

Seed Placement of Phosphates in Paddy

1—Preliminary Experiments on the Application of Phosphate Solutions to Seed

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FERTILIZER placement attempts combining economy of fertilizers with efficacy. Methods that aim at placing the fertilizer within reach of the plant, and at avoiding losses by immobilization in the soil or by leaching have received much attention in recent years. The most extreme form of placement is that which deposits the fertilizer on the seed coat, or inside the seed by absorption from solutions. Roberts (1947) obtained striking results with seed of wheat, oats and barley soaked in solutions of dipotassium hydrogen phosphate. The concentrations tolerated varied from five per cent. in the instance of wheat to 30 per cent. for oats. On phosphate deficient soils, soaking of wheat seed in a five per cent. solution of dipotassium hydrogen phosphate gave a yield increase of 1.1 cwt. per acre for an application of only 1.4 lb./acre of P_2O_5 in the soaking solution; under comparable conditions, 64 lb. of basic slag gave an increase in yield of 1.5 cwt. Roberts results indicate that phosphate (associated with potash) was about 60 times more efficient when applied as a solution to the seed than when applied to the soil. With oats, she secured a yield increase of 8 cwt./acre for 13.6 lb./acre of tribasic potassium phosphate (or 4.6 lb/acre of P_2O_5) expended in seed soaking. This paper presents preliminary results of similar trials with paddy.

PART 1*—POT EXPERIMENTS

Experiment (1)

This experiment was set down in late *Maha*, 1948, with the pure line, *Pachchaiperumal 2,462/11*. Seed from the 1947 *Yala* crop, was soaked

* Part 1 of this communication formed the subject of a paper read at the 1948 Session of the Ceylon Association of Science. "A Note on Pre-soaking in Phosphate Solutions for Increasing Yield in Rice" by Narayanan, T. R. & Gopal Krishnan, S., 1949 has since appeared.

in the following concentrations of disodium and dipotassium hydrogen phosphates :—

Treatment No.	Phosphate	Concentration Percentage	Duration
1	—	Tap water	48 hours and 72 hours (two series)
2	K ₂ H PO ₄	5	
3	do.	10	
4	do.	20	
5	Na ₂ H PO ₄	5	
6	do.	10	
7	do.	20	

Twenty-five gm. of seed were soaked in 110 ml. of solution in each of the fourteen treatments that composed the two series.

The soil used was a yellowish brown loam from village paddy fields at Gannoruwa in the Central Province. This soil had a pH of 6.16 and was fairly satisfactory as regards phosphate (25 p.p.m.), but was very low in potash and rather low in nitrogen. After thorough mixing, 12 in. × 12 in. pots were filled with this soil, and kept in a plant cage that had wire-mesh sides and a plate-glass roof. Growth was poor; both in this experiment and the succeeding one; reduction in light intensity in the cage appeared to interfere with growth. Pairs of pots were sown with treated seeds at the rate of one-hundred per pot. Seedlings were later thinned to ten per pot. Seeds were sown on January 15, and the harvest was on April 30, 1948; the life period was 106 days

Effect on Germination.—Germination records are presented in Table 1. The salt solutions caused a retardation of the rate of germination, the effect increasing with the concentration of solution and duration of soaking. There was no marked effect on the final germination percentages, except in the series soaked for 72 hours, in which (as is shown in the variance analysis, presented in Table 2, of germinations percentages transformed to the inverse sine scale appropriate to binomial distributions) there was a significant reduction in final germination from 96.5 per cent. in tap water to 86.0, 80.5 and 70.5 per cent. in 5, 10 and 20 per cent. solutions of K₂H PO₄ respectively, and to 84.0, 87.0 and 82.0 per cent. in the corresponding series for the sodium salt. The effect of the treatments on germination has been a delaying of germination in all instances, the delay increasing *pari passu* with rise in concentration of the solutions. Apart from the fact that the sodium salt has depressed germination somewhat more in the 48 hours soaking, there is no appreciable difference in germination effects between the Na and K salts. The effect on final germination percentage is uncertain, and not of a magnitude to be of practical importance.

