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# TROPICAL AGRICULTURIST

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JANUARY - DECEMBER, 1978

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THE DEPARTMENT OF AGRICULTURE

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# An Approach to Integrated Pest Control of Rice

NALLINI WICKRAMASINGHE

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## SUMMARY

In its efforts towards self sufficiency in the staple food, Sri Lanka's intensification of rice culture has caused an aggravation of rice pests. Yield losses due to insect damage recorded in experiments range between 17-61%. There is thus an immediate need for a proper pest control program if rice production increases are to be sustained. Insecticides alone cannot achieve this. They have to be used in combination with other control techniques, so as to avoid adverse side effects of these chemicals. A strategy known as integrated pest control could achieve this end but there are several constraints that prevent its early implementation. However, research findings indicate that several pest control techniques could be harmoniously combined so as to reduce over reliance on chemicals. In the absence of a pest monitoring system seven practices are recommended for insect control in the rice crop, which would discourage the build up of pests.

## INTRODUCTION

The urgent need for self-sufficiency in the staple diet over the last two decades has led to intensification of rice cultivation in Sri Lanka. The major inputs have been new varieties, balanced fertilizer applications and pesticide use. Rice yields have increased substantially from an average of 26 bushels per acre in the early fifties to 58 bushels per acre for the Maha cropping season in 1979/80. However, the extension of areas with double and triple cropping; the widescale replacement of hundreds of indigenous varieties with comparatively fewer high-yielding varieties; the increased usage of nitrogenous fertilizers and the indiscriminate use of persistent insecticides have caused an aggravation of the pest situation in the land.

The extent to which the rice crop is damaged by insect and other pests varies greatly in time and place. On the basis of field plots where the crop had received insecticidal protection throughout its growth, yield increases due to pest control ranging from 17-61 percent are possible. It is therefore apparent that a concerted effort to reduce pest damage would to a large extent bridge the current gap of 30% in attaining self-sufficiency in rice. But a pest control program to effect a significant and sustained increase in rice production cannot rely on routine pesticide schedules. The development of resistant strains of pest species, the upsurge of secondary pests the impact on non-target organisms and the spiralling cost of pesticides, limit their use.



*Pests of Rice in Sri Lanka*

The major pests of rice in Sri Lanka are the Brown plant hopper *Nilaparvata lugens*, the rice leaf folder *Cnaphalocrocis medinalis*, the gall midge *Orzeolia oryzae*, the paddy thrip *Baliothrips biformis*, the yellow stem borer *Tryporyza incertulas*, the white backed plant hopper *Sogatella forcifera*, the paddy field mole rat *Bandicoota bengalensis* and the paddy bug *Leptocoris vari-cornis*. From time to time and in localized areas, minor pests such as case bearer *Nymphula depunctalis*, the swarming caterpillar *Spodoptera mauritia*, the paddy stem fly *Atherigona exigua* and paddy field crabs of the genus *Paratelpusa* have flared into prominence. Though certain of the environmental factors that permit specific insect species to achieve pest status are known, the manipulation of these are not practicable. The rational approach is to manage the rice crop so as to reduce the build up of pests by all the practical methods now available, but once insect numbers reach economic damage levels, chemical measures are the only dependable tools. However, alternative techniques (based on the ecology of the pest species) which would selectively affect the target organism alone, are available only for specific situations.

*Integrated Pest Control*

The ecological approach to minimize pest damage is far from new, nevertheless, as an aftermath of the over reliance on chemicals during the post, World War II era, this concept was relabelled as integrated pest control (Smith and Reynolds 1966). An incisive definition made by Van den Bosch *et al* 1971 is as follows:—

“Integrated control is a pest population management system that utilizes all suitable techniques either to reduce pest populations and maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing such injury. Integrated control achieves this ideal by harmonizing techniques in an organized way, by making the techniques compatible and by blending them into a multifaceted flexible system. In other words, it is an holistic approach aimed at minimizing pest impact while simultaneously maintaining the integrity of the ecosystem.” The underlying principle is comprehensible and convincing. However, integrated pest control cannot always be immediately realized in practice as a high level of expertise is essential for the execution of such a programme (FAO 1966). Background knowledge even at a minimum level is required on

- a. the bionomics of the key pests,
- b. the approximate threshold levels of the pest population at which crop protection measures are required,
- c. the significant natural enemies and the times and places of their occurrence,



## AN APPROACH TO INTEGRATED PEST CONTROL OF RICE

- d. the impact of control measures on the significant parasite predator or pathogen species.

Further, in order to establish an integrated programme, the monitoring of pests and ecological changes must be continued to detect the need for the establishment or modification of control procedures (Corbet & Smith 1976)

The high level of scientific background and the development of the feedback mechanism from the field, requires trained and permanent personnel at all levels of crop protection—research, surveillance, extension and administration. The lack of these is the major constraint in adopting a comprehensive programme of integrated control. Nevertheless, a beginning has been made with integration of a few straightforward techniques which embody the basic principles of integrated control.

### *The IPC Perspectives in Entomological Research*

Twenty five years of nonselective pesticide use have shown that the management of pests exclusively in terms of pesticidal efficacy was not technically sound. The change over from the routine prophylactic spray schedules for the control of stem borer—the then major pest of paddy—to intentional timed sprays was made in the mid sixties. Steiner (1965) considers the progressive decrease in the amount of pesticide applied to the environment as a first step towards integration. the next major step may have been taken when the search for genes resistant to insects and diseases of major importance was initiated. As a consequence, new varieties which have resistant genes to blast, gall midge, brown and white backed plant hoppers have been or are being developed by our scientists. Detailed information on the ecology of the key pests are by no means complete, but data on the impact of agronomic practices, natural enemies and the growth stage or duration of the host plant on the population dynamics of certain pests have been accumulating. These findings have enabled entomologists to modify their recommendations so as to avoid some of the adverse effects of pesticides which however will remain as the main weapon in reducing pest outbreaks to sub economic levels.

### *Available IPC Techniques*

For the regulation of major pests at levels that will not lead to substantial yield losses, the various techniques available are: (i) the selective use of chemicals; (ii) The preservation of natural enemies; (iii) the use of resistant varieties and (iv) several cultural and agronomic practices. These must be integrated in the manner advocated by Smith (1967), to achieve the “fullest practical utilization of the existing mortality and suppressive factors.” i.e. the integration of techniques with the naturally regulating and limiting parameters of the environment.



*The Selective Use of Pesticides*

Many of the recommended chemicals for controlling rice insects have a broad spectrum of activity, but their efficacy has been evaluated in terms of the degree of pest damage controlled, than on their ability to give 100% kill. Compared to Endrin and Parathion, the recommended chemicals are inherently less toxic compounds. Further, certain of these broad-spectrum insecticides BHC, Diazinon and Carbofuran, are used in an ecologically selective manner so that their greatest effect or impact is on the target species. This has been done by using granular formulations (for stem borer, gall midge and brown plant hopper) timed to coincide with either the most critical stage of the pest (stem borer and baits for paddy field mole rat) or of the host plant (gall midge, paddy bug) and in a restricted manner. The recommendation of a preventive treatment for nurseries was based on the fact that these are likely to become loci or reservoirs for pests that have migrated from ratoons, rice stubble or weeds in adjacent fields. The area so treated is small (usually about 1/10) in relation to the area that may require treatment once the pest is dispersed with the seedlings at transplanting. This tactic of using pesticides in restricted areas is also apparent in the use of chemicals in baits for crabs, mole rats and birds.

*Preservation of Natural Enemies*

Not all the natural enemies of a pest are significant in regulating pest populations. Before one makes an effort to protect beneficial organisms from the impact of chemical control measures, one has to determine which species are really suppressive. The identification and the evaluation of biological agents for their capacity to control pests has to be carried out. If they are efficient all efforts must be made to make full use of this factor which contributes to pest mortality.

The sporadic outbreaks of populations of the pentatomid bug, paddy swarming caterpillar and the rice leaf folder, in those high-risk rainfed tracts where fertilizer inputs are minimal and the crop is usually left unprotected or receives only partial protection, is mainly due to adverse environmental factors affecting the usually very efficient parasites of these pest species.

A careful study of the various natural enemies of the yellow stem borer has indicated that of the nine species parasitizing the immature stages of the host, only the egg parasites play a major role in regulating or limiting the pest. (Fernando 1970). The recommendation of broadcasting granules of Diazinon, BHC or Carbofuran into the standing water of rice fields, controls the borer feeding inside the plant leaving the balance in favour of the beneficial forms developing within the egg masses deposited on the leaves.



## AN APPROACH TO INTEGRATED PEST CONTROL OF RICE

In regulating plant hopper populations predatory spiders and the mirid bug act in a density dependent manner. The first symptom of hopper damage is generally localized patches of dead or dying plants. Close examination will reveal high pest numbers and usually significant populations of the predators, especially the green mirid bug. If these areas are very few or if they appear after grain hardening they should be observed over a two week period, giving a chance for the predators to operate. If, however, there be any sign of the damage spreading, or if there be widespread build-up of the pest in the tract, immediate action must be taken to treat the fields chemically. As the hoppers colonize the base of the plant, a granular application with a chemical having systemic or fumigant action would be ecologically preferable to the use of a spray which could have effects on non-target organisms such as the natural enemies of the rice leaf folder.

### *Resistant Varieties*

The breeding of high-yielding varieties with genes for resistance to a few key pests has been a heavy research input. Rice varieties in all three age-classes having gall midge resistance are in the pre-release stage. Varieties with Bph resistance are in yield trials this year. However, for those insect species which are highly adaptive to the host variety, there are indications that varietal resistance will not prove to be the major control strategy. This has been so in the case of Bph control in the Philippines, where biotypes have developed on resistant varieties. In this context in Bph endemic areas 3-3 1/2 month age resistant varieties would be suitable. Even if biotypes develop, the plants will escape injury, as the duration of the crop in the field is not sufficient for damaging populations of the third generation hoppers to develop.

### *Cultural Practices*

Several cultural practices used in rice cultivation are compatible with the above-mentioned techniques for controlling specific pests. The clearing and reforming of bunds necessary for efficient water management has an adverse effect on crabs and mole rats. Weeding of fields and slashing of weeds on bunds prior to flowering removes alternate hosts of gall midge, brown plant hopper and the paddy bug. Manipulation of the water level is very effective in limiting populations of plant hoppers, swarming caterpillars, case bearers and stem fly. The adoption of the transplanting method, instead of broadcasting seed, leads to natural reduction in brown plant hopper populations. The reverse holds for a minor pest-the whorl maggot. The optimal spacing for high yields and low hopper population for Bg 34-6 is 6"x6". However, both stem borer and gall midge in endemic areas could be more widely dispersed under transplanted conditions if preventive measures are not taken during the nursery period. Further, as water stress is experienced by transplants, thrips can be more damaging at this stage than under broadcast con-



ditions. The practice of multiple cropping or growing of an alternate Yala crop in the intermediate and dry zone tracts leads to marked reduction-populations of stem borer, whorl maggot and case bearer due to scarcity of their food source, while an increase in rat population is to be expected.

#### *Practices recommended for Rice Pest Control*

Rice is a low-value crop, and under rainfed conditions prone to high risk. To protect such a crop every measure should be taken to reduce the annual input of effort and money. The techniques to be used must meet the needs of the farmer and their adoption will be conditioned by climate, the existing cropping systems, the local pest species, the weed flora, the efficiency of water management and socio-economic factors.

Based on the available knowledge and in the absence of a surveillance or forecasting system to guide pest control, the following practices are strongly recommended for the rice crop:

1. Use resistant or tolerant varieties in areas endemic to specific pests.
2. Avoid staggered planting.
3. Use agronomic practices of spacing, fertilizer-level and high-yielding short-age varieties judiciously.
4. Encourage cultural practices that minimize pest problems-deep ploughing, manipulation of water level, slashing of weeds on bunds and clean weeding.
5. Raise nurseries (where feasible) and apply chemicals to obtain pest-free seedlings.
6. Use insecticides only on a need basis and when possible in a selective manner for Bph and stem borer.
7. Monitor Bph (by actual counts in the fields) and stem borer (by light traps or egg mass counts) for timing of insecticides.

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## AN APPROACH TO INTEGRATED PEST CONTROL OF RICE

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### ABSTRACT

The effect of Eppawala rock phosphate, fused Eppawala rock phosphate, sodium phosphate, fused ammonium phosphate, ammonium phosphate and acidulated superphosphate at 30 ppm P and 40 ppm P on the growth of paddy in a soil of pH 4.5. At the 30 ppm P level, acidulated superphosphate and Eppawala phosphate gave best while Eppawala rock phosphate, fused rock phosphate and ammonium phosphate gave poor results. At the 40 ppm P level, acidulated superphosphate gave best while Eppawala rock phosphate gave poor results. In general, acidulated superphosphate gave best results, especially at the higher level of P.

### INTRODUCTION

An acidic deposit was discovered at Eppawala, Sri Lanka in 1971. The total phosphorus content of the crushed rock varies from 14-15% and the citric acid soluble phosphorus content from 1 to 2.5% P. While the total phosphorus content compares favourably with other phosphate deposits in the world, the citric acid soluble P content is much lower in the Eppawala rock phosphate. However, the conversion of Eppawala rock phosphate by fusion with soda ash and acid to a product with a citric acid solubility of about 5.5-7.5% P has been reported (2). Sri Lanka imports about 40,000 tonnes of rock phosphate annually from the Middle East, the citric acid content of which is about 4.0 to 4.5% P.

While several field experiments have been conducted with fertilized rice which have shown that Eppawala rock phosphate does not fare well as a source of phosphate fertilizer (3), information on its performance on upland crops is very scant. In this study *Parasari* varietal was used as the test crop to compare Eppawala rock phosphate and its fused product with other phosphates.

### MATERIALS AND METHODS

A soil of pH 4.5 and medium bicarbonate soluble P of 3 ppm was used in the greenhouse experiment. Each pot contained 4.5 kg air dried soil particles

# AN APPROACH TO INTEGRATED FISHMANAGEMENT OF RICE

The main purpose of this paper is to present a preliminary approach to the problem of integrated fishmanagement in rice areas. The approach is based on the concept of integrated fishmanagement, which is defined as the management of fish resources in a way that is compatible with the management of other resources in the same area. This approach is based on the concept of integrated fishmanagement, which is defined as the management of fish resources in a way that is compatible with the management of other resources in the same area.

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1. The first step in the approach is to identify the fish resources in the area.
2. The second step is to identify the other resources in the area.
3. The third step is to identify the interactions between the fish resources and the other resources.
4. The fourth step is to identify the management objectives for the fish resources.
5. The fifth step is to identify the management objectives for the other resources.
6. The sixth step is to identify the management objectives for the integrated fishmanagement.
7. The seventh step is to identify the management objectives for the integrated fishmanagement.

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# Evaluation of Eppawela Rock Phosphate as a phosphate fertilizer for *Panicum maximum*

S. L. AMARASIRI

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## ABSTRACT

The effect of Eppawela rock phosphate, fused Eppawela rock phosphate, saphos phosphate, fused magnesium phosphate, Rhenania phosphate and concentrated superphosphate at 20 ppm P and 40 ppm P on the supply of phosphorus to *Panicum maximum* was studied in the greenhouse on a soil of pH 4.5. At the first cut concentrated superphosphate and Rhenania phosphate fared best while Eppawela rock phosphate fared worst, being not even better than the control. Eppawela rockphosphate improved in its effectiveness at the second cut but still fared poorly compared to the other phosphates. In comparison fused Eppawela rock phosphate fared better, especially at the higher level of P.

## INTRODUCTION

An apatite deposit was discovered at Eppawela, Sri Lanka in 1971. The total phosphorus content of the crushed ore ranges from 11-15% and the citric acid soluble phosphorus content from 1 to 2.5 % P. While the total phosphorus content compares favourably with other phosphate deposits in the world, the citric acid soluble P content is much lower in the Eppawela rock phosphate. However, the conversion of Eppawela rock phosphate by fusion with soda ash and silica to a product with a citric acid solubility of about 5.5-7.5% P has been reported (2). Sri Lanka imports about 40,000 tonnes of rock phosphate annually from the Middle East, the citric acid content of which is about 4.0 to 4.5%P.

While several field experiments have been conducted with flooded rice which have shown that Eppawela rock phosphate does not fare well as a source of phosphate fertilizer (7), information on its performance on upland crops is very scarce. In this study *Panicum maximum* was used as the test crop to compare Eppawela rock phosphate and its fused product with other phosphates.

## MATERIALS AND METHODS

A soil of pH 4.5 and sodium bicarbonate soluble P of 5 ppm was used in the greenhouse experiment. Each pot contained 4.5 kg air dried soil passing

through a 2 mm sieve. Six forms of phosphorus fertilizer namely, Eppawela, rock phosphate (ERP), saphos phosphate (SaP), Rhenania phosphate (RhP.) fused Eppawela rock phosphate (FERP), fused magnesium phosphate (FMP) and concentrated superphosphate (CSP) at 20 ppm P and 40 ppm P were used. In one treatment <sup>4</sup>phosphorous was not added. The thirteen treatments were replicated four times. Rhenania phosphate is a fertilizer product from West Germany manufactured by fusing phosphatite rock with soda ash and quartz at 1100° C, while fused Eppawela rock phosphatite was prepared similarly using Eppawela rock phosphate (2). The analyses of the two phosphates are given in Table 1. Total phosphorus was determined by digestion with concentrated hydrochloric acid and the available phosphorus determined by treatment with 2% citric acid (1). The phosphate fertilizers were mixed thoroughly with the soil which was then brought to field capacity. Ten seeds of *Panicum maximum* were sown to each pot. After establishment the seedlings were thinned to one plant per pot. The soils were maintained at field capacity throughout the experiment.

Two weeks after sowing 20 ppm N and 20 ppm K were added to all plots including the control. Six weeks after sowing a further 20 ppm N was added. Ten weeks after sowing the grass was cut 5 cm above ground level. The regrowth was fertilized in an identical manner to the primary growth except that no phosphorus was added. All additions of N and K were made in the form of ammonium sulphate and muriate of potash respectively. The grass was cut again 10 weeks after the first harvest. The plant material collected was dried to constant weight in an oven at 65° C digested in a mixture of hydrochloric, sulphuric and perchloric acids, and the phosphorus content determined by the vanado molybdate method (3).

For purposes of facilitating the comparison of a given phosphate source with concentrated superphosphate, the parameter Relative Phosphorus Supplying Index (RPSI) is used. This is calculated from the equation below for a specific level of phosphorus added, where  $P_0$ ,  $P_{ps}$ , and  $P_{csp}$  are the amounts of P uptake by the grass to which no phosphorus was added, to which the phosphate source under comparison was added, and to which CSP was added respectively.

$$RPSI = \frac{P_{ps} - P_0}{P_{csp} - P_0} \times 100$$

## RESULTS AND DISCUSSION

The effect of the phosphates on % P, and P uptake are given in Table 2. The % P values were low compared to those of many other plants, and did



## EPPAWELA PHOSPHATE AS FERTILIZER FOR P. MAXIMUM

not change significantly with type or amount of phosphate added, or with time of cutting, while the dry matter content varied widely. Perhaps a value of 0.06-0.10% P is on the higher side as far as this particular grass is concerned. In fact it has been reported that different grasses can have very variable P contents at their maximum yields (4).

At the first cut the lowest P uptake was from the control pot and ERP treated pots, while the highest P uptake was from the CSP and RhP pots. ERP was inferior to all other phosphates. CSP at second level had higher P uptake than SaP, FERP and FMP. There were no marked differences between SaP, FERP and FMP. The second level of FERP was inferior only to the second level of CSP. Of the six forms of phosphate only FERP and CSP showed a significant increase in P uptake on doubling the rate.

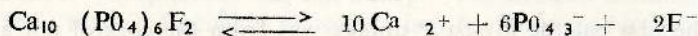
At the second cut the highest uptake was from CSP and the lowest from no phosphate pots. However, unlike at the first cut ERP had higher uptake than the control. There were no marked differences between the other phosphates. P uptake was significantly higher at the second level than the at first level in FERP, FMP and CSP. Here again the second level of FERP was inferior only to the second level of CSP.

All treatments showed a greater growth and a higher P uptake at the second cut than at the first cut, the mean values of P uptake for the first and second cuts for all treatments being 3.72 and 8.91 mg P/pot respectively. The effect of doubling the quantity of phosphorus on the sum total of phosphorus supplied to the plant during the first and the second cut are shown in Figure 1. From the slope of the ERP line it appears that even adding higher doses cannot expect to make it as effective as the other phosphates. Similar results have been reported (6) where, after incubating five soils of pH ranging from 4.8 to 5.5 with two levels of ERP, SaP and CSP for a period of one year, the highest available P content ( $\text{NaHCO}_3$  method) was observed for soil mixed with CSP and lowest for soil mixed with ERP. For some of these soils ERP did not lead to any increase in the amount of available P in soil. Yet it is noteworthy that in the present study ERP increased the Relative Phosphorus Supplying Index from 12 to 62 at level 1, and from 17 to 37 at level 2, from the 70 day harvest to the 140 day harvest, although it fared poorly amongst the six phosphates (Table 3).

In the soil incubation method referred to above a chemical extractant was used to evaluate phosphates, while in this study phosphorus uptake by the plant is used for the same purpose. While the two methods of assessment are different, there is perhaps also a real difference in the factors which cause the solubilization of the rock phosphate in the two systems. The difference is basically due to the influence of the root system. Further, different plants may solubilize phosphates differentially owing to the influence of the varying rhizosphere biologies generated by each of them.



It has been suggested (5) that uptake of calcium ions by the roots can lead to a greater P solubilization of say, fluorapatite, by driving the equilibrium of the reaction below to the right. In addition roots may directly dissolve rock phosphate by its exudates.



They may also indirectly do so by promoting the growth of certain microorganisms which could themselves cause solubilization of the phosphate. It has been reported (6) that the isolates from the rhizosphere of plants had more apatite solubilizing fungi and bacteria than from nearby soil. All of the above seem to illustrate the importance of including the plant in a comparison of the effectiveness of different phosphates.

Of the phosphates tested CSP is water soluble, while the others are very sparingly soluble in water. From the excellent performance of Rhenania phosphate which had a Relative Phosphorus Supplying Index ranging from 75 to 105 it is clear that water solubility is not a satisfactory criterion to evaluate phosphate fertilizers.

While Eppawela rock phosphate fared poorly, fused Eppawela rock phosphate fared better, especially at the higher level where it was inferior only to CSP. If the citric acid solubility of FERP can be further increased it is likely that a better fertilizer will result.

#### ACKNOWLEDGEMENTS

The author wishes to express his thanks to Mrs. V. Abeykoon and Mr. A. Thillainathan for their assistance in this study.

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# EPPAWELA PHOSPHATE AS FERTILIZER FOR P. MAXIMUM

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**Table 1: Total, citric acid soluble and water soluble phosphate contents of the different phosphorus fertilizers**

| Fertilizer                    |     |     | Total<br>phosphate<br>% P | Citric<br>soluble<br>phosphate<br>% P | Water<br>soluble<br>phosphate<br>% P |
|-------------------------------|-----|-----|---------------------------|---------------------------------------|--------------------------------------|
| Eppawela rock phosphate       | ... | ... | 12.7                      | 1.5                                   | 0.01                                 |
| Saphos                        | ... | ... | 12.9                      | 4.1                                   | 0.01                                 |
| Fused Eppawela rock phosphate | ... | ... | 10.5                      | 7.5                                   | 0.24                                 |
| Rhenania phosphate            | ... | ... | 11.9                      | 11.4                                  | 0.93                                 |
| Fused magnesium phosphate     | ... | ... | 8.7                       | 6.6                                   | 0.07                                 |
| Concentrated superphosphate   | ... | ... | 18.8                      | 18.8                                  | 18.45                                |

**Table 2: Effect of phosphates on % P and P Uptake by *Panicum maximum***

| Fertilizer |     |     | Amount<br>ppm P | First Cut<br>% P | P Uptake<br>mg P/pot* | Second Cut<br>% P | P Uptake<br>mg P/pot* |
|------------|-----|-----|-----------------|------------------|-----------------------|-------------------|-----------------------|
| No P       | ... | ... | 0               | 0.06             | 0.06 f                | 0.11              | 2.86 e                |
| ERP        | ... | ... | 20              | 0.10             | 0.63 f                | 0.08              | 7.27 d                |
| ERP        | ... | ... | 40              | 0.09             | 1.32 f                | 0.07              | 7.08 d                |
| SaP        | ... | ... | 20              | 0.08             | 3.80 cde              | 0.08              | 9.09 bc               |
| SaP        | ... | ... | 40              | 0.09             | 5.06 bc               | 0.08              | 9.84 b                |
| FERP       | ... | ... | 20              | 0.08             | 2.84 e                | 0.07              | 7.41 d                |
| FERP       | ... | ... | 40              | 0.08             | 4.47 bed              | 0.08              | 9.88 b                |
| FMP        | ... | ... | 20              | 0.11             | 3.25 de               | 0.08              | 7.60cd                |
| FMP        | ... | ... | 40              | 0.09             | 3.89 cde              | 0.07              | 10.44 b               |
| RhP        | ... | ... | 20              | 0.08             | 5.10 bc               | 0.09              | 9.33 b                |
| RhP        | ... | ... | 40              | 0.08             | 5.86 ab               | 0.09              | 11.35 b               |
| CSP        | ... | ... | 20              | 0.08             | 4.84 bed              | 0.09              | 9.95 b                |
| CSP        | ... | ... | 40              | 0.09             | 7.27a                 | 0.11              | 14.14 a               |
| CV %       | ... | ... |                 | 18.5             | 20.6                  | 21.8              | 9.4                   |

\* Duncan's Multiple Range Test at 1% level of significance. Means followed by the same letters within the column are not significantly different.

Table 3: Relative Phosphorus Supplying Index of the different phosphates

| Fertilizer | Amount<br>ppm P | Relative Phosphorus<br>Supplying Index |            |
|------------|-----------------|----------------------------------------|------------|
|            |                 | First cut                              | Second cut |
| ERP        | 20              | 12                                     | 62         |
| SaP        | 20              | 78                                     | 88         |
| FERP       | 20              | 58                                     | 64         |
| FMP        | 20              | 67                                     | 70         |
| RhP        | 20              | 105                                    | 91         |
| CSP        | 20              | 100                                    | 100        |
| ERP        | 40              | 17                                     | 37         |
| SaP        | 40              | 69                                     | 62         |
| FERP       | 40              | 61                                     | 62         |
| FMP        | 40              | 53                                     | 67         |
| Rhp        | 40              | 80                                     | 75         |
| CSP        | 40              | 100                                    | 100        |



# EPPAWELA PHOSPHATE AS FERTILIZER FOR P. MAXIMUM

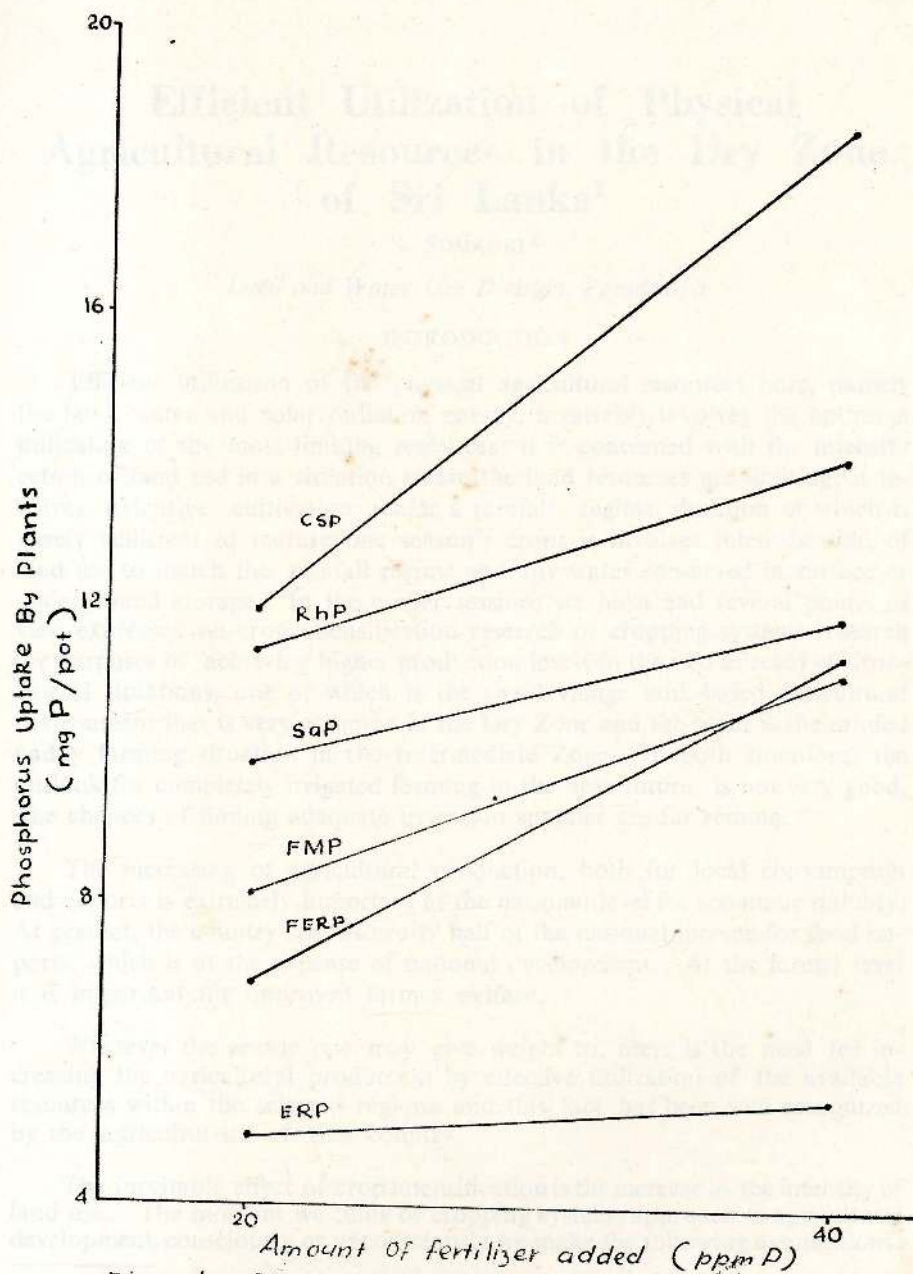
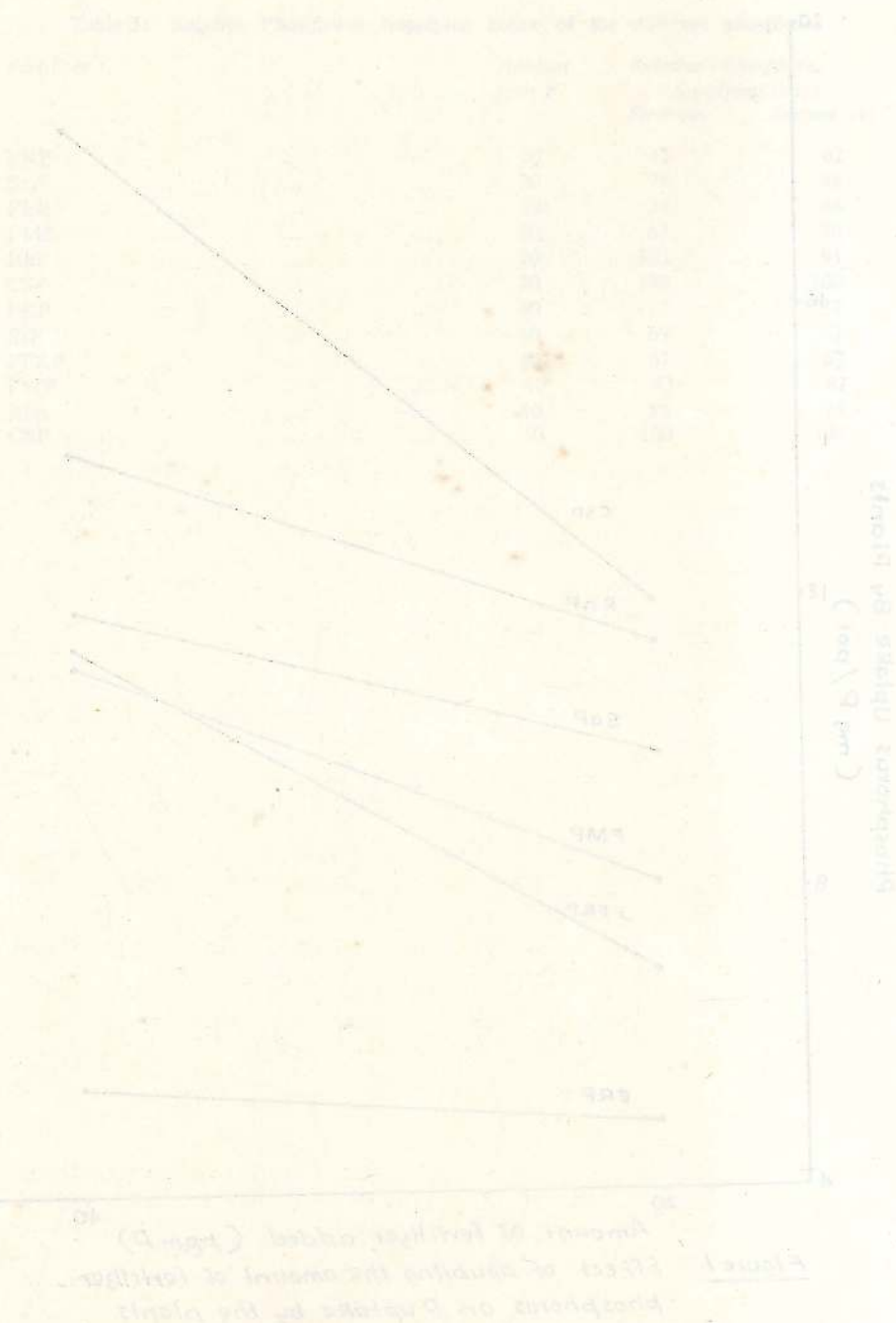


Figure 1. Effect of doubling the amount of fertilizer phosphorus on P uptake by the plants.

# RELATIONSHIP BETWEEN PHOSPHORUS AND POTASSIUM





# Efficient Utilization of Physical Agricultural Resources in the Dry Zone of Sri Lanka<sup>1</sup>

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## INTRODUCTION

Efficient utilization of the physical agricultural resources base, namely the land, water and solar radiation energy, invariably involves the optimum utilization of the most limiting resources; it is concerned with the intensification of land use in a situation where the land resources are limiting; it involves extensive cultivation under a rainfall regime, duration of which is barely sufficient to mature one season's crop; it involves intensification of land use to match the rainfall regime and any water conserved in surface or underground storage. In the earlier sessions we have had several points of view expressed on crop intensification research or cropping systems research for purposes of achieving higher production levels in the two selected environmental situations, one of which is the small village tank-based agricultural environment that is very common in the Dry Zone and the other is the rainfed paddy farming situation in the Intermediate Zone. In both situations, the outlook for completely irrigated farming in the near future, is not very good. The chances of finding adequate irrigation supplies are far remote.

The increasing of agricultural production, both for local consumption and exports is extremely important at the national level for economic stability. At present, the country spends nearly half of the national income for food imports, which is at the expense of national development. At the farmer level it is important for improved farmer welfare.

Whatever the reason one may give weight to, there is the need for increasing the agricultural production by effective utilization of the available resources within the selected regions and this fact has been well recognized by the agriculturists of this country.

