EFFECT OF DUAL APPLICATION OF NITROGEN AND SILICON ON PHYSIOLOGICAL TRAITS AND YIELD OF RICE

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ABSTRACT: Field experiments were conducted in two seasons in farmer's field in Typic Ustifluvent soil to assess the impact of silicon nitrogen interactions on physiological traits of lowland rice. The treatment consists of factor A- N levels (0, 50, 100 and 150 kg/ha) and factor B- Silicon levels (0, 50,100,150 kg Si/ha)., totalling sixteen treatment combination laid out in Factorial RBD with three replications employing test crop Rice var. ADT 43 (kharif) and CR1009 (rabi) seasons Physiological traits viz., tiller count, chlorophyll, growth analysis viz., CGR, RGR, NAR, root density and rice yield. The results revealed that physiological traits were significantly improved by silicon or nitrogen alone or both over control. The physiological traits increased with nitrogen and silicon levels and the maximum value was recorded when both were applied at 150 kg/ ha each. Grains and straw increased linearly with increase in nitrogen and silicon levels. The highest grain yield was observed with 150 kg N/ha + 150 kg Si/ha (5600, 6786 kg/ha) in kuruvai and samba season respectively. It was comparable with 150 kg N/ha+ 100 kg Si/ha, and 100 kg N/ha + 150 kg Si/ha in kuruvai and samba seasons. The maximum straw yield was observed with 150 kg N/ha + 150 kg Si/ha (6811, 8031 kg/ha) in kuruvai and samba season respectively
(Key *words*- Nitrogen, silicon, rice, physiological traits, yield)

INTRODUCTION

Rice is the staple food for about 50 per cent of the world's population (72.7 billion) that resides in Asia where 90 per cent of the world's rice is grown and consumed. With nearly 154 million hectares harvested each year, rice is one of the most important cereal crops in the world. It is the major source of calorie intake and the staple food for more than three billion people in the world (Datta *et al.*, 2017). Crop production can be improved by adding plant nutrients. Soil fertility often does not support optimum growth and yield due to lack of or low doses of specific nutrients. Nitrogen is the key element in the production of rice and gives by far the largest response. It is the most essential element in determining the yield potential of rice and nitrogenous fertilizer is one of the major inputs to rice production (Shukla *et al.*, 2015). Silicon (Si) is ranked as the second-most abundant element (after oxygen) in the earth's crust with nearly 29% mean content (Sommer *et al*, 2006). Plant available Si in the soils of tropical and subtropical areas including Vietnam is generally low (Meena *et al.*, 2014). Si has already been recognized as a functional nutrient for a number of crops, particularly rice and sugarcane, and plays an important role in the growth and development of crops, especially gramineae crops (Hodson *et al.* 2005). Si has been reported to benefit rice in a number of ways (Shivay and Dinesh, 2009). Rice requires large amounts of nitrogen and silicon for growth. Apparently applied Si seems to interact favourably with other applied fertilizer nutrients (namely N, P and K) and offers the potential to improve their agronomic performance and efficiency in terms of yield response. With this background, study was contemplated to find interaction effect of silicon and nitrogen on physiological traits and yield of rice.

MATERIALS AND METHODS

Two field experiments was conducted in farmer's field belonging to Padugai series (Typic Ustifluvent) during kharif and rabi 2018 to understand the interaction effect of nitrogen and silicon on physiological traits and yield of lowland rice. The experimental soil was sandy clay loam in texture, pH- 7.25 , EC -0.24 dS m^{-1}, organic carbon - 3.5g/kg , $KMnO_4$- N- 251 kg/ha, Olsen-P- 17.4 kg/ha and NH_4OAc- K -228 kg/ha and avaialble silicon- 25 mg/kg.The tretament consists of four levels of N (0,50,100, 150 kg/ha) and four levels of Si(0,50, 100, 150 kg/ha). The experiment was conducted in RBD with three replications involving test crop rice var ADT 43 (kharif) and CR1009(rabi). The biometric observations like tiller count, LAI, crop growth rate, realtive growth rate, net assimilation rate and chlorophyll content (SPAD values) besides grain and strawyield was recorded.