Effect on Grain Yields.—Complete grain and straw data are presented in Table 3. The analysis of variance of grain yields does not reach significance, but the separate analysis of the 48-hour series shown in Table 4 indicates a significant effect of phosphate. All the phosphate soakings, except five per cent. disodium hydrogen phosphate have given significantly higher grain yields than the control. The 20 per cent. dipotassium hydrogen phosphate was significantly superior to the 10 and 5 per cent. The 20 and

10 per cent. disodium hydrogen phosphate are significantly better than the 5 per cent. The effect of potash as against sodium is not clear. A response to potash was to be expected in this soil which is low in that nutrient.

TABLE 1
Germination percentages of Seeds soaked in Phosphate Solutions

Soaking Solution Percentage	Duration of Soaking (hours)	Number of Days after sowing					
		4	5	6	7	8	9
Tap water	.. 48	.. 69	.. 77	.. 86	.. 88	.. 89	.. 89
K ₂ HPO ₄	5 .. 48	.. 64	.. 73	.. 76	.. 79	.. 79	.. 82
K ₂ HPO ₄	10 .. 48	.. 32	.. 56	.. 74	.. 78	.. 82	.. 84
K ₂ HPO ₄	20 .. 48	.. 15	.. 44	.. 64	.. 71	.. 84	.. 85
Na ₂ HPO ₄	5 .. 48	.. 70	.. 77	.. 79	.. 79	.. 84	.. 85
Na ₂ HPO ₄	10 .. 48	.. 66	.. 71	.. 75	.. 75	.. 85	.. 86
Na ₂ HPO ₄	20 .. 48	.. 56	.. 68	.. 74	.. 77	.. 83	.. 86
Tap water	.. 72	.. 73	.. 86	.. 96	.. 97	.. 97	.. 97
K ₂ HPO ₄	5 .. 72	.. 52	.. 70	.. 84	.. 85	.. 85	.. 86
K ₂ HPO ₄	10 .. 72	.. 36	.. 59	.. 72	.. 77	.. 79	.. 81
K ₂ HPO ₄	20 .. 72	.. 19	.. 35	.. 54	.. 66	.. 71	.. 71
Na ₂ HPO ₄	5 .. 72	.. 47	.. 71	.. 81	.. 83	.. 84	.. 84
Na ₂ HPO ₄	10 .. 72	.. 57	.. 68	.. 80	.. 86	.. 87	.. 87
Na ₂ HPO ₄	20 .. 72	.. 32	.. 45	.. 61	.. 80	.. 82	.. 82

TABLE 2

Analysis of variance of percentage
Seeds germinated nine days after sowing in the 72-hour series
(Data transformed to inverse sine scale, $\theta = \sin^{-1} \sqrt{p}$)

	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio	5 per cent. Point
Treatments	.. 6	.. 547.10	.. 91.18	.. 5.27	.. 3.87
Error	.. 7	.. 121.09	.. 17.30		
Total	.. 13				

Percentage standard error : 6.20.

Degrees ($\theta = \sin^{-1} \sqrt{p}$)	Soaking Solution						General Mean	Standard Error	Significant Difference	
	Tap Water	K ₂ HPO ₄			Na ₂ HPO ₄					
		5%	10%	20%	5%	10%				20%
	79.7	68.0	64.2	57.3	66.4	68.9	64.9	67.05	±2.94	.. 9.84
Percentage germination	.. 96.8	.. 86.0	.. 81.0	.. 70.2	.. 84.0	.. 87.0	.. 82.0			

TABLE 3

Yields of Grain and Straw in Pot Experiment 1

Means per 10-plant pots.

