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Effects of Rice Hull, Lime, and Nitrogen Fertilizer on the silica Content and Growth of Rice in a Strongly Acid Sand-shale Alluvial Soil[1]

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ABSTRACT

This experiment was conducted to study the effects of rice hull, dolomitic quicklime and nitrogen fertilizer on the silica content and the growth of rice in a strongly acid sand-shale alluvial soil. The results of this experiment suggested that low water soluble silica and exchangeable bases were the two main factors that limited the normal growth and caused the lodge and blast in rice plants at high level of nitrogen fertilizer in this strongly acid sand shale alluvial soil.

Generally speaking, increasing the rates of nitrogen fertilizer increased the growth, but decreased the silica content and the resistatnce of rice plants to blast and lodge except the high nitrogen control in which the height of rice plant was decreased, possibly due to the nitrogen toxicity.

Liming helped to reduce the blast and promote the continuous growth of rice plants at high nitrogen level, but the rice plants was still susceptible to lodge due to the low silica content.

Soil treatment of rice hull alone significantly increased the silica contents in rice plants, neck blast and lodge resistance, and panicle number. The grain yields in the three nitrogen levels of the treatments were all increased but they were not statistically significant.

The silica contents in the rice leaves in the three lime-rice hull treatments were respectively twice as much as those in the three checks, and were signifi-cantly higher than those in the three simple rice hull treatments at the same nitrogen level. However, the growth of rice plants was only increased at the highest nitrogen treatment in which the plant height, panicle number, 1000 grain weight, resistance to neck blast and lodge, and grain yield were all significantly increased as compared with the highest nitrogen check; and the plant height, neck blast resistance, 1000 grain weight, and grain yield were significantly increased as compared with the highest nitrogen rice hull treat-ment. Althought the blast and lodge resistance in the low

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and medium nitrogen levels of the treatments were increased, the plant growth in the two treatments were not corresponding increased apparently due to the inadequate supply of nitrogen. Therefore for obtaining the best grown rice plants with high blast and lodge resistance to perform the highest grain yield in this strongly acid sand-shale alluvial soil, it is not only necessary to apply lime and rice hull to raise sillca and basic ions in the soil, but also necessary to provide enough nitrogen fertillzer for the requirement of the increased growth of rice plants.

Introduction

The basic cations and water soluble silica in the strongly acid sand-shale alluvial soils in Taichung and Nantou Hsiens are usually very low, and the rice plants in these soils are easy to lodge and blast due to the slightly improper rate of nitrogen fertilizers. This seems to be the main reason why the rice yields in these two places are usually lower than those in the slate alluvial soil area of Changhua Hsien where the soils are mostly neutral to slightly alkaline, the basic cations and water soluble silica in the soils are 5-10 times higher than those in the former, and the rice plants are not fallen down even greater than twice of nitrogen fertilizers are applied.

Silicon is essential for the growth of diatoms. Without silica in the growth medium, the cell division of diatoms is completely impaired. In the diatom cells, silica appears to serve as the skeleton of cell structure(5) However the essentiality of silicon in the higher plants are still contradicting in view between the workers. Many workers in Japan have reported that silicon is important for the growth of rice plants (1,3,4,8,11,14,17) Some of them have studied the silica supplying power and the uptake of silicon in the paddy field(2,10) The silicon deficient rice plants had droopy leaves and was susceptible to blast and mite damage (6,15) The distribution, localization, or histochemistry of silicon (16,18,19,20,21) and its effect on the uptake and movement of other nutrients were also reported (12,13) The effect of silicon on the growth of wheat, barley, and some vegetable crops have also been studied by some workers(9) Soil treatment of silicate slag was reported to invrease the grain yield of rice(7)

Since the soil treatment of rice hull has been reported to be helpful to the grain yield of rice by professor Yang in Chunghsing University in Taiwan(22,23), many workers in the island have started to conduct the experiments on the effect of rice hull on the grain yield of rice was largely different from place to place. It seems that the main effect of rice hull is its high silica content, and it should be more helpful to rice yield in the strongly acid soils where the water soluble silica is usually very low. However the decompostion of rice hull is slow when it is applied to the soils alone. In this experiment dolomitic quicklime was considered to be helpful to the decomposition of rice hull, the release of silica, and the maintenance of available silica in the acid soils through the formation of calcium silicate. Therefore when dolomitic quicklime is conbined with rice hull in the soil treatment, the available silica in the soils will be greatly increased for the absorption by rice plants, and therefore the rice plants may be able to tolerate higher rate of nitrogen fertilizers to obtain greater increase in grain yields.