RESULTS

Effect of silicon on physiological traits and yield

The exogenous addition of silicon brought significant alterations in various physiological traits and rice yield over control in both seasons (Table 1 and 2). All the physilogcal traits increased with graded dose of silicon. The maximum tiller count (17.8, 24.5) , LAI (5.90,6.03), CGR (3.83,10.7 g m^{-2} d^{1}), RGR (13.9, 15.2 mg g^{-1} d^{-1}), NAR (3.83, 4.16 g dm^{-2} d^{-1}) and chlorophyll as SPAD value (40.6,42.7) was with 150 kg Si/ha in kharif and rabi seasons respectively. It was significantly superior to rest of the silicon levels. The per cent increase in various physiological traits due to silicon @150 kg /ha over control ranged from 3.1 to 29.3

Grain and straw yield of rice showed progressive increase due to different dose of silicon over control in both seasons. The grain yield response due to silicon levels ranged from 679 to 1908 kg/ha (kharif) and 657 to 1642 kg/ha (rabi). The maximum grain yield (5291, 6054 kg/ha) and straw yield (6520, 7482 kg/ha) was observed with 150 kg Si/ha in kharif and rabi seasons respectively. The percent increase in grain yield over control was (20.1, 14.9) at 50 kg Si/ha, (36.6, 26.9) at 100 kg Si/ha and (56.4, 37.4) at 150 kg Si/ha in kharif and rabi respectively.

Effect of nitrogen levels on physiological traits and yield

The graded dose of nitrogen brought out significant changes in physiologcal traits and rice yield over control in both seasons (Table 3,4). All the parrametrs showed linera increase with N levels. Application of 150 kg/N resulted in maximum tiller count (19.1, 24.00,) LAI (5.82,6.09), CGR (3.99, 12.3 g m^{-2} d^{1}), RGR (17.5, 17.0 mg g^{-1} d^{-1}), NAR (3.99, 4.39 g dm^{-2} d^{-1}) and chlorophyll as SPAD value (41.2, 45.3) in kharif and rabi seasons respectively. The per cent increase in various physiolgical traits due to 150 kg N/ha ranged from 10.5 to 102 over control.

Rice grain yield varied from 3600 to 4983 kg/ha (kharif.) and 4635 to 5893 kg/ha (rabi) and straw yield ranged from 4908 to 6233 kg/ha (kharif) and 5950 to 7137 kg/ha(rabi) due to graded dose of nitrogen applied . Overall, rice yield increased with increasing nitrogen applied rate and the maximum grain yields were achieved under 150 kg N/ha. The percent increase in grain yield over control was (15.1, 8.8) at 50 kg N/ha,(28.6, 20.1) at 100 kg N/ha and (38.4, 27.1) at 150 kg N/ha, in kharif and rabi seasons respectively.

Interaction effect of silicon and nitrogen on physiological traits and yield

The different physiological traits of rice improved further when it received both nitogen and silicon fertilization compared to their individual additions (Table 5). A synergist effect between nitrogen andsilicon was noticed on parameters studied. All the physiological traits improved progrssively and the highest tiller coint (21.3,24.5), LAI(6.48, 6.53), CGR(4.22,13.5 g m^{-2} d^{1}), RGR(19.0, 18.9 mg g^{-1} d^{-1}),NAR(4.22, 4.79 g dm^{-2} d^{-1}) and chlorophyll as SPAD value (43.4,45.5) was recorded with 150 kg N/ha plus 150 kg Si/ha. However it was comparable with 150 kgN/ha + 100kg Si/ha and 100 kg N/ha +150 kg Si/ha.

Combined application of nitrogen and silicon at different levels caused significant increase in rice yield over their individual applications (Table 6). In the absence of silicon, graded levels of nitrogen caused 19.9% to 69.9% (kharif) and 19.2% to 31.1% (rabi) increase in grain yield over control. Similarly in the absence of nitrogen, graded levels of silicon caused 36.6 to 87.9% (kharif) and 24.4 to 41.3% (rabi) increase in grain yield over control. But when both silicon and nitrogen were applied together, percent increase in grain yield over control ranged from 56.6 (N_1Si_1) to 123.9 (N_3Si_3) in kharif and 27.7 (N_1Si_1) to 82.6 (N_3Si_3) in rabi. The highest grain yield was observed with 150 kg N + 150 kg Si/ha (5600, 6786 kg/ha) in kharif and rabi season respectively. It was comparable with 150 kg N/ha+ 100 kg Si/ha (N_2Si_2), and 100 kg N/ha + 150 kg Si/ha (N_2Si_3) in kuruvai and samba seasons. Similarly the maximum straw yield was observed with 150 kg N/ha+ 150 kg Si/ha (6811, 8031 kg/ha) in kuruvai and samba season respectively However it was comparable with 150 N /ha + 100 kg Si/ha (N_3 Si_2).100 kg N/ha + 150 kg Si/ha (N_2 Si_3) in both seasons

DISCUSSION

In the present study, all the physiological tarits increased linearly with graded dose of nitrogen and silicon. The maximum tiller count was noticed with 150 kg N/ha + 150 kg Si/ha Tillering is an important trait for grain production and thereby it is critical aspect for the growth (Ling ,2000). Under field condition, the application of N is the most common and effective way to enhance tiller production, as it increases the cytokinin content within tiller nodes and further enhances the germination of the tiller primordium (Liu et al., 2011). Increase in the availability, absorption and accumulation of N by rice plant increased tiller number (Kumar et al., 2015). Yosef (2012) recorded maximum tiller count at 150kg N/ha Tillering is the production of expanding axillary bud, which is clearly associated with nutritional condition of the mother clump because tillers reserve carbohydrate and nutrients from the mother clump during early growth period and this was improved by silicon application

