Lodging resistance, growth and yield of selected aromatic rice varieties in relation to application of silicon

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Abstract

An experiment was conducted at the Agronomy field of Bangladesh Institute of Nuclear Agricultural (BINA), Mymensingh during Aman season of 2014-15 with a view to examining the effect of soil and foliar application of silicon on the lodging resistance, growth and yield of selected aromatic rice varieties. Two rice varieties (Kalizira and Binadhan-13) were evaluated under four rates of silicon with two application methods. Silicon rates were 0, 200, 400 and 600 Kg ha^{-1}.Two application methods, soil and foliar spray, were evaluated for each silicon rate. Soil applications were made just prior to planting. Foliar sprays were made at vegetative, reproductive and ripening growth stage. At 45 DAT, the chlorophyll content was 31.1 and 30.1 at Binadhan-13 and Kalizira, respectively. However, at 105 DAT it was 32.1 and 30.0 at Binadhan-13 and Kalizira, respectively. The results showed that the highest grain yield (3.01 t ha^{-1}) was obtained by Binadhan-13 followed by Kalizira which produced 2.69 t ha^{-1}. Method of fertilizer application showed that highest grain yield (3.04 t ha^{-1}) was produced in soil incorporation method and the second highest yield (2.65 t ha^{-1}) in foliar application method. In case of silicon rates, 600 Kg ha^{-1} silicon produced the highest grain yield (3.06 t ha^{-1}) due to the maximum number of total tiller $hill^{-1}$ (8.40) and number of filled grain $panicle^{-1}$ (169.9) followed by 400 Kg ha^{-1} silicon (2.97 t ha^{-1}), 200 Kg ha^{-1} silicon (2.77 t ha^{-1}) and lowest by control (2.59 t ha^{-1}). Interactions between varieties, method and silicon rates showed that the highest grain yield in soil incorporation method with 600 Kg ha^{-1} silicon by Binadhan-13 (3.59 t ha^{-1}).

Key words: Rice, silicon, growth, yield and aromatic rice

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Introduction

Rice occupies a unique position in many nations because for its importance in traditional diets and the main source of income of many peoples in the whole world. It was estimated 34.8

million metric tons in the year 2014 among all cereals in Bangladesh (FAO, 2014). Aromatic rice varieties have occupied about 14 percent of the total transplant aman rice area (BBS, 2013). It is also preferred by some consumers despite their high price. Farmers' net income may be increased by 23% with the adoption of the modern aromatic rice varieties (Shrestha et al., 2002).

Hence, increasing productivity and keeping pace with the rising food demand with minimal environmental disturbance has become a challenge to the farmers and scientists. Therefore, adequate nutrient management is essential to enhance productivity of rice as it is an exhaustive feeder crop (Thind et al. 2012). Silicon exists in all plants grown in soil and its content in plant tissue ranges from 0.1 to 10% (Elmer and Datnoff 2014). In modern agriculture, 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). Effects of silicon on yield are related to the deposition of the element under the leaf epidermis which results a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses (Korndörfer *et al*., 2004). Many scientists working on role of silicon in plant growth have concluded that reduced amount of silicon in plant develops necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduces grain yield in cereals (Shashidhar *et al.*, 2008). Although silicon has not been considered important for vegetative growth but it aids the plant in healthy development under stresses in different grasses especially in rice. Plant tissue analysis has revealed the optimum amount of silicon is necessary for cell development and differentiation (Liang *et al.*, 2005). Under changing socio-economic conditions all around the world, reduction in paddy yield is not affordable by the agricultural system. Major nutrients (N, P, K) are already in practice at optimum level but yield gap is still present so following the recent research it is needed to enter micronutrients like silicon (Si) rice production system.

The objective of the study were (i) to determine the optimum rate of silicon and (ii) to resolve the best method of silicon application on lodging resistance, growth and yield of selected aromatic rice varieties.