The inevitable effect of crop intensification is the increase in the intensity of land use. The moment we think of cropping systems approach to agricultural development, consciously or unconsciously we make the following assumptions:

1. Paper presented at the Cropping System Workshop at Maha Illuppallama, Sri Lanka, April 20-21, 1976.
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1. that the available physical resource base is under-utilized or the level of land use is inefficient or ineffective;
2. that the available resources could be used much more effectively compared to the present levels achieved; and
3. that the farmer has the will to improve his living conditions by increasing his farm income, if he is given an acceptable technology to do so, or that the farmer is progressive enough to innovate and accept improved technology in place of the traditional.

The purpose of this paper is to discuss the nature of the physical resource base in the dry zone environment, particularly in relation to Walagambahuwa site, to discuss the present level of resource utilization, to discuss the various problems associated with more efficient levels of utilization, of the resources and to indicate the strategies in the development of village tank-based agriculture.

#### PHYSICAL RESOURCE BASE

"Land" in this context would mean a specific area of the earth's surface, which is characterized by all the stable or predictably cyclic attributes, both above and below the surface. The properties of the atmosphere, biosphere, hydrology, soils and underlying geology taken together thus, would describe the characteristics of a specific tract of land. With this definition of land in mind, the nature of the land resources of the project site at Walagambahuwa is described.

The project site at Walagambahuwa is quite representative of the Agro-ecological Region, DL<sub>1</sub>. Thus it would suffice to make use of the data from Maha Illuppallama Research Station to fill gaps in information on the environment of the project site at Walagambahuwa.

The characteristics of the atmosphere are adequately expressed by the climate. Only the salient features of the climate of this region are described here, as more details would be discussed under water resources. The characteristic feature of the climate is the bimodal distribution of the monthly rainfall, with two distinct dry periods one short and the other prolonged. During the prolonged dry period high-dessicating winds prevail. The annual average temperature is 80° F. The evaporation from a free water surface averages to about 0.25 inches (6mm) per day.

Walagambahuwa, as well as the entire agro-ecological region DL<sub>1</sub> is underlain by metamorphic crystalline rocks of the Khondalite series and they are of pre-Cambrian age, (Hunting Survey Report, 1962). The composition of these rocks is such that on weathering, the products formed are moderately fine-textured. The depth of the weathered zone is generally shallow.



## EFFICIENT UTILIZATION OF PHYSICAL RESOURCES

The natural vegetation in this region is dry mixed ever-green forest (Andrews, 1961). However, due to the clearing of the forest for shifting or "chena" cultivation around the project site, what is left of the forest vegetation is quite small. A greater part of the area used for "chena" cultivation by the farmers of Walagambahuwa consists of secondary vegetation-scrub jungle of 8 to 10 years.

The physiography of the region is gently-undulating to rolling, with 3 to 4 per cent slopes. The landscape is a composite of minor watersheds or micro-catchment basins. Walagambahuwa Settlement itself is in one of these numerous watersheds. The particular area is in the uppermost section of the drainage basin.

The soils occur in a catenary sequence in the undulating landscape of the dry zone (Abeyratne 1956; Panabokke, 1958) Fig.1. Well-drained and imperfectly-drained Reddish Brown Earths (Rhodustalfs) occur on the convex uplands and lower mid-slopes respectively. Low Humic Gley soils (Tropaqualfs), the poorly-drained member of the catenary sequence, occur on the concave valleys and bottomlands.

Reddish Brown Earths consist of sandy loam to sand clay loam surface horizons, underlain by sandy clay loam to sand clay sub-soil horizons. Usually a massive and structureless gravel horizon occurs within the solum, which sometimes is thick enough to prevent good root growth. These soils are very hard to extremely hard when dry and sticky and plastic when wet. They are moderately deep, the bulk densities of these soils are fairly high and the porosity ranges from 35 to 40 per cent by volume. The air pore volume at field capacity is quite low-11 to 12 percent. As a result the soils get saturated quite easily. The available moisture of the Reddish Brown Earths on the average is about 1.6 to 2 inches per foot depth of soil (Mahaweli Ganga Development Project Report, 1972). The soil reaction is slightly acidic to neutral and low in soluble salts. The available phosphorus and nitrogen content of these soils is quite low and need addition of these major nutrients for intensive crop production. The cation exchange capacities are fairly low (10-30 meq/100 g of soil) but the degree of base saturation is quite high, ranging from 60-80 per cent (Mahaweli Ganga Development Project Report, 1972).

At the site at Walagambahuwa, the more important soil group so far as the project is concerned, is the imperfectly-drained Reddish Brown Earths on the lower slopes (see diagram). In extent it is greater than the poorly-drained soils and at the same time these soils can be brought under the command of the tank. This soil consists of a dark brown sandy loam to sandy clay loam surface horizon underlain by a sub-soil of brown to yellowish brown sandy clay loam to sandy clay. The imperfectly-drained soil member is quite similar to the

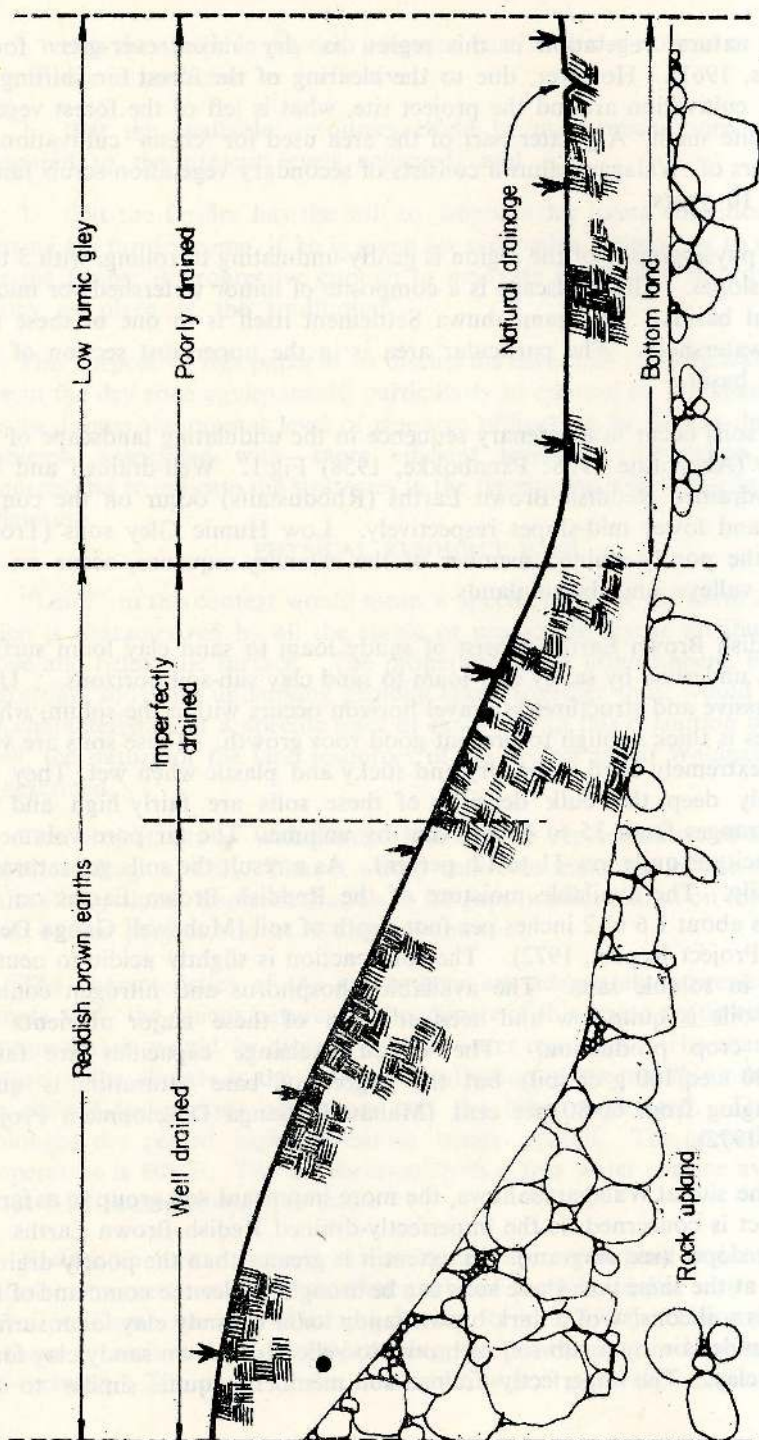
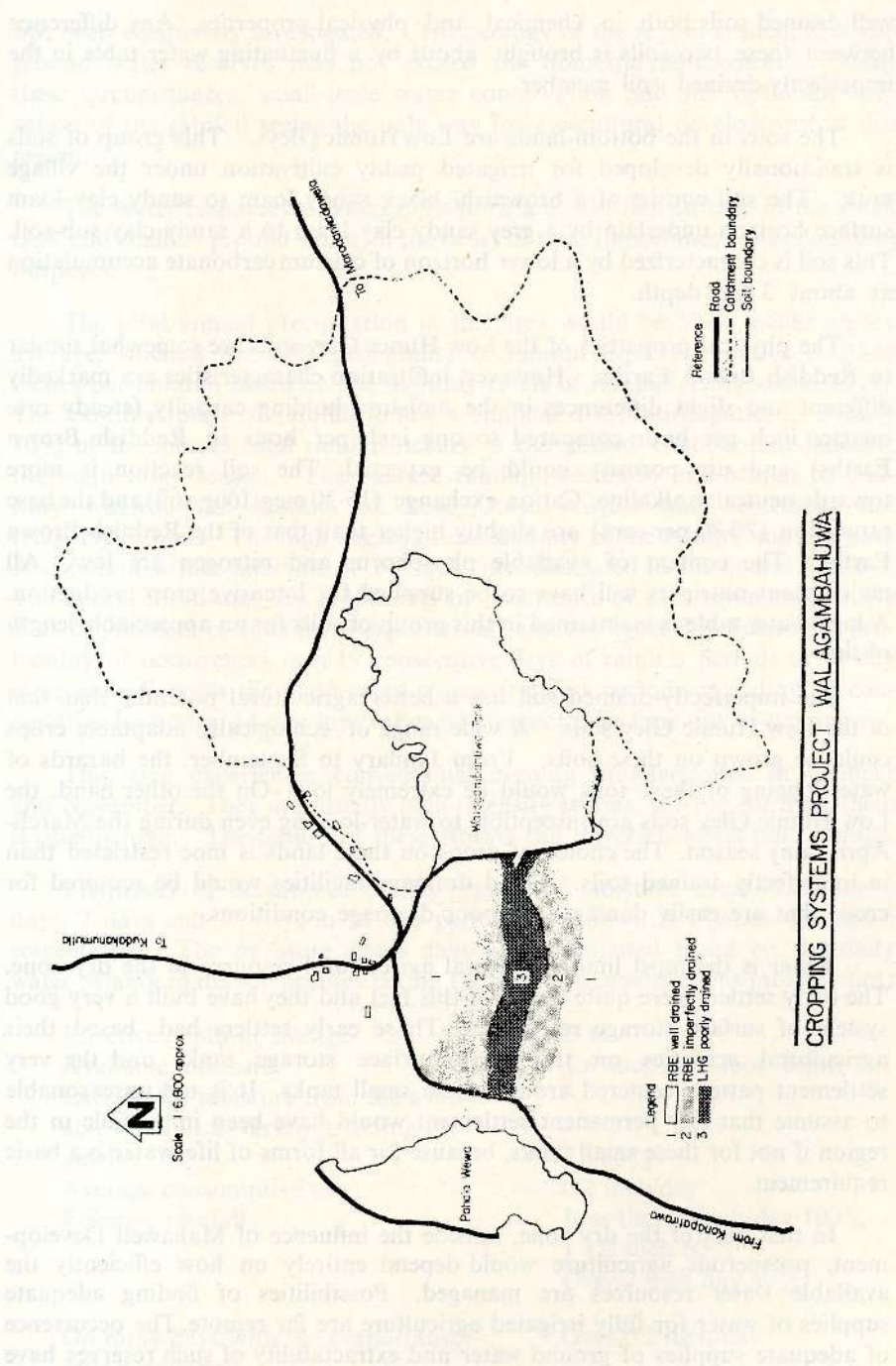


Fig. 1. Distribution of soils in the Dry Zone Landscape.





well drained soils both in chemical and physical properties. Any difference between these two soils is brought about by a fluctuating water table in the imperfectly-drained soil member.

The soils in the bottom-lands are Low Humic Gleys. This group of soils is traditionally developed for irrigated paddy cultivation under the village tank. The soil consist of a brownish black sandy loam to sandy clay loam surface horizon underlain by a grey sandy clay loam to a sandy clay sub-soil. This soil is characterized by a lower horizon of calcium carbonate accumulation at about 3 feet depth.

The physical properties of the Low Humic Gley soils are somewhat similar to Reddish Brown Earths. However, infiltration characteristics are markedly different and slight differences in the moisture holding capacity (steady rate quarter inch per hour compared to one inch per hour in Reddish Brown Earths) and air porosity could be expected. The soil reaction is more towards neutral to alkaline. Cation exchange (15-30 meg/100g soil) and the base saturation (70-80 per cent) are slightly higher than that of the Reddish Brown Earths. The content of available phosphorus and nitrogen are low. All major plant nutrients will have to be supplied for intensive crop production. A high water table is maintained in this group of soils for an appreciable length of time.

The imperfectly-drained soil has a better agricultural potential than that of the Low Humic Gley soils. A wide range of ecologically adaptable crops could be grown on these soils. From January to September, the hazards of water-logging of these soils would be extremely low. On the other hand, the Low Humic Gley soils are susceptible to water-logging even during the March-April rainy season. The choice of crops on these lands is more restricted than in imperfectly-drained soils. Good drainage facilities would be required for crops that are easily damaged by poor drainage conditions.

Water is the most limiting natural agricultural resource in the dry zone. The early settlers were quite aware of this fact and they have built a very good system of surface storage reservoirs. Those early settlers had based their agricultural activities on the small surface storage tanks and the very settlement pattern centered around these small tanks. It is not unreasonable to assume that any permanent settlement would have been impossible in the region if not for these small tanks, because for all forms of life, water is a basic requirement.

In that part of the dry zone, outside the influence of Mahaweli Development, prosperous agriculture would depend entirely on how efficiently the available water resources are managed. Possibilities of finding adequate supplies of water for fully irrigated agriculture are far remote. The occurrence of adequate supplies of ground water and extractability of such reserves have



## EFFICIENT UTILIZATION OF PHYSICAL RESOURCES

not been adequately investigated. The geology of the region is such, that any ground water reserves may not exceed the domestic requirements. Under these circumstances, small-scale water conservation and the optimum utilization of the rainfall seems the only way for agricultural development in this region.

The water resources at Walagambahuwa are rain fall, storage in the small tank and shallow ground water, in the order of their importance for agricultural purposes.

The total annual precipitation in this area would be 50-60 inches on the average, whereas the 75% probability of rainfall expectancy value is 30-35 inches per annum, based on the monthly totals of rainfall (Panabokke, 1975). The monthly totals of rainfall follow a bimodal distribution pattern. Nearly 70% of the annual total rainfall occurs in the period October-mid-January, the main rainy season. The balance rainfall occurs in mid-March to mid-May whereas the months of June, July, August and September are relatively rainless. The high degree of uncertainty of the rainfall and the poor distribution within intervals of 14 days, are illustrated in the figures 2 and 3. The figure 2 indicates the probability of occurrence of over seven consecutive days of rainless periods in 14-day intervals and the figure 3 indicates the probability of occurrences over 19 consecutive days of rainless periods in 14-day intervals. Even in the main rainy season, rainless periods exceeding 10 consecutive days on a 14-day interval can be expected in four out of ten years.

This area experiences convectional evening thunderstorms in October and November. They are usually high-intensity storms, the run-off from them is usually high. The failure of these storms can adversely affect tank storage.

Frequency of occurrence of the periods of moisture stress exceeding 3 days, 7 days and 12 days in 14 day periods are shown in Figures 4,5 and 6 respectively. The moisture stress days were computed based on the daily water balance in the soil profiles taking the following assumptions into account:

|                                                                                |                                                                      |
|--------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Effective depth of storage                                                     | — 2 ft.                                                              |
| Available moisture                                                             | — 1.6 inch per foot depth                                            |
| Extractable moisture from the available without adversely affecting the yields | — 75-80%                                                             |
| Average consumptive use                                                        | — 0.2 inch/day                                                       |
| Effective rainfall                                                             | — Less than 1 inch/day 100%<br>1 1/2 inch 60%<br>Over 2 inch day 40% |

On rainy days with the evapotranspiration neglected. Over 0.2 inch/day

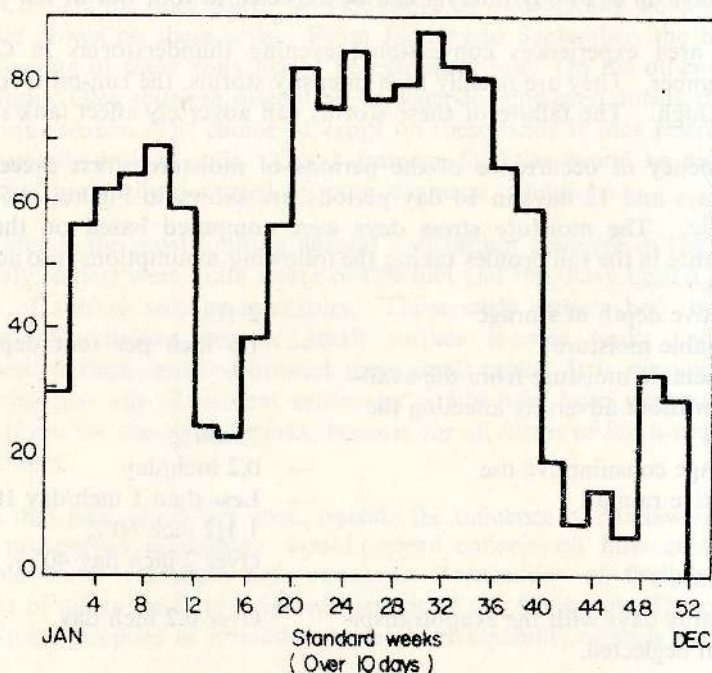
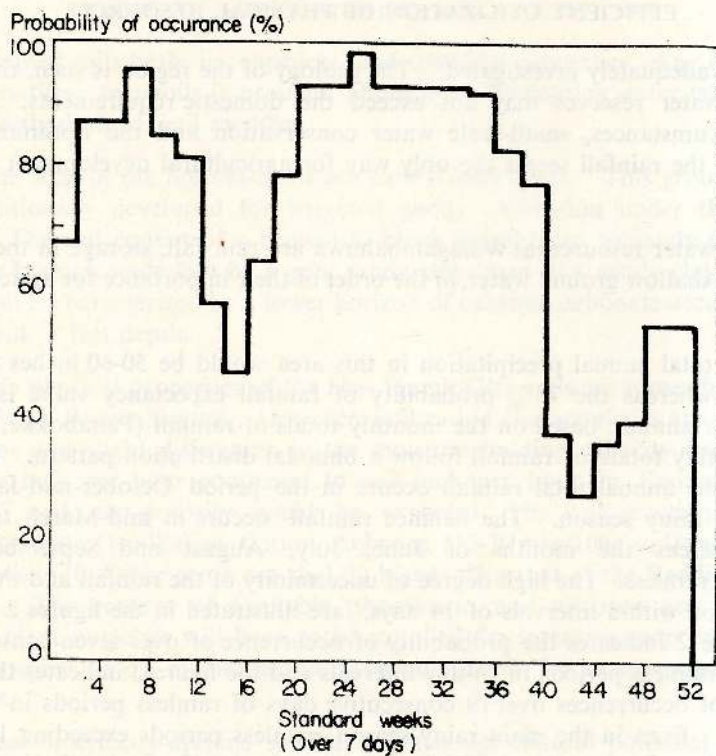


Fig. 263. Probability of occurrence of consecutive rainless days at Maha-Illuppallama.



# EFFICIENT UTILIZATION OF PHYSICAL RESOURCES

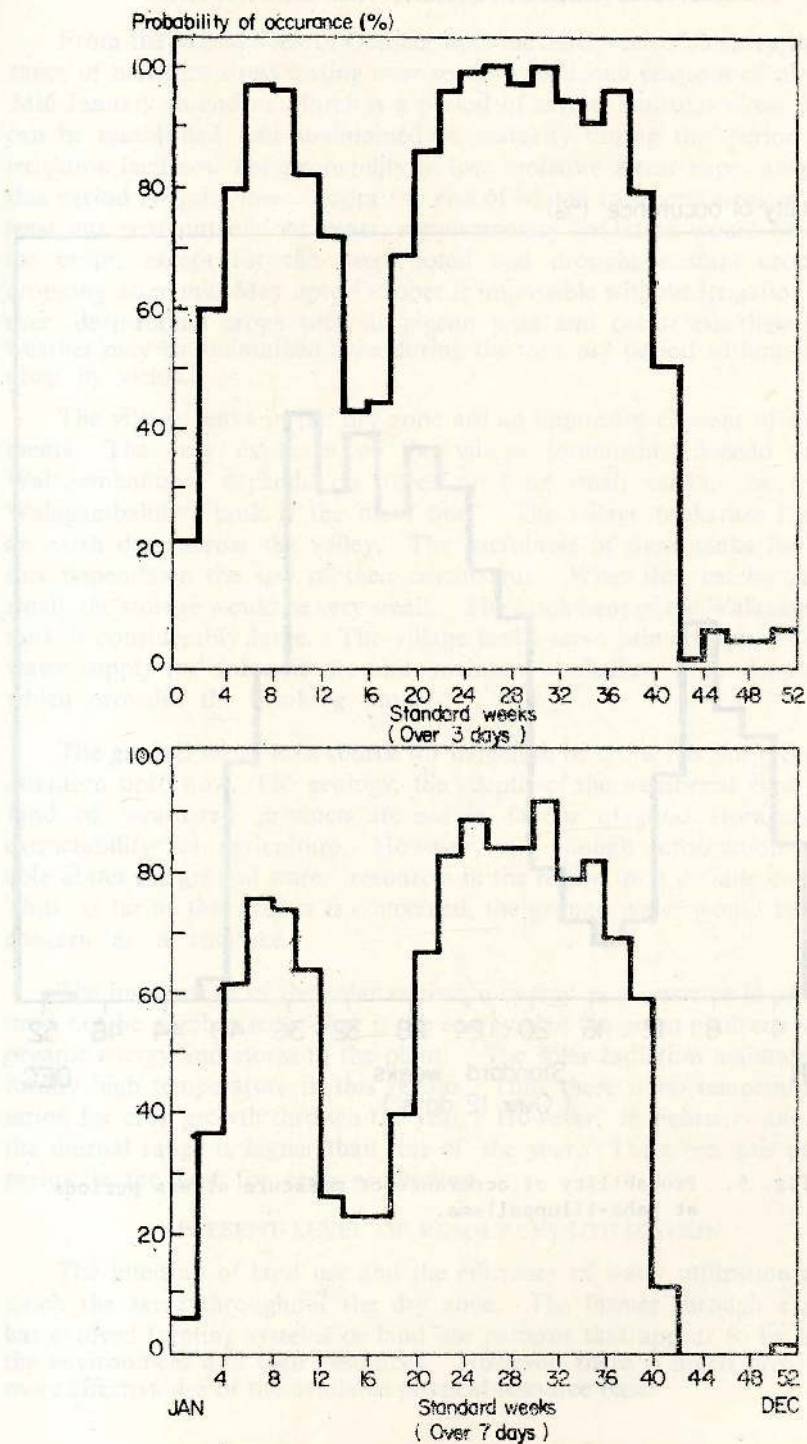


Fig. 465. Probability of occurrence of moisture stress periods at Maha-illuppallama.

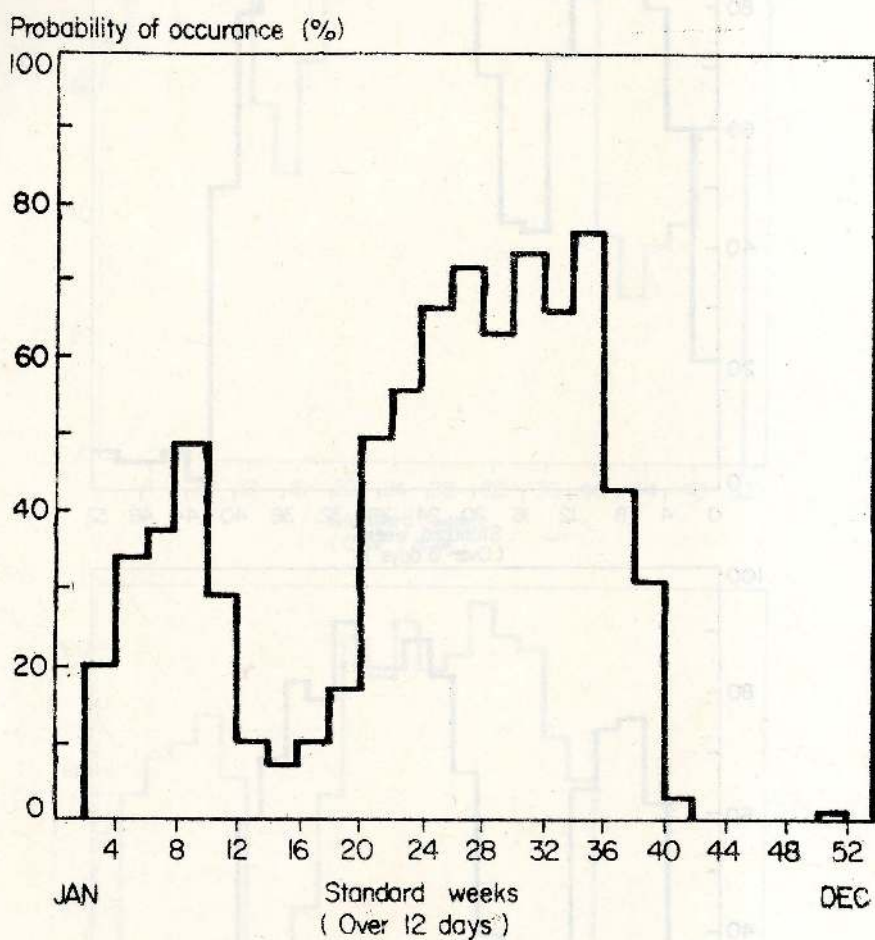


Fig. 6. Probability of occurrence of moisture stress periods. at Maha-Illuppallama.



## EFFICIENT UTILIZATION OF PHYSICAL RESOURCES

From the second week of October upto the third week of January, the expectancy of moisture stress lasting over seven days is one year out of nine years. Mid-January to end of March is a period of severe moisture stress. No crop can be established and maintained to maturity during this period without irrigation facilities. The probability of low moisture stress expectancy during this period is quite low. From the end of March to second week of May, at least one year out of four years, supplementary irrigation would be required for crops, except for the deep-rooted and drought-resistant crops. Any cropping after mid-May upto October is impossible without irrigation. However, deep-rooted crops such as pigeon peas and castor established in wet weather may be maintained even during the long dry period without a serious drop in yields.

The village tanks in the dry zone are an important element of the settlements. The very existence of the village settlements depend on them. Walagambahuwa depends on three or four small tanks, of these the Walagambahuwa tank is the main one. The village tanks are formed by an earth dam across the valley. The usefulness of these tanks for agriculture depends on the size of their catchments. When the catchment is too small, the storage would be very small. The catchment of the Walagambahuwa tank is considerably large. The village tanks serve primarily as a source of water supply for domestic use and maintain a shallow ground water table which provides the drinking water.

The ground water as a source for irrigation of crops has not received any attention upto now. The geology, the depth of the weathered zone and the kind of weathered products are not in favour of good storage or easy extractability for agriculture. However, not enough information is available about the ground water resources in the region for a definite conclusion. Thus as far as this project is concerned, the ground water would be our last concern as a resource.

The importance of the solar radiation energy as a resource in agriculture need not be emphasized. That is the energy that the green plant converts into organic energy and stores in the plant. The solar radiation maintains a uniformly high temperature in this region. Thus there is no temperature limitation for crop growth through the year. However, in February and March, the diurnal range is higher than rest of the year. Therefore, this particular period is the best for crop production.

## PRESENT LEVEL OF RESOURCES UTILIZATION

The intensity of land use and the efficiency of water utilization are very much the same throughout the dry zone. The farmer through experience has evolved farming systems or land use patterns that appear to be fitting to the environment and their resources. However, there is much provision for more effective use of the available physical resource base.



The lowland below the tank adjacent to the settlement has been developed for irrigated paddy cultivation. The soils of these bottomlands are more suited for paddy cultivation—they are most easily worked by puddling in standing water or just above saturation. Usually only one crop of paddy is cultivated in an year. Sometimes only a part of the irrigable land is cultivated in a season, in such cases the overall intensity of land use in the bottom-land would be less than one. Rest of the time, these lands serve as natural pastures for livestock.

The work in bottomlands is never started until the tanks are filled to a least risk level. Thus, the land preparation is commenced in late Maha season—sometimes in December to January. The crop is matured with the tank water. Occasionally, after the first crop, if there is water in the tank in excess of the domestic requirement, a small extent of paddy is sown in Yala (March-April). However, instances of getting two crops of paddy on the same land in a year are extremely rare.

According to these practices, the benefits of the early Maha rains and the Yala rains are completely lost. Also by planting a second crop of paddy with the tank water, instead of planting some other crop whose water requirements are lower than paddy, the overall land use intensity is reduced and tank water is used less effectively.

Upland farming is a system of shifting cultivation. The rainless months prior to the Maha rainy season are ideal for felling the jungle and preparing the land for sowing. The “chena” is usually planted with a variety of crops at the beginning of Maha season. Most of the chena work would be completed by the time the tank is filled sufficiently for lowland cultivation. Normally during the Yala, the chena is planted with gingelly, some millets and pulses. After four seasons of cropping, the land is left to fallow. In the dry zone, in places where there is no limitation on the availability of forest land, the intensity of land use is not more than 10 per cent. At Walagambahuwa, there is hardly any forest land remaining. There is a shortage of uplands for chena cultivation and the forest fallow is reduced to five to seven years. Therefore, the land use intensity is increased, may be up to 29 percent. However, the production may be reduced as the fallow period is insufficient to build up the soil nutrients that were lost through erosion and crop removal. Also the weed flora would be still active and would compete with crops for both moisture and nutrients.

The present level of resource utilization is the result of farming practices that evolved through the experiences of several generations. The present practices have not reached an end, rather they are in the process of undergoing continuous changes. Only the basic land use patterns appear to remain without a recognizable change.



## EFFICIENT UTILIZATION OF AGRICULTURAL RESOURCES

To achieve more efficient levels of resource utilization, it is worthwhile to examine in detail the present systems to identify the constraints and the problems that may have prevented the more efficient use of land and water. Take the case of lowland (irrigable) under the village tank. The farmer is experienced enough to know that if a crop of highland paddy can mature with the rainfall alone, a crop of paddy in his lowland should have a better chance, because these lands are developed for very good conservation of water. But the farmer makes no attempt to raise a crop of paddy in the lowland to make use of the Maha rainfall. This practice may be attributed to the difficulties of tillage with the available implements, towards the end of the long dry season. The land holding may not be extensive enough compared to the investment required. The farmer may also be devoting too much of his labour on the upland, and the risk of investment in the lowland may appear to be high. The lowland soils are easily worked with standing water. Therefore the work can be started only in the latter half of the rainy season. However, until the rainy season is over, conditions are unsuitable for sowing of paddy. Thus the farmer is forced to delay the cultivation on the lowland. Due to the population growth, the land to man ratio in the lowland is very small. The extensive cropping of the highland under rainfed conditions would be more efficient way of utilizing the rainfall than working on the small plot in the lowland. The investment on weed control in the paddy land may be high in terms of cash and labour when cropped under rainfed conditions. This would result in poor weed control and reduced yields.

More efficient use of the land and the uncertain water resources involves taking high risks. But the farmer's practices are to take the least risk. This is quite understandable, for generations the dry zone farmer existed at a subsistence level and there is no need for him to take unnecessary risk. However, a change in the farmers outlook on agriculture is needed. This may be an area more in the line of socio-economic experts.

### TOWARDS BETTER UTILIZATION OF RESOURCES

At Walagambahuwa, both land and water are limiting resources but water is the most limiting of the two. Our endeavour is to evolve the technology needed for efficient use of land and water resources, the technology that is acceptable to the farmer and that can be easily transmitted to the rest of the dry zone. The strategy should be to draw from the farmers' experience and match it against the available quantitative information on the environment and research findings from the Dry Zone Research Station at Maha Illupallama, for the identification of research priorities in the Project site.

Efficient utilization of water would mean making use of both Maha rainfall and the Yala rainfall for two crops in the respective seasons in the lowland and use of the tank storage for a short-age irrigated crop in between. By selecting the correct dates of planting in the upland, both Maha and Yala rain-



fall is used quite effectively, though the same practices are not adopted on the lowland. Based on the daily rainfall records over the last 70 years, for making the best use of the Maha rainfall, a paddy crop of matching age class with the low moisture stress period, if sown before the end of the 42nd week for harvesting in the latter half of January, its chances of success would be nineteen out of twenty. From the third week of January to the fourth week of March no crop, except the deep rooted or drought resistant crops, can be grown without irrigation facilities. A crop grown during this period needs to be harvested before the end of the fourth week of March. By conserving the tank water in the Maha rainfall season and by following the tankwater balance and applying efficient water management practices, short-age crops can be taken during this period. A third season of cropping would be possible with the Yala rainfall supplemented by the tank storage. As an alternative sequence, after a rainfed paddy crop in Maha, a second crop may be established in March with irrigation from the tank storage and maintained with the Yala rainfall, further supplemented by the tank storage. Under the small tank environment no crop can be grown in land developed for paddy after the 20th week in the year. A word of caution must be added here. A good understanding of the water resources, ability to forecast the tank storage by estimating all the gains and losses, the domestic requirements etc. are essential for the preparation of the cropping programmes, crop sequences and crop combinations.

#### PROBLEMS ASSOCIATED WITH CROP INTENSIFICATION

There is hardly any information on the hydrology of the minor watersheds. The micro-catchment water balance needs investigation. It is essential to determine the run-off model for the micro catchments in the dry zone for the assessment of the tank water balance. Presently the farmers manage the tank water in certain ways, but it needs quantification. There is no adequate information on ground water for extraction for agricultural purposes.

In the bottomlands, the lands where the intensification of cropping would be undertaken, occupying the lowest area of the landscape, the soils are poorly drained. The ground water table remains high during the possible cropping seasons. When it is proposed to follow a paddy crop with other crops that are sensitive to excess moisture, a very good system of drainage will be needed.

In a normal rainfall year, the ground water table remains quite high in the poorly-drained soil areas during the cropping seasons. The contribution from the water table to consumptive use could be appreciable. Therefore the irrigation requirements of crops in the imperfectly-drained soils and the poorly drained soils would differ, and the irrigation frequencies are bound to be different. However, there is insufficient information on these aspects.

The introduction of highly efficient water management practices in one part of the minor valley can affect the water balance of the small tanks in the



## EFFICIENT UTILIZATION OF AGRICULTURAL RESOURCES

lower end of the watershed. By trying to intensify in one part of the watershed, another part may go completely out of production.

The existing irrigation layout is meant to irrigate a crop of paddy. The irrigation efficiency achieved would be extremely low under the present practices. For crop intensification, the farmer is expected to use the same irrigation layout for the irrigation of the crops other than paddy and also reduce the water losses in the field. Any attempt to change the layout may not be feasible without consideration of the social and other problems.

