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STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

7. The Alluvial Sandy Soil at Pothukulama

by

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SUMMARY

Seven experiments were carried out with the alluvial soil from Pothukulama to assess its nutrient status.

The soil was found to be deficient in N, P, K and S.

In absence of added nitrogen the relative yields (NPK=100) quickly dropped to 10%. It is suggested that the most effective form and method of nitrogen fertilization would be to apply ammonium sulphate in small and frequent doses.

Phosphorus was equally deficient and in the absence of applied phosphorus there was very little plant growth at the early stages. There was however a temporary elevation where relative yields rose from 10% to 40%, but they dropped back to 10% later. The lowest rate of applied phosphorus (3cwt. $NaH_2PO_4 . 2H_2O$) gave maximum yields. It is highly probable that a smaller rate (1½ cwt.) would be equally effective.

Potassium was less effective at the early stages of growth, but with time (120 days) relative yields dropped to below 10%. Of the rates studied the lowest applied (3 cwt. K_2SO_4) gave maximum yields at the first harvest. At the third harvest there was a linear response to the various levels of applied potassium. A point of interest was the progressive drop in yield at all levels with time. Here again small and frequent doses would be beneficial.

The soil was found to be highly deficient in sulphur and an application of 56 lb. elemental sulphur would meet all demands of plants.

The Pothukulama soil was not deficient in calcium, magnesium and the trace elements.

INTRODUCTION

Pothukulama is situated in the Chilaw district about two miles south of Ambakelle. The natural vegetation is low tropical forest. Patches have been cleared at different times for planting to coconuts. Recently the area has been cleared extensively for Middle Class Colonisation. The Coconut Research Institute has acquired 200 acres of the forest for experimentation with coconuts from the seedling stage onwards.

Perera (1962) has described the soil as an alluvial sand, similar in origin to that at Ambakelle studied by *Paltridge and Salmond* (1957), *Santhirasegaram and Salmond* (1958) and *Santhirasegaram and Ferdinandez* (1959).

Samples were taken from under forest, new clearing and from under an old stand of coconuts. The results from the three soil conditions were similar and only the soil from under forest is described here in detail. These would be comparable with the results obtained with the Ambakelle soil.

In collecting soil samples, setting up and maintaining experiments and recording data, the techniques adopted by *Paltridge and Santhirasegaram* (1957) were followed. Samples were taken at two depths: 0 ″-9 ″ and 9 ″-18 ″ designated "top-soil" and "sub-soil" respectively.

EXPERIMENTAL

(a) Experiment to assess the status of major nutrients (N,P,K,Ca and Mg).

This was a 2^5 factorial of two levels of the five nutrients with two replicates of all treatments planted to *Paspalum commersonii,* and one replicate planted to *Phaseolus lathyroides.*

All nutrients were applied as solution in forms and rates given in Table 1, except Ca which was applied as $CaCO_3$ powder and mixed with the top $1\frac{1}{2}$ ″ of the soil. A basal application of the minor nutrients (Fe, Cu, Zn, Mn, Mo and B) was made.

P.commersonii was harvested on three occasions in the top-soil and on two occasions in the sub-soil. *P.lathyroides* was harvested twice in both soils. "Thinnings" at an early stage of growth was made in all experiments to provide additional information.

TABLE—1

Forms and rates of nutrients applied

Designation	*Chemical*	*Rate of application/acre*
N_5	$(NH_4)_2SO_4$	5 cwt. = 118 lb.N + 135 lb. S
P_3	$NaH_2PO_4.2H_2O$	3 cwt. = 67 lb.P + 49 lb.Na
K_3	K_2SO_4	3 cwt. = 150 lb.K + 70 lb.S
Ca_{10}	$CaCO_3$	10 cwt. = 440 lb.Ca
$Mg_{1\frac{1}{2}}$	$MgSO_4.7H_2O$	$1\frac{1}{2}$ cwt. = 18 lb.Mg + 21 lb.S
Fe_7	$FeSO_4.\ 7H_2O$	7 lb. = 1.4 lb.Fe + 1.3 lb.S
Cu_7	$CuSO_4.\ 5H_2O$	7 lb. = 1.8 lb.Cu + 0.9 lb.S
Zn_7	$ZnSO_4.\ 7H_2O$	7 lb. = 1.5 lb.Zn + 0.8 lb.S
Mn_7	$MnSO_4.\ 4H_2O$	7 lb. = 1.8 lb.Mn + 1.0 lb.S
Mo_1	$(NH_4)_6Mo_7.\ 24H_2O$	1 lb. = 0.5 lb.Mo + 0.07 lb.N
B_3	$Na_2B_4O_7.10H_2O$	3 lb. = 0.13 lb.B + 0.13 lb.Na

(b) Experiment to assess the status of S.