Material and Methods

The experiment was under a 3x2x2 factorial experiment consisted of three levels of nitrogen, 2 levels of rice hull, and 2 levels of dolomitic quicklime. Each Wagner pot was first filled with 15kg of strongly acid sand-shale alluvial soil, and the 12 treatments were arranged in randomized complete block design with four replications for experiment as follows:

(1) L-N:70 ppmw of nitrogen on the soil weight basis is the form of ammonium sulfate was applied as the standard method, i.e., 25% at one day before transplanting, 20% on the 10th day after transplanting, 30% on the 20th day after transplanting, and 25% on the 43rd day after transplanting.

(2) M-N:105 ppmw of nitrogen as the above was applied as (1).

(3) H-N: 140 ppmw of nitrogen as the above was applied as (1).

(4) L-Nxlime:70 ppmw of nitrogen as the above was applied as(1), and 1200 ppmw of dolomitic quicklime on the soil weight basis was applied and mixed with the upper half of the pot soil one week before transplanting.

(5) M-NxLime: 105 ppmw of nitrogen as the above was applied as(1), and 1200 ppmw of dolomitic quicklime was applied as (4).

(6) H-NxLime:140 ppmw of nitrogen as the above was applied as (1), and 1200 ppmw of dolomitic quicklime was applied as (4).

(7) L-NxR.hull:70 ppmw of nitrogen as the above was applied as (1), and 6000 ppmw of rice hull on the soil weight basis was applied one week before transplanting.

(8) M-NxR.hull:105 ppmw of nitrogen as the above was applied as (1), and 6000 ppmw of rice hull was applied as (7).

(9) H-NxR.hull:140 ppmw of nitrogen as the above was applied as (1),and 600 ppmw of rice hull was applied as (7).

(10) L-NxLimexR.hull:70 ppmw of nitrogen as the above was applied as(1), and 1200 ppmw of dolomitic quicklime was applied as (4), and 6000 ppmw of rice hull was applied as(7).

(11) M-NxLimexR.hull:105 ppmw of nitrogen as the above was applied as (1), 1200 ppmw of dolomitic quicklime was applied as (4), and 6000 ppmw of rice hull was applied as (7).

(12) H-NxLimexR.hull:140 ppmw of nitrogen as the above was applied as (1), 1200 ppmw of dolomitic quicklime was applied as (4), and 6000 ppmw of rice hull was applied as (7).

Calcium superphosphate was applied to all pots at the rate of 50 ppmw of P_2O_5 on the soil weight basis one day before transplanting. Potassium chloride was applied to all pots in the same rate in two splits. The first split was applied to the pots 10 days after transplanting at the rate of 14.4 ppmw of K_2O and the second split was applied to the pots 20 days after transplanting at the rate of 21.6 ppmw of K_2O on the soil weight basis. A popular variety of Japonica type of rice, Tainung 67, was transplanted to the pots on August 10 to make four hills in each pot, and four plants in each hill. Leaf blades were sampled on the 43 days after transplanting, and the whole plants were sampled on the 112 days transplanting for chemical analysis. Tiller number in each pots were counted, and plant heights in each pots were measured on the 43 days and the 112 days after transplanting for statistical analysis. The rice plants were harvested on the 112 days after transplanting for calculating their yield components, and grain and straw yields. The soils were sampled before transplanting and after harvest for chemical analysis. After the harvest of rice, the soil was washed with tap water, and the remained rice hull was collected, dried, and weighed.

Results and Discussion

The results of chemical analysis for the soils showed that the original soils in the experiment pots were 5.2-5.4 in pH, 7.35-7.90 m.e./100g in CEC, 598-665 ppm in exchangeable cations, and 14-18 ppm in water soluble silica (Table 1). From our experiences, the rice plants in this kind of soils are easy to lodge and blast due to slightly improper application of nitrogen fertilizers. In some of these soils where organic matter or sulfur content is high, and the soils are imperfectly to poorly drained, the rice plants are often partly harmed or sometimes almost completely killed by hydrogen sulfide in the second crop when the temperature is high.