Thus along with Cropping Systems Research, there are other investigations, that are critically important for the success of the whole endeavour. It is essential to find the solutions for the problems of soil and water management.

### ACKNOWLEDGEMENTS

I am very grateful to Mr. T. M. J. Bandara, for all the computations made on the daily water balance, presented in this paper.

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lower end of the watershed. In using to advantage in one part of the watershed another part may be completely out of production.

The existing irrigation layout is usually in a crop of land. The irrigation efficiency is usually very low in the present crop. For crop production, the layout is expected to be the same. The layout for the irrigation of the crop other than paddy and the other crops is in the line. Any attempt to change the layout may not be feasible without consideration of the social and other problems.

There is a growing concern among the people in the watershed that the existing layout is not the best for the whole watershed. It is essential to find the solution for the problem of irrigation layout in the watershed. The solution is to find the best layout for the whole watershed.

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# Influence of Nitrogen and Potash on Cassava

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## INTRODUCTION

Cassava (*Manihot esculenta* crantz.) responds well to fertilizer application. Remarkable yield response to addition of nitrogen, phosphorus and potassium has been observed (3). The response of fresh tuber yield of cassava to nitrogen and potash is reported to be more pronounced (2,4,11,16.) In general potash is considered to be the most important nutrient for tuber crops as it is involved in the production and translocation of starch (10,13). However it has been shown that, in root crops, potash may have negative effects too, e.g. dioscorea (7,12), sweet potato (6) and cassava (9).

The amounts of nutrients removed by cassava as shown by Altmannsberger (1), Amarasiri (2) and Velly (15) also stresses the importance of nitrogen and potassium to cassava. (Table 1).

The national average yield of 8.5 tonnes of fresh tubers per hectare (14) could be considered very low, taking into account the yield potential of the popular cassava varieties available in Sri Lanka. (Table 2). It was therefore envisaged to study the optimum requirement of nitrogen and potash in the Dry Zone, where there is a potential for expansion of cassava cultivation.

These studies were conducted at the Agricultural Research Station, Tinnevely (Jaffna) and Agricultural Research Station, Alutharama (Mahiyangana). These two sites were selected due to their differences in soil and climatic conditions (Table 3).

## MATERIALS AND METHODS

A randomized complete block design as a 4x3 factorial with an additional treatment having three replicates was used in both locations.

Nitrogen levels used were 0, 45, 90 and 135 kg. N per hectare supplied as sulphate of ammonia (21%N) given in three equal split applications, as basal dressing, one month after planting and three months after planting.

Potassium application was done at the rate of 0, 45 and 90 kg. K<sub>2</sub>O per hectare, supplied as Muriate of potash (50% K<sub>2</sub>O). This was applied in two equal splits, as basal and at three months after planting.



Phosphorus was incorporated as a blanket application at the rate of 45 kg.  $P_2O_5$  per hectare which was furnished by concentrated superphosphate (43%  $P_2O_5$ ).

The additional treatment consisting of 45 kg/ha. N, 45 kg/ha.  $K_2O$  only (without P) was also included in the experiment.

Cuttings 22 to 25 cm. long, extracted from mature sticks of the cultivar MU 22, was used as planting material. The cuttings were planted upright with two-thirds of the cuttings buried in the soil. The cuttings were spaced at a distance of 90 cm. by 90 cm. A plot consisted of 25 plants making a plot size of 4.5x4.5 m. The nett plot for yield assessment consisted of 9 plants after leaving a one-plant border.

Basal fertilizer was applied the day before planting and subsequent top dressings as described earlier were done after weeding.

The crop was planted in September 1972, and was grown purely under rain-fed conditions. Harvesting was done nine months after planting.

Soil samples were taken at the commencement of the experiment prior to fertilizer application and were analysed for nitrogen, potassium, phosphorus and organic matter (Table 4).

#### RESULTS AND DISCUSSION

Considerable variation was observed in fresh tuber yields in the two locations (Table 5). The general mean yield at Alutharama was 61.69 tonnes per hectare and at Tinnevely was 30.58 tonnes of fresh tubers per hectare. Alutharama recording almost 100% more than at Tinnevely. The crop at Tinnevely was subject to a period of nearly 6 months drought, while at Alutharama the rainfall distribution was such that no serious moisture stress was experienced during the period of the experiments for more than 50 days at a stretch.

Statistical analysis of fresh tuber yield showed that the treatment combinations were significant at 5% level in both the locations. However the response due to various treatments did not show the same trend at the two locations. At Alutharama the highest yield of 80.87 tonnes per hectare of fresh tubers was obtained with the fertilizer treatment  $N_1PK_1$  supplying 45 kg/ha of all the three components N,  $P_2O_5$  and  $K_2O$ . At Tinnevely, the highest yield was obtained at the fertilizer combination of  $N_3PK_2$  supplying 135 kg/ha N, 45 kg/ha.  $P_2O_5$  and 90 kg/ha.  $K_2O$ . Cassava tuber yield corresponding to this fertilizer treatment was 36.61 kg/ha. At Alutharama the lowest yield of 56.50 kg/ha was obtained at a fertilizer level of 45 kg/ha. N, 45 kg/ha.  $P_2O_5$  and 90 kg/ha.  $K_2O$  whereas at Tinnevely the lowest yield of 23.63 kg/ha. was obtained corresponding to the fertilizer treatment 0 kg/ha. N 45



## INFLUENCE OF NITROGEN & POTASH ON CASSAVA

kg/ha.  $P_2O_5$  and 90 kg/ha.  $K_2O$ . The treatment differences as regards to fresh tuber yield at both the locations as calculated by the Duncan's Multiple Range Test are shown in Table 5. The response of fresh tuber yield as influenced by individual nutrients is described below.

### Nitrogen

Levels of nitrogen showed significant differences at both locations. positive linear response was obtained for nitrogen application at both locations. This is in agreement with the results obtained by Chew (4). The response functions of fresh tuber yield to nitrogen are:—

$$\text{Alutharama} \quad \dots\dots\dots Y = 55.2538 + 4.6054X$$

$$\text{Tinnevely} \quad \dots\dots\dots Y = 25.8468 + 2.0407X$$

In deriving the regression equations coded values of 1,2,3 and 4 were used for X corresponding to 0, 45, 90 and 135 kg/ha. N. The regression graphs for the two locations are shown in Figure 1.

At Alutharama the response to nitrogen levels was significant at 1% level and it is shown that the response to doses of 45, 90 and 135 kg/ha. N was 7.0, 4.46 and 12.85 tonnes fresh tubers per hectare respectively over the zero nitrogen level. At Tinnevely a 5% response was observed to nitrogen treatments and the respective increase in yield due to application of 45, 90 and 135 kg/ha. N over the no nitrogen control was found to be 2.71, 1.96 and 5.75 tonnes per hectare of fresh cassava tubers (Table 6).

At Alutharama the application of 135 kg/ha. N gave the highest response which was found to be 13.85 tonnes per hectare more than the zero nitrogen control and this response was highly significant. At Tinnevely the superiority of 135 kg/ha. N over the on nitrogen control was 5.75 tonnes of fresh tubers per hectare and this superiority reached 5% significance level.

The importance of nitrogenous fertilizers to cassava has been pointed out by several workers (5, 8, 11, 12) and a response upto 168.5 kg/ha. N has been observed (4). The linearity in response to nitrogen application and the amount of nitrogen removed by cassava as shown by Table 1 indicate that the tuber yield could be further increased with additional amounts of nitrogen at both locations. However economics must decide any increase in the dose of fertilizers.

### Potassium

The response to application of potash did not reach significant levels in any of the locations (Table 6). Application of 45 kg/ha.  $K_2O$  was found to be slightly superior to zero potash control at both locations. In both locations, however, the mean effect of increasing the level of potash from 45 kg/ha.  $K_2O$  to



90 kg/ha.  $K_2O$  was associated with a slight non-significant reduction in fresh tuber yield (Table 6). Significant negative response to potash over and above a certain limit has been cited by Kumar, Mandal and Magoon (9) and Prevot Olagner (13). The phenomenon of yield depression to excess potash has also been reported on several other root and tuber crops, such as sweet potato (6) and dioscorea (7, 12). Further experimentation is necessary to ascertain the negative effects of potash on cassava in Sri Lanka.

At Alutharama, incorporation of 45 kg/ha.  $P_2O_5$  to a mixture of similar quantities N and  $K_2O$  furnished a 17.47 kg/ha. increase in yield over the fertilizer treatment containing 45 kg/ha. N and 45 kg/ha.  $K_2O$  without additional  $P_2O_5$ . This response was found to be significant at 5% level. At Tinnevely no such significant response was observed. This may be possibly due to the lower  $P_2O_5$  content in Alutharama soils and a higher soil  $P_2O_5$  level at Tinnevely (Table 4).

Significant (5%)  $N \times K$  interaction was observed at Alutharama and not at Tinnevely (Table 7). The only significant interaction however at Alutharama was at  $K_0$  level,  $N_3$ , (135 kg/ha. N) being superior to  $N_3$  (zero N).

Perusal of Table 5 shows a distinct superiority of tuber yield at Alutharama to all the fertilizer treatments which could be due to the following reasons:

1. Higher soil nitrogen content at Alutharama (Table 4) which is also substantiated by the linear response to nitrogen application upto 135 kg/ha. N.
2. High potash content in the soils at Tinnevely which would have contributed to a depression in fresh tuber yields.
3. The drought which prevailed at Tinnevely may be another factor for the lower yields at that location.

#### SUMMARY

An experiment was conducted to study the effect of application of nitrogenous and potassic fertilizers on fresh tuber yield of cassava in the Dry Zone. The response due to various combinations of nitrogen and potash behaved in a differential manner at the two locations. A positive linear response to addition of nitrogen upto 135 kg/ha. was observed both at Alutharama and Tinnevely. There was no significant yield response due to addition of potash. However a negative effect was observed due to the addition of 90 kg/ha.  $K_2O$  at both locations. At Alutharama supplying 45 kg/ha.  $P_2O_5$  in combination with similar amounts of N and  $K_2O$  resulted in a significantly higher yield over the treatment which received similar quantities of N and  $K_2O$  without  $P_2O_5$ . This treatment gave almost a 100% superiority in fresh tuber yields.

#### ACKNOWLEDGEMENTS

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locations and Mr. A Goonasekara for his assistance in statistical analysis. The authors also thank Mr. M. E.R. Pinto for his valuable suggestions and criticisms in preparation of the manuscript.

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**Table 1: Estimated Nutrient Removal in Kg/ha by Cassava Tubers (different workers)**

| <i>Nutrient</i>                   | <i>Altmannsberger</i> | <i>Amarasiri</i> | <i>Velly</i> |
|-----------------------------------|-----------------------|------------------|--------------|
| <i>N</i>                          | 80                    | 62               | 73           |
| <i>P<sub>2</sub>O<sub>5</sub></i> | 20                    | 12               | 28           |
| <i>K<sub>2</sub>O</i>             | 120                   | 375              | 54           |

**Table 2: Yield Potentials of Popular Cultivars of Cassava in Sri Lanka**

| <i>Variety</i> | <i>Local Name</i> | <i>Age (Months)</i> | <i>Yield (kg/ha)</i> |
|----------------|-------------------|---------------------|----------------------|
| MU 10          | Kolumbumaravalli  | 05-06               | 18-22                |
| KU 71          | Moneragala White  | 05-06               | 18-22                |
| Mu 22          | Peradeni Manyokka | 09-10               | 40-45                |
| Mu 44          | Sudu Manyokka     | 08-09               | 40-45                |

**Table 3: Soil and Agro-Ecological Factors at Tinnevely and Alutharama**

| <i>Station</i> | <i>Elevation</i> | <i>Rainfall</i> | <i>Soil Type</i>           | <i>Topography</i> |
|----------------|------------------|-----------------|----------------------------|-------------------|
| Tinnevely      | 3 m              | 1270-1900 mm.   | Calcic Red Yellow Latosols | Level Terrian     |
| Alutharama     | 243 m            | 1900-2540 mm.   | Reddish Brown Earths       | Undulating.       |

**Table 4: Soil Analysis Data**

| <i>Nutrients</i>                   | <i>Alutharama</i>                        | <i>Tinnevely</i>                         |
|------------------------------------|------------------------------------------|------------------------------------------|
| <i>N</i>                           | 0.163 %                                  | 0.106 %                                  |
| <i>P<sub>2</sub> O<sub>5</sub></i> | 112.0 Kg. ha <sup>-1</sup>               | 358.0 kg. ha <sup>-1</sup>               |
| <i>K<sub>2</sub> O</i>             | 0.416 Ex. Kmc. 100- <sup>1</sup> g soils | 0.524 Ex. K me. 100- <sup>1</sup> g soil |
| <i>O.M.</i>                        | 0.803 %                                  | 2.394 %                                  |



# INFLUENCE OF NITROGEN AND POTASH ON CASSAVA

**Table 5: Average Yield of Fresh Tubers (Tonnes Per Hectare)**

| No.          | Fertilizer Treatment | Location   |            |
|--------------|----------------------|------------|------------|
|              |                      | Alutharama | Tinnevelly |
| 1.           | $N_0PK_0$            | 57.64      | 29.88      |
| 2.           | $N_1PK_0$            | 66.96      | 27.21      |
| 3.           | $N_2PK_0$            | 64.97      | 28.16      |
| 4.           | $N_3PK_0$            | 79.99      | 33.75      |
| 5.           | $N_0PK_1$            | 61.54      | 30.81      |
| 6.           | $N_1PK_1$            | 80.87      | 32.94      |
| 7.           | $N_2PK_1$            | 65.46      | 29.70      |
| 8.           | $N_3PK_1$            | 70.75      | 36.61      |
| 9.           | $K_0PK_2$            | 57.33      | 23.63      |
| 10.          | $N_1KP_2$            | 56.50      | 32.28      |
| 11.          | $N_2PK_2$            | 66.16      | 32.35      |
| 12.          | $N_3PK_2$            | 74.05      | 34.84      |
| 13.          | $N_1P_0K_1$          | 63.40      | 29.12      |
| General Mean |                      | 61.69      | 30.58      |
| C.V.         |                      | 11.79%     | 12.37%     |

Significant Differences According to DMR Test.

Alutharama: 10 9 1 5 13 3 7 11 2 8 12 4 6

Tinnevelly: 9 2 3 13 7 1 4 5 10 11 6 12 8

**Table 6: Effect of Nitrogen and Potash on Fresh Tuber Yield (Tonnes per Hectare)  
At Alutharama and Tinnevelly**

| Nutrient (kg. ha-1) | Alutharama      | Tinnevelly |
|---------------------|-----------------|------------|
| 0 N                 | 61.07           | 28.11      |
| 45 N                | 68.11           | 30.81      |
| 90 N                | 65.53           | 30.07      |
| 135 N               | 74.92           | 33.86      |
| L.S.D. (p=5%)       | 7.69            | 3.18       |
| (p=1%)              | 10.43           | —          |
| 0 K <sub>2</sub> 0  | 67.39           | 28.83      |
| 45 K <sub>2</sub> 0 | 68.66           | 32.51      |
| 90 K <sub>2</sub> 0 | 63.51           | 30.78      |
| L.S.D.              | Not Significant |            |

TABLE 7  
Nitrogen and Potash Interaction on Fresh Tuber Yield (Tonnes per Hectare).

|                     | Alutharama     |                |                |       | Timevelly      |                | Mean  |
|---------------------|----------------|----------------|----------------|-------|----------------|----------------|-------|
|                     | K <sub>0</sub> | K <sub>1</sub> | K <sub>2</sub> | Mean  | K <sub>0</sub> | K <sub>2</sub> |       |
| N <sub>0</sub>      | ...            | 57.64          | 61.54          | 57.33 | 58.84          | 29.88          | 28.11 |
| N <sub>1</sub>      | ...            | 66.96          | 80.87          | 56.50 | 68.11          | 27.21          | 30.81 |
| N <sub>2</sub>      | ...            | 64.97          | 65.46          | 66.16 | 65.53          | 28.16          | 30.81 |
| N <sub>4</sub>      | ...            | 79.99          | 70.75          | 74.05 | 74.93          | 30.08          | 30.07 |
| L.S.D. (N×K) (p=5%) | 18.86          |                |                |       |                |                | 33.84 |

Not significant

\*\*\*

NITROGEN

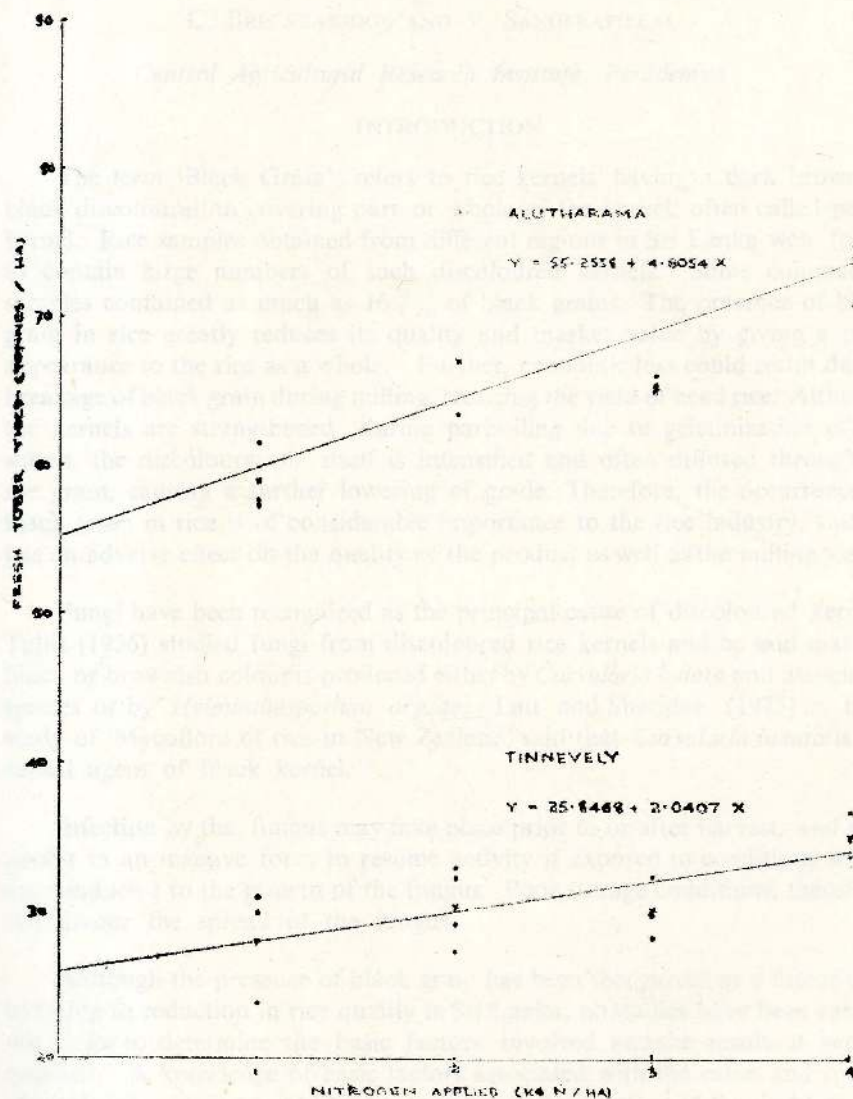
POTASH

N<sub>0</sub>, N<sub>1</sub>, N<sub>2</sub> and N<sub>3</sub> corresponding to zero, 45, 90 and 135 nitrogen (kg. ha<sup>-1</sup>)K<sub>0</sub>, K<sub>1</sub> and K<sub>2</sub> corresponding to zero, (45, and 90 K<sub>2</sub>O (kg. ha<sup>-1</sup>).



# EFFECT OF NITROGEN & POTASH ON CASSAVA

Figure -1



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# Study of the Incidence of 'Black Grain' in Rice and its Effect on Quality.

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## INTRODUCTION

The term 'Black Grain' refers to rice kernels having a dark brown to black discolouration covering part or whole of the kernel, often called pecky kernel. Rice samples obtained from different regions in Sri Lanka were found to contain large numbers of such discoloured kernels. Some commercial samples contained as much as 16.7% of black grains. The presence of black grain in rice greatly reduces its quality and market value by giving a poor appearance to the rice as a whole. Further, economic loss could result due to breakage of black grain during milling, reducing the yield of head rice. Although the kernels are strengthened during parboiling due to geletinization of the starch, the discolouration itself is intensified and often diffused throughout the grain, causing a further lowering of grade. Therefore, the occurrence of black grain in rice is of considerable importance to the rice industry, since it has an adverse effect on the quality of the product as well as the milling yields.

Fungi have been recognized as the principal cause of discoloured kernels. Tullis (1936) studied fungi from discoloured rice kernels and he said that the black or brownish colour is produced either by *Curvularia lunata* and associated species or by *Helminthosporium oryzae*. Lau and Sheridan (1975) in their study of 'Mycoflora of rice in New Zealand' said that *Curvularia lunata* is the causal agent of black kernel.

Infection by the fungus may take place prior to or after harvest, and may persist in an inactive form to resume activity if exposed to conditions which are conducive to the growth of the fungus. Poor storage conditions, therefore, can favour the spread of the fungus.

Although the presence of black grain has been recognized as a factor contributing to reduction in rice quality in Sri Lanka, no studies have been carried out so far to determine the basic factors involved and the resultant economic loss. A knowledge of basic factors associated with the cause and spread of black grain in rice would lead to a better understanding of the problem and adoption of protective measures for controlling excessive damage and economic loss.

The present investigation deals with a study of some of these factors including:-

1. incidence of 'black grain' with regard to variety, location and season,
2. the causal organism,
3. stage of grain infection and
4. effect on storage.

#### MATERIAL AND METHODS

##### 1. *Incidence of 'black grain' with regard to variety, location and season.*

This study was carried out using the harvested grain from several 4 1/2 month rice varieties, grown in different locations in Sri Lanka for two seasons. Ten varieties were obtained for the Yala Season (1975) from Batalagoda, Bombuwela, Ambalantota and Gannoruwa. Of these varieties only seven could be obtained for the Maha Season (1975/76) and these too from locations, Batalagoda, Bombuwela and Amblanatota only.

The extent of natural incidence of black grain in these samples was determined in the following manner. A representative sample of one hundred and twenty five grams of rough rice was taken from each variety and dehulled using a 'Satake' dehuller. Black grains were separated from the brown rice by hand picking and the percentage incidence of black grain by weight for each sample was determined. Each variety was tested in duplicate.

##### 2. *The Causal Organism*

Infected grains were examined and further investigations were carried out in two stages, as follows:

Pecky rice kernels were collected from samples of brown rice. These kernels were surface-sterilized with mercuric chloride (1:1000) for 1 to 2 min, and then washed in sterile water. All kernels were cultured on potato-dextrose agar medium. The cultured organism was examined microscopically. An attempt was made to identify this organism in our laboratories. At the same time, a culture was sent to the Commonwealth Mycological Institute for identification. Uninfected grains after surface-sterilization were inoculated with the previously isolated culture in order to see whether this organism produces characteristic 'black grains.'

The second stage of this experiment was the preparation of microtomic sections of the infected grains to study the extent of development of the causal organism within the infected grain. Parboiled black grains were soaked in a solution containing 2% sodium sulphite & 2% lactic acid for three days to soften the kernels. These grains were then fixed in FAA solution, dehydrated,



## BLACK GRAIN AND ITS EFFECT ON RICE QUALITY

cleared and then embedded in paraffin wax (60°C melting point.) Sections were cut at a thickness of 20  $\mu$  using a rocking type microtome. The sections obtained were stained with Thionin and Orange G (Stoughton's method) and permanent preparations were made.

### 3. Stage of Infection

A pot experiment was carried out in the green house; using two varieties namely Bg 34-8 and Bg 33-2 (of the 3-3 1/2 month age group) to find out the stage of grain development at which it is most susceptible to attack by the fungus.

The previously isolated fungus was cultured and used as inoculant. Plants were inoculated separately at four stages of grain development:-

- (1) flowering stage
- (2) milk stage
- (3) soft dough stage
- (4) immediately after harvest.

A control experiment with no inoculation was also included. Inoculation was done by rubbing a suspension of fungal spores in sterile distilled water on to the developing grains of the plant. The inoculated plants were enclosed in polythene bags so as to maintain high humidity within, and also ventilated periodically to ensure aeration. Plants were harvested at the same time and percentage infection was determined by taking visual counts of the infected grains.

### 4. Effect on Storage

Since grain moisture content is an important criterion determining the spread of fungal infection during storage, in this study the grain (variety Bg 90-2) was maintained at two levels of moisture during a storage period of three months. In the first instance the grain was maintained at 12-13% moisture which is the average moisture content during normal storage. In this case the grain was stored in different forms as paddy, brown rice, polished rice, par-boiled paddy and parboiled rice. In the second case a sample of paddy only was maintained at a grain-moisture content of 19.5 to 20.5% for a period of three months.

Counts of black kernels, in an aliquot of each sample at two-week intervals, were taken during the three-month storage period. The samples stored in the form of paddy were dehulled prior to counting.

## RESULTS AND DISCUSSIONS

### 1. Incidence of 'black grain' with regard to variety, location and season,

Statistical analysis of the data in table I showed that there was no significant difference in varietal susceptibility to natural infection by the fungus.



With reference to location and season, the dry zone station Ambalantota and the wet zone station Bombuwela showed the lowest and highest percentage of black grain incidence respectively. This was true for both the Yala and Maha seasons; incidence being higher during Maha season. This could be associated with the higher rainfall and humidity prevalent during the Maha season when compared to the Yala season. The significantly higher incidence obtained at the wet zone station Bombuwela when compared to the dry zone station Ambalantota could also be attributed to the same factors.

Therefore, it could be concluded that incidence of black grain in rice has no varietal significance but could be correlated with agro climatic conditions prevalent in different regions of the country during the different seasons.

## 2. Causal Organism

Surface examination of the infected grains showed that the grains which were slightly infected had a characteristic round black dot on their surface, (Fig.1). Just beneath this black area, the endosperm had an opaque appearance and was crumbly in texture, causing the grain to be weak. The surface of heavily infected grains were entirely covered with the black pigment and had a completely opaque endosperm.

The organism cultured from pecky rice was of similar microscopic appearance to the previously reported species *Curvularia*. It had the typical curved spores characteristic of *Curvularia*. Our deductions have been subsequently confirmed by the Commonwealth Mycological Institute. The causative organism has been identified by them as *Curvularia fallus*.

Innoculation of uninfected grains with the isolated organism produced typical black grains confirming that the cultured organism is the causative agent. Parboiling of the infected grains caused the surface pigment to diffuse into the endosperm intensifying its colour (see photos.) Sections of parboiled black grains revealed fungal hyphae traversing the endosperm. Their appearance differed somewhat from the surface hyphae in being smaller and more compact.

## 3. Stage of Infection.

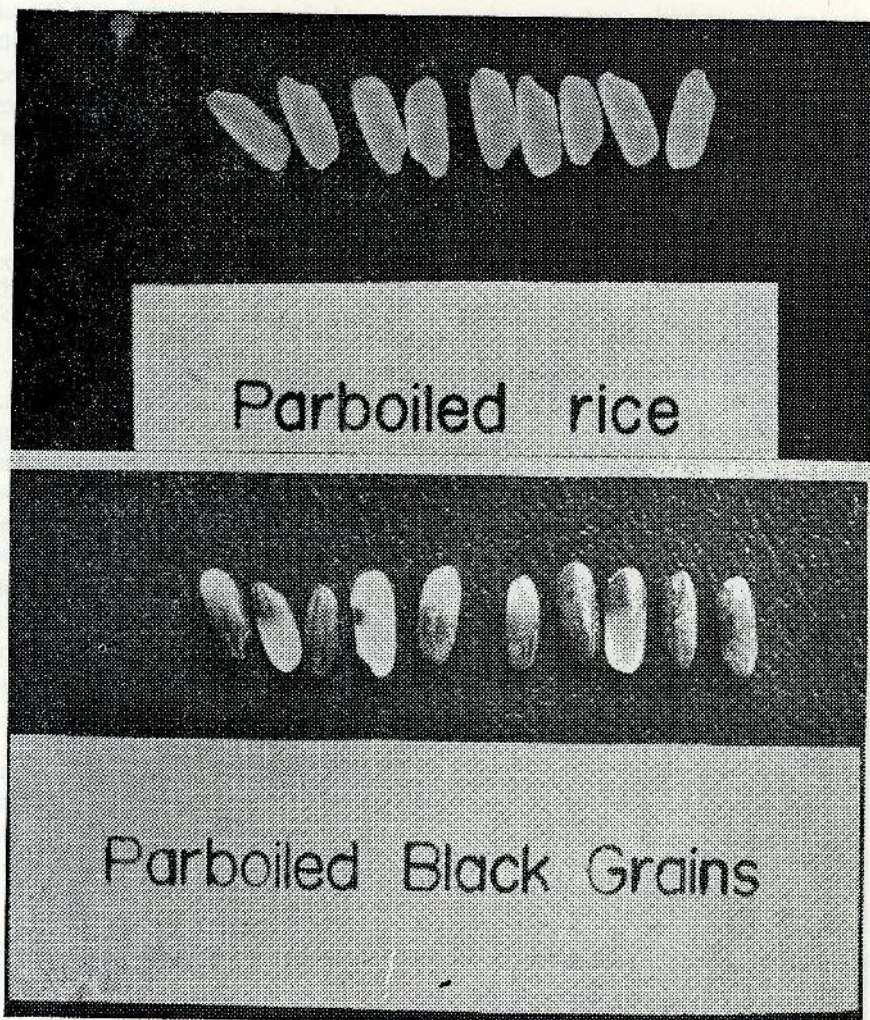
The data (Table 2 and Fig 1) showed that at the tender stages, the grains are more susceptible to fungal attack than at the more mature stages. Innoculation at the flowering stage resulted in intense infection, even the hull being externally covered with the pigment. On harvesting it was found that the grains were almost completely unfilled, producing mostly chaff, showing that apart from its effects on rice quality, the yield itself could be drastically affected.

During the successive developmental stages of the grain (viz: milk stage and soft dough stage) the results showed a gradual reduction in susceptibility

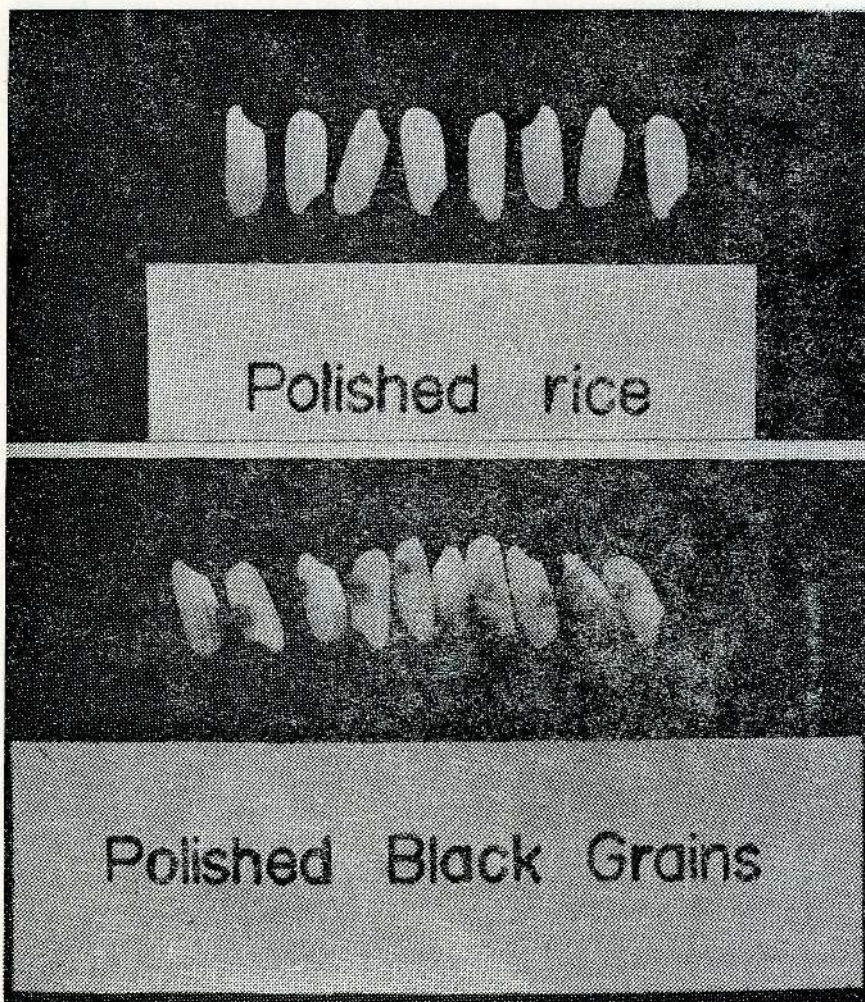


## BLACK GRAIN AND ITS EFFECT ON RICE QUALITY

to the infusion. This may be reasonably attributed to the reduction in the level of the essential fatty acid and change in cholesterol composition as the grain proceeds to ripen. The values obtained for the last experiment for the reduction of grain hardness after harvest were 9.7% and 12.0% for 14-4 and Bg 33-2 respectively. These values may have been a little higher









## BLACK GRAIN AND ITS EFFECT ON RICE QUALITY

to the infection. This may be reasonably attributed to the increase in resistivity by the maturing hull and changes in endosperm composition as the grain proceeds to ripeness. The values obtained for the last treatment (i.e. inoculation of grains immediately after harvest) were 9.3% and 13.6% for Bg 34-8 and Bg 33-2 respectively. These values may have been a little higher had the moisture content of the grain at harvest been higher. In practice, the moisture content at harvest ranges from 19-24% whereas the moisture content of the grain at harvest in this treatment was only 18%. The storage experiment discussed later too indicates a higher incidence of infection with higher moisture content.

### 4. Effect on Storage

At low grain-moisture content which is prevalent under normal storage conditions it was found that there was no spread of infection in the samples throughout the 3-month storage period. This was true irrespective of the form in which rice was stored, whether as paddy milled rice or parboiled rice.

The data in Table 3, Fig. 2 revealed that at high grain-moisture content (19.5-20.5%) there was a spread of infection through the grains. A gradual increase in incidence during the first six weeks was followed by a rapid increase in the remaining period. It should be noted however that the source of infection was already infected grains present at the beginning of the experiment. At this stage the fungus was present in a dormant stage and the period of six weeks was apparently the time required for the mold to become active, develop mycelia and spores, infect fresh grains and show visible signs on the freshly infected grains. Once proliferation was complete, the infection of fresh grains was rapid, thus the rapid increase in black grain content in the latter part of the storage period.

Thus, poor storage conditions, inducing high moisture content in the grain, causes a build up of black grains in stored paddy. Prolonged exposure to such conditions could mass-infect a stock of paddy causing serious damage and resultant loss of grain.

### SUMMARY

The control of 'Black Grain' or pecky kernels in rice is of considerable importance to the rice industry as it reduces the quality of milled rice, milling yields, and could have an adverse effect on storage. The preliminary work described includes study of the causal organism, stage of infection, its incidence with regard to variety, location and season and the effects on storage.

The organism cultured and isolated from pecky kernel was similar in microscopic appearance to the species *Curvularia* which has been previously reported as the causal organism. It has been subsequently identified as *Curvularia fallus* by the Commonwealth Mycological Institute. The black pigment produced on the surface of infected grain diffused throughout the endosperm on parboiling, intensifying the colour. In raw rice, beneath the black spots were opaque areas of crumbly texture which caused the grains to break on

milling. Microtomic sections of parboiled pecky kernels showed that the endosperm was transversed by fungal hyphae.