This was a simple comparison of $SO_4^=$ against Cl^- of K, Mg and H (acids); $CO_3^=$ of Ca and S as element against nil. All nutrients were applied in equivalent quantities. N and P were applied as basal in the form of NH_4NO_3 and $NaH_2PO_4.\ 2H_2O$ respectively. The various nutrients other than S were balanced in all treatments by the application of the non $SO_4^=$ forms.

The experiment was planted to *P.commersonii* and *P.lathyroides* on the top soil only and harvested on two occasions.

(c) Experiment to assess the status of minor nutrients (Fe,Cu,Zn and Mn).

This was a 2^4 factorial of two levels of the four nutrients planted to *P.commersonii* and *P.lathyroides* on the top and sub-soils. All other nutrients were applied as basal. The nutrients under study and those applied as basal were in forms and rates as shown in Table 1.

The experiment was harvested on two occasions for both species in the two soils.

(d) Experiment to assess the status of Mo and B.

This was a $2^2 \times 3$ factorial of two levels of Mo and B, and 3 forms of Ca ($Ca(OH)_2$, $CaCO_3$ and $CaSO_4 . 2H_2O$) with equivalent quantities of Ca. All other deficient nutrients were applied as basal in forms and rates shown in Table 1.

The experiment was planted to *P.lathyroides* and *Medicago sativa* in the top soil only and harvested on two occasions.

(e) Experiment to study the effect of forms of N and Ca.

This was a 4^2 factorial of four forms of N(Nil, NH_4NO_3, $(NH_4)_2SO_4$ and $CO(NH_2)_2$ at 118 lb.N/ac.) and Ca (Nil, $Ca(OH)_2$, $CaCO_3$ and $CaSO_4 . 2H_2O$ at 440 lb. Ca/ac.). A basal application of P, K and Mg at rates and forms given in Table 1 was made.

The experiment was planted to *P.commersonii* in the top soil only and harvested on two occasions.

(f) Experiment to determine the optimum dosage of P,K and Mg.

This was a 4^3 factorial of four levels of P (0, 3, $4\frac{1}{2}$ and 6 cwt/ac. $NaH_2PO_4 . 2H_2O$), K(0, 3, $4\frac{1}{2}$ and 6 cwt/ac. K_2SO_4) and Mg (0, 1, 2 and 3 cwt/ac. $MgSO_4 . 7H_2O$). A basal application of N and Ca in forms and rates given in Table 1 was made.

The experiment was planted to *P.commersonii* in the top soil only and harvested on two occasions.

(g) Experiment to determine the optimum dosage of S.

This was a comparison of the effect of five levels of S (0, $\frac{1}{2}$, $1\frac{1}{2}$ and 2 cwt/ac. elemental S). A basal application of NH_4NO_3(118 lb. N/ac.), $N_aH_2PO_4 \cdot 2H_2O$(67lb. P/ac.), KCl(150 lb. K/ac.), $CaCO_3$(440 lb. Ca/ac.) and $MgCl_2$ (18 lb. Mg/ac.) was made.

The experiment was planted to *P.commersonii*, *P.lathyroides* and *M.sativa* in the top-soil only and harvested on two occasions.

RESULTS

(a) Major nutrients (N.P.K. Ca and Mg)

Except for some minor negative interactions at the early stages of growth ("thinning"), calcium and magnesium were without effect in either soil. Phosphorus had highly significant positive effect at all stages of growth of both species in the two soils. Nitrogen also had similar effect on the grass, but was less marked on the legume. In the top-soil, potassium almost doubled the yield of both species particularly in presence of nitrogen and phosphorus. In the sub-soil however, while it had similar effect on the grass as in the top-soil, there was little or no effect on the growth of the legume. The cumulative effect of these three nutrients in all combinations on the two species in the two soils are given in Table 2.

