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Response of rice to potassium fertilizer in the Matara district

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SUMMARY

THE low status of available potassium in most rice soils of the wet zone probably limits productivity. Yield responses to higher levels of potassium over that currently recommended for the area confirm this view.

A yield increase of approximately 10 bushels paddy per acre was obtained by increasing the basal application of muriate of potash from 56 to 84 lbs. per acre at 40 lbs. nitrogen per acre. An additional 42 lbs. muriate of potash applied two weeks before heading resulted in a further yield increase of approximately 7.0 bushels paddy per acre. A basal application of 126 lbs. per acre of muriate of potash together with 60 lb. nitrogen per acre yielded approximately 10 bushels paddy per acre over the lower levels of nitrogen and potassium.

The yield increase from the use of the granular-compound-fertilizer 15–15–15 : $N–P_2O_5–K_2O$ over that of 15–15–6–4 : $N–P_2O_5–K_2O_2$—MgO adds confirmation to the above results.

These results demonstrate the importance of applying a high amount of potassium as a basal dressing and the benefit of applying some potassium as a top dressing two weeks before heading time.

INTRODUCTION

Potassium is an element essential for the growth of all plants. Among the basic metallic elements, potassium is absorbed in the largest quantities by plants although its functions are still not fully known.

Yield increases in rice due to potassium are generally less than those due to nitrogen and phosphorus. While the importance of nitrogen and phosphorus in the nutrition of rice is well recongised that of potassium is still controversial. According to Grist (7), potassium applications may have negative effects on yield under certain conditions unless the soils is deficient in this element. On the other hand, remarkable responses to potassium have been reported from several countries (3, 4, 8, 10, 13, 15). The need for high rates of potassium fertilization may not be so obvious under low levels of management as under high levels when high grain yields are expected with improved varieties of rice.

Potassium has been shown (I) to play an important role in carbodyhrate metabolism, (ii) to increase the resistance of rice plants to disease and (iii) to help plants in adapting themselves to adverse climatic conditions. The poor status of available potassium in most rice soils of the low country wet-zone of Sri Lanka is probably a factor which limits productivity.

Potassium fertilization is always recommended at planting for rice in Sri Lanka (5). In the wet zone top dressings are invariably recommended in addtion to the basal dressing because this element is easily lost from the soil due to leaching in this region of relatively high rainfall. The intensity of leaching of potassium from soils depends on the composition of the soil. It is held very weakly on organic colloids as compared to adsorption on two or three layered clay minerals (9,14,19,20). This relatively larger amount of potassium is lost from soils in which organic matter contributes largely to the exchange properties of soils, as for example the high humic and sandy rice soils of low clay content. Fertilizer potassium added to such soils will remain largely in the soil solution and run the risk of being easily lost from the soil due to leaching or surface run-off.

This paper presents results of fertilizer experiments conducted in the Matara district, a preliminary report of which was presented earlier (21).

MATERIALS AND METHODS

The administrative district of Matara is situated in the Southern Province of Sri Lanka. The greater part of the district is within the wet zone. This district receives an annual rainfall between 50 to 125 inches. An appreciable part of this rainfall is confined to the period of the South-West Monsoon in the area of the district which comes within the wet-zone. The mean annual temperature of the area is 80°F., the mean annual minimum and maximum temperatures being 75°F and 82°F respectively.

The characteristics of the soils at the locations of the experiments are shown in Table 1.

A. A field experiment was conducted at the Department of Agriculture farm, Mapalana in the Matara district during Maha season 1966/67 to study the effect of potassium fertilization on rice.

The treatments were as follows :—

(1) No potassium fertilizers.

(2) Potassium at the rate of 28 lbs. of K_2O per acre applied as a preplant dressing.

(3) Potassium at the rate of 42 lbs. of K_2O per acre applied as a preplant dressing.

(4) Potassium at the rate of 63 lbs. of K_2O per acre applied as a preplant dressing.

(5) Potassium at the rate of 28 lbs. of K_2.O per acre applied as a preplant dressing, and 14 lbs. K_2O per acre applied as a top dressing 2 weeks before heading.

(6) Potassium at the rate of 28 lbs. of K_2O per acre applied as a preplant dressing and 28lbs. of K_2O per acre applied as a top dressing 2 weeks before heading.

Treatment 5 corresponds to the fertilizer recommendation of the Department of Agriculture for the area (5).

All treatments received nitrogen and phosphorus at rates and times recommended by the Department of Agriculture for the area. They were 39 lbs. N and 47 lbs. P_2O_5 per acre in the form of urea and rock phosphate (saphos phosphate) respectively. The entire quantity of phosphorus was applied as a preplant (basal) dressing and nitrogen was applied in three split doses ; 1 week after planting, 2 weeks before heading and at heading. Potassium was applied in the form of muriate of potash, 50% grade.

The experiment was laid down as a randomized complete block design with 4 replicates. The variety of rice used was H-8.

B. During Yala 1967 a series of trials were conducted in cultivators' fields in the Matara district to study the response of rice to increased applications of both potassium and nitrogen. They were conducted in seven locations viz. Talalla, Dampella, Lalpe, Hathamune, Mapalana, Karagoda-Uyangoda and Pallegama.

Seven fertilizer treatments were tested out at each location where treatments were randomized and each location was treated as a replicate of the main experiment, which was considered a randomized complete block design.

The treatments were as follows :—

(1) Nitrogen, phosphorus and potassium applied at rates and times specified in the recommendations of the Department of Agriculture.

(2) Potassium at the rate of 42 lbs. of K_2O per acre applied as a preplant dressing and nitrogen at the rate of 40 lbs. per acre applied as top dressings.

(3) Potassium at the rate of 63 lbs. of K_2O per acre applied as a preplant dressing and nitrogen at the rate of 40 lbs. per acre applied as top dressings.

(4) Potassium at the rate of 42 lbs. of K_2O per acre applied as a preplant dressing and nitrogen at the rate of 40 lbs. per acre with potassium at the rate of 21 lb. K_2O per acre applied as top dressings.

(5) Potassium at the rate of 42 lbs. of K_2O per acre applied as a preplant dressing and nitrogen at the rate of 60 lbs. per acre applied as top dressings.

(6) Potassium at the rate of 63 lbs. K_2O per acre applied as a preplant dressing and nitrogen at the rate of 60 lbs. per acre applied as top dressings.

(7) Potassium at the rate of 42 lbs. of K_2O per acre applied as a preplant dressing and nitrogen at the rate of 60 lbs. per acre with potassium at the rate of 21 lbs. K_2O applied as top dressings.

Phosphorus at the rate of 48 lbs. P_2O_5 per acre was applied a as preplant dressing of rock phosphate (saphos phosphate) to all treatments, as recommended by the Department of Agriculture (5). Nitrogen was applied in the form of urea and was applied in split doses at times recommended by the department i.e. at 2, 10 and 12 weeks after planting. Potassium was applied as muriate of potash 50 percent grade. The variety H4 was used at all locations, and was row sown at 6 locations and row planted at 1 location with equal number of rows in each plot.

C. Results of an investigation with granular-compound-fertilizers conducted in cultivators' fields of the Matara district during the Yala season of 1967, and which have been reported elsewhere (22), are also briefly included in this report for it affords further evidence that increased yields of rice could be obtained by increased use of potassium on these rice soils. This investigation was also conducted at the same locations as the straight fertilizer experiment described above. The treatments were as follows :—

(1) No fertilizers.

(2) Straight fertilizers applied according to recommendations of the Department of Agriculture.

(3) 300 lbs. per acre of granular-compound-fertilizer 15–15–15 : $N-P_2O_5-K_2O$ applied at sowing or planting to supply 45 lbs. each of N, P_2O_5 and K_2O.

(4) 300 lbs. per acre of granular-compound-fertilizer 15–15–15 : $N-P_2O_5-K_2O$ applied four weeks after sowing or one week after planting to supply 45 lbs. each of N, P_2O_5 and K_2O.

(5) 300 lbs. per acre of granular-compound-fertilizer 15–15–6–4 : $N-P_2O_5-K_2O-MgO$ applied at sowing or planting to supply 45 lbs. each of N and P_2O_5, 18 lbs. K_2O and 12 lbs. MgO.

(6) 300 lbs. per acre of granular-compound-fertilizer 15–15–6–4 : $N-P_2O_5-K_2O-MgO$ applied four weeks after sowing or one week after planting to supply 45 lbs. each of N and P_2O_5, 18 lbs. K_2O and 12 lbs. MgO.

In the three experiments A, B and C, the size of plots was 30 ft. by 14½ ft. Bunds 1 foot broad and 9 inches high separated adjacent plots.

During the Yala season the optimum amount of water was manitained throughout the growing period upto two weeks before harvesting. Pests and diseases were controlled whenever they appeared. A one foot border row was removed from each of the treatments. The balance area was harvested and paddy dried, threshed, winnowed and grain yields recorded. Corrections for moisture content were made before calculating plot yields.

RESULTS AND DISCUSSION

A. *Response to potassium fertilizer at Department of Agriculture Farm, Mapalana.*

The effect of potassium fertilization on the yield of grain at the Department of Agriculture Farm, Mapalana, is shown in Table 2. It will be noted that grain yields were significantly reduced when no potassium was applied to the soil and that 28 lbs. K_2O per acre was sufficient to increase grain yield from 36.6 bushels per acre to 44.7 bushels per acre. This yield increase was satistically significant. Levels of potassium above 28 lbs. K_2O (i.e. 56 lbs. muriate of potash) per acre applied either totally as a preplant basal application or in split applications did not significantly increase yields of grain at this location under the conditions of this experiment. This is most probably because the soil at the farm had sufficient exchangeable potassium (0.22 to 0.26 m.e.k+ per 100 gm soil) which together with the supplemental preplant basal dressing of 28 lbs. K_2O per acre could meet the demands of the rice crop.

B. *Response of potassium and nitrogen fertilizers in cultivatiors' fields*

The yield data of the experiments in cultivators' fields at seven locations of the district are presented in Table 3. The table includes yields per treatment at each location and the corresponding average yields of the seven locations. The results were significant at the 0.1 percent level of probability.

Treatment 1 which received nitrogen, phosphorus and potassium according to recommendations of the Department of Agriculture yielded less than all other treatments. This treatment received a preplant application of only 28 lbs. of K_2O per acre plus a top dressing of 14 lbs. K_2O per acre two weeks before heading together with a total quantity of approximately 39 lbs. N per acre at five locations. These are the departmental recommendations for the Morawak Korale, the Kandabada Pattuwa and the Gangabada Pattuwa of the district. Yield due to fertilizers applied according to the rates and times recommended by the Department of Agriculture, that is treatment 1, was inferior to treatment 2 and all other treatments at the 0.1 percent level of probability.

The main difference between treatments 1 and 2 was that 42 lbs. K_2O per acre were all applied at or before planting in the latter treatment while only 28 lb. of K_2O per acre were applied at or before planting in the former. These results indicate that it is more beneficial when 42 lbs. K_2O per acre were all applied as a basal dressing than when only 28 lbs. were applied as a basal dressing and the balance 14 lbs. were top dressed two weeks before heading.

It will also be noted that a preplant application of 63 lbs. K_2O per acre with 40 lbs. N per acre, as in treatment 3, contributed to a yield increase of only approximately 4 bushels per acre, and this difference was not significant. On the other hand two split applications of the total 63 lbs. K_2O per acre at the same level of nitrogen in treatment 4 resulted in a significant yield increase of 7.3 bushels per acre over treatment 2 which received only 42 lbs. K_2O per acre. Apparently the soil is incapable of retaining the relatively high concentration of cations from 126 lbs. of muriate of potash, 63 lbs. K_2O per acre, when all are applied at once to enable plants to utilize this nutrient during the course of their growth. Hence, the superiority of split applications, where 42 lbs. K_2O are supplied at or before planting and the balance is supplied two weeks before heading, as in treatment 4. The superiority of split applications involving top dressings of potassium for rice on the humic rice soils of Bombuwela have been reported by Fernando (6), and split applications of this element are recommended for rice in most parts of the wet zone (5).

