TROPICAL AGRICULTURIST

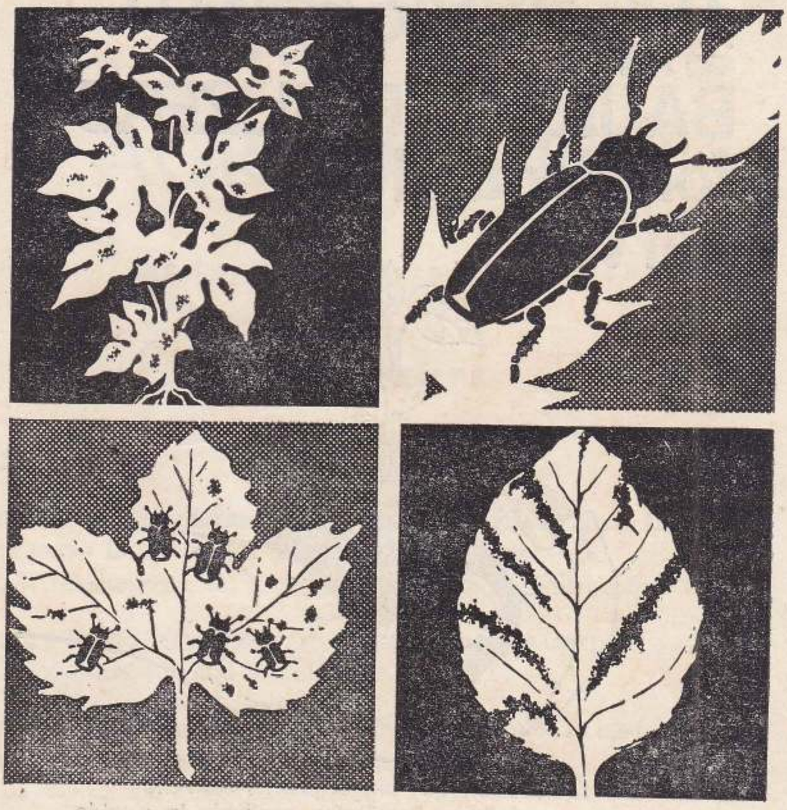
AGRICULTURAL JOURNAL OF CEYLON

29

DEPARTMENT OF AGRICULTURE
CEYLON

VOLUME CXXV, NUMBERS 1 & 2

JANUARY – JUNE, 1969



2---J 3788---608 (6/69)

VOLUME CXXV NUMBERS 1 & 2 JAN.-JUNE, 1969

TROPICAL AGRICULTURIST

Agricultural Journal of Ceylon

CONTENTS

PUBLISHED BY
THE DEPARTMENT OF AGRICULTURE
CEYLON

Studies on the placement of ammonium sulphate for lowland rice using isotopically labelled fertilizers

M. W. Thenabadu, M. M. M. Jauffer and S. M. Willenberg

Division of Agricultural Chemistry, Central Agricultural Research Institute, Peradeniya

(Received: March, 1969)

INTRODUCTION

Placement of fertilizer in relation to the plant generally ensures better utilization of applied nutrients. Under conditions that exist in flooded rice culture sub-surface placement of ammonium fertilizers prior to flooding or ball placement after transplanting leads to their more efficient use, because ammonium nitrogen is not likely to be lost due to oxidation and denitrification if placed in the reduced regions of the profile (2, 3, 7, 8).

The use of isotopically labelled fertilizers enables the evaluation of the efficiency of fertilizer uptake from a source and the estimation of the percentage taken up. Earlier work in Ceylon with labelled nitrogen and phosphorus fertilizers indicated that placement of ammonium sulphate at a depth of 5 cm. from the surface resulted in better uptake of both nitrogen and phosphorus by rice (5).

This report contains the results of the fourth investigation conducted in Ceylon under the Co-ordinated Contract Programme sponsored by the Joint FAO/IAEA Division of Atomic Energy in Agriculture, Vienna, to determine the most efficient use of nitrogenous and phosphate fertilizers for rice using isotopically labelled fertilizers The findings of previous investigations in this series have already been reported (1, 4, 5).

The objects of this investigation were—

(i) to study the efficiency of utilization of ammonium sulphate by different placement methods ;

(ii) to study the interaction between nitrogen placement and the utilization of superphosphate, applied broadcast at transplanting.

EXPERIMENTAL

Five methods of nitrogen application for rice were studied at the Agricultural Research Station, Maha Illuppallama, during the wet season, Maha 1966/67. The experiment was a randomized complete block design of five treatments with six replicate on a soil, some characteristics of which are presented in Table I. The treatments were as follows :—

A	..	Broadcast on the surface
B	..	In rows, on the surface
C	..	In rows at 5 cm. depth from the surface
D	..	In rows at 10 cm. depth from the surface
E	..	In rows at 15 cm. depth from the surface

Fertilizers were placed at different depths according to the procedure adopted by Nagarajah and Al-Abbas (5). Ammonium sulphate at the rate of 60 Kg. N per ha. was used for all treatments. The excess of N^{15} in sub-plots with labelled fertilizers was 0.90 atom per cent. Superphosphate at the rate of 60 Kg. P_2O_5 per ha. was broadcast on the surface in all treatments. In the sub-plots with labelled fertilizers, the superphosphate was labelled with P^{32} at approximately 0.2 to 0.4 mc. per gm. P_2O_5. All plots received muriate of potash at 60 Kg. K_2O per ha. as a basal application at planting.

The construction of plots, nursery preparation, transplanting, precautions observed in the handling of P^{32} fertilizer and other cultural practices were similar to those of earlier experiments (1, 4, 5).

Each experimental plot was divided into three sub-plots as follows :—

1. Radioactive sub-plot	..	1.56 sq. metres
2. Intermediate yield sub-plot	..	1.88 sq. metres
3. Final yield sub-lot	..	3.44 sq. metres

The 4–4½ month Indica variety of rice H_4 was used in this investigation. Mean monthly climatological data from nursery to harvest are presented in Table II.

Plants were sampled at two stages ; 40 days and 122 days from transplanting. At the earlier harvest two fully developed young leaves of each of the nine centre hills were harvested from the labelled (radioactive) sub-plots. These were bulked and dried at 70°C. From the intermediate yield sub-plots all twelve centre hills were harvested completely, dried at 70°C and dry weights recorded.

At the final harvest nine centre hills of the labelled (radio-active) sub-plots were harvested, the grain and straw separately. All twenty-seven centre hills of the final yield sub-plots were also harvested, grain and straw separately.

Leaf samples from the radioactive sub-plots at 40-day harvest were analysed for N^{15} and P^{32} at the IAEA Laboratory, Vienna ; while the material from the intermediate yield sub-plots were analysed for N^{14} and P^{31}. Details of analytical procedure were as described in the first experiment of the series (4). Grain and straw samples at the final harvest could not be analysed as intended because the samples were lost in transit from Ceylon to Vienna.

RESULTS AND DISCUSSION

Plant Growth

Plant Height. The mean heights of plants as affected by treatments at three stages of growth are presented in Table III. The differences in plant height were not significant at 14 and 40 days from transplanting most probably because it was too early for treatments to be effective. At final harvest, 122 days from transplanting, however the differences in plant height were highly significant. Plants in plots where nitrogen was placed in rows at 5, 10 and 15 cm. depth were significantly taller than those in plots where the fertilizer was broadcast on the surface.

The height of a rice plant is not always positively related to grain yield. Excessive height may in fact contribute to loss of yield if plants were to lodge before grain filling. In this experiment there appears to be a positive relationship between plant height and weight of filled grain (Table V).

Tiller Numbers. As in plant height the number of tillers per hill was not significantly affected by treatments at 14 and 40 days from transplanting, probably because it was too early for treatments to be effective (Table III). At harvest, however, 122 days from transplanting, the treatments showed highly significant differences. Plants in plots where nitrogenous fertilizer was broadcast on the surface or applied in rows on the surface hand significantly lesser number of tillers per hill than plants in plots where the fertilizer was placed in rows at 5, 10 and 15 cm. depth. There was a close parellelism between tiller numbers and the number of panicles per hill which is also reflected in grain yield. It will be noted later, that among the yield components the number of panicles per hill contributed most to grain yield (Table V). There appears to be a positive relationship between number of tillers and weight of straw.

Dry Matter Production. The effect of the method of fertilizer application on total dry matter production is seen in Table IV.

At the early harvest, 40 days from transplanting, the total dry matter produced by plants in plots where nitrogenous fertilizer was applied in rows at depths of 5, 10 and 15 cm. was greater than that produced by plants in plots where fertilizer was broadcast or applied in rows on the surface. At this stage the greatest dry matter production was in plots where ammonium sulphate was placed at a depth of 5 cm. As the depth of placement of fertilizer increased the dry matter production is observed to decrease. This perhaps is related to the depth of root development in the soil and most probably the fertilizer at the 5 cm. depth was more available to plants at this stage of growth, than that placed deeper. Among the surface treatments the indications are that broadcasting the fertilizer is better than concentrating it in rows, as the former method distributes it over a larger area for absorption by roots than does the latter method. Dry matter production at the early harvest is related to plant height and number of tillers per hill.

The data at the final harvest in Table IV indicates that deeper placement of ammonium sulphate (15 cm. from surface) yielded more dry matter than shallow placement (5 cm. from surface) although the opposite relationship was observed at the earlier harvest. This may be related to the extent and depth of root development during the atter half of plant growth. It is probable that plants in plots where ammonium sulphate was placed deepest had longer (and more) roots than those in plots where it was placed closer to the surface. The increased root surface would have enabled these plants to absorb other nutrients as well compared to those with shorter and less extensive root systems from other treatments. It must however be noted that increased dry matter production is of little value with rice unless accompanied by proportional increases in grain yield.

Among the surface applications, broadcasting the fertilizer uniformly produced more dry matter than when it was concentrated in rows as seen at the earlier harvest.

The data on yield in Table V shows a close parellelism between total dry matter production up to final harvest and yield of filled grain. This relationship will not be true under all conditions for excessive vegetative growth is known to depress grain yields in rice.

As expected the weight of straw at final harvest appeared to be directly related to the total dry matter produced.

Grain Yield and Yield Components

The effect of treatments on grain yield and yield components is shown in Table V.

Filled and unfilled Grain. The effect of treatments on yield of filled and unfilled grain was highly significant. Sub-surface placement of ammonium sulphate at 5, 10 or 15 cm. produced significantly higher yields than surface applications, broadcast or in rows. The highest yield was obtained when the fertilizer was placed 15 cm. below the surface and the lowest yield was obtained when the fertilizer was applied in rows on the surface.

Filled Grain. The yield of filled grain followed the same trends as that of filled plus unfilled grain, the treatments showing highly significant effects. Placement of ammonium sulphate 15 cm. below the surface produced approximately 1,900 Kg. per ha. (1695 lbs. per acre) more than when this fertilizer was applied in rows on the surface. Further, the effectiveness of fertilizer applications increased with greater depth of placement. The 15 cm. placement gave an additional yield of 1,322 Kg. per ha. over the surface broadcast application, while the yield increases from the 10 and 5 cm. placements over the surface broadcast application were 828 and 723 Kg. per ha. respectively. The lower yields in plots where ammonium sulphate was applied on the surface may most probably be due to losses of fertilizer through oxidation and denitrification as has been postulated by Pearsall (6).

Number of Panicles per Hill. Treatments had highly significant effects on the number of panicles per hill. Placement of fertilizer nitrogen at depths of 5, 10 and 15 cm. encouraged more panicles per hill than surface applications. There appears to be a positive correlation between the number of tillers and the number of panicles per hill.

Panicle Weight, Weight per 1,000 Grains and Percentage Ripened Grain. Method of nitrogen application had no significant effect on panicle weight, weight per 1,000 grains and on the percentage of ripened grains although grain yields were affected at the 1 per cent level of probability. These results are similar to those of Nagarajah and Al-Abbas (5).

Grain : Total Dry Matter Ratio. The efficiency of grain production in comparison to dry matter production as influenced by method of nitrogen placement is seen in Table V. Deeper placement of fertilizer, (10 or 15 cm. from the surface) resulted in narrower ratios than shallow placement (5 cm. from the surface). Broadcast application of fertilizer on the surface appears to result in better grain production in comparison to total dry matter, than surface application in rows.