TABLE—2

The total yield (gm.dry matter/pot) from the first two harvests of *P. commersonii* and *P.lathyroides* grown in the top and sub-soils from Pothukulama with the addition of N, P and K in all combinations

	Top Soil		*Sub Soil*	
	P.c.	*P.l.*	*P.c.*	*P.l.*
Nil	1.12	0.73	0.13	0.27
N	3.71	1.96	0.13	0.43
P	2.62	4.99	0.24	5.30
K	2.30	0.89	0.17	0.59
NP	9.40	5.68	3.61	5.71
NK	5.55	0.89	0.08	0.04
PK	3.42	7.16	0.22	5.57
NPK	17.85	8.17	6.97	5.29
L.s.d. (5 %)	2.13	0.42	0.55	0.17
(1 %)	2.86	0.63	0.74	0.25
(0.1%)	3.76	1.02	0.97	0.41

The effect of the three nutrients changed with time. These are shown in Fig. 1 for *P.commersonii* in the top-soil, where the yield in absence of a particular nutrient is calculated as a percentage of the yield from the complete fertilizer. (NPK).

In the absence of nitrogen, a relative yield of 50% was recorded for the "thinnings" which decreased to 25% at the first harvest, and thereafter decreased gradually to 10% at the third harvest. In the absence of phosphorus the pattern was different. From an initial value of 10% it increased linearly to 40% at the second harvest, and then dropped again to 10% at the next harvest. In the absence of potassium, relative yields around 70% were recorded up to the first harvest. At the next harvest it dropped to 30% and at the final harvest a value of 10% was recorded.

(b) Sulphur

All sources of sulphur increased the yields of both species, potassium sulphate more so than the others (Table 3).

The response from *P.lathyroides* was less marked than from *P.commersonii*.

