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Effect of Silicon and Nitrogen nutrition on major pest and disease intensity in low land rice

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Nutrition management is one of the most important factors for enhancing yield, but it may affect the response of rice plants to pests and diseases due, in part, to the change of microclimate under the rice plant canopy. Therefore, knowledge of the relationship of nutrition management and pests and diseases is an important component in setting up a high yield production system. The pest and disease control procedures used by farmers can as also include soil fertility management since these nutrition practices can impact the physiological susceptibility of crop plants to pest and diseases by affecting plant resistance. Silicon content is particularly important in pest and disease reduction in rice and certain rice genotypes are more efficient accumulators of silicon than others making them more resistant. In the absence of natural heritable resistance in rice varieties, resistance can be induced by alternate strategies to suppress certain pest and pathogens. Hence experiments were carried out at Jabugam Farm, Anand Agricultural University Anand Gujarat (India). Treatments were arranged in a factorial randomized block design with the silicon factor at four levels (0, 200, 400 and 600 kg ha^{-1}), four levels of nitrogen (0, 75, 100, and 125 kg ha^{-1}), and with three replicates. Indian improved and high – yielding rice variety, GR-13, was used. The overall yield ranged from 4991 to 6439 kg ha^{-1} with a mean of 5936 kg ha^{-1}. The plots which did not receive any fertilizer, that is, (N0 + Si0) exhibited the highest pest incidence (dead hearts, leaf folder and stem borer) and disease incidence (leaf blight, brown spot and grain discoloration) compared to other treatments which received both N and Si.

Key words: Nutrition management, conventional rice, silicon, yield, pest and diseases.

INTRODUCTION

Nutrition management is one of the most important factors for enhancing yield, but it may affect the response of rice plants to pests and diseases due, in part, to the change of the microclimate under the rice plant canopy. Therefore, knowledge of the relationship of nutrition management and pests and diseases is an essential component in setting up a high yield production system. The pest and disease control procedures adopted by farmers can also include soil fertility management since these nutrition practices can affect the physiological susceptibility of crop plants to pest and diseases.

Soils with high organic matter and active biological

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activity generally exhibit good soil fertility. Studies have shown that the shift from organic soil management to chemical fertilizers has increased the potential of certain pest and diseases causing economic losses. Ramesh et al. (2005) reported that organic crops are more tolerant to insect attack, and organic rice is reported to have a thicker cell wall and lower levels of amino acid than conventional rice. Silicon is particularly effective against pest and diseases in rice and certain rice genotypes are more efficient accumulators of silicon than others making them more resistant (Winslow, 1992). In the absence of natural heritable resistance in rice varieties, resistance can be induced by alternate strategies to suppress certain pest and pathogens. Hence the present study was undertaken to study induced resistance and its impact on major pests and diseases of rice.

MATERIALS AND METHODS

The experiments were carried out at the Jabugam Farm, Anand Agricultural University Anand Gujarat (India), during *kharif* 2014. Geographically, Jabugam is situated at 22°17'37.70" North latitude, 73°46'41.02" East longitude with an elevation of 92 m 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 field experiment was conducted in sandy clay loam to clay loam textured soils of rice growing areas. The nature of soil was acidic to neutral and pH ranged from 6.32 to 7.20. The soluble salts content was low to high and mean value was 0.43 ds m^{-1}. The available nitrogen, phosphorus, potassium and sulphur ranged from medium to high. Treatments were arranged in a factorial randomized block design with silicon factor at four levels (0, 200, 400 and 600 kg ha^{-1}) and four levels of nitrogen (0, 75, 100, and 125 kg ha^{-1}) consisting of 16 treatments with three replicates. Indian improved and high –yielding rice variety, GR-13, was used. To know the available silicon status of rice growing plots, representative soil samples were also collected and were estimated as per standard procedure given by Korndorfer et al. (2001). Grain and straw yields were recorded at harvest of rice crops. Recommended doses of phosphorus (50 kg ha^{-1}) were applied basally to all treatments in the form of single super phosphate (SSP). Nitrogen was applied as per the treatment schedules in the form of ammonium sulphate in three equal splits (1/3 basal, 1/3 at active tillering stage and 1/3 at panicle initiation stage). Silicon was applied in the form of calcium silicate (20% silicon content) as a basal application as per the treatment composition. Evaluation of the incidence of various pests *viz.,* the yellow stem borer (*Scirpophaga incertulas*) which causes dead hearts, and the rice leaf folder (*Cnaphalocrosis medinalis*) were recorded during tillering vegetative and reproductive phases by following standard procedures (Anonymous, 2007b). The disease incidence was assessed by recording the severity of leaf blight (*Xanthomonas oryzae*) and brown spot (*Helminthosporium oryzae*) during boot leaf, tillering and at harvest stage, whereas, sheath rot (*Sarocladium oryzae*) and grain discoloration (complex disease caused by fungi and bacteria) were recorded at harvest of the rice crop in accordance with a standard evaluation system by adopting a 0 to 9 scale and calculating percent disease intensity (PDI) as per Wheeler (1969). The analysis of variance for grain and straw yield, pest and diseases was calculated using INDOSTAT software.