Grain : Straw Ratio. The most efficient distribution of dry matter between grain and straw was observed when ammonium sulphate was placed at a depth of 15 cm. from the surface. This was followed by treatments where fertilizer was placed at 10 cm. from the surface, and broadcast on the surface. The narrow grain : straw ratio as a result of deeper placement (15 cm.) in spite of the significantly higher straw yield (Table IV) is a reflection of the higher grain yields in this treatment.

Utilization of Fertilizer Nitrogen and Phosphorus

The only data available on N^{15} and P^{32} analysis is of plant material from the first harvest (40 days after transplanting), because plant material harvested at maturity was lost during transport to Vienna.

The effect of treatments on the concentration of nitrogen in plant shoots and the percentage of nitrogen derived from the fertilizer were highly significant (Table VI).

The highest concentration of nitrogen was in plants from plots where ammonium sulphate was placed at a depth of 15 cm. from the surface. This was significantly different only from the broadcast application at the surface. The relatively higher concentrations of nitrogen in treatments where fertilizer was placed at depth is probably reflected in the higher grain yields in these treatments.

The highest percentage of nitrogen derived from the fertilizer was also found in plants from plots where ammonium sulphate was placed at a depth of 15 cm. from the surface. This value was different only from the treatment where fertilizer was placed in rows on the surface.

The method of nitrogen placement had no effect on either the percentage total phosphorus in plant shoots or on the percentage of this nutrient derived from fertilizer phosphorus broadcast on the surface. However it appears that placement of ammonium sulphate at 15 cm. depth resulted in the highest concentration of phosphorus in the shoots in comparison to other treatments, although the percentage of the nutrient derived from the fertilizer appeared to be the lowest.

CONCLUSIONS

The results of this investigation substantiates the findings of other investigators (2, 3, 7, 8) that sub-surface placement of ammonium sulphate gives increases in yield over surface applications of the fertilizer. This yield increase is associated with a higher concentration of nitrogen in plants. (Only data available is for plants 40 days from transplanting.) Among the yield components, the greatest contribution to yield was from the number of panicles per hill.

It is possible that losses of ammonium sulphate were responsible for the low yields and lower concentration of nitrogen in plants from plots where surface applications were made.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of the I.A.E.A., Vienna, and permission to publish these results. Sincere thanks are due to Miss T. Shanmugam, Statistician, C.A.R.I., for analysis of the data and to Mr. P. Ganeshan, Research Officer, Plant Breeding Maha Illuppallama, for assistance throughout this investigation.

REFERENCES

1. Kathirgamathaiyah, S., Thenababadu, M. W. and Al-Abbas, A. H. 1968 Utilization of nitrogen and phosphorous by rice as affected by form and time of application of fertilizer nitrogen using N_{15} and P_{32}. Trop. Agric., CXIV, 1-3.

2. Mikkelesen, D. S. and Finfrock, D. C. (1957). Availability of ammonacal nitrogen to lowland rice as influenced by fertilizer placement. Agron. J. 49 : 296-300.

3. Mitsui, S. (1954). Inorganic nutrition, fertilization and soil amelioration, for lowland rice. Yokendo Ltd., Tokyo.

4. Nagarajah, S. and Al-Abbas, A. H. (1965). Co-ordinated contract programme on the application of isotopes and radiation in rice cultivation in Ceylon. *Trop. Agric.* 121 : 1-23.

5. NAGARAJAH, S. and AL-ABBAS, A. H. (1965). Nitrogen and phosphorous fertilizer placement studies on rice using N_{15} and P_{32} *Trop. Agric.* 121 : 89-103.

6. PEARSALL, W. H. (1950). The investigation of wet soils and its agricultural implication, *Emp. J. Exptl Agric.* 18 : 289-298.

7. RAMIAH, K. (1951). A rational method of applying sulphate of ammonia to rice. *Current Sci.* 20 : 227-228.

8. SHIOIRI, M. and TANADA, T. (1954). The chemistry of paddy soils in Japan. Ministry of Agriculture and Forestry, Japan

TABLE I.—Characteristics of the Soil at Location of Experiment (Maha Illuppallama)

Depth (cm.)	0–20	20–40
Texture	Sandy Loam	Sandy Loam
pH (1 : 1–Soil : H_2O)	6·7	6·6
E. C. (1 : 5), (1 : 5) millimhos/cm.	0·1260	0·1121
Organic Matter%	2·39	1·94
Total Nitrogen%	0·127	0·123
Available P_2O_5 (Olsen's) (lbs P_2O_5/acre)	20·90	16·72
Cation Exchange Capacity (m.e/100g.)	15·2	14·0
Exchangeable Cations (m.e./100g.)		
Calcium	8·06	7·57
Magnesium	4·83	4·21
Potassium	0·21	0·18
Sodium	0·76	0·74
Total Exchangeable Bases (m.e./100g.)	13·88	12·74

TABLE II.—Mean Monthly Climatological Data from Nursery to Harvest

	Temperature °F		*Wind* * (*m.p.h.*)	*Sunshine* (*hrs./day*)	*Rainfall* (*inches*)
	Maximum	*Minimum*			
1966					
December	84·1	71·1	0·48	5·8	0·291
1967					
January	84·5	69·0	0·74	7·3	0·022
February	85·8	68·8	1·19	8·4	0·181
March	91·4	71·8	1·48	9·1	0·186
April	93·4	73·5	0·60	9·9	0·089

* Measured at 6 feet from ground.

TABLE III.—Effect of Treatments on Plant Height and Number of Tillers per Plant at Three Stages of Growth

Treatment	Plant Height (cm.) No of days from transplanting			No. of Tillers Per Hill No. of days from transplanting		
	14	40	122	14	40	122
A—Broadcast on the surface	41·2	71·8	117·7*a**	3·7	13·4	11·3*ab*
B—In rows, on the surface	40·7	69·3	111·4*ab*	3·6	11·2	10·2*a*
C—In rows, 5 cm. depth	43·0	74·7	121·1*b*	3·5	13·6	11·8*bc*
D—In rows, 10 cm. depth	41·0	72·6	121·4*b*	3·7	13·5	12·9*c*
E—In rows, 15 cm. depth	38·8	70·6	127·1*b*	3·4	12·9	12·8*c*
Coefficient of Variation (%)	8·14	5·33	6·07	12·77	13·27	9·08

*Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE IV.—Effect of Treatments on Dry Matter Production

(Kg.[1]ha.) (Mean of six replicates)

Treatment	*60 day early harvest 40 days from transplanting*	*Final harvest 122 days from transplanting*
A—Broadcast on the surface	920*ab**	10178*b*
B—In rows, on the surface	821*a*	8881*ab*
C—In rows, 5 cm. depth	1195*b*	11233*bc*
D—In rows, 10 cm. depth	1033*ab*	11849*c*
E—In rows, 15 cm. depth	964*ab*	13286*d*
Coefficient of variation (%)	19·88	9.35

* Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE V.—Effect of Treatments on Grain Yield and Yield Components

Treatments	*Grain Yield (Filled and Unfilled) (Kg/ha)*	*Grain Yield (Filled) (Kg/ha)*	*Panicle Number per Hill*	*Panicle Weight (gm.)*	*Weight per 1,000 Grains (gm.)*	*Percentage Ripened Grain*	*Grain Total Dry Matter (%)*	*Grain Straw*
A—Broadcast on the surface	5636*a**	5233*a*	11·8*ab*	3·17	28·17	89·4	55·6*b*	1·36
B—In rows on the surface	5049*a*	4652*a*	10·8*a*	3·08	28·12	88·4	57·0*b*	1·43
C—In rows, 5 cm. depth	6385*b*	5956*b*	12·8*bc*	3·29	28·15	86·8	57·1*c*	1·44
D—In rows, 10 cm. depth	6468*b*	6061*b*	13·1*cd*	3·28	28·51	89·7	54·8*ab*	1·31
E—In rows, 15 cm. depth	6999*b*	6555*b*	14·2*d*	3·28	28·24	90·1	52·7*a*	1·21
Coefficient of variation (%)	8·29	8·67	7·74	5·38	1·37	3·94	3·34	—

* Duncan's Multiple Range Test at 5% level of significance.

Means not followed by the same letter within a column are significantly different from each other.

TABLE VI.—Effect of Treatments on the Concentration of Nitrogen and Phosphorus and Percentage of Nitrogen and Phosphorus derived from Fertilizer in Plants 40 Days from Transplanting

	Nitrogen		*Phosphorus*	
Treatments	*% in Tissue*	*% Derived from Fertilizer*	*% in Tissue*	*% Derived from Fertilizer*
A—Broadcast on the surface	2·63	54·7	·185	71·1
B—In rows, on the surface	2·77	49·0	·186	72·6
C—In rows, 5 cm. depth	3·30	54·5	·189	71·6
D—In rows, 10 cm. depth	2·98	65·0	·185	75·1
E—In rows, 15 cm. depth	3·44	67·9	·197	67·8
L. S. D. at 1%	0·68	13·8	N.S.	N.S.
Coefficient of variation	12·4%	13·0%	8·0%	7·0%

Dithizone extractable zinc in rubber soils of Ceylon

V. PAVANASASIVAM AND F. S. C. P. KALPAGE

Division of Agricultural Chemistry, Faculty of Agriculture, University of Ceylon, Peradeniya

(Received April, 1969)

SUMMARY

ZINC is an essential micro-nutrient whose deficiency in Malayan rubber soils has been considered to predispose rubber seedlings to *Oidium hevea* attack. Results of preliminary investigation on dithizone extractable zinc in surface soils of the main rubber growng districts of Ceylon are reported. The extractable zinc content varies from 2 ppm to 56.4 ppm with an average value of 16 ppm. Soils of the Deniya series have the highest values (40 ppm) and those of the Ratnapura series the lowest (9.5 ppm). Results indicate that zinc deficiency is not likely to limit growth of rubber or be a predisposing factor in the incidence of *Oidium hevea* in acid soils with high dithizone extractable zinc contents. Low availability due to high soil pH is compensated by high amounts of extractable zinc. Excessive uptake of zinc is possible in acid, ill-drained Deniya soils.

INTRODUCTION

In addition to the macro-nutrients, a number of micro-nutrients are essential for optimum plant growth. Zinc is one such micro-nutrient.

Plant physiologists have often described the beneficial effects of zinc on plant growth as stimulation. Diseases such as "white bud" of corn (Viets, 1951) and rosetting of fruit trees have been shown to be due to zinc deficiency. Woody plants exhibit abnormalities in twigs and leaves due to deficiency of this element. Reduction of hormonal activity due to zinc deficiency results in failure of stem elongation. Zinc also functions as a catalyst in oxidation reactions in the plant.

The importance of zinc in cacao growing is well known (Greenwood & Hayfron, 1951). Zinc deficiency is the cause of sickle leaf disease. Investigations on sickle leaf disease of cacao in Ceylon by Vermaat (1956) revealed zinc contents of 6 ppm and 20 ppm in mature leaves obtained from affected and healthy trees respectively. In Ceylon, zinc deficiency has become increasingly common in tea nurseries and young plantations (Tolhurst, 1962) and remedial measures have been recommended. Malayan workers (Bolle-Jones and Hilton, 1956) have reported a striking relationship between zinc content of leaves and susceptibility of rubber seedlings to *Oidium hevea* attack. Zinc deficiency resulted in rosetting, malformation and death of young leaves in the 3rd month; in the 6th month, a severe infection of *Oidium hevea* was noted. Disease symptoms similar to those attributed to zinc deficiency were noticed in young hevea plants in two areas in Ceylon, namely Nakiadeniya estate in Galle district and Kumarawatte group in Moneragala. Zinc status of healthy and deficient leaf samples from these areas was reported by Jeevaratnam (1958).

In the present study, dithizone extractable zinc in representative surface soils from the rubber growing districts of Ceylon is reported. According to Viets & Boawn (1965) ammonium acetate-exchangeable and water-soluble zinc are usually regarded as being available for plants. However, the amounts of zinc so extracted are extremely low unless complexing agents like dithizone are also included in the extracting solutions. In soils with histories of deficiency or non-deficiency, Shaw & Dean (1952) showed that extractable zinc data could be interpreted better if soil pH was also considered.