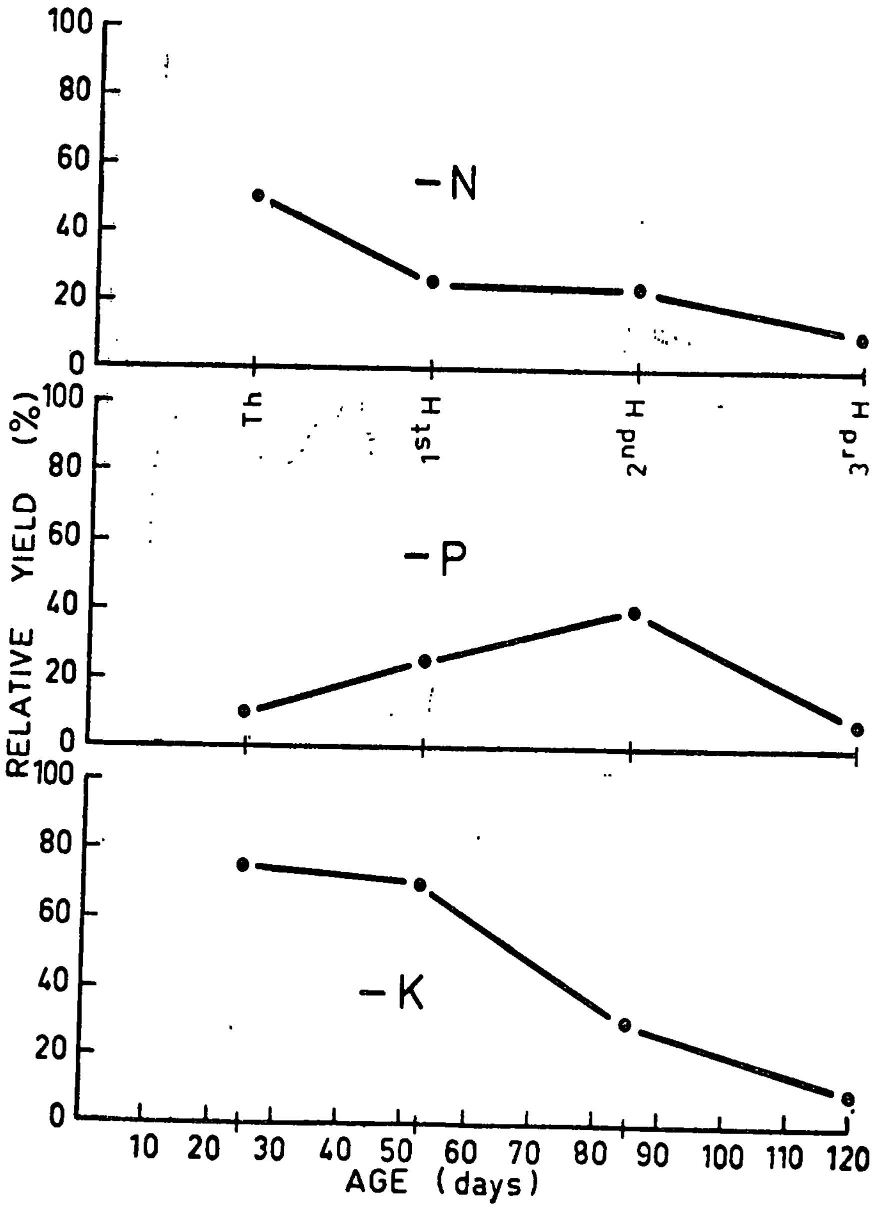

Fig. 1 Relative yield of *P. commersonii* with time in the top soil from Pothukulame in absence of N, P and K.

TABLE—3

The total yield (gm. dry matter/pot) from two harvests of *P.commersonii* and *P.lathyroides* grown in presence and absence of sulphur in the top soil from Pothukulama

	P.commersonii		*P.lathyroides*	
	Nil	*S*	*Nil*	*S*
K	2.43	10.21	2.75	9.20
Ca	3.81	6.05	4.45	6.60
Mg	5.58	7.85	3.98	6.07
Acid	4.57	8.18	3.91	6.40
Element	5.16	9.20	3.71	6.25
Mean	4.39	8.30	3.76	6.90
L.s.d. for any comparison,	5%=1.30 1%=2.15 0.1%=4.03			

(c) Minor nutrients (Fe, Cu, Zn, and Mn)

None of the tested nutrients had any effect on plant growth. Iron had entered into some minor negative interactions with copper and zinc which were however not consistent.

(d) Molybdenum and Boron with different forms of Calcium

Calcium hydroxide (lime) depressed yields of both species at the first harvest (Table 4). At the second harvest, while this was maintained with *P.lathyroides*, there was no significant effect from the forms of calcium on *M.sativa.*

TABLE—4

Yield (gm. dry matter/pot) in presence of three forms of calcium of *P.lathyroides* and *M.sativa* grown in the top soil from Pothukulama

	1st Harvest		*2nd Harvest*	
	P.l.	*M.s.*	*P.l.*	*M.s.*
$Ca(OH)_2$	1.76	1.69	2.12	1.40
$CaCO_3$	2.91	2.97	2.67	1.36
$CaSO_4.2H_2O$	2.93	2.71	2.54	1.20
L.s.d. 5%	0.17	0.39	0.07	0.13
1%	0.24	0.56	0.10	0.19
0.1%	0.34	0.79	0.14	0.27

Molybdenum and boron had no effect on the growth of *M.sativa*. With *P.lathyroides* however and particularly at the second harvest, boron alone, and boron and molybdenum in combination entered into interaction with forms of calcium. In the presence of calcium hydroxide (lime) there had been some improvement in yield due to added boron (Table 5) while the reverse held with calcium sulphate. These effects were more pronounced in presence of molybdenum. The two nutrients did not interact with calcium carbonate.