Comparison of yields in treatments 5 and 2 shows a highly significant yield increase of 8.3 bushels per acre due to an additional 20 lbs. nitrogen per acre in the former treatment. The level of potassium in both treatments was 42 lbs. K_2O per acre, applied at or before planting. Application of 63 lbs. K_2O per acre together with 60 lbs. N per acre as in treatment 6 gave a yield increase of 10.4 bushels per acre over treatment 2 which received only 42 lbs. K_2O and 40 lbs. N per acre. This yield difference was significant at the 0.1 per cent level of probability. The yield difference between treatments 7 and 2 was not as wide as between treatments 6 and 2, and this difference was significiant only at the 5 percent level of probability. This may probably mean that at higher levels of nitrogen more potassium is required initially to obtain maximum yields. It should be noted that treatment 7 received only 42 lbs. K_2O as a basal application in contrast to treatment 6 which received 63 lbs. K_2O per acre as a basal application. There were, however, no significant differences between treatments that received 60 lbs. N per acre together with 42 or 63 lbs. K_2O per acre. The response to an additional 20 lbs. N per acre when 63 lbs. K_2O were applied as a preplant dressing was a significiant 6.2 bushels per acre (comparison of treatments 6 and 3).

C. *Response to granular-compound-fertilizers of different potassium contents*

The results of fertilizer trials using the two granular-compound-fertilizers, 15-15-15 : N-P_2O_5-K_2O and 15-15-6-4 : N-P_2O_5-K_2O-MgO, Sunfoska grades A and B respectively, conducted in cultivators' fields of the district are presented in Table 4 and have been reported elsewhere (22).

The use of the fertilizer 15-15-6-4 : N-P_2O_5-K_2O-MgO resulted in a relatively lower yield in comparison to the fertilizer 15-15-15 : N-P_2O_5-K_2O. This average yield reduction of approximately 10 bushels grain per acre may be attributed to the lower content of K_2O (27 lbs. less) supplied by the former in comparison to the latter. While 300 lbs. of the former supplies 45 lbs. each of N, P_2O_5 and K_2O the same quantity of the latter supplies 45 lbs. each of N and P_2O_5 but only 18 lbs. K_2O per acre (and 12 lbs. MgO).

The yields of both treatments which received the fertilizer 15-15-6-4- N-P_2O_5-K_2O-MgO were not significantly different from that of the straight fertilizer treatment (Treatment 2). The straight fertilizer treatment received 28 lbs. K_2O per acre at planting at all locations and an additional top dressing of 14 lbs. K_2O per acre at five locations.

The source of potassium in the two granular-compound-fertilizers was the same as that in the straight fertilizer treatment,i.e., muriate of potash. The relatively low yield due to this, that is, 15-15-6-4, N-P_2O_5-K_2O-MgO, granular-compound-fertilizer treatment, could reasonably be attributed to the low K_2O content supplied to the plants.

According to results of Noguchi, and Sugawara (16) rice needs potassium for its entire growth period, and according to Kiuchi(II) potassium absorbed during 35-45 days before heading was most effective in increasing grain yields. Potassium has been reported to exert a favourable influence on tillering, grain size and the weight per 1,000 grains (8, 16). This element together with phosphorus increases the resistance of the plants to lodging and to both fungal and bacterial diseases even under adverse climatic conditions. (1, 2, 8, 10, 12, 17, 23). The susceptibility to disease due to inadequacy of potassium is more when plants are fertilized with only nitrogen. Since this element has been shown to be effective in promoting healthy plant growth, the use of potassium fertilizers would be most important when varieties capable of responding to higher levels of fertilizers are used in the future. With these varieties it would be very essential to supply balanced amounts of both potassium and phosphorus together with heavy applications of nitrogen.

D. *Potassium availability in rice soils of the district.*

The levels of exchangeable potassium in soils at experimental locations were presented in Table 1. An idea of exchangeable potassium in the district is given below.

The poor status of available potassium in rice soils of the district is seen from data in Table 5 which presents the frequency distribution of exchangeable potassium in 134 samples of top soils collected at random from rice fields.

It will be noted that as much as 70 per cent. of the samples had values of less than 0.20 m.e. K^+ per 100 gm. soil in the exchangeable-plus-soluble fraction of soil potassium. These results are in agreement with the findings of Panabokke and Nagarajah (18). A value of less that 0.20 m.e. exchangeable-plus-soluble potassium per 100 gm. soil is considered to be low, and this emphasises the need for adequate potassium fertilization for rice in this district.

Economics of fertilizer use in cultivators' fields.

The economics of the use of potassium and nitrogen straight fertilizers according to data is shown in Table 6.

The cost of the fertilizers was calculated from c.i.f. values furnished by the Sri Lanka Fertilizer Corporation and the price of paddy was taken at Rs. 14/–per bushel. Yield increases and net returns have been calculated relative to treatment 1, which is the fertilizer recommendation of the Department of Agriculture. Total net income is the value of yield at the above price of paddy minus the cost of fertilizers. Net return is taken as the value of yield increase (relative to treatment 1) due to fertilizer application minus the cost of fertilizer. It will be noted that the highest net income and net return were from treatment 6 the yield of which was significantly different only from treatments 1, 2 and 3. Further, among treatments 4, 5 and 6 which were not significantly different from each other, treatment 4 cost the least. From these figures it appears that it is economical to apply 63 lbs. K_2O and 40 lbs. N, per acre. than to apply 42 lbs. K_2O and 60 lbs. N per acre as in treatment 5.

Between treatments 3 and 4, fertilizers for which cost the same, the latter treatment appears to be superior to the former. This is probably because 63 lbs. K_2O were given in two split applications rather than in a single dose at or before planting.

The economics of the use of the two granular compound fertilizers in the district are presented in Table 7. The use of 15-15-6-4 : N-P_2O_5- K_2O-MgO has been shown to give a lower return than 15-15-15 : N-P_2O_5-K_2O, and this could be attributed to the lower content of potassium in the former fertilizer.

CONCLUSIONS

The results of these experiments indicate that a yield increase of approximately 10 bushels paddy per acre could be obtained by increasing the basal or preplant application of muriate of potash from 56 to 84 lbs. per acre (to supply 42 lbs. K_2O per acre) with 40 lbs. nitrogen per acre. A top dressing of 42 lbs. muriate of potash (21 lbs. K_2O) per acre two weeks before heading could give an additional yield of approximately 7.0 bushels per acre. At the higher level of nitrogen fertilization (i.e., 60 lbs. per acre) the indications are that the higher rate of 126 lbs. per acre of muriate of potash (to supply 63 lbs. K_2O per acre) yields approximately 10 bushels grain over the lower levels of nitrogen and potassium (40 lbs. N and 42 lbs. K_2O per acre). Data from experiments using granular-compound-fertilizers confirm the need for the higher basal dressing of muriate of potash at the present level of nitrogen fertilization—i.e., 40—45 lbs. N per acre.

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TABLE 1

Soil characteristics at locations of the experiments

No.	*Location*	*Texture*	*PH*	*C.E.C. m.e/100 gms.*	*Organic matter %*	*Total N%*	*Available P_2O_5 (Olsen's)— lbs./acre*	*Exchangeable cations m.e./100 gms.*		
								K+	*Ca++*	*Mg++*
1	Govt. Farm, Mapalana	Clayloam	6.0	—	—	0.25	63.8	0.26	—	—
2	Talalla	Sandy clay loam	5.0	8.5	2.0	0.10	22.8	0.04	1.95	0.87
3	Dampella	Sandy clay loam	4.7	12.0	6.0	0.30	26.2	0.16	2.17	0.65
4	Lalpe	Sandy clay loam	5.3	22.2	4.3	0.25	63.8	0.26	9.77	5.88
5	Hathamune	Clay loam	4.8	16.8	6.4	0.37	9.1	0.26	4.12	1.95
6	Mapalana	Clay loam	5.0	10.8	3.8	0.21	43.3	0.08	3.04	0.65
7	Karagoda-Uyangoda	Clay loam	5.1	16.8	8.2	0.49	33.1	0.10.	7.60	1.09
8	Pallegama	Clay loam	5.1	12.0	6.0	0.33	65.0	0.12	1.74	0.65

TABLE 2

Effect of potassium fertilization on yield of rice at Department of Agricluture Farm, Mapalana—Maha 1966/67 (Paddy yield—Bushels per acre)

Treatments	*Yield*
(1) NO K_20, only N and P_20_5	36.6
(2) 28 lbs. K_20 per acre as a preplant dressing plus N and P_20_5 ..	44.7
(3) 42 lbs. K_20 per acre as a preplant dressing plus N and P_20_5	44.5
(4) 63 lbs. K_20 per acre as a preplant dressing plus N and P_20_5	47.0
(5) 28 lbs. K_20 per acre as a preplant dressing and 14 lbs. K_20 per acre as a top dressing plus N and P_20_5	41.1
(6) 28 lbs. K_20 per acre as a preplant dressing and 28 lbs. K_20 per acre a as top dressing plus N and P_20_5	45.0
L. S. D. at 5 %	4.8
Coefficient of variation	7.5

All plots received 39 lbs. N and 47 lbs .P_20_5 per acre as Urea and Saphos phosphate respectively.

TABLE 3

Effect of potassium and nitrogen fertilization on yield of rice in cultivators' fields of the Matara district, Yala 1967

(Paddy yield—Bushels per acre)

Treatments	*Talalla* 1	*Dampella* 2	*Lalpe* 3	*Hathamune* 4	*Mapalana* 5	*Karagoda Uyangoda* 6	*Pallegama* 7	*Average of locations* 1—7
1. K_2O, N and P_2O_5 applied according to recommendations of the Department of Agriculture*	59.2	64.4	63.9	54.5	63.0	61.0	53.3	59.9
2. 42 lbs. K_2O per acre before planting and 40 lbs. N per acre as top dressings	62.4	69.5	79.7	56.7	72.1	90.7	57.3	69.8
3. 63 lbs. K_2O per acre before planting and 40 lbs. N per acre as top dressings	65.9	70.0	81.1	67.1	72.9	90.4	70.4	74.0
4. 42 lbs. K_2O per acre before planting ; 40 lbs. N and 21 lbs. K_2O per acre as top dressings	62.8	87.5	82.7	64.1	73.9	94.9	73.7	77.1
5. 42 lbs. K_2O per acre before planting and 60 lbs. N per acre as top dressings	71.7	83.7	83.1	68.8	73.9	90.9	74.4	78.1
6. 63 lbs. K_2O per acre before planting and 60 lbs. N per acre as top dressings	70.5	87.1	88.9	67.7	89.1	92.5	65.3	80.2
7. 42 lbs. K_2O per acre before planting ; 60 lbs. N and 21 lbs. K_2O per acre as top dressings	68.3	86.8	81.1	66.8	86.9	85.0	62.6	76.8
L.S.D. at 0.1%								9.9
L.S.D. at 1.0%								7.6
L.S.D. at 5.0%								5.6
Coefficient of Variation								7.04%

*Recommendations of the Department of Agriculture :—Locations 1 and 2 received 26 lbs. N, 48 lbs. P_2O_5 and 28 lbs. K_2O per acre as urea, saphosphate and muriate of potash respectively. Locations 3 to 7 received 39 lbs. N, 48 lbs. P_2O_5 and 42 lbs. K_2O per acre in the same forms of fertilizers as above.

TABLE 4

Effect of fertilizer treatments with different potassium contents on yield of rice in cultivators' fields of the Matara District, Yala 1967
(Paddy yield—Bushels per acre)

Treatments	*Talalla* 1	*Dampella* 2	*Lalpe* 3	*Hathamune* 4	*Mapalana* 5	*Karagoda Uyangoda* 6	*Pallegama* 7	*Average of locations* 1—7
1. No. K_2O, N or P_2O_5 fertilizers	43.7	56.6	50.4	42.8	46.9	52.6	40.4	47.6
2. K_2O, N and P_2O_5 applied according to recommendations of the Department of Agriculture*	59.5	69.4	63.7	58.9	64.4	67.1	53.1	62.3
3. 45 lbs. each of K_2O, and N P_2O_5 per acre applied as (15-15-15) granular compound fertilizer at sowing or planting	52.2	80.4	80.1	79.6	70.5	87.8	68.2	74.1
4. 45 lbs. each of K_2O, N and P_2O_5 per acre applied as (15-15-15) granular compound fertilizer four weeks after sowing or one week after planting	53.6	91.1	76.6	77.6	72.1	84.8	61.9	74.0
5. 18 lbs. K_2O, 45 lbs. each of N and P_2O_5 and 12 lbs. MgO per acre applied as (15-15-6-4) granular-compound-fertilizer at sowing or planting	56.6	68.9	66.2	68.9	67.7	87.1	55.3	67.2
6. 18 lbs. K_2O, 45 lbs. each of N and P_2O_5 and 12 lbs. MgO per acre applied as (15-15-6-4) granular compound-fertilizer four weeks after sowing or one week after ploughing	48.1	72.1	67.1	67.7	68.9	69.3	51.5	63.5
L.S.D. at 0.1%								10.3
L.S.D. at 1.0%								7.8
L.S.D. at 5.0%								5.8
Coefficient of Variation								8.2%

*Recommendations of the Department of Agriculture :
Location 1 and 2 received 26 lbs. N, 48 lbs. P_2O_5 and 28 lbs. K_2O per acre as Urea. Saphosphosphate and Muriate of Potash respectively.
Locations 3 to 7 received 39 lbs. N, 48 lbs. P_2O_5 and 42 lbs. K_2O per acre in the same forms of fertilizer as above.