MATERIALS AND METHODS

Surface soils of three profiles from each of the seven soil series recognised and described by Silva (1968) in the rubber growing regions of Ceylon, were analysed. The soils are briefly described in Table 1. Soil samples were collected in polythene bags, air dried in the laboratory, crushed with a wooden pestle and sieved through a 2mm sieve. Demineralised distilled water was used to prevent contamination. Glassware was washed with soap and rinsed with demineralised distilled water.

pH was determined on 1:4 soil:water suspensions using a Cambridge portable pH meter. Texture was determined with a soil colloid tester. Zinc was estimated by the method of Shaw & Dean (1952) using a Spekker absorptiometer.

RESULTS AND DISCUSSION

Soil analytical data are given in Table 2.

With the exception of the limestone-derived Kirigalpotta soil (pH 8.2), the other samples studied have pH values ranging from 4.1 to 5.7.

Zinc content varies widely, from 2.5 ppm in the biotite gneiss derived Parambe series soils of Dehiowita to 56.4 ppm in the low-lying, water-logged Deniya soils of Kalutara, with an average value of 16 ppm. On an average, Ratnapura series has the lowest (9.5 ppm) and Deniya series has the highest (40 ppm) dithizone extractable zinc contents.

Mitchell (1963) reported a range of 1-10 ppm of zinc as being extractable by an appropriate diagnostic agent from normal soils, excluding the seriously toxic or deficient ones. Jansen and Lamm (1963) indicated a value of 10 ppm as being high for most of the soils they studied. On these criteria, with the exception of three samples, the zinc contents of the soils investigated are generally high.

The high dithizone extractable zinc content (25.5-56.4 ppm) of Deniya soils may be explained in terms of drainage. Under ill-drained conditions, the minerals in which the micro-nutrients are bound up break down more readily and provide increased amounts of these elements (Mitchell 1963).

In the case of limestone-derived soils of the Matale series, the high extractable zinc content may be suggestive of a high total zinc content as well. Kalpagé and Silva (1968) observed high total manganese values in these limestone-derived soils and suggested that the noncalcareous material associated with the limestone is rich in manganese. It would, therefore, be interesting to ascertain whether the noncalcareous material is rich in the other micronutrients as well.

There is wide variation within soils of the Parambe series (22.1 ppm 7.4 ppm, 2.5 ppm). Kalpagé and Silva (1968) observed a similar variation in the total manganese content of soils in this series and attributed this to the wide variability in the composition of the parent material.

Soil pH is one of the main factors influencing deficiency and toxicity levels. Massey (1957) obtained a negative correlation between zinc uptake and soil pH. As reported by Shaw and Dean (1952), zinc deficiency symptoms are least likely to occur in the pH range 5 to 6.5 and under these pH conditions dithizone extractable soil zinc values of as low as 0.5 ppm will not produce deficiency symptoms. On the other hand, at pH values above 6.5 deficiency symptoms may occur unless dithizone extractable zinc contents are above 2.5 ppm. The availability of zinc to plants is greatly reduced under strongly acidic and highly alkaline conditions.

CONCLUSION

Zinc deficiency is not likely to limit growth or be a predisposing factor for *Oidium hevea* attack in acid soils with high dithizone extractable zinc contents. However, in soils such as the Kirigalpotta soils of the Matale series, although the soil pH is high (8.2) since extractable zinc amounts to as much as 20.1 ppm, zinc deficiencies may not arise.

These preliminary studies indicate that zinc deficiency is unlikely to occur in most rubber growing districts of Ceylon. Excessive uptake, however, is possible under acid conditions where extractable zinc contents are also high. This can occur in the ill-drained soils of the Deniya series.

ACKNOWLEDGMENT

The authors are deeply indebted to Dr. M. W. Thenabadu for his valuable suggestions.

REFERENCES

1. Bolle-Jones, E. W. & Hilton, R. N. (1955). Zinc deficiency of *Hevea brasiliensis* as a predisposing factor to Oidium infection. Nature Lond. *177*, 619-620.

2. Jansen, H. L. & Lamm, C. G., (1963). Zinc status of Danish soils. Soils Fertil; Harpenden, 2205.

3. Jeevaratnam, A. J. (1958). Zinc deficiency of young *Hevea brasiliensis*. Paper read at C. A. A. S. (Sect. B).

4. Greenwood, M. & Hayfron, R. J. (1951). Iron and Zinc deficiency in cacao in the Gold Coast. Soils Fertil, Harpenden, *14*, 412.

5. Kalpage, F. S. C. P. & Silva, C. G. (1968). Studies on the manganese status of the rubber soils of Ceylon. Rubb. Res. Inst. Ceylon. Quart. J. 44, 8-15.

6. Massey, H. F. (1957). Relation between dithizone extractable zinc in the soil and zinc uptake by corn plant. Soil Sci. *83*, 123-129.

7. Mitchell, R. L. (1963). Soil aspects of trace element problems in plants and animals. Jl R. agric. Soc. *124*, 75-86.

8. Shaw, E. & Dean, L. A. (1952). Use of dithizone as an extractant to estimate the zinc nutrient status of the soil. Soil Sci. *73*, 341-348.

9. Silva, C. G. (1968). A provisional classification of the rubber soils of Ceylon and their relationships to Malayan soils. Paper read at the Natural Rubber Conference, August, 1968.

10. Tolhurst, J. A. H. (1962). Zinc deficiency of tea in Ceylon. Tea Q. *33*, 134-137.

11. Vermaat, J. G. (1956). Report to the Govt. of Ceylon on Soil and Paddy problem. Sessional paper XIX, 30.

12. Viets, F. G. Jr. (1951). Zinc deficiency of corn and beans on newly irrigated soils in Central Washington. Agron. J. *43*, 150-151.

13. Viets, F. G. Jr. & Boawn, L. C. (1965). Methods of Soil Analysis. American Society of Agronomy Publication p. 1090. Ed: C. A. Black.

TABLE I.—Some soil relationships (from Kalpagé and Silva, 1968)

Soil Series	*Parent Material (or distingusihing features)*	*Great Soil Group*
1. Matale ..	Limestone derived ..	Reddish brown latosolic and immature brown loam
2. Parambe ..	Biotite gneiss derived ..	Reddish brown latosolic and immature brown loams
3. Ratnapura ..	Garnetiferous granulite derived ..	Red-yellow podzolic
4. Homagama ..	Quartzite derived ..	Red-yellow podzolic
5. Agalawatta ..	Granite derived ..	Red-yellow podzolic
6. Boralu ..	Laterization evident ..	Red-yellow podzolic
7. Deniya ..	Low-lying, waterlogged ..	Low-humic gley

TABLE II.—Soil analytical data

Soil Series	Location	Depth (in)	Texture	pH	Dithizone extractable zinc (ppm)	Average zinc value for each series (ppm)
1. Matale	(a) Wariyapola Group, Matale	0—4	Sand	5·70	18·9	16·8
	(b) Viharagama Estate, Matale	0—4	Sand	5·30	11·5	
	(c) Kirigalpotta, Matale	0—4	Loamy sand	8·20	20·1	
2. Parambe	(a) Parambe Group, Undugoda	0—6	Light loam	4·35	22·1	10·7
	(b) Golinda Group, Kegalle	0—17	Sand	4·48	7·4	
	(c) Ernan Division, Dehiowita	0—10	Sand	4·92	2·5	
3. Ratnapura	(a) Carney Estate, Ratnapura	0—3	Sandy grit	4·90	7·6	9·5
	(b) Ratnapura Town	0—17	Sandy grit	5·10	10·2	
	(c) Near Rest House, Ratnapura	0—7	Loamy sand	4·90	10·8	
4. Homagama	(a) Ambadeniya Group, Aranayake	0—9	Sandy loam	4·40	5·4	10·1
	(b) Narangala Group, Aranayake	0—9	Loamy sand	4·30	11·8	
	(c) Dalkeith Group, Lathpandura	0—18	Loamy sand	4·50	13·8	
5. Agalawatta	(a) Mirihankande, Badureliya	0—11	Sand	4·10	10·9	11·6
	(b) Hedigalla Division Badureliya	0—8	Sand	4·50	12·9	
	(c) Dartonfield, Agalawatta	0—10	Loamy sand	4·30	11·1	
6. Boralu	(a) Culloden Group, Neboda	0—14	Loamy sand	4·10	36·5	18·8
	(b) Tudugalla Estate, Tudugalla	0—14	Sandy grit	4·50	11·4	
	(c) Nellunuyana Estate, Bentota	0—8	Sandy loam	5·00	8·7	
7. Deniya	(a) Rajamalwagura, Agalawatta	0—10	Sandy grit	4·90	25·5	40·0
	(b) Attiville, Kalutara	0—10	Sand	4·40	56·4	
	(c) Durampitiya Estate, Avissawella	0—8	Sand	4·90	38·2	

Forms and levels of nitrogenous fertilizer for flue-cured tobacco in the dry zone of Ceylon

E. JAYANETTI AND P. SABANATHAN

Tobacco Division, Department of Agriculture, Peradeniya, Ceylon

(Received April, 1969)

INTRODUCTION

FLUE-cured tobacco is exacting in its nutrient requirements and application of nitrogen which has a marked effect on the growth, yield and quality of the crop produced needs to be carefully adjusted. Inadequate nitrogen results in tobacco low in both yield and quality. An excess of this nutrient tends to retard maturity and produces a cured leaf of undesirable colour, poor texture and other characteristic associated with low quality.

In an attempt to improve the yield and quality of the leaf produced from the irrigated ricelands of the Dry Zone where large acreages are available, studies on nitrogen fertilisation have been carried out. The need to improve the quality of the leaf produced from these tracts have recently become further important consequent to some of the better tobaccos produced from the limited land in the hill country of the Island being utilised to meet the requirements of the export market. As the domestic requirements of flue-cured tobacco are also progressively increasing the cultivation of this crop is being extended into areas of the Dry Zone.

PRELIMINARY TRIALS

Preliminary trials were carried out with the variety Harrison's Special in Maha 1960-61, Yala 1961 Yala 1962 to study the relative efficiency of 3 different nitrogenous fertilisers, viz : ammonium sulphate, ammonium sulphate nitrate and ammophos (16 per cent. N, 40 per cent. P_2O_5 at varying levels of nitrogen.

In Maha 1960-61 the experiment was carried out under upland conditions at the Agricultural Station, Hingurakgoda and the 3 forms of nitrogen were tried at 15 lbs. and 30 lbs. per acre rates. All the fertilisers were applied at the time of planting. The variety used in these experiments was Harrison's Special.

Table I shows the cured leaf yield for the various treatments. The data demonstrate that fertilisation improves yield significantly over no fertilisation. At 15 lbs. nitrogen per acre rate amophos was superior to ammonium sulphate and ammonium sulphate nitrate, though at the higher level ammonium sulphate nitrate was better. The mean difference in yield for the two levels of nitrogen was, however, not significant.

The experiment was repeated at the same station in a riceland during the 1961 Yala season. In this experiment the results (table 2) showed that 30 lbs. nitrogen per acre in all the 3 forms tried was significantly superior to 15 lbs. nitrogen per acre. The results also indicated that amophos and ammonium sulphate nitrate increased the yields significantly over ammonium sulphate. At 15 lbs. nitrogen per acre only amophos was significantly superior to no fertilisation.

It is evident from the results of the above two experiments that flue-cured tobacco production in these tracts is more profitable when grown as an irrigated Yala crop in the ricelands than as a Maha crop under upland conditions, provided the quality of the leaf produced is acceptable in manufacture. Subsequent trials were, therefore, carried out in the Yala seasons.

In Yala 1962 a similar experiment was carried out in which the effects of split application of the fertiliser was also studied. The split application treatment consisted of half the fertiliser being applied at the time of planting followed by a top dressing of the balance half 3 weeks later.

This trial was sited at two locations, viz. Agricultural Station, Hingurakgoda and Agricultural Station, Malwatte (Gal Oya) and the data obtained for the two locations are presented in tables 3 and 4. The yield responses for 15 lbs. and 30 lbs. nitrogen per acre were not significantly different at both the locations. The difference in yield between the 3 fertiliser forms and the 2 methods of application were also non-significant at both levels.