TABLE—5

Yield (gm. dry matter/pot) from the second harvest of *P.lathyroides* grown in the top soil from Pothukulama with the addition of three forms of calcium and two levels of molybdenum and boron in all combinations

	Nil	*B*	*Mo*	*B.Mo*
$Ca(OH)_2$	1.99	2.23	1.95	2.33
$CaCO_3$	2.68	2.86	2.51	2.64
$CaSO_4 \cdot 2H_2O$	2.60	2.42	2.76	2.37
L.s.d. for any comparison	5%=0.28 1%=0.39 0.1%=0.56			

(e) Forms of Nitrogen and Calcium on P.commersonii

At the first harvest (Table 6) there was significant increase in yields from all forms of nitrogen, compared to the nil treatment. The basic forms of calcium ($Ca(OH)_2$ and $CaCO_3$) depressed yields slightly. In the absence of added calcium, ammonium sulphate was superior to the others,

TABLE—6

Yield (gm. dry matter/pot) of *P.commersonii* at the first harvest grown in the top soil from Pothukulama with the application of different forms of calcium and nitrogen in all combinations

	Nil	*$Ca(OH)_2$*	*$CaCO_3$*	*$CaSO_4$*	*Mean*
Nil	4.41	4.42	3.56	4.68	4.27
NH_4NO_3	11.48	8.94	11.75	14.16	11.57
$(NH_4)_2SO_4$	13.85	9.10	10.20	12.71	11.47
$CO(NH_2)_2$	10.14	10.26	10.02	11.05	10.37
Mean	9.97	8.26	8.90	10.65	
L.s.d. for any comparison,	5%=3.10 1%=4.29 0.1%=5.93				

particularly urea. In the presence of the basic forms of calcium ($Ca(OH)_2$ and $CaCO_3$), ammonium sulphate was less effective than in their absence and was equal to that of urea. With the acidic form of calcium there had been some improvement in all forms of nitrogen, notably ammonium nitrate.

At the second harvest these trends were maintained but they were not significant.

(f) Optimum dosage of Phosphorus, Potassium and Magnesium

Magnesium had no effect on growth at any stage. There was a significant increase in yield from the nil to the first level of added phosphorus (P_3). Thereafter there was no significant increase. This pattern was consistent with time (Table 7). The response to potassium was similar

TABLE—7

Yield (gm. dry màtter/pot) of *P.commersonii* at successive harvests grown in the top soil from Pothukulama with the application of four levels of phosphorus

	Harvest 1	*Harvest* 2	*Harvest* 3	*Mean*
Nil	0.28	1.08	0.60	0.65
P_3	7.23	5.44	3.31	5.33
$P_{4\frac{1}{2}}$	7.42	5.19	3.65	5.42
P_6	7.06	4.79	3.80	5.22
L.s.d. (5%)	0.12	0.29	0.21	0.21
(1%)	0.16	0.39	0.28	0.28
(0.1%)	0.21	0.47	0.37	0.35

to that of phosphorus at the first two harvests. At the third, however there was a linear response to the four levels. (Fig. 2). The response to the various levels of phosphorus and potassium at the first harvest are shown in Plates 1 and 2.

(g) Optimum dosage of Sulphur

In all three species a high response to the first added level of sulphur ($S\frac{1}{2}$) over the nil treatment was obtained. Thereafter there was no significant change in the yields to the higher levels of sulphur (Table 8).

