INVESTIGATIONS ON THE RÔLE OF SILICON IN PLANT NUTRITION.

Part IV. Effect of Silicate Fertilisation on the Growth of the Rice Plant and Yield of Paddy.

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Although it has long been recognised that the rice plant requires maintenance of swamp soil conditions for optimum growth and yield of grain, yet very little definite information is available regarding the need for such excessive water requirement of the crop. It has been suggested (Nanji and Shaw, 1925) that the high silicon content of the different parts of the rice plant may in some way be due to the peculiar (swamp) soil conditions under which that plant is generally cultivated. Indeed, comparative studies on the intake of silicon under conditions of dry as well as wet cultivation (Sreenivasan, 1936) have shown that the plant absorbs considerably greater quantities from the soil system in the latter than in the former cases. The availability of silica (Sreenivasan, 1935) has also been found to increase with moisture content of the soil being greatest in flooded soils. Observations by Suzuki (1935) on the effect of variations in soil moisture on the susceptibility of the rice plant to helminthosporium and blast diseases have also shown that susceptibility increases with the aridity of the soil. The susceptibility seems to be closely connected with the thickness of the outer wall and the silicated outermost layer of the epidermal cell which was greatest in the flooded series. Rate of infection in arid and in flooded soils alike decreases with supply of soluble silica. Other workers (Miyake and Adachi, 1922 ; Kawashima, 1927 ; Miyake and Ikeda, 1932, etc.) have also reported that the resistance of the plant to disease is closely connected with the silica content of the plant, the latter increasing with the quantity of silicates applied to the soil.

The foregoing observations bring out the importance of silicon in the nutrition of the rice plant. They do not, however, entirely explain its significance in the physiology of the crop. The presence of such large quantities of silica in the plant under conditions of optimum growth (Sreenivasan, *loc. cit.*) would suggest that the supply of soluble silica may be an important

factor governing the growth of the plant and yield of grain. The present experiments which are only preliminary in character were designed to show whether under conditions of dry cultivation and in presence of a free supply of soluble silica secured by the addition of sodium silicate to the soil, the yield of paddy can be improved to the same level as when grown under swamp conditions.

Experimental.

Glazed earthenware pots were made up in the usual way with 50 lbs. each of a clay soil (3 mm. sieve) from an adjoining area. The pots were then divided into four series (each of 50) as follows :—(*a*) unmanured and maintained at 60 per cent. saturation ; (*b*) unmanured and puddled with water ; (*c*) manured with 100 g. of green manure per pot and maintained as in (*a*) ; (*d*) manured as in (*c*) but maintained as in (*b*).

The green manure was applied in the form of fresh leaves of *Pongamia glabra* cut into small bits and was thoroughly incorporated into the soil to a depth of about 6″.

The pots in each series were again sub-divided into five groups as follows :—(1) untreated (control) ; (2) treated with 2 g. per pot of potassium phosphate applied as a 10 per cent. solution ; (3) treated with 20 c.c. of a 25 per cent. solution of Kahlbaum's sodium silicate applied after diluting five times ; (4) treated with 80 c.c. of 25 per cent. sodium silicate applied also after being diluted five times ; and (5) treated as in (4) but the silicate was added in four equal instalments during the life of the crop.

Phosphate was employed in one of the treatments (Group II) in view of the fact that the application of the silicates is known to increase phosphorus availability to the plant (Sreenivasan, 1934). The soil used in the present set of experiments was known to be deficient in phosphorus and hence any effect that the added silicate may have in stimulating plant growth by increased intake of phosphorus will be only insignificant. However, it was thought desirable to run a check series with phosphate in order to overcome any effect the added silicate may have in this direction.

There were thus 20 treatments in all with 10 pots for each treatment.

The pots in series (*b*) and (*d*) were made as above on 22nd May 1935, while those in series (*a*) and (*c*) were made on 31st May 1935. The chemicals were all added on 4th June 1935 and where the sodium silicate was added in instalments (Group V), the first addition was made on the above date while the subsequent additions were made as above on 25th June 1935, 15th July 1935, and 15th August 1935 respectively.

The above dates corresponded roughly with the stages of tillering, active vegetative growth and flowering respectively. In view of the observation that the intake of silicon by the plant ceases after the flowering stage (Sreenivasan, 1936) all the silicate was added before this period in the life of the crop.

Paddy (variety Adt. 3, a short duration *Kar* crop) was sown in separate seed beds on 8th May 1935. The seedlings were transplanted into the experimental pots on 6th June 1935 when they had attained an average height of about 6 inches. Six seedlings were planted to each pot. When the seedlings had become well established in the soil, enough water was added to the pots in series (*b*) and (*d*) so as to keep the soil well under submergence (3 inches). Slow drainage was allowed, water being added at frequent intervals to keep the level of submergence nearly constant. This was continued until about the middle of September when grains had formed in all the cases. Pots in series (*a*) and (*c*) were just kept moist by daily addition of water, which was also stopped during the ripening stage.

Results.