Materials and Methods

The research work was conducted at BINA HQ, Mymensingh, Bangladesh during the period 2014-15. The experiment was laid out as factorial randomized complete block design with three replications. The unit plot size was 3 m × 2 m. Thirty days old seedlings were transplanted @ 2-3 seedlings hill^{-1} with a planting spacing of 20 cm x 15 cm. Two rice varieties (Kalizira and Binadhan-13) were evaluated under four rates of silicon with two application methods. Silicon rates were 0, 200, 400 and 600 Kg ha^{-1}. Two application methods, soil and foliar spray, were evaluated for each silicon rate. Soil applications were made just prior to planting. Foliar sprays were made at vegetative, reproductive and ripening growth stage. The plots were fertilized with 165, 85, 120, 90 and 5 kg ha^{-1} of N, P, K, S, Zn as urea, Triple Super Phosphate (TSP), Murate of Potash (MoP), gypsum and zinc oxide, respectively. All the fertilizers except urea were applied at final land preparation in full amount. Urea was applied in three splits 30% at 7-10 days after transplanting (DAT), 30% at 20-30 DAT and the last 40% at panicle initiation stage. The crop was harvested at different dates at maturity. The recorded data were analyzed using the Analysis of Variance Technique. The mean differences were adjudged by Ducan's New Multiple Range Test.

Result and Discussion

Plant growth attributes

Plant height

The interaction effect of varieties, method and silicon rates on plant height were not significant. Therefore, the single effect of varieties, method and silicon rates on plant height are shown in Table 1. Generally, plant height increased with increasing age of plant (Table 1). At 45 DAT, plant heights were 100.0 cm and 96.96 cm at Binadhan-13 and Kalizira, respectively. However, at 105 DAT, it was 152.1 cm and 157.5 cm at Binadhan-13 and Kalizira, respectively. Plants tend to grow to a certain height in each of its growth state (Sritarapipat *et al.*, 2014). Plant height was affected by method of fertilizer application (Table 1). The taller plant (98.79 cm) was observed with foliar application of silicon and shorter one (97.92 cm) with soil incorporation at 45 DAT. On the other hand, at 105 DAT, the taller plant (156.0 cm) was observed with soil incorporation of silicon and shorter one (153.6 cm) with foliar application. Plant height was significantly affected by rates of silicon (Table 1). At 45 DAT, the taller plant (100.0 cm) was observed at 400 kg ha^{-1} @ silicon and shorter one (97.50 cm) at 200 kg ha^{-1} @ silicon. On the other hand, at 105 DAT, the taller plant (158.0 cm) was observed at 600 kg ha^{-1} @ silicon and shorter one (152.5 cm) with control. Similar finding was recorded by Li-Zhilin (1997), who stated that plant height increased significantly because of increasing fertilizer. The increase in plant height because of application of increased level of fertilizer might be associated with stimulating effect of fertilizer on various physiological processes.

Table 1. Effect of varieties, method of fertilizer application and rates of silicon on plant height at different DAT in in aman season during 2014-15 at BINA HQ, Mymensingh

Treatments	45 DAT	55 DAT	65 DAT	75 DAT	85 DAT	95 DAT	105 DAT
Varieties							
Kalizira (V_1)	96.96	100.1	114.7	115.8	131.8	144.0	157.5
Binadhan-13 (V_2)	100.0	100.4	108.4	110.7	128.6	131.9	152.1
$LSD_{0.05}$	**	NS	**	**	*	**	**
Method							
Soil Incorporation (M_1)	97.92	100.4	111.5	112.0	130.1	135.3	156.0
Foliar application (M_2)	98.79	100.1	111.6	114.5	130.3	140.6	153.6
$LSD_{0.05}$	**	NS	NS	*	NS	**	NS
Silicon rates							
Control (S_0)	98.33	100.7	113.7	114.5	133.0	142.0	152.5
200 kg ha^{-1} (S_1)	97.50	99.83	110.6	114.8	132.1	137.0	152.8
400 Kg ha^{-1} (S_2)	100.0	100.5	112.1	112.9	126.6	136.9	155.9
600 Kg ha^{-1} (S_3)	97.58	100.0	109.8	110.8	129.1	135.9	158.0
$LSD_{0.05}$	0.86	NS	2.53	2.63	3.37	4.98	4.96
CV%	1.05	1.28	2.72	2.78	3.10	4.33	3.84

