Effect of Calcium, Magnesium and Silicon on the Productive Factors and Yield of Rice*

P. PADMAJA[1] AND E. J. VERGHESE[2]

Division of Chemistry, Agricultural College & Research Institute, Vellayani

Received for publication December 14, 1965

The soils of Kerala are generally of a low fertility level and highly deficient in bases particularly calcium and magnesium. The tropical climate and heavy rainfall have depleted the soils of their bases and rendered them acidic. The limited data available at present on the level of magnesium in our soils indicate that it falls below the optimum necessary for satisfactory plant growth. As regards silicon, much work has not been done on its availability in the red loam soils of Kerala though these soils should be considered as deficient ia soluble silicates due to heavy leaching. It is quite probable that due to the deficiency of these nutrients, the fertility status of Kerala soils has been stabilised at a comparatively low level, so that manuring with major nutrients does not produce the expected [illegible] increment. Recent work in Japan, Philippines and other rice growing countries has shown that silicon applied as calcium magnesium silicate in combination with the scheduled doses of N, P and K considerably increased the yield of rice. The object of the present investigation was to study this problem under Kerala conditions.

Review of Literature

The beneficial influence of calcium, magnesium and silicon on the growth and yield of rice has been studied by a number ofworkers. Nambiar (1960), Verghese (1963) and Bhat (1964) obtained better vegetative growth in rice as revealed by increased production of healthy tillers by the application of calcium, A similar effect has been reported for magnesium by Sadapal and Das (1961) who also showed that Magnesium increased the number of grains per ear and the thousand grain weight. Kido *et al* (1958) recorded increased thousand grain weight with increased application of calcium. Bhat (1964) obtained delayed flowering due to calcium application. The fact that liming can increase the yield of rice is clear from the review by Chakrabarthy *et al* (1961). Increase in yield in various crops due to magnesium fertilization was obtained by Nagai (1959).

The importance of silicon in plant nutrition has been studied extensively in Japan. Increase in the dry matter, height, length of earhead and roots has been reported by

* Condensed from the thesis submitted by P. Padmaja to the University of Kerala in partial fulfilment of the requirements for the M. Sc. (Agri.) degree, 1964. Published by kind permissioa of the University of Kerala, Trivandrum.

1. Research Assistant.
2. Professor, University Grants* Commission Scheme.

Okamoto (1957) and Azuma *et al* (1961). Yoshida (1957) reported the yield increasing capacity of silicon. Similar work in India was carried out by Srinivasan (1936) and Dutta *et at* (1962).

The present investigation has been undertaken with a view to studying the effect of calcium, magnesium and silicon on the growth characters and yield of rice in Kerala soils.

Materials and Methods

The effect of calcium, magnesium and silicon, singly and in combination, on the productive factors and yield of rice was investigated in a pot culture experiment with a 2^3 X 4 Factorial Randomized Block design. The treatments consisted of two levels each of the three nutrients. The two levels of silicon used were 0 and 25 lb Si per acre; those of magnesium 0 and 100 lb Mg per acre and of calcium 0 and 1 ton CaO per acre. Calcium, magnesium and silicon were applied in the form of burned lime, magnesium carbonate and sodium silicate respectively. Weighed quantities of these materials were well mixed with 40 lb of soil in the pot, a week prior to planting. Powdered cattle manure at the rate of 5 tons and N, P and K at 30 lb each per acre as ammonium sulphate, superphosphate and muriate of potash were also added. Half the dose of ammonium sulphate was applied just before flowering. Four twenty days old seedlings of the rice variety PTB 10 were transplanted in each pot.

The effect of different treatments on plant performance was studied by observing the total number of vegetative and productive tillers, plant height, leaf width, flowering duration, cumulative earhead emergence counts, grain and straw yield, earhead length, thousand grain weight and by root measurements,

Results and Discussion

The importance of silicon in the nutrition of the rice crop has been fairly well established by Japanese workers. The need for soil amendments for increasing the productivity of laterite and lateritic soils of Kerala has also been widely accepted. The results of the present investigation indicate that silicon in combination with calcium and magnesium helps to improve the growth and yield of rice appreciably.