The growing period was from 6th June 1935 to 6th October 1935. Systematic periodical records of the maximum height of the plants in each pot and the number of tillers of every plant were maintained until the harvesting date. The different developmental stages of the plant together with the approximate dates are given below.

Germination on 14th May 1935.
Transplantation on 6th June 1935.
Tillering stage (about) 20th July 1935.
Flowering stage (about) 2nd September 1935.
Panicle formation (about) 15th September 1935.
Harvesting on 6th October 1935.

The average number of tillers per plant as also the maximum height of the above ground portion of the plant in each group under the different series at different times are given in Table I.

The yield of grain and of straw on harvesting are recorded in Table II. The results represent the total yield (in g.) of all the plants (60) in each series.

Discussion of Results.

Addition of phosphate increases tillering and also the number of earing tillers. The proportion of grain formed also increases considerably. Phosphate was also found to have a quicker ripening effect (Hall and Morison, 1906). The effect of phosphate treatment was nearly the same in the manured as well as unmanured series, both arid and flooded.

TABLE I. *Tillering and height at various stages of growth.*
(*Figures represent the data per plant being the average of* 60 *plants in a series.*)

Treatment Group		Age of Plant—Days															
		Unmanured arid series				Unmanured flooded series				Green manured arid series				Green manured flooded series			
		67	111	124	145	67	111	124	145	67	111	124	145	67	111	124	145
(i) Untreated check.	Number* of tillers	2·0	3·4 (1·1)	3·8 (2·0)	1·4 (0·6)	2·2	3·7 (1·0)	4·0 (3·2)	3·6 (3·3)	3·0	4·6 (1·3)	5·2 (2·0)	4·6 (3·4)	4·5	8·4 (5·0)	8·8 (8·0)	9·0 (8·4)
	Maximum height (cms.)	40	50	64	55	43	60	67	58	45	66	69	61	54	80	94	86
(ii) Treated with phosphate.	Number* of tillers	2·8	3·6 (2·4)	3·2 (2·8)	1·8 (1·4)	2·7	4·0 (2·2)	4·4 (3·7)	4·0 (2·9)	3·4	5·0 (3·1)	5·6 (3·2)	4·7 (3·2)	6·0	9·2 (6·2)	10·8 (9·1)	9·9 (8·2)
	Maximum height (cms.)	43	57	61	50	47	62	70	54	48	65	72	57	57	85	99	85
(iii) Treated with silicate, small quantity.	Number* of tillers	2·2	3·5 (2·2)	3·0 (2·7)	1·6 (1·1)	2·0	3·6 (2·0)	4·4 (3·6)	3·8 (3·4)	3·0	4·4 (2·7)	5·4 (3·4)	4·7 (3·0)	5·6	10·0 (5·4)	10·4 (8·2)	9·6 (8·0)
	Maximum height (cms.)	36	48	62	54	40	58	57	60	42	63	70	62	52	76	92	80
(iv) Treated with silicate, large quantity.	Number* of tillers	..	3·5 (1·8)	3·4 (2·9)	2·2 (1·5)	..	3·9 (1·9)	4·6 (3·9)	4·1 (2·7)	3·0	4·6 (2·8)	6·0 (4·2)	4·7 (3·0)	4·2	9·8 (6·3)	11·0 (9·4)	9·8 (8·0)
	Maximum height (cms.)	38	46	69	58	40	60	69	59	43	63	71	64	49	77	98	90
(v) Treated with silicate, large quantity in instalments.	Number* of tillers	2·0	3·2 (0·8)	4·0 (2·6)	2·0 (1·0)	2·4	3·8 (2·0)	4·5 (3·9)	3·8 (2·6)	2·9	5·0 (2·8)	6·2 (3·7)	5·1 (3·4)	5·8	9·2 (5·4)	11·0 (9·5)	10·0 (8·0)
	Maximum height (cms.)	38	50	63	52	45	64	71	58	45	67	74	59	56	84	96	87

* Bracketed figures are the number of earing tillers per plant (average), while the first figure represents the total number (earing and non-earing) of tillers.

TABLE II.

Yield of grain and straw (total of 60 plants in each case).