Table 1 Chemical analysis for the experimental soils sampled before transplanting of rice plants*

Treatments	Texture	pH	Organic matter %	CEC m.e./100g	Bray1 P ppm	Exchangeable					Water soluble SiO_2 ppm
						Ca	Mg	Na	K	Total	
						-------ppm------					
1. L-N	Sandy loam	5.3	1.04	7.43	86	428	66	57	50	601	15
2. M-N	Sandy loam	5.3	1.11	7.76	84	465	66	61	50	642	18
3. H-N	Sandy loam	5.3	1.11	7.90	86	487	66	61	51	665	16
4. L-NxLime	Sandy loam	5.4	1.04	7.76	85	445	67	60	53	625	18
5. M-NxLime	Sandy loam	5.3	1.04	7.65	82	463	66	56	51	636	16
6. H-NxLime	Sandy loam	5.3	1.11	7.90	87	480	66	59	53	658	17
7. L-NxR. hull	Sandy loam	5.4	1.11	7.83	85	465	66	61	52	644	16
8. M-NxR. hull	Sandy loam	5.4	1.11	7.70	82	468	66	63	52	649	17
9. H-NxR. hull	Sandy loam	5.2	1.08	7.43	80	440	66	58	52	616	15
10.L-NxLime xR. hull	Sandy loam	5.3	1.08	7.52	82	430	66	60	51	607	14
11.M-NxLime xR. hull	Sandy loam	5.3	1.11	7.60	81	423	67	58	50	598	17
12.H-NxLime xR. hull	Sandy loam	5.3	1.08	7.35	83	448	66	58	52	624	18

*The figures in the table are the average values of four pots.

Application of 1200 ppmw of dolomitic quickime to the soils raised the soil pH to 6.3-6.4, and the exchangeable cations to 851-915 ppm, and the others are unchanged. Application of 6000 ppmw of rice hull to the soil significantly increased the water soluble silica to 16.3-22.3 ppm in the soils after harvest, and the exchangeable potassium are slightly increased, but they are not statistically significant. The other soil factors are also unchanged. Application of 1200 ppmw of dolomitic quicklime combined with 6000 ppmw of rice hull to the soil raised the soil pH to 6.5-6.6, exchangeable cations to 878-1034 ppm, water soluble silica to 25.8-27.3 ppm, and the exchangeable potassium are also slightly increased, but they are also not statistically significant(Table 2). The increase in water soluble silica in this lime-rice hull treatment was significantly higher than those in the simple rice hull treatment. These results suggested that rice hull released its silica (Table 3) to the soils during the course of decomposition. However, under the help of quicklime the decomposition of rice hull was faster (Table 4) and the released silica was easier to combine with the lime to form calcium silicate to remain in the soil in a more available form.

Table 2 Chemical analysis for the experimental soil after the harvest of rice

Treatments	Texture	pH	Organic matter %	CEC m.e./100g	Bray1 P ppm	Exchangeable Ca	Mg	Na	K	Total	Water soluble SiO_2 ppm
						-------ppm------					
1. L-N	Sandy loam	5.4	1.10	7.39	64	500	65	53	29[a]*	647	16.8[c]*
2. M-N	Sandy loam	5.2	1.14	8.26	67	520	70	55	17[cd]	662	18.0[c]
3. H-N	Sandy loam	5.0	1.14	7.83	64	513	72	48	14[de]	647	14.3[d]
4. L-NxLime	Sandy loam	6.4	1.15	8.69	85	638	143	44	26[a]	851	17.3[c]
5. M-NxLime	Sandy loam	6.4	1.10	8.26	83	665	148	53	20[bc]	886	18.3[c]
6. H-NxLime	Sandy loam	6.3	1.16	8.26	82	700	153	49	13[e]	915	14.0[d]
7. L-NxR. hull	Sandy loam	5.4	1.08	7.39	68	460	70	46	27[a]	603	22.3[b]
8. M-NxR. hull	Sandy loam	5.4	1.12	7.83	72	515	70	52	20[bc]	657	21.0[b]
9. H-NxR. hull	Sandy loam	5.0	1.10	8.26	71	495	70	49	17[cd]	631	16.3[cd]
10.L-NxLime xR. hull	Sandy loam	6.6	1.08	8.26	75	808	150	48	28[a]	1034	27.3[a]
11.M-NxLime xR. hull	Sandy loam	6.5	1.15	8.26	73	653	150	54	21[b]	878	28.0[a]
12.H-NxLime xR. hull	Sandy loam	6.5	1.10	8.69	78	683	145	57	14[de]	899	25.8[a]

* Means followed by at least one common letter in the same column are not significantly different at 5% level by Duncan's multiple range test.