Data in regard to the effect of silicon on the productive factors of rice are presented in Tables I and II. It may be seen from Table I that the application of Mg in combination with Si and Ca alone in addition to the normal schedule of manuring is highly beneficial for tillering which is one of the most important productive factors contributing to higher yields, Volker (1905) observed that magnesium treated plants were stronger and better tillered than untreated plants. Winifred *et at* (1927) found that the rate of tillering was closely related to the amount of silicon applied. Liming is also found to have a favourable influence on tillering.

Flowering duration and the number of days required for the completion of flowering (number of days taken for the completion of flowering after the appearance of the first flower) are both subject to wide variations, depending on soil conditions and manuring. It may be observed from Table I that the duration of flowering was significantly reduced to the extent of 10 days and 9 days by the treatments of Si alone and magnesium in combination with silicon. Application of magnesium in combination with silicon reduced both flowering duration, as well as the time taken for the completion of flowering (Table III). Both these characters have significant practical

TABLE I

Influence of Calcium, Magnesium and Silicon on the productive factors of rice

Treatment	Total tillers per pot	Average height of plants	Flowering duration	Average leaf width	Average earhead length
1. Control	12.7	92.0	69,3	6.1	15.4
2. Si	14.0	98.4	59.9	6.6	17.9
3. Mg	15.2	97.6	60.4	7.1	17.0
4. Mg + Si	20.0	107.0	60.0	6.6	18.7
5. Ca	17.0	104.2	62.2	6,8	17.5
6. Ca + Si	14.5	104.6	61.1	7.1	18.0
7. Ca + Mg	14.8	104.4	63.2	6.5	18.7
8. Ca+Mg+Si	15.0	98.2	62.7	6.5	17.1
Significance	•*	N. S.	**	N. S	*
SEM	1.58	••	0.67	—	0.93
CD	3.29	*•	2.08		2.08
Conclusion	4.5.3,8,7,,6,2,1		1,7,8,5,6,3,4,		(4,7,)6.2,5.8.3.1

* Significant at 5 per cent level

** Significant at I per cent level

TABLE II

Influence of Calcium, Magnesium and Silicon on the grain characters and root system of rice

Treatment	1000 grain weight (g)	Root measurements Weight (g)	Root measurements Depth (cm)	Percentage of immature earhead
1. Control	21.6	2.1	19.0	20.5
2. Si	22.8	5.9	30.8	4.0
3. Mg	22.5	10.7	39.5	5.4
4. Mg+Si	24.2	12.7	65.5	4.2
5. Ca	22.3	9.6	44.5	5.9
6. Ca+Si	22,5	6.3	34.0	3.5
7. Ca+Mg	22.7	4.9	38.0	3.6
8. Ca+Mg+Si	22,5	4.4	56.0	5.1

TABLE III

Cumulative earhead emergence counts as influenced by Calcium, Magnesium and **Silicon**

Dates of observation	Treatments Control	Si	Mg	Mg+Si	Ca	Ca+Si	Ca+Mg	Ca+Mg+Si
5-1-64	0	2	4	5	1	4	2	3
7-1-64	0	4	10	8	6	5	4	5
9-1-64	3	5	10	12	8	6	5	11
11-1-64	5	11	10	12	10	5	9	6
13-1-64	4	8	8	12	10	5	9	6
15-1-64	5	6	6	12	10	11	5	9
17-1-64	4	7	3	10	8	9	5	4
19-1-64	1	7	2	4	4	10	6	8
21-1-64	3	1	2	3	5	2	7	2
23-1-64	4	1	I	1	1	0	1	1
25-1-64	4	0	1	0	1	0	1	2
27-1-64	4	0	1	0	1	0	1	1
29-1-64	5	0	0	0	1	0	1	1
31-1-64	5	0	0	0	0	0	O	0
Total	47	52	58	79	66	57	56	59