TABLE 5

Frequency distribution (%) of exchangeable potassium in the top soils of 134 samples from rice fields of Matara District

m.e.K+ per 100 *gm. soil*	%
>0.30	9.7
0.26-0.30	14.9
0.21-0.25	5.2
0.16-0.20	11.9
0.10-0.15	25.4
<0.10	32.8

TABLE 6.—Economics of the use of potassium and nitrogen fertilizers in the Matara district (Yala 1967)

Treatments	Cost of Fertilizer	Average yield	Yield Increase		Total Net Income	Net Return
	Rs. c.	Bus/acre	Bushels	Percentage	Rs. c.	Rs. c.
1. K_2O, N and P_2O_5 applied according to the recommendations of the Department of Agriculture	45 54	59.9	—	—	793 06	—
2. 42 lbs. K_2O per acre before planting and 40 lbs. N per acre as top dressings	46 34	69.8	9.9	16.5	931 06	92 46
3. 63 lbs. K_2O per acre before planting and 40 lbs. N per acre as top dressings	51 06	74.0	14.1	23.5	984 94	146 34
4. 42 lbs. K_2O per acre before planting ; 40 lbs. N and 21 lbs. K_2O per acre as top dressings	51 06	77.1	17.2	28.7	1,028 34	189 74
5. 42 lbs. K_2 per acre before planting and 60 lbs. N per acre as top dressings	56 04	78.1	18.2	30.4	1,037 36	198 76
6. 63 lbs. K_2O per acre before planting and 60 lbs. N per acre as top dressings	61 06	80.2	20.3	33.9	1,061 74	223 14
7. 42 lbs. K_2O per acre before planting ; 60 lbs. N per and 21 lbs. K_2O per acre as top dressings	61 06	76.8	16.9	28.2	1,014 14	175 54

TABLE 7.—Economics of the use of granular-compound-fertilizers of different potassium contents in the Matara district (Yala 1967)

Treatments	Cost of Fertilizer Rs. c.	Yield Bus/acre	Yield Increase Bushels	Yield Increase Percentage	Total Net Income Rs. c.	Net Return Rs. c.
1. No Fertilizers	—	47.6	—	—	666 40	—
2. Straight fertilizers applied according to recommendations of the Department of Agriculture	45.54	62.3	14.7	31.0	826 66	160 26
3. Granular-compound-fertilizer (15-15-15) at 300 lbs. per acre applied at planting	64.35	74.1	26.5	55.7	973 05	306 65
4. Granular-compound-fertilizer (15-15-15) at 300 lbs. per acre applied 4 weeks after sowing or one week after planting	64.35	74.0	26.4	55.5	971 65	305 25
5. Granular-compound-fertilizer (15-15-6-4) at 300 lbs. per acre applied at planting	64.35	67.2	19.6	41.2	876 45	210 05
6. Granular-compound-fertilizer (15-15-6-4) at 300 lbs. per acre applied 4 weeks after sowing or one week after planting	64.35	63.5	15.9	33.4	824 65	158 25

Effect of variety and method of stand establishment on the growth and yield of rice, *Oryza sativa L.*

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INTRODUCTION

The methods of stand establishment in lowland rice culture can be broadly classified into direct seeding or transplanting. There are two methods of direct seeding, namely, broadcasting or row seeding, while transplanting is done either in rows or at random. A modified form of broadcasting referred to as "Strip cultivation" has been recently reported (Manikkavasagar, 1968), but this method is not yet widely adopted.

Available evidence suggests that varietal differences in growth and grain yield exists under different methods of stand establishment (Tanaka, Navasero, Garcia, Parao and Ramirez, 1964). It appears that at optimum plant densities, the lodging resistant varieties give increased grain yields. The improved rice varieties are short stemmed, lodging resistant with erect leaves and it has been suggested that these varieties could be grown at very high plant densities without having any adverse affects on yield (1967–68 Report of the Director of Agriculture).

The object of this experiment was to evaluate the physiological basis for the variation in growth and yield of 2 rice varieties under 4 different methods of stand establishment. The varieties selected were H-4 and IR-8, both of which complete their life cycle in 4½ months. H-4 is a tall, lodging susceptible variety with long and lax leaves while IR-8 is a short stemmed, lodging resistant variety with dark green, erect leaves. IR-8 is strikingly different in its growth habit in comparison with H-4 and it was assumed that a comparison of these 2 varieties under different systems of culture would give information on the possibility of growing improved rice varieties by direct seeding methods.

MATERIALS AND METHODS

The experiment was carried out on the University paddy fields during January–May, 1970. The soil was a normal lowland paddy soil and its profile has been described by Kalpage' (1965). The top 25cm. of the soil contained 49 per cent clay and 22 per cent silt. The nitrogen status was moderately high (206 mg/100g of soil, Kjeldhal). The pH was 5.6.

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The treatments consisted of 2 varieties (H-4 and IR-8) and 4 methods of stand establishment, (broadcasting, row seeding, transplanting in rows and transplanting at random). Broadcasting and row seeding were done by hand. When row seeded the spacing between rows was 25.4 cm. the seeding within the row being continuous. In row transplanting the plant spacing was 25.4 cm× 20.3 cm. The 8 treatment combinations were arranged in randomized blocks and replicated 3 times. Each plot measured 7.62m×2.44m (1.86×10^{-3} ha) and was separated from the neighbouring plots by bunds 100 cm. wide and 25 cm. high. Nitrogen as urea (46 per cent N), phosphate as concentrated super phosphate (42 per cent P_2O_5) and potash as muriate of potash (50 per cent K_2O) were applied to the plots at the rates and times given in Table 1. In the direct seeded plots the seed was sown at the rate of 89.3 kg/ha on January, 6. When transplanted the seedlings were raised in dapog nurseries and were transplanted at 2 seedlings per hill on January, 16.

The plants were sampled regularly at two weekly intervals, commencing 25 and 14 days after direct seeding or transplanting respectively. At each sampling a metal grid having an area of 3,613 cm^2 was used to remove samples from each plot. For each sample, the total number of plants, tillers, panicles and spikelets per panicle were determined.

Leaf area of 50–150 leaves was estimated by using a compensating planimeter of the type used by Jenkins (1959). By this method the area of a known weight of leaves was determined for each plot. Knowing the leaf area : leaf weight ratio and the total fresh weight of the leaves for each plot the total leaf area could be calculated and from this the leaf area index.

The rest of the sample was then separated into the componenets of yield and wherever necessary sub-samples were removed for dry-matter determination.

RESULTS

General Obervations

Severe lodging was first observed in the plots where the seed was broadcast and least in plots that were transplanted in rows. A lodging index combining the extent and duration of lodging was calculated by the method of Jennings and Sornchai (1964) (Table 2).

Total plant number/m². (including main culm)

The total number of plants were 1,419, 1,129, 878 and 516 per m^2 under broadcasting, row seeding, random transplanting and row transplanting respectively. This result was expected as a higher seed rate was used when direct seeded than when transplanted. IR-8 and H-4 recorded a maximum of 1,212 and 707 plants per m^2 respectively.

Tillers per plant

Transplanting increased the number of tillers per plant when compared with direct seeding. The maximum number of tillers were 3, 4, 5 and 13 per plant under broadcasting, row seeding random and row transplanting respectively.

The tiller numbers gradually decreased after the maximum numbers were produced and at the final harvest (147 DAS) row transplanting contained 12 tillers while the other methods of stand establishment had about 3 tillers per plant. IR-8 increased tiller number per plant compared with H-4. H-4 had a maximum of 4 tillers per plant and retained virtually all the tillers produced until the final harvest. IR-8 had a maximum of 8 tillers per plant. In the subsequent harvests tiller number per plant in IR-8 decreased and at the final harvest a reduction of 18 per cent. was recorded when compared with H-4. At the 4th, 6th and 7th harvests (72, 104 and 126 DAS) row transplanted IR-8 had more tillers per plant than H-4 in comparison with other methods of stand establishment.

Total and panicle dry-matter yield

Broadcasting produced more dry-matter than row seeding throughout the entire growing season (Fig. 1 a). Random transplanting decreased total dry-matter yield in the early stages of growth while row transplanting reduced the total dry-matter yield throughout the entire growth period when compared with broadcasting and row seeding. There were no significant differences in the dry-matter yield between varieties up to the 6th harvest (104 DAS) (Fig. 1 b). Subsequently H-4 lodged and the total dry-matter yield decreased, while in IR-8 dry-matter yield increased throughout the entire growth period.

At the 6th harvest (104 DAS) direct seeding increased panicle dry weight compared with transplanting, while at the 8th harvest (147 DAS) row seeding was superior to all other methods of stand establishment (Table 3). H-4 had a higher panicle dry weight at the 6th harvest (104 DAS) while IR-8 increased panicle dry-matter yield when compared with H-4 at the 7th and 8th harvests (126 and 147 DAS) by 42 and 48 per cent. respectively. At the 7th harvest H-4 had a higher panicle dry-matter yield when transplanted, while IR-8 yielded more panicle dry-matter under other methods of stand establishment.

Analysis of Grain Yield

Row transplanting had the highest percentage of productive tillers(77 per cent.) while the lowest was recorded for broadcasting (48 per cent.) (Table 4). H-4 increased the percentage of productive tillers in comparison with IR-8. Random transplanted IR-8 had a higher percentage of productive tillers compared with either row transplanted or row seeded stands of H-4. Row seeding increased the panicle number per m^2 and at the 7th harvest (126 DAS) and it was significantly better than row transplanting, while the 8th harvest it (147 DAS) was superior to all other methods of stand establishment.

IR-8 increased the panicle number per m^2 by 25 per cent. compared with H-4.

Row transplanting increased the total number of spikelets per panicle compared with other methods of stand establishment. IR-8 had fewer spikelets per panicle and the panicles were significantly shorter compared with H-4. IR-8 increased the percentage of fertile spikelets by 53 per cent. and 1,000-grain weight by 10 per cent. compared with H-4. Row seeding increased grain yield significantly compared with all other methods of stand establishment while IR-8 increased grain yield by 87 per cent. compared with H-4.

Leaf area index (*L*)

Direct seeding increased L compared with transplanting. Maximum L for broadcasting was 49 per cent. more than that recorded for row transplanting (Fig. 2 a). Varieties did not differ significantly in their L values up to the 3rd harvest (56 DAS) but in the subsequent harvests large varietal differences were recorded (Fig. 2 b). IR-8 recorded an L value of 9.1 at the 6th harvest (104 DAS) which was an increase of over 100 per cent. compared with H-4. The main effect of treatments on the integral of L with time, the leaf area duration (D) is given in Table 5. Direct seeding increased D compared with transplanting while IR-8 increased D by over 100 per cent. when compared with H-4.

DISCUSSION

In the direct seeded stands panicles initiated earlier and this may be a reflection of the differences in the plant population. As the plant population increase the availability of nutrients would be limiting (Donald, 1951) and the early panicle initiation in direct seeded stands of rice could be partly attributed to differences in plant population in relation to nutrient availability. The early panicle intitiation in direct seeded stands of rice could be of some significance as it may increase the period of grain development.

The final grain yield of rice has been suggested to be a function of the number of panicles per unit area, number of spikelets per panicle, percentage of filled grains, and 1,000-grain weight (Matsushima, 1955 ; IRRI, 1968). Any difference in one or more of these yield components could therefore cause a variation in the final grain yield. There were close relationships between grain yield (Y) and grain number (Gn) and 1,000-grain weight (Gw), and these relationships could be represented by the equations $Y=15.35+2.09\ Gn$ ($R^2=90\%$) and $Y=-27.26+11.05\ Gw$ ($R^2=60$ per cent.) respectively. It is apparent that the main determinants of grain yield were the grain number per unit area and 1,000—grain weight. Only row seeding had more grains per unit area than other methods of stand establishment, and this accounted for the significantly higher grain yield obtained with row seeding. IR-8 had more panicles per unit area, a higher percentage of fertile spikelets and a heavier 1,000-grain weight, and these accounted for its significantly higher grain yield compared with H-4. Differences in panicle number accounted for only 33 per cent. of the variation in grain yield which is in agreement with the available evidence which indicates that between the range of panicle numbers obtained in this experiment (389—948/m^2) there was little correlation between the grain yield and panicle numbers (Summers, 1921). However, there was a close relationship between the grain yield (Y) and panicle dry weight (Pd) which could be represented by the equation : $Y=13.43+1.04\ Pd$ ($R^2=97\%$). Therefore it is not only the panicle number, but the panicle dry weight could also be a determinant of the final grain yield.