Soaking Solution	Percentage	Duration of Soaking			
		48 hours		72 hours	
		Grain (gm.)	Straw (gm.)	Grain (gm.)	Straw (gm.)
Tap water	..	3.5 ..	9.5 ..	4.3 ..	11.0
K ₂ HPO ₄	5	4.2 ..	11.3 ..	3.9 ..	11.9
K ₂ HPO ₄	10	4.1 ..	11.7 ..	3.8 ..	11.3
K ₂ HPO ₄	20	4.7 ..	11.7 ..	4.5 ..	12.7
Na ₂ HPO ₄	5	3.5 ..	9.9 ..	4.9 ..	12.0
Na ₂ HPO ₄	10	4.7 ..	12.2 ..	4.9 ..	12.0
Na ₂ HPO ₄	20	4.5 ..	11.3 ..	3.9 ..	10.9

TABLE 4

Analysis of Variance of Grain Yields in 48-hour series in Pot Experiment 1

	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio	5 per cent. Point	One per cent. Point
Treatments	6	3.220	0.5367	12.75	3.87	7.19
Error	7	0.295	0.0421			
Total	13	3.515				

Percentage standard error : ± 4.94 .

Mean Yield per 10 plant pot in gm.	Soaking Solution						General Mean	Standard Error	Signifi- cant Difference	
	Tap Water	K ₂ HPO ₄			Na ₂ HPO ₄					
		5%	10%	20%	5%	10%				20%
..	3.45	4.15	4.1	4.7	3.5	4.7	4.45	4.15	± 0.145	0.485
Per cent.	100	120.3	118.8	136.2	101.4	136.2	129.0	—	± 4.20	14.0

The magnitude of the increases in the 48-hour series are considerable, amounting to as much as 36.2 per cent. in the instance of 20 per cent. dipotassium hydrogen phosphate and 10 per cent. disodium hydrogen phosphate. It may be concluded that the effect of phosphate solutions on the seed has been definite and considerable.

In the 72-hour series, plants derived from phosphate-soaked seed showed no increase in yield of grain over the control. It appears that the 72 hours soaking has been too severe and has damaged the seed.

Effect on Straw Yields.—Though there has been a consistent increase in straw within the 48-hour series, the error variance was high and statistical significance was not reached. The means of all phosphate treatments exceeded the mean of the control. There are indications that the sodium salt is more injurious to the seed at high concentrations than the potassium salt. Increase of the concentration of the sodium salt from 10 per cent. to 20 per cent. is accompanied by a reduction in the yield of both grain and straw; there is no parallel reduction in the instance of the potassium salt.

Experiment II

This trial, which was largely a repetition of the first one, was set down in *yala*, 1948. The same soil was used with an application of compost of 2.5 per cent. and half the pots received a dressing of potash of 0.0025 per cent. K_2O as muriate. This potash treatment was given because the soil was known to be deficient in potash and there were indications in the first experiment of a response to potash. Tests were confined to one salt, viz., dipotassium hydrogen phosphate, and to one soaking duration, viz., 48 hours. Seed of the pure line, *Pachchaiperumal 2462/11* was sown on July 3, and reaped on October 20, 1948; the life period was 109 days. The large amount of shattering that occurred contributed to the high error in the variance analysis of grain yields.

Effect on Germination.—Soaking in phosphate solutions depressed the rate of germination in a manner similar to the first experiment. The final germination percentages decreased with increase in concentration of solutions, except for the anomalous behaviour in the instance 20 per cent. phosphate on potash-treated soil. The seeds were germinated in the pots and it appears that germination was adversely affected by the potash dressing in the second series. The potash soil dressing caused a significant increase in the height of the plants, whereas heights had not been noticeably affected by any of the treatments in the first experiment.

Effect on Grain Yields.—Complete grain and straw yields are given in Table 5. The potash dressing on the soil produced a highly significant increase in grain. The phosphate soaking showed no significant effects. Individual pot yields were erratic, and the error was high. Nevertheless, apart from the depression in the instance of the 20 per cent. phosphate on potash-dressed soil, all phosphate-soaking treatments exhibited yield increases.

Effect on Straw Yields.—Table 6 presents the variance analysis of straw yields. Both phosphate and potash produced large effects on the straw yields. Potash added to the soil increased the straw significantly, and there is an indication of a positive interaction between potash and phosphate.

The phosphate soaking as a whole significantly increased the yields of straw. Except for the anomalous figures for 20 per cent. phosphate on potash-dressed soil, the straw yields rose with increasing concentration of phosphate.