(Liang et al., 1994). Coung et al., (2017) reported higher number of tillers count on silicon fertilization. Leaf area index is an important parameter which influences the growth and yield of crops and is mainly responsible for photosynthetic activity of the plant. In the present study, LAI increased linearly with silicon and nitrogen levels and the maximum value was obtained at 150 kg/ha in both seasons. The increasing trend of LAI with nitrogen can be attributed to the positive effect of nitrogen on both leaf development and leaf area duration of the crop (Fageria, 2007). Higher leaf area index due to silicon could be due to erectness of leaves. Silicon improves high interception of light by keeping leaves erect thereby stimulating canopy photosynthesis in rice. Silicon increased number of tillers which increased LAI. Chen et al., (2011) reported silicon nutrition increased the source and sink strength and might have a possible to provide resistance against diseases and insects through which leaf become healthier and increased LAI. Lie et al., (2012) reported decrease in chlorophyll by 8% when fed with low N and increase by 12% when fed with high N Crops grown on soils with sufficient amount of available N showed a rapid growth with healthy green colour and quality (Cen et al., 2006). Improvement in chlorophyll content due to silicon is due to reinforcement of the cell wall due to deposit of silicon in the form of amorphous silica. Further erectness of the leaves and synthesis of chloroplast resulted in higher concentration of chlorophyll per unit area of leaf tissue (Song *et al*. 2014). Nitrogen due to the having role in production and translocation of cytokinin from the root to shoot increased in cell division rate and growth of rice. CGR, RGR and NAR has direct relationship with photosynthetic surface (Azarpour et al., 2014). There is direct relationship between leaf area index and CGR.LAI seems to indicate photosynthetic potential and dry matter accumulation in crop. In the present study, leaf area index increased with silicon addition. Ahmad et al. (2012) reported increased CGR, RGR and NAR on silicon addition

Grain yield of rice grown in both seasons were significantly enhanced either by individual application of nitrogen or silicon or both over control. Nitrogen is a constituent of amino acids, proteins, nucleic acids and chlorophyll Thus, both vegetative and reproductive phases of growth are highly dependent on adequate N supply. The rice plants which did not receive N fertilizer registered the lowest grain yield. This indicated that plants which received sub-optimal quantity of soil nutrients recorded poor response in term of grain yield. While plant which received fertilizer treatments recorded higher response. This also buttressed the fact that the experimental site was low in nitrogen and required soil amendment with N fertilizer for better performance of rice crop. Accordingly the grain yield showed a linear improvement with graded dose of nitrogen. The maximum grain yield was noticed with 150 kg N/ha. Djmann *et al*., (2018) reported maximum grain yield at 150 kg N/ha. Biological yield depends on many factors like tiller count, LAI, chlorophyll, CGR, RGR and NAR. These factors are affected by increasing in nitrogen levels. The present study also witnessed the significant influence on above said parameters due to N levels. This was confirmed with significant positive correlation that grain yield had with tiller count (r=0.896**, r=0.879**), chlorophyll (r= 0.876**,0.777**) , CGR(r= 0.802**, r= 0.832**), RGR (r= 0.758**,r= 0.885**) and NAR (r= 0.860**,r= 0.917**) in kharif and rabi seasons, respectively

Silicon effect on yield are related to the deposition of the element under the leaf epidermis, which results in physical mechanism of defense, production of phenols which stimulate phytoalexin production, reducing lodging, decreases transpiration losses and increases photosynthetic capacity of rice plant (Ahmad *et al*., 2012). The enhanced grain yield could be due to increased large leaf area and high chlorophyll content, which might have accumulated more photosynthates and produced higher biological yield. Silicon improves high interception of light by keeping leaves erect their by stimulating canopy photosynthesis in rice. (Ahmad *et al*., 2011). Growth analysis viz., CGR, RGR and NAR, which are directly related to DMP also contributed to increase in grain yield. Silicon application increased CGR, RGR and NAR and in turn it has significantly contributed to enhance grain yield. (Pati *et a*l., 2016)

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Table 1 Effect of silicon levels on physiological traits of rice