H-4 lodged 104 days after sowing and this may have reduced its potential yield. It has been reported that the final development of the grain depends on the carbohydrates and mineral nutrients translocated to it during the ripening period (Togari, Okamoto and Kumura, 1954). Lodging increases the percentage of sterile spikelets in rice (Jennings and Sornchai, 1964), probably because it interferes with the translocation of assimilates to the developing grain. In this experiment the spikelet sterility in H-4 was 49 per cent. while in IR-8 it was only 23 per cent. The spikelet sterility also tended to be greater in methods of stand establishment which had higher lodging indices, viz. broadcasting 38 per cent., row seeding 40 per cent., row and random transplanting 33 per cent. This indicates that improved rice varieties such as IR-8 which do not lodge could be grown at higher plant densities than H-4.

Although there was no difference in the total dry-matter yield at the final harvest between H-4 and IR-8, the difference in grain yield was highly significant. This could be attributed to the favourable partitioning of dry-matter for grain formation in IR-8 when compared with H-4. In IR-8 60 per cent. of the total dry-matter was located in the panicle, while in H-4 the proportion of panicle in the total dry-matter was only 41 per cent. The distribution of dry-matter between plant parts is further shown by the close relationship between the grain yield (Y) and the panicle/straw ratio (P/S) which could be shown by the equation $Y=14.90+24.19\ P/S$ ($R^2=75$ per cent). Therefore a major character of improved rice varieties is the efficient distribution of dry-matter in favour of grain yield.

Tanaka, Kawano and Yamaguchi (1966) reported the existence of a relationship between grain yield and total dry-matter yield only when the latter is less than 6,000 Kg/ha at flowering. In the present experiment the dry-matter yields at flowering were greater than 6,000 Kg/ha and the total dry-matter yield accounted for only 24 per cent. of the variation in grain yield. However, when the varieties were considered separately, the grain yield (Y) of only IR-8 was significantly correlated with total dry-matter yield (Td) and accounted for 94 per cent. of the variation in grain yield. This relationship could be shown by the equation $Y=-20.78+0.70\ Td$. and it suggests that in improved rice varieties such as IR-8 a correlation could exist between the final grain yield and total dry-matter yield even when the latter exceeds 6,000 Kg/ha at flowering.

Since there were large variations in the Net assimilation rate values between treatments, L could be assumed to be the major factor causing variations in total and grain dry-matter yields. Table 6 shows the relationship between total and grain dry-matter yields and D. Variations in D accounted for 83 per cent. of the variation in total dry-matter yield and 56 per cent. of the variation in grain dry-matter yield. The relationship between grain dry-matter yield and D was improved when D was calculated for the last 45 days before harvest when the latter accounted for 69 per cent. of the variation in grain dry-matter yield. This indicates that D after panicle initiation is an important criterion in determining the final grain yield of rice.

SUMMARY

An experiment was conducted to examine the effect of 2 varieties and 4 methods of stand establishment on the growth and yield of lowland rice. Row seeding increased the final grain yield significantly compared with broadcasting and row or random transplanting, by increasing the grain number per unit area. IR-8 increased the final grain yield by increasing the panicle number, percentage of fertile spikelets and 1,000-grain weight in comparison with H-4. The final grain yield was closely correlated with grain number and 1,000-grain weight and in IR-8 it was also correlated with total dry-matter yield. The total and grain dry-matter yields were linearly correlated with leaf area duration (D) and the relationship between grain dry-matter yield and D was improved when D calculated for the last 45 days before harvest was used in the calculation.

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TABLE 1

The rates and times of fertliizer application

Time of application	Rates of fertilizer (Kg./ha.) H-4 N	P	K	IR-8 N	P	K
Basal (3 days before planting	11.2	84.0	50.0	22.5	84.0	50.0
3 weeks after seeding	22.5	—	—	22.5	—	—
6 weeks after seeding	—	—	—	45.0	—	—
Panicle initiation stage (66 days after seeding)	22.5	—	—	45.0	—	—
9 weeks after seeding	—	—	—	—	—	25.0
77 days after seeding (Heen bandi stage)	67.5	—	25.0	—	—	—
Heading stage 106 days after seeding	11.3	—	—	—	—	—
Total	135.0	84.0	75.0	135.0	84.0	75.0

TABLE 2

Lodging in variety H-4 as affected by methods of stand establishment

Methods of stand establishment	Days before harvest: 45 Lodging %	Index	33 Lodging %	Index	27 Lodging %	Index	Total Lodging Index
Row transplanting	—	—	33.33	2.0	100	27.0	29.0
Random transplanting	—	—	40.00	2.4	100	27.0	29.0
Row seeding	—	—	100.00	6.0	100	27.0	33.0
Broadcasting	33.33	4.0	100.00	6.0	100	27.0	37.0

Calculated after the method of Jennings and Sornchai (1964).

TABLE 3

Main effects of treatments on panicle dry-matter accumulation (100Kg./ha.)

Treatment	Sample number and days after sowing: S_6 (104 *DAS*)	S_7 (126 *DAS*)	S_8(147 *DAS*)
Row transplanting	3.91	17.19	57.03
Random transplanting	9.09	26.25	61.74
Row seeding	15.92	24.68	89.40
Broadcasting	15.56	19.23	58.57
LSD (P = 0.05)	7.10	N.S	22.69
H-4	15.74	18.10	53.59
IR-8	6.29	25.57	79.77
LSD (P = 0.05)	5.02	6.03	16.04
C.V. (%)	52.02	31.06	27.06

Table 4.—Main effects of treatments on yield components and final grain yield of rice

Treatments	*Productive tillers %*	*Panicle number (100/m₂)* S_6	S_7	S_8	*Spikelets per panicle (Total)*	*Fertile spikelets (% by number)*	*1,000 grain weight at 13% moisture content*	*Final grain yield (100 kg./ha.)*
Row transplanting	77.23	0.73	3.05	3.86	107.57	65.96	29.66	47.88
Random transplanting	61.89	2.41	5.36	6.17	81.32	67.23	30.04	52.89
Row seeding	75.60	4.88	5.86	9.48	88.23	60.47	29.69	74.17
Broadcasting	47.67	5.91	5.74	6.99	76.20	62.15	29.55	48.20
LSD (P=0.05)	13.24	1.45	1.17	1.01	22.19	N.S.	N.S.	20.95
H—4	71.54	3.95	3.75	5.96	105.52	50.52	28.27	39.27
IR—8	59.66	3.01	6.28	7.31	71.14	77.39	31.20	72.30
LSD (P=0.05)	9.48	N.S.	0.83	0.71	15.70	8.91	0.48	14.81
C.V. (%)	16.06	33.06	18.09	12.03	20.03	16.0	1.09	30.04

TABLE 5

Main effects of treatments on Leaf area duration weeks

	D-weeks	*Increase over row transplanting* (%)
Row transplanting	32.58	—
Random transplanting	51.17	57.1
Row seeding	59.82	83.6
Broadcasting	68.58	110.5
LSD (P = 0.05)	5.78	—
		Increase over H-4 (%)
H-4	35.01	—
IR-8	71.07	103.0
LSD (P = 0.05)	4.07	
C. V. (%)	8.08	

TABLE 6

The relationship between total and grain dry-matter yields and leaf area duration

		R^2 (%)	*Level of significance*
Total dry-matter yield (Y)/D	Y — 62.25 + 0.090 D	83	0.01
Grain yield (G)/D (total)	G — 18.81 + 0.07 D	56	0.05
Grain yield (G)/D_1 (45 days before harvest)	G — 22.72 + 1.02 D_1	69	0.01

Fig. I—The main effect of (a) methods of stand establishment and (b) variety on total dry-matter accumulation

Legend :

- o Row transplanting
- ● Random transplanting
- △ Row seeding
- ▲ Broadcasting
- — H_4
- .... IR_8

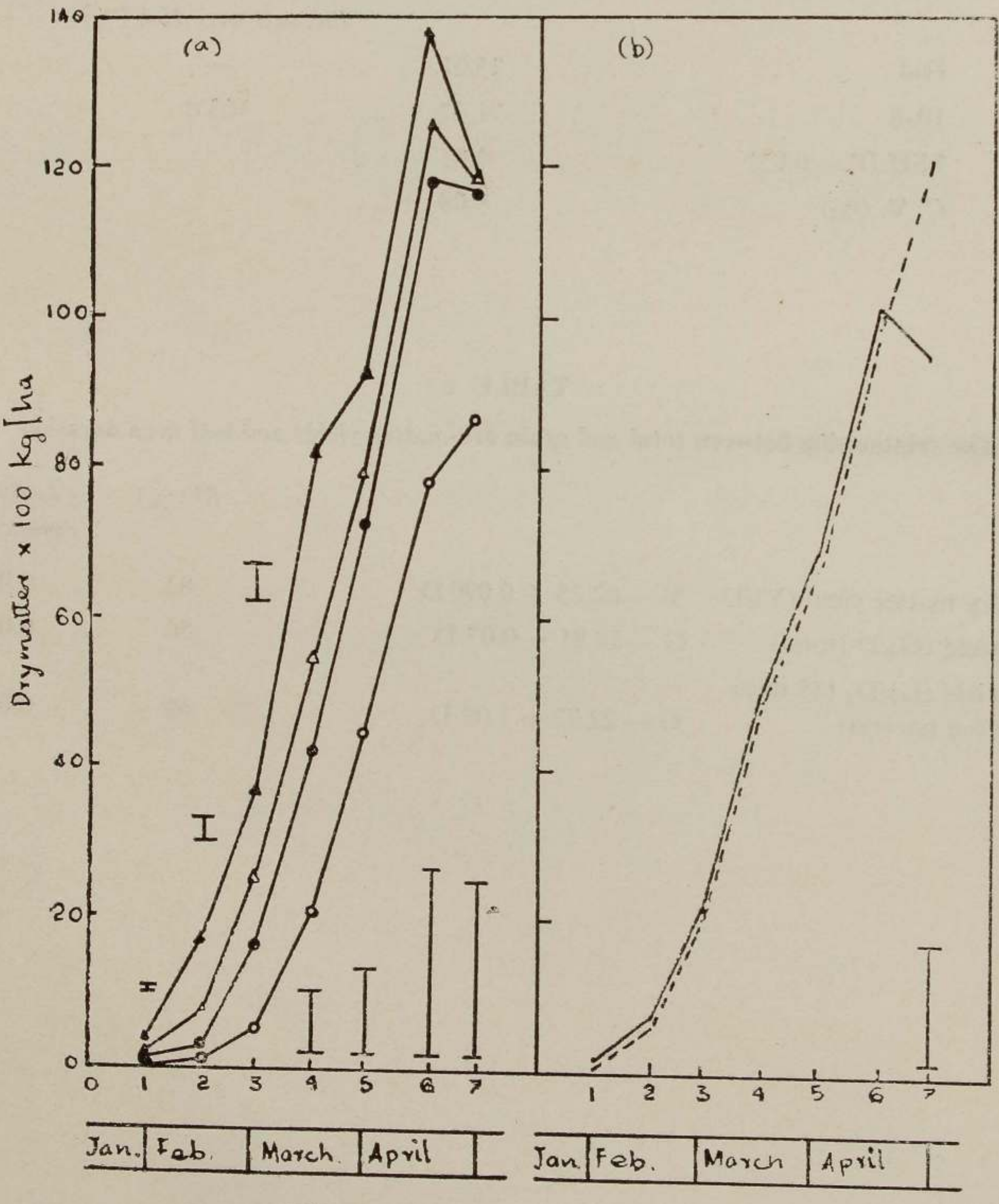
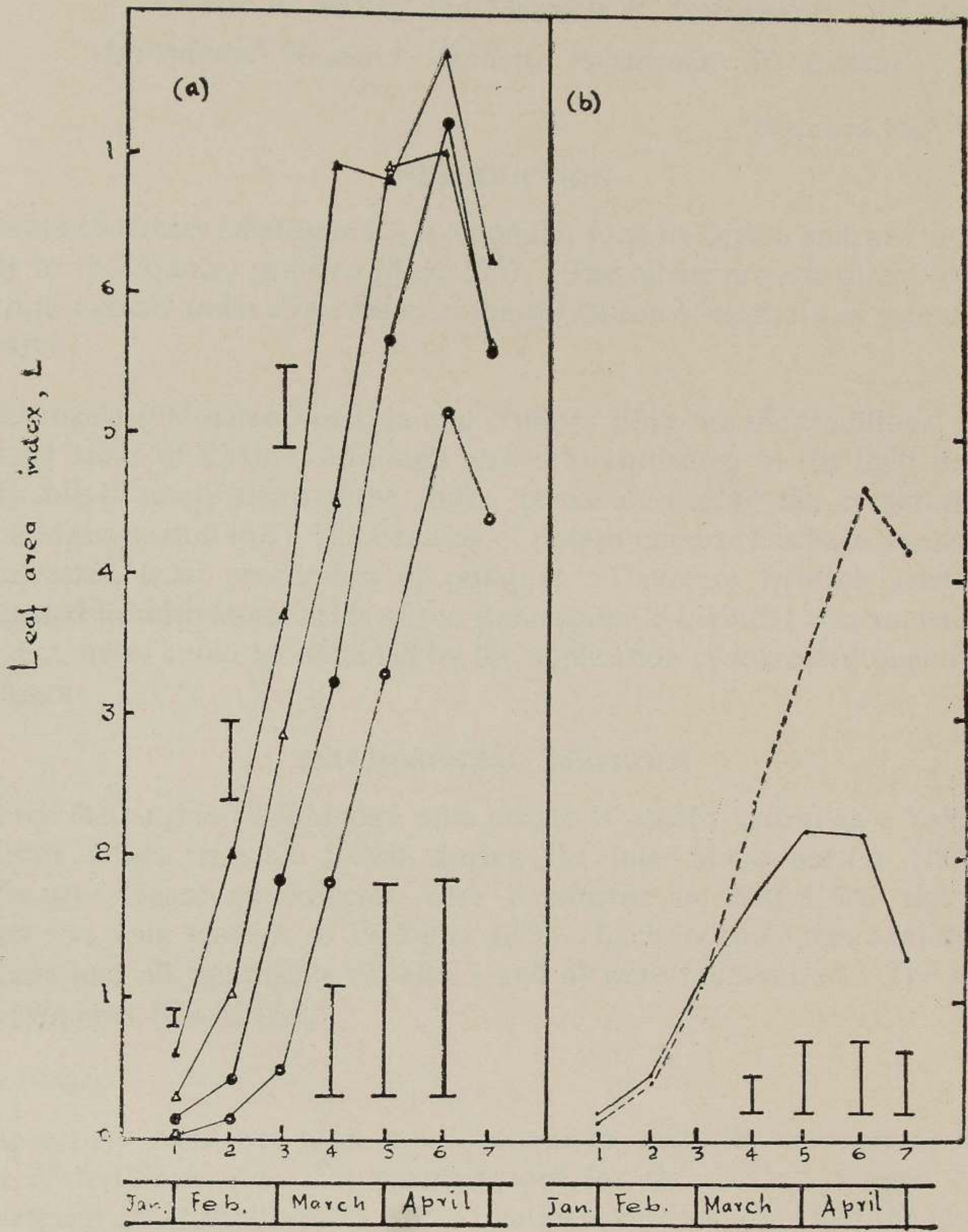