TABLE 5

Yields of Grain and Straw in Experiment II

		<i>Muriate of Potash</i>							
		<i>None</i>				<i>0.0025%</i>			
		<i>Control</i>	<i>Seed soaked in K₂HPO₄</i>			<i>Control</i>	<i>Seed soaked in K₂HPO₄</i>		
			<i>5%</i>	<i>10%</i>	<i>20%</i>		<i>5%</i>	<i>10%</i>	<i>20%</i>
Grain	Mean per 10-plant pot in gm. . .	7.1	7.7	7.7	8.1	11.6	12.2	13.1	10.7
	Per cent. . .	100	108.5	108.5	114.1	163.4	171.8	184.5	150.7
Straw	Mean per 10-plant pot in gm. . .	22.9	24.0	23.9	25.8	29.4	35.9	41.7	34.0
	Per cent. . .	100	104.8	104.4	112.7	128.4	156.8	182.1	148.5

TABLE 6

Analysis of Variance of Straw yield in Experiment II

	<i>Degrees of Freedom</i>	<i>Sum of Squares</i>	<i>Mean Square</i>	<i>Variance Ratio</i>	<i>5 per cent. point</i>	<i>1 per cent. point</i>	<i>0.1 per cent. point</i>
Treatments . .	3	885.96	295.32				
Phosphate . .	1	100.59	100.59	6.06*			
Potash . .	1	742.59	742.59	44.71†	4.35	8.10	14.82
Interaction . .	1	42.78	42.78	2.58			
Error . .	20	332.19	16.61				
Total . .	23	1,218.15					

Percentage standard error : ± 13.8 .

* Significant at 5 per cent. point.

† Significant at 0.1 per cent. point.

ABSORPTION OF PHOSPHATE BY PADDY SEED

The results of determinations of the intake of phosphate by seed of the variety used in the preceding experiments from 5, 10 and 20 per cent. solutions of dipotassium hydrogen phosphate, are presented in Table 7. Controls with tap water as the soaking solution are included. Parallel determinations were made on seed washed in 10 changes of distilled water, and on unwashed seed. The loss on washing was expected to provide an estimate of the quantity seated on the outer surface of the husk (lemma & palea). After air drying, the husk was separated from the rice, and determinations of the P_2O_5 content of the two components were made.

Table 7 indicates that quantities of P_2O_5 , ranging from 0.15 gm. to 0.27 gm. were absorbed by 100 gm. of seed. Slightly over half the quantity of P_2O_5 taken up is removed by washing, and may be assumed to be deposited on the outer surface of the husk. The greater part of the remaining fraction is seated inside the tissues of the husk and very little, if any, of the P_2O_5 taken up appears to have entered the kernal.

TABLE 7

The content in P_2O_5 of components of Soaked SeedDistribution of P_2O_5 in 100 gm.
Quantities of oven-dried Seed

Soaking Solution	Unwashed			Washed		
	Husk	Rice	Total	Husk	Rice	Total
Tap water	0.04 gm.	0.68 gm.	0.72 gm.	0.04 gm.	0.68 gm.	0.72 gm.
5% K_2HPO_4	0.19 "	0.76 "	0.95 "	0.10 "	0.72 "	0.82 "
10% K_2HPO_4	0.17 "	0.70 "	0.87 "	0.14 "	0.68 "	0.82 "
20% K_2HPO_4	0.19 "	0.80 "	0.99 "	0.18 "	0.68 "	0.86 "

SUMMARY

In pot experiments set down at Peradeniya, with the paddy pure line, *Pachchaiperumal 2462/11*, significant and striking increases in the yield of both grain and straw were obtained by soaking seeds in phosphate solutions. Forty-eight hours' soaking in 5, 10 and 20 per cent. K_2HPO_4 produced significant increases in the yield of grain of 20.3, 18.8 and 36.2 per cent. over the control. Forty-eight hours' soaking in 10 and 20 per cent. Na_2HPO_4 gave significant increases in the yield of grain of 36.2 and 29.0 per cent. over the control.