Table 3 chemical analysis for the rice hull and dolomitic quicklime used in the experiment

Material	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu
	-----------%----------						--------ppm--------			
Rice hull* (Indica)	0.5	0.16	0.70	0.08	0.06	14.50	150	125	33	8
Rice hull (Japonica)	0.5	0.13	0.30	0.06	0.03	11.00	225	100	45	8
Dolomitic quicklime	—	—	0.02	24.00	12.50	0.17	3500	60	13	30

*The hull of Indica rice were not used in this experiment.

Table 4 The amount of rice hull consumed in the pots during one season of experiment*

Treatments	Amount of rice hull applied g/pot	Rice hull remained in the pots at harvest			Amount of rice hull consumed	
		g/pot	%	color	g/pot	%
L-NxR. hull	90	66.4	73.8	Brown	23.6	26.2
M-NxR. hull	90	68.0	75.6	Brown	22.0	24.4
H-NxR. hull	90	67.7	75.2	Brown	22.3	24.8
L-NxLime xR. hull	90	58.6	65.1	Grey	31.4	34.9
M-NxLime xR. hull	90	58.3	64.8	Grey	31.7	35.2
H-NxLime xR. hull	90	57.9	64.3	Grey	32.1	35.7

*The figures in the table are the average values of four pots.

The chemical analysis for the leaves at panicle initiation stage(Table 5) showed that the silica contents in rice leaves were decreased with the increased levels of nitrogen in the rice leaves in all treatments. However, when those in the same level of nitrogen were compared separately, we can find that the silica contents in the three lime-rice hull treatments were the highest. They were 11.9,9.2, and 7.5% that were respectively significantly higher than the 8.6,6.8 and 5.9% in the three simple rice hull treatments, that were also significantly higher than the 6.6, 4.8, and 3.8% in the simple lime treatments, and the 5.9, 4.5, and 4.4% in the three checks. The silica contents in the whole rice plants at harvest time(Table 6) were similar to the leaves, but their differences between treatments were smaller. These results suggested that rice hull released considerable amount of silica for the uptake by rice plants during the course of its decomposition, and this seemed to be the main reason why the rice plants in the treatments with rice hull generally had upright leaves, stronger culm(Fig. 1 and 2), and higher blast resistance(Table 7).

Table 5 Chemical analysis for the second leaf from the top of rice plant on the 43rd day after transplanting(panicle initiation stage)

Treatments	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu
	-----------%----------						--------ppm--------			
1. L-N	3.4^{g}*	0.42	2.3^{ab}*	0.38	0.32	5.9^{d}*	250	875	49	25
2. M-N	4.3^{cde}	0.44	2.2^{abc}	0.33	0.35	4.5^{ef}	375	758	53	32
3. H-N	5.0^{a}	0.42	1.8^{c}	0.32	0.33	4.4^{ef}	288	606	47	30
4. L-NxLime	3.6^{fg}	0.37	2.3^{ab}	0.43	0.37	6.6^{cd}	263	708	42	20
5. M-NxLime	4.0^{def}	0.39	2.2^{abc}	0.39	0.42	4.8^{e}	375	725	51	27
6. H-NxLime	4.7^{abc}	0.37	1.8^{c}	0.35	0.46	3.8^{f}	288	538	44	25
7. L-NxR. hull	3.8^{efg}	0.40	2.6^{a}	0.36	0.29	8.6^{b}	233	725	40	20
8. M-NxR. hull	4.0^{def}	0.40	2.4^{ab}	0.34	0.31	6.8^{cd}	294	683	47	24
9. H-NxR. hull	4.4^{bcd}	0.39	2.0^{bc}	0.31	0.29	5.9^{d}	388	506	57	25
10.L-NxLime xR. hull	3.4^{g}	0.37	2.5^{a}	0.36	0.31	11.9^{a}	333	413	35	20
11.M-NxLime xR. hull	4.1^{def}	0.36	2.3^{ab}	0.33	0.34	9.2^{b}	250	463	40	30
12.H-NxLime xR. hull	4.9^{ab}	0.38	2.0^{bc}	0.31	0.37	7.5^{c}	300	394	38	20

* Means followed by at least one common letter in the same column are not significantly different at 5% level by Duncan's multiple range test..