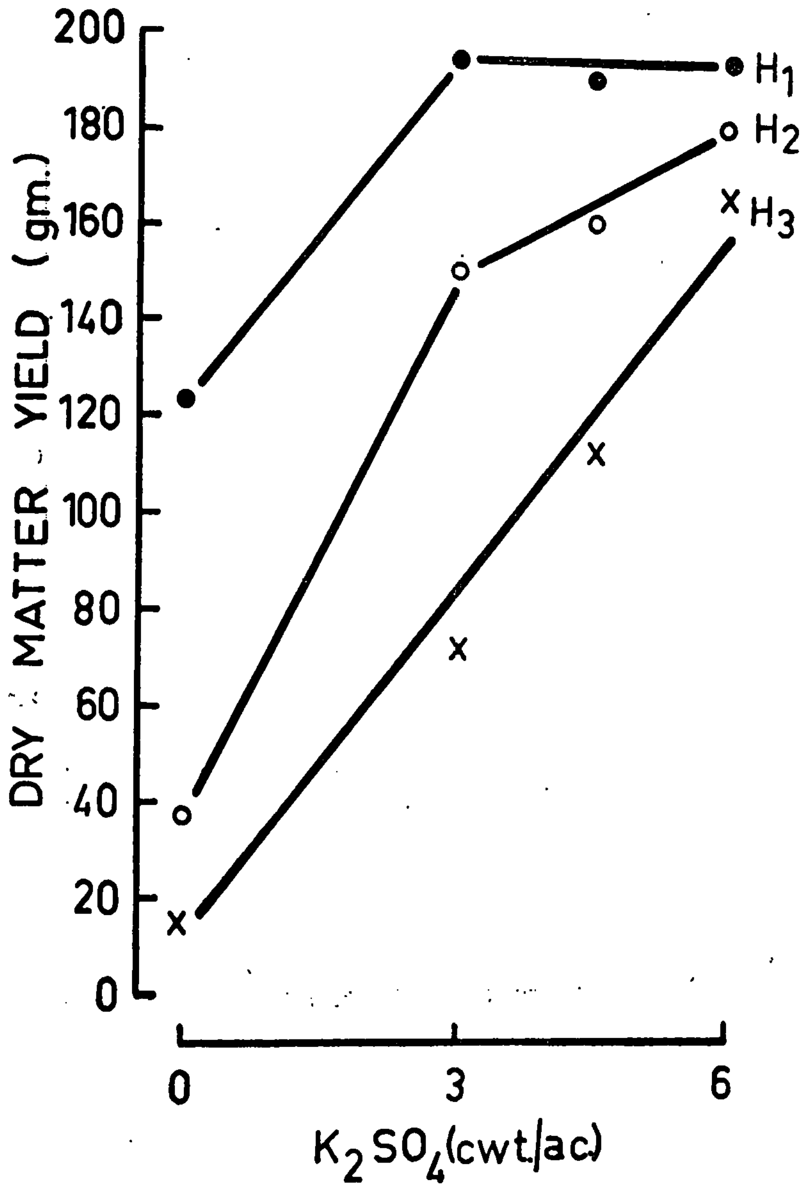

Fig. 2. Dry matter yield of *P.commersonii* at successive harvests to levels of K in the top soil from Pothukulama.

TABLE—8

Total yield (gm. dry matter/pot) from the first two harvests of three species grown in the top soil from Pothukulama at different levels of sulphur application

	P.c.	*P.l.*	*M.s.*	*Mean*
Nil	4.37	1.80	1.77	2.65
$S_{\frac{1}{2}}$	19.55	7.29	6.14	10.99
S_1	17.31	6.74	6.17	10.07
$S_{1\frac{1}{2}}$	18.94	7.23	6.07	10.75
S_2	18.74	7.47	5.71	10.64
L.s.d. (5%)	3.06	0.83	1.82	1.90
(1%)	5.08	1.37	3.01	3.15
(0.1%)	9.50	2.56	5.64	5.90

DISCUSSION

The alluvial soils from Pothukulama would require application of nitrogen for proper growth of plants at all stages, with the exception of legumes, which have the ability to nodulate effectively. In the case of grasses yields would be reduced to below 10% of the potential possible if sufficient nitrogenous fertilizers are not applied. No attempts were made to study the optimum requirements of this nutrient due to the already established fact that in similar soils from Ambakelle (*Santhirasegaram and Salmond* 1958) frequent applications of small doses of nitrogenous fertilizers would be more efficient than occasional large doses.

Application of phosphorus was also found to be necessary at all stages of growth. It is a matter of interest to note that relative yields in absence of phosphorus rose from an initial value of 10% to 40% at the second harvest but dropped back to 10% at the next harvest. With the Ambakelle soils however, *Paltridge and Salmond* (1957) observed a similar change in response but the changes there were very much less marked and relative yields did not drop below 40% at any stage.