Fig. 2—The main effect of (a) methods of stand establishment and (b) variety on leaf area index

Legend : See legend for Fig. I



Studies on fertilizer responses in potato in Rahangala (Udukinda) area *

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is a popular food in Ceylon and was imported freely to the country prior to May, 1967. The tubers provide direct food for man and animals and is a raw material for distillation of alcohol and manufacture of starch.

Rahangala (Udukinda) of Uva and Nuwara Eliya are the traditional potato growing areas of Ceylon, although now it is cultivated in the light textured sandy soils or sandy loams of the Jaffna peninsula during the cooler months of the Maha season (6). The banning of potato imports has been an incentive to increased local production of potatoes. Therefore fertilizer trials were conducted in cultivators' fields of the Rahangala (Udukinda) area to determine if higher yields could be obtained by the application of increased quantities of fertilizers.

EXPERIMENTAL METHODS

In the Rahangala (Udukinda) area potato is usually grown as a Yala crop in fields where rice is grown during the late Maha season (January/ February). Hence experiments were conducted in cultivators' rice fields during the Yala seasons of 1969 and 1970. Each location was considered a replicate and all treatments (Tables 3 and 4) were randomized. The size of each plot was 10×15 feet.

Yala 1969

The variety Arka was used in 6 locations to study the response to higher doses of fertilizers over that recommended for the area at present by the Department of Agriculture (1). One treatment received only half the quantity of fertilizer recommended by the Department of Agriculture. In additionl the response to 10 cwt. per acre of ground dolomitic limestone was studied. Details of treatments are presented in Table 3. Characteristics of the soil, from the 6 locations are presented in Table 1.

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* Adapted from a paper presented at the Twenty-Sixth Annual Session of the Ceylon Association for the Advancement of Science, 1970.

Yala 1970

The variety Delaware was used in 10 locations to study the response to increased application of fertilizers (N, P and K) and to additional quantities of phosphorus and potassium over the quantity of fertilizers currently recommended for the area by the Department of Agriculture (1). Details of treatments are presented in Table 4. Characteristics of the soil from the 10 locations are presented in Table 2. During both sets of investigations fertilizers were applied in the furrow before the plots were planted·

RESULTS AND DISCUSSION

Effect of dolomite limestone on Yields. Yala 1969

Potato grows best in well-aerated slightly to moderately acid soils. Howevre, different pH ranges have been stated as ideal by various authorities. According to Thompson (7) the best pH range is between 5.0 and 5.5 while according to Jacob and Uexküll (3) the optimum pH range lies between 4.8 and 6.0. The latter authors further state that although this plant can be grown up to pH 6.5 it is liable to suffer from potato scab if grown at a pH of above 6.0.

As seen from Table 1 the soils on which the investigation was carried out in Yala 1969 had pH values between 5.2 and 6.0. These soils were not considered to be too acidic for potato. Ground dolomitic limestone at the rate of 10 cwt. per acre was applied to these soils. This form of lime was used in preference to other limestone because of its ready availability in the area and its magnesium content. The mean response to 10 cwt. per acre of dolomitic limestone was 0.66 tons tubers per acre (Table 3). This yield increase was inspite of not affecting an appreciable change of soil pH. Further, it appears that dolomitic limestone is as good as NPK fertilizers in increasing yields over the control treatment. As stated above these soils were not excessively acidic for potato in terms of ideal pH ranges quoted by authorities. Therefore, it is reasonable to conclude that the response to dolomitic limestone would have been due to its action in liberating nutrients from soil and soil organic matter, especially nitrogen and phosphorus, and to its content of calcium and magnesium.

Ponnamperuma (5) reported a highly significant effect due to 5 cwt. per acre of ground dolomitic limestone on the acid (pH 3.8 to 4.0) soils of Rahangala where an average yield increase of 1.34 tons per acre was obtained. He obtained no significant responses to lime beyond this level and concluded that liming a soil of pH 5.0 appears to be unnecessary for increasing yields and that the effect of dolomitic limestone may be due to its content of magnesium and calcium.

Response to fertilizers

Potato removes large quantities of nutrients from soil and therefore requires heavy application of fertilizers for maximum yields. Hence this plant is referred to as a gross feeder. This plant also synthesizes appreciable quantities of dry matter within a relatively short growing period. It is also reported that the nutrient requirements of potato are likely to be higher under tropical or sub-tropical conditions due to the more intensive growth and shorter growing period, and that the rate of nutrient removal is closely related with tuber growth.

Yala 1969

The effect of treatments on fresh weight of tubers is shown in Table 3. It will be observed that half the quantity of fertilizers recommended by the Department of Agriculture gave a higher significant increase of tuber yield over the no fertilizer control treatment. Increasing the quantity of fertilizers beyond this rate did not appear to be beneficial, for there were no siginficant differences in yield among treatments receiving ½, 1, 1½ or 2 times the quantity of fertilizers recommended by the Department of Agriculture. Ponnamperuma (1958) obtained highly significant responses to nitrogen, phosphorus, potassium and cattle manure on a strongly acid (pH 4.0) lateritic (highland) soil at Rahangala. This highland soil was however, relatively low in nutrients compared to the rice soils on which this investigation was carried out.

Yala 1970.

The results of the second season's fertilizer investigations are presented in Table 4. Application of fertilizer according to recommendations of the Department of Agriculture gave a mean yield increase of more than 3 tons per acre of tubers over the control no fertilizer treatment. This difference was significant at the 1 percent level of probability. Increasing the quantity of NPK fertilizers to 1½ or 2 times had no beneficial effect on mean yield. There was however, a slight depression in yield which was not statistically significant.

Response to phosphorus

Application of an additional 3 cwt. concentrated superphosphate per acre had no significant effect in increasing the mean yield of tubers. It is often stated that phosphorus is more important for potato in the tropics and sub-tropics than in temperate zones. Phosphorus is said to have a favourable effect on starch content and to hasten maturity and promote a healthy condition of the tubers. No attempt was made in this investigation to evaluate quality of the tubers.

Kandiah and Rodrigo (4) found 2 cwt. of saphos phosphate per acre sufficient to meet the entire requirement of a crop of potato, and the higher rate of 4 cwt. of this fertilizer per acre was not superior to the lower rate. They preferred to use saphos phosphate in preference to super phosphate because it was relatively cheaper being one third that of superphosphate, and because phosphate in the more expensive super phosphate was likely to be fixed by the acid lateri soils of Rahangala.

Ponnamperuma (5) obtained a striking linear response to phosphorus in the range 0-300 lbs. P_2O_5 on a highland soil at Rahangala. A dressing of 200 lbs. P_2O_5 as concentrated super phosphate gave a response of 5.2 tons per acre during the Maha season 1957-58 with the variety Up-to-date. It will be noted

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from Table 2 that the soils in which this investigation was done were all well supplied with available phosphorus, probably because the rice crop of the previous season was adequately fertilized.

Response to potassium

There was no significant effect on yield of tubers due to the application of and additional ½ cwt. per acre of muriate of potash. Potassium, is however, reported to play a very important role in increasing yields of root crops like potato. The results obtained in this investigation confirm those of Kandiah and Rodrigo (4) who reported no increase in yields due to potassium supplied as potassium sulphate. On the contrary they reported a depression in yield at Rahangala.

On the other hand Ponnamperuma (5) obtained a highly significant response to the application of 100 lbs. K_2O per acre applied as muriate of potash on a strongly acid medium textured soil containing 0.10 m.e exchangeable potassium during Maha 1956–57 at Rahangala. There was, however, no response to potassium in a similar experiment conducted during Maha 1957-58 on a strongly acid soil containing 0.22 m.e. exchangeable potassium per 100 gm. soil.

From the data on soil characteristics presented in Table 2 it will be observed that the status of exchangeable potassium in the majority of soils was less than 0.20 m.e. per 100 gm. soil. A characteristic of soils in this region is the low value of exchangeable potassium. Exchangeable potassium may not be a reliable measure of the potassium supplying power of these soils. It is likely that a reversible equilibrium of the various forms of potassium exists in these soils and that exchangeable potassium is released from the total potassium in the soil as plants utilize the readily available forms of the nutrient.

CONCLUSIONS

From the results of two season's experiments in cultivators' fields it is apparent that application of fertilizers in excess of those recommended by the Department of Agriculture have little effect in increasing yields of potato in the Rahangala area. The mean yields obtained in this area with this quantity of fertilizer are not appreciably lower than the national average yields of most countries (2), some of which are located in temperate zones. Under the present conditions, therefore it is not economical to use more fertilizers than recommended by the Department of Agriculture (1) for potato in the Rahangala area.

Applying the quantity of fertilizers recommended currently is indeed a paying proposition giving high monetary returns. The economics of fertilizer use may be estimated approximately as follows. Fertilizers recommended by the Department of Agriculture costing nearly Rs. 366 per acre give a yield increase of 2.5 tons. At a price of 50 cts. per pound of potato this gives a profit of Rs. 1,400 per acre.

