'37.70" north latitude, 73⁰46'41.02" east longitude with an elevation of 92 meters above mean sea level. The climate of Jabugam region is semi-arid and sub-tropical with hot summer and cold winter. In this region, generally monsoon commences in the month of June and retreats from the end of September. Most of the rainfall is received from south-west monsoon currents. July and August are the months of heavy showers.

The soil type of Gujarat varies from medium black to loamy sand with a good drainage capacity. The important soil orders in this region are *Inceptisols, Entisols*and *Vertisols*. The total rainfall of the region is about 800-1000 mm. Average minimum and maximum temperature of both the year of study was 19.6°C and 33.3°C, respectively. The soil was loamy sand, with a sand, fine sand, silt and clay composition of 49.85, 26.6, 10.0 and 12.1%, respectively. The soil chemical analysis indicates: pH at 6.32 and estimated the following nutrients in their available form: N = 313 kg ha^{-1}, Si = 190.8 kg ha^{-1}, P_2O_5 = 88 kg ha^{-1}, K_2O = 221 kg ha^{-1}, OC = 6.32 g kg^{-1}, EC = 0.43 dSm^{-1}.

The experiment was based on a Randomized Block Design with factorial concept and three replications and sixteen combined treatments. The entire dose of phosphorus as per recommendation was applied through single super phosphate. Four levels (0, 75, 100 and 125 kg) of N were applied through ammonium sulphate and four levels (0, 200, 400 and 600 kg) of Si were applied through calcium silicate at the time of sowing. Nitrogen was applied as per the treatments as scheduled in the form of Ammonium sulphate in 3 equal splits (1/3 basal, 1/3 at active tillering stage and 1/3 at panicle initiation stage).

RESULTS AND DISCUSSION

Plant height had significant effect under nitrogen and silicon treatment in 5 % probability level (Table 1). The lowest plant height (92.5cm) was noted for control (no nitrogen application) and maximum of that (122.4 cm) was for 125 kg ha^{-1} nitrogen. Plant height increased 14 % by silicon application. Minimum plant height (104.5 cm) was obtained for control (no silicon application) and greatest of that (118.7 cm) was for 600 kg ha^{-1} silicon application (Table 1). 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, 2012). Yoshida *et al.* (1962) stated that plant height increased by increase of calcium 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

Table 1: Effect of nitrogen and silicon on number of plant height, total no. of tillers, test weight, grain and straw yields of rice (pooled 2 years)

Treatments		Plant height (cm)	Total no. of tillers (plant^{-1})	Panicle length (cm)	Test weight(g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Nitrogen levels (kg ha^{-1})							
N 0		91.5	6.06	21.18	17.54	5241	6961
N 75		115.6	7.60	24.45	17.56	6040	7982
N 100		118.4	8.31	25.04	17.58	6163	8541
N 125		122.4	8.93	26.28	17.62	6445	8658
Silicon levels (kg ha^{-1})							
Si 0		104.4	7.12	22.23	17.53	5693	7319
Si 200		109.2	7.22	23.30	17.57	5944	7934
Si 400		115.6	7.85	25.35	17.58	6091	8354
Si 600		118.7	8.72	26.06	17.62	6163	8536
S. Em. +	N	2.1	0.17	0.45	0.01	78	149
	Si	2.1	0.17	0.45	0.01	78	149
	N x Si	4.2	0.34	0.90	0.02	156	298
CD (0.05)	N	5.9	0.49	1.27	0.03	221	422
	Si	5.9	0.49	1.27	0.03	221	422
	N x Si	NS	NS	NS	NS	NS	NS
CV %		9.1	10.9	9.0	0.28	6.2	9.5

height had significant effect in tillering time by nitrogen contributing treatments in 1 % probability level.

Increment of panicle length occurred with increasing nitrogen rates (Table 1). The lowest panicle length (21.18 cm) was noted for control (no nitrogen application) and maximum of that (26.28 cm) was for 125 kg ha^{-1} nitrogen. Panicle length increased 17 % by silicon application. The least panicle length (22.23 cm) was obtained for control (no silicon application) and highest of that (26.06 cm) was for 600 kg ha^{-1} silicon application (Table 1). This behaviour is a consequence of the participation of N in structural functions of the plant, such as cell multiplication and differentiation, genic inheritance and formation of tissues (Malavolta *et al.,* 1997). These results agree with those reported by Barbosa and Filho (1991). Hassan *et al.* (2013) showed that with the application of nitrogen fertilizer, panicle length had increased 7.41%. Bindra *et al.* (2000) reported that increasing panicle numbers in per unit area are the main factor of yield increment as a result of nitrogen application. Panicle length effects on grain yield due to more transport of photosynthesis material in presence of nitrogen (Dobermann *et al.* 2002). Absorbed silicon is located in leaf area in rice and by this, decreased cuticle transpiration and it decreases plant elongation (Datnoff *et al.* 2001). Silicon improved panicle length, inter-node length and fresh weight in rice (Fallah, 2012). Yoshida *et al.* (1962) stated that panicle length increased by increase of sodium silicate levels because of the silicon effect on straight stature of leaves.