Treatment		(*a*) Unmanured—arid			(*b*) Unmanured—flooded			(*c*) Green manured—arid			(*d*) Green manured—flooded		
		Yield of grain (gms.)	Yield of straw (gms.)	Grain/Straw ×100	Yield of grain (gms.)	Yield of straw (gms.)	Grain/Straw ×100	Yield of grain (gms.)	Yield of straw (gms.)	Grain/Straw ×100	Yield of grain (gms.)	Yield of straw (gms.)	Grain/Straw ×100
(1) Untreated check	Fresh wt.	19·2	138·6	..	30·6	211·2	..	80·4	340·2	..	286·8	1185·6	..
	100° dry wt.	14·4	44·4	32·4	22·8	66·0	34·5	60·0	114·6	52·4	218·4	394·8	55·3
(2) Treated with phosphate	Fresh wt.	48·0	175·2	..	91·2	252·0	..	186·6	666·4	..	373·8	1464·0	..
	100° dry wt.	38·4	60·0	64·0	67·2	85·2	78·9	138·0	226·8	60·8	278·4	486·0	57·3
(3) Treated with silicate =S	Fresh wt.	54·0	150·0	..	76·8	205·8	..	236·4	766·8	..	360·0	1173·6	..
	100° dry wt.	40·8	49·2	82·9	56·4	73·2	77·0	180·6	261·0	69·2	276·0	402·0	68·7
(4) Treated with silicate =4S	Fresh wt.	60·6	157·2	..	73·2	228·6	..	251·4	806·4	..	384·0	1296·0	..
	100° dry wt.	46·2	54·0	85·6	54·6	81·6	66·9	194·4	273·0	71·2	288·0	427·2	67·4
(5) Treated with silicate =4S in instalments	Fresh wt.	60·0	152·4	..	82·8	228·0	..	264·0	768·0	..	433·2	1261·8	..
	100° dry wt.	45·6	50·4	90·5	64·2	76·2	84·3	199·2	259·8	76·7	334·8	423·0	79·1

Addition of small amounts of silicate definitely increases growth as well as yield in all the cases. Addition of larger amounts of silicateinc reases growth and yield to a greater extent, but this is not in proportion to the amount of silicate added. It was noticed that in these cases, there was a general set-back on the growth of the plants in the early stages due no doubt to excessive alkalinity. The plants, however, tillered actively during later stages and came to ripening at about the same time as the other series. Where the silicate was added in instalments (Group V), best results were obtained as the initial harmful effects of silicate were not noticed in these cases. The yields were also definitely higher than in the corresponding Group (IV).

While the results show a similarity between silicate and phosphate treatments in that both of them increase growth and yield of grain, there is at the same time a distinct difference between the two treatments when comparing the different series. Phosphate application to dry series (manured as well as unmanured) does not increase the yield of grain so much as silicate application whereas in the " wet " series, they both raise the yield to about the same extent. Again a comparison of the relative yields in the arid and flooded series under the different groups shows that silicate application has considerably increased the yield from dry series nearer to that from flooded series than phosphate application.

The above observations are made clear from Table III, where the increase

TABLE III.

Per cent. increase over check in yield of grain and Grain/Straw ratio.

Series	Yield of Grain				Grain/Straw Ratio			
	Treatment							
	Treated with Phosphate	Treated with Silicate=S	Treated with Silicate=4S	Treated with Silicate=4S in instalments	Treated with Phosphate	Treated with Silicate=S	Treated with Silicate=4S	Treated with Silicate=4S in instalments
	Per cent. increase over check.							
Unmanured—arid	166·7	183·2	220·9	216·8	97·5	155·9	164·3	179·4
Unmanured—flooded	194·5	147·2	139·5	181·6	130·1	123·2	93·9	144·3
Green manured—arid	130·0	201·0	224·0	232·0	16·1	32·1	36·0	46·5
Green manured—flooded	27·5	26·4	31·8	53·3	3·4	24·2	21·9	43·1

over the check (control) in the yield of grain and in the grain/straw ratio (Table II) are given for the different groups of the arid and flooded series.

Thus, the increase over check is in every case more in arid series than in flooded ones. In other words, there is greater response to growth and yield on fertilisation of arid soil with silicate. The yield of grain under arid conditions in pots treated with silicate compares very nearly with the yield of grain in flooded series.

Although the application of silicate to the unmanured soil increases the yield of grain and straw, yet it would appear from a comparison with the yields in the manured series that organic manure is the chief limiting factor governing crop growth and yield. Even in the experiments with green manure, the yield is far more in flooded series than in arid ones and as has been found earlier (Sreenivasan, *loc. cit.*), the plant absorbs larger amounts of silica in the former than in the latter cases. Since the present enquiry has shown that application of sodium silicate to manured dry series improves yield and raises it to nearly the same level as in the wet series, it would follow that the swamp soil conditions supply the plant with large amounts of silica which are otherwise unavailable. This is further supported by the fact that in the manured flooded series, silicate addition does not appreciably improve the yield. Further work is, however, needed to show whether under dry soil conditions and in the presence of a supply of soluble silica the rice plant absorbs more of silica from the soil system and whether intake of silica and yield of crop are primarily related to each other.

In the application of the principle of silicate fertilisation to the rice crop in field practice, the possible harmful effects of the silicate on the reaction and texture of the soil and on subsequent crops should not be ignored. Trials should be conducted with judicious combinations of sodium silicate with other acid fertilisers like ammonium sulphate, calcium superphosphate, etc.

Further work relating to the effect of silicate fertilisers on (*a*) the yield of dry and wet cultivated rice grown under field conditions, (*b*) the intake of silica, and (*c*) the physical properties of the soil, is under progress.

Summary.

Observations have been made on the growth of the rice plant and yield of paddy under arid and flooded conditions with and without addition of organic (green) manure, sodium silicate and potassium phosphate respectively. It is found that treatment with sodium silicate increases the yield of grain and straw and that both in unmanured and manured soils the response is greater in arid than in flooded series.

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