Artificial inoculation in green house experiments showed the tender stages of the kernel to be more susceptible to the organism. There was no varietal difference in susceptibility but agroclimatic differences had significant effect on its natural incidence.

Storage at room temperature and at two levels of grain moisture showed that there was no spread of infection at low moisture, but remained a viable and potentially dangerous organism, which after six weeks of high moisture could result in rapid spread of infection.

#### ACKNOWLEDGEMENTS

Grateful acknowledgement is made to Plant Pathologist, C.A.R.I., and Miss T. Premila, Research Officer/Plant Pathology, C.A.R.I., for their interest in the investigation of the causal organism. The authors are also grateful to Entomologist/C.A.R.I., and Prof. Dassanayake, Dept. of Botany, University of Sri Lanka, Peradeniya Campus for providing facilities to carry out microtechnique study.

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**Table 1: Natural 'Black Grain' Incidence (In Percentage) in Rice with regard to Variety, Location and Season**

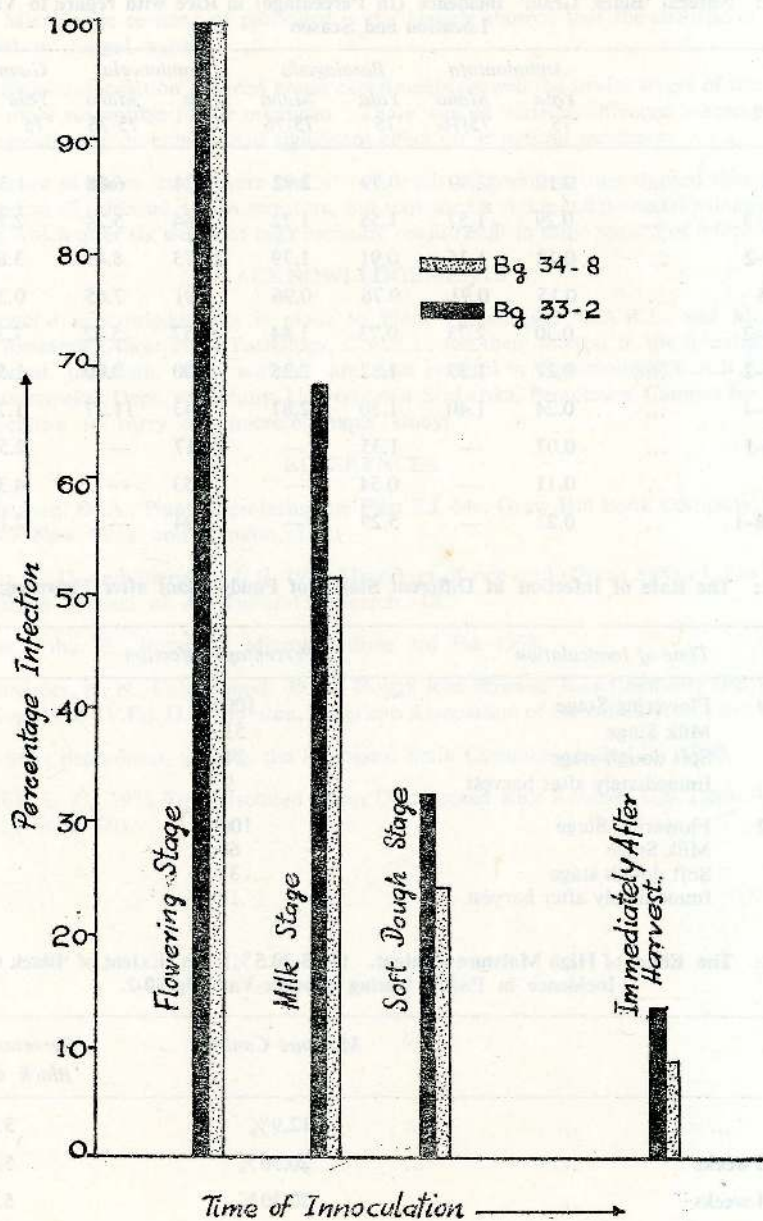
| Variety  | Ambalantota |            | Batalagoda |            | Bomuwela |            | Gannoruwa |  |
|----------|-------------|------------|------------|------------|----------|------------|-----------|--|
|          | Yala '75    | Maha 75/76 | Yala '75   | Maha 75/76 | Yala '75 | Maha 75/76 | Yala '75  |  |
| IR 26    | 0.19        | 2.39       | 0.79       | 2.92       | 6.24     | 6.88       | 1.52      |  |
| Bg 96-3  | 0.29        | 1.57       | 1.58       | 1.72       | 3.54     | 5.24       | 2.75      |  |
| Bg 96-2  | 0.18        | 1.36       | 0.91       | 1.79       | 10.73    | 8.49       | 3.86      |  |
| LD 125   | 0.15        | 0.91       | 0.76       | 0.96       | 5.91     | 7.65       | 0.30      |  |
| Bg 90-2  | 0.30        | 2.73       | 0.73       | 1.44       | 3.57     | 5.92       | 7.34      |  |
| Bg 97-2  | 0.27        | 1.33       | 1.82       | 2.25       | 8.00     | 9.00       | 1.57      |  |
| Bg 95-4  | 0.24        | 1.40       | 1.30       | 2.87       | 7.43     | 11.27      | 1.70      |  |
| Bg 98-1  | 0.07        | —          | 1.35       | —          | 10.17    | —          | 2.57      |  |
| PD 99    | 0.11        | —          | 0.54       | —          | 2.53     | —          | 4.30      |  |
| BW 248-1 | 0.23        | —          | 5.29       | —          | 5.94     | —          | 2.13      |  |

**Table 2: The Rate of Infection at Different Stages of Paddy Plant after Flowering.**

| Variety | Time of Inoculation       | Percentage Infection |
|---------|---------------------------|----------------------|
| Bg 34-8 | Flowering Stage           | 100.0                |
|         | Milk Stage                | 51.4                 |
|         | Soft dough stage          | 24.7                 |
|         | Immediately after harvest | 9.3                  |
| Bg 33-2 | Flowering Stage           | 100.0                |
|         | Milk Stage                | 68.5                 |
|         | Soft dough stage          | 32.4                 |
|         | Immediately after harvest | 13.6                 |

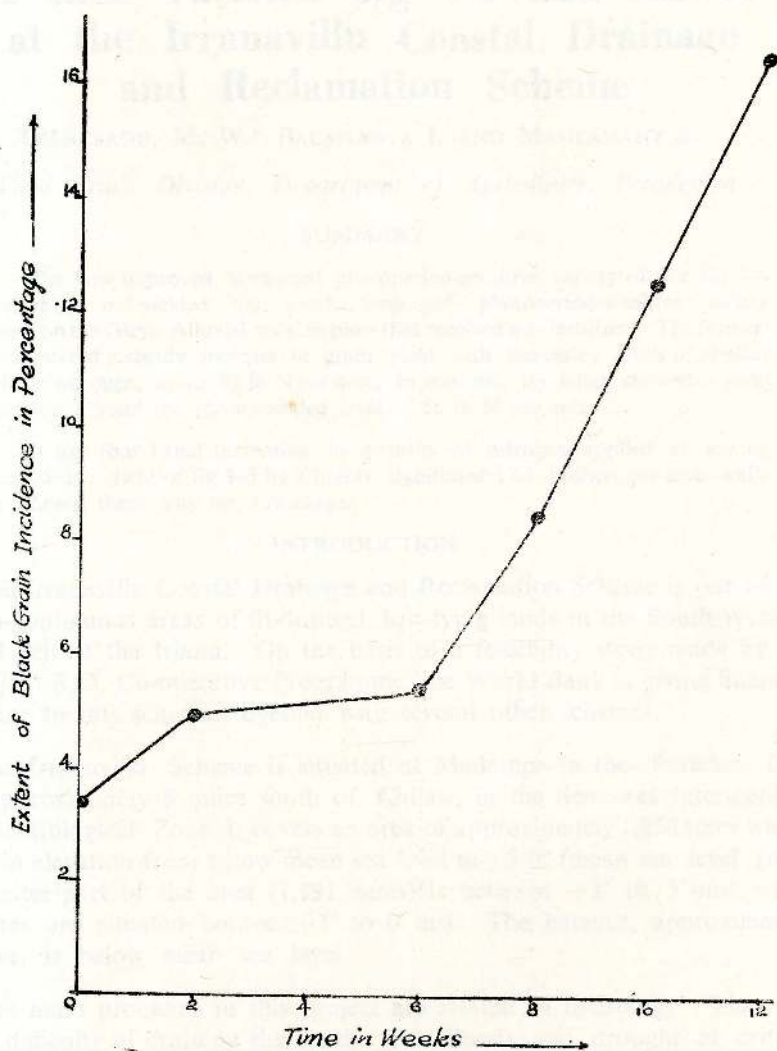
**Table 3: The Effect of High Moisture Content. (19.5-20.5%) On Extent of 'Black Grain' Incidence in Paddy During Storage-Var: Bg 90-2.**

| Time           | Moisture Content | Percentage 'Black Grain' |
|----------------|------------------|--------------------------|
| 0              | 12.9%            | 3.40                     |
| After 2 weeks  | 20.50%           | 5.00                     |
| After 4 weeks  | 20.30%           | 5.22                     |
| After 6 weeks  | 20.30%           | 5.38                     |
| After 8 weeks  | 20.00%           | 8.40                     |
| After 10 weeks | 19.50%           | 12.49                    |
| After 12 weeks | 19.50%           | 16.54                    |

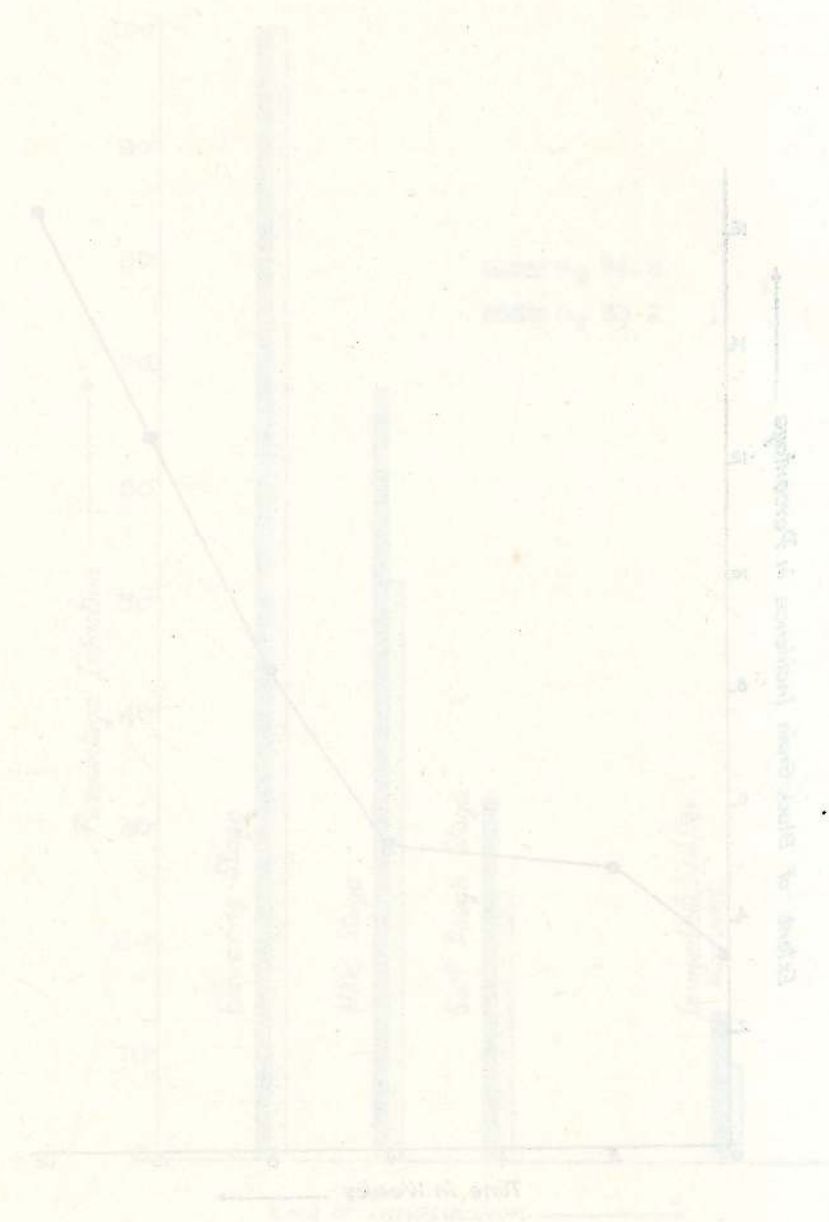




## BLACK GRAIN AND ITS EFFECT ON RICE QUALITY



# BLACK GRAIN AND ITS EFFECT ON RICE QUALITY





# Studies on Fertilizer Response of Rice Varieties Bg 3-5 and Mawee at the Irranavillu Coastal Drainage and Reclamation Scheme

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## SUMMARY

The new improved, long-aged photoperiod-sensitive variety of rice Bg 3-5 significantly out-yielded the local long-aged photoperiod-sensitive variety *Mawee*, on the Gleyic Alluvial soils, in plots that received no fertilizer. The former also registered a steady increase in grain yield with increasing levels of applied fertilizer nitrogen, up to 81 lb N per acre. In contrast, the latter showed a yield depression beyond the recommended level of 56 lb N per acre.

It was found that increasing the quantity of nitrogen applied at sowing increased the yield of Bg 3-5 by a highly significant 17.4 bushels per acre while with *Mawee* there was no advantage.

## INTRODUCTION

The Irranavillu Coastal Drainage and Reclamation Scheme is one of the six non-contiguous areas of ill-drained, low-lying lands in the South-Western Coastal belt of the Island. On the basis of a feasibility study made by the F.A.O./I.B.R.D. Co-operative Programme, the World Bank is giving financial assistance to this scheme, together with several other schemes.

The Irranavillu Scheme is situated at Madampe in the Puttalam District, approximately 8 miles south of Chilaw, in the Semi-wet Intermediate Agroclimatological Zone. It covers an area of approximately 1,850 acres which ranges in elevation from below mean sea level to +5 ft. (mean sea level (msl)) The greater part of the area (1,191 acres) is between +1' to 5' msl, while 611 acres are situated between +1' to 0 msl. The balance, approximately 50 acres, is below mean sea level.

The main problems in this project are related to hydrology. They are floods, difficulty of draining the lands after floods and drought at critical

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periods of crop growth. While the Department of Irrigation is concerned with problems of flood protection and drainage, the Department of Agriculture is involved in the extension of efficient agricultural practices to enable farmers to achieve reasonable yields of rice, based on results of research and experimentation on these low-lying lands.

The predominant soils belong to the Gleyic Alluvial group (Dimantha, 1971). The mean total rainfall for the Chilaw area is 61.5 inches (1948-1967), the range varying between 60 and 80 inches. There are two distinct rainfall periods, viz, April-May and October-December, during which times flooding is a common occurrence in the low-lying areas. Droughts are also frequent during August-September, at which time the *Maha* crop is usually at the seedling stage or early vegetative stage, when water requirements are critical. During January-February dry weather prevails in most years, and this is helpful for harvesting operations.

In this area a single, long-aged, photoperiod sensitive variety of rice is planted in the *Maha* season. The period of sowing is usually from mid-end July, and rainfall is generally supplemented by irrigation in most fields.

The present investigation was carried out to compare the response of the new, improved, long-aged, variety of rice Bg 3-5 with *Mawee*, the long-aged, local (village) variety usually grown in the Irranavillu area.

#### MATERIALS AND METHODS

Field experiments were laid down on Gleyic Alluvial soils in farmers' fields of the Irranavillu Drainage and Reclamation Scheme during the *Maha* season 1974-75. The new, improved, long-aged, variety of rice Bg 3-5 and the local, long-aged variety *Mawee*, which is usually grown in the area during this season, were compared for their responses to fertilizer application.

The variety Bg 3-5 which was bred at the Central Rice Breeding Station, Bathalagoda, has been issued to farmers recently. It is a medium-sized, white-grained variety which has been derived by crossing Engatek and 63-1583. The line 63-1583 is a selection of a cross between *Panduruwee* and Mas.

*Mawee* which is the most popular long-aged village variety sown in the Irranavillu area, is photoperiod sensitive, of 'samba' grain type and of 5 1/2 to 6 months duration. It is tall and susceptible to lodging.

#### Treatments

Each of the two varieties were tested in 5x8 m plots which were separated by perimeter bunds to prevent movement of fertilizer from plot to plot. Each plot was provided with separate inlets and outlets for irrigation water.



## FERTILIZER RESPONSE OF Bg 3-5 AND MAWEE

The fertilizer treatments were as follows:

1. no fertilizer control
2. (i) 1 1/2 cwt V 2 mixture/ac-at sowing  
(ii) 1/4 cwt urea/ac-2 weeks after sowing  
(iii) 1/2 cwt urea/ac-6 weeks after sowing  
(iv) 1 cwt T.D.M. 1 mixture/ac-16 weeks after sowing.

This is the recommendation of the Department of Agriculture for new, improved, long-aged (5-6 months) varieties in the area. The total quantity of nutrients applied was 81.6 N; 28.6 P<sub>2</sub> O<sub>5</sub> and 38.4 K<sub>2</sub> O lb/acre.

3. (i) 1 1/2 cwt V-2 mixture/ac-at sowing  
(ii) 1/4 cwt urea/ac-2 weeks after sowing  
(iii) 1 cwt T.D.M. 1 mixture/ac-16 weeks after sowing

This is the recommendation of the Department of Agriculture for local, long-aged (5-6 months) varieties in the area, and supplies the following total quantities of nutrients, 56.1 N; 28.6 P<sub>2</sub> O<sub>5</sub> and 38.4 K<sub>2</sub> O lb/ac

The above three treatments were common to both Bg 3-5 and the local village variety *Mawee*. In the fourth treatment, each of these varieties was tested giving the same quantities of N, P<sub>2</sub> O<sub>5</sub> and K<sub>2</sub> O as recommended by the Department of Agriculture, but the quantity of nitrogen supplied with the pre plant application of fertilizer was increased from 4.5 lb to 10 lb per ac.

Thus treatment No. 4, which was only for the variety Bg 3-5 was as follows-

4. (i) 1 1/2 cwt V-2 mixture plus 5.5 lb nitrogen (as urea) per acre at sowing.  
(ii) 44.4 lb urea/ac-2 weeks after sowing  
(iii) 56.0 lb urea/ac- 6 weeks after sowing  
(iv) 3/4 cwt T.D.M.-1 mixture per acre 16 weeks after sowing.

The total quantity of nutrients supplied in this treatment was the same as in the treatment No. 2 (ie, 56.1 N; 28.6 P<sub>2</sub> O<sub>5</sub> and 38.4 K<sub>2</sub> O lb per acre). The corresponding treatment with *Mawee* was as follows:

- (i) 1 1/2 cwt V-2 mixture plus 5.5 lb nitrogen (as urea) per acre at sowing.
- (ii) 44.4 lb urea/ac 6 weeks after sowing.
- (iii) 3/4 cwt T.D.M.-1 mixture per acre 16 weeks after sowing which supplies a total nutrient quantity of 56.1 N; 28.6 P<sub>2</sub> O<sub>5</sub> and 38.4 K<sub>2</sub> O lb/ac.

These treatments were tested at 8 locations on Low-Humic-Gleyic Alluvial soils between +2 and +3 feet msl. The experimental design was a randomized complete block with 8 plots. All plots were broadcast sown with sprouted seed at the rate of 2 bushels per acre, which is the usual practice of farmers in the area. Management practices recommended by the Department of Agriculture were observed at all locations.

At harvest, a border of 1 m (ie, 3'4") was left out in each plot. The nett plot area harvested in each treatment was therefore 3 × 6 m.

The characters of the soils in the experimental locations were follows:

Texture: clay loam

pH (1:0): 4.0-5.4

Conductivity: 0.02-0.12 m. mhos/cm

Total nitrogen: 0.095-0.254 %

Available P<sub>2</sub> O<sub>5</sub> (Olsen's): 0-46 lb/ac.

Exchangeable potassium: 0.15-0.55 me/100gm

Organic matter: 2.7-6.7%

## RESULTS AND DISCUSSION

The effect of treatments on the grain yield of the varieties Bg 3-5 and *Mawee* are presented in table 1.

### 1. The No-fertilizer Control Treatments

The results show clearly that the new, improved variety Bg 3-5 gave higher grain yields than the long-aged, local variety *Mawee* in the No-Fertilizer Control treatments. This is contrary to the idea that high-yielding varieties in general require more care and pampering compared with the local or village varieties that are adapted to their environment. The common belief that a negative relationship exists between high yield-potential and the ability to perform under poor management conditions does not hold good according to the results of this investigation, at least as far as fertilizer application is concerned.

The yield difference of more than 10 bushels per acre exhibited by the variety Bg 3-5 over the local variety *Mawee* was highly significant. In a fertilizer, investigation conducted during the *Maha* season of 1973-74 with these two varieties at Irranavillu, it was found that the local variety with fertilizer was superior to Bg 3-5 without fertilizer at the +2 to +3 ft. elevation and at elevation above +3 ft., the difference being highly significant. At lower elevations (+1 to +2 ft.) however, the difference in yield between the two varieties was not significantly different although Bg 3-5 out-yielded *Mawee*. Similar results were obtained at the Kiralakelle Scheme at Matara and at the Bentota Left Bank Scheme (Thenabadu *et al.*, 1974)



## FERTILIZER RESPONSE OF Bg 3-5 AND MAWEE

### 2. Fertilizer recommendation for local, long-aged varieties

According to the recommendation of fertilizer of the Department of Agriculture, long-aged, local varieties of rice in Irranavillu area (Pitigal Korale of the Puttalam District) get 56 lb per ac N, 28.6 lb per acre  $P_2O_5$  and 38.4 lb per acre.  $K_2O$ . When this quantity of nutrients was applied to soil it was found that the new, improved, variety Bg 3-5 out-yielded the local variety *Mawee* by approximately 6 bushels per acre (compare treatments  $V_1T_3$  versus  $V_2T_3$ ). The yield of Bg 3-5 in this treatment was significantly lower than in the treatment which received fertilizer recommended for the improved long-aged varieties ( $V_1T_2$ ). However, these results indicate that even with less fertilizers than recommended at present, this new, improved variety can give a reasonable yield. Thus, according to these results, even in a fertilizer shortage situation Bg 3-5 would perform better than its local counterpart *Mawee*. These results are in accordance with yields obtained from the no-fertilizer control treatment where Bg 3-5 out-yielded *Mawee*, presented earlier.)

The fertilizer-responsive character of the variety Bg 3-5 is apparent when the treatment which received more nutrients ( $V_1T_2$ ) is compared with that which received less nutrients, ( $V_1T_3$ ). This variety Bg 3-5 displayed a significant depression of yield when the quantity of fertilizers was reduced. The opposite was true with *Mawee* where reducing the quantity of nutrients significantly increased grain yields, thus showing that it is not economical to apply more than the currently recommended quantities of N,  $P_2O_5$  and  $K_2O$  per acre for the local variety.

### 3. Fertilizer recommendation for improved, long-aged varieties

The performance of Bg 3-5 and *Mawee* according to fertilizer recommendations of the Department of Agriculture for improved, long-aged varieties can be evaluated from comparison of treatment  $V_1T_2$  and  $V_2T_2$  which shows that the former out-yielded the latter by a highly significant 28.7 bushels per acre. This is to be expected because this high level of fertilizer was meant for new, improved varieties like Bg 3-5 which possess the potential to utilize the nutrients supplied for increased grain yields.

The difference in the nutrients applied by these treatments is 25.5 lb/nitrogen per acre. While the new improved variety responded to this additional amount, the local variety showed a depression in grain yield of 5.6 bushels per acre compared to treatment  $V_2T_3$ . Excessive amounts of nitrogen may be detrimental to some varieties of rice for this would stimulate the synthesis of protein and develop fresh vegetative tissue using the greater part of the assimilated carbohydrates for the formation of amino acids and proteins. This would, in the first instance, promote lodging of the crop because the synthesis of structure-strengthening tissue from the limited carbohydrate reserve



would be restricted. Thus the newly synthesized tissue becomes dark-green due to large amounts of chlorophyll in them, while at the same time becoming spongy and weak. Such plants are susceptible to wind and rain damage and to leaf diseases and insect pests. In addition, flowering and ripening of the grain are delayed, and grain quality is often said to be adversely affected.

Because differences in treatments are due to different amounts of nitrogen applied and differences in the quantities split-applied at different stages of growth, it is appropriate to consider the effects of these treatments on grain-yield of the varieties.

#### 4. Response to increasing amounts of nitrogen applied

Treatments  $V_1T_1$ ,  $V_1T_3$  and  $V_1T_2$  supply 0, 56.1 and 81.6 lb nitrogen per acre to the variety Bg 3-5 while treatments  $V_2T_1$ ,  $V_2T_3$ , and  $V_2T_2$  supply the same quantities of this nutrient to the variety *Mawee*.

With Bg 3-5, it is clear that with increase of nitrogen fertilizer there is a highly significant increase in grain yield. An increase of 25.5 lb of the element per acre yielded 16.9 bushels grain per acre. With *Mawee*, on the other hand, increasing the nitrogen by 25.5 lb. per acre resulted in a depression in grain yield of 5.6 bushels per acre. Thus it is clear that the local variety does not respond to nitrogen fertilization beyond the currently recommended rate, while the new variety Bg 3-5 is indeed fertilizer-responsive.

#### Lodging data

Information on lodging of the two varieties at eight sites at Irranvavillu is given in Table 2.

At the stage of 5 percent heading, none of the varieties had lodged. However, at the time of 85 percent heading, the range of lodging, which indicates the intensity of lodging, showed that the variety *Mawee* lodged to a greater extent than the variety Bg 3-5. The range for the former was between 10 and 50 percent while that for the latter was between 0 to 10 percent in the first three treatments, while treatment 4 showed no lodging whatsoever at this stage of growth. With Bg 3-5, plants in treatment 1 and 2 showed lodging at only one site each, while plants in treatment 3 recorded lodging of 0 to 10 percent in two out of the eight sites.

With *Mawee*, the control treatment (No.5) showed a minimum of 26 to 50 percent lodging in one out of the eight sites. There was no lodging in three sites while another 3 sites showed 0 to 10 percent lodging. A single site showed 11 to 25 percent lodging. In treatments 6, 7 and 8 the range was 0 to 25 percent and the distribution of the extent of lodging was as follows: three sites



## FERTILIZER RESPONSE OF Bg 3-5 AND MAWEE

had no lodging, three sites showed 0-10 percent lodging and 2 sites showed 11 to 25 percent lodging.

At harvesting, there were no differences between the two varieties in the range of lodging, both being between 0 to 50 percent. However, the extent of lodging of *Mawee* was greater than that of Bg 3-5, because with the former, treatments 5, 6 and 7 each had lodged at six sites and treatment 8 had lodged only at five sites.

In the case of Bg 3-5, treatment 1 had lodged at 3 sites while treatments, 2, 3 and 4 had lodged at four sites.

With *Mawee*, out of the six sites that had lodged in treatments, 5, 6 and 7, two showed 0-10 percent lodging, equal numbers showed 11-25 percent, and 26 percent to 50 percent lodging. In the case of treatment 8 only one site had 0 to 10 percent lodging, whereas 2 sites each showed 11 to 25 percent and 26 to 50 percent lodging.

With Bg 3-5, treatment 1 had lodged at three sites, two having 0 to 10 percent lodging and the other 26 to 50 percent lodging.

The treatments 2, 3 and 4, three of the four sites had 0 to 10 percent lodging and the other sites had 26 to 50 percent lodging.

### CONCLUSION

It is evident that a substantial increase in rice production can be brought about over the present average level in the Irranvillu Drainage and Reclamation Scheme area, by the use of new, improved variety Bg 3-5 that responds well to fertilization. This practice is within reach of the ordinary farmer and will give him a substantially higher net return from his land than at present. Investigations conducted in his own field will help to build up the faith of the farmer more than those conducted at research stations.

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Table 1—Effect of fertilizer treatments on grain yields of Bg 3-5 and Mavee at Irranavillu (Maha 1974/75)

| No. | Variety | Treatment                                                                                                                                                  | Yield<br>(Bu/ac) |
|-----|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| 1   | Bg 3-5  | $V_1 T_1$ No fertilizer control treatment ...                                                                                                              | 74.85 f*         |
| 2   |         | $V_1 T_2$ Fertilizer recommendation of the Department of Agriculture for improved, long-aged varieties                                                     | 119.16 b         |
| 3   |         | $V_1 T_3$ Fertilizer recommendation of the Department of Agriculture for local, long-aged varieties ...                                                    | 102.30 c         |
| 4   |         | $V_1 T_4$ Fertilizer recommendation of the Department of Agriculture for improved, long-aged varieties, with more pre-plant nitrogen than in $V_1 T_2$ ... | 136.63 a         |
| 5   | Mavee   | $V_2 T_1$ No fertilizer control treatment ...                                                                                                              | 64.27 g          |
| 6   |         | $V_2 T_2$ Fertilizer recommendation of the Department of Agriculture for improved, long-aged varieties                                                     | 90.42 e          |
| 7   |         | $V_2 T_3$ Fertilizer recommendation of the Department of Agriculture for local, long-aged varieties                                                        | 96.06 cd         |
| 8   |         | $V_2 T_4$ Fertilizer recommendation of the Department of Agriculture for local, long-aged varieties with more pre-plant nitrogen than $V_2 T_2$ ...        | 91.72 de         |

\* Significant at 1% level using Duncan's Multiple Range Test.



# FERTILIZER RESPONSE OF Bg 3-5 AND MAWEE

Table 2—Lodging data of the varieties Bg 3-5 and Mawee at Irranavillu (Maha 1974/75)

| No. | Treatments                           | Number of sites Lodged at<br>5% Heading |   |   |   |   | Number of sites Lodged at<br>85% Heading |   |   |   |   | Number of sites Lodged<br>at Harvesting |      |   |   |   |   |   |
|-----|--------------------------------------|-----------------------------------------|---|---|---|---|------------------------------------------|---|---|---|---|-----------------------------------------|------|---|---|---|---|---|
|     |                                      | Lodging<br>Range %                      |   |   |   |   | Lodging<br>Range %                       |   |   |   |   | Lodging<br>Range %                      |      |   |   |   |   |   |
|     |                                      | A                                       | B | C | D | E | A                                        | B | C | D | E | A                                       | B    | C | D | E |   |   |
| 1   | V <sub>1</sub> T <sub>1</sub> Bg 3-5 | —                                       | 8 | — | — | — | 0-10                                     | 7 | 1 | — | — | —                                       | 0-50 | 5 | 2 | — | 1 | — |
| 2   | V <sub>1</sub> T <sub>2</sub> "      | —                                       | 8 | — | — | — | 0-10                                     | 7 | 1 | — | — | —                                       | 0-50 | 4 | 3 | — | 1 | — |
| 3   | V <sub>1</sub> T <sub>3</sub> "      | —                                       | 8 | — | — | — | 0-10                                     | 6 | 2 | — | — | —                                       | 0-50 | 4 | 3 | — | 1 | — |
| 4   | V <sub>1</sub> T <sub>4</sub> "      | —                                       | 8 | — | — | — | —                                        | 8 | — | — | — | —                                       | 0-40 | 4 | 3 | — | 1 | — |
| 5   | V <sub>2</sub> T <sub>1</sub> Mawee  | —                                       | 8 | — | — | — | 0-50                                     | 3 | 3 | 1 | 1 | —                                       | 0-50 | 2 | 2 | 2 | 2 | — |
| 6   | V <sub>2</sub> T <sub>2</sub> "      | —                                       | 8 | — | — | — | 0-25                                     | 3 | 3 | 2 | — | —                                       | 0-50 | 2 | 2 | 2 | 2 | — |
| 7   | V <sub>2</sub> T <sub>3</sub> "      | —                                       | 8 | — | — | — | 0-25                                     | 3 | 3 | 2 | — | —                                       | 0-50 | 2 | 2 | 2 | 2 | — |
| 8   | V <sub>2</sub> T <sub>4</sub> "      | —                                       | 8 | — | — | — | 0-25                                     | 3 | 3 | 2 | — | —                                       | 0-50 | 3 | 1 | 2 | 2 | — |

| Number of Sites—8 | Lodging Rating: |          | 0% Plants Lodged per Plot |   |
|-------------------|-----------------|----------|---------------------------|---|
|                   | A=              |          |                           |   |
|                   | B=              | 0-10%    | "                         | " |
|                   | C=              | 11-25%   | "                         | " |
|                   | D=              | 26-50%   | "                         | " |
|                   | E=              | over 50% | "                         | " |