TABLE IV

Effect of Calcium, Magnesium and Silicon on the yield of grain and straw

Treatment	Weight of filled grains per pot (g)	Weight of straw per pot (g)	Grain to straw ratio
1. Control	8.3	11.8	0.70
2. Si	12.4	17.2	0.72
3. Mg	13.5	19.5	0.69
4. Mg+Si	20.4	23.8	086
5. Ca	14.9	22.0	0.68
6. Ca+Si	14.9	21.8	0.68
7. Ca+Mg	132	20.5	0.64
8. Ca+Mg+Si	13.6	20.5	0.64
Significance	**	**	
S. E. M,	1.66	1.1	0.66
C. D.	3.45	2.30	
Conclusion	4,(6,5),8,3,7,2,1	4,6,5,(8,7),3,2,1	

** Significant at 1 percent level

utility. Early flowering saves time and early completion of flowering helps uniform ripening of grain, thereby increasing the grain weight. This is observed in the higher thousand grain weight for the treatment magnesium in combination with silicon (Table II). This is in agreement with the findings of Okamoto (1959) Mitsui and Taktohu (1960) obtained early heading for silicon-treated plants. The influence of silicon in inducing early heading can be attributed to the effect of this element in increasing the availability of soil phosphorus. This effect of silicon, however, is slightly decreased when it is combined with magnesium. Nagai (1959) and Sadapal and Das (1961) recorded delayed flowering due to magnesium application. In the present study application of calcium delayed flowering and also the time taken for the completion of flowering.

It is also clear from Table I that the earhead length is significantly increased by the treatments magnesium in combination with silicon and magnesium in combination with calcium.

Thousand grain weight (Table II) for the treatment magnesium in combination with silicon is 12 per cent more than that of the control and 7.5 per cent more than that of the treatment Mg alone. Nagai (1959) and Sadapal and Das (1961) similarly recorded an increased thousand grain weight by Mg application.

Okamoto (1959) emphasized the importance of silicon in increasing the thousand grain weight in their studies on cereals. Thus it would appear that silicon and magnesium together have an additive effect in enhancing the thousand grain weight.

The treatments Mg alone and Mg in combination with Si considerably increased the root weight, the increase being five and six times respectively over control (Table II). Magnesium in combination with silicon and also with calcium, and silicon alone increased the depth of peneration of the root system by 244.7 per cent and 194.7 per cent respectively over the control. All the three nutrients Mg, Ca and Si are found to increase the root weight more than in the control and Mg is found to be the most effective when individual nutrients are compared. From Plate II it is clear that the root system is more spreading in the case of the treatments Mg and Mg in combination with Si. The general tendency of Ca and Si is to produce a deeper root system whereas the effect of Mg is to induce better root spread. The proportion of thicker to thinner roots was higher in treatments which included silicon. An extensive and healthy root system gives the plant, the necessaryi prerequisite for maximum productivity, under the limitations imposed by soil conditions and other factors. The increase on the length of roots by the application of silicon was observed by Lipman (1936) and a similar observation on the effect of lime was noted by Rothwell (1957). The level of Mg in the soil being very low, application of Mg might have contributed towards better photosynthesis as in indicated by increased leaf width by Mg treated plants (Table I). The enhanced photosynthetic activity might have indirectly increased the root weight. The best treatment which had an overall effect on the root system is the treatment Mg in combination with Si, which incidentally recorded the maximum grain and straw yields (Plates I and II).

The results obtained show that Ca in combination with Si has reduced the proportion of immature to mature earheads magnesium-silicon combination having slightly lesser effect. Taktohu (1960) and Azuma *et al* (1961) obtained increased percentage of ripened grains by applying silicon.