Soaking in phosphate solutions delayed germination, the delay increasing *pari passu* with concentration of solution and duration of soaking.

Determinations of the quantities of phosphate that had entered the soaked grain were made.

PART II—FIELD EXPERIMENTS

Experiment I

The seed soaking treatments that had shown promise in pot experiments were tested on a field scale at the Experiment Station, Maha-Illupalama, in the *Maha* season, 1948-49. In this experiment, three concentrations of dipotassium hydrogen phosphate, viz., 0, 5 and 10 per cent., and two durations of soaking, viz., 24 and 48 hours, were tested with two 3-months pure lines, viz., *Pachchaiperumal 2462/11* and *Dahanala 37 YM 2014*. The design was factorial.

Material and Methods.—The twelve treatments were distributed over three randomized blocks each of twelve 1/170-acre plots. The land was ploughed, harrowed and levelled in the usual way, but received no manure. The plots were broadcast with sprouted seed on January 3, 1949. Each plot was sown with $\frac{1}{2}$ lb. (227 gm.) of seed which had been soaked in 227 ml. of the appropriate solution.

Results.—Three-weeks-old plants derived from phosphate-soaked seed developed a more marked green colour than the controls. This colour difference persisted up to the sixth week.

Flowering records showed no effect of the soaking treatments on age. The analysis of variance of the yields of grain given in Table 8 indicated the superiority of *Pachchaiperumal 2462/11* over *Dahanala 37 YM 2014*. The percentage standard error of the experiment was 9.6. The results are presented below in the two two-way Tables 9 and 10.

TABLE 8
Analysis of Variance of Grain Yields in Field Experiment I

	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio	Five per cent. Point	One per cent. Point
Treatments ..	11	30.759	2.796			
Pure lines ..	1	22.189	22.189	20.5	4.30	7.94
Phosphate concentrations ..	2	5.082	2.541	2.3	3.44	5.72
Soaking durations ..	1	0.002	0.002			
Interactions—						
Pure lines × concentrations ..	2	0.817	0.408			
Pure lines × durations ..	1	0.406	0.406			
Concentrations × durations ..	2	2.102	1.051			
Pure lines × concentrations × durations ..	2	0.161	0.080			
Blocks ..	2	0.666	0.333			
Error ..	22	23.785	1.081			
Total ..	35	55.210				

TABLE 9
Yields of Grain in Field Experiment I

Variety Soaking Solution	<i>Pachchaiperumal</i> 2462/11	<i>Dahanala</i> 37 YM 2014	Mean
Distilled water ..	2,065 lb./acre 90.6 per cent.	2,494 lb./acre 109.4 per cent.	2,279 lb./acre 100.0 per cent.
5 per cent. K_2HPO_4 ..	1,972 lb./acre 86.5 per cent.	2,227 lb./acre 97.7 per cent.	2,100 lb./acre 92.1 per cent.
10 per cent. K_2HPO_4 ..	2,098 lb./acre 92.0 per cent.	2,453 lb./acre 107.6 per cent.	2,276 lb./acre 99.9 per cent.
Mean ..	2,045 lb./acre 89.7 per cent.	2,391 lb./acre 104.9 per cent.	

TABLE 10
Yields of Grain in Field Experiment I

<i>Soaking Duration Soaking Solution</i>	<i>24 hours</i>	<i>48 hours</i>	<i>Mean</i>
Distilled water	.. 2,227 lb./acre 97·7 per cent.	.. 2,231 lb./acre 102·3 per cent.	.. 2,229 lb./acre 100·0 per cent.
5 per cent. $K_2 HPO_4$.. 2,083 lb./acre 91·4 per cent.	.. 2,116 lb./acre 92·8 per cent.	.. 2,100 lb./acre 92·1 per cent.
10 per cent. $K_2 HPO_4$.. 2,350 lb./acre 103·1 per cent.	.. 2,202 lb./acre 96·6 per cent.	.. 2,276 lb./acre 99·9 per cent.
Mean	.. 2,220 lb./acre 97·4 per cent.	.. 2,183 lb./acre 97·2 per cent.	