Table 1. Effect of fertilizer treatments on grain yield and straw yield of *Brassica napus* L. cv. *Westfield Wonder* in 1954-55

| No. | Fertilizer       | Grain yield (lb/acre) |      |      | Straw yield (lb/acre) |      |      | Total yield (lb/acre) |      |      |
|-----|------------------|-----------------------|------|------|-----------------------|------|------|-----------------------|------|------|
|     |                  | 1954                  | 1955 | 1956 | 1954                  | 1955 | 1956 | 1954                  | 1955 | 1956 |
| 1   | Control          | 1.2                   | 1.1  | 1.0  | 2.5                   | 2.4  | 2.3  | 3.7                   | 3.5  | 3.3  |
| 2   | N <sub>1</sub>   | 1.5                   | 1.4  | 1.3  | 2.8                   | 2.7  | 2.6  | 4.3                   | 4.1  | 3.9  |
| 3   | N <sub>2</sub>   | 1.8                   | 1.7  | 1.6  | 3.1                   | 3.0  | 2.9  | 4.9                   | 4.7  | 4.5  |
| 4   | N <sub>3</sub>   | 2.1                   | 2.0  | 1.9  | 3.4                   | 3.3  | 3.2  | 5.5                   | 5.3  | 5.1  |
| 5   | N <sub>4</sub>   | 2.4                   | 2.3  | 2.2  | 3.7                   | 3.6  | 3.5  | 6.1                   | 5.9  | 5.7  |
| 6   | N <sub>5</sub>   | 2.7                   | 2.6  | 2.5  | 4.0                   | 3.9  | 3.8  | 6.7                   | 6.5  | 6.3  |
| 7   | N <sub>6</sub>   | 3.0                   | 2.9  | 2.8  | 4.3                   | 4.2  | 4.1  | 7.3                   | 7.1  | 6.9  |
| 8   | N <sub>7</sub>   | 3.3                   | 3.2  | 3.1  | 4.6                   | 4.5  | 4.4  | 7.9                   | 7.7  | 7.5  |
| 9   | N <sub>8</sub>   | 3.6                   | 3.5  | 3.4  | 4.9                   | 4.8  | 4.7  | 8.5                   | 8.3  | 8.1  |
| 10  | N <sub>9</sub>   | 3.9                   | 3.8  | 3.7  | 5.2                   | 5.1  | 5.0  | 9.1                   | 8.9  | 8.7  |
| 11  | N <sub>10</sub>  | 4.2                   | 4.1  | 4.0  | 5.5                   | 5.4  | 5.3  | 9.7                   | 9.5  | 9.3  |
| 12  | N <sub>11</sub>  | 4.5                   | 4.4  | 4.3  | 5.8                   | 5.7  | 5.6  | 10.3                  | 10.1 | 9.9  |
| 13  | N <sub>12</sub>  | 4.8                   | 4.7  | 4.6  | 6.1                   | 6.0  | 5.9  | 10.9                  | 10.7 | 10.5 |
| 14  | N <sub>13</sub>  | 5.1                   | 5.0  | 4.9  | 6.4                   | 6.3  | 6.2  | 11.5                  | 11.3 | 11.1 |
| 15  | N <sub>14</sub>  | 5.4                   | 5.3  | 5.2  | 6.7                   | 6.6  | 6.5  | 12.1                  | 11.9 | 11.7 |
| 16  | N <sub>15</sub>  | 5.7                   | 5.6  | 5.5  | 7.0                   | 6.9  | 6.8  | 12.7                  | 12.5 | 12.3 |
| 17  | N <sub>16</sub>  | 6.0                   | 5.9  | 5.8  | 7.3                   | 7.2  | 7.1  | 13.3                  | 13.1 | 12.9 |
| 18  | N <sub>17</sub>  | 6.3                   | 6.2  | 6.1  | 7.6                   | 7.5  | 7.4  | 13.9                  | 13.7 | 13.5 |
| 19  | N <sub>18</sub>  | 6.6                   | 6.5  | 6.4  | 7.9                   | 7.8  | 7.7  | 14.5                  | 14.3 | 14.1 |
| 20  | N <sub>19</sub>  | 6.9                   | 6.8  | 6.7  | 8.2                   | 8.1  | 8.0  | 15.1                  | 14.9 | 14.7 |
| 21  | N <sub>20</sub>  | 7.2                   | 7.1  | 7.0  | 8.5                   | 8.4  | 8.3  | 15.7                  | 15.5 | 15.3 |
| 22  | N <sub>21</sub>  | 7.5                   | 7.4  | 7.3  | 8.8                   | 8.7  | 8.6  | 16.3                  | 16.1 | 15.9 |
| 23  | N <sub>22</sub>  | 7.8                   | 7.7  | 7.6  | 9.1                   | 9.0  | 8.9  | 16.9                  | 16.7 | 16.5 |
| 24  | N <sub>23</sub>  | 8.1                   | 8.0  | 7.9  | 9.4                   | 9.3  | 9.2  | 17.5                  | 17.3 | 17.1 |
| 25  | N <sub>24</sub>  | 8.4                   | 8.3  | 8.2  | 9.7                   | 9.6  | 9.5  | 18.1                  | 17.9 | 17.7 |
| 26  | N <sub>25</sub>  | 8.7                   | 8.6  | 8.5  | 10.0                  | 9.9  | 9.8  | 18.7                  | 18.5 | 18.3 |
| 27  | N <sub>26</sub>  | 9.0                   | 8.9  | 8.8  | 10.3                  | 10.2 | 10.1 | 19.3                  | 19.1 | 18.9 |
| 28  | N <sub>27</sub>  | 9.3                   | 9.2  | 9.1  | 10.6                  | 10.5 | 10.4 | 19.9                  | 19.7 | 19.5 |
| 29  | N <sub>28</sub>  | 9.6                   | 9.5  | 9.4  | 10.9                  | 10.8 | 10.7 | 20.5                  | 20.3 | 20.1 |
| 30  | N <sub>29</sub>  | 9.9                   | 9.8  | 9.7  | 11.2                  | 11.1 | 11.0 | 21.1                  | 20.9 | 20.7 |
| 31  | N <sub>30</sub>  | 10.2                  | 10.1 | 10.0 | 11.5                  | 11.4 | 11.3 | 21.7                  | 21.5 | 21.3 |
| 32  | N <sub>31</sub>  | 10.5                  | 10.4 | 10.3 | 11.8                  | 11.7 | 11.6 | 22.3                  | 22.1 | 21.9 |
| 33  | N <sub>32</sub>  | 10.8                  | 10.7 | 10.6 | 12.1                  | 12.0 | 11.9 | 22.9                  | 22.7 | 22.5 |
| 34  | N <sub>33</sub>  | 11.1                  | 11.0 | 10.9 | 12.4                  | 12.3 | 12.2 | 23.5                  | 23.3 | 23.1 |
| 35  | N <sub>34</sub>  | 11.4                  | 11.3 | 11.2 | 12.7                  | 12.6 | 12.5 | 24.1                  | 23.9 | 23.7 |
| 36  | N <sub>35</sub>  | 11.7                  | 11.6 | 11.5 | 13.0                  | 12.9 | 12.8 | 24.7                  | 24.5 | 24.3 |
| 37  | N <sub>36</sub>  | 12.0                  | 11.9 | 11.8 | 13.3                  | 13.2 | 13.1 | 25.3                  | 25.1 | 24.9 |
| 38  | N <sub>37</sub>  | 12.3                  | 12.2 | 12.1 | 13.6                  | 13.5 | 13.4 | 25.9                  | 25.7 | 25.5 |
| 39  | N <sub>38</sub>  | 12.6                  | 12.5 | 12.4 | 13.9                  | 13.8 | 13.7 | 26.5                  | 26.3 | 26.1 |
| 40  | N <sub>39</sub>  | 12.9                  | 12.8 | 12.7 | 14.2                  | 14.1 | 14.0 | 27.1                  | 26.9 | 26.7 |
| 41  | N <sub>40</sub>  | 13.2                  | 13.1 | 13.0 | 14.5                  | 14.4 | 14.3 | 27.7                  | 27.5 | 27.3 |
| 42  | N <sub>41</sub>  | 13.5                  | 13.4 | 13.3 | 14.8                  | 14.7 | 14.6 | 28.3                  | 28.1 | 27.9 |
| 43  | N <sub>42</sub>  | 13.8                  | 13.7 | 13.6 | 15.1                  | 15.0 | 14.9 | 28.9                  | 28.7 | 28.5 |
| 44  | N <sub>43</sub>  | 14.1                  | 14.0 | 13.9 | 15.4                  | 15.3 | 15.2 | 29.5                  | 29.3 | 29.1 |
| 45  | N <sub>44</sub>  | 14.4                  | 14.3 | 14.2 | 15.7                  | 15.6 | 15.5 | 30.1                  | 29.9 | 29.7 |
| 46  | N <sub>45</sub>  | 14.7                  | 14.6 | 14.5 | 16.0                  | 15.9 | 15.8 | 30.7                  | 30.5 | 30.3 |
| 47  | N <sub>46</sub>  | 15.0                  | 14.9 | 14.8 | 16.3                  | 16.2 | 16.1 | 31.3                  | 31.1 | 30.9 |
| 48  | N <sub>47</sub>  | 15.3                  | 15.2 | 15.1 | 16.6                  | 16.5 | 16.4 | 31.9                  | 31.7 | 31.5 |
| 49  | N <sub>48</sub>  | 15.6                  | 15.5 | 15.4 | 16.9                  | 16.8 | 16.7 | 32.5                  | 32.3 | 32.1 |
| 50  | N <sub>49</sub>  | 15.9                  | 15.8 | 15.7 | 17.2                  | 17.1 | 17.0 | 33.1                  | 32.9 | 32.7 |
| 51  | N <sub>50</sub>  | 16.2                  | 16.1 | 16.0 | 17.5                  | 17.4 | 17.3 | 33.7                  | 33.5 | 33.3 |
| 52  | N <sub>51</sub>  | 16.5                  | 16.4 | 16.3 | 17.8                  | 17.7 | 17.6 | 34.3                  | 34.1 | 33.9 |
| 53  | N <sub>52</sub>  | 16.8                  | 16.7 | 16.6 | 18.1                  | 18.0 | 17.9 | 34.9                  | 34.7 | 34.5 |
| 54  | N <sub>53</sub>  | 17.1                  | 17.0 | 16.9 | 18.4                  | 18.3 | 18.2 | 35.5                  | 35.3 | 35.1 |
| 55  | N <sub>54</sub>  | 17.4                  | 17.3 | 17.2 | 18.7                  | 18.6 | 18.5 | 36.1                  | 35.9 | 35.7 |
| 56  | N <sub>55</sub>  | 17.7                  | 17.6 | 17.5 | 19.0                  | 18.9 | 18.8 | 36.7                  | 36.5 | 36.3 |
| 57  | N <sub>56</sub>  | 18.0                  | 17.9 | 17.8 | 19.3                  | 19.2 | 19.1 | 37.3                  | 37.1 | 36.9 |
| 58  | N <sub>57</sub>  | 18.3                  | 18.2 | 18.1 | 19.6                  | 19.5 | 19.4 | 37.9                  | 37.7 | 37.5 |
| 59  | N <sub>58</sub>  | 18.6                  | 18.5 | 18.4 | 19.9                  | 19.8 | 19.7 | 38.5                  | 38.3 | 38.1 |
| 60  | N <sub>59</sub>  | 18.9                  | 18.8 | 18.7 | 20.2                  | 20.1 | 20.0 | 39.1                  | 38.9 | 38.7 |
| 61  | N <sub>60</sub>  | 19.2                  | 19.1 | 19.0 | 20.5                  | 20.4 | 20.3 | 39.7                  | 39.5 | 39.3 |
| 62  | N <sub>61</sub>  | 19.5                  | 19.4 | 19.3 | 20.8                  | 20.7 | 20.6 | 40.3                  | 40.1 | 39.9 |
| 63  | N <sub>62</sub>  | 19.8                  | 19.7 | 19.6 | 21.1                  | 21.0 | 20.9 | 40.9                  | 40.7 | 40.5 |
| 64  | N <sub>63</sub>  | 20.1                  | 20.0 | 19.9 | 21.4                  | 21.3 | 21.2 | 41.5                  | 41.3 | 41.1 |
| 65  | N <sub>64</sub>  | 20.4                  | 20.3 | 20.2 | 21.7                  | 21.6 | 21.5 | 42.1                  | 41.9 | 41.7 |
| 66  | N <sub>65</sub>  | 20.7                  | 20.6 | 20.5 | 22.0                  | 21.9 | 21.8 | 42.7                  | 42.5 | 42.3 |
| 67  | N <sub>66</sub>  | 21.0                  | 20.9 | 20.8 | 22.3                  | 22.2 | 22.1 | 43.3                  | 43.1 | 42.9 |
| 68  | N <sub>67</sub>  | 21.3                  | 21.2 | 21.1 | 22.6                  | 22.5 | 22.4 | 43.9                  | 43.7 | 43.5 |
| 69  | N <sub>68</sub>  | 21.6                  | 21.5 | 21.4 | 22.9                  | 22.8 | 22.7 | 44.5                  | 44.3 | 44.1 |
| 70  | N <sub>69</sub>  | 21.9                  | 21.8 | 21.7 | 23.2                  | 23.1 | 23.0 | 45.1                  | 44.9 | 44.7 |
| 71  | N <sub>70</sub>  | 22.2                  | 22.1 | 22.0 | 23.5                  | 23.4 | 23.3 | 45.7                  | 45.5 | 45.3 |
| 72  | N <sub>71</sub>  | 22.5                  | 22.4 | 22.3 | 23.8                  | 23.7 | 23.6 | 46.3                  | 46.1 | 45.9 |
| 73  | N <sub>72</sub>  | 22.8                  | 22.7 | 22.6 | 24.1                  | 24.0 | 23.9 | 46.9                  | 46.7 | 46.5 |
| 74  | N <sub>73</sub>  | 23.1                  | 23.0 | 22.9 | 24.4                  | 24.3 | 24.2 | 47.5                  | 47.3 | 47.1 |
| 75  | N <sub>74</sub>  | 23.4                  | 23.3 | 23.2 | 24.7                  | 24.6 | 24.5 | 48.1                  | 47.9 | 47.7 |
| 76  | N <sub>75</sub>  | 23.7                  | 23.6 | 23.5 | 25.0                  | 24.9 | 24.8 | 48.7                  | 48.5 | 48.3 |
| 77  | N <sub>76</sub>  | 24.0                  | 23.9 | 23.8 | 25.3                  | 25.2 | 25.1 | 49.3                  | 49.1 | 48.9 |
| 78  | N <sub>77</sub>  | 24.3                  | 24.2 | 24.1 | 25.6                  | 25.5 | 25.4 | 49.9                  | 49.7 | 49.5 |
| 79  | N <sub>78</sub>  | 24.6                  | 24.5 | 24.4 | 25.9                  | 25.8 | 25.7 | 50.5                  | 50.3 | 50.1 |
| 80  | N <sub>79</sub>  | 24.9                  | 24.8 | 24.7 | 26.2                  | 26.1 | 26.0 | 51.1                  | 50.9 | 50.7 |
| 81  | N <sub>80</sub>  | 25.2                  | 25.1 | 25.0 | 26.5                  | 26.4 | 26.3 | 51.7                  | 51.5 | 51.3 |
| 82  | N <sub>81</sub>  | 25.5                  | 25.4 | 25.3 | 26.8                  | 26.7 | 26.6 | 52.3                  | 52.1 | 51.9 |
| 83  | N <sub>82</sub>  | 25.8                  | 25.7 | 25.6 | 27.1                  | 27.0 | 26.9 | 52.9                  | 52.7 | 52.5 |
| 84  | N <sub>83</sub>  | 26.1                  | 26.0 | 25.9 | 27.4                  | 27.3 | 27.2 | 53.5                  | 53.3 | 53.1 |
| 85  | N <sub>84</sub>  | 26.4                  | 26.3 | 26.2 | 27.7                  | 27.6 | 27.5 | 54.1                  | 53.9 | 53.7 |
| 86  | N <sub>85</sub>  | 26.7                  | 26.6 | 26.5 | 28.0                  | 27.9 | 27.8 | 54.7                  | 54.5 | 54.3 |
| 87  | N <sub>86</sub>  | 27.0                  | 26.9 | 26.8 | 28.3                  | 28.2 | 28.1 | 55.3                  | 55.1 | 54.9 |
| 88  | N <sub>87</sub>  | 27.3                  | 27.2 | 27.1 | 28.6                  | 28.5 | 28.4 | 55.9                  | 55.7 | 55.5 |
| 89  | N <sub>88</sub>  | 27.6                  | 27.5 | 27.4 | 28.9                  | 28.8 | 28.7 | 56.5                  | 56.3 | 56.1 |
| 90  | N <sub>89</sub>  | 27.9                  | 27.8 | 27.7 | 29.2                  | 29.1 | 29.0 | 57.1                  | 56.9 | 56.7 |
| 91  | N <sub>90</sub>  | 28.2                  | 28.1 | 28.0 | 29.5                  | 29.4 | 29.3 | 57.7                  | 57.5 | 57.3 |
| 92  | N <sub>91</sub>  | 28.5                  | 28.4 | 28.3 | 29.8                  | 29.7 | 29.6 | 58.3                  | 58.1 | 57.9 |
| 93  | N <sub>92</sub>  | 28.8                  | 28.7 | 28.6 | 30.1                  | 30.0 | 29.9 | 58.9                  | 58.7 | 58.5 |
| 94  | N <sub>93</sub>  | 29.1                  | 29.0 | 28.9 | 30.4                  | 30.3 | 30.2 | 59.5                  | 59.3 | 59.1 |
| 95  | N <sub>94</sub>  | 29.4                  | 29.3 | 29.2 | 30.7                  | 30.6 | 30.5 | 60.1                  | 59.9 | 59.7 |
| 96  | N <sub>95</sub>  | 29.7                  | 29.6 | 29.5 | 31.0                  | 30.9 | 30.8 | 60.7                  | 60.5 | 60.3 |
| 97  | N <sub>96</sub>  | 30.0                  | 29.9 | 29.8 | 31.3                  | 31.2 | 31.1 | 61.3                  | 61.1 | 60.9 |
| 98  | N <sub>97</sub>  | 30.3                  | 30.2 | 30.1 | 31.6                  | 31.5 | 31.4 | 61.9                  | 61.7 | 61.5 |
| 99  | N <sub>98</sub>  | 30.6                  | 30.5 | 30.4 | 31.9                  | 31.8 | 31.7 | 62.5                  | 62.3 | 62.1 |
| 100 | N <sub>99</sub>  | 30.9                  | 30.8 | 30.7 | 32.2                  | 32.1 | 32.0 | 63.1                  | 62.9 | 62.7 |
| 101 | N <sub>100</sub> | 31.2                  | 31.1 | 31.0 | 32.5                  | 32.4 | 32.3 | 63.7                  | 63.5 | 63.3 |
| 102 | N <sub>101</sub> | 31.5                  | 31.4 | 31.3 | 32.8                  | 32.7 | 32.6 | 64.3                  | 64.1 | 63.9 |
| 103 | N <sub>102</sub> | 31.8                  | 31.7 | 31.6 | 33.1                  | 33.0 | 32.9 | 64.9                  | 64.7 | 64.5 |
| 104 | N <sub>103</sub> | 32.1                  | 32.0 | 31.9 | 33.4                  | 33.3 | 33.2 | 65.5                  | 65.3 | 65.1 |
| 105 | N <sub>104</sub> | 32.4                  | 32.3 | 32.2 | 33.7                  | 33.6 | 33.5 | 66.1                  | 65.9 | 65.7 |
| 106 | N <sub>105</sub> | 32.7                  | 32.6 | 32.5 | 34.0                  | 33.9 | 33.8 | 66.7                  | 66.5 | 66.3 |
| 107 | N <sub>106</sub> | 33.0                  | 32.9 | 32.8 | 34.3                  | 34.2 | 34.1 | 67.3                  | 67.1 | 66.9 |
| 108 | N <sub>107</sub> | 33.3                  | 33.2 | 33.1 | 34.6                  | 34.5 | 34.4 | 67.9                  | 67.7 | 67.5 |
| 109 | N <sub>108</sub> | 33.6                  | 33.5 | 33.4 | 34.9                  | 34.8 | 34.7 | 68.5                  | 68.3 | 68.1 |
| 110 | N <sub>109</sub> | 33.9                  | 33.8 | 33.7 | 35.2                  | 35.1 | 35.0 | 69.1                  | 68.9 | 68.7 |
| 111 | N <sub>110</sub> | 34.2                  | 34.1 | 34.0 | 35.5                  | 35.4 | 35.3 | 69.7                  | 69.5 | 69.3 |
| 112 | N <sub>111</sub> | 34.5                  | 34.4 | 34.3 | 35.8                  | 35.7 | 35.6 | 70.3                  | 70.1 | 69.9 |
| 113 | N <sub>112</sub> | 34.8                  | 34.7 | 34.6 | 36.1                  | 36.0 | 35.9 | 70.9                  | 70.7 | 70.5 |
| 114 | N <sub>113</sub> | 35.1                  | 35.0 | 34.9 | 36.4                  | 36.3 | 36.2 | 71.5                  | 71.3 | 71.1 |
| 115 | N <sub>114</sub> | 35.4                  | 35.3 | 35.2 | 36.7                  | 36.6 | 36.5 | 72.1</                |      |      |



# Studies on Propagation of Grape Vine in Sri Lanka

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## ABSTRACT

Basal and subterminal hardwood cuttings of the variety Improved Issabella were successfully rooted in sand and in a medium of sand and top soil. The older the canes of this variety, the better was percentage rooting. In another investigation where some levels of I. A. A. and I. B. A. were used alone and in combination, on the variety Semillon, rooting was found to be better when treated with a 50 ppm solution of J. B. A. prior to planting.

## INTRODUCTION

Grape vines established in Sri Lanka over 75 years ago by Christian Missionaries in the dry coastal areas of Puttalam and Jaffna, produce fruit yields of over 300 lb per vine per year even today. Some interest was taken on its cultivation by the Department of Agriculture in the mid-1940s but expansion of the area under this crop was very slow due to the availability of imported grapes. However with the banning of imports of table grapes in 1963, the interest in local cultivation was resumed. A planned programme of research and extension was then initiated. New varieties were introduced from abroad and their performance studied at a number of locations in the Island.

Voluminous research data on grapevines including that for vegetative propagation have been published. However, most of these refer to studies carried out in subtropical and temperate conditions and were not expected to give similar results under Sri Lanka conditions.

Since the dreaded pest phyloxera *Dactylasphaera vitifoliae* has not yet been recorded in this country, the use of robust rooted cuttings can be used for propagation.

Winkler (1962) defined a cutting as a piece of parent plant that will develop into a new plant when placed under conditions favourable for growth. He further stated that for grape cuttings, segments of canes are always used and that the most common and practical method of raising planting material is by rooted cuttings.

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In Sri Lanka pruning can be done twice a year and John (1970) has recommended early December and late May or early June pruning for Maha Illuppallama conditions in the dry zone. Usually, cuttings for propagation can be obtained from these prunings.

Investigations were carried out on the type of cuttings and rooting media, and further studies were made on age of cuttings and also on the use of growth regulators to increase percentage of rooting. These studies are dealt with separately in this paper.

Experiment No. 1 Type of cuttings and rooting media.

MATERIAL AND METHODS

This study was conducted in a greenhouse at the Agricultural Research Station, Rahangala, situated at an elevation of 4100 ft. above mean sea level. This station is in the hill-country dry zone. The variety Improved Issabella, a *Vitis labrusca* type was used.

One-year old canes were carefully removed and cuttings with 3 nodes from the basal, middle and apical portions of mature brown wood were taken. Green coloured stem was not used.

Lots of these groups were cured by placing the bundles upside down in a wooden box. The cuttings were covered with moist sand and were kept in shade for two weeks. Cured cuttings were then planted in wooden boxes with at least one node buried in the rooting media. Three types of rooting media were tested. These were six-inch thick layer of (a) sand only (b) saw dust (c) a mixture made up of equal parts of topsoil and sand.

Each treatment had 30 callused cuttings. All treatments were regularly and uniformly hand-watered with a fine rose. The study was concluded 45 days after planting.

RESULTS AND DISCUSSION

The curing for two weeks produced sufficient callus formation in more than 75% of cuttings. There were no observable differences in callus formation in the three groups of cuttings used. The rooting percentages are shown in table 1.

Table 1: Percentage rooting of different cuttings in different rooting media

| Type of Cutting       | Rooting Media |         |         |       | Mean |
|-----------------------|---------------|---------|---------|-------|------|
|                       | Sand          | Sawdust | Topsoil | Total |      |
| Terminal (apical) ... | 30.5          | 22.0    | 33.0    | 85.0  | 28.3 |
| Sub-terminal ...      | 65.2          | 50.5    | 63.0    | 168.7 | 56.2 |
| Basal ...             | 69.0          | 43.0    | 82.2    | 194.2 | 64.8 |
| Total ...             | 164.7         | 105.5   | 178.2   | —     | —    |
| Mean ...              | 54.9          | 35.2    | 59.4    | —     | —    |



## PROPAGATION OF GRAPE VINE

The percentage of rooting of sub terminal portions is nearly double that of terminal (apical) portions. There is no appreciable difference between subterminal and basal portion. This result is in agreement with that obtained by Calma and Ricky (1931).

With regard to rooting media, it is apparent from table 1, that either sand alone or a mixture of equal parts of top soil and sand, are much better rooting media than sawdust. The highest percentage of rooting is when basal portions are grown in a mixture of topsoil and sand.

### Experiment No: 2. Age of cuttings.

#### MATERIAL AND METHODS

The study on age of cuttings was carried out at Rahangala using the identical variety as in experiment No. 1. Three maturity grades were used, namely one-season, two-season and three-season old wood. In the one-season old canes there were small canes, medium-long canes and bull canes. These were also investigated.

Using the experience gained from the previous experiment, only basal and sub terminal cuttings and a rooting medium having a mixture of sand and soil were used. The cuttings were cured, and 30 cuttings for each treatment planted and irrigated as in experiment 1. This study was also completed 45 days after planting.

#### RESULTS AND DISCUSSION

There are differences between the different types of cuttings used. Percentage of rooting is shown in table II.

Table 11: Percentage of Rooting in Cuttings of different Age and Size

| Type and Age of Cuttings |     |                   | % Rooting |
|--------------------------|-----|-------------------|-----------|
| 1. One-season old wood   | (a) | Small canes       | 21.5      |
|                          | (b) | Medium-long canes | 58.0      |
|                          | (c) | Bull canes        | 24.0      |
|                          |     | Total             | 103.5     |
|                          |     | Average           | 34.5      |
| 2. Two-season old wood   |     |                   | 78.0      |
| 3. Three-season old wood |     |                   | 87.0      |

The above results clearly show that the more mature the cuttings, the better is the percentage rooting. This study also shows that in one-season old vines, the best planting material comes from medium-long canes and not from small canes and bull canes.

This result poses a problem in that the better type of material, namely two or three-season old canes are not usually available from forward prunings.



Experiment No: 111 Use of Growth Regulators for Rooting of Cuttings.

## MATERIAL AND METHODS

This study was conducted at Maha Illuppallama in a lathhouse which allowed about 50% light flow. Medium long canes from 4-year old Semillon vines were selected. Eight inches long brown-wood cuttings from the basal and sub terminal portions were collected separately.

The bases of these different cuttings were kept in different growth-regulator solutions for a period of 24 hours before curing. Freshly prepared solutions of Indole acetic acid (IAA), Indole butyric acid (IBA) and a combination consisting of equal parts of IAA and IBA were tested. Each had concentrations of 25, 50, 100, 250, 500 and 1000. ppm. A control treatment where the cuttings were kept in the normal way but in water was included as additional treatment. Each treatment had 10 cuttings selected at random. These treatments were replicated twice.

Cuttings treated in the manner described above were allowed to callus for a period of 2 weeks and were then planted in wooden boxes. The rooting media was a six-inch layer of a mixture of equal parts of topsoil and sand. Irrigations were supplied once in two days. The experiment was concluded 45 days after planting in the boxes.

## RESULTS AND DISCUSSION

Although Weaver (1956) reported that cuttings treated with growth regulators had given no higher percentage of rooting in the nursery than untreated cuttings, the present study shows a different result (Table III). IBA is definitely superior to IAA alone. However the mixture of the two growth regulators shows better results than IAA alone.

This table also shows that 50 ppm concentration is the best. However higher levels, especially those of 500 ppm and 1000 ppm were lethal. In fact the control is even better than the 1000 ppm concentration. There is a general reduction of rooting at higher concentration than 50 ppm.

Table 111: The effects of growth regulators on rooting of cuttings Maha '68. Calculated on percentage data transformed to arc-sine with  $\theta=0.25$

| Levels                       | Growth Regulators |             |         |   | Mean of 12 values |
|------------------------------|-------------------|-------------|---------|---|-------------------|
|                              | IAA               | IBA         | IBA-IAA |   |                   |
| 25 ppm                       | 156.31            | 280.18      | 255.50  |   | 57.67             |
| 50 ppm                       | 184.66            | 298.03      | 281.70  |   | 63.70             |
| 100 ppm                      | 176.56            | 199.12      | 206.33  |   | 48.50             |
| 250 ppm                      | 158.78            | 125.42      | 137.02  |   | 35.35             |
| 500 ppm                      | 90.56             | 98.55       | 95.23   |   | 23.73             |
| 1000 ppm                     | 11.48             | 60.99       | 30.20   |   | 8.55              |
| Mean of 24 values            | 32.43             | 44.40       | 41.92   |   |                   |
| Water                        | ...               | —           | —       | — | 21.93             |
| L.S.D. for Means of Levels   |                   | p=0.01=0.15 |         |   |                   |
| L.S.D. for Means of Hormones |                   | p=0.01=0.24 |         |   |                   |
| C.V.=2.94%                   |                   |             |         |   |                   |



## PROPAGATION OF GRAPE VINE

Table IV shows that in this study the better response to growth regulators is by basal cuttings rather than sub terminal ones.

**Table IV: The Effects of Growth Regulators on Rooting of different types of Cuttings.**

|                         |     |     | <i>Growth Regulators</i> |            |                | <i>Mean of<br/>36 values</i> |
|-------------------------|-----|-----|--------------------------|------------|----------------|------------------------------|
| <i>Type of Cuttings</i> |     |     | <i>IAA</i>               | <i>IBA</i> | <i>IBA-IAA</i> |                              |
| Sub terminal            | ... | ... | 325.32                   | 456.75     | 449.34         | 34.21                        |
| Basal                   | ... | ... | 453.03                   | 608.94     | 556.64         | 44.96 **                     |
| Mean of 24 values       | ... | ... | 32.43                    | 44.40      | 41.92          |                              |

\*\* Highly Superior.

### CONCLUSION

Experiment I showed that Improved Issabella basal and sub terminal brown-wood cuttings were suitable for production of rooted cuttings in either sand or a sand and top soil medium.

Experiment 2 showed that the more aged the canes of Improved Issabella were, the better these were as planting material. In one-season old canes, the medium-long canes were to be preferred to small canes and bull canes.

Experiment 3 showed that IBA at 50 ppm is suitable as a root-promoting substance in Semillon.

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Table IV shows that in this study the better response to growth regulator is by basal cutting rather than top terminal cuts.

Table V: The effects of basal cutting on the growth of *Pinus taeda* L. in the first year after cutting. The basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.

Table VI: The effects of basal cutting on the growth of *Pinus taeda* L. in the second year after cutting. The basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.

Experiment I showed that improved basal and sub-terminal growth-cutting were suitable for the production of rooted cuttings in either sand or a sand and top soil medium. The basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.

Experiment II showed that the more sand the better the basal and sub-terminal growth-cutting were. The basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.

Experiment III showed that the basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.

| Year | Basal Cutting | Top Terminal Cutting |
|------|---------------|----------------------|
| 1957 | 1.25          | 0.75                 |
| 1958 | 1.50          | 1.00                 |
| 1959 | 1.75          | 1.25                 |
| 1960 | 2.00          | 1.50                 |
| 1961 | 2.25          | 1.75                 |
| 1962 | 2.50          | 2.00                 |
| 1963 | 2.75          | 2.25                 |
| 1964 | 3.00          | 2.50                 |
| 1965 | 3.25          | 2.75                 |
| 1966 | 3.50          | 3.00                 |
| 1967 | 3.75          | 3.25                 |
| 1968 | 4.00          | 3.50                 |
| 1969 | 4.25          | 3.75                 |
| 1970 | 4.50          | 4.00                 |
| 1971 | 4.75          | 4.25                 |
| 1972 | 5.00          | 4.50                 |
| 1973 | 5.25          | 4.75                 |
| 1974 | 5.50          | 5.00                 |
| 1975 | 5.75          | 5.25                 |
| 1976 | 6.00          | 5.50                 |
| 1977 | 6.25          | 5.75                 |
| 1978 | 6.50          | 6.00                 |
| 1979 | 6.75          | 6.25                 |
| 1980 | 7.00          | 6.50                 |
| 1981 | 7.25          | 6.75                 |
| 1982 | 7.50          | 7.00                 |
| 1983 | 7.75          | 7.25                 |
| 1984 | 8.00          | 7.50                 |
| 1985 | 8.25          | 7.75                 |
| 1986 | 8.50          | 8.00                 |
| 1987 | 8.75          | 8.25                 |
| 1988 | 9.00          | 8.50                 |
| 1989 | 9.25          | 8.75                 |
| 1990 | 9.50          | 9.00                 |
| 1991 | 9.75          | 9.25                 |
| 1992 | 10.00         | 9.50                 |
| 1993 | 10.25         | 9.75                 |
| 1994 | 10.50         | 10.00                |
| 1995 | 10.75         | 10.25                |
| 1996 | 11.00         | 10.50                |
| 1997 | 11.25         | 10.75                |
| 1998 | 11.50         | 11.00                |
| 1999 | 11.75         | 11.25                |
| 2000 | 12.00         | 11.50                |
| 2001 | 12.25         | 11.75                |
| 2002 | 12.50         | 12.00                |
| 2003 | 12.75         | 12.25                |
| 2004 | 13.00         | 12.50                |
| 2005 | 13.25         | 12.75                |
| 2006 | 13.50         | 13.00                |
| 2007 | 13.75         | 13.25                |
| 2008 | 14.00         | 13.50                |
| 2009 | 14.25         | 13.75                |
| 2010 | 14.50         | 14.00                |
| 2011 | 14.75         | 14.25                |
| 2012 | 15.00         | 14.50                |
| 2013 | 15.25         | 14.75                |
| 2014 | 15.50         | 15.00                |
| 2015 | 15.75         | 15.25                |
| 2016 | 16.00         | 15.50                |
| 2017 | 16.25         | 15.75                |
| 2018 | 16.50         | 16.00                |
| 2019 | 16.75         | 16.25                |
| 2020 | 17.00         | 16.50                |
| 2021 | 17.25         | 16.75                |
| 2022 | 17.50         | 17.00                |
| 2023 | 17.75         | 17.25                |
| 2024 | 18.00         | 17.50                |
| 2025 | 18.25         | 17.75                |
| 2026 | 18.50         | 18.00                |
| 2027 | 18.75         | 18.25                |
| 2028 | 19.00         | 18.50                |
| 2029 | 19.25         | 18.75                |
| 2030 | 19.50         | 19.00                |

Table VII: The effects of basal cutting on the growth of *Pinus taeda* L. in the third year after cutting. The basal cutting treatment resulted in a significant increase in growth compared to the top terminal cutting treatment. The basal cutting treatment also resulted in a significant increase in the number of new shoots per plant.



# Effect of Rooting of Seed Tubers Presprouting and Nitrogen on the Yield of Potato (*Solanum tuberosum* L)

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## INTRODUCTION

The use of minichitted seed tubers as planting material is the established practice in Sri Lanka. These are seeds which have just broken dormancy, with yellowish white sprouts about 1/2 cm in length. Such seed take almost 3 weeks to emerge and establish as individual plants. Thus, any agronomic practice which can shorten this period can be expected to extend foliage growth and prolong the period of tuber bulking which could lead to higher yield.

The presprouting of seed tubers alters the growth pattern of the plant in two distinct ways. Firstly, the seed tuber and sprouts undergo considerable modification before planting, and secondly, planting presprouted seed results in a partial displacement of the vegetative period (Toosey, 1963). At a given stage of growth, plants from presprouted seed are therefore exposed to a set of environmental conditions different from those arising from unsprouted seed (Emilsson, 1950).

Nitrogen also appreciably influences leaf growth and plays a significant role on the time of tuber initiation. An early tuber initiation is non conducive to leaf development and may result in the reduction of both the rate and duration of tuber bulking (Borah and Milthorpe 1959, 1962). Therefore, nitrogen controls and dominates two vital factors which determine potential yield, namely leaf growth and time of tuber initiation, and rate and duration of tuber bulking.

The foregoing evidence indicates that it is feasible to manipulate seed tubers and employ cultural practices which would result in increased tuber yield under a short growing period available for a potato crop in Sri Lanka. With the objective of exploiting the available short day regime, an experiment was designed using presprouted seed and artificial root inducement at base of sprouts prior to planting. As presprouted seed will result in an increased number of main stems and consequently a higher number of stems per hill, the response of different N levels was also incorporated into the investigations.

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## MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Station Sita Eliya, during October 1973-February 1974, following a two year rotation of grass. The soil was well drained and contained 5.3% organic matter, 0.44% available nitrogen, 113.12 kg/ha  $P_2O_5$  and 0.40 me exchangeable potassium /100 g of soil. The pH was 4.9.

The climatic data are given in Table 1. During the first 65 days after planting (DAP) the rainfall received was well distributed, but a subsequent drought prevailed till final harvest. At 80 DAP, the crop was subjected to frost which caused negligible damage as the plants were senescing.

The treatments consisted of 3 levels of N. (low N-112 kg/ha; medium N-156 kg/ha and high N-200 kg/ha) two seed types, (presprouted and minichitted) with or without artificial root inducement at the sprout base. The seeds were presprouted by placing desprouted tubers in wooden trays stored in diffused sunlight at 20-22 °C for 50 days. This resulted in about 5 sturdy, dark green sprouts per tuber, 1 1/2 cm long. The minichitted seed was also desprouted and stored in the dark under conditions described for presprouting. This resulted in about 5 brittle, yellowish white sprouts per tuber, 1/2 cm long. Rooting was induced by placing seeds in wooden trays covered with moist sand. They were stored for 7 days at 20-22 °C; one lot in diffused sunlight to obtain presprouted seed, and the other in darkness for minichitted seed.