Statistical analysis

Experimental data were analyzed using analysis of variance method. Correlation and regression coefficients were worked out and the results are reported at 5 and 1% level of significance (Steel and Torrie, 1982).

RESULTS AND DISCUSSION

Effect of silicon and nitrogen on grain and straw yield

Data in Table 1 illustrate that application of N and Si had a significant effect on the seed yield of rice. The highest grain (6439 kg ha^{-1}) and straw yields (8892 kg ha^{-1}) recorded due to application of 125 kg N ha^{-1} and 600 kg Si ha^{-1} and were on a par with the yield obtained from other treatments receiving N at 100 and 125 kg ha^{-1} along with silicon at 200, 400 and 600 kg ha^{-1}. Even the treatments with N at 100 and 125 kg ha^{-1} without any silicon supplementation recorded significantly lower grain and straw yields of 4991 and 6539 kg ha^{-1}, respectively compared to the treatments which received silicon along with nitrogen (Table 1).

This might be due to the increased phosphate uptake that occurs with the application of silicon (Ma and Takahashi, 2002). But in the case of treatments which received no nitrogen and nitrogen at 75 kg ha^{-1}, the average yields were less than the treatments which received N at 100 kg ha^{-1} and 125 kg ha^{-1}. This may be due to the influence of conjunctive application of Si and N, which decreases percent spikelet sterility with increased Si levels (Snyder, 1991). Application of silica increased rice yield on histosols mainly due to the supply of plant available Si and not due to supply of other nutrients (Snyder, 1986). Similar to grain yields, the results revealed a significant influence of fertility levels as well as their interactions on rice straw yields. This higher straw yield could also be attributed to increased number of tillers per hill and plant height.

The dry matter production increased significantly with each increment in N and Si fertility level due to increased chlorophyll formation which ultimately improved photosynthesis in different rice soils of India (Singh et al., 2006). Nitrogen fertilization elicited an increase in this component which is associated to a greater availability of N since this nutrient is related to the formation of tissues (Matichenkov et al., 2001). The yield plateau observed at the highest level of N application could be due to the reason that increases in the number of stalks provided by increasing rates of N fertilization contributed to an increase in the number of leaves which could have caused shading, decreasing the area of active photosynthesis. Above all, excess N also prolongs the vegetative growth at the cost of reproductive growth, thus, diminishing the production of carbohydrates (Mauad et al 2003).

Table 1. Influence of different levels of nitrogen and silicon on grain yield (kg ha^{-1}) of rice under low land conditions.