MAIN EXPERIMENT

After this preliminary work further research using the varity White Gold which is the most acceptable varity to the cultivators among the three varieties found to be superior to Harrison's Special was carried out in Yala 1966 (1). In view of the higher responsiveness of this variety of nitrogen over Harrison's Special the levels of nitrogen were modified and the experiment was carried out in Yala, 1967.

Urea is becoming increasingly important as a nitrogenous fertiliser with the replacement of amonium sulphate by this for rice in many parts of the Island (2). In view of this, the economies of its usage and the prospects of this fertiliser being manufactured in this country, it was also included in the trial along with ammonium sulphate, ammonium sulphate nitrate and ammophos.

MATERIALS AND METHODS

The experiment was located at the Agricultural Station, Hingurakgoda in a well drained riceland. The soil was a sandy loam.

Previous Crops and Fertilisers used

		Fertiliser applied (lbs./acre)					
Season	*Crop*	*Ammonium sulphate*	*Saphos phosphate*	*Muriate of potash*	*Conc. Super phosphate*	*Sulphate of potash*	*Total*
Yala, 1964..	Paddy (H-4)	224 ..	112 ..	56 ..	— ..	— ..	392
Maha, 64/65	Paddy (H-4)	224 ..	112 ..	56 ..	— ..	— ..	392
Yala, 1965..	Cigarette Tobacco ..	100 ..	— ..	— ..	200 ..	150 ..	450
Maha, 65/66	Paddy (H-4)	224 ..	112 ..	56 ..	— ..	— ..	392
Yala, 1966..	Paddy (H-4)	224 ..	112 ..	56 ..	— ..	— ..	392
Maha 66/67	Paddy (H-4)	224 ..	112 ..	56 ..	— ..	— ..	392
	Total ..	1220	560	280	200	150	2410

Treatments

A. Forms of Nitrogen			*B. Levels of Nitergen*	
Ammonium sulphate (20%N)	—F1	..	0 lb. Nitrogen per acre	—N0
Ammonium sulphate nitrate (26%N	—F2	..	20 lbs. Nitrogen per acre	—N1
Ammophos (16%N&40% P205)	—F3	..	40 lbs. Nitrogen per acre	—N2
Urea (43%N)	—F4			

Design : 4 × 2 factorial with control, having 3 replicates

Block size : 135′ × 30′

Plot size : 15′ × 30′ (5 rows of 12 plants at a spacing of 3′ × 2½′. The net harvested area after leaving a border row of one plant all round was 30 plants—1/200 acre)

The plots received a uniform application of concentrated superphosphate (42 per cent. P_2O_5) at 200 lbs. per acre rate (adjustment was made in case of ammophos treatment) and sulphate of potash (48 per cent. K_2O) at 125 lbs. per acre rate along with the different nitrogen treatments as a basal dose at the time of planting. On 16.5.1967 uniform 6 weeks old seedlings were transplanted on ridges. The crop was given 6 irrigations after planting. Standard cultural and curing practices were followed.

RESULTS

The weights of the cured leaf according to grade from the different treatments were recorded and valued on the basis of the prices fixed for the grades for the year 1967. The data are presented in tables 5 and 6.

The results clearly indicate that there is significant response in terms of yield and monetary returns per acre for nitrogen fertilisation over no-fertilisation. There was no significant difference between the different fertiliser forms.

DISCUSSION

The results obtained from the experiment firstly indicate that applications of nitrogen at 20 lbs. per acre has a marked effect on the growth and development of the crop resulting in significantly higher value per acre over no-fertilisation. This is supported by the findings in an earlier experiment carried out at the same station (1). It is also shown that application of 40 lbs. nitrogen has distinctly depressed the quality of the leaf produced, thereby giving a lower value per acre. This is quite understandable because it is well known that in cigarette tobacco the quality of leaf is inversely related to the level of leaf nitrogen which is conditioned by the nitrogen fertility of the soil. Gopinath (3) on a study of NPK fertilisation of flue-cured tobacco in the fertile soils of Andhra Pradesh has reported that more than 20 kg/ha nitrogen was detrimental to leaf quality.

In regard to the different sources of nitrogen, the main experiment (Yala 1967) has shown that there is no significant difference between ammonium sulphate, ammonium sulphate nitrate, ammophos or urea in terms of the market value of the crop, although ammophos has given the highest yield of cured leaf in this trial as in the preliminary trials. Therefore, the use of urea for the fertilisation of cigarette tobacco cultivated as a Yala crop especially under the environmental conditions of Hingurakgoda appears feasible. Massantini and Favilli (4) have reported that urea form of nitrogen appears to perform well on tobacco and that quality characteristics responded similar to yield. Atkinson (5) working on uramite, a synthetic nitrogenous fertiliser material, has found that for burley tobacco this fertiliser at equivalent amounts of nitrogen did not differ in yield or value in relation to ammonium nitrate. Jungermann (6) has reported that tobacco does not react unfavourably to urea (biuret content 4.7 per cent.). It would, therefore, appear that ammonium sulphate can suitably and be replaced by urea as a nitrogenous fertiliser for flue-cured tobacco under conditions obtaining in the Dry Zone of Ceylon.

SUMMARY AND CONCLUSIONS

A number of experiments were conducted at Hingurakgoda (Polonnaruwa District) and at Malwatte (Gal Oya Valley) over a number of years to study the responses of flue-cured tobacco to fertiliser nitrogen in different forms. The results obtained from these studies permit the following conclusions :—

1. On the basis of equivalent amounts of nitrogen, ammonium sulphate, ammonium sulphate nitrate, ammophos and urea did not significantly differ from each other in respect of the yield, quality and value of the leaf produced. Therefore, urea which is likely to be produced locally in the near future and which is being used extensively for fertilising rice could be considered suitable for use in flue-cured tobacco.
2. From the point of view of yield, flue-cured tobacco is more profitable to the farmer when grown as an irrigated Yala crop, provided the quality of the leaf produced is acceptable in manufacture and trade.
3. The income per acre is higher under conditions at Hingurakgoda than at Gal Oya. The lands in the former area are evidently richer.
4. Application of inorganic nitrogen at 20 lbs. per acre increased yield and improved leaf quality over the no-nitrogen treatment.
5. The optimum level of nitrogen under Hingurakgoda conditions would be 20 lbs. per acre whereas for Gal Oya higher doses of nitrogen may be desirable.
6. Application of all the nitrogen at the time of planting seems satisfactory at Hingurakgoda. Further studies in this respect are necessary for Gal Oya.

ACKNOWLEDGEMENTS

Our thanks are due to Messrs. K. H. N. S. Seneviratne and the late A. Ratnayake Farm managers Hingurakgoda and Malwatte respectively for providing the necessary facilities during the trials. We are also thankful to Mr. V. Navaratnam and Miss S. Shanmugam, Statisticians for their assistance in the analysis of the results.

REFERENCES

1. JAYANETTI, E. and SABANATHAN, P.—(1967). 'Flue-cured Tobacco Trials in the Dry Zone Ricelands of Ceylon'. *Trop. Agrist.* 123 : 111-123.

2. WEERAWICKREME, S. K. A. and CONSTABLE, D. H.—(1968). 'Ceylon Fertiser Project'. 7th Field report to the Government of Ceylon.

3. GOPINATH, D. M.—(1965). 'Response to N. P. K. fertilisation in Flue-cured Tobacco.' *Fert. News.* 10 (12) : 131-6, 1965 : Soils. Fert. 29 (4), No. 2908. Aug. 1966.

4. MASSANTINI, F. and FAVILLI, R.—(1966). 'Effectiveness of the Various Forms of Nitrogen in the Production, Quality and Nicotine Content of Tobacco.' *Corseta Inform, Bull. Spec.* (3) : No. 3013.

   (Istitute di Agronomica Generale c' Coltivaziane Erbacce della Universita di Pisa, Italia. Paper presented at the 4th International Tobacco Scientific Congress, Athens, 1966.)

5. ATKINSON, W. D.—(1966). 'Nitrogen Sources for Fertilising Burley Tobacco.' *Ky. Agr. Exp. Sta. Anna.* Rpt. 79 : 31.

6. JUNGERMANN, K.—(1964). 'Biuret in Urea and Plant Growth.' Landw. Forsch. 17 : 93-9, 1964 (German).

TABLE I.—Effects of different forms and levels of nitrogen on the cured leaf yield of flue-cured tobacco in Maha, 1960-61 at Hingurakgoda—(lbs. per acre)

	Am. Sulphate	*Am. sulphate nitrate*	*Ammophos*	*Mean*
0 lb. N/ac.	—	—	—	397
15 lbs. N/ac.	487	450	615	517
30 lbs. N/ac.	484	662	562	569
Mean	484	556	588	—

L. S. D. (5%) 76.2

C. V. 14.62%

TABLE II.—Effects of different forms and levels of nitrogen on the cured leaf yield of fluecured tobacco in Yala, 1961 at Hingurakgoda—(lbs. per acre)

	Am. sulphate	*Am. sulphate nitrate*	*Ammophos*	*Mean*
0 lbs. N./ac.	—	—	—	1404
15 lbs. N./ac.	1520	1538	1616	1558
30 lbs. N./ac.	1741	1900	1970	1870
Mean	1630	1719	1793	—

L. S. D. (5%) 137·5

C. V. 5·17%

TABLE III.—Effects of different forms, levels and split application of nitrogen on the cured leaf yield of fluecured tobacco in Yala, 1962 at Hingurakgoda—(lbs. per acre)

	Am. sulphate		*Ammonium sulphate nitrate*		*Ammophos*		*Mean*	
	Single Appln.	*Split Appln.*	*Single Appln.*	*Split Appln.*	*Single Appln.*	*Split Appln.*	*Single Appln.*	*Split Appln.*
0 lb. N./ac.	2162		1687		1825		1891	
15 lbs. N./ac.	1800	2237	2312	2350	2037	1912	2049	2166
30 lbs. N./ac.	2412	1977	1925	2075	2050	2325	2129	2125
Mean	2106	2107	2118	2212	2043	2118		

L. S. D. NS.

C. V. 13·82%

TABLE IV.—Effects of different forms, levels and split application of nitrogen on the cured leaf yield of flue-cured tobacco in Yala 1962 at Malwatte (Gal-Oya)—(lbs. per acre)

	Amsulphate		*Amsulphate nitrate*		*Ammophos*		*Mean*	
	Single Appln.	*Split Appln.*	*Single Appln.*	*Split Appln.*	*Single Appln.*	*Split Appln.*	*Single Appln.*	*Split Appln.*
0 lb. N./ac.	525		712		562		599	
15 lbs. N./ac.	600	1012	712	1075	750	962	687	1016
30 lbs. N./ac.	987	900	825	987	962	925	924	937
Mean	793	956	768	1031	856	943		

L. S. D. 5% 256

C. V. 22·44%

TABLE V.—Effects of different forms and levels of nitrogen on the cured leaf yield of flue-cured tobacco in Yala, 1967 at Hingurakgoda (lbs. per acre)

	Ammonium sulphate	*Ammonium sulphate nitrate*	*Ammophos*	*Urea*	*Mean*
0 lb. N./ac.	—	—	—	—	914
20 lbs. N./ac.	1320	1326	1416	1408	1367
40 lbs. N./ac.	1145	1185	1283	1160	1193
Mean	1233	1255	1349	1284	

L. S. D. 5% 459

C. V. 8·64

TABLE VI.—Effects of different forms and levels of nitrogen on the value of flue-cured tobacco in Yala 1967 at Hingurakgoda (Rs.' per acre)

	Ammonium sulphate	*Ammonium sulphate nitrate*	*Ammpohos*	*Urea*	*Mean*
0 lb. N./ac.	—	—	—	—	2289
20 lbs. N./ac.	3455	3265	3483	3373	3394
40 lbs. N./ac.	2922	2809	3112	2862	2926
Mean	3188	3037	3297	3117	

L. S. D. } 5%—459
1%—632

C. V. 8·64%

Influence of pre-treatment of some seeds on the rhizosphere microflora of the seedlings

G. Rangaswami

University of Agricultural Science, Hebal, Bangalore, India

(Received May, 1969)

As early as in 1904, Duggeli reported that healthy seeds contain specific bacterial flora in respect of number and species. Since then, innumerable reports have appeared in the literature on the variations in the quality and quantity of microflora carried by the seeds of different plant species, both healthy and diseased (Chranowska 1965) Bloomberg 1966, Ordin 1966, Jackson and Press 1967). At present many plant diseases are known to be transmitted through internally and/or externally seed-borne infections which cause pre-emergence and/or post emergence rot, systemic infections of the seedlings spreading upto plant maturity, etc. To eradicate the pathogenic organisms carried by the seed both physical and chemical agents have been tried; hot-water treatment has been recommended to eliminate the internally borne infections of certain organisms; treatments with organic and inorganic substances to eliminate the pathogens on the surface of the seed have also been recommended; more recently certain anibiotic substances have been recommended for treatment against internally and externally borne organisms, particularly bacterial pathogens. These recommendations have come into wide use all over the world.