Tiller production

The interaction effect of varieties, method and silicon rates on tiller production were not significant. Therefore, the single effect of varieties, method and silicon rates on tiller production are shown in Table 2. The total number tillers hill^{-1} was significantly affected at 45, 55, 75 and 95 DAT in Table 2. At 45 DAT, maximum number of tillers hill^{-1} was 10.2 and 8.63 at Binadhan-13 and Kalizira, respectively. However, at 105 DAT it was 7.58 and 7.54 at Binadhan-13 and Kalizira, respectively. Total number tillers of hill^{-1} were affected by method of fertilizer application (Table 2). The highest total number of tillers hill^{-1} was observed with foliar application of silicon (10.0) and soil incorporation (8.83) at 45 DAT. On the other hand, at 105 DAT, the highest total number of tillers hill^{-1} was observed with soil incorporation of silicon (7.79) and foliar application (7.73). The total number of tillers hill^{-1} was not affected by rates of silicon (Table 2). At 45 DAT, the total number tillers hill^{-1} was observed at 600 kg ha^{-1} @ silicon (9.58) and at control (9.26). On the other hand, at 105 DAT, the total number tillers hill^{-1} was observed at 600 kg ha^{-1} @ silicon (7.75) and at control (7.25). These findings are similar to Rodrigues *et al.* (2003) and Mobasser *et al.* (2008). They reported that increase in applied silicon amount enhanced the total number of tillers hill^{-1}.

Table 2. Effect of varieties, method of fertilizer application and rates of silicon on total number of tillers hill^{-1} at different DAT in aman season during 2014-15 at BINA HQ, Mymensingh

Treatments	**45 DAT**	**55 DAT**	**65 DAT**	**75 DAT**	**85 DAT**	**95 DAT**	**105 DAT**
Varieties							
Kalizira (V_1)	8.63	10.1	8.96	7.67	9.25	8.29	7.54
Binadhan-13 (V_2)	10.2	11.0	9.00	8.83	9.58	9.04	7.58
$LSD_{0.05}$	**	*	NS	*	NS	*	NS
Method							
Soil Incorporation (M_1)	8.83	10.3	8.79	8.00	9.38	8.46	7.79
Foliar application (M_2)	10.0	10.8	9.17	8.50	9.46	8.88	7.33
$LSD_{0.05}$	*	NS	NS	NS	NS	NS	NS
Silicon rates							
Control (S_0)	9.26	10.2	9.08	8.17	9.67	8.33	7.25
200 kg ha^{-1} (S_1)	9.33	10.4	9.17	8.50	9.50	8.75	7.75
400 Kg ha^{-1} (S_2)	9.50	10.7	8.92	7.83	9.17	9.00	7.58
600 Kg ha^{-1} (S_3)	9.58	10.9	8.75	8.50	9.33	8.58	7.67
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS
CV%	16.20	11.94	18.24	20.53	12.77	12.73	24.00

Chlorophyll content

The interaction effect of varieties, method and silicon rate on Chlorophyll content was not significant. Therefore, the single effect of varieties, method and silicon rates on chlorophyll content are shown in Table 3. At 45 DAT, the chlorophyll content was 31.1 and 30.1 at Binadhan-13 and Kalizira, respectively. However, at 105 DAT it was 32.1 and 30.0 at Binadhan-13 and Kalizira, respectively. Chlorophyll content was significantly affected by method of fertilizer application (Table 3). The chlorophyll content was observed with foliar application of silicon (30.6) and soil incorporation (30.2) at 45 DAT. On the other hand, at 105 DAT, the chlorophyll content was observed with foliar application (31.2) and soil incorporation of silicon (31.0). The chlorophyll content was affected by rates of silicon (Table 3). At 45 DAT, the chlorophyll content was observed highest at 600 kg ha^{-1} @ silicon (31.9) and lowest at 400 kg ha^{-1} @ silicon (31.9). On the other hand, at 75 DAT, the maximum chlorophyll content was observed highest at 600 kg ha^{-1} @ silicon (34.3) and lowest at control (34.1). These findings are similar with Mutters et al. (2003).They reported that the amount of chlorophyll and leaf N content rice on 55DAT is lower than these parameters on 80DAT, moreover, they mentioned that nitrogen status in the flag leaf varies throughout the life cycle of rice and the rice plant transitions through the most nitrogen sensitive growth stages within a few days.

Table 3. Effect of varieties, method of fertilizer application and rates of silicon on Chlorophyll content (SPAD READING) at different DAT in aman season during 2014-15 at BINA HQ, Mymensingh