All treatments received a blanket application of 672 kg/ha concentrated super phosphate (42%  $P_2O_5$ ); and 112 kg/ha muriate of potash (60%  $K_2O$ ). At planting N as sulphate of ammonia (21% N) was applied per treatments, basally. Tamaron and Antracol were sprayed at weekly intervals at 28/15g litres of water as a prophylactic measure for insect and disease control.

The treatments were arranged in a randomised block design, replicated 3 times. Each plot measured 3.05 mx4.88 m (14.9m<sup>2</sup>). The plots were thrown into ridges and furrows at a spacing of 61 cm from the centre of one furrow to the other. The tubers were planted at a distance of 25.4 cm in the furrow on 27, October 1973. Each plot had 8 rows of potatoes, with 12 plants per row, giving a total of 96 plants per plot.

Sequential sampling was carried out at 15 day intervals commencing 30 DAP. Sampling was restricted to alternate plants in the centre rows, leaving 2 plants within each row as border plants. Two plants per plot were removed at each harvest for determining tuber fresh weight, tuber number and dry matter yield. Any swollen tip of a stolon was considered a tuber. At the final harvest tubers were grouped into 3 size grades based on diameter as follows; ware 45-55 mm; seed 35-45mm; and chat 25-35mm. The starch percentage in tubers was determined at the final harvest using a starch balance.



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The leaf area was estimated by the disk method (Watson and Watson, 1953). The cross sectional area of the punch was 1.76 cm<sup>2</sup>.

### RESULTS AND DISCUSSION

#### *Tuber fresh weight-yield*

High N reached maximum tuber yield at 90 DAP, with increases of 4.7% and 3.4% over the low and medium N respectively (Table, 2). High N significantly outyielded the low and medium N at all harvests except at 75 DAP, showing a trend in response to increased N, mainly due to a longer period of tuber bulking (Fig:1). Thus, although increased N caused a 15 day delay in attaining maximum tuber yield, it amply compensated by outyielding both low and medium N. These results confirm the findings of several workers, Widdowson and Penny, (1962); Simpson (1962); Radley (1963); Ivinś and Bremner (1965); and Gunasena (1969) who reported that with sufficient N, although crop maturity may be delayed due to a greater initial haulm growth, the final yields would be high owing to the presence of a larger leaf area at the stage of tuber development.

Presprouted seed increased final tuber yield by 12.4% at 75 DAP over minichitted seed which took 90 days to reach a maximum, (Table, 2) confirming the results of earlier reports. (de Vaz and Gunasena 1977). This could be associated with the physiologically advanced stage of growth in plants arising from presprouted seed compared with minichitted.

Except at 75 DAP, root inducement significantly increased tuber yield over non root induced tubers. At the initial (30 DAP) and final harvests (90 DAP) tuber yield with induced rooting was higher by 56% and 5.5% compared to those without root induction. This was probably due to quicker plant establishment and consequently an extended tuber bulking period.

#### *Tuber number per plant*

At 30 DAP, medium N recorded a significant increase of 23% in tubers per plant (16.5) compared with low and high N which had equal tuber numbers (13.42). In the subsequent harvests the differences were not significant (Table, 3). Maximum tubers per plant were seen at 30 DAP for medium N and 45 DAP for low and high N (Fig. 2). Consequently, the influence of N appeared to be a less critical factor for tuber initiation under a short growth period. Apparently, other factors such as hormones may be involved (Gregory, 1954; Chapman, 1958, Slater 1963).

The initial harvest (30 DAP) showed a 47% increase in tuber number per plant for presprouted seed over minichitted, (Table, 3) which could be attributable to earliness in the growth and a significantly greater partitioning of total dry matter for tuber development. At maximum tubers per plant, presprouted seed (17.2) gave an increase of 19% compared with minichitted seed (14.4).

Fig. 1 MAIN EFFECT OF TREATMENTS ON TUBER FRESH WEIGHT YIELD

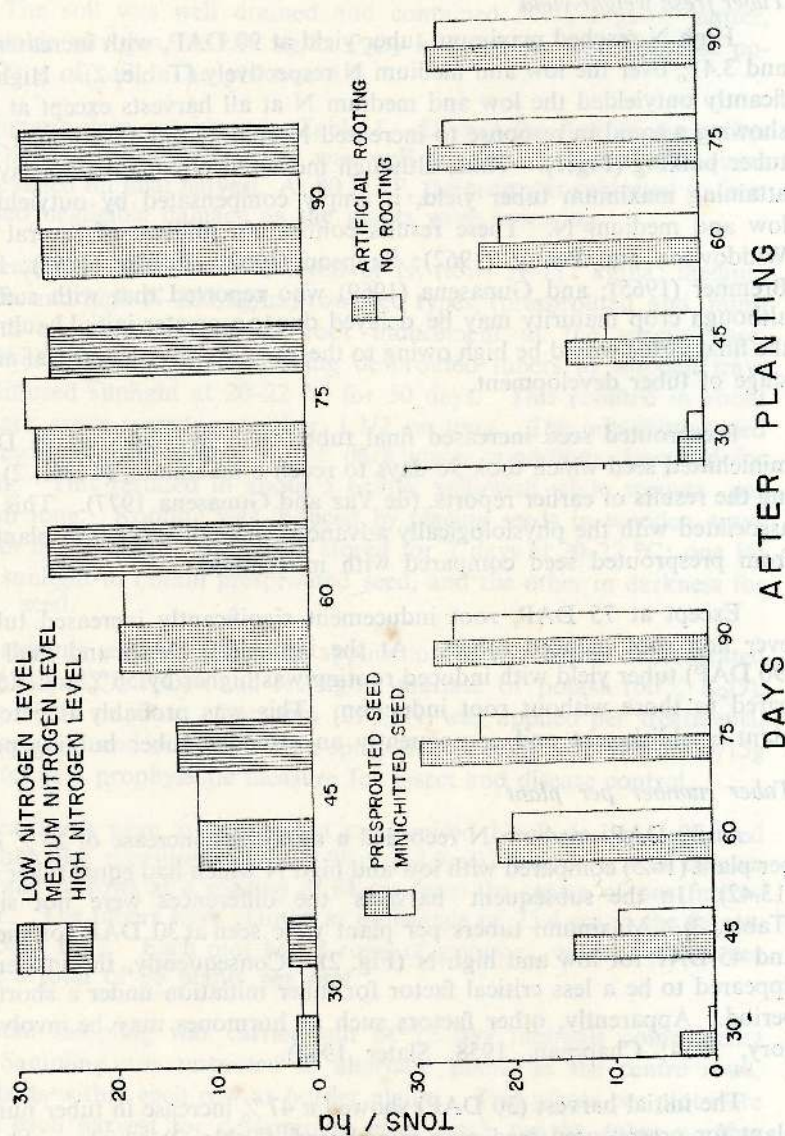
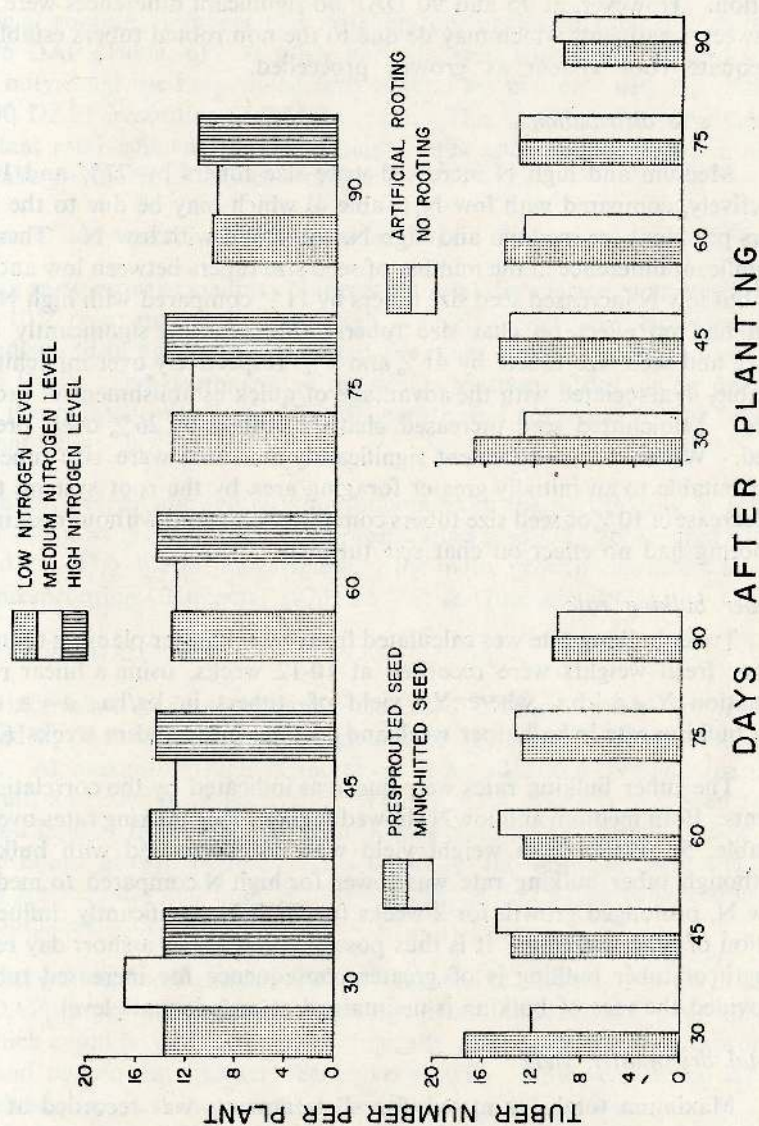




Fig. 2 MAIN EFFECT OF TREATMENTS ON TUBER NUMBER PER PLANT



At 30 and 60 DAP, artificial rooting increased tubers per plant by 31% and 12% over those without root inducement, (Table. 3) probably associated with increased nutrient uptake from a greater foraging area due to root initiation. However, at 75 and 90 DAP no significant differences were recorded between treatments which may be due to the non rooted tubers establishing an adequate root system as growth proceeded.

#### *Tuber size distribution*

Medium and high N increased ware size tubers by 77% and 100% respectively, compared with low N, (Table 4) which may be due to the lesser tubers per plant for medium and high N, compared with low N. There was no significant difference in the number of seed size tubers between low and medium N, but low N increased seed size tubers by 11% compared with high N. Nitrogen had no effect on chat size tubers. Presprouting significantly increased ware and seed size tubers by 41% and 7%, respectively over minichitted seed, (Table, 4) associated with the advantage of quick establishment of presprouted seed. Minichitted seed increased chat size tubers by 26% over presprouted seed. While root inducement significantly increased ware size tubers (90%) attributable to an initially greater foraging area by the root system, there was a decrease of 10% of seed size tubers compared with seed without root induction. Rooting had no effect on chat size tubers.

#### *Tuber bulking rate*

Tuber bulking rate was calculated from 4 weeks after planting till maximum tuber fresh weights were recorded at 10-12 weeks, using a linear regression equation  $Y = a + b.t$ , where  $Y$  = yield of tubers in kg/ha;  $a$  = a constant;  $b$  = bulking rate in kg/ha per week and  $t$  = time measured in weeks (Table, 5).

The tuber bulking rates were linear as indicated by the correlation coefficients. Both medium and low N showed higher tuber bulking rates over high N, (Table, 5). Tuber fresh weight yield was not correlated with bulking rate. Although tuber bulking rate was lower for high N compared to medium and low N, prolonged growth for 2 weeks for high N significantly influenced duration of tuber bulking. It is thus possible, that under a short day regime the length of tuber bulking is of greater consequence for increased tuber yield, provided the rate of bulking is maintained at an adequate level.

#### *Total dry matter yield*

Maximum total dry matter for all treatments was recorded at 75 DAP (Table, 6). At this harvest medium N significantly outyielded the low N in total dry matter, the differences between other two N levels being not significant.

At 30 DAP, presprouted seed recorded an increase of 96% in total dry matter yield over minichitted (Table, 6). Except at 60 DAP presprouted seed



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continued to outyield the minichitted seed in total dry matter, confirming the earliness in growth attributed to presprouting (Beukema, 1973; de Vaz & Gunasena, 1977).

Artificial rooting of tubers had no effect on maximum total dry matter yield at 75 DAP (Table, 6). At other harvests, seed with roots induced significantly outyielded the non rooted seed in total dry matter. with the initial harvest (30 DAP) recording a 56% increase. This could mainly be due to quicker plant establishment, greater foraging area and presumably more nutrient uptake in the root induced tubers.

### *Distribution of dry matter as percentage of total*

During early growth, medium N increased total dry matter partitioned for tubers by 10% compared to low and high N levels (Table, 7). However, as the crop advanced in age, total dry matter for tuber growth increased to over 80% at 75 DAP. This demonstrated the general pattern of dry matter distribution in the potato; initially for haulm growth and subsequently for tuber development (Fig: 3a).

The initial harvest showed striking differences in the partitioning of total dry matter for tuber growth (Fig: 3b) in presprouted seed, (32%) compared with minichitted, (1.79%) due to the earliness in the many growth characters attributed to presprouting (Beukema, 1973; de Vaz & Gunasena 1977).

### *Leaf area index (L)*

Each increment of N significantly increased L (Fig: 4). Maximum L was attained at 60 DAP for low and high N, and at 45 DAP for medium N, (Table, 8). At maximum, high N increased L by 20% and 39% compared with medium and low N respectively. While a L of above 3 was seen for medium and high N from 45 DAP, L for low N continued to remain below 3 during the entire growth period. This could be the result of adequate N availability for medium and high N over a longer period which enhanced leaf growth, compared with low N.

Both presprouted and minichitted seed reached maximum L at 60 DAP. Upto 45 DAP, presprouted seed recorded significant increases in L over minichitted, which could be due to the physiologically older condition of presprouted seed and consequent quicker vegetative growth. However, in the later harvest, minichitted seed increased L compared with presprouted.

Seed tubers with or without rooting attained maximum L at 60 DAP. The increase in L from 30-60 DAP was equal (50%) for both treatments, probably due to the root system in the non root induced seed growing to similar proportions as the root induced seed, with time.



Fig. 3a MAIN EFFECT OF NITROGEN LEVELS ON % DISTRIBUTION OF DRY MATTER  
HAULMS Vs TUBERS

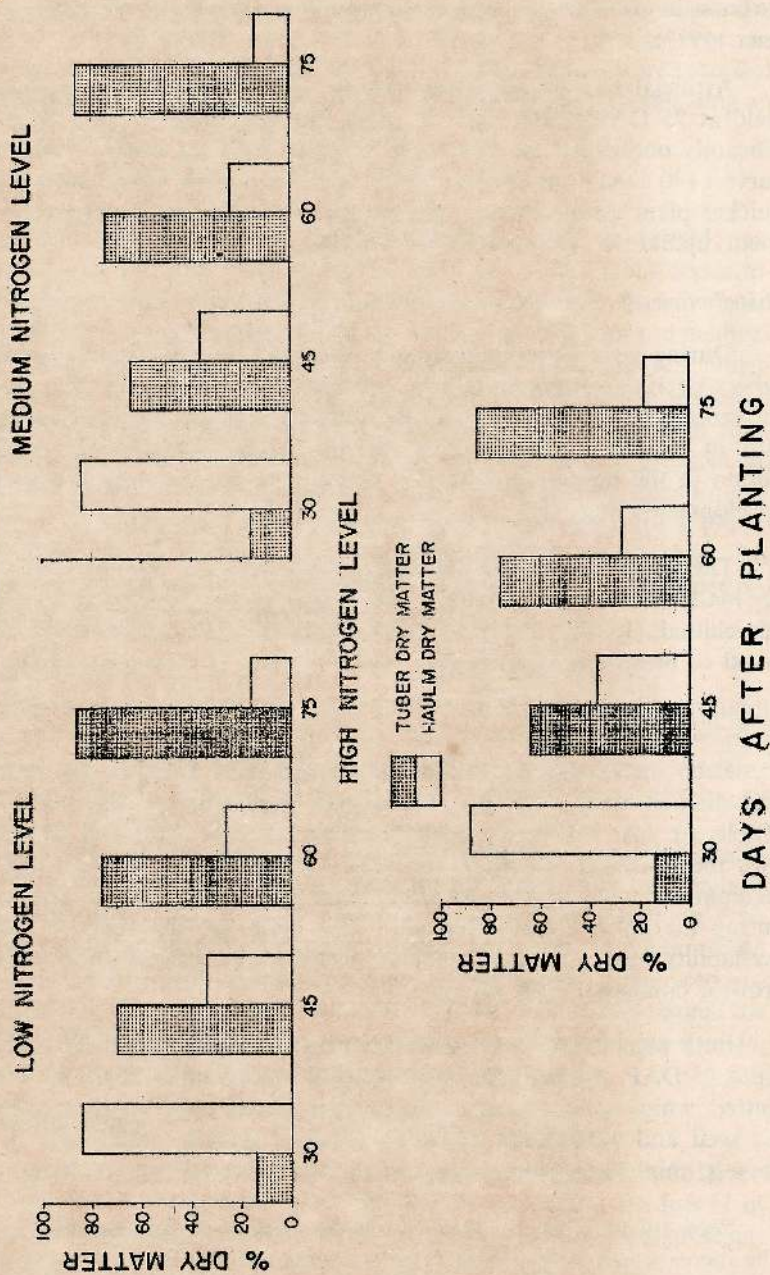




Fig. 3b MAIN EFFECT OF SEED TYPES & ROOTING OF SPROUTS ON % DISTRIBUTION OF DRY MATTER - HAULMS Vs TUBERS

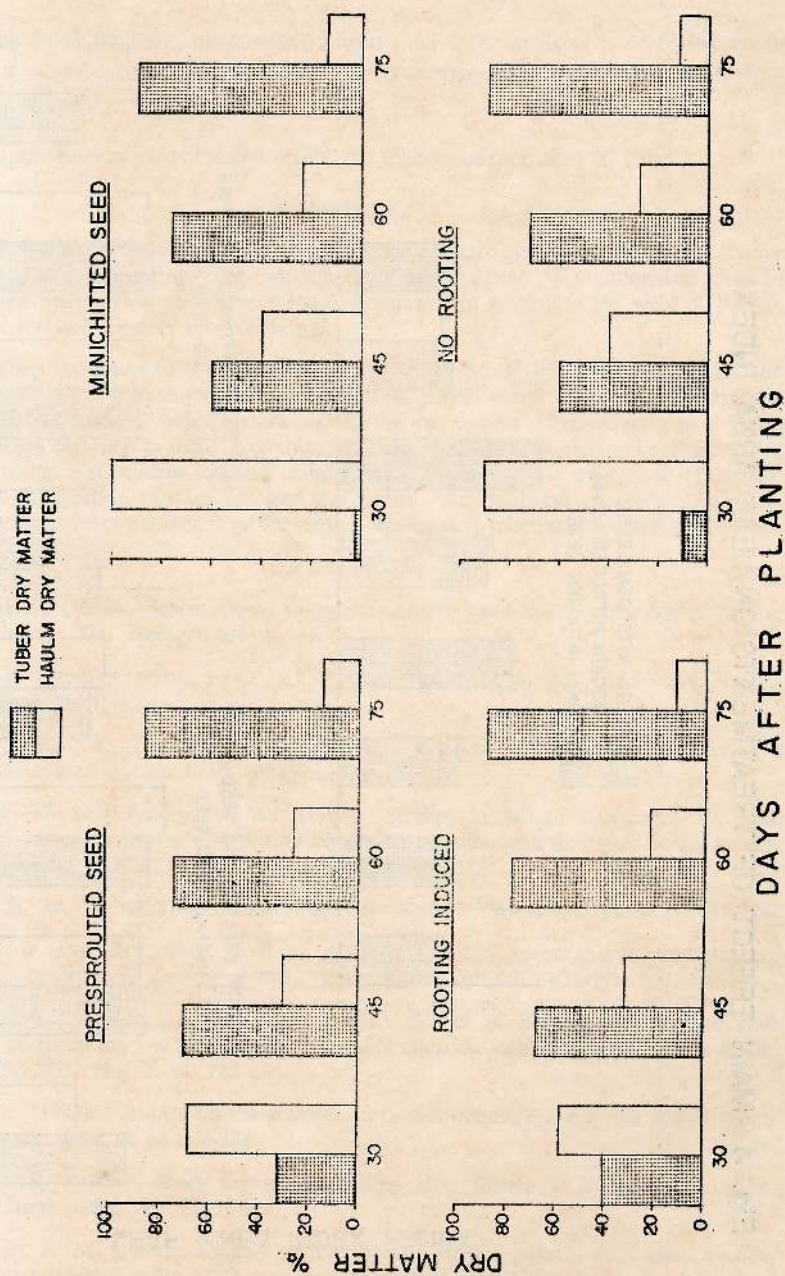
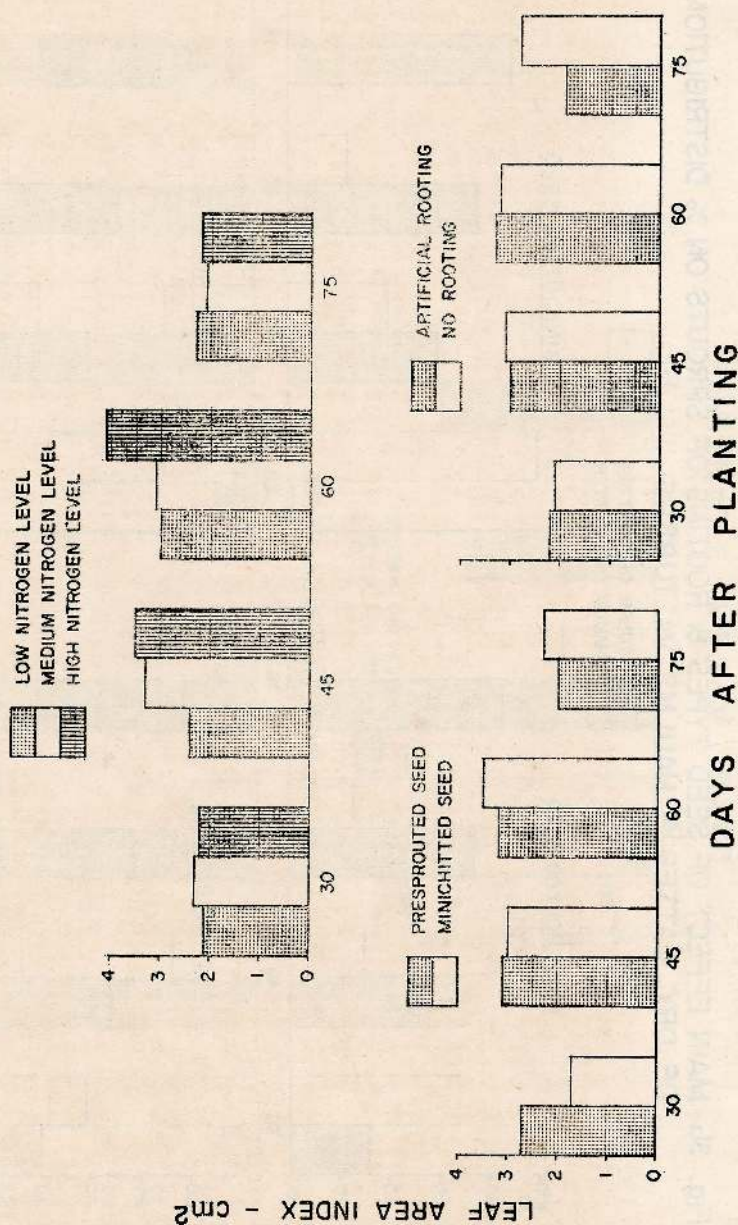


Fig. 4 MAIN EFFECT OF TREATMENTS ON LEAF AREA INDEX





## EFFECT OF ROOTING, PRESROUTING AND NITROGEN ON POTATO

### *Starch percentage in tubers*

At the final harvest, presprouted seed and seed without root inducement recorded a significant 2% increase in starch, compared with the corresponding treatments (Table, 9).

Nitrogen had no significant effect on starch percentage in tubers.

### SUMMARY

To exploit the short growing period available for a potato crop in Sri Lanka agronomic practices such as presprouting, root inducement on sprouts prior to planting and levels of N were tested with a view to influence the two parameters governing the yield of potato, namely rate and duration of tuber bulking.

The highest increment of N showed significantly more tuber yield and L, compared with medium or low N. Nitrogen appeared to be a less critical factor for tuber initiation and indicated the likelihood of other factors influencing the process. Presprouting seed tubers showed striking earliness in many growth aspects compared with minichitted. Presprouted seed while giving a significant increase in tuber yield 15 days earlier over minichitted, also increased the proportion of ware and seed size tubers. Artificial root inducement in tubers prior to planting, appeared beneficial for earlier emergence, tuberization and higher yields.

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Table 1. Climatic data, Sita Eliya, 1973/74

| Period            |     | Temperature |      | Soil<br>Temperature<br>°C | Rainfall<br>mm | Rainfall<br>days | Frost<br>days |
|-------------------|-----|-------------|------|---------------------------|----------------|------------------|---------------|
| October 1973      |     | Min. Max,   |      | (10 cm depth)             |                |                  |               |
| October 27-31     | ... | 13.4        | 19.6 | 18.0                      | 11.94          | 5                | 0             |
| November 1-15     | ... | 12.0        | 15.2 | 17.8                      | 3.05           | 7                | 0             |
| November 16-30    | ... | 11.0        | 19.0 | 17.8                      | 10.67          | 9                | 0             |
| December 1-15     | ... | 11.0        | 19.0 | 17.2                      | 5.84           | 8                | 0             |
| December 16-31    | ... | 12.0        | 18.0 | 16.7                      | 20.57          | 15               | 0             |
| January 1974 1-15 | ... | 8.5         | 19.0 | 15.8                      | 0              | 0                | 6             |
| January 16-31     | ... | 9.5         | 20.0 | 15.0                      | 0              | 0                | 2             |
| February 1-15     | ... | 9.0         | 20.0 | 17.2                      | 3.30           | 3                | 2             |



# EFFECT OF ROOTING, PRESROUTING AND NITROGEN ON POTATO

Table 2. Main effect of treatments on tuber fresh weight yield, tons/ha  
Days after planting

| Treatments                    |     |     |     | 30   | 45    | 60    | 75    | 90    |
|-------------------------------|-----|-----|-----|------|-------|-------|-------|-------|
| <b>(a) Levels of nitrogen</b> |     |     |     |      |       |       |       |       |
| 112 kg/ha (low)               | ... | ... | ... | 1.85 | 10.94 | 18.94 | 26.98 | 25.53 |
| 156 Kg/ha (medium)            | ... | ... | ... | 1.62 | 11.31 | 18.04 | 27.30 | 26.24 |
| 200 Kg/ha (high)              | ... | ... | ... | 2.39 | 13.03 | 25.75 | 24.88 | 28.24 |
| L.S.D. (P=0.05)               | ... | ... | ... | 0.45 | 1.04  | 1.39  | 1.77  | 1.45  |
| <b>(b) Sprouting</b>          |     |     |     |      |       |       |       |       |
| Presprouted                   | ... | ... | ... | 3.53 | 14.04 | 21.69 | 28.98 | 27.56 |
| Minichitted                   | ... | ... | ... | 0.60 | 9.48  | 20.14 | 23.78 | 25.78 |
| L.S.D. (P=0.05)               | ... | ... | ... | 0.37 | 0.85  | 1.13  | 1.45  | 1.19  |
| <b>(c) Rooting</b>            |     |     |     |      |       |       |       |       |
| Rooting induced               | ... | ... | ... | 2.52 | 13.86 | 21.75 | 26.95 | 27.37 |
| Rooting not induced           | ... | ... | ... | 1.61 | 9.67  | 20.07 | 25.82 | 25.95 |
| L.S.D. (P=0.05)               | ... | ... | ... | 0.37 | 0.85  | 1.13  | NS    | 1.19  |
| C.V. %                        | ... | ... | ... | 25.7 | 10.4  | 7.8   | 7.9   | 6.4   |

Table 3—Main effect of treatments on tuber number per plant  
Days after planting

| Treatments                    |     |     |     | 30   | 45   | 60   | 75   | 90   |
|-------------------------------|-----|-----|-----|------|------|------|------|------|
| <b>(a) Levels of nitrogen</b> |     |     |     |      |      |      |      |      |
| 112 Kg/ha (low)               | ... | ... | ... | 13.4 | 14.7 | 13.0 | 13.0 | 9.9  |
| 156 Kg/ha (medium)            | ... | ... | ... | 16.5 | 12.9 | 12.9 | 11.8 | 9.5  |
| 200 Kg/ha (high)              | ... | ... | ... | 13.4 | 14.5 | 14.3 | 13.5 | 10.5 |
| L.S.D. (P=0.05)               | ... | ... | ... | 1.8  | NS   | NS   | NS   | NS   |
| <b>(b) Sprouting</b>          |     |     |     |      |      |      |      |      |
| Presprouted                   | ... | ... | ... | 17.2 | 13.7 | 12.4 | 12.5 | 10.1 |
| Minichitted                   | ... | ... | ... | 11.7 | 14.4 | 14.4 | 13.1 | 9.8  |
| L.S.D. (P=0.05)               | ... | ... | ... | 1.5  | NS   | 1.1  | NS   | NS   |
| <b>(c) Rooting</b>            |     |     |     |      |      |      |      |      |
| Rooting induced               | ... | ... | ... | 16.4 | 14.3 | 14.2 | 12.8 | 9.5  |
| Rooting not induced           | ... | ... | ... | 12.5 | 13.8 | 12.7 | 12.8 | 10.5 |
| L.S.D. (P=0.05)               | ... | ... | ... | 1.5  | NS   | 1.1  | NS   | NS   |
| C.V. %                        | ... | ... | ... | 15.1 | 16.3 | 11.5 | 15.8 | 19.7 |

Table 4—Main effect of treatments on size grading of tubers at final harvest

| Treatments                    |     |     |     | Ware sizes per plant |        | Seed sizes per plant |         | Chat sizes per plant |         |
|-------------------------------|-----|-----|-----|----------------------|--------|----------------------|---------|----------------------|---------|
|                               |     |     |     | ha                   | ha     | ha                   | ha      | ha                   | ha      |
| <b>(a) Levels of nitrogen</b> |     |     |     |                      |        |                      |         |                      |         |
| 112 Kg/ha (low)               | ... | ... | ... | 0.09                 | 5,808  | 5.81                 | 374,983 | 2.84                 | 183,296 |
| 156 Kg/ha (medium)            | ... | ... | ... | 0.16                 | 10,326 | 5.58                 | 360,138 | 2.89                 | 186,523 |
| 200 Kg/ha (high)              | ... | ... | ... | 0.18                 | 11,617 | 5.22                 | 336,904 | 2.88                 | 185,878 |
| L.S.D. (P=0.05)               | ... | ... | ... | 0.04                 | 2,581  | 0.43                 | 27,752  | NS                   | NS      |
| <b>(b) Sprouting</b>          |     |     |     |                      |        |                      |         |                      |         |
| Presprouted                   | ... | ... | ... | 0.17                 | 10,971 | 5.74                 | 370,465 | 2.53                 | 163,288 |
| Minichitted                   | ... | ... | ... | 0.12                 | 7,744  | 5.33                 | 344,003 | 3.21                 | 207,176 |
| L.S.D (P=0.05)                | ... | ... | ... | 0.03                 | 1,936  | 0.35                 | 22,589  | 0.33                 | 21,298  |
| <b>(c) Rooting</b>            |     |     |     |                      |        |                      |         |                      |         |
| Rooting induced               | ... | ... | ... | 0.19                 | 12,262 | 5.23                 | 337,549 | 2.84                 | 183,296 |
| Rooting not induced           | ... | ... | ... | 0.10                 | 6,454  | 5.85                 | 577,564 | 2.91                 | 187,814 |
| L.S.D. (P=0.05)               | ... | ... | ... | 0.03                 | 1,936  | 0.35                 | 22,589  | NS                   | NS      |
| C.V. %                        | ... | ... | ... | 29.79                | 29.79  | 9.25                 | 9.25    | 16.56                | 16.56   |

Table 5—Main effect of treatments on tuber bulking rate

| Treatments                    |     |     | Tuber bulking rate |      | r      |
|-------------------------------|-----|-----|--------------------|------|--------|
|                               |     |     | Kg/ha/week         |      |        |
| <b>(a) Levels of nitrogen</b> |     |     |                    |      |        |
| 112 Kg/ha (low)               | ... | ... | ...                | 3891 | 0.9995 |
| 156 Kg/ha (medium)            | ... | ... | ...                | 3909 | 0.9978 |
| 200 Kg/ha (high)              | ... | ... | ...                | 2965 | 0.9201 |
| <b>(b) Sprouting</b>          |     |     |                    |      |        |
| Presprouted                   | ... | ... | ...                | 2940 | 0.9455 |
| Minichitted                   | ... | ... | ...                | 3019 | 0.9608 |
| <b>(c) Rooting</b>            |     |     |                    |      |        |
| Rooting induced               | ... | ... | ...                | 2930 | 0.9481 |
| Rooting not induced           | ... | ... | ...                | 3020 | 0.9587 |

Table 6—Main effect of treatments of total dry matter yield Kg/ha

| Treatments                    |     |     | Days after planting |         |         |         |
|-------------------------------|-----|-----|---------------------|---------|---------|---------|
|                               |     |     | 30                  | 45      | 60      | 75      |
| <b>(a) Levels of nitrogen</b> |     |     |                     |         |         |         |
| 112 Kg/ha (low)               | ... | ... | 916.74              | 2897.06 | 4892.71 | 6478.80 |
| 156 Kg/ha (medium)            | ... | ... | 1140.22             | 2753.53 | 4727.70 | 6668.51 |
| 200 Kg/ha (high)              | ... | ... | 1056.02             | 3422.00 | 5433.49 | 6581.08 |
| L.S.D. (P=0.05)               | ... | ... | 141.50              | 147.40  | 122.52  | 140.83  |
| <b>(b) Sprouting</b>          |     |     |                     |         |         |         |
| Presprouted                   | ... | ... | 1430.09             | 3383.29 | 4788.79 | 7147.54 |
| Minichitted                   | ... | ... | 730.49              | 2590.06 | 5220.46 | 5999.15 |
| L.S.D. (P=0.05)               | ... | ... | 197.80              | 226.70  | 101.40  | 243.50  |
| <b>(c) Rooting</b>            |     |     |                     |         |         |         |
| Rooting induced               | ... | ... | 1532.68             | 3342.46 | 5087.66 | 6434.69 |
| Rooting not induced           | ... | ... | 984.40              | 2703.31 | 4976.08 | 6552.78 |
| L.S.D. (P=0.05)               | ... | ... | 198.80              | 226.70  | 101.40  | NS      |
| C.V. %                        | ... | ... | 10.2                | 9.2     | 8.3     | 9.4     |

Table 7—Distribution of dry matter as percentage of the total

| Treatments                    |       |  | Days after planting |    |    |    |    |    |    |   |    |    |   |    |
|-------------------------------|-------|--|---------------------|----|----|----|----|----|----|---|----|----|---|----|
|                               |       |  | 30                  |    |    | 45 |    |    | 60 |   |    | 75 |   |    |
|                               |       |  | *L                  | S  | T  | L  | S  | T  | L  | S | T  | L  | S | T  |
| <b>(a) Levels of nitrogen</b> |       |  |                     |    |    |    |    |    |    |   |    |    |   |    |
| 112 Kg/ha (low)               | ...   |  | 55                  | 30 | 15 | 22 | 11 | 67 | 17 | 7 | 76 | 9  | 6 | 85 |
| 156 Kg/ha (medium)            | ...   |  | 50                  | 25 | 25 | 24 | 12 | 64 | 18 | 7 | 75 | 7  | 6 | 87 |
| 200 Kg/ha (high)              | ...   |  | 57                  | 29 | 14 | 25 | 11 | 64 | 17 | 7 | 76 | 10 | 6 | 84 |
| <b>(b) Sprouting</b>          |       |  |                     |    |    |    |    |    |    |   |    |    |   |    |
| Presprouted                   | ...   |  | 46                  | 22 | 32 | 22 | 9  | 69 | 19 | 6 | 75 | 7  | 6 | 87 |
| Minichitted                   | ...   |  | 62                  | 36 | 2  | 26 | 14 | 60 | 15 | 8 | 77 | 10 | 7 | 83 |
| <b>(c) Rooting</b>            |       |  |                     |    |    |    |    |    |    |   |    |    |   |    |
| Rooting induced               | ...   |  | 40                  | 20 | 40 | 21 | 11 | 68 | 15 | 7 | 78 | 5  | 6 | 89 |
| Rooting not induced           | ...   |  | 62                  | 28 | 10 | 27 | 12 | 61 | 20 | 7 | 73 | 10 | 6 | 84 |
| *L                            | Leaf  |  |                     |    |    |    |    |    |    |   |    |    |   |    |
| S                             | Stem  |  |                     |    |    |    |    |    |    |   |    |    |   |    |
| T                             | Tuber |  |                     |    |    |    |    |    |    |   |    |    |   |    |



# EFFECT OF ROOTING, PRESROUTING AND NITROGEN ON POTATO

Table 8—Main effect of treatments on leaf area index

| Treatments                    | Days after planting |      |      |      |
|-------------------------------|---------------------|------|------|------|
|                               | 30                  | 40   | 60   | 75   |
| <b>(a) Levels of nitrogen</b> |                     |      |      |      |
| 112 Kg/ha (low)               | 1.95                | 2.31 | 2.80 | 2.30 |
| 156 Kg/ha (medium)            | 2.30                | 3.25 | 3.03 | 2.06 |
| 200 Kg/ha (high)              | 2.24                | 3.58 | 3.90 | 2.09 |
| L.S.D. (P=0.05)               | 0.13                | 0.15 | 0.13 | 0.14 |
| <b>(b) Sprouting</b>          |                     |      |      |      |
| Presprouting                  | 2.64                | 3.09 | 3.12 | 1.96 |
| Minichitted                   | 1.68                | 2.87 | 3.37 | 2.34 |
| L.S.D. (P=0.05)               | 0.11                | 0.12 | 0.11 | 0.11 |
| <b>(c) Rooting</b>            |                     |      |      |      |
| Rooting induced               | 2.20                | 2.96 | 3.28 | 1.78 |
| Rooting not induced           | 2.12                | 3.00 | 3.20 | 2.52 |
| L.S.D. (P=0.05)               | NS                  | NS   | NS   | 0.11 |
| C.V. %                        | 7.04                | 5.90 | 4.78 | 7.42 |

Table 9—Main effect of treatments on starch percentage in tuber at final harvest

| <i>Treatments</i>             | <i>Starch percentage in tuber</i> |     |       |
|-------------------------------|-----------------------------------|-----|-------|
| <b>(a) Levels of nitrogen</b> |                                   |     |       |
| 112 Kg/ha (low)               | ...                               | ... | 15.81 |
| 156 Kg/ha medium)             | ...                               | ... | 15.73 |
| 200 Kg/ha (high)              | ...                               | ... | 16.06 |
| L.S.D. (P=0.05)               | ...                               | ... | NS    |
| <b>(b) Sprouting</b>          |                                   |     |       |
| Presprouted                   | ...                               | ... | 16.04 |
| Minichitted                   | ...                               | ... | 15.69 |
| L.S.D. (P=0.05)               | ...                               | ... | 0.32  |
| <b>(c) Rooting</b>            |                                   |     |       |
| Rooting induced               | ...                               | ... | 15.69 |
| Rooting not induced           | ...                               | ... | 16.04 |
| L.S.D. (P=0.05)               | ...                               | ... | 0.32  |
| C.V. %                        | ...                               | ... | 2.92  |

Appropriate Technology Services

121, POINT PULLE ROAD

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# Further Studies on Silica Content in Rice Husk

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## SUMMARY

The content of silica in the husk of several rice varieties grown at three locations, in the Co-ordinated Rice Varietal Trials of the Research Division of the Department of Agriculture during the dry season (*Yala*) 1975, was determined.