In assessing the optimum requirements, the lowest level of applied phosphorus tested was 3 cwt./ac. $NaH_2PO_4.2H_2O$, and there was no further response to the higher levels tested. It would therefore appear that 3 cwt./ac. $NaH_2PO_4.2H_2O$ is the level of phosphorus application for optimum growth of plants in this soil. *Santhirasegaram* and *Salmond* (1958) observed that with the Ambakelle soils $1\frac{1}{2}$ cwt./ac. $NaH_2PO_4.2H_2O$ would be sufficient for optimum growth of plants. It Is therefore highly likely that in the Pothukulama soils too $1\frac{1}{2}$ cwt./ac. $NaH_2PO_4.2H_2O$ should be sufficient, at least as an initial application. In a separate study with the Pothukulama soils *Santhirasegaram* (1965) recorded that soluble forms of phosphates ($NaH_2PO_4.2H_2O$ and super phosphate) would be superior to the less soluble rock phosphate Saphos phosphate) particularly with *P.commersonii.*

Potassium was found to be deficient in this soil, the severity of which, increased between the second and third harvests. This pattern of low response at the early stages and then a sudden increase was observed with soils from Ambakelle too (*Paltridge and Salmond* 1957 and *Santhirasegaram and Ferdinandez* 1959). Here again, the lowest level of applied potassium was 3 cwt/ac. K_2SO_4. At the first harvest maximum response was observed at this level. At the next harvest there was some improvement from the other levels and at the third harvest there was a linear response with increasing levels of applied potassium. It must be pointed out that in this and similar experiments, on the assessment of optimum levels of a nutrient, except for the initial application of the nutrient, no further repetitions were made. Thus a change in the optimum level would indicate either progressive depletion by the plant of the nutrients and/or a gradual fixation by the soil. It has already been shown that there was a sudden drop in relative yields in absence of potassium, and *Paltridge and Santhirasegaram* (1957) suggested that such a pattern indicated fixation of potassium in the soil. Under such circumstances the initial application may be made sufficient to overcome the "saturation deficit" in the soil. It is however a matter of practical importance whether such an application is economically possible. On the other hand, smaller doses applied frequently would supply the immediate needs of the crop and gradually build up the level of the available potassium to the optimum level. There is a time lag between applications and fixation of potassium, and a considerable portion of a heavy dosage may be lost by leaching under tropical conditions. Further, fixation is a reversible process and the alternate wetting and drying of the soils, due to the alternate wet and dry seasons, also needs to be considered.

These soils are not deficient in magnesium or calcium.

Contrary to the finding of *Paltridge and Salmond* (1957) with the Ambakelle Soils, the Pothukulama soil has given very high response to sulphur. There has been significant differences between the forms of sulphur. While in all treatments, equivalent quantities of sulphur (123·6 lb/ac.S) was applied, it is not possible to explain the differences between forms. An application of 56 lb/ac. elemental sulphur would meet the demands of plants in this soil.

This high response to sulphur on the Pothukulama soil compared to the Ambakelle soil is of considerable interest. The two soils are similar in origin and to the best of our knowledge they are of similar history. *Perera* (1962) based on a soil survey has placed them in the same series.

The Pothukulama soil was not deficient in any of the minor nutrients (Fe, Cu, Zn, Mn, Mo and B).

The different forms of calcium on this soil have probably brought about a change in pH. The normal soil pH is 5.4. Application of $Ca(OH)_2$ (lime) would increase it drastically, $CaCO_3$ (lime stone) would cause slight increase in the pH while $CaSO_4.2H_2O$ (Gypsum) would decrease it. Under such pH regimes the responses obtained from the different forms of nitrogen could be explained. *Santhirasegaram and Rajaratnam* (1965) have demonstrated that the loss of nitrogen from urea was greater than from ammonium sulphate in sandy soils, but when lime was applied both forms of nitrogenous compounds lost higher and equal amounts of nitrogen.

Similar pH regimes have apparently influenced the availability of boron and molybdenum. The positive response to applied boron decreased with decrease in pH, indicating a decrease in the availability of soil boron with increase in pH, and applied molybdenum had enhanced this relationship.