Treatments	45 DAT	55 DAT	65 DAT	75 DAT	85 DAT	95 DAT	105 DAT
Varieties							
Kalizira (V_1)	30.1	31.8	32.4	34.5	31.8	31.2	30.0
Binadhan-13 (V_2)	31.1	32.5	33.4	33.1	33.0	32.5	32.1
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	*
Method							
Soil Incorporation (M_1)	30.2	32.3	32.6	33.6	31.8	31.7	30.3
Foliar application (M_2)	30.6	32.1	33.3	34.1	33.0	32.0	31.2
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS
Silicon rates							
Control (S_0)	30.1	31.8	31.4	34.1	32.3	31.7	31.6
200 kg ha^{-1} (S_1)	31.0	32.8	32.5	34.0	32.3	32.2	31.8
400 Kg ha^{-1} (S_2)	29.3	30.9	33.6	32.8	32.3	32.2	30.3
600 Kg ha^{-1} (S_3)	31.9	33.3	34.3	34.3	32.9	31.4	30.6
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS
CV%	12.78	13.58	11.87	8.72	7.26	11.57	9.78

Yield attributes and grain yield

Analysis of data showed that the number of filled grain $panicle^{-1}$, number of unfilled grain $panicle^{-1}$, 1000 seed wt. were significant in different cultivars but not significant in method of fertilizer application. Grain and straw yield were significant in both different cultivars and method of fertilizer application. But in different rates of silicon, the number of total tiller $hill^{-1}$, the number of effective tiller $hill^{-1}$ and straw yield were significant. From varieties study at HQ, Mymensingh, the maximum number total tiller $hill^{-1}$ (7.50), Number of filled grain $panicle^{-1}$ (168.8), panicle length (25.8 cm) produced by Binadhan-13 and number of unfilled grain $panicle^{-1}$ (21.7) by Kalizira. The results showed that the highest grain yield (3.01 t ha^{-1}) was obtained by Binadhan-13 (Table. 4) followed by Kalizira which produced 2.69 t ha^{-1}. The result from method of fertilizer application, the maximum number total tiller $hill^{-1}$ (8.05), number of filled grain $panicle^{-1}$ (166.8) was showed soil incorporation method. Method of fertilizer application that highest grain yield (3.04 t ha^{-1}) was produced in soil incorporation method and the second highest yield (2.65 t ha^{-1}) in foliar application method. In case of silicon rates, 600 Kg ha^{-1} silicon produced the highest grain yield (3.06 t ha^{-1}) due to the maximum number total tiller $hill^{-1}$ (8.40) and number of filled grain $panicle^{-1}$ (169.9) followed by 400 Kg ha^{-1} silicon (2.97 t ha^{-1}), 200 Kg ha^{-1} silicon (2.77 t ha^{-1}) and lowest by control (2.59 t ha^{-1}). Similar finding was recorded by Antonio *et al*., (2012) who stated that grain yield increased the application of silicon rates.

Interaction between varieties and method showed that the highest grain yield in soil incorporation method by Binadhan-13 (3.33 t ha^{-1}) and second highest (2.76 t ha^{-1}) in soil incorporation method by Kalizira. Interaction between varieties and silicon rates showed that the highest grain yield in 600 Kg ha^{-1} silicon by Binadhan-13 (3.25 t ha^{-1}). On the other hand, interaction between method and silicon rates showed that the highest grain yield in soil incorporation method with 400 Kg ha^{-1} silicon (3.26 t ha^{-1}). Finally, interaction between varieties, method and silicon rates showed that the highest grain yield in soil incorporation method with 600 Kg ha^{-1} silicon by Binadhan-13 (3.59 t ha^{-1}).

Table 4. Yield and yield contributing characters as affected by varieties, method of fertilizer application and rates of silicon at different DAT in aman season during 2014-15 at BINA HQ, Mymensingh