There were differences in the silica content in husk of plants grown at Gannoruwa, Bathalagoda and Ambalantota. The values varied between 8 and 12% in plants from Gannoruwa and between 17 and 20% in those from Ambalantota. Plants from Bathalagoda, in the Intermediate Zone, had values ranging from 11 to 14%.

There were no marked differences in silica content of paddy husk between varieties grown in the same locations. Although the percentage of silica varied between the Wet Zone and the Dry Zone locations, the percentage husk in the grain was not found to vary.

## INTRODUCTION

Silicon, a major element of the soil, is important for the growth of graminaceous plants like rice, barley and wheat. However, this element is still not included in the list of elements essential for plants. Adequate silicon has been shown to prevent manganese toxicity and to offer resistance to "bronzing" and lodging in rice in addition to improving the resistance of plants to attack by fungi and insects.

Silicon, which is absorbed from the soil solution through the root systems of plants, generally gets concentrated in supporting tissue of the stems and in the leaves. In rice, the highest concentration of this element is in the husk.

The beneficial effects of silica on the rice plant have been reported by several investigators (Ishibashi, 1957; Okamoto, 1959; Okuda and Takahashi, 1962; Sommer, 1926; and Volk *et al.*, 1958). The variations in content of silica in rice husk as determined by soil conditions and varietal differences, in four varieties of rice grown at seven locations distributed in the wet, intermediate and dry zones of Sri Lanka, were studied and reported earlier (Thena-

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Part of a paper presented at the Thirty Second Annual Session of the Sri Lanka Association for the Advancement of Science, (Sect. B), on 9th December, 1976.



badu, 1975). The work reported here is a continuation of the earlier investigation on differences in silica content of rice husk as influenced by soil conditions and variety.

#### MATERIAL AND METHODS

Silica content in the husk of rice varieties grown at three locations in the Co-ordinated Rice Varietal Trials of the Research Division of the Department of Agriculture during dry season (Yala) 1975 was determined. The varieties tested were as follows:

##### *Varieties Tested at Gannoruwa (Wet Zone)*

- |             |             |             |               |
|-------------|-------------|-------------|---------------|
| (1) IR 26   | (4) Bg 97-2 | (7) Bg 98-1 |               |
| (2) PD 99   | (5) Bg 90-2 | (8) Bg 96-2 | (10) LD 125   |
| (3) Bg 95-4 | (6) Bg 96-3 | (9) PD 98   | (11) BW 248-1 |

##### *Varieties Tested at Batalagoda (Intermediate Zone)*

- |           |             |             |
|-----------|-------------|-------------|
| (1) PD 99 | (3) LD 125  | (5) Bg 96-3 |
| (2) PD 98 | (4) Bg 96-2 |             |

##### *Varieties Tested at Ambalantota (Dry Zone)*

- |             |             |             |               |
|-------------|-------------|-------------|---------------|
| (1) IR 26   | (4) Bg 97-2 | (7) Bg 98-1 | (10) LD 125   |
| (2) PD 99   | (5) Bg 90-2 | (8) Bg 96-2 | (11) BW 248-1 |
| (3) Bg 95-4 | (6) Bg 96-3 | (9) Pg 98   |               |

#### RESULTS AND DISCUSSION

The variation in silica content of rice husk is shown in Table 1. The husk of rice grown at Gannoruwa had between 8.9 and 13.9% while that from Batalagoda contained between 11.9 and 14.3%, according to varieties. Plants from Ambalantota, where the climate (and soil) are distinctly different from these two areas, contained between 17.0 and 20.0%.

Differences in silica content of rice husk between varieties in an area are not great; however, there are striking variations between different agroclimatic zones. Except for PD 98, varieties grown at Batalagoda had the lowest content of silica in the husk and those grown at Ambalantota had the highest content. Although silica percentages vary in these areas, the contribution of husk to grain weight is between 18 to 24% (Table 2). These results confirm earlier findings (Thenabadu, 1975).

According to Okuda and Takahashi (1962), absorption of silicon by plants depends on factors such as condition of the root system, light, metabolic processes and content of sugars and organic acids, presence of metabolic inhibitors etc. The silica content in rice husk depends on the availability of this compound in soil and on factors that influence its absorption by plants.



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## SILICA CONTENT IN RICE HUSK

Results presented in Table 1 show that silica content in rice husk of varieties grown at Ambalantota are distinctly higher than those grown at Gannoruwa. Soils in the Hambantota districts where Ambalantota is situated, generally contain between 450 to 600 lb/acre of available silica (Panabokke and Nagarajah, 1964). Soils of Kandy District have also been reported to contain more than 600 lb/acre available silica, by the same authors; and the lower silica content in husk of plants grown at Gannoruwa cannot be explained only on the basis of available silica in soil. It is probable that differences in agro-climatic zones play a role in this phenomenon.

The soils of the Kurunegala district have also been reported to contain between 450 to 600 lb/acre of available silica (Panabokke and Nagarajah, 1964), but the silica contents in rice husk in grain of the five varieties grown at Bathalagoda are not as high as in those grown at Ambalantota. The findings of the earlier investigation were also similar (Thenabadu, 1975), and this could probably be due to local soil conditions at Bathalagoda. Ueda *et al.* (1957) have reported that silica content of rice is related to the silica-sesquioxide ratio of soils.

### ACKNOWLEDGEMENTS

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Table 1—Silica content in rice husk in grain at three locations  
(% of SiO<sub>2</sub>, dry weight)

| Variety |       |     |     | Gannoruwa | Bathalagoda | Ambalantota |
|---------|-------|-----|-----|-----------|-------------|-------------|
| IR      | 26    | ... | ... | 9.7       | —           | 17.7        |
| PD      | 98    | ... | ... | 12.8      | 13.4        | 18.2        |
| PD      | 99    | ... | ... | 13.0      | 14.3        | 18.6        |
| Bg      | 90-2  | ... | ... | 10.2      | —           | 19.3        |
| Bg      | 95-4  | ... | ... | 10.1      | —           | 20.6        |
| Bg      | 96-2  | ... | ... | 9.4       | 14.3        | 20.1        |
| Bg      | 96-3  | ... | ... | 10.0      | 12.4        | 19.1        |
| Bg      | 97-2  | ... | ... | 10.8      | —           | 17.0        |
| Bg      | 98-1  | ... | ... | 8.9       | —           | 19.6        |
| LD      | 125   | ... | ... | 11.7      | 11.9        | 17.8        |
| BW      | 248-1 | ... | ... | 10.3      | —           | 20.0        |

Table 2—Relative weight of husk in grain at three locations  
(% oven dried weight)

| Variety |       |     |     | Gannoruwa | Bathalagoda | Ambalantota |
|---------|-------|-----|-----|-----------|-------------|-------------|
| IR      | 26    | ... | ... | 23.0      | —           | 22.8        |
| P       | 98    | ... | ... | 23.0      | 24.0        | 24.1        |
| PD      | 99    | ... | ... | 21.0      | 19.3        | 20.0        |
| Bg      | 90-2  | ... | ... | 20.6      | —           | 18.5        |
| Bg      | 95-4  | ... | ... | 20.5      | —           | 20.1        |
| Bg      | 96-2  | ... | ... | 20.2      | 18.1        | 19.4        |
| Bg      | 96-3  | ... | ... | 20.7      | 17.6        | 19.1        |
| Bg      | 97-2  | ... | ... | 18.6      | —           | 19.0        |
| Bg      | 98-1  | ... | ... | 23.0      | —           | 24.1        |
| LD      | 105   | ... | ... | 23.1      | 19.5        | 21.3        |
| BW      | 248-1 | ... | ... | 21.4      | —           | 22.1        |



# Studies on the Relationship between some Morphological Characteristics and Tuber Yield of Sweet Potato (*Ipomoea batata* L.)

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## SUMMARY

Both local sweet potato cultivars and Nigerian introductions showed high variability in their petiole length, vine length, tuber number and tuber yield.

Petiole length was not significantly correlated with either tuber yield or tuber number per plant and indicates that such correlations cannot be used as a selection index to evaluate the yield potential of sweet potato cultivars. Although not significant, vine length was negatively correlated with the yield due to unfavourable distribution of assimilates in favour of vine growth.

## INTRODUCTION

Although there are several local clones of sweet potato, little research has been undertaken to produce improved varieties with a high yield potential. Thus a programme of breeding and selection of sweet potato based on relationships between quantitative and qualitative characters, degrees of heritability influence or interference of gene action and factors pertaining to adaptability may be useful. The petiole and vine length in sweet potato have been cited as important yield parameters (Kamalam *et al* 1976; Degras, 1967). As sweet potato is propagated by cuttings the selection of hybrid material could be possibly terminate in the  $f_1$  progeny and consequently further segregation of petiole and vine length in subsequent progenies will not arise. Therefore studies were initiated to ascertain the correlations that may exist between petiole and vine length and tuber yield in some local and Nigerian introductions of sweet potato.

## MATERIALS AND METHODS

Two field experiments were carried out at the Central Agricultural Research Institute, Gannoruwa, during April-August, 1978. The soil was a clay-loam.

In experiment 1, 20 introductions from Nigeria were raised by seeds (Table 1) and in experiment 2, 15 local selections were established by cuttings

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(Table 2). The maturity period of the varieties varied from 3-4 months. Both cuttings and seedlings were exposed to similar conditions by planting them on ridges at a spacing of 0.26 x 0.26 m. All varieties received 29 kg N/ha as Urea (46% N), 35 kg  $P_2O_5$  / ha as super phosphate (20%  $P_2O_5$ ) and 76  $K_2O$  / ha as muriate of potash (60%  $K_2O$ ) at planting. A top dressing of 29 kg N/ha was applied 35 days after planting (DAP) to all plots. All cultural practices recommended for sweet potato were adapted as per local recommendations. A randomized block design with three replicates was used.

Measurements of length of petiole and vine were recorded at crop maturity. Petiole and vine length, tuber number and tuber yield per plant were recorded from 8 randomly selected plants per variety. Petiole length was measured for 5 fully expanded leaves per plant, discarding 5 apical leaves.

### RESULTS AND DISCUSSIONS

In both experiments there were highly significant differences in petiole and vine length, tuber yield and tuber number per plant. These differences may be attributed to the genetic differences among the cultivars.

There were no significant correlations between petiole length and tuber yield per plant and petiole length and tuber numbers per plant in both experiments (Table 3). Limited information is available on the correlation studies on yield components of sweet potato. Kakalam *et al.*, (1976) in a study of 10 selections of sweet potato reported that tuber yield was significantly and positively correlated with tuber numbers. They did not report any significant correlation between tuber yield and petiole length. Hrish and Nair (1973) obtained a positive correlation between lengths of petiole and tuber yield and they suggested that this character may be effectively utilized as a selection index for yield in sweet potato. But data obtained in this study did not show any correlation between petiole length and tuber yield and agrees with the findings of Kamalam *et al.*, (1976) who reported similarly.

There was a negative correlation between vine length and tuber yield in all varieties in both experiments (Table 4). This finding confirms the report of Kamalam *et al* (1976) who also showed that the vine length and its weight are negatively correlated with tuber yield, although contrary to the findings of Li (1965) and Thamburaj and Muthukrishnan (1976). The negative relationship may be attributed to the differential distribution of assimilates in the form of vine growth at the expense of tuber growth. When vine growth increases respiratory surface also increases and a part of assimilates will also be utilized for respiration. This could further reduce the availability of carbohydrates for root growth (Burt, 1964). On the other hand, excessive vegetative growth may reduce light transmission through the crop canopy due to mutual shading of the leaves. This could reduce assimilation, although res-



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piration may be normal. Consequently the amount of assimilates available for tuber growth will be less and tuber yield will decrease (Chapman & Cowling, 1965). Therefore it could be interpreted that vines of medium length with adequate leaf area would be more efficient in photosynthesis and assimilate production for root development.

Results suggests that neither petiole length nor tuber number per plant could be used to evaluate the yield potential of sweet potato varieties. However the differences in the length of petiole may be of some use in characterizing and identifying sweet potato varieties. Vine length may be a suitable criterion to evaluate the yield potential, although vine growth may vary under different environmental conditions.

Table 1—Petiole length, vine length, tuber yield and tuber number per plant of Nigerian introductions

| Name of variety                      |              |     |     | Mean petiole length cm | Mean vine length cm | Mean No. of tubers/plant | Mean tuber yield/plant |
|--------------------------------------|--------------|-----|-----|------------------------|---------------------|--------------------------|------------------------|
| T <sub>15</sub> 3055 D <sub>38</sub> | 3 months     | ... | ... | 20.71                  | 193.00              | 5                        | 0.355                  |
| T <sub>15</sub> 2328 A <sub>2</sub>  | ...          | ... | ... | 12.87                  | 283.00              | 4                        | 0.283                  |
| T <sub>15</sub> 3055 D <sub>33</sub> | 3 1/2 months | ... | ... | 18.62                  | 276.00              | 4                        | 0.425                  |
| T <sub>15</sub> 2328 A <sub>3</sub>  | ...          | ... | ... | 17.79                  | 199.00              | 5                        | 0.292                  |
| T <sub>15</sub> 2330 B <sub>3</sub>  | ...          | ... | ... | 21.66                  | 287.00              | 3                        | 0.294                  |
| T <sub>15</sub> 2328 A <sub>1</sub>  | ...          | ... | ... | 17.17                  | 251.00              | 4                        | 0.354                  |
| T <sub>15</sub> 2332 C <sub>6</sub>  | 4 months     | ... | ... | 14.47                  | 296.33              | 4                        | 0.564                  |
| T <sub>16</sub> 8 E <sub>2</sub>     | ...          | ... | ... | 14.03                  | 146.00              | 2                        | 0.156                  |
| T <sub>15</sub> 2332 C <sub>4</sub>  | ...          | ... | ... | 17.55                  | 329.00              | 1                        | 0.121                  |
| T <sub>16</sub> 8 E <sub>5</sub>     | ...          | ... | ... | 15.37                  | 334.00              | 2                        | 0.171                  |
| T <sub>15</sub> 2328 A <sub>12</sub> | ...          | ... | ... | 18.42                  | 569.00              | 1                        | 0.036                  |
| T <sub>15</sub> 2332 C <sub>3</sub>  | ...          | ... | ... | 14.88                  | 242.00              | 2                        | 0.333                  |
| T <sub>16</sub> 8 E <sub>1</sub>     | ...          | ... | ... | 18.04                  | 362.00              | 1                        | 0.055                  |
| T <sub>15</sub> 3055 D <sub>28</sub> | ...          | ... | ... | 19.57                  | 512.00              | 2                        | 0.259                  |
| T <sub>15</sub> 2330 B <sub>1</sub>  | ...          | ... | ... | 15.88                  | 322.00              | 4                        | 0.554                  |
| T <sub>15</sub> 2332 C <sub>1</sub>  | ...          | ... | ... | 15.50                  | 247.00              | 4                        | 0.422                  |
| T <sub>15</sub> 2332 C <sub>15</sub> | ...          | ... | ... | 15.75                  | 5.13                | 1                        | 0.029                  |
| T <sub>15</sub> 2332 C <sub>5</sub>  | ...          | ... | ... | 16.13                  | 374.00              | 1                        | 0.129                  |
| T <sub>15</sub> 2330 B <sub>2</sub>  | ...          | ... | ... | 15.50                  | 439.00              | 1                        | 0.187                  |
| T <sub>15</sub> 2332 C <sub>2</sub>  | ...          | ... | ... | 23.42                  | 335.00              | 2                        | 0.134                  |
| LSD (5%)                             | ...          | ... | ... | 8.53                   | 2.74                | 3.36                     | 0.156                  |
| CV%                                  | ...          | ... | ... | 15.03                  | 21.4                | 26.4                     | 36.60                  |

Table 2—Petiole length, vine length, tuber yield and tuber number per plant of local sweet potato varieties

| <i>Varieties</i> |            |     | <i>Mean<br/>petiole<br/>length<br/>cm</i> | <i>Mean<br/>vine<br/>length<br/>cm</i> | <i>Mean<br/>No. of<br/>tubers</i> | <i>Mean<br/>tuber<br/>yield</i> |
|------------------|------------|-----|-------------------------------------------|----------------------------------------|-----------------------------------|---------------------------------|
| Selection II     | (3 months) | ... | 13.41                                     | 208.00                                 | 3                                 | 0.266                           |
| Cinchi           | ...        | ... | 19.71                                     | 209.00                                 | 3                                 | 0.349                           |
| Borgia Red       | (3 months) | ... | 10.88                                     | 291.00                                 | 3                                 | 0.286                           |
| Norin            | ...        | ... | 18.41                                     | 170.00                                 | 4                                 | 0.411                           |
| Wariapola        | ...        | ... | 14.62                                     | 181.00                                 | 2                                 | 0.128                           |
| F.A.—            | ...        | ... | 17.06                                     | 185.00                                 | 3                                 | 0.330                           |
| Selection 14     | (4 months) | ... | 16.87                                     | 279.00                                 | 1                                 | 0.050                           |
| Selection 1      | ...        | ... | 12.28                                     | 292.00                                 | 1                                 | 0.240                           |
| Selection 5      | ...        | ... | 12.08                                     | 237.00                                 | 4                                 | 0.185                           |
| B'nas            | ...        | ... | 26.00                                     | 75.00                                  | 3                                 | 0.164                           |
| N.S.F. White     | ...        | ... | 17.87                                     | 264.00                                 | 2                                 | 0.120                           |
| Bentota-B        | ...        | ... | 19.21                                     | 271.00                                 | 1                                 | 0.360                           |
| Selection 12     | ...        | ... | 11.58                                     | 258.00                                 | 4                                 | 0.187                           |
| Selection 13     | ...        | ... | 12.62                                     | 246.00                                 | 2                                 | 0.067                           |
| Selection 6      | ...        | ... | 17.38                                     | 237.00                                 | 3                                 | 0.156                           |
| L S D (5%)       | cm/plant   | ... | 7.71                                      | 111.20                                 | 2.298                             | 0.109                           |
| CV %             | ...        | ... | 14.46                                     | 14.69                                  | 28.47                             | 35.67                           |

Table 3—Correlation coefficients of growth attributes of sweet potato varieties

*Correlation Coefficients*

| <i>Varieties used</i>               | <i>Petiole length/<br/>Tuber yield<br/>per plant</i> | <i>Petiole length/<br/>Tuber number<br/>per plant</i> | <i>Vine length/<br/>Tuber yield<br/>per plant</i> |
|-------------------------------------|------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------|
| 3 1/2 months Local selections       | 0.49                                                 | 0.31                                                  | -0.08                                             |
| 3 1/2 months Nigerian introductions | 0.25                                                 | 0.43                                                  | -0.09                                             |
| 4 months Local selections           | 0.16                                                 | 0.14                                                  | -0.44                                             |
| 4 months Nigerian introductions     | 0.33                                                 | 0.42                                                  | -0.06                                             |



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### INTRODUCTION

Surface charge characteristics of soil colloids are responsible for various important physico-chemical properties such as ion exchange, ion mobility, aggregate stability, etc. The difference in behaviour of tropical soils from temperate soils with respect to these properties is often due to their basic difference in the surface charge characteristics. Soils of the temperate region are mainly of the constant surface charge type, whereas the charges arise from isomorphous substitution in the 2:1 clays, whereas the soils of the humid tropics are of the constant potential type where the charges arise from the ionization of organic or the sil silanol and siloxanol groups. The Gouy-Chapman theory of the electrical double layer explains that the charges of the constant potential type are strongly dependent on the electrolyte concentration and a range of cations, ions and therefore making measurement of cation exchange or anion exchange capacities used in the temperate countries are of doubtful value when applied to tropical soils. Studies reported on Oxisols and Inceptisols in a Florida (Dorcas et al., 1972) and on Ultisols (Dorcas et al., 1972) and on Alfisols (Dorcas et al., 1972) and Ultisols (Dorcas et al., 1972) from Brazil and on Alfisols and Ultisols from Nigeria (Odeh et al., 1976) showed that the surface charge characteristics of the humid tropical soils are distinctly different from those of the temperate soils.

# MORPHOLOGICAL CHARACTERISTICS AND YIELD

| Table 1. Morphological characteristics and yield of wheat genotypes |                     |                     |                     |
|---------------------------------------------------------------------|---------------------|---------------------|---------------------|
| Genotype                                                            | Grain yield (kg/ha) | Straw yield (kg/ha) | Total yield (kg/ha) |
| Genotype 1                                                          | 1.2                 | 0.8                 | 2.0                 |
| Genotype 2                                                          | 1.5                 | 1.0                 | 2.5                 |
| Genotype 3                                                          | 1.8                 | 1.2                 | 3.0                 |
| Genotype 4                                                          | 2.0                 | 1.5                 | 3.5                 |
| Genotype 5                                                          | 2.2                 | 1.8                 | 4.0                 |
| Genotype 6                                                          | 2.5                 | 2.0                 | 4.5                 |
| Genotype 7                                                          | 2.8                 | 2.2                 | 5.0                 |
| Genotype 8                                                          | 3.0                 | 2.5                 | 5.5                 |
| Genotype 9                                                          | 3.2                 | 2.8                 | 6.0                 |
| Genotype 10                                                         | 3.5                 | 3.0                 | 6.5                 |
| Genotype 11                                                         | 3.8                 | 3.2                 | 7.0                 |
| Genotype 12                                                         | 4.0                 | 3.5                 | 7.5                 |
| Genotype 13                                                         | 4.2                 | 3.8                 | 8.0                 |
| Genotype 14                                                         | 4.5                 | 4.0                 | 8.5                 |
| Genotype 15                                                         | 4.8                 | 4.2                 | 9.0                 |
| Genotype 16                                                         | 5.0                 | 4.5                 | 9.5                 |
| Genotype 17                                                         | 5.2                 | 4.8                 | 10.0                |
| Genotype 18                                                         | 5.5                 | 5.0                 | 10.5                |
| Genotype 19                                                         | 5.8                 | 5.2                 | 11.0                |
| Genotype 20                                                         | 6.0                 | 5.5                 | 11.5                |
| Genotype 21                                                         | 6.2                 | 5.8                 | 12.0                |
| Genotype 22                                                         | 6.5                 | 6.0                 | 12.5                |
| Genotype 23                                                         | 6.8                 | 6.2                 | 13.0                |
| Genotype 24                                                         | 7.0                 | 6.5                 | 13.5                |
| Genotype 25                                                         | 7.2                 | 6.8                 | 14.0                |
| Genotype 26                                                         | 7.5                 | 7.0                 | 14.5                |
| Genotype 27                                                         | 7.8                 | 7.2                 | 15.0                |
| Genotype 28                                                         | 8.0                 | 7.5                 | 15.5                |
| Genotype 29                                                         | 8.2                 | 7.8                 | 16.0                |
| Genotype 30                                                         | 8.5                 | 8.0                 | 16.5                |
| Genotype 31                                                         | 8.8                 | 8.2                 | 17.0                |
| Genotype 32                                                         | 9.0                 | 8.5                 | 17.5                |
| Genotype 33                                                         | 9.2                 | 8.8                 | 18.0                |
| Genotype 34                                                         | 9.5                 | 9.0                 | 18.5                |
| Genotype 35                                                         | 9.8                 | 9.2                 | 19.0                |
| Genotype 36                                                         | 10.0                | 9.5                 | 19.5                |
| Genotype 37                                                         | 10.2                | 9.8                 | 20.0                |
| Genotype 38                                                         | 10.5                | 10.0                | 20.5                |
| Genotype 39                                                         | 10.8                | 10.2                | 21.0                |
| Genotype 40                                                         | 11.0                | 10.5                | 21.5                |
| Genotype 41                                                         | 11.2                | 10.8                | 22.0                |
| Genotype 42                                                         | 11.5                | 11.0                | 22.5                |
| Genotype 43                                                         | 11.8                | 11.2                | 23.0                |
| Genotype 44                                                         | 12.0                | 11.5                | 23.5                |
| Genotype 45                                                         | 12.2                | 11.8                | 24.0                |
| Genotype 46                                                         | 12.5                | 12.0                | 24.5                |
| Genotype 47                                                         | 12.8                | 12.2                | 25.0                |
| Genotype 48                                                         | 13.0                | 12.5                | 25.5                |
| Genotype 49                                                         | 13.2                | 12.8                | 26.0                |
| Genotype 50                                                         | 13.5                | 13.0                | 26.5                |
| Genotype 51                                                         | 13.8                | 13.2                | 27.0                |
| Genotype 52                                                         | 14.0                | 13.5                | 27.5                |
| Genotype 53                                                         | 14.2                | 13.8                | 28.0                |
| Genotype 54                                                         | 14.5                | 14.0                | 28.5                |
| Genotype 55                                                         | 14.8                | 14.2                | 29.0                |
| Genotype 56                                                         | 15.0                | 14.5                | 29.5                |
| Genotype 57                                                         | 15.2                | 14.8                | 30.0                |
| Genotype 58                                                         | 15.5                | 15.0                | 30.5                |
| Genotype 59                                                         | 15.8                | 15.2                | 31.0                |
| Genotype 60                                                         | 16.0                | 15.5                | 31.5                |
| Genotype 61                                                         | 16.2                | 15.8                | 32.0                |
| Genotype 62                                                         | 16.5                | 16.0                | 32.5                |
| Genotype 63                                                         | 16.8                | 16.2                | 33.0                |
| Genotype 64                                                         | 17.0                | 16.5                | 33.5                |
| Genotype 65                                                         | 17.2                | 16.8                | 34.0                |
| Genotype 66                                                         | 17.5                | 17.0                | 34.5                |
| Genotype 67                                                         | 17.8                | 17.2                | 35.0                |
| Genotype 68                                                         | 18.0                | 17.5                | 35.5                |
| Genotype 69                                                         | 18.2                | 17.8                | 36.0                |
| Genotype 70                                                         | 18.5                | 18.0                | 36.5                |
| Genotype 71                                                         | 18.8                | 18.2                | 37.0                |
| Genotype 72                                                         | 19.0                | 18.5                | 37.5                |
| Genotype 73                                                         | 19.2                | 18.8                | 38.0                |
| Genotype 74                                                         | 19.5                | 19.0                | 38.5                |
| Genotype 75                                                         | 19.8                | 19.2                | 39.0                |
| Genotype 76                                                         | 20.0                | 19.5                | 39.5                |
| Genotype 77                                                         | 20.2                | 19.8                | 40.0                |
| Genotype 78                                                         | 20.5                | 20.0                | 40.5                |
| Genotype 79                                                         | 20.8                | 20.2                | 41.0                |
| Genotype 80                                                         | 21.0                | 20.5                | 41.5                |
| Genotype 81                                                         | 21.2                | 20.8                | 42.0                |
| Genotype 82                                                         | 21.5                | 21.0                | 42.5                |
| Genotype 83                                                         | 21.8                | 21.2                | 43.0                |
| Genotype 84                                                         | 22.0                | 21.5                | 43.5                |
| Genotype 85                                                         | 22.2                | 21.8                | 44.0                |
| Genotype 86                                                         | 22.5                | 22.0                | 44.5                |
| Genotype 87                                                         | 22.8                | 22.2                | 45.0                |
| Genotype 88                                                         | 23.0                | 22.5                | 45.5                |
| Genotype 89                                                         | 23.2                | 22.8                | 46.0                |
| Genotype 90                                                         | 23.5                | 23.0                | 46.5                |
| Genotype 91                                                         | 23.8                | 23.2                | 47.0                |
| Genotype 92                                                         | 24.0                | 23.5                | 47.5                |
| Genotype 93                                                         | 24.2                | 23.8                | 48.0                |
| Genotype 94                                                         | 24.5                | 24.0                | 48.5                |
| Genotype 95                                                         | 24.8                | 24.2                | 49.0                |
| Genotype 96                                                         | 25.0                | 24.5                | 49.5                |
| Genotype 97                                                         | 25.2                | 24.8                | 50.0                |
| Genotype 98                                                         | 25.5                | 25.0                | 50.5                |
| Genotype 99                                                         | 25.8                | 25.2                | 51.0                |
| Genotype 100                                                        | 26.0                | 25.5                | 51.5                |



# Surface Charge Characteristics of Some Acid Soils of Sri Lanka

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## SUMMARY

Surface charge characteristics of 14 samples belonging to three Great Soil Groups, Ultisol, Alfisol and Entisol, at different pH and ionic strengths showed that soils contain predominantly the "constant surface potential" type of colloids; the Alfisols contain also some colloids of the "constant surface charge" type. The point of zero charge of the soils ranged from pH 3.0 to 4.3 with the Alfisols having the lowest values and the Ultisols the highest. Net surface charge densities at the soil pH and pH 7.0 and ionic strengths of 0.005 M and 1 M showed that cation exchange capacity as determined by the routine  $\text{NH}_4\text{OAc}$  method may give very unrealistic values compared to the actual field situation.

Addition of phosphorus decreased the point of zero charge and increased the negative surface charge densities of these soils.

## INTRODUCTION

Surface charge characteristics of soil colloids are responsible for various important physico-chemical properties such as ion exchange, ion mobility, aggregate stability, erosivity etc. The difference in behaviour of tropical soils from temperate soils with respect to these properties is often due to their basic differences in the surface charge characteristics. Soils of the temperate region are mainly of the constant surface charge type, where the charges arise from isomorphous substitution in the 2:1 clays, whereas the soils of the humid tropics are of the constant potential type where the charges arise from the ionisation of hydroxyls of the 1:1 clays and hydrous oxides. The Gouy-Chapman theory of the electrical double layer predicts that the charges of the constant potential type of colloids vary markedly with pH, electrolyte concentration and valence of counter ions and therefore routine measurements of cation exchange or anion exchange capacities used in the temperate countries are of doubtful value when applied to tropical soils. Studies reported on Oxisols and Inceptisols from Hawaii (El-Swaify and Sayegh, 1975) on Oxisols, Alfisols (van Raij and Peech, 1972; Ilton Morais *et al.*, 1976) and Ultisols (Ilton Morais *et al.*, 1976) from Brazil and on Alfisols and Ultisols from Nigeria (Gallez *et al.*, 1976) showed that the surface charge characteristics of the humid tropical soils are distinctly different from those of the temperate soils.

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Paper presented at the Annual Sessions of the Soil Science Society of Ceylon on 3rd December 1977.



As there is no information on the surface charge characteristics of Sri Lanka soils and their dependence on pH, ionic strength and the nature of ions in the ambient solution, this study was undertaken. This paper presents data on these aspects for some of the important coconut growing acid soils belonging to the Great Soil Groups, Ultisol, Alfisol and Entisol.

## MATERIALS AND METHODS

Seven soils belonging to three Great Soil Groups, Ultisol, Alfisol and Entisol were selected from the Intermediate and Wet rainfall zones of the coconut-growing regions. Surface and sub surface soil samples were collected from the fertilized area in close proximity to coconut palms and unfertilized area at the centre of square formed by 4 palms. They were air dried and ground to pass through 2 mm sieve. Some relevant properties of the soil samples are shown in Table 1.