The average yields of grain and straw in the various treatments are given in Table IV. The treatment Mg in combinationwith Si recorded the maximum yield of grain which is 146 percent more than the control. All the other treatments are also found to give better yields than the control. Stenut and Piot (1958) obtained similar increase in grain yield by the application of magnesium while Dutta *et al* (1962) obtained the same result by the application of Silicon. In I. R. R. I Phlippines, application of calcium magnesium silicate increased yield by about 500 kg per hectare (Anon., 1963),

The maximum yield of straw is obtained for the treatment Mg in combination with Si. The total number of tillers, plant height and leaf width are characters which contribute to the higher yield of straw.

The grain to straw ratio is a maximum in the treatment magnesium in combination, with silicon followed by silicon alone, Calcium, either alone or in combination tended to reduce the above ratio. Silicon is well known to influence the production of grain in comparison to straw. Srinivasan (1936) obtained appreciable increase in grain yield when compared to straw yield in oats and rice. Combination of magnesium with silicon is found to be more efficient in increasing the grain to straw ratio. The ability of Mg for increasing the grain yield has been recorded by Hashimoto and Kavaguchii (1955) Calcium was found to have an adverse effect on this ratio because of its influence in increasing the straw weight.

Summary and Conclusions

A pot culture experiment using a 2 x 4 randomised block design was carried out to study the effect of calcium, magnesium and silicon singly and in combination on the productive factors and yield of rice. The chief findings are the following :

1. Application of 100 lb of magnesium as magnesium carbonate and 25 b of silicon as sodium silicate over and above the normal schedule of N, P and K considerably increased all the productive factors, such as tillering height of plants, earhead length and thousand grain weight. One ton of CaO in combination with 25 lb. of silicon as sodium silicate was found to be less effective.

2. Magnesium in combination with silicon was found to have a highly beneficial effect on the root system. When the individual nutrients were compared, Mg was found to produce a more extensive root system while Ca and Si deeper root systems.

3. Flowering duration was reduced to the extent of 10 days by silicon, while Mg was found to have a slightly lesser effect. The early ripening of grain induced by the treatment Mg in combination with Si was reflected in an increased thousand grain weight.

4. Grain and straw yield were significantly increased by applying Mg in combination with Si over and above the normal shedule of manuring.

5. Grain to straw ratio was a maximum with Mg in combination with Si. Ca tended to reduce the ratio when applied alone or in combination with Si.

Plate I. General view of the plants under the different **treatments**

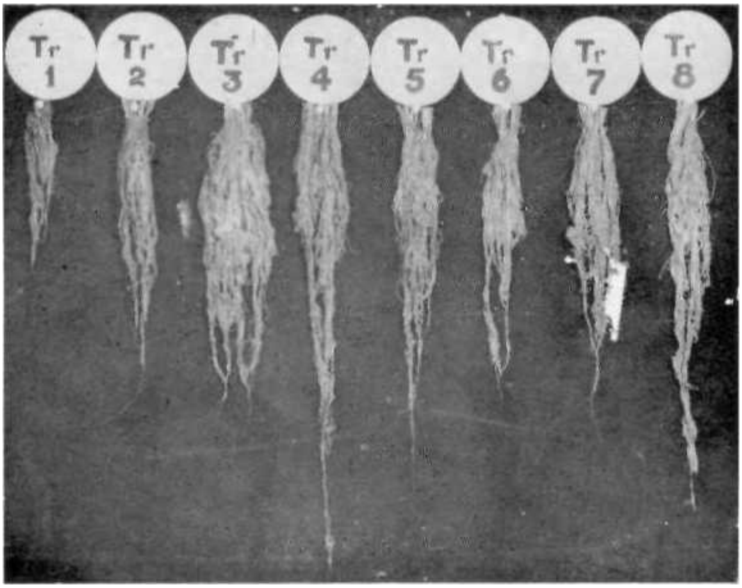

Plate II. Root systems of the plants under the different treatments.