Treatments	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Panicle Length (cm)	1000 Seed wt. (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Varieties									
Kalizira (V_1)	151.2	7.50	7.46	160.0	21.7	25.3	10.91	2.69	4.10
Binadhan-13 (V_2)	154.9	8.14	6.83	168.8	11.3	25.8	15.11	3.01	5.69
$LSD_{0.05}$	NS	NS	NS	*	*	NS	**	*	**
Method									
Soil Incorporation (M_1)	151.8	8.05	7.32	166.8	29.1	25.4	13.04	3.04	4.47
Foliar application (M_2)	154.3	7.59	6.97	162.0	33.8	25.6	12.98	2.65	5.31
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	*	**
Silicon rates									
Control (S_0)	150.8	7.09	6.62	163.0	32.7	25.5	12.98	2.59	5.14
200 kg ha^{-1} (S_1)	154.3	7.88	7.08	157.8	39.6	25.5	12.99	2.77	4.86
400 Kg ha^{-1} (S_2)	153.6	7.92	7.20	167.0	27.9	25.4	13.06	2.97	4.84
600 Kg ha^{-1} (S_3)	153.4	8.40	7.67	169.9	25.8	25.6	13.00	3.06	4.73
$LSD_{0.05}$	NS	0.76	0.74	NS	NS	NS	NS	NS	0.43
Variety X Method									
V_1 M_1	151.6	8.23	7.42	176.2	48.5	25.3	10.89	2.61	4.03
V_1 M_2	150.9	8.05	7.50	161.5	54.8	25.2	10.92	2.69	4.16
V_2 M_1	152.0	7.87	7.22	157.4	9.73	25.6	15.19	3.33	4.91
V_2 M_2	157.7	7.13	6.43	162.5	12.8	25.9	15.04	2.76	6.47
$LSD_{0.05}$	4.38	NS	NS	NS	NS	NS	NS	NS	NS
Variety X Silicon rates									
V_1 S_0									
V_1 S_1	151.1	7.87	7.37	169.3	54.9	25.2	10.90	2.49	4.22
V_1 S_2	151.2	8.50	7.70	160.0	62.6	25.3	10.98	2.69	3.95
V_1 S_3	151.8	7.87	7.23	175.1	47.0	25.6	10.92	2.70	4.28
V_2 S_0	150.8	8.33	7.53	171.0	42.1	25.1	10.83	2.87	3.95
V_2 S_1	150.5	6.31	5.87	156.6	10.5	25.9	15.06	2.68	6.06
V_2 S_2	157.5	7.27	6.47	155.6	16.6	25.7	15.00	2.86	5.77
V_2 S_3	155.4	7.97	7.17	158.9	8.73	25.3	15.21	3.24	5.41
	156.1	8.47	7.80	168.8	9.37	26.1	15.17	3.25	5.51
$LSD_{0.05}$	NS	NS	1.05	NS	NS	NS	NS	NS	NS
Method X Silicon rates									
M_1 S_0	147.7	6.78	6.37	159.8	31.0	25.5	13.17	2.83	4.91
M_1 S_1	154.4	7.87	6.97	158.0	25.6	25.3	12.98	2.92	4.48
M_1 S_2	153.2	8.53	7.93	171.5	31.0	25.3	12.90	3.26	4.39
M_1 S_3	151.9	9.03	8.00	177.9	28.9	25.7	13.11	3.17	4.11
M_2 S_0	153.9	7.40	6.87	166.2	34.4	25.5	12.80	2.34	5.37
M_2 S_1	154.3	7.90	7.20	157.6	53.6	25.6	13.00	2.63	5.23
M_2 S_2	154.0	7.30	6.47	162.4	24.8	25.6	13.23	2.68	5.30
M_2 S_3	155.0	7.77	7.33	161.9	22.6	25.6	12.89	2.95	5.35

$LSD_{0.05}$	NS	1.07	1.05	NS	NS	NS	NS	NS	NS
Variety X Method X Silicon rates									
$V_1 M_1 S_0$	150.1	7.27	6.67	175.3	51.0	24.9	11.11	2.54	4.45
$V_1 M_1 S_1$	152.1	8.47	7.47	162.3	43.2	25.4	11.02	2.66	3.89
$V_1 M_1 S_2$	153.0	8.33	7.80	178.7	52.0	25.4	10.68	2.93	4.35
$V_1 M_1 S_3$	151.0	8.87	7.73	188.2	47.8	25.5	10.75	2.92	3.45
$V_1 M_2 S_0$	152.0	8.47	8.07	163.3	58.9	25.4	10.69	2.45	3.99
$V_1 M_2 S_1$	150.2	8.53	7.93	157.7	82.1	25.1	10.94	2.72	4.00
$V_1 M_2 S_2$	150.7	7.40	6.67	171.4	41.9	25.7	11.16	2.48	4.20
$V_1 M_2 S_3$	150.5	7.80	7.33	153.8	36.5	24.7	10.90	2.81	4.45
$V_2 M_1 S_0$	145.3	6.29	6.07	144.2	11.1	26.1	15.23	3.12	5.38
$V_2 M_1 S_1$	156.6	7.27	6.47	153.6	8.07	25.3	14.94	3.18	5.08
$V_2 M_1 S_2$	153.3	8.73	8.07	164.3	9.80	25.1	15.11	3.41	4.43
$V_2 M_1 S_3$	152.8	9.20	8.27	167.6	10.0	25.9	15.46	3.59	4.78
$V_2 M_2 S_0$	155.7	6.33	5.67	169.1	9.87	25.7	14.90	2.23	6.75
$V_2 M_2 S_1$	158.3	7.27	6.47	157.6	25.0	26.1	15.06	2.54	6.47
$V_2 M_2 S_2$	157.4	7.20	6.27	153.5	7.67	25.6	15.30	2.89	6.40
$V_2 M_2 S_3$	159.4	7.73	7.33	170.0	8.73	26.4	14.88	3.09	6.25
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	3.42	11.61	12.37	14.05	55.36	2.57	2.73	17.86	10.55