### *Point of zero charge (PZC) by $\Delta pH$ method*

Three gm soil samples were placed in 25 ml beakers and pH values were adjusted with HCl or NaOH to cover the expected PZC. The final volume of the suspensions was made to 20 ml. After 2 days of equilibrium with intermittent stirring within a constant humidity chamber, pH values were recorded, 0.5 ml of 2 M NaCl added and pH values were re-recorded after 3 hours of frequent stirring. The pH in at which  $\Delta pH = 0$  is the PZC and this was obtained from a plot of  $\Delta pH$  vs pH in  $H_2O$ .

pH was measured using a Corning Expandometric pH meter with a combination glass and calomel electrodes.

### *Potentiometric titrations*

A series of 5 gm acid washed soil samples were equilibrated with known amounts of acid (HCl) and base (NaOH) in various concentrations of NaCl for 2 days in a closed humidified chamber to prevent evaporation. The pH was determined at the end of this period. The amounts of  $H^+/OH^-$  ions adsorbed at a given pH value is equal to the amount of HCl and NaOH added after correction for the amount of acid or base required to bring the electrolyte solution alone to the same pH value. The net surface charge is plotted against equilibrium pH for all ionic strengths. According to Gouy-Chapman's double layer theory, the point where these curves intersect is the PZC.

## RESULTS AND DISCUSSION

Potentiometric titration curves at different ionic strengths for three samples—one each belonging to Ultisol, Alfisol and Entisol—are shown in Figures 1 to 3. The other samples in each of these Great Soil Groups behaved in a similar manner. The charge-pH curves measured in the various ionic strengths



# SURFACE CHARGE CHARACTERISTICS OF ACID SOILS

Table 1—Classification and selected properties of the soils

| Soils          | Classification                   | Depth (cm) | Treatment    | Sand % | Silt % | Clay % | pH (1:5 H <sub>2</sub> O) | 1M NH <sub>4</sub> OAc pH=7 CEC me/g | Organic carbon % | Free oxide % |
|----------------|----------------------------------|------------|--------------|--------|--------|--------|---------------------------|--------------------------------------|------------------|--------------|
| Naiwala        | Ultisol<br>(Red yellow Podzolic) | 0-15       | Unfertilized | 58.6   | 5.9    | 29.4   | 4.9                       | 0.074                                | 1.73             | 1.33         |
|                |                                  | 25-40      | —do—         | 50.8   | 4.7    | 35.9   | 4.9                       | 0.060                                | 2.14             | 1.85         |
|                |                                  | 0-15       | Fertilized   | 59.0   | 7.7    | 25.6   | 5.9                       | 0.094                                | 1.94             | 1.45         |
|                |                                  | 25-40      | —do—         | 58.6   | 10.2   | 30.2   | 4.5                       | 0.085                                | 1.19             | 1.68         |
| Bandirippuwa   | —do—                             | 0-15       | Unfertilized | 73.7   | 3.8    | 13.5   | 5.0                       | 0.042                                | 1.28             | 1.51         |
|                |                                  | 25-40      | —do—         | 74.2   | 3.3    | 20.7   | 4.9                       | 0.031                                | 2.80             | 2.10         |
| Alubomulla     | —do—                             | 0-50       | —do—         | 67.7   | 3.8    | 23.0   | 4.4                       | 0.140                                | 2.24             | 1.71         |
| Halmillakotuwa | Alfisol<br>(Reddish Brown Earth) | 0-15       | —do—         | 74.1   | 7.5    | 15.6   | 6.3                       | 0.079                                | 0.76             | 2.31         |
|                |                                  | 25-40      | —do—         | 67.1   | 6.5    | 22.2   | 6.3                       | 0.077                                | 0.51             | 2.73         |
| Indihena       | Alfisol<br>(Non Calcic Brown)    | 0-15       | —do—         | 89.3   | 3.9    | 5.9    | 5.9                       | 0.044                                | 0.51             | 0.17         |
|                |                                  | 25-40      | —do—         | 88.7   | 2.1    | 7.4    | 5.8                       | 0.035                                | 0.39             | 0.21         |
| Keenakelle     | Entisol (Regosol)                | 0-15       | —do—         | 86.6   | 3.0    | 9.3    | 5.9                       | 0.030                                | 0.57             | 0.84         |
|                |                                  | 25-40      | —do—         | 81.3   | 3.2    | 14.8   | 5.5                       | 0.036                                | 0.44             | 1.19         |
| Waikkala       | —do—                             | 0-50       | —do—         | 88.5   | 2.0    | 8.1    | 4.7                       | 0.033                                | 0.47             | 1.01         |

intersected one another at single points indicating that these soils belong to the constant potential type of colloids with  $H^+$  and  $OH^-$  as the potential determining ions. In the case of Entisols (Figure 3) the curves for any two ionic strengths converged or intersected at pH 6, in addition to the PZC around pH 3.5 Gallez *et al.* (1976) also reported similar results for a Nigerian soil and a kaolinite of recent formation. They explained that in kaolinites of recent formation, the interaction of kaolinite edge surface and iron oxides had not advanced to a greater degree to give a single PZC which is that of the kaolinite-iron oxide system after complete interaction. This explanation may also apply to the case of the Entisols as they are of recent formation.

The charge-pH curves for all samples show that at any pH, increase of ionic strength increases the surface charge as predicted by the Gouy-Chapman double layer theory for constant potential type of colloids.

The PZC values obtained from the potentiometric titration method for the Ultisols and Alfisols ranged between 3.0 to 3.8 (Table 2). These values agreed fairly well with those determined by the  $\Delta pH$  method and values of around 3.5 for Alfisols and 4.0 for Ultisols reported for Nigerian soils (Gallez *et al.*, 1976) and values of 3.4 to 3.8 for Alfisols of Brazil (van Raij and Peech, 1972).

Table 2—Zero point of charge and effect of ionic strength on the net surface charge of the soils

| Soils<br>(Unfertilized) | Depth<br>(cm) | PZC                   | PZC                          | Net charge at soil pH (me/g) |         | Net charge at |        |
|-------------------------|---------------|-----------------------|------------------------------|------------------------------|---------|---------------|--------|
|                         |               | $\Delta pH$<br>method | potentio<br>metric<br>method | $I=0.005 M$                  | $I=1 M$ | pH=7 (me/g)   |        |
|                         |               |                       |                              |                              |         | $I=0.005M$    | $I=1M$ |
| Naiwala                 | 0-15          | 3.6                   | 3.8                          | -0.019                       | -0.040  | -0.069        | -0.120 |
|                         | 25-40         | 3.6                   | 3.7                          | -0.018                       | -0.035  | -0.073        | -0.120 |
| Bandirippuwa            | 0-15          | 4.3                   | 3.4                          | -0.015                       | -0.025  | -0.040        | -0.063 |
|                         | 25-40         | 4.2                   | 3.5                          | -0.013                       | -0.023  | -0.032        | -0.057 |
| Halmillakotuwa          | 0-15          | 3.6                   | 3.4                          | -0.048                       | -0.071  | -0.071        | -0.098 |
|                         | 25-40         | 3.5                   | 3.5                          | -0.044                       | -0.060  | -0.058        | -0.083 |
| Indihena                | 0-15          | 3.9                   | 3.1                          | -0.020                       | -0.026  | -0.026        | -0.045 |
|                         | 25-40         | 3.8                   | 3.0                          | -0.023                       | -0.038  | -0.032        | -0.054 |
| Keenakelle              | 0-15          | 3.7                   | 3.4                          | -0.023                       | -0.028  | -0.034        | -0.039 |
|                         | 25-40         | 3.8                   | 3.5                          | -0.025                       | -0.029  | -0.038        | -0.044 |
| Waikkala                | 0-50          | 3.8                   | 4.2                          | -0.004                       | -0.009  | -0.020        | -0.029 |

The low PZC may be attributed to the presence of predominantly kaolinitic type of minerals in these soils. Among the soils studied Alfisols had the lowest PZC. This is probably due to the presence of some 2:1 minerals in these soils (De Alwis and Pannaboake, 1972-73) which is expected to have perma-



## SURFACE CHARGE CHARACTERISTICS OF ACID SOILS

nent negative charges. The PZC in these soils is far to the acid side of the zero point of titration (where equal quantities of  $H^+$  and  $OH^-$  were added) indicating the presence of permanent negative charges (van Raij and Peech, 1972).

Table 2 gives the net surface charge densities at the field pH and ionic strength of the soils and at the conditions of the routine laboratory measurements of cation exchange capacity. The results show that for Ultisols the net surface charge at ionic strength 1M and pH 7 is about 4 to 6 times higher than that under field conditions and for Entisols and Alfisols it is about 2 times higher. Therefore the cation exchange capacity determined by 1 M  $NH_4$  OAc at pH 7 and exchange acidity by 1 M  $BaCl_2$  pH 8 may result in extremely high values. During the determination of cation exchange capacity the soil is washed with alcohol to remove the excess salts and thereby the ionic strength is lowered. This reduces the charge on the surface and desorbs some of the adsorbed ions. This is probably one of the main reasons for the lower cation exchange capacity values by  $NH_4$  OAc method (Table 1) relative to the net negative charge density values at pH 7 and ionic strength 1M (Table 2). A more realistic method of determination of cation exchange capacity is to use a dilute electrolyte with concentrations similar to those in the field soil solution or by the determination of exchangeable bases and " $H+Al$ " by dilute unbuffered extractants (van Raij and Peech, 1972; Gallez *et al.*, 1976).

For Alfisols, the effects of pH and ionic strength were not strikingly high as in the case of Ultisols. This is probably due to the presence of some constant surface charge type of colloids in addition to the constant potential type in the Alfisols-the charges of the former type are not affected by pH and ionic strength.

Addition of phosphate to Alubomulla decreased the PZC from 4.0 to 3.7 and increased the net negative charge (Table 3 and Figure 4). These effects are due to the specific adsorption of phosphate. Specifically adsorbing anions shift the PZC to the acid side and cations to the alkaline side (Hingston *et al.*, 1967). Indifferent electrolytes have no effect on the PZC. Reduction of PZC on addition of phosphate to an Inceptisol and an Oxisol from Hawaii was reported by El-Swaify and Sayegh (1975). The degree of reduction depends on the amount of phosphate added per gm of soil. A sample collected from a rock phosphate treated area in a long term fertilizer experiment showed a PZC lower than the sample from the unfertilized area and negative charges about 4 times higher (Table 3 and Figure 5). This is most likely due to the specific adsorption of the phosphate ions in the soils of the fertilized area. The cation exchange capacity measured with 1M  $NH_4$  OAc, pH 7 is also higher in the fertilized area (Table).1



Table 3—Effect of phosphate treatment on PZC and net surface charge

| Soil       | Depth (cm) | Treatment | PZC | Net charge at soil pH and $I=0.005\text{ M (me/g)}$ |
|------------|------------|-----------|-----|-----------------------------------------------------|
| Alubomulla | 0-50       | -P        | 4.0 | -0.005                                              |
|            | 0-50       | +P        | 3.7 | -0.020                                              |
| Naiwala    | 0-15       | -P        | 3.8 | -0.006                                              |
|            | 0-15       | +P        | 3.4 | -0.028                                              |

It was reported for some soils that the surface layers had very much lower PZC than the subsoil and attributed this to the presence of higher amounts of organic matter in the surface soils, which tend to lower the PZC (van Raij and Peech, 1972; Ilton Marais *et al.*, 1976). In contrast, the soils studied here had no such marked differences in PZC (Table 2) perhaps due to the presence of nearly equal contents of organic matter in the surface and sub soils (Table 1).

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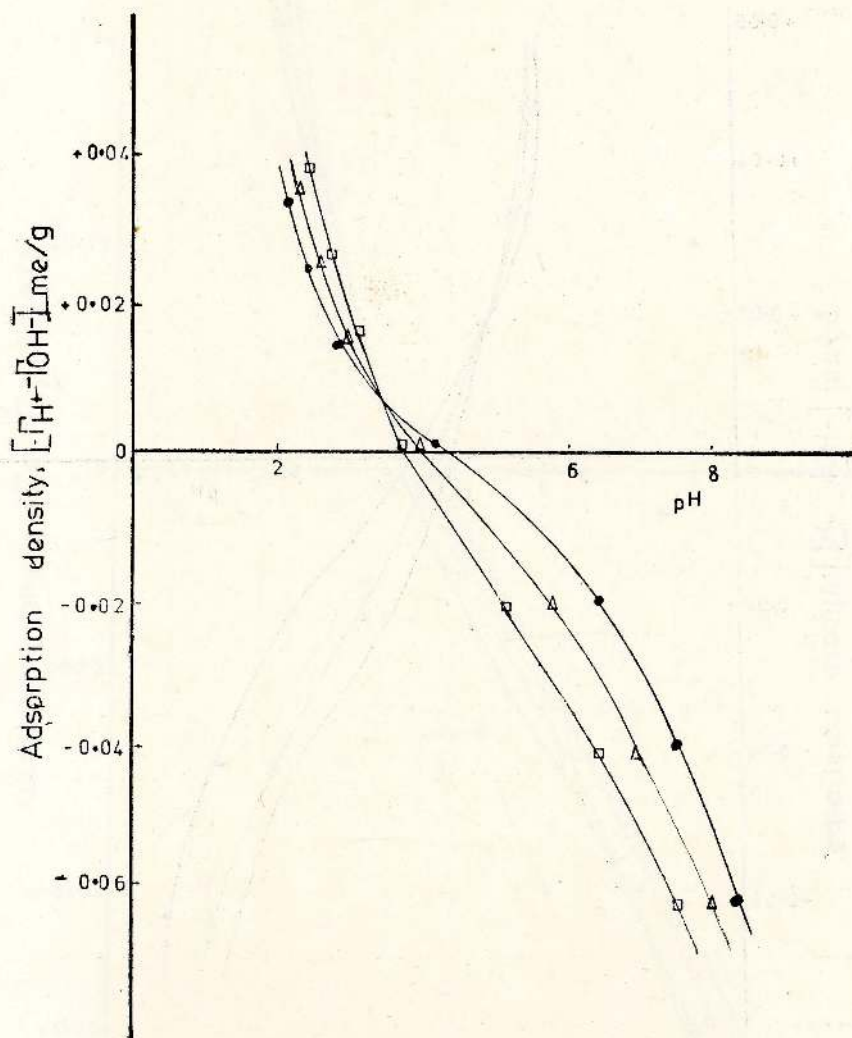
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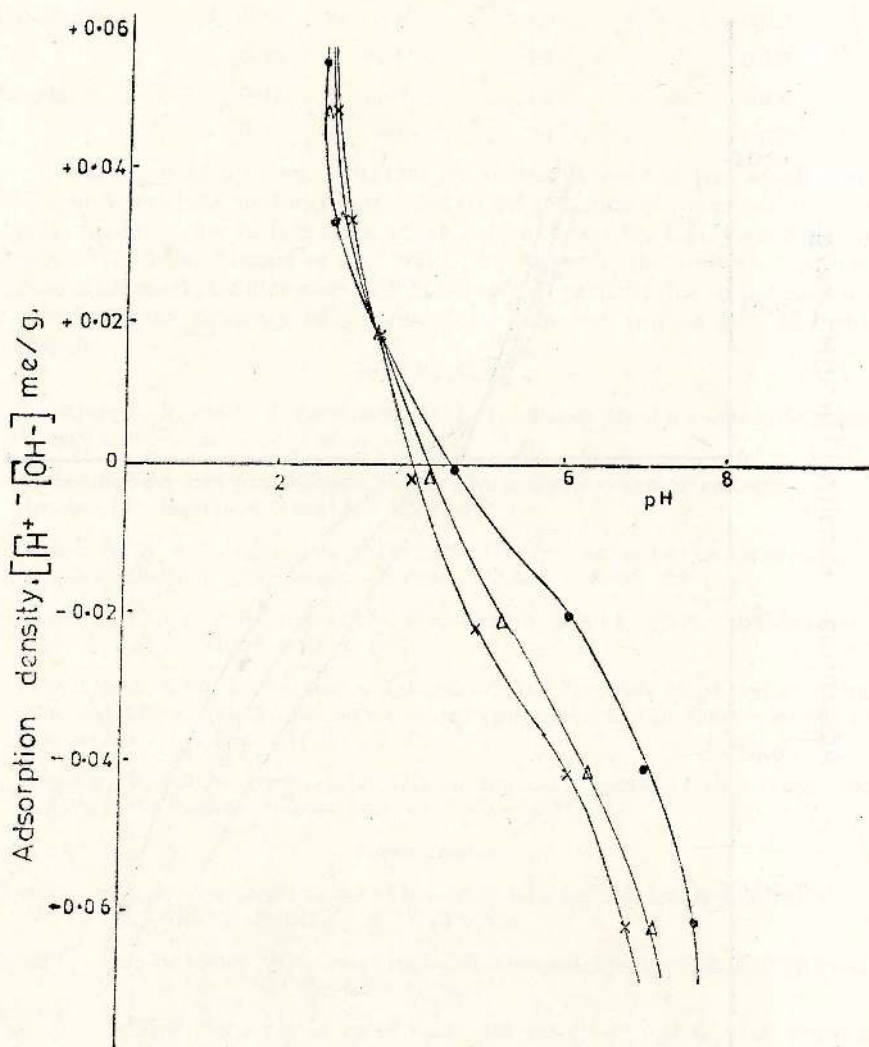
## Figure Captions

- Figure 1 Surface charge-pH curves of Bandirippuwa soil (25-40 cm). ●-0.005 M NaCl; △-0.050 M NaCl; □-0.500 M NaCl.
- Figure 2. Surface charge pH curves of Halmillakotuwa soil, 25-40 cm). ●-0.005 M NaCl; △-0.050 M NaCl; ×-0.500 M NaCl.
- Figure 3. Surface charge-pH curves of Keenakelle soil (25-40 cm). ●-0.005 M NaCl; △-0.050 M NaCl; ×-0.200 M NaCl; □-0.500 M NaCl.
- Figure 4. Surface charge-pH curves of Alubomulla soil .050 cm). ●-0.0015 M NaCl; △-0.0150 M NaCl; □-0.1500 M NaCl. Solid lines without P, dotted lines-with P.
- Figure 5. Surface charge-pH curves of Naiwala soil (0.15 cm). ●-0.005 M NaCl; △-0.050 M NaCl; □-0.200 M NaCl. Solid lines-without P, dotted lines-with P.



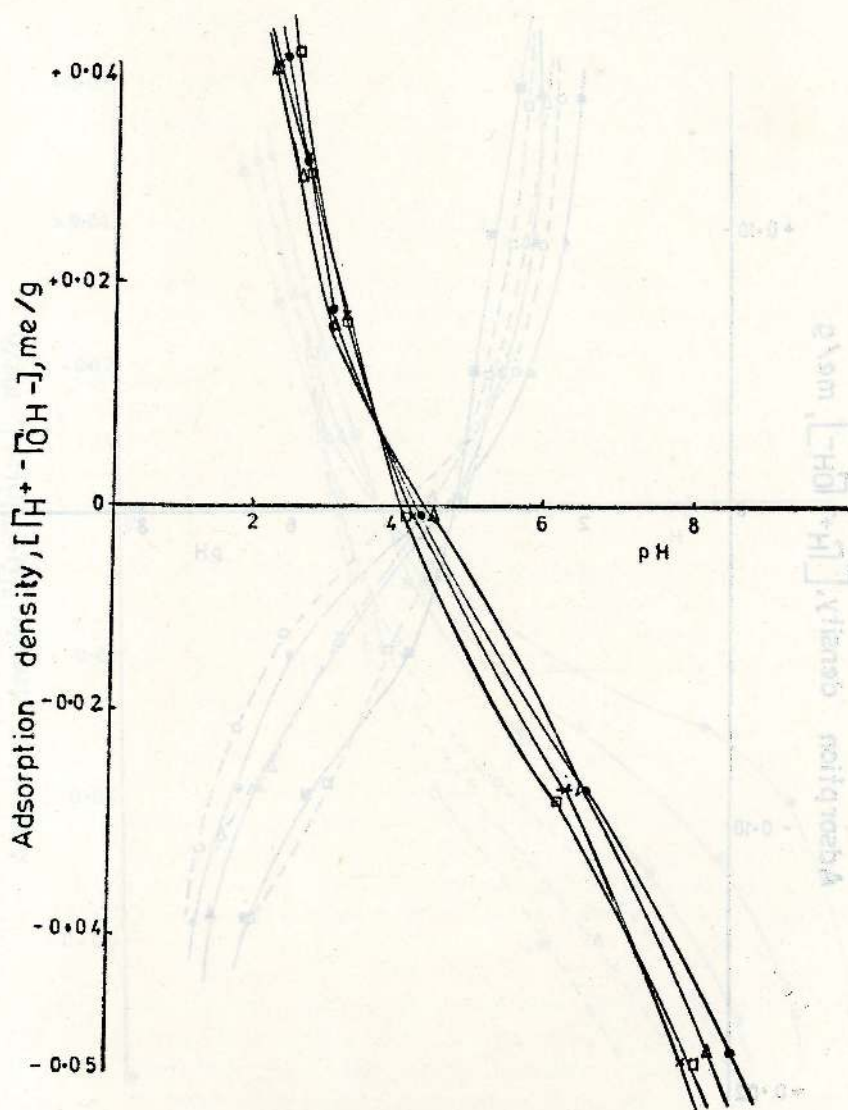
# SURFACE CHARGE CHARACTERISTICS OF ACID SOILS

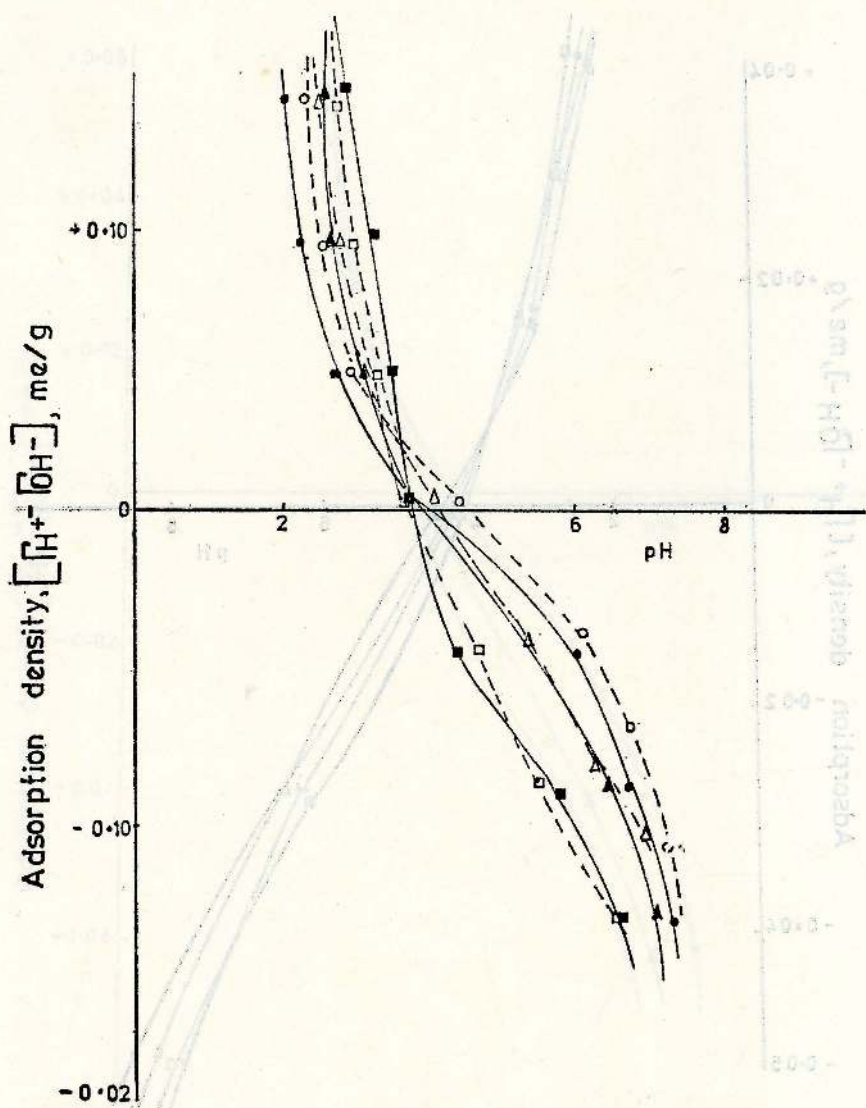






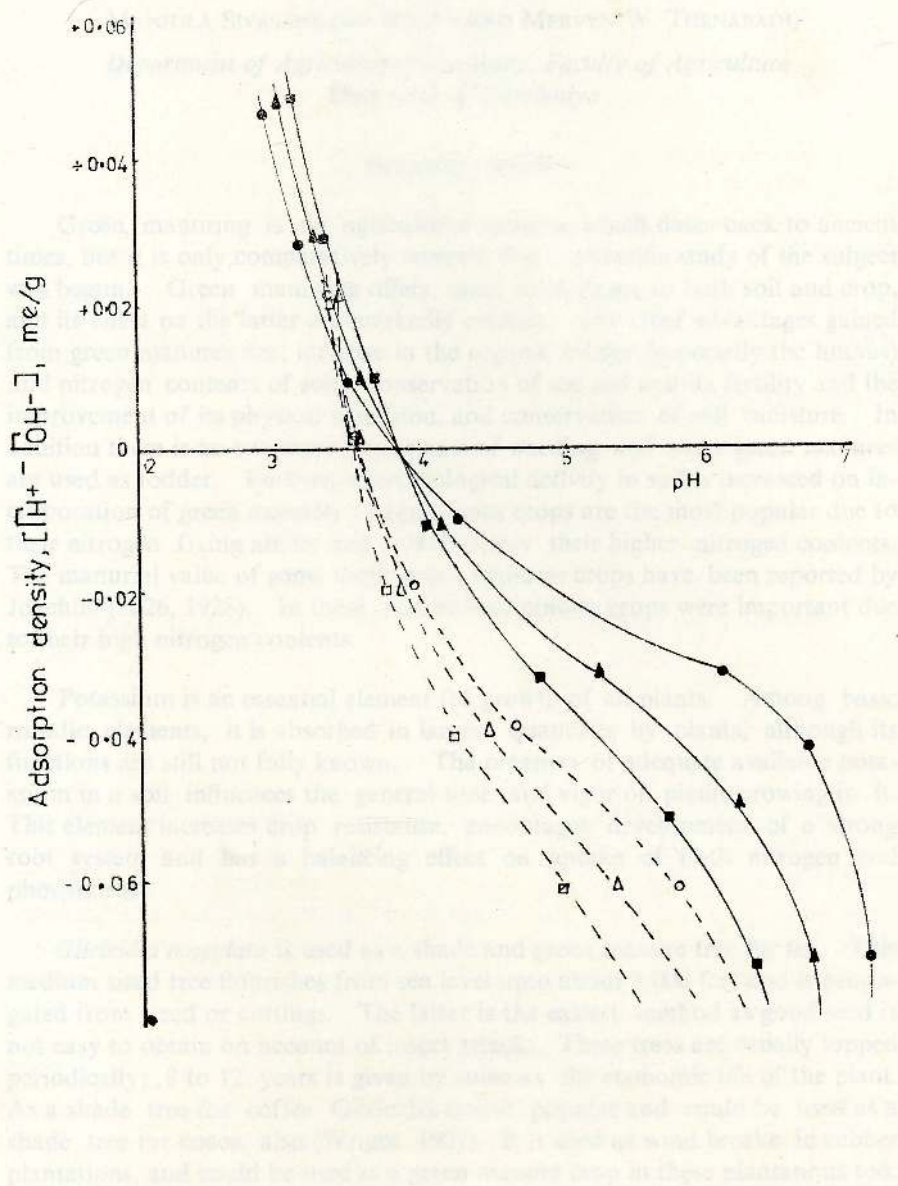
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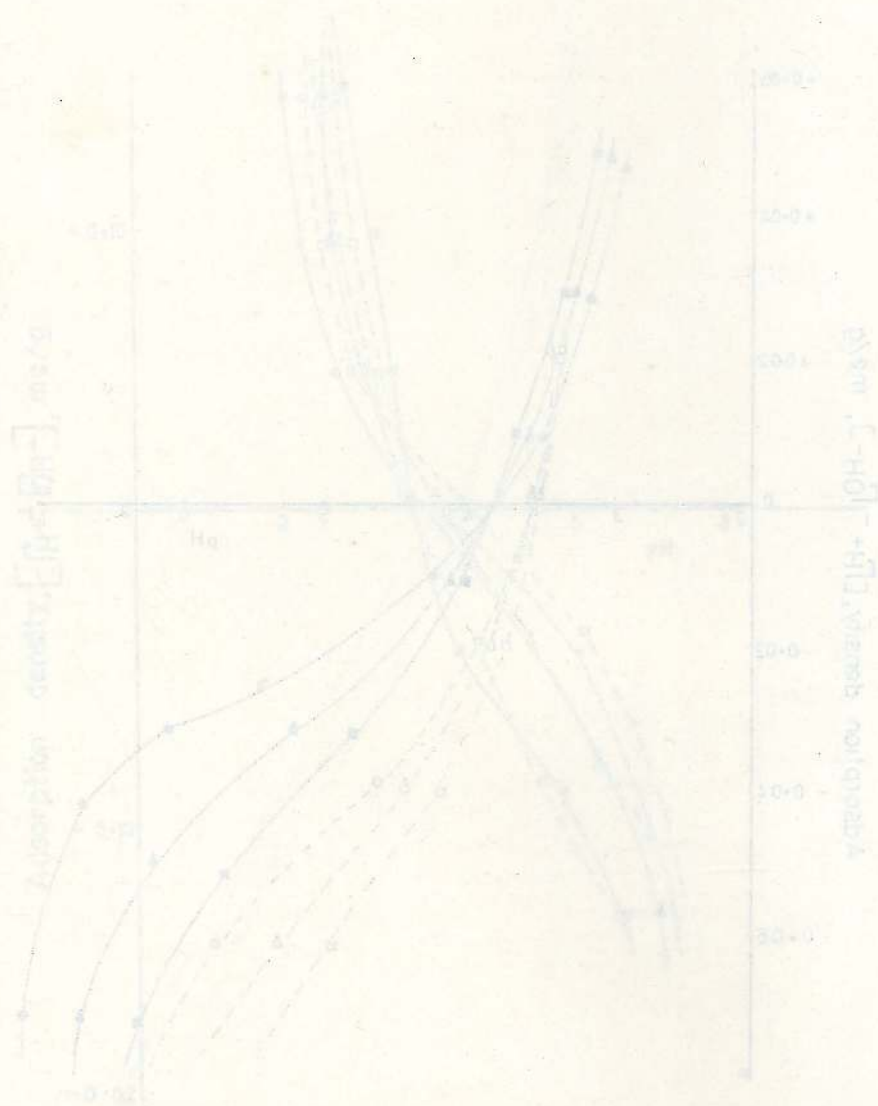






# SURFACE CHARGE CHARACTERISTICS OF ACID SOILS







# Potassium Content of *Gliricidia maculata* Leaves and Tender Stems

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## INTRODUCTION

Green manuring is an agricultural practice which dates back to ancient times, but it is only comparatively recently that a scientific study of the subject was begun. Green manuring offers many advantages to both soil and crop, and its effect on the latter are markedly evident. The chief advantages gained from green manures are: increase in the organic matter (especially the humus) and nitrogen contents of soils; conservation of the soil and its fertility and the improvement of its physical condition, and conservation of soil moisture. In addition there is an economy in the cost of weeding and some green manures are used as fodder. Further, microbiological activity in soil is increased on incorporation of green manures. Leguminous crops are the most popular due to their nitrogen fixing ability and consequently their higher nitrogen contents. The manurial value of some local green manures crops have been reported by Joachim (1926, 1928). In these studies leguminous crops were important due to their high nitrogen contents.

Potassium is an essential element for growth of all plants. Among basic metallic elements, it is absorbed in largest quantities by plants, although its functions are still not fully known. The presence of adequate available potassium in a soil influences the general tone and vigor of plants growing in it. This element increases crop resistance, encourages development of a strong root system and has a balancing effect on uptake of both nitrogen and phosphorus.

*Gliricidia maculata* is used as a shade and green manure tree for tea. This medium sized tree flourishes from sea level upto about 3,000 feet and is propagated from seed or cuttings. The latter is the easiest method as good seed is not easy to obtain on account of insect attack. These trees are usually lopped periodically; 8 to 12 years is given by some as the economic life of the plant. As a shade tree for coffee *Gliricidia* is also popular and could be used as a shade tree for cocoa also (Wright 1907). It is used as wind breaks in rubber plantations, and could be used as a green manure crop in these plantations too.

In view of the frequent inquiries made on the chemical composition of the more extensively cultivated green manure crops, and in order to ascertain to what extent leguminous green manure crops are richer in nitrogenous constituents than non-leguminous crops used for green manuring, analyses of the more important species of these plants were made, (Joachim, 1926, 1928).

#### MATERIALS AND METHODS

Samples of *Gliricidia maculata* collected from the Faculty of Agriculture, pasture unit at Peradeniya were used for this study.

Tender stem and leaf samples were air dried to constant weight and ground to pass a 0.5 mm sieve. Ground samples 0.5 g were used for analysis of total K by digesting the samples with  $\text{HNO}_3$  and ternary mixture according to the method Jackson (1958).

Water soluble potassium in the material was determined using samples ground to pass a 0.5 mm sieve. Two gm. samples were extracted with 50 ml distilled water on a mechanical shaker for 1 hour. After filtering, filtrate was analysed for potassium using a flamephotometer.

#### RESULTS AND DISCUSSION

Relevant characteristics of *Gliricidia maculata* leaves and tender stems are presented in Table 1.

**Table 1. Percentages of moisture, total and water soluble potassium**

|                 |      |
|-----------------|------|
| Moisture        | 84.7 |
| Total K         | 1.57 |
| Water soluble K | 1.50 |

The emphasis on *Gliricidia maculata* has been mainly on its higher nitrogen content. In this study it was found that even though the total potassium content of plant material was only 1.57 % a substantial amount of it, i.e. 95.56% was in a readily available, water soluble form. Thus this readily available form of element (1.50%) can be efficiently utilized to supplement imported potassium fertilizers to a certain extent, and a fair amount of foreign exchange could be saved.

#### CONCLUSIONS

*Gliricidia maculata* could be not only used for its higher nitrogen content but also for its higher potassium content which is mainly in a water soluble readily available form.



## GLIRICIDIA MACULATA LEAVES AND TENDER STEMS

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# GLYCEROL MONOACETATE EMULSIONS AND TENDER STEAKS

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## RESULTS AND DISCUSSION

Relevant characteristics of the emulsions are presented in Table 1.

Table 1. Percentages of proteins, lipids, and carbohydrates in emulsions.

| Protein | Lipid | Carbohydrate |
|---------|-------|--------------|
| 1.0     | 1.0   | 1.0          |
| 2.0     | 2.0   | 2.0          |
| 3.0     | 3.0   | 3.0          |
| 4.0     | 4.0   | 4.0          |
| 5.0     | 5.0   | 5.0          |

The emulsions of glycerol monoacetate were prepared by the method of Johnson (1937). In this study, it was found that the emulsions were stable for a period of 24 hours. The emulsions were then used for the tendering of steaks. The results of the tendering are presented in Table 2.

## CONCLUSIONS

Glycerol monoacetate could be used as a tenderizer for steaks. The emulsions of glycerol monoacetate were found to be stable for a period of 24 hours.



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