Treatment (kg ha^{-1})		Yield (kg ha^{-1})	
		Grain	Straw
T_1	(N 0 + Si 0)	4991	6539
T_2	(N 0 + Si 200)	5494	7206
T_3	(N 0 + Si 400)	5556	7485
T_4	(N 0 + Si 600)	5594	7553
T_5	(N 75 + Si 0)	5487	7224
T_6	(N 75 + Si 200)	5901	7814
T_7	(N 75 + Si 400)	6086	8205
T_8	(N 75 + Si 600)	6283	8493
T_9	(N 100 + Si 0)	5818	7804
T_{10}	(N 100 + Si 200)	6185	8527
T_{11}	(N 100 + Si 400)	6249	8638
T_{12}	(N 100 + Si 600)	6357	8751
T_{13}	(N 125 + Si 0)	5741	7839
T_{14}	(N 125 + Si 200)	6350	8772
T_{15}	(N 125 + Si 400)	6405	8806
T_{16}	(N 125 + Si 600)	6439	8892
S.Em.±		161	215
C.D. (0.05)		466	620
CV %		9.43	9.26

Pest incidence

The data on the incidence of pests as influenced by different levels of N and Si in rice during the crop growth period is presented in Table 2. Three different pests viz., stem borer, dead hearts and leaf folder were observed at vegetative and panicle initiation stage, respectively. Among the fertility levels, the T_1 treatment which did not receive any N or Si levels recorded the highest incidence of stem borer and dead hearts as well as leaf folder as evidenced by stem borer, dead hearts and leaf folder, compared to other treatments which received both N and Si. An increase in the level of N increased the incidence of stem borer, dead hearts and leaf folder; which of course is common for rice (Savant et al., 1999). However, when N was integrated with Si, the incidence was decreased. Even among the treatment combinations, the treatments which received higher doses of Si in combination with N recorded lower incidence of stem borer, dead hearts and leaf folder compared to the treatments which received low Si content in combination with N.

The main cause for the death of insects due to silicon application was wearing of mandibles and main feeding organs of insects which resulted in functionless mandibles so that the insects of paddy die without food (Datnoff et al., 2001). There is increasing evidence for the necessity to modify the traditional view of silicon deposition in the cell walls as a purely physical process leading to mechanical stabilization (rigidity) of the tissue and acting as a mechanical barrier to pathogens. Silicon deposition is under rather strict metabolic and temporal control. Cell wall metabolites interact with silicic acid (forming ester bonds) leading to bulk deposition of silicon into the mature cell wall structure (Perry et al., 1987).

Panda et al. (1975) and Sasamoto (1961), reported that the larvae of the rice yellow stem borer, brown plant hopper, and leaf roller were unable to attack rice plants which became resistant because of high Si content in their stems; and a significantly negative correlation was shown between Si content and pest incidence. Savant et al. (1997) reported that plants with higher Si contents in their tissues had a higher level of resistance to rice pests. Several economically important insect pests such as stem borer, brown plant hopper, green leaf hopper have been suppressed by increasing the Si concentration in plants (Aziz et al., 2002).

Disease incidence

The data on the intensity of various diseases as influenced by different levels of N and Si in rice during the crop growth period is presented in Table 3. Diseases *viz.,* leaf blight, brown spot and grain discoloration were observed and studied. Conjunctive use of Si and N on control of diseases (leaf blight, brown spot and grain discoloration) was observed at vegetative and panicle

Table 2. Influence of different levels of nitrogen and silicon on pest incidence under low land rice conditions.

Treatment (kg ha^{-1})		Pest incidence (%)		
		Dead hearts	Leaf folder	Stem borer
T_1	(N 0 + Si 0)	1.23	1.59	1.60
T_2	(N 0 + Si 200)	1.18	1.57	1.50
T_3	(N 0 + Si 400)	1.09	1.47	1.45
T_4	(N 0 + Si 600)	0.97	1.23	1.32
T_5	(N 75 + Si 0)	1.26	1.69	1.65
T_6	(N 75 + Si 200)	1.11	1.35	1.44
T_7	(N 75 + Si 400)	1.08	1.28	1.38
T_8	(N 75 + Si 600)	0.95	1.20	1.28
T_9	(N 100 + Si 0)	1.28	1.74	1.66
T_{10}	(N 100 + Si 200)	0.97	1.27	1.38
T_{11}	(N 100 + Si 400)	0.89	1.20	1.28
T_{12}	(N 100 + Si 600)	0.87	1.14	1.08
T_{13}	(N 125 + Si 0)	1.30	1.78	1.71
T_{14}	(N 125 + Si 200)	0.92	1.20	1.23
T_{15}	(N 100 + Si 400)	0.88	1.14	1.19
T_{16}	(N 125 + Si 600)	0.85	1.11	0.97
S.Em.±		0.03	0.04	0.05
C.D. (0.05)		0.08	0.11	0.13
CV %		8.72	9.35	11.70

Table 3. Influence of different levels of nitrogen and silicon on disease intensity during crop growth under low land rice conditions.