The role of the normal flora of micro-organisms on seed germination and subsequent plant growth has been investigated by a few workers. It has been shown that certain organisms cause beneficial effects to the seeds because of their certain biochemical characteristics. Some workers have also reported on the excretions from the seed coat at the time of germination, which greatly influence the quality and quantity of the microflora on the seed and in the immediate vicinity (Picci 1959 a, b, Flentje 1959, Vagnerova, Macura and Catska 1960, Pearson and Parkinson 1961 Schroth and Snyder 1961, Schroth, Toussoun, and Snyder 1963; Schroth and Cook 1964, Stanek and Lasik 1965, Parkinson 1965, Cook and Flentje 1967). Secretions from the seed of certain antimicrobial substances have also been reported by

3——J.3788 (6/69)

some workers (Osborn 1943, Ivanovics and Horvath 1947, Osborn and Harper 1951, Frenczy 1956, Ark and Thompson 1958, Jacobs and Dadd 1959, Garber and Houston 1959, Thompson 1960, Bowen 1961).

For the past two decades, attempts have been made by several workers, particularly in U. S. S. R., to treat the seeds with some bacteria like *Azotobacter* and Phosphobacterium, to favourably influence the growth of the seedlings and very encouraging results have been obtained. However, the reasons for beneficial effects due to bacterization of the seed have not been investigated in detail.

Some workers have reported that the organic tissues, including the seed coats, when added to soil form an excellent medium for colonization by certain groups of soil micro-organisms. There are reasons to believe that certain micro-organisms utilize the nutrients present in the added organic tissues and produce anitibiotic substances which are inhibitory to other organisms in the vicinity, including the pathoganic ones (Wright 1954, 1955, 1956a, b, c, Grossbard 1948, 1952, Lockwood 1960, Krassilnikov, Kuchaeva and Skryabin 1959, Lingappa and Lockwood 1962, Lockwood and Lingappa 1963, Lloyd, Neverorke and Lockwood 1965).

The changes in the normal seed-microflora due to various chemical and physical seed treatments have been reported by some workers (Sowell 1965, Batra and Bajaj 1966, Maude 1966, Rao and Durgapal 1966).

It has been established through the studies of some workers that the rhizosphere effect is initiated in the seedlings within a few days after germination and the rhizosphere organisms in the initial stages are mostly related to the seed-microflora, thereby indicating that the seedlborne organisms are carried to the rhizosphere (Borodulina 1941, Wallace and Lochhead 1951, Rovira 1956, Rouatt 1959). Patterson (1959) and Parkinson, Taylor and Pearson 1963), however, found that the seed-microflora did not materially alter the rhizosphere microflora. Bacterization of seed and its effect on rhizosphere microflora has also been studied by some workers (Jensen 1942, Federov and Tepper 1945, Maska and Fabian 1952, Cooper 1959). The results obtained by these authors, however, are inconclusive as to the added bacterium establishing in the rhizopheres.

In our laboratory we have been interested during the past five years to examine the possibility of altering the rhizosphere microflora through pre-treatment of the seeds. In the present paper certain principles involved and the interpretations of the results reported earlier are presented.

EXPERIMENTAL

Bacterization and plant growth: Rangaswami and Mahadeviah (1963) reported on the general increase in the rate of plant growth when rice seeds were pre-treated with *Azotobacter chroococcum*. Such an effect was significantly more when the pre-treated seed was sown in semi-dry soil as compared to water-logged soil. Neelakantan (1964) examined the effect of bacterilization with *A. chroococcum* on the germination, rate of growth and the wet and dry weights of rice, sorghum, bajra, ragi, setaria, bhendi, tomato and amaranthus. There was an increase of more than 10 per cent. germination of the pre-treated seeds than the respective controls of bajra, ragi and tomato, whereas in the other crops there were no large changes. The seedlings arising from the treated seeds grew more rapidly for about 8-10 days after sowing and they were tall, vigorous and darker green as compared to the respective controls. The increased growth rate of the treated plants over control was statistically significant at various stages in sorghum, and to a lesser extent in rice, bajra, ragi, setaria, and amaranthus, and not significant in bhendi and tomato. There were varying increases in dry weights of treated plants over the control, at the end of 60 days after sowing; the percentage increase in rice was 8.7, sorghum 34.7, bajra 6.7, ragi 17.0, setaria 10.6, bhendi 1.2, tomato 5.1 and amaranthus 6.3. Of these, the increase in the dry weights of rice, sorghum and ragi were significant. Similar results were obtained with some crop plants by Gopalakrishnamurthy, Mahadevan and Rangaswami (1967).

Seed coat exudates and seed and soil microflora: In another study Balasubramanian and Rangaswami (1967a) found the germination percentages of sorghum, sunnhemp and tomato seeds when sown in normal and steam-sterilized soils varied considerably. Also, the average shoot lengths and dry weights of the seedlings arising out of the seeds sown in the normal and stream-sterilized soils varied significantly, thereby indicating the role of soil micro-organisms in influencing germination of seed and subsequent growth of the seedlings. The same authors (1967b) reported on the presence of certain chemical inhibitors of fungal spores in the seed coats of sorghum, ragi and tomato. The seed coat leachates from the three varieties of seeds caused delay in germination of spores of *Helminthosporium oryzae* Breda de Haan, malformation and subsequent lysis of germ-tubes of the fungus and considerable inhibition of germination ranging upto 80 per cent. These studies indicated certain types of inter-relationships between the seed-microflora and the seed that might exist at the time of seed germination.

Seed treatment and rhizosphere microflora : In another series of experiments the possibility of seed-microflora entering the rhizosphere region of the plants was examined. Neelakantan (1964) found that when seeds of rice were treated with *A. chroococcum* at the rate of about 7,000 cells/g of seed and sown in sterile soil the bacterial population increased upto about 20 million/g rhizosphere sample in 50 days and declined thereafter and when sown in normal unsterile soil it increased to 12.3 million/g of rhizophere sample in 50 days and declined later on. In the case of bhendi when about 16,000 cells/g of seed were added, the rhizosphere population increased to 7.5 million/g in 60 days in sterile soil and 10.8 million/g in 40 days in normal unsterile soil. Such treatments also materially altered the quantities of bacteria, actinomycetes and fungi in the rhizosphere. Gopalakrishnamurthy, Mahadevan and Rangaswami (1967) studied the changes in the rhizosphere microflora of rice plants at different stages of growth, when the studies were pre-treated with *A. chroococcum, Phosphobacterium* sp. and *Helminthosporium oryzae,* alone and in different combinations. When the seeds were treated with either. *A. chroococcum* or *Phosphobacterium* sp. the respective bacteria readily got established in the rhizosphere and multiplied in number upto 70-80 days, whereas the pathogen, *H. oryzae,* when added to the seed increased only slightly.

In a further attempt to alter the rhizosphere microflora through seed-treatments, cotton seeds were treated with concentrated sulphuric acid, Agrosan GN, and streptomycin sulphate and the rhizophere microflora was studied both quantitatively and qualitatively (Prasad and Rangaswami 1967). When untreated cotton seeds were sown in sterile soil there was readily colonisation of the rhizosphere by the epiphytic microflora by about the fourth day ; when sown in unsterile soil the epiphytic flora continued to be predominant for some time and in about 15 days it declined, giving place to slow colonization of the region by the soil microflora. The quantity and quality of the bacteria, actinomycetes and fungi establishing in the rhizophere of seedlings arising from the different pre-treated seeds varied significantly.

DISCUSSION

The works of Picci (1959a, b) and others brought to light the influence of seed on the seed-microflora and the soil microflora in the vicinity of germinating seed, which influence is termed 'spermosphere effect'. That the spermosphere effect would vary with plant species, soil and various other environmental factors is to be recognized in analogy with "the rhizosphere effect'. When the seeds of crop plants are treated in different ways, we are interfering with the normal relationships between seed, its microflora and the spermosphere effect. For nearly a century agriculturists have been advised to pre-treat the seeds with chemicals to get rid of the pathogens. Such treatments not only kill the pathogens but also most other organisms carried by the seed. That these treatments bring in changes in the quantity and quality of the micro-organisms establishing in the rhizosphere of certain plants at various stages of growth has been brought out through our studies.

Bacterization of seed to obtain better seed germination, plant growth and the resultant crop yield has become an approved practice in many parts of U. S. S. R. The results obtained in this country also substantiate these results (Sankaram 1963, Sundara Rao and Sinha 1963, Sundara Rao, Bajpal Sharma and Subbiah 1963, Rangaswami and Mahadeviah 1963, Neelakantan and Rangaswami 1965, 1967, Gopalakrishnamurthy, Mahadevan and Rangaswami (1967). Furthermore, our studies also indicate that by pre-treating the seeds with *A. chroococcum* and *Phosphobacterium* sp., the organisms are transported to the rhizosphere region, where they materially alter the quantity and quality of the microflora.

There are also many reports in the literature on the beneficial effects by way of better seed germination, rapid growth, robust stand and increased wet and dry weights of seedlings through pre-treating the seeds with certain chemicals, particularly organo mercurials (Cristensen and Stakman 1935, Jamalainen 1962, Clark 1963, Kukin 1963). There are also some reports on the adverse effect of such treatments on the seed germination (Dempsey and Chandler 1963, Timonin 1964). In the light of the more recent observations made by the various workers on the role of seed-microflora and spermosphere microflora on seed germination and subsequent growth of the seedling, re-examination of some of the results reported by earlier workers to understand the role of various groups of micro-organisms appears necessary.

SUMMARY

The various internally and externally borne seed microflora greatly influence the percentage germination and subsequent growth of the plant. The different physical and chemical as well as microbial treatments given to the seed not only alter the effect of the normal flora on the seed but also cause certain beneficial effects to the plant growth. The normal microflora of the seed is also carried to the

rhizosphere of young seedlings of certain plant species. The various physical and chemical pre-treatments given to the seed therefore alter the rhizosphere microflora, and this has been confirmed by the earlier works of the author and his associates. It is suggested that more work in this direction is required to examine the possibility of altering the rhizosphere microflora in desired lines through pre-treatment of the seeds with different chemicals and micro-organisms.

REFERENCES

ARK, P. and THOMPSON, F. (1958), *Plant Dis. Reptr.*, 42 : 959.

BALASURRAMANIAM, A. *and* RANGASWAMI, G. (1967b), *Curr. Sci.*, 36 : 615. *1* : 1.

BALASUBRAMANIAM, A. *and* RANGASWAMI, G. (1967b), *Curr Sci.*, *36* : 615.

BATRA, S. K. and Bajaj, B. S. (1966), *Plant Dis. Reptr.*, 50 : 299.

BALOOMBERG, W. J. (1966), *Can. J. Bot.*, *44* : 413.

BORODULINA, V. S. (1941), *Microbiol, U. S. S. R.*, *10* : 924.

BOWEN, G. D. (1961), *Plant & Soil*, *15* : 155.

CHRANOWSKA, H. (1965), *Refrat. Zh. Rasten.*, *14* : 434.

CHRISTENSEN, J. J. and STAKMAN, E. C. (1935), *Phytopathology*, *25* : 309.

CLARK, R. V. (1963), *Plant Dis. Surv.*, *43* : 27.

COOK, R. J. and FLENTJE, N. T. (1967), *Phytopathology*, *57* : 178.

COOPER, R. (1959), *Soil & Fert.*, *22* : 327.

DEMPSEY, A. H. and CHANDLER, W. A. (1963), *Plant Dis. Reptr.*, *47* : *325*.

DUGGELI, M. (1904), *Centbl. Bakt.*, *12* : 56.