Table 6 chemical analysis for the whole rice plant at 112 days after transplanting(harvest time)

Treatments	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu
	-----------%----------						--------ppm--------			
1. L-N	0.66^{def}*	0.19	1.2^{ab}*	0.32	0.15	6.3^{de}*	588	375	66	10
2. M-N	0.72^{bcd}	0.21	1.2^{ab}	0.34	0.18	5.9^{c}	592	313	78	12
3. H-N	0.83^{a}	0.23	0.9^{c}	0.33	0.19	4.9^{f}	625	225	58	10
4. L-NxLime	0.57^{fg}	0.16	1.2^{ab}	0.37	0.16	7.4^{bc}	575	238	52	11
5. M-NxLime	0.69^{cde}	0.19	1.2^{ab}	0.35	0.18	5.7^{ef}	506	256	59	10
6. H-NxLime	0.84^{a}	0.16	0.9^{c}	0.35	0.21	5.0^{f}	558	200	58	10
7. L-NxR. hull	0.61^{efg}	0.15	1.4^{a}	0.35	0.14	8.1^{b}	492	258	60	11
8. M-NxR. hull	0.65^{def}	0.18	1.2^{ab}	0.34	0.16	6.0^{de}	531	258	73	11
9. H-NxR. hull	0.78^{abc}	0.19	1.1^{bc}	0.37	0.18	5.6^{ef}	717	250	76	10
10.L-NxLime xR. hull	0.53^{g}	0.15	1.3^{ab}	0.32	0.14	9.6^{a}	419	150	39	10
11.M-NxLime xR. hull	0.65^{def}	0.15	1.2^{ab}	0.32	0.16	8.0^{b}	450	225	49	10
12.H-NxLime xR. hull	0.81^{ab}	0.16	1.2^{ab}	0.31	0.22	6.8^{cd}	419	375	69	11

*See table 5

Table 7 Plant height, tiller number and neck blast of rice

Treatments	Plant height (cm)		Tiller number per pot		Neck blast %
	43 days after transplanting	112 days after transplanting	43 days after transplanting	112 days after transplanting	
1. L-N	66.4^{de}*	84.4^{d}*	51.5^{ef}*	48.3^{f}*	5.09^{bc}*
2. M-N	72.3^{a}	90.3^{bc}	65.5^{c}	64.0^{cd}	8.00^{b}
3. H-N	72.6^{a}	88.8^{c}	71.5^{b}	70.3^{b}	15.86^{a}
4. L-NxLime	66.3^{de}	84.9^{d}	48.8^{f}	47.5^{f}	3.82^{bc}
5. M-NxLime	69.1^{bc}	89.3^{c}	63.3^{c}	61.0^{de}	3.78^{bc}
6. H-NxLime	70.0^{abc}	92.1^{ab}	73.0^{b}	69.8^{b}	4.14^{bc}
7. L-NxR. hull	64.5^{e}	85.6^{d}	57.8^{d}	55.8^{e}	2.27^{bc}
8. M-NxR. hull	68.7^{cd}	90.7^{bc}	74.8^{b}	71.8^{ab}	2.44^{bc}
9. H-NxR. hull	71.5^{ab}	91.4^{bc}	79.5^{a}	75.5^{a}	2.68^{bc}
10.L-NxLime xR. hull	64.9^{e}	85.6^{d}	53.5^{e}	49.5^{f}	0.49^{c}
11.M-NxLime xR. hull	68.8^{cd}	90.1^{bc}	73.5^{b}	67.0^{bc}	0.70^{c}
12.H-NxLime xR. hull	70.7^{abc}	94.3^{a}	80.3^{a}	75.5^{a}	0.97^{c}

* Means followed by at least one common letter in the same column are not significantly different at 5% level by Duncan's multiple range test.

Fig. 1 Droopy leaves on the rice plants in check and liming pots, upright leaves in rice hull pot, and strongly upright leaves in rice hull x Lime pot.

Fig 2 The rice plants in check and liming pots aging faster and easily fallen, and those in rice hull and rice hull x Lime pots showing greenish and stronger culm.