Experiment II

This experiment tested the effect of soaking seed of the 4-months selections, *Vellai-ilankalayan 28061* and *Honderawala 868*, for 48 hours in a 10 per cent. solution of disodium hydrogen phosphate. Controls which had been soaked in distilled water for the same period were maintained.

Material and Methods.—In the instance of each of the four treatments, 3 lb. (1361 gm.) of seed were soaked in 1361 ml. for 48 hours, and the sprouted seed was sown in 300 sq. ft. of nursery on December 8, 1948. The seedlings were transplanted at the rate of three per hill, in hills spaced six inches apart, to six randomized blocks each of four 1/150-acre plots. Neither the nursery nor the field plots received any manure.

Results.—Striking superiority in vigour and height of plants derived from phosphate-soaked seed was noted 10 days after transplanting. These plants were, moreover, darker green. Height measurements of random samples of 25 plants in three of the blocks, made on February 21, 1949, are given below in Table 11. By this date, the benefit of the phosphate soaking was evident only in *Honderawala 868*.

TABLE 11
Mean Plant Height in Field Experiment II

<i>Pure Line Soaking Solution</i>	<i>Vellai-ilankalayan 28061</i>	<i>Honderawala 868</i>	<i>Mean</i>
Distilled water	.. 105·0 cm. 103·5 per cent.	.. 97·9 cm. 96·5 per cent.	.. 101·5 cm. 100·0 per cent.
10 per cent. $Na_2 HPO_4$.. 104·5 cm. 103·0 per cent.	.. 104·8 cm. 103·3 per cent.	.. 104·7 cm. 103·1 per cent.
Mean	.. 104·8 cm. 103·2 per cent.	.. 101·4 cm. 99·9 per cent.	

Flowering records revealed no effect of soaking treatments. The analysis of variance of grain yields given in Table 12 demonstrated the significant and striking superiority of *Vellai-ilankalayan 28061* over *Honderawala*

868. The phosphate soaking showed no significant benefit. The experiment had a standard error of 7.8 per cent. The yields of grain are presented below in the two-way Table 13.

TABLE 12
Analysis of Variance of Grain Yields in Field Experiment II

	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio	Five per cent Point	One per cent. Point
Varieties ..	1	130.378	130.378	124.86	4.54	8.68
Soaking treatments ..	1	2.098	2.098	2.00	4.54	8.68
Interaction ..	1	2.080	2.080	1.99	4.54	8.68
Blocks ..	5	61.867	12.373			
Error ..	15	15.675	1.045			
Total ..	23	256.098				

TABLE 13
Yields of Grain in Field Experiment II

Soaking Solution	Variety	Vellai-ilankalayan 2061	Honderawala 868	Mean
Distilled water		3,562 lb./acre	2,748 lb./acre	3,155 lb./acre.
		112.9 per cent.	87.1 per cent.	100.0 per cent.
10 per cent. Na ₂ HPO ₄		3,562 lb./acre	2,445 lb./acre	3,004 lb./acre
		112.9 per cent.	77.5 per cent.	95.2 per cent.
Mean		3,562 lb./acre	2,597 lb./acre	
		112.9 per cent.	82.3 per cent.	

DISCUSSION

In the field, there were in plants derived from phosphate-soaked seed, early but evanescent indications of superiority in vegetative vigour. The failure to reproduce the yield increases obtained in preliminary pot experiments may find an explanation in the lower degree of precision of the field trials, or in limiting soil factors. It is not possible to pronounce on the value of the pretreatment technique without extensive and exact experiments with various-placement methods and with a wide range of soil types.

The height measurements in the second experiment suggest a variety-treatment interaction within the same age class. Information is desired on the effect of age on response to phosphate-soaking. On the assumption that effects on yield are likely to be more marked when the sowing-harvest interval is short, preliminary trials have been confined to 3 and 4-months paddies. If however, the accumulation of early phosphate-soaking benefits follows Blackman's compound interest law, the longer-aged varieties are likely to show more striking yield responses.

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