FEDEROV, M. V. and TEPPER, E. S. (1945), *Moskov, Orderna Lenina Selsk. Acak. Timiziazeva Dok.*, *1* : 61.

FLENTJE, N. T. (1959), In *Plant Pathology—Problems* and *Progress* (Eds.) C. S. Holton *et al.*, Univ. Wisconsin Press, pp 76.

FRENCZY, L. (1956), *Acta Biol.*, *6* : 317.

GARBER, R. H. and HOUSTON, B. R. (1959), *Phytopathology*, *49* : 449.

GOPALAKRISHNAMURTHY, A., MAHADEVAN, A. and Rangaswami, G. (1967), *Indian J. Microbiol.*, 7 : 21.

GROSSBARD, E. (1948), *Rept., Exp. Res. Sta. Cheshunt*, pp 29-30.

GROSSBARD, E. (1952), *J. Gen. Microbiol.*, *6* : 295.

IVANOVICS, G. and HORVATH, S. (1947), *Nature* (Lond.), *160* : 297.

JACKSON, C. R. and PRESS, A. F. (1967), *Oleagineux, 22* : 165.

JACOBS, S. E. and DADD, A. H. (1959), *Ann. appl. Biol., 47* : 666.

JAMALAINEN, E. A. (1962), *Ann. Agric. Fenniae, 1* : 175.

JENSEN, H. L. (1942), *Austr. J. Sci., 4* : 117.

KRASSILINIKOV, N. A., KUCHEVA, A. G. and SKRYABIN, G. K. (1959), *Ann. Inst. Pasteur, 96* : 548.

KUKIN, V. F. (1963), *Nauchn. Tr. Selekt—Genet. Inst., 5* : 162.

LINGAPPA, B. T. and LOCKWOOD, J. L. (1962), *Abs. Phytopathology,* 52 : 739.

LLOYD, A. B., NEVEROSKE, R. L. and LOCKWOOD, J. L. (1965), *Phytopathology, 55* : 871.

LOCKWOOD, J. L. (1960), *Phytopathology, 50* : 787.

LOCKWOOD, J. L. and LINGAPPA, B. L. (1963), *Phytopathology, 53* : 917.

MASKA, J. and FABIAN, J. (1952), *Sborn. Vys. Skol. Zemed. Lesn. Brno., 3-4* : 298.

MAUDE, R. B. (1966), *Ann. appl. Biol., 57* : 193.

NEELAKANTAN, S. (1964), Studies on the effect of pre-treatment of seeds on some non-legumes with *Azotobacter chroococcum* on the germination and growth of the seedlings. *M. Sc. Thesis Annamalai Univ.*

NEELAKANTAN, S. and RANGASWAMI, G. (1965), *Curr. Sci., 34* : 157.

NEELAKANTAN, S. and RANGASWAMI, G. (1967), *Mysore J. Agri. Sci., 1* : 66.

ORDIN, A. P. (1966), *Mikrobiologiya, 35* : 337.

OSBORN, E. M. (1943), *J. Exp. Path., 24* : 227.

OSBORN, E. M. and HARPER, J. L. (1951), Nature (Lond.), *167* : 685.

PARKINSON, D., (1965), *Proc. Symp., Plant Microbes Relationships,* Prague, pp. 69-75.

PARKINSON, D., TAYLOR, G. S. and PEARSON, R. (1963), *Plant & Soil, 19* : 332.

PETERSON, E. A. (1959), *Can, J. Microbiol., 5* : 579.

PEARSON, R. and PARKINSON, D. (1961), *Plant & Soil, 13* : 391.

PICCI, G. (1959a), *Agricoltura Ital., 59* : 155.

PICCI, G. (1959b), *Agricoltura Ital., 59* : 216.

PRASAD, N. N. and RANGASWAMI, G. (1967), *Mysore J. Agri. Res., 1* : 88.

RANGASWAMI, G. and MAHADEVIAH, S. (1963), Proc. All India Microbiol. Congress, Bombay, Nov. 5, 1963.

RAO, Y. P. and DURGAPAL, J. C. (1966), *Indian Phytopath.*, *19* : 402.

ROUATT, J. W. (1959), *Can. J. Microbiol.* *5* : 67.

ROVIRA, A. D. (1956), *J. Appl. Bacteriol.*, *19* : 72.

SANKARAM, A. (1963), *Sci. & Cult.*, *29* : 182.

SCHROTH, M. N. and COOK, R. J. (1964), *Phytopathology*, *54* : 670.

SCHROTH, M. N. and SNYDER, W. C. (1961), *Phytopathology*, *51* : 389.

SCHROTH, M. N., TOUSSOUN, T. A. and SNYDER, W. C. (1963), *Phytopathology*, *53* : 809.

SOWELL, G. (1965), *Plant Dis. Reptr.*, *49* : 895.

STANEK, M. and LASIK, J. (1965), *Proc. Symp.*, *Plant Microbes Relationships*, Prague, pp. 69-75.

SUNDARA RAO, W. V. B., BAJPAI, P. D., SHARMA, J. P. and SUBBIAH, B. V. (1963), *J. Indian Soc. Soil Sci.*, *11* : 209.

SUNDARA RAO, W. V. B., and SINHA, N. K., (1963), *Indian J. Agri., Sci.*, *33* : 272.

THOMPSON, J. A. (1960), *Nature* (Lond.), *187* : 619.

TIMONIN, M. I. (1964), *Can. J. Microbiol.*, *10* : 17.

VAGNEROVA, K., MACURA, J. and CATSKA, V. (1960), FOLIA *Microbiol.* 5 : 311.

WALLACE, R. H. and LOCHHEAD, A. G. (1951), *Soil Sci.*, *71* : 159.

WRIGHT, J. M. (1954), *Ann. Appl. Biol.*, *41* : 280.

WRIGHT, J. M. (1955), *Ann. Appl. Biol.*, *43* : 288.

WRIGHT, J. M. (1956a), *Ann. Appl. Biol.*, *44* : 461.

WRIGHT, J. M. (1956b), *Plant & Soil*, 7 : 132.

WRIGHT, J. M. (1956c), *Ann. Appl. Biol.*, *44* : 561.

Drought incidence in relation to rainfed rice

W. S. Alles
Research Officer, Central Agricultural Research Institute, Peradeniya, Ceylon

(Received June, 1969)

INTRODUCTION

During the active growth stages of a plant, a high state of turgidity is necessary in the tissues for their normal growth. The turgidity which exists in a field crop at a particular instant of time is a function of several variables, namely the availability of moisture in the root zone, the evaporative demand of the shoot environment and any controlling influences which may exist within the plant itself. But in general, if the soil is drier than pF 4.2, plants would be subjected to moisture stress and consequently growth activity reduced, unless the atmospheric humidity is exceedingly high. The present study is an attempt to use available information of meteorological and soil conditions, to estimate the number of days on which certain selected root zones have been drier than pF 4.2. Such days are designated as Agricultural Drought Days.

There is no published work on drought incidence in Ceylon which takes account of soil moisture. Drought defined in terms of rainfall, alone is considered in meteorological records and this information is published in the annual reports of the Colombo observatory. Drought in an agricultural sense does not begin when rain ceases, but rather when soil moisture is diminished so that plant roots can no longer absorb water from the soil rapidly enough to replace that lost by the shoot to the atmosphere. This concept has been adopted and widely used in the work of Thorntwaite (1955), Penman (1961), Veihmeyer (1956), Veihmeyer and Hendriksen (1955), Zahner (1956), Van Bavel (1953), and others. The work of Van Bavel and Verlinden (1956), is particularly useful as it provides a means of estimating drought incidence from meteorological records, of rainfall and

4——J 3788 (6/69)

evaporation, and the moisture holding capacity of soil. The computations are however subject to the following assumptions :—

(*a*) moisture above field capacity is rapidly lost as deep percolation or as run-off.

(*b*) moisture below wilting percentage is not available to plants ;

(*c*) all moisture between field capacity and wilting percentage is equally available through the whole range, and evapotranspiration proceeds at the potential rate down to wilting percentage and when the base amount is exhausted no further evapotranspiration occurs.

Although these assumptions are controversial, nevertheless there is no practical alternative at the present time, for dealing with a long-term past record, and where elaborate computational assistance is not available.

In the present study drought incidence has been calculated for 63 years, and from this information the statistical expectancy of drought conditions has been derived. This information has been combined with available data on the yield and drought conditions prevalent during seven seasons of rainfed rice cultivation at Maha Illupallama to determine the long-term yield.

Drought day information may similarly be used to determine the yield pattern of other crops, as well as their requirement of irrigation, in order to obtain consistently high yields.

PROCEDURE

Drought days have been calculated for Maha Illupallama in respect of three selected root zones, for the period 1905-1968. The selected root zones are specified in terms of the base amount of available soil moisture rather than in terms of depth of soil in order that the drought information would be applicable to all soils in a region. The base amounts of available soil moisture for which drought days have been calculated are one, two and three inches. Available soil moisture is defined as the amount between field capacity and permanent wilting percentage. When these two values and the bulk density of a soil are known, the particular root zone associated with any base amount of available soil moisture can readily be found. Thus for a soil of field capacity 20 per cent, permanent wilting percentage 10 percent and bulk density 100 lb. per cubic foot, a base amount of one inch refers to the root zone consisting of the top six inches, and if soil conditions are uniform, a base amount of two inches refers to a foot depth of soil and three inches to 1½ feet of soil.

If the actual moisture percentage of a soil can be determined for a particular date, the subsequent soil moisture conditions depend on the accretions from rainfall and the depletions of water by evapotranspiration losses.

Daily rainfall records were available for Maha Illupallama from January 1905, while June and July 1905, were completely without rain Hence it could be reasonably assumed that for all selected base amounts of soil moisture, the soil was at permanent wilting percentage on August 1st 1905. This date was therefore taken as the starting point for the computations.

Although daily rainfall measurements exists, measured evapotranspiration values are not available and requires to be estimated. Pan evaporation measurements were available for several years. In the present study, the average monthly values of pan evaporation were divided by the days in each month to obtain a value for the daily evaporation in respect of each month. These values have been assumed to be equal to the potential evapotranspiration. Although this is not strictly valid, nevertheless, it is not a disadvantage for the particular use made of the data in relation to rainfed rice. However, in future work it is proposed to use more refined estimates of evapotranspiration in order to make the drought day information more reliable and widely applicable.

RESULTS

During the maha seasons 1962/63 to 1968/69, the rainfed rice crop at the Maha Illupallama Research Station has been grown on the same land under more or less similar conditions, with tillage practices, varieties sown, fertiliser application, weed control methods, pest and disease control, etc. remaining the same. Hence most of the yield variations may be reasonably attributed to variation in the moisture factor. The period of drought susceptibility has been taken as the three-month period October 15—January 15, while the root zone from which moisture is drawn has been taken as the top six to nine inches of soil. In tables I and II are given the drought day incidence during the seven maha seasons considered, while in Figure I and tables III and IV are given the long-term drought day expectancies.

TABLE I—Drought Days and Yield in Seven Seasons of Rainfed Rice

Season	*Acreage*	*Yield in Bushels/acre*	*Total Drought Days*
1962/63	25	30	18
1963/64	24	71	8
1964/65	10	8	23
1965/66	12	40	19
1966/67	20	40	19
1967/68	24	25	22
1968/69	20	12	21
Average of seven seasons (not weighted for acreage)		32	

TABLE 2.—Number of periods of consecutive drought days of duration equal to or greater than specified below, during the period October 15—January 15

Season	*5 Days*	*7 Days*	*10 Days*	*15 Days*
1962/63	2	1	Nil	Nil
1963/64	1	Nil	Nil	Nil
1964/65	3	2	1	Nil
1965/66	2	1	1	Nil
1966/67	2	1	1	Nil
1967/68	2	1	1	Nil
1968/69	3	1	Nil	Nil

TABLE 3.—Long-term expectancy in percentage of years, of consecutive drought day periods of duration equal to or greater than specified below, for the period October 15—January 15

Specified Duration in Days	*With at least one period*	*With at least two periods*	*With at least three periods*
5	89	64	38
7	75	38	16
10	51	11	Nil
15	19	Nil	Nil

TABLE 4.—Long-term expectancy, in percentage of years, of consecutive drought day periods of duration equal to or greater than specified below, for the period October 15—December 31

Specified Duration in Days	*With at least one period*	*With at least two periods*	*With at least three periods*
5	66	30	6
7	51	15	1
10	32	4	Nil
15	14	Nil	Nil

DISCUSSION

In this study rainfed rice yields have been viewed from two aspects of the moisture factor, namely the total number of drought days and the occurence of drought days on successive days for specified durations.