Conclusion

The research work was conducted at BINA HQ, Mymensingh, Bangladesh during the period of 2014-15. Two rice varieties (Kalizira and Binadhan-13) were evaluated under four rates of silicon with two application methods. Silicon rates were 0, 200, 400 and 600 Kg ha^{-1}. Two application methods, soil and foliar spray, were evaluated for each silicon rate. Soil applications were made just prior to planting. Foliar sprays were made at vegetative, reproductive and ripening growth stage. Binadhan-13 showed the maximum grain yield. Soil incorporation method showed maximum grain yield in most cased. In case of silicon rates, 600 Kg ha^{-1} silicon produced the highest grain yield (3.06 t ha^{-1}) due to the maximum number total tiller $hill^{-1}$ (8.40) and number of filled grain $panicle^{-1}$ (169.9) followed by 400 Kg ha^{-1} silicon (2.97 t ha^{-1}), 200 Kg ha^{-1} silicon (2.77 t ha^{-1}) and lowest by control (2.59 t ha^{-1}).

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Reference

Antonio, N., Reginaldo, J. F., Gaspar, H. K. and Tiago, R. B. S. 2012. Effect of silicon on drought tolerance of upland rice. J. of Food, Agric. & Environ. 10(1): 269-272

BBS, 2013. Hand book of Agricultural Statistics Bangladesh Bureau of Statistics. Ministry of Planning, Government People's Repub. Bangladesh. p: 14.

Elmer, W. H., and L. E. Datnoff. 2014. Mineral nutrition and suppression of plant disease. In Encyclopedia of agriculture and food systems, ed. N. Van Alfen, vol. 4, 231–44. Elsevier: San Diego

FAO. 2014. Food and Agriculture Organization. www.fao.org

Hodson, M. J., P. J. White, A. Mead, and M. R. Broadley. 2005. Phylogenetic variation in the silicon composition of plants. Annals of Botany 96:1027–46. doi:10.1093/aob/mci255.

Li-zhilin., Sarkar, R.S. , Nayak, S.K., Ravi, I. and Li, Z.L. 1997. Physiological effect of nitrogen application on aromatic rice. J. South China Agric. Univ., 18(3): 13-17.

Liang Y.C., W.C. Sun, J. Si, V. Römheld, 2005 - Effects of foliar- and rootapplied silicon on the enhancement of induced resistance to powdery mildew in *Cucumis sativus*. Plant Pathology. 54: 678–685.

Korndörfer G.H., H.S. Pereira, A. Nolla, 2004 - Silicon analysis in soil, plant and fertilizers. Brazil, GPSi/ICIAG/UFU.

Mobasser H.R., G.A. Malidarh, H. Sedghi, 2008 - Effects of silicon application to nitrogen rate and splitting on agronomic characteristics of rice (*Oryza sativa*). Silicon in Agriculture: 4th International Conference 26-31 October, South Africa: 76.

Mutters, R.G., Eckert, J.W., Williams, J., Fenn, G. and J., Cardosa. 2003. Development of a leaf color chart for California rice varieties. UC Cooperative Extension. University of California.

Rodrigues F.Á, F.X.R. Vale, L.E. Datnoff, A.S. Prabhu, G.H. Korndörfer, 2003 - Effect of rice Book Co. Inc. Singapore pp: 204- 227.

Shashidhar H.E., N. Chandrashekhar, C. Narayanaswamy, A.C. Mehendra, N. B. Prakash, 2008 - Calcium silicate as silicon source and its interaction with nitrogen in aerobic rice. Silicon in Agriculture: 4th International Conference 26-31 October, South Africa: 93.

Shrestha, S., K. Goeppert., M. A. Bell and K. Douangsila. 2002. The impact of modern varieties on rice production and farmers income in Laos. Int. Rice Res. Notes, 27:11–12

Sritarapipat, T., Rakwatin, P., & Kasetkasem, T. (2014). Automatic rice crop height measurement using a field server and digital image processing. Sensors, 14 (1), 900–926.