The potassium contents in the rice leaves and the whole plants in the three rice hull treatments, and the three lime-rice hull treatments were similarly slightly higher than those in the three checks and the three simple lime treatments, and the revrse was true in nitrogen contents(Table 5 and 6). The higher potassium content in the treatments with rice hull suggested that rice hull also released considerable amount of potassium for the uptake by rice plants during the course of its decomposition; and the lower nitrogen contents in the treatments with rice hull suggested that the assimilation of nitrogen by the rice plants in the treatments with rice hull was more efficient than those in the treatments without rice hull, apparently due to the effect of higher silica in the former.

The differences in rice growth was seen in plant height, tiller and panicle number, 1000 grain weight, grain and straw yields (Table 7 and 8), and resistance to neck blast (Table 7), and lodging (Fig. 1 and 2).

The plant heights in the three lime and the three lime-rice hull treatments were significantly increased with the increased levels of nitrogen. However, in the three checks, the plant heights decreased at the high nitrogen level(Table 7). This suggested that lime may help the assimilation of nitrogen in the rice plants in this acid soil. Without lime, the assimilation of the high rate of the absorbed nitrogen by rice plants in this acid soil may be retarded to become toxic.

The tiller and panicle number of rice plants were generally increased with the increased levels of nitrogen in all treatments. However, this increases were larger in the simple rice hull, and the lime-rice hull treatments, apparently due to the effect of rice hull(Table 7 and 8). It seemed that rice hull provided silica for the rice plants and thus promted the continuous tillering of rice plants under the increased rates of nitrogen supply.

The 1000 grain weights in all treatments were generally similar except the high nitrogen check and the high nitrogen rice hull treatment in which the 1000 grain weight significantly lowered, apparently due to the higher incidence of neck blast (Table 8).

Table 8 Yield components and straw yields of rice

Treatments	Panicle number per pot	Grain numberper panicle	Ripened grains %	1000 grain weight (g)	Grain		straw		Grain/ straw ratio
					yield g/pot	Index	yield g/pot	Index	
1. L-N	48.3^{f}*	71.8	91.9	25.6^{a}*	88.2^{de}*	100.0	79.5^{cd}*	100.0	1.11
2. M-N	64.0^{cd}	73.6	92.3	25.3^{a}	118.7^{bc}	100.0	112.0^{b}	100.0	1.06
3. H-N	70.3^{b}	68.6	91.3	23.8^{b}	114.9^{bc}	100.0	132.0^{a}	100.0	0.87
4. L-NxLime	47.5^{f}	67.8	93.5	26.0^{a}	83.6^{e}	94.8	76.3^{d}	96.0	1.10
5. M-NxLime	61.0^{de}	71.6	92.5	25.9^{a}	113.1^{c}	95.3	107.0^{b}	95.5	1.06
6. H-NxLime	69.8^{b}	69.5	92.7	25.3^{a}	123.1^{bc}	107.1	133.8^{a}	101.4	0.92
7. L-NxR. hull	55.8^{e}	68.0	93.0	25.9^{a}	98.1^{d}	111.2	84.5^{c}	106.3	1.16
8. M-NxR. hull	71.8^{ab}	68.0	93.3	25.7^{a}	125.3^{bc}	105.6	113.8^{b}	101.6	1.11
9. H-NxR. hull	75.5^{a}	69.8	93.6	24.4^{b}	127.7^{b}	111.1	135.8^{a}	102.9	0.94
10.L-NxLime xR. hull	49.5^{f}	69.6	93.4	26.3^{a}	90.4^{de}	102.5	78.3^{cd}	98.5	1.16
11.M-NxLime xR. hull	67.0^{bc}	68.9	94.5	25.7^{a}	118.6^{bc}	99.9	110.5^{b}	98.7	1.08
12.H-NxLime xR. hull	75.5^{a}	72.5	92.8	26.2^{a}	143.4^{a}	124.8	137.0^{a}	103.8	1.05

*See table 7

In this experiment, the highest grain yield was obtained from the high nitrogen lime-rice hull treatment. While the grain yields of the medium and low nitrogen lime-rice hull treatments were respectively similar to those of the medium and low nitrogen checks. The grain yields of the three rice hull treatments were respectively higher than those of the same nitrogen levels of checks, but they were not statistically significant. The grain yield of high nitrogen lime treatment was higher than that of the high nitrogen check, and the grain yields of medium and low nitrogen lime treatments were respectively lower than those of the medium and low nitrogen check, although they were not statistically significant. These results suggested that liming may increase the grain yield of rice in this acid soil only when increased rate of nitrogen is applied; however, soil treatment of rice hull alone may increase the grain yield at all levels of nitrogen, but their increases were not very large. Combine lime with rice hull may only increase the grain yield at the higher levels of nitrogen, but its increase will be much greater.