In the seven seasons of data available, the most favourable season was in 1963/64, while the most unfavourable was in 1964/65.

Tables III and IV and Figure I show that conditions more favourable as well as conditions more unfavourable could be expected to occur in some years. The percentage of such years can be ascertained. In the 1963-64, season when the highest grain yield was obtained, the total drought days was eight and there was one period of five consecutive drought days, but none of seven or more days. In about ten per cent. of the years, conditions would be even more favourable ; i.e., without a single period of five consecutive drought days and less than a total of eight days. Therefore yields would exceed 70 bushels/acre in about ten per cent. of the years and possibly average about 80 bushels/acre.

In 1964-65, when the lowest yield was obtained the total drought days was 23 and twelve days occurred consecutively. Fifteen consecutive drought days did not occur in any of the seven seasons of study. But such an event is likely in 19 per cent. of the years, while in 40 per cent. of the years the total drought days would exceed 23. It may be concluded therefore that in about 20 per cent. of the years rice yields would be less than 10 bushels/acre.

Extremely high variability is to be expected in rainfed rice cultivation in Dry Zone locations such as Maha Illupallama. It is not possible to deduce the exact long-term pattern of yield from the available information, but it is clear from the present data that the long-term average yield is unlikely to be higher than the average value of the seven seasons of information. In fact indications are that it may be slightly lower. A figure of 30 bushels/acre is a reasonable tentative value for the long-term average yield of the four month age class varieties that are available.

At these yield levels it is hardly profitable to grow rainfed rice. The cost of cultivation of a rainfed rice crop according to the recommendations of the Maha Illupallama Research Station has been estimated at Rs. 420 per acre. This is equivalent in value to 30 bushels of paddy at Rs. 14 per bushel and thus there is no profit margin. However, at lower levels of management with lower inputs such as under chena conditions, rainfed rice cultivation may be profitable although yields also would be lower.

The adverse effects of drought can be considerably reduced by growing a good 3 1/2 month variety. This is clearly indicated in Table IV. In this case the proportion of seasons without even a five-day consecutive drought period is 35 per cent. as against 10 for the four month varieties, while the proportion of very unfavourable seasons with a 15 day drought period is 14 as against 19 earlier. It should be possible to achieve a long-term yield level of about 50 bushels/acre with a 3 1/2 month variety whose yield potential is similar to that of the existing four month varieties. An intensified research programme in rainfed rice agronomy is therefore a worthwhile venture.

Lastly, the type of land on which rainfed rice has been at Maha Illuppalama deserves mention. The land is a lower member in the Reddish Brown Earth catena and mapped as the Talawa and Manewa soil series. Drainage is described as moderate to poor, and the land slope is about three to four per cent. Broadbased terraces have been constructed on the land but otherwise the natural external drainage is unimpeded. Ponded water does not occur except is isolated patches.

Rainfed rice would grow much better if land is bench terraced to form 'liyaddas' so that ponded water may remain, as in typical irrigated paddy lands with provision to drain off excess water when necessary. Under these conditions the onset of drought during rainless periods may be considerably delayed. The extra cost of bench terracing the lands would be amply justified by the increased yields that would be obtained.

SUMMARY

The concept of a "Drought Day" has been used to study the moisture stress suffered by plants, and the incidence of drought days has been calculated for a period of 63 years, based on the climatological records of Maha Illuppallama. Relevant information from this study has been used to determine the long-term yield of rainfed rice.

ACKNOWLEDGEMENTS

The co-operation of the Director of Meteorology and his staff in obtaining daily rainfall data, and the assistance of Mr. J. Amarasena, laboratory assistant in carrying out the calculations is gratefully acknowledged.

LITERATURE CITED

1. Annual Reports of the Colombo Observatory.

2. PENMAN, H. L., (1961) The Movement and Availability of Soil Water Soils and Fertilizers, *Comm. Bur. Soil Sci 19* : 221-225.

3. THORNTWAITE, C. W., (1955). The Water Balance, Drexel Institute of Technology. Publications in Climatology Vol. II, No. 1. Centerton, New Jessey.

4. VEIHMEYER, F. J., (1956) Soil Moisture, Hanbuck der Pflanzenphysiologie *3* : 64-123.

5. VEIHMEYER, F. J. and HENDRIKSEN, A. H., (1955) Does Transpiration Decrease as Soil Moisture Decreases ? Trans. Amer. Geoph. Union *36* : 425-428.

6. VAN BAVEL, C. H. M., (1953) A Drought Criterion and Its Application in Evaluating Drought Incidence and Hazard *Agron Journ*, *45* : 167-172.

7. VAN BAVEL, C. H. M. and VERLINDEN, F. J., (1956) Agricultural Drought in North Carolina *Agric. Expt. Sta. Tech. Bul.* No. 122.

8. ZAHNER, R., (1956) Evaluating Summer Water Deficiencies Southern Forest *Expt. Sta. U. S. D. A. Occasional Paper* No. 150.

9. Reports of the Rainfed Rice Research Section, *Agric. Research Sta. Mahailuppallama.*

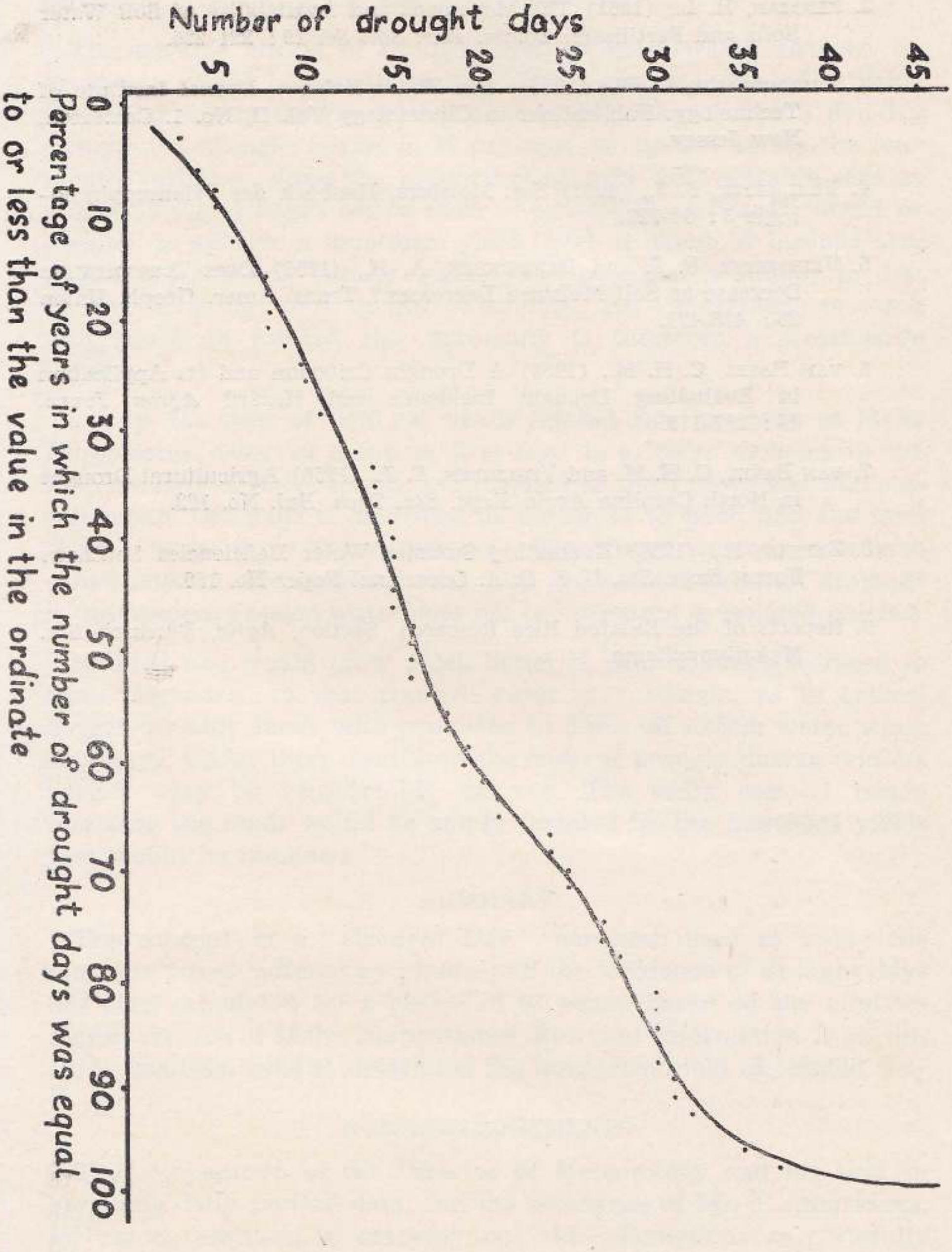


Figure 1—Cumulative frequency diagram of total drought days occurring between October 15-January 15, based on 63 years record.

METEOROLOGICAL REPORT

Quarterly weather summary—January to March, 1969

JANUARY : The rainfall during January was below normal. Spells of dry weather alternated with short spells of rainy weather. There was practically no rain from the 1st to the 3rd and on the 8th, from he 16th to the 18th and from the 24th to the end of the month. A low pressure area which formed in the South Bay of Bengal on the 9th deepened into a depression on the 11th near latitude 4° North longitude 88° East, but remained stationary and filled up by the 15th. This strengthened the easterlies and rain was experienced in the East during this period, with evening thunderstorms in the southwest. Noteworthy features of the weather during January were the severe thunderstorms in Colombo on the 13th evening (which gave 4.91″ of rain) and the low night temperatures in the North from the 25th the end of the month. The thunderstoms on the 13th was accompanied by strong gusts of wind, probably about 60 m.p.h. over parts of Colombo city, where some roofs were blown off. The low night temperatures in the North were due to Indian continental air being drawn over the Island due to a deep depression near Gan Island. The larger monthly totals of rainfall (totals over 20 inches) were experienced along the north-eastern slopes of the central hills in the Gammaduwa area. In parts of the Nuwara Eliya and Badulla districts, the rainfall ranged between 15 and 20 inches, while over the adjoining areas, the rainfall was mainly between 5 and 15 inches. In the south-west quarter and in the North, rainfall was mainly below 5 inches, except for isolated areas in the Colombo district where the rainfall ranged between 5 and 10 inches. Rainfall was below average over practically the whole Island, except for a few isolated stations mainly in the south-west. Day temperatures were generally above normal. Night temperatures were well below normal at Kankesanturai, above normal at Nuwara Eliya and about normal elsewhere. Day humidity ranged from 63 per cent. to 80 per cent., while night humidity ranged from 78 per cent. to 95 per cent. The air was unusually dry at Nuwara Eliya on several days, 2nd, 3rd, 26th and 31st. On the 3rd and on the 26th, extreme humidity values of 16 per cent. and 18 per cent. were recorded, which are exceptionally low values. Cloud amounts were about normal and the mean air pressure slightly below normal. Wind mileages were below normal in the north-west and generally above normal elsewhere, while the direction was north-easterly.

FEBRUARY : The rainfall during February continued to be below average over the greater part of the Island. Due to a dry north-easterly air stream over the Island at the beginning of the month, no rain was experienced during the first four days. A moist easterly wind stream set in on the 5th and generally light rain was experienced in the North and East from the 5th to the 11th, with scattered evening thundershowers in the south-west. From the 12th to the 14th and from the 20th to the 26th, dry weather prevailed, while on the remaining days generally light rain was experienced in the North and East, with scattered thundershowers in the south-west. The larger monthly totals of rainfall (totals over 10 inches) were experienced mainly along the north-eastern slopes of the central hills, particularly in the Gammaduwa area. Over the adjoining regions and over parts of the south-west, the rainfall ranged mainly between 5 and 10 inches. In the North and East, the rainfall ranged mainly between 2 and 10 inches. Rainfall was below average over most of the Eastern Province and the central region of the Island. Day temperatures were generally above normal. Night temperatures were below normal at Kankesanturai, above normal at Nuwara Eliya and about normal elsewhere. Day humidity ranged from 59 per cent. to 72 per cent. while night humidity ranged from 74 per cent. to 93 per cent. The air was unusually dry at Nuwara Eliya on the 12th, being 17 to 19 per cent. during the afternoon, which is extremely low. Cloud amounts were a little below normal and the mean air pressure was a little above normal. Air pressure over the Island was high on the 27th morning, the highest value being at Mannar, 1017.1 mb. Wind mileages were generally below normal and the wind direction was mainly north-easterly.