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Table 1.—Characteristics of soils at locations of experiment (Yala 1969)

No.	Location	Texture	pH 1 : 1 Soil: H_2O	Organic matter %	Total N%	Available (Olsen's) P_5O_2 lbs/acre	Exchangeable cations Me/100 gm soil		
							K+	Ca‡	Mg‡
1	Kumbalwala	Sandy Clay loam	5.6	3.24	0.18	47.88	0.17	5.46	1.68
2	Helakadurugamuwa	Sandy clay loam	6.0	2.87	0.15	68.40	0.20	5.04	0.42
3	Kandepuhulpola	Sandy loam	5.2	4.04	0.17	68.40	0.08	2.94	0.42
4	Erabadde	Clay sandy clay	5.6	2.87	0.14	45.60	0.16	7.14	2.12
5	Uva-Paranagama	Sandy clay-Sandy clay loam	5.8	2.58	0.12	118.56	0.20	6.30	0.84
6	Rahangala—A.R.S.	Sandy loam-Sandy clay loam	5.4	5.30	0.22	45.60	0.08	2.52	0.42

Table 2.—Characteristics of soils at locations of experiment (Yala 1970)

No.	Location	Texture	pH 1 : 1 : Soil H_2O	Organic Matter %	Total N%	Available (Olsen's) P_2O_5 lba/acre	K me/100 gms soil
1	Wangiyakumbura	Sandy Clay-clay	5.4	2.42	0.13	41.04	0.16
2	Bogahakumbura	Sandy Clay-clay	5.6	2.87	0.12	79.80	0.18
3	Nugatalawa	Sandy Clay-clay	5.9	2.04	0.12	79.80	0.10
4	Kahagolla	Sandy Clay loam-Sandy loam	5.8	2.42	0.12	34.20	0.32
5	Uda-Kumbalwela	Sandy clay loam	5.9	2.87	0.16	45.60	0.12
6	Nawala	Clay-Sandy Clay	5.6	2.59	0.11	123.12	0.16
7	Kadurugamuwa	Sandy clay loam	5.8	3.33	0.20	152.76	0.20
8	Rahangala—A.R.S.	Sandy Clay loam	5.4	3.77	0.15	114.00	0.12
9	Uva-Paranagama	Sandy Clay-Sandy Clay loam	6.2	2.81	0.15	319.20	0.20
10	Rathkarauwa	Sandy Clay-Sandy Clay loam	5.8	1.92	0.10	364.80	0.20

Table 3.—Effects of treatments on mean yield of tubers (fresh weight tons/acre)—Yala 1969

No.	Treatments	Kumbalwela	Hela Kadurugamuwa	Kandapulpola	Erabedda	Uva-Paranagama	Rahangala A.R.S.	Mean
1	Control—No fertilizers	5.07	4.03	2.99	6.24	5.72	3.38	4.57
2	Ground dolomitic limestone at 10 cwt/acre	8.06	7.80	5.72	7.54	7.02	7.28	7.24
3	Half quantity of fertilizers recommended per acre by the Department of Agriculture	6.89	8.45	3.12	7.93	8.19	7.28	6.96
4	Quantity of fertilizers recommended per acre by the Department of Agriculture*	10.14	7.80	6.24	10.14	6.24	8.06	8.10
5	1½ times quantity of fertilizers recommended per acre by the Department of Agriculture	8.84	9.10	4.16	5.85	8.58	8.19	7.45
6	2 times quantity of fertilizers recommended per acre by the Department of Agriculture	1.43	8.71	4.94	7.67	2.86	6.24	5.31
		L.S.D. (P=0.05)						1.95
		L.S.D. (P=0.01)						2.64
		C.V.%						24.89

*Quantity of fertilizer recommended per acre by the Department of Agriculture for cultivators' fields in the area is as follows :—

4½ cwt. Ammonium sulphate

6 cwt. Concentrated superphosphate and

1 cwt. muriate of potash (50% grade).

Table 4.—Effect of treatments on mean yield of tubers (fresh weight, tons/acre)—Yala 1970

No.	Treatment	Locations: *Wangiya-kumbura*	*Bogaha-kumbura*	*Nuga-talawa*	*Kaha-golla*	*Kumbal-wala*	*Nawala*	*Kaduru-gamuwa*	*Raha-gala A.R.S.*	*Uva Paranagama*	*Ratha-karuwa*	*Mean*
1 ..	Control—No fertilizers ..	7.28..	8.19..	6.24..	3.44..	4.03..	6.50..	1.89..	5.33..	5.98..	3.51..	5.24
2 ..	Quantity of fertilizers recommended per acre by the Department of Agriculture*	11.96..	12.35	8.84..	5.53..	4.55..	11.58..	9.36..	10.05..	12.35..	4.81..	9.14
3 ..	1½ times quantity of fertilizers recommended per acre by the Department of Agriculture	10.92..	12.35..	6.76..	5.98..	5.20..	9.36..	5.92..	10.28..	12.74..	5.20..	8.47
4 ..	2 times quantity of fertilizers recommended per acre by the Department of Agriculture	10.79..	12.74..	6.11..	5.72..	5.33..	12.35..	5.98..	8.97..	14.69..	4.81..	8.75
5 ..	Quantity of fertilizers recommended by the Department of Agriculture plus concentrated superphosphate at 3 cwt. per acre	11.58..	13.92..	7.54..	7.15..	5.33..	12.61..	7.61..	9.88..	10.92..	5.46..	9.20
6 ..	Quantity of fertilizers recommended by the Department of Agriculture plus muriate of potash at ½ cwt. per acre..	11.70..	12.48..	7.41..	6.24..	3.25..	9.75..	8.19..	12.61..	13.39..	5.46..	9.05
						L.S.D (P=0.05)..		..		..	..	1.16
						L.S.D. (P=0.01)		..		..	..	1.55
						C.V.%	..	..		..	..	15.44

*Quantity of fertilizers recommended per acre by the Department of Agriculture for cultivators' fields in the area is as follows :—

4½ cwt. Ammonium sulphate
6 cwt. concentrated superphosphate and
1 cwt. muriate of potash (50% grade).

A comparative study of two-wheel and four-wheel tractor operation and performance in the dry zone

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MECHANIZATION of agriculture in Sri Lanka and the dry zone in particular commenced in the mid-forties. Most of the import of tractors and equipment was done by the Government, but some where during 1949/50, the private sector entreed this field. The first large scale introduction appeared to have been the Massey Ferguson TE-20 model with tyne tiller. The population of four wheel tractors in 1945 was approximately 60, in 1949 the number increased to 650 and in 1965 it stood at 10,000. Today it is in the region of 13,900. Two wheel tractors appeared to have come into the island in 1960, with " Mitsubishi ", which is one of the heavy duty Japanese make, and the Land-Master which is a part assembled Garden Tractor in Sri Lanka. It was not until 1968 that this range of tractors made any impression in local agriculture. The population of two wheel tractors today stands at 6,354.

Despite the fact that there are 13,867 four wheel and 6,354 two wheel tractors there is yet an unsatisfied demand for tillage facilities. There appears to be a great deal of confusion at the moment with regard to the farmers choice of the class of tractor most suited for his needs. The main objective of this article is to serve as a guide in the choice of the proper class of tractor.

COST ANALYSIS

The following notations are used in the discussion on cost analysis :—

D	—	Depreciation of Machinery	(Rs/hr)
F	—	Fuel cost	(Rs/hr)
H	—	Housing Insurance and Management expenditure ...	(Rs/hr)
I	—	Interest on capital investment	(Rs/hr)
L	—	Lubrication cost	(Rs/hr)
N	—	Life span	(years)
P	—	Purchase price	(Rupees)
R	—	Repair, spares & Maintenance	(Rs/hr)
T	—	Work span	(hours)
W	—	Operators wages	(Rs/hr)
t	—	Annual hourly use	(hours)

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A cost analysis of land preparation with various types of tractors and implements used for agricultural purposes would aid the selection of a suitable tractor power unit. Generally it is impossible to state accurately the cost of machine power in a farm as it is influenced by a wide range of factors which include :—

(1) Weather condition during cultivating period.
(2) Type and condition of soil (specially soil moisture condition)
(3) Skill of the machinery operator,
(4) Annual hourly use in the field.

The cost of machine power for mechanization of agriculture can be divided into two main groups, namely : fixed costs and running costs.

A. Fixed Costs

Fixed cost is the expense incurred when the tractor is in the farmer's possession irrespective of the number of hours for which such a machine is used annually. Fixed cost consists of :—

(i) Depreciation of the machine
(ii) The interest on capital investment
(iii) The housing, insurance and management expenditure, etc.

(i) *Depreciation.*—Depreciation of a tractor depends on its total working hours (*i.e.* its work span) which is determined by two factors. One is the time taken for the tractor to wear out and become unfit for further use, and the other is the obsolescence due to new technical improvements. The life period of a tractor (2, 3 and 4) estimated from its annual hourly rate of working is presented in Table I. The salvage value of the tractor and its implements is estimated as 10 percent of the purchase price.

$$\text{The hourly rate of depreciation} = \frac{0.9 \times \text{Purchase price}}{\text{Total hours of use.}}$$

$$\text{ie. } D = \frac{0.9 \times P}{T} \text{ Rs/hr.}$$

(ii) *Interest on capital investment.*—Average annual interest paid on loaned capital is 10 percent.

$$\text{The hourly rate of interest} = \frac{0.1 \times \text{Purchase Price}}{\text{Annual hourly use}}$$

$$= \frac{0.1 \times P}{t} \text{ Rs/hr.}$$

(iii) *Housing, Insurance and Management Expenditure* (3), (4).—It is essential for the tractor to be sheltered when it is not in use. The construction and maintenance of this shelter is considered as a part of the fixed cost.

The Motor Traffic Act requires that all 4 wheel tractors be insured against accidents, at least against 3rd party risks.

The expenditure on management and care of tractors hired for services such as ploughing, haulage, etc. is taken as additional costs incurred.

These annual rates are estimated as follows :—

Housing	...2.5%	Of the Purchase price
Insurance	...0.5%	
Management Expenditure	... 3%	

$$\text{The hourly cost} = \frac{0.06 \times \text{Purchase price}}{\text{Annual hourly use}}$$

$$H = \frac{0.06 \times P}{t} \text{Rs/hr.}$$

Note.—Since two wheel tractors are not registered as road vehicles, being utilized by the owner operator, insurance and management costs are not applicable.

$$\therefore \ H = \frac{0.025 \times P}{t} \text{Rs/hr.}$$

B. Running cost (*Variable cost*)

Running cost may be defined as the cost incurred in utilizing the machine for various operations. This cost is made up for of the following :—

(i) Repair, spares and maintenance
(ii) Fuel consumption
(iii) Oil and Lubricant
(iv) Operators wages.

(i) *Repairs, spares and maintenance.*—Total amount of repair cost on a tractor is directly proportional to its total use. The cost is low when the machine is new and increases as the machine becomes older. Tractor spares are very costly being subjected to import control. Repair and service facilities are not available or are generally unsatisfactory in remote villages. In general, farmers do not maintain an accurate record of repair cost incurred on their machines.

From the popular makes widely used for agricultural purposes, one 45-HP (Diesel) 4—wheel tractor and one 7 H.P. (diesel) 2—wheel tractors were selected for this study and a record of maintenance, service and operation is being maintained at the Farm Machinery Research Centre, Maha Illuppallama. These records together with whatever information obtained from farmers were used to develop emporical estimates of the total accumulated repair cost during the entire life of the tractors (fig. 1). The hourly rate of repair cost of tractor and implements corresponding to their annual use calculated from Fig. 1 is given in Table 2.

(ii) *Fuel Consumption.*—Various makes and models of tractors were tested at the Farm Machinery Research Centre, Maha Illuppallama, to estimate their capacity and quality performance under local conditions. From the test results for continous operation of 8 hrs/day the specific fuel consumption per acre and corresponding tilling capacity were estimated (1). In addition the following factors were considered.

(1) Different and irregular field sizes.
(2) Variation in the type of soil and its moisture content across the field.
(3) Obstructions (Boggy plots, hidden stones, roots, etc. in the field).
(4) Reduced efficiency due to wear and tare.
(5) Operators rest period.

In consideration of the above factors an additional allowance of 33 percent had to be made on the test values of fuel consumption, and 75 percent of the estimated tilling capacity (2, 4) were used for the derivation of fuel cost given in table—3.

Hourly cost of fuel consumption (F) could be calculated for different categories of tractors.

Average price of fuel :

	Rs. c.	
Diesel	... 1 84	Per gallon
Petrol	... 3 56	
Kerosene ...	... 1 0	

(iii) *Oil and Lubricant (L).*—It was estimated from the records of different tractors that the cost of oil and lubricant was proportional to the fuel consumtion and was determined as 30 percent of the fuel cost

Therefore hourly cost of oil and lubricant.

$$L = 0.3.\ F\ Rs/hr.$$

(iv) *Operator's wages* (*W*).—From district to district the tractor operators wages vary with the season (*Viz*. Maha & Yala)

The average wages are :—

4—wheel tractor operator—10 Rs./day or 1.25 Rs./Hr.
2—wheel tractor operator—7.5 Rs./day or 0.95 Rs./Hr.