The total number of tillers is determined during the reproductive stage (Machado, 1994). Nitrogen fertilization increase of this variable (Table 1) and the result is associated to a greater availability of nitrogen, since this nutrient is related to the formation of tissues (Malavolta *et al.,* 1997). The lowest amount of total no. of tillers (6.06) was noted for control and maximum of that (8.93) was for 125 kg ha^{-1} nitrogen. The lowest total no. of tillers (7.12) was obtained for control (no silicon application) and maximum of that (8.72) was for 600 kg ha^{-1} silicon application (Table 1). Total no. of tillers increased 22 % by silicon application. Silicon rates influence the total number of tillers per plants ($P > 0.05$) in opposition to results of Deren *et al.* (1994), who verified a positive response to the application of this element. However, Carvalho (2000), also did not observe any influence of silicon fertilization on this yield component. Nitrogen fertilization did modify spikelet fertility. This behavior could be related to the fact that at the vegetative stage there was greater amount of nitrogen available for the plant, which increased tillering and number of panicles (Table 1). Greater tillering caused shading, reducing the area of active photosynthesis, therefore reducing the production of assimilates, that otherwise would be directed to grain filling, and increasing the number of blank spikelets, consequently reducing spikelet fertility.

Increasing nitrogen rates increased the mass of 1,000 grains (Table 1), probably because the amount of carbohydrates was sufficient to fill the greater number of spikelets produced (Table 1). The lowest weight of 1000 g of seeds (17.54) was noted for control (no nitrogen application) and maximum of that (17.62) was for 125 kg ha^{-1} nitrogen. Minimum weight of 1000 g of seeds (17.54) was obtained for control (no silicon application) and maximum of that (17.62) was for 600 kg ha^{-1} silicon application (Table 1). These results are similar to those obtained by Arf (1993), who verified increased in the mass of 1000 grains for cultivar GAR-13 in the order of applied nitrogen. However, they results of Stone *et al.* (1999), who observe differences for the mass of 1,000 grains as nitrogen rates increased. The mass of 1,000 grains increased as the level of silicon fertilization increased. Even though silicon deposition on rice grain hulls was not evaluated, the likely explanation for the increase in grain mass would be the greater deposition of this element on the paleae and lemmas, as reported by Balastra *et al.* (1989). This greater deposition is attributed to intense panicle transpiration during the grain filling stage, since the process of transportation and deposition of silicon in plant tissues depends upon the transpiration rates that occur in different plant organs (Yoshida *et al.* 1962). When a given plant organ is developing, transpiration tends to become more intense, and consequently silicon deposition tends to be higher. This result corroborates those found by Balastra *et al.* (1989), Deren *et al.* (1994); Meshram *et al.* (2015) and Carvalho (2000), who also observed increasing grain mass with increasing levels of silicon fertilization.

Grain yield had significant effect under nitrogen treatment in 5 % probability level (Table 1). The maximum grain yield (6445 kg ha^{-1}) was observed for 125 kg ha^{-1} nitrogen application and minimum of that (5241 kg ha^{-1}) was for control (Table 1). The maximum grain yield of rice was significantly increased with the application of Si @ 600 kg ha^{-1}; which was at par with 400 kg Si ha^{-1}. 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 Takahashi, (1990); Malav *et al.* (2015); Mobasser *et al.* (2008) reported that grain yield increased by silicon application. Grain yield increased by 120 kg ha^{-1} nitrogen contributing in three times (transplanting time, tillering time and panicle initiation) (Singh *et al.,* 2002).

The straw yield of rice had significant effect under nitrogen and silicon treatment in 5 % probability level (Table 1). The significantly maximum straw yield (8658 kg ha^{-1}) was observed for 125 kg ha^{-1} N application and minimum of that (6961 kg ha^{-1}) was for control (Table 1). The higher straw yield (8536 kg ha^{-1}) of rice was significantly increased with the application of Si @ 600 kg ha^{-1}; which was at par with 400 kg Si ha^{-1}. Agarie *et al.* (1993) showed that silicate fertilizers increased dry matters by effect on vegetation growth consequently increase grain and straw yields. 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.

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