MARCH : March was dry and warm and for the third consecutive month this year, rainfall was below average. There was a dry spell from the 4th to the 12th, when there was practically no rain anywhere over the Island. Absolute drought conditions prevailed at many stations, particularly in the north-western, northern and eastern provinces. Even though there were 17 days of thunderactivity during the month, the rainfall was isolated and mainly light. The larger monthly totals of rainall (totals over 10 inches) were experienced mainly in Sabaragamuwa. Over the adjoining areas of the south-west quarter, the rainfall ranged between 2 and 10 inches. Over most of the north-western, northern and eastern provinces, the rainfall was below 2 inches, many stations recording no rain at all. Rainfall was below average over practically the whole Island, except for a few isolated stations in the southwest and at Vavuniya. Day temperatures were well above normal, being appreciably so at Nuwara Eliya, Kurunegala and Anuradhapura, where the average maximum temperature were more than 4 degrees above normal. Night temperatures were mostly a little above normal. Day humidity ranged from 53 per cent. to 70 per cent., while the night humidity ranged from 73 per cent. to 95 per cent. The air was unusually dry at Nuwara Eliya during the mornings of the 7th, 8th and 9th, when very low humidities of about 20 per cent. were recorded. Also Katugastota experienced a very dry day on the 6th, when an extreme value of 22 per cent. was recorded. Cloud amounts were a little below normal and the mean air pressure slightly above normal. Wind mileages were above normal in the south-east, north and north-west and below normal elsewhere, the direction being variable.

L. A. D. I. Ekanayaka,
Director.

Department of Meteorology,
Bauddhaloka Mawatha,
Colombo 7, 15th May, 1969.

කාලගුණ විද්‍යාත්මක වාර්තාව
METEOROLOGICAL REPORT

March 1969 1969 මාර්තු මස

ස්ථානය Station		උෂ්ණත්වය Temperature F°			ආද්‍රතාවය Humidity			වලාකුළු ප්‍රමාණය Cloud Amount	ප්‍රමාණය Amount	වර්ෂාපතනය Rainfall		
	මධ්‍ය උපරිම *Mean Max.*	අනු ලම්බ *Off set*	මධ්‍ය අවම *Mean Min.*	අනු ලම්බ *Off set*	දිවා *Day*	රාත්‍රී *Night*				අනුලම්බ *Off set*	වැසි දිනගණන *Rain Days*	අනු ලම්බ *Off set*
අනුරාධපුරය Anuradhapura	95.7	+4.0	72.8	+1.3	58	93	2.9	1.49	–2.40	4	–3
බදුල්ල Badulla	85.4	+2.9	63.8	–0.5	66	94	3.0	4.24	–0.09	5	–6
මඩකලපුව Batticaloa	87.7	+2.3	76.2	+1.1	69	86	3.2	0.01	–3.33	1	–7
කොළඹ Colombo	90.0	+2.2	75.2	+1.2	69	91	3.7	2.30	–2.33	3	–8
දියතලාව Diyatalawa	79.1	+1.2	57.5	–0.7	65	85	3.4	2.92	–1.86	6	–6
ගාල්ල Galle	88.1	+1.8	75.8	+0.8	67	82	3.2	2.43	–2.16	8	–3
හම්බන්තොට Hambantota	89.1	+2.1	75.9	+1.5	66	82	3.8	0.36	–2.25	2	–5
යාපනය Jaffna	90.8	+2.0	77.4	+1.6	66	86	2.6	0	–1.18	0	–3
නුවර Kandy	90.8	+2.8	67.6	+0.7	53	87	3.2	2.26	–2.47	4	–4
කන්කසන්තුරය Kankesanturai	91.2	+2.5	74.5	+0.4	66	90	2.7	0	–0.97	0	–2
කටුනායක Katunayake	90.0	—	74.2	—	66	88	3.6	3.16	—	3	—
කුරුණෑගල Kurunegala	97.0	+4.2	73.0	+1.0	56	93	3.8	1.88	–4.82	6	–4
මහඉලුප්පලම Maha Illuppalama	94.4	+2.2	73.0	+2.5	57	88	2.6	4.73	—	5	—
මන්නාරම Mannar	91.4	+2.3	76.5	+1.1	68	88	3.0	0	–1.75	0	–4
නුවරඑළිය Nuwara Eliya	76.3	+5.1	48.6	+2.3	58	73	4.0	1.53	–2.27	8	–3
පුත්තලම Puttalama	93.2	+3.1	74.9	+1.9	65	90	3.3	0.01	–2.98	1	–6
රත්මලාන Ratmalana	89.8	+1.4	74.4	+0.5	70	86	3.2	1.92	—	6	—
රත්නපුරය Ratnapura	94.9	+2.7	72.2	–0.3	55	95	4.2	5.00	–4.59	12	–6
ත්‍රිකුණාමලය Trincomalee	88.9	+3.1	77.9	+1.2	66	82	3.2	0	–1.90	0	–5
වවුනියාව Vavuniya	94.0	—	72.0	—	57	85	2.8	3.98	+1.52	6	+1

කාලගුණ විද්‍යාත්මක වාර්තාව
METEOROLOGICAL REPORT

February 1969 1969 පෙබරවාරි මස

ස්ථානය Station	උෂ්ණත්වයංප Temperature F°				ආද්‍රතාවය Humidity		වළාකු ප්‍රමාණය	වර්ෂාපතනය Rainfall			
	මධ්‍ය උපරිම *Mean Max.*	අනු ලම්බ *Off set*	මධ්‍ය අවම *Mean Min.*	අනු ලම්බ *Off set*	දිවා *Day*	රාත්‍රී *Night*	*Cloud Amount*	ප්‍රමාණය *Amount*	අනු ලම්බ *Off set*	වැසිදින ගණන *Rain Days*	අනු ලම්බ *Off set*
අනුරාධපුරය Anuradhapura	89.3	+2.1	68.8	−0.5	66	95	3.3	1.87	−0.24	6	0
බදුල්ල Badulla	80.8	+1.9	62.5	−0.8	72	91	3.5	3.06	−1.69	9	−1
මඩකලපුව Batticaloa	84.0	+1.2	73.5	−0.3	70	84	3.7	2.23	−4.79	8	−2
කොළඹ Colombo	87.6	+0.6	72.8	+0.6	71	90	3.6	3.05	−0.73	7	0
දියතලාව Diyatalawa	76.4	+1.4	56.5	−0.7	68	85	3.4	2.15	−1.22	10	0
ගාල්ල Galle	85.8	+0.7	73.9	+0.2	69	86	3.2	3.23	−1.33	8	−1
හම්බන්තොට Hambantota	87.2	+1.4	73.8	+0.8	68	84	3.1	0.58	−1.72	2	−3
යාපනය Jaffna	86.6	+1.0	72.4	0	66	90	3.1	2.62	+1.17	3	0
නුවර Kandy	87.2	+2.0	64.1	−0.2	59	86	2.9	0.91	−2.36	5	0
කන්කසන්තුරේ Kankesanturai	86.0	+0.9	70.9	−3.1	71	93	3.0	0.81	−0.53	3	+1
කටුනායක Katunayake	89.3	—	71.1	—	66	90	3.1	3.87	—	7	—
කුරුණෑගල Kurunegala	92.1	+2.2	70.3	+0.7	62	93	2.9	0.75	−1.60	6	0
මහඉලුප්පල්ලම Maha Illuppallama	89.0	+1.1	69.0	+0.7	60	87	2.2	1.59	—	6	—
මන්නාරම Mannar	86.2	+0.3	73.0	−1.0	72	90	3.0	2.94	+1.62	5	+2
නුවරඑළිය Nuwara Eliya	73.1	+3.4	49.4	+3.6	63	74	3.7	1.80	−1.19	8	−1
පුත්තලම Puttalam	90.0	+1.7	71.0	+0.6	67	93	2.9	0.58	−1.22	4	−1
රත්මලාන Ratmalana	87.7	+0.3	72.0	+0.3	66	88	3.0	3.65	—	7	—
රත්නපුරය Ratnapura	93.3	+1.8	71.5	+0.2	66	93	4.3	6.64	−0.47	10	−1
ත්‍රිකුණාමලය Trincomalee	83.8	+1.3	75.2	−0.6	70	79	3.6	4.20	+0.45	7	+1
වවුනියා Vavuniya	87.4	—	67.4	—	65	87	2.6	2.54	+0.	5	+1

කාලගුණ විද්‍යාත්මක වාර්තාව
METEOROLOGICAL REPORT

January 1969 1969 ජනවාරි මස

ස්ථානය Station	උෂ්ණත්වය Temperature F° මධ්‍ය උපරිම Mean Max.	අනු ලම්බ Off set	මධ්‍ය අවම Mean Min.	අනු ලම්බ Off set	ආර්ද්‍රතාවය Humidity දිව Day	රාත්‍රි Night	වළාකුළු ප්‍රමාණය Cloud Amount	ප්‍රමාණය Amount	වර්ෂාපතනය Rainfall අනු ලම්බ Off set	වැසි දින ගණන Rain Days	අනු ලම්බ Off set
අනුරාධපුරය Anuradhapura	84.6	+1.1	68.7	−0.5	76	95	4.2	1.59	−3.26	10	−2
බදුල්ල Badulla	77.0	+0.8	63.9	−0.1	80	94	5.4	8.42	−0.60	16	−1
මඩකලපුව Batticaloa	82.1	+0.6	73.2	−0.5	73	84	5.7	6.13	−4.86	16	0
කොළඹ Colombo	87.4	+0.8	72.3	+0.4	67	85	5.0	6.05	+2.59	9	+1
දියතලාව Diyatalawa	72.7	+0.9	57.4	−0.2	78	94	5.0	6.90	+0.90	18	+1
ගාල්ල Galle	84.0	+0.2	73.3	+0.2	73	86	4.6	2.12	−2.33	10	−1
හම්බන්තොට Hambantota	85.6	+0.6	73.7	+0.9	68	81	4.8	1.28	−2.69	7	−2
යාපනය Jaffna	83.2	+0.1	71.6	−0.6	68	88	4.6	0.73	−3.07	4	−4
නුවර Kandy	83.3	+1.1	65.1	+0.1	66	89	4.4	4.92	+0.26	9	+1
කන්කසන්තුරේ Kankesanturai	82.8	−0.3	71.9	−3.1	73	83	4.2	2.34	−0.87	5	−1
කටුනායක Katunayake	89.5	—	70.7	—	63	87	4.3	1.82	—	4	—
කුරුණෑගල Kurunegala	86.8	+0.3	69.6	−0.2	69	93	4.2	3.28	−0.58	9	0
මහ ඉලුප්පල්ලම Maha Illuppallama	84.5	+0.5	69.1	+0.1	74	90	4.2	2.34	—	12	—
මන්නාරම Mannar	83.7	+0.5	74.1	−0.3	73	86	4.6	0.80	−2.64	5	−3
නුවරඑළිය Nuwara Eliya	69.2	+1.4	50.5	+2.9	72	81	4.8	4.63	−1.08	13	0
පුත්තලම Puttalama	86.7	+1.0	69.8	−0.4	70	93	4.2	1.30	−1.58	8	−1
රත්මලාන Ratmalana	87.4	+0.1	71.3	−0.3	66	85	4.2	2.43	—	7	—
රත්නපුර Ratnapura	91.2	+1.7	71.0	−0.2	70.	95	5.5	2.29	−3.67	7	−6
ත්‍රිකුණාමලය Trincomalee	81.0	+0.4	75.0	+0.5	78	78	5.4	3.16	−5.13	13	0
වවුනියා Vavuniya	84.1	—	67.7	—	70	90	4.3	2.76	−2.69	12	−2