Purchase price.—Average prices given in Table—4 for tractors of same horse power class but of different makes were calculated on the market prices prevailing in 1970 and are therefore subject to change.

ESTIMATION

A. Maximum operational capacity :—

Assuming 40 days (320 working hours) are available for preparatory land operation per season and using Table 3, the maximum operational capacity of the machines could be evaluated.

Examples :

If a 45 HP tractor is used for tyne tilling operation for the whole period in single cropping season then from Table 3 hourly capcaity of the tractor .. .. = 0.63 acres

∴ for 40 days (320) hours capacity .. .. = 0.63 × 320

≃ 200 acres.

Similarly when the tractor is used for two cropping seasons (80 days = 640 hours) per year the operational capacity will be 400 acres

B. Cost per acre for preparatory land operation

With different horse power class of tractors the cost per acre for various operations involved in land preparation were calculated for their corresponding annual hourly use Fig. 2, 3 & 4. These figures could be used to estimate the cost involved for different hourly use of implements to suit the need of individual farms.

Example :

If a 45 HP tractor is used for 1,000 hours annually of which tyne tilling include 320 hours, rotary tilling 320 hours, and its remaining period of 360 hours for transport work:—

Then from Fig. 2, cost of tractor power (1,000 hours annual use) .. = 11.60 Rs/hr
From Fig. 3, cost of tyne tilling implement and operation (320 hours) = 6.50 Rs/hr
∴ Total operational cost .. .. .. = 18.10 Rs./hr
From Table 3 the tyne tilling capacity of 45 HP tractor = 06.3 ac/hr

∴ Cost per acre fo rtyne tilling .. .. = $\frac{18.10}{0.63}$

= 29.00 Rs./-

Similarly from Fig 2, 3 and Table 3 cost per acre for rotavating (320 hours per year) .. .. = 37.40 Rs./acre

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Using the above methods of analysis, the maximum operational capacity and the cost per acre with different categories of tractors for different operations are given in Table 5, both in relation to one cropping season and two cropping seasons per year.

These results were obtained for a tractor with 1,000 hours (total) annual use, wherein implement use for single and double cropping amounted to 40 days of 320 working hours and 80 days of 640 working hours respectively. The calculations are based on the use of a particular implement exclusively throughout the period of tillage corresponding to 40 days in single cropping and 80 days in double cropping.

Management and Maintenance

The efficiency of management will largely influence the cost structure of mechanization, particularly in our developing country where imported machinery, are used for field operation under extreme conditions. For successful mechanization the machinery operator should be acquanited with the principle functions of the machinery and necessary care to maintain it efficiently. The personal attention and supervision by the farmer (owner of the land where the machinery is used) is an important factor determining the efficiency of mechanized operation. The farmer should bear in mind the following points in the use of machinery for agriculture :

(1) Selection of correct power unit capacity for his requirements.
(2) Awareness of proper cultivation practices in relation to soil conditions at the time of land preparation.
(3) Utilization of proper gear for optimum performance of the machinery and maximum economy of fuel consumption.
(4) Attend to the scheduled system of service, maintenance and adjustments that are required for easy and trouble free operation.
(5) Field supervision of the machine to ensure efficient operation.

DISCUSSION

In working out the economics of tractor operation the two main variables include fixed cost and running cost. The fixed cost which constitute depreciation, interests and other expenditures involving housing, insurance and management is largely a percentage of the capital cost of equipment which is not affected by the working condition. On the other hand, running cost which include expenditures on repair, fuel, oil and lubricants and operator's wages influence the working cost to a great extent and therefore it is in this area that maximum care is needed in the exercise of skills.

It will be noticed that 45 HP. is about the ideal among four wheel tractors. Four wheeler below or above the 45 HP. range appear to be uneconomical. It will also be observed that for optimum returns this class of machine should be in use for at least 1,000 hours a year. From the operational point of view it will be noticed that, of the three operations namely rotavating, ploughing and tyne tilling the cost of tyne tilling is the least, followed by rotavation, whereas ploughing costs are high. In double cropped areas, these operational costs are a little lower than in single cropped areas, mainly due to the longer period of machinery used. It would therefore become apparent that unless the machine is in use for at least 1,000 hours per year the investment will not give a desirable margin of profit. However the advantages in having more than 1,000 hours of work per year is that, the income will be greater but at the expense of a shorter life period of the machine.

The factors which influence fixed and running cost of four wheel tractors are also used in the estimation of working cost for two wheel tractors, except insurance and managent expenditure. The three classes of two wheelers are the diesel, kerosene and petrol machines which possess a horsepower range of 6—7. The tests carried out indicate that the diesel tractors of this horse power range gave the highest field performance resulting in reduced cost per acre though the investment cost of the diesel tractor is high. It was also observed that the diesel engine is relatively free from troubles particularly when operated under wet and muddy field conditions.

As far as paddy cultivation is concerned rotary tilling with the two wheel tractor appears to meet the requirement of the farmer and is cheaper than ploughing, except in instances of land heavily infested with weeds and stubbles as in fallow rice fields where ploughing is essential. In order to obtain the maximum benefit from the two wheel tractors it must be utilized for 1,000 hours on preparatory land operation (rotavating). However the owner of this class of tractor may be able to use his tractor for subsequent operations such as ridging, seeding, intercultivating and harvesting, and as stationary power source for operating water pumps, threshing machines, hulling machines, etc. which brings him additional income.

CONCLUSION

The power unit on which a programme of mechanization of paddy is to be based has become a controversial issue today. The two protoganists being those who favour the use of two wheel power tillers and those who support the use of the conventional four wheel tractors. While it must be admitted that both types have their place in the mechanization of agriculture in Sri Lanka, the relatively new idea of the two wheel power tiller demand examination, from both the technical and economical points of view.

The use of either categories of tractors will depend largely on the size of holdings. Some suggestions can be made on the selection of power sources for land preparation in the developed paddy land (1962). There are in Sri Lanka approximately 30,000 acres under small holdings of less than ½ acre, which can be cultivated with animal power. The extent of 600,000 acres in holdings between ½ and 5 acres, where the effective power sources which can be used are the hired services of both two wheel tractors and four wheel tractors. Owned two wheel tractors or hired services of four wheel tractors can be efficiently used in the 50,000 medium size holdings between 5 and 25 acres covering an extent of 350,000 acres of land. For the remaining areas where the individual land holdings exceed 25 acres the four wheel tractor is recommended.

From the above evaluation it can be concluded that the two classes of tractors namely the four wheel tractors and two wheel tractors have specific roles to play in the mechanization of agriculture in Sri Lanka. The popular falacy that the two wheelers can replace the four wheelers and vice versa is not based on any scientific evaluation.

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TABLE 1

Annual hourly use and estimated life period (2, 3, 4)

A.—4-WHEEL TRACTOR (20—25—35—40—45—60 HP)

Annual hourly use—t hours ..	500..	600..	750..	1,000..	1,250..	1,500
Useful life—N years ..	15..	14..	12..	10..	8..	7
Workspan T = Nt hours ..	7.500..	8,400..	9,000..	10,000..	10,000..	10,500

B.—4-WHEEL TRACTOR IMPLEMENTS (ROTARY, PLOUGH & TINE TILLER)

Annual hourly use—t hours ..	100..	200..	300..	400..	500..	600
Useful life—N years	12..	10..	8..	7..	6..	5
Workspan T = Nt hours ..	1,200..	2,000..	2,400..	2,800..	3,000..	3,000

C.—2-WHEEL TRACTORS WITH IMPLEMENTS

Annual hourly use — t hours ..	300..	450..	600..	750..	900..	1,000
Useful life—N years	8..	7..	6..	5..	4.5..	4
Workspan T = Nt hours ..	2,400..	3,150..	3,600..	3,750..	4,000..	4,000

TABLE 2

Repair costs on tractors and implement (Figure I)

A.—4-WHEEL TRACTOR (20—25—35—40—45—60 HP)

Annual use—t hours	500..	600..	750..	1.000..	1,250..	1,500
Repair cost R = $\times$ 10^{-4} P Rs/hr ..	2.7..	2.38..	2.20..	2.0..	2.0..	1.95

B.—4-WHEEL TRACTOR IMPLEMENTS

Annual use—t hours	100..	200..	300..	400..	500..	600
Repair cost R = $\times 10^{-4}$ P Rs./hr ..	8.1..	5.0..	4.20..	3.58..	3.33..	3.33

C.—2-WHEEL TRACTOR WITH EQUIPMENT

Annual use—t hours	300..	450..	600..	750..	900..	1,000
Repair cost R = $\times$ 10^{-4} P Rs/hr ..	4.2..	3.14..	2.8..	2.70..	2.65..	2.65

TABLE 3

Estimation of practical operational capacity and fuel consumption for different land preparation (I)

Machinery details (H.P. class)	*Operational capacity acres per hour*	*Fuel consumption gallon/per hour*
I—ROTARY TILLING (WET)		
(*a*) 4-*wheel tractor*		
60 HP Diesel	0.75	1.76
45 HP Diesel	0.63	1.80
40 HP Diesel	0.60	1.80
35 HP Diesel	0.48	1.80
25 HP Diesel	0.46	0.86
20 HP Diesel	0.35	1.20
15 HP Diesel	0.26	0.89
(*c*) 2-*wheel tractor*		
7 HP Diesel	0.16	0.28
6 HP Kerosene	0.10	0.36
6 HP Petrol	0.10	0.42
II—PLOUGHING (DRY)		
(*a*) 4-*wheel tractor*—		
60 HP Diesel	0.4	0.85
45 HP Diesel	0.4	0.96
35 HP Diesel	0.31	0.98
25 HP Diesel	0.28	0.70
(*c*) 2-*wheel* tractor		
7 HP Diesel	0.10	0.24
6 HP Kerosene	0.08	0.33
6 HP Petrol	0.08	0.28
III—TINE TILLING (DRY)		
(*a*) 4-*wheel tractor*		
60 HP Diesel	0.63	1.50
45 HP Diesel	0.63	1.43
25 HP Diesel	0.36	0.74
IV—TRANSPORTING (ON LEVEL ROAD)		
(*a*) 4-*wheel tractor*		
45 HP Diesel	—	0.74

TABLE 4

The average purchase price (P) for different catagories of tractors, implements, etc. (1970 market price subject to change)

Machinery details	*Price Rs.*
(*a*) 4-*wheel tractor*	
60 HP Diesel	28,000
45 HP Diesel	23,000
40 HP Diesel	21,000
35 HP Diesel	18,750
25 HP Diesel	16,350
20 HP Diesel	15,750
15 HP Diesel	15,275
(*b*) 4-*wheel tractor implement*	
Howard Rotavator (RMK 40/50) ..	5,500
Disc plough (2 furrow)	4,500
Tine tiller (9 points)	2,500
Trailer (3-ton capacity)	6,700
(*c*) 2-*wheel tractor*	
7 HP (Diesel)) Rotary and wet wheel ..	6,400
6 HP (Kerosene) Rotary and wet wheel ..	5,160
6 HP (Petrol) Rotary and wet wheel	5,330
7 HP (Diesel) Mould plough and wheel ..	5,300
6 HP (Kerosene) Mould plough and wheel ..	4,450
6 HP (Petrol) Mould plough and wheel ..	4,500

TABLE 5

Estimation of cost per acre for rotary tilling, ploughing and tine tilling operations in relation to single cropping areas and double cropping areas (assuming 4-wheel tractor is used 1,000 hours (total) annually, irrespective of implement use)

Tractor details	*Single cropping season (Yala or Maha) 40 days per year* — *Maximum operational capacity (acre/yr.)*	*Single cropping season* — *Cost per acre Rs. c.*	*Double cropping season (Yala or Maha) 40 days per year* — *Maximum operational capacity (acre/yr.)*	*Double cropping season* — *Cost per acre Rs. c.*
I—ROTARY TILLING (WET)				
(*a*) 4-*wheel tractor*				
60 HP Diesel	240	34 50	480	31 20
45 HP Diesel	200	37 40	400	33 40
40 HP Diesel	190	37 80	380	33 60
35 HP Diesel	150	45 40	350	40 0
25 HP Diesel	145	42 50	290	40 0
20 HP Diesel	110	54 0	220	46 50
15 HP Diesel	70	68 60	140	60 0
(*c*) 2-*wheel tractor*				
7 HP Diesel	50	57 50	100	39 0
6 HP Kerosene	40	73 0	80	51 0
6 HP Petrol	40	83 0	80	59 0
II—PLOUGHING (DRY)				
(*a*) 4-*wheel tractor*				
60 HP Diesel	125	54 0	250	49 70
45 HP Diesel	125	50 0	250	42 70
35 HP Diesel	100	59 0	200	53 60
25 HP Diesel	90	61 0	180	54 80
(*c*) 2-*wheel tractor*				
7 HP Diesel	32	77 0	64	54 0
6 HP Kerosene	25	85 0	50	56 0
6 HP Petrol	25	95 0	50	67 0
III—TINE TILLING (DRY)				
60 HP Diesel	200	32 35	400	30 0
45 HP Diesel	200	29 0	400	27 0
25 HP Diesel	200	43 0	400	39 0