Silicon levels (kg/ha)	Tiller count		LAI		CGR ($g\ m^{-2}\ d^{-1}$)		RGR ($mg\ g^{-1}\ d^{-1}$)		NAR ($g\ dm^{-2}\ d^{-1}$)		Chlorophyll (SPAD Value)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
0	14.0	20.8	4.56	4.78	2.94	7.76	11.0	11.2	2.94	3.41	37.6	41.4
50	15.4	22.5	5.27	5.42	3.50	9.63	12.0	12.7	3.50	3.18	39.0	42.0
100	16.8	23.4	5.52	5.71	3.80	10.1	12.6	13.5	3.80	3.90	39.9	42.6
150	17.8	24.5	5.90	6.03	3.83	10.7	13.9	15.2	3.83	4.16	40.6	42.7
P(< 0.05)	0.33	0.93	0.13	0.23	0.21	0.41	0.40	0.55	0.21	0.16	0.42	0.23

Table 2. Effect of silicon levels on rice yield (kg/ha)

Silicon levels (kg/ha)	Kharif		Rabi	
	Grain yield	Straw yield	Grain yield	Straw yield
0	3383	4613	4412	5640
50	4062	5318	5069	6335
100	4620	5917	5602	6928
150	5291	6520	6054	7482
P(< 0.05)	192.8	176.4	224.0	276.7

Table 3 Effect of nitrogen levels on physiological traits of rice

Nitrogen levels (kg/ha)	Tiller count		LAI		CGR ($g\ m^{-2}\ d^{-1}$)		RGR ($mg\ g^{-1}\ d^{-1}$)		NAR ($g\ dm^{-2}\ d^{-1}$)		Chlorophyll (SPAD Value)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
0	13.1	21.7	4.35	4.47	2.91	7.28	8.64	10.2	2.91	3.16	37.3	38.2
50	14.9	22.7	5.26	5.45	3.50	8.67	9.99	10.9	3.50	3.57	38.5	41.2
100	16.9	23.5	5.83	5.93	3.72	9.81	13.5	14.5	3.72	4.04	40.0	43.4
150	19.1	24.0	5.82	6.09	3.99	12.3	17.5	17.0	3.99	4.39	41.2	45.3
P(< 0.05)	0.33	0.92	0.13	0.23	0.21	0.41	0.40	0.55	0.21	0.16	0.42	0.23

Table 4. Effect of nitrogen levels on rice yield (kg/ha)

Nitrogen levels (kg/ha)	Kharif		Rabi	
	Grain yield	Straw yield	Grain yield	Straw yield
0	3600	4908	4635	5950
50	4145	5361	5044	6371
100	4629	5865	5565	6874
150	4983	6233	5893	7137
P(< 0.05)	192.8	176.4	224	276.7

Table 5 Interaction effect of silicon and nitrogen on physiological traits in rice

N x Si (kg/ha)	Tiller count		LAI		CGR (g m^{-2} d^{-1})		RGR (mg g^{-1} d^{-1})		NAR (g dm^{-2} d^{-1})		Chlorophyll (SPAD Value)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
N_1Si_1	14.7	22.7	5.21	5.34	3.30	8.57	9.80	10.2	3.30	3.42	38.7	41.0
N_1Si_2	15.3	23.0	5.20	5.53	3.72	8.94	10.16	11.3	3.72	3.67	39.0	41.8
N_1Si_3	16.4	24.9	5.59	5.83	3.80	9.21	11.30	13.3	3.80	3.95	39.3	42.1
N_2Si_1	16.0	23.3	5.74	5.68	3.53	9.82	12.9	13.8	3.53	3.94	39.8	43.5
N_2Si_2	17.8	24.6	6.07	6.14	3.92	10.2	13.3	14.8	3.92	4.13	40.6	43.6
N_2Si_3	18.7	25.8	6.19	6.31	4.00	10.8	15.0	16.5	4.00	4.34	41.5	43.9
N_3Si_1	18.7	22.5	5.44	5.96	4.09	12.2	17.3	16.8	4.09	4.27	40.5	45.5
N_3Si_2	20.3	23.4	6.02	6.23	4.16	12.4	18.4	17.4	4.16	4.48	42.1	45.5
N_3Si_3	21.3	24.5	6.48	6.53	4.22	13.5	19.0	18.9	4.22	4.79	43.4	45.5
P(< 0.05)	1.65	1.85	0.27	0.47	0.42	0.83	0.80	1.10	0.42	0.32	0.84	0.47

Table 6 Interaction effect of silicon and nitrogen on rice yield (kg/ha)

N x Si (kg/ha)	Grain yield		Straw yield	
	Kharif	Rabi	Kharif	Rabi
N_1Si_1	3916	5200	4745	6021
N_1Si_2	4283	5512	5250	6535
N_1Si_3	5383	6611	5750	7239
N_2Si_1	4333	5531	5339	6615
N_2Si_2	4916	6143	5862	7138
N_2Si_3	5483	6744	6432	7922
N_3Si_1	4583	5869	5572	6829
N_3Si_2	5500	6741	6342	7598
N_3Si_3	5600	6811	6786	8031
P(< 0.05)	385.7	352.9	448	553.5