Treatment (kg ha^{-1})		Diseases intensity (%)		
		Leaf blight	Brown spot	Grain discoloration
T_1	(N 0 + Si 0)	0.224	0.554	0.929
T_2	(N 0 + Si 200)	0.182	0.511	0.906
T_3	(N 0 + Si 400)	0.158	0.401	0.819
T_4	(N 0 + Si 600)	0.149	0.181	0.647
T_5	(N 75 + Si 0)	0.241	0.570	0.943
T_6	(N 75 + Si 200)	0.160	0.361	0.778
T_7	(N 75 + Si 400)	0.136	0.209	0.691
T_8	(N 75 + Si 600)	0.114	0.152	0.513
T_9	(N 100 + Si 0)	0.263	0.601	1.055
T_{10}	(N 100 + Si 200)	0.140	0.182	0.614
T_{11}	(N 100 + Si 400)	0.127	0.145	0.594
T_{12}	(N 100 + Si 600)	0.117	0.139	0.479
T_{13}	(N 125 + Si 0)	0.271	0.625	1.073
T_{14}	(N 125 + Si 200)	0.132	0.162	0.540
T_{15}	(N 100 + Si 400)	0.123	0.138	0.515
T_{16}	(N 125 + Si 600)	0.107	0.123	0.464
S.Em.±		0.005	0.011	0.022
C.D. (0.05)		0.014	0.031	0.062
CV %		10.18	11.82	10.32

initiation stage respectively, during crop growth period. It was observed that increased levels of N alone increased the intensity of diseases. Disease intensity was significantly influenced by the different N and Si combinations. Among the different N and Si level treatments, T_{10} (N_{100} + Si_{200}), T_{11} (N_{100} + Si_{400}), T_{12} (N_{100} + Si_{600}), T_{14} (N_{125} + Si_{200}), T_{15} (N_{125} + Si_{400}) and T_{16} (N_{125} + Si_{600}) recorded the lowest disease incidence compared to other treatments which received lower levels of nitrogen + silicon doses. However, there was significant reduction in diseases (leaf blight, brown spot and grain discoloration) as well as insect pests (stem borer, dead hearts and leaf folder) with increased levels of Si along with varied levels of N which ultimately resulted in increased grain yield. Promoter or carrier-induced silicon transportation into rice in relation to disease resistance has been investigated by Voleti et al. (2008).

They reported that simple amino acids, such as histidine, imidazole, glutamic acid, glycine and glutamine significantly enhanced the levels of $Si(OH)_4$ in the stem and resulted in 14 to18% silicon transport into the leaf surface. Deren et al. (1994) concluded that the increase in rice yield with added Si was attributing to increased resistance against diseases such as brown spot, being negatively correlated with Si concentration in the plant tissue. In Brazil, Korndorfer et al. (1999) found that an increase in the Si application rate reduced grain discoloration from 46% in the control to 29% at the highest Si rate (960 kg Si ha^{-1}). It was also found that this difference corresponded to a 64 per cent reduction in grain discoloration.

It was previously reported that silicon has the capacity to reduce the severity of several important diseases of rice *viz.,* blast, brown spot, sheath blight, leaf scald, and grain discoloration (Seebold et al., 2001). The fungal hyphae and haustoria successfully infect the plant cell will break the cell wall through chemical and physical means. Formation of a physical barrier in epidermal cells by Si deposition may contribute to plant resistance against diseases and pests (Epstein, 1994).

Conclusion

The nitrogen and silicon have shown significant impact on the pest and disease incidence with higher doses reducing the incidence.

Conflict of Interest

The authors have not declared any conflict of interest.

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