Plate III. Comparison of treatment 4 (Mg + Si) with treatment 1 (control)

Acknowledgements

Thanks are due to Dr. R. S. Money for his constructive and useful suggestions during the course of this study.

Thanks are also due to Dr. M. M. Koshy or valuable suggestions during the preparation of this paper,

References

1. Anonymous (1963) Annual report of the International Rice Research Institute, Philippines, 1963, pp. 99-100.

2. Azumay, Okudo A. and Takahashi, E-. (1961) Silicon supply period in the growth of a rice plant and its nutrient uptake. Abstracted in *Chem. Abst.* Vol. 58 : 1963,(11913)

3. Bhat K. K. S. (1964) The effect of liming on the availability of nitrogen and phosphorus in some acid soils of South India. Dissertaion for M Sc, (Ag.) Degree submitted to the University of Madras.

4. Chakrabarthy, M. Chakravarthy, B. and Mukherjee, S. K. (1961) Liming in crop production in India. *Indian Soc. Soil Sci. Bul.* 7.

5. Dutta, N. P., Shind, J. E., Kamath, M. B. and Datta, S. K. (1962) Effect of sodium silicate on the uptake of soil and fertilizer phosphorus by wheat, rice and berseem. *Ind. J. Agri. Sci.* **32 :** 3, 219-27.

6. Hashimoto, S, and Havaguchii, K. (1955) Magnesium in barley plants on magnesium deficient soils. *Soil Plant Food* I - 9-10.

7. Kido, M. (1958) Physiological and ecological studies of rice plant in well drained and ill drained fields. 4. Difference in quality and ripening of rice grains as affected by fertilizers. *Proc. Crop Sci. Soc. Japan,* 26 ; 1958.

8. Lipman, B. C. (1938) Importance of silicon, aluminium and chlorine for higher plants. *Soil. Sci. 45* : 189-98.

9. Nagai, (1959) Japonica rice-its breeding and culture. Yokendo Ltd., Tokyo 575.

10. Nambiar, E. P. (1960) Studies on the effect of liming in lateriate soils of West Coast (Kerala) Dissertaion for M. Sc. (Ag.) Degree submitted to the University of Madras,

11. Okamoto, Y. (1957) Physiological studies on the effect of silicic acid on rice. 3. Effect of silica supplied at various itages of growth. *Proc. Crop Sci. Soc. Japan* 25 : 11-16.

12. Okamoto, Y. (1959) Physiological studies on the effects of silicic acid on rice plant. *Proc. Crop. Sci, Soc. Japan 21* :1-2.

13. Rothwell, D. F. (1957) The effect of lime on root distribution soil. *Crop. Sci. Soc. Am. Proc.* 17 : 67-71.

14. Sadapal, M. N. and Das, N. B. (1961) Effect of micronutrient elements on wheat. 2. Effect on yield and chemical constitutents. *J. Indian. Soc. Soil. Sci.* **9 :** 4, 257-67.

15. Srinivasan K. (1936) Investigation on the role of silica on plant nutrition. IV. Effect of silicate fertilizers on the growth of rice plant. *Proc. Indian Acad. Sci*, 3: B, 302-9.

16. Verghese, Thomas (1963) The influence of calcium and magnesium in increasing the efficiency of fertilizers for rice and the calcium and magnesium status of some typical rice soils. Thesis submitted to tbe University of Kerala for M, Sc, (Ag.) degree.

17. Volker, J. (1905) Woburn Expt. Stn. Rpt. 17-20.

18. Winifred, E. Brenchley, 0, Sc. and Marshal, E, J, (1927) The inter relation between silicon and other elements in plant nutrition. *Annals of Applied Biology* 14 : 45-81

19. Yoshida, O., (1959) Role of silicon in rice nutrition. *Soil Plant Food.* 5: No. 3.