The results of the experiment also showed that lime and rice hull helped increased the resistance of rice plants to blast and lodging either independently or corporatively. The incidence of neck blast in the lime, rice hull, and lime-rice hull treatments were all significantly decreased (Table 7). However, it seemed that lime only helped reduce the blast by improving the efficiency of nitrogen assimilation under the high nitrogen supply. While rice hull helped reduce the blast and lodging by providing silica for the rice plants to improve its nitrogen assimilation and the hardiness of rice leaves and culm (Fig. 1 and 2). Therefore the effect of rice hull was much greater.

To sum up, the height of rice plants, panicle number, and the grain and straw yields were increased with the increased levels of nitrogen in all treatments, except the high nitrogen check in which the plant height was decreased, and the reverse was true on the silica contents and the blast and lodge resistance in rice plants.

Soil treatment of dolomitic quicklime raised the exchangeable bases in the soils, reduced the neck blast, and increased the plant height, 1000 grain weight, and the grain yield at the highest level of nitrogen, but slightly decreased the grain yields at the low to medium levels of nitrogen. It seemed that lime helped the continuous assimilation of nitrogen and the growth of rice plants under the high nitrogen supply in this strongly acid sand-shale alluvial soil.

Soil treatment of rice hull significantly increased the water soluble silica in the soil, and the silica content in the rice plants, and therefore increased the blast and lodge resistance, panicle number, and the grain and straw yields of rice at all levels of nitrogen. Apparently the main effect of rice hull was its high silica content that promoted the tillering and the blast and lodge resistance of rice plants under the high nitrogen supply.

Soil treatment of dolomitic quicklime combined with rice hull accelerated the decomposition of rice hull. Therefore the water soluble silica in the soil, and the silica content in the rice plants in this treatment were more significantly increased than the simple rice hull treatment. As a result, the rice plants performed the best growth and the highest resisitance to blast and lodge to attain the highest grain yield at the highest nitrogen level.

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穀殼、石灰及氮肥對生長於強酸性砂頁岩沖積土稻株之矽酸含量及生長之影響[1]

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摘 要

本試驗之目的在研究穀殼、石灰及氮肥對生長於強酸性砂頁岩沖積土稻株之矽酸含量及生長之影響。試驗結果顯示強酸性砂頁岩沖積土土壤中水溶性矽酸含量及交換性鹽基過低，是造成水稻在高氮肥情況下無法正常生長並容易倒伏及罹患稻熱病之兩個主要因素。除了高氮肥對照區之水稻株高減少之外，一般而言之，增加氮肥用量則水稻之發育相對地增加，但稻株矽酸含量及強健性剛好相反，隨著氮肥用量之增加而相對地減少或降低。石灰單獨處理可以促進水稻在高氮肥情況下繼續正常生長並減少穗頸稻熱病之發生率，但由於稻株矽酸含量低，本處理之水稻仍易倒伏。穀殼單獨施於土壤，使稻株之矽酸含量，抗穗頸稻熱病力，抗倒伏性，及穗數顯著地提高，稻穀產量在三氮素級均有增加，但未達到顯著標準。

在石灰、穀殼及三氮素級合併處理之稻葉矽酸含量分別較同氮素級之對照增加一倍，而較同氮素級之單獨穀殼處理顯著地增高，可是水稻之發育僅在高氮素級有顯著增加，也就是說本處理高氮素級之株高、穗數、千粒重、抗穗頸稻熱病力、抗倒伏性、及稻穀產量均較高氮素級對照區顯著增加。但如與高氮素級穀殼單獨處理比較則只有株高、千粒重、抗穗頸稻熱病力及稻穀產量顯著增加。雖然本處理中低、中氮素級之抗氮穗頸稻熱病力及抗倒伏性均顯著增加，但顯然由於氮肥之供應不夠，以致稻株生長並未相對地增加，因此欲在此一強酸性質砂頁岩沖積土獲得抗病力強，不倒伏，發育最佳而產量最高之稻株，不但需要施用穀殼及石灰以提高土壤中之矽酸及鹽基離子含量，更需要充分供應氮肥以應水稻增加生長之需要。

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