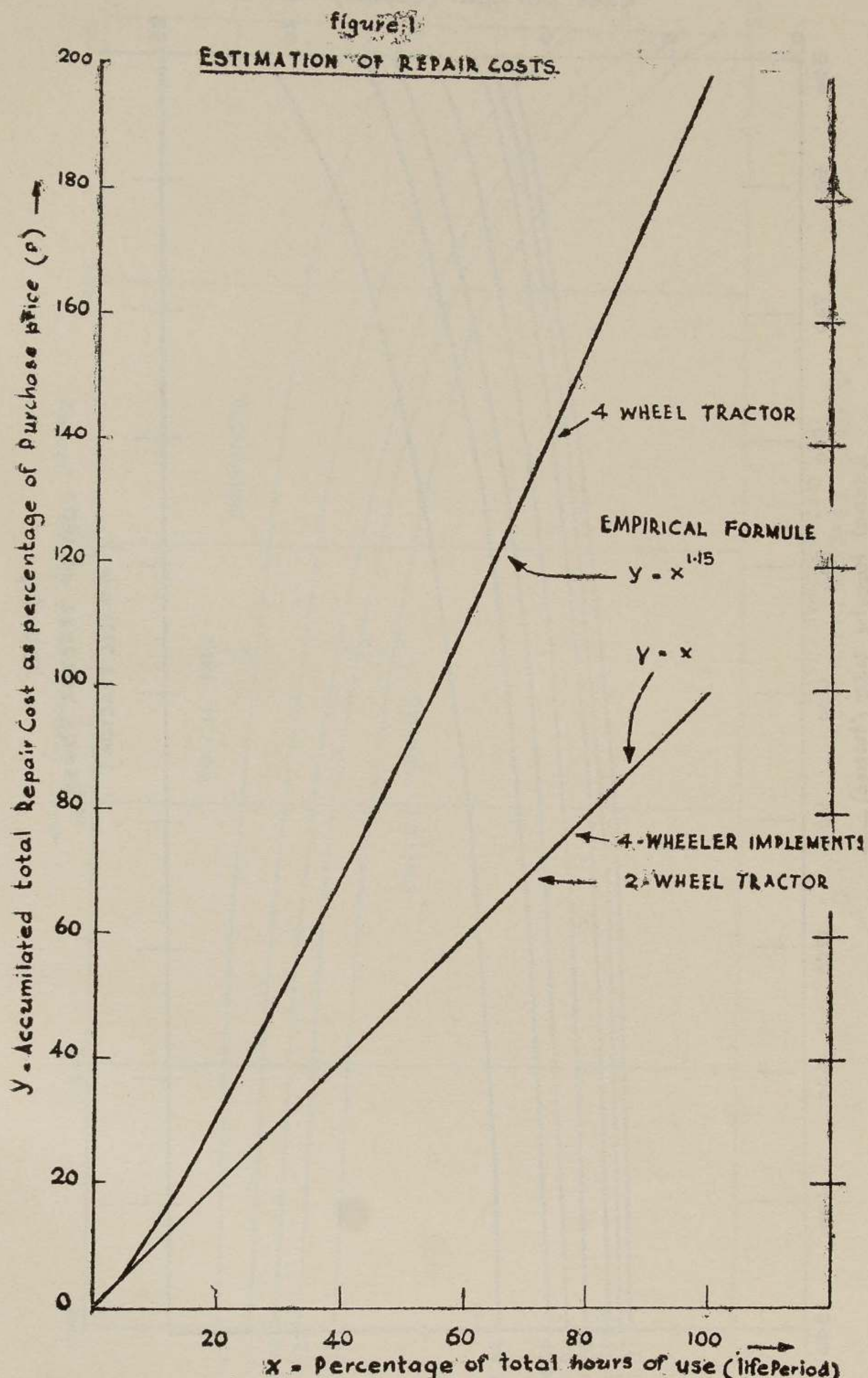
figure 1
ESTIMATION OF REPAIR COSTS.
4 WHEEL TRACTOR
EMPIRICAL FORMULE
Y = X 1.15
Y = X
4-WHEELER IMPLEMENTS
2-WHEEL TRACTOR
Y = Accumilated total Repair Cost as percentage of Purchase price (P)
X = Percentage of total hours of use (lifePeriod)
0
20
40
60
80
100
120
140
160
180
200

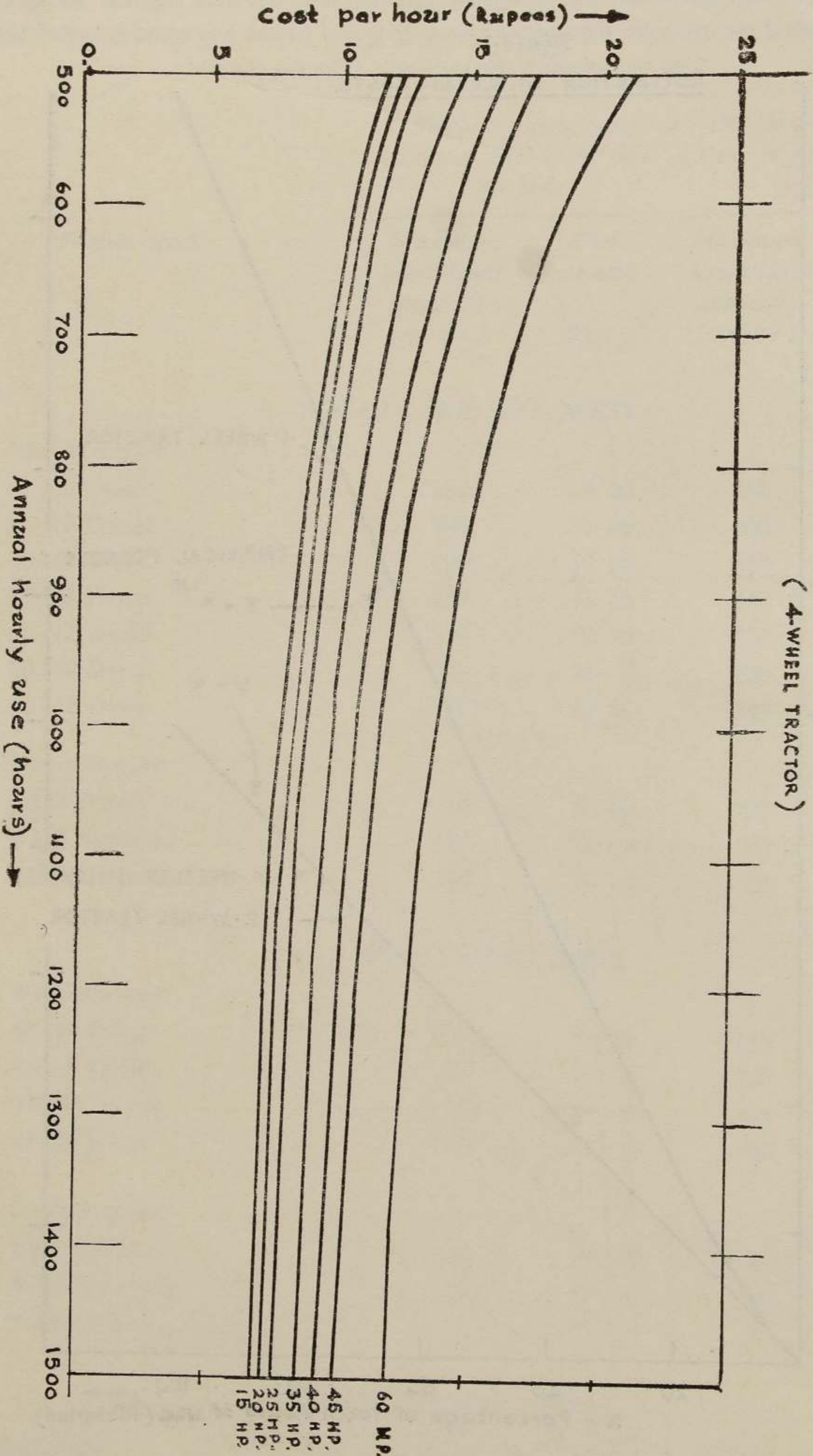

figure 2.
COST OF TRACTOR POWER
(4-WHEEL TRACTOR)

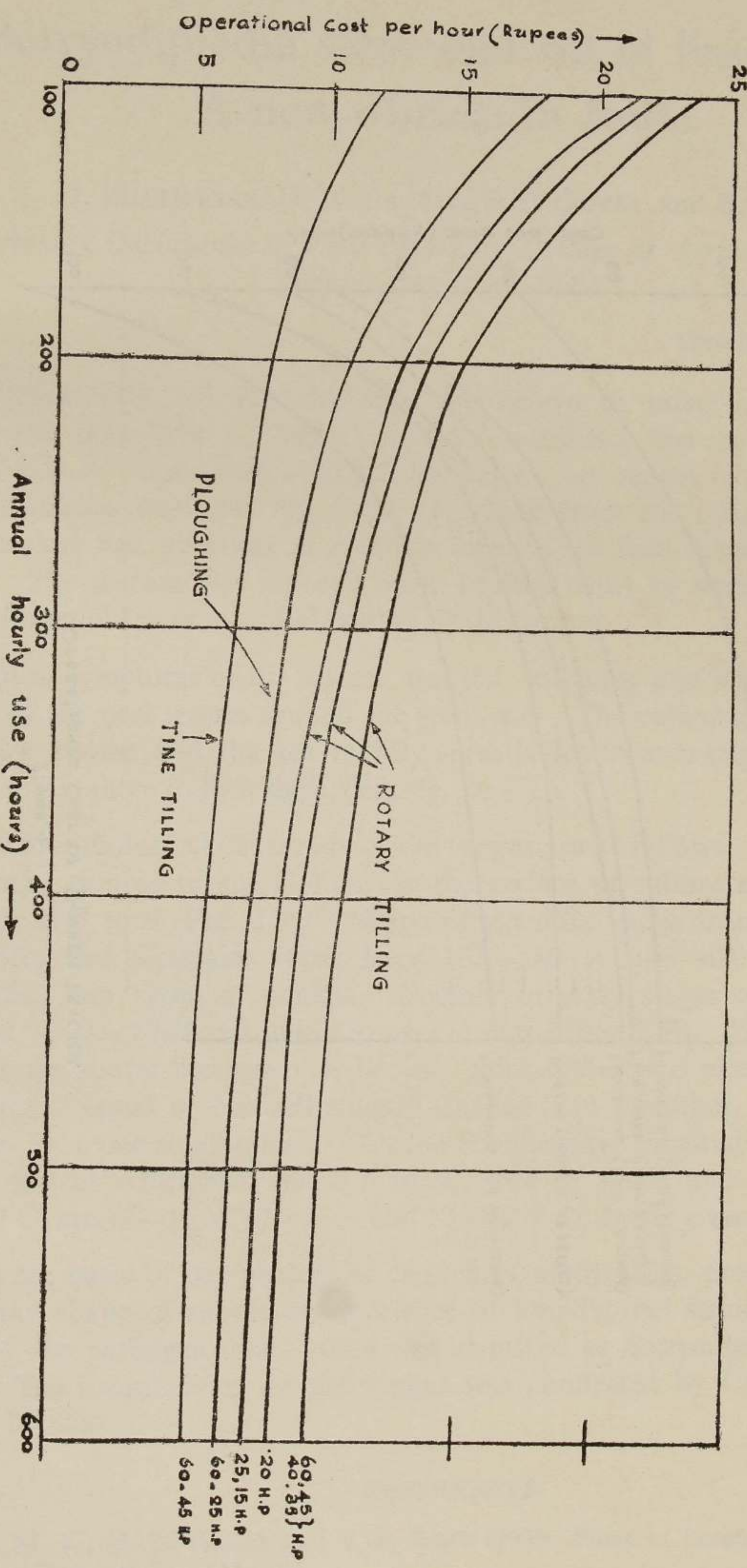

Figure 3

4-WHEEL TRACTOR IMPLEMENTS AND OPERATIONAL COSTS.