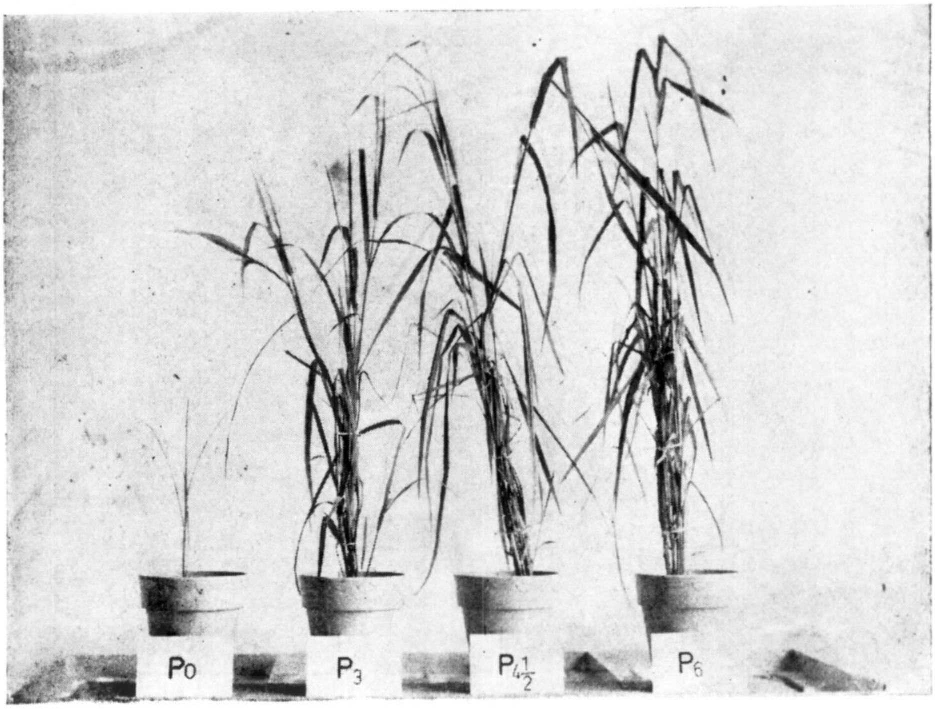

Plate 1. Growth of *P.commersonii* to levels of P at first harvest in the top soil from Pothukulama.

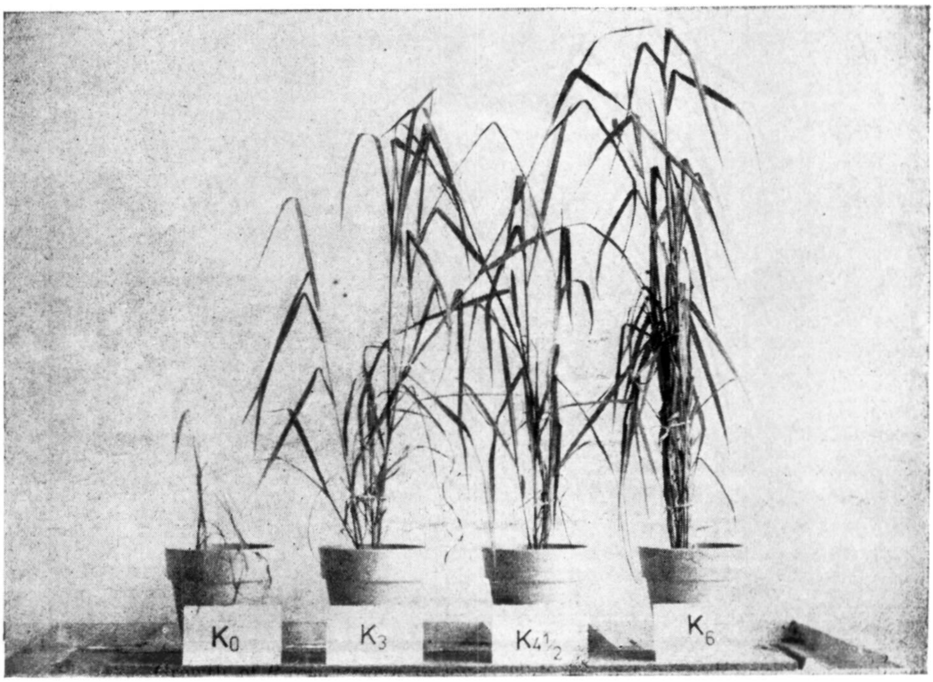

Plate 2. Growth of *P.commersonii* to levels of K at first harvest in the top soil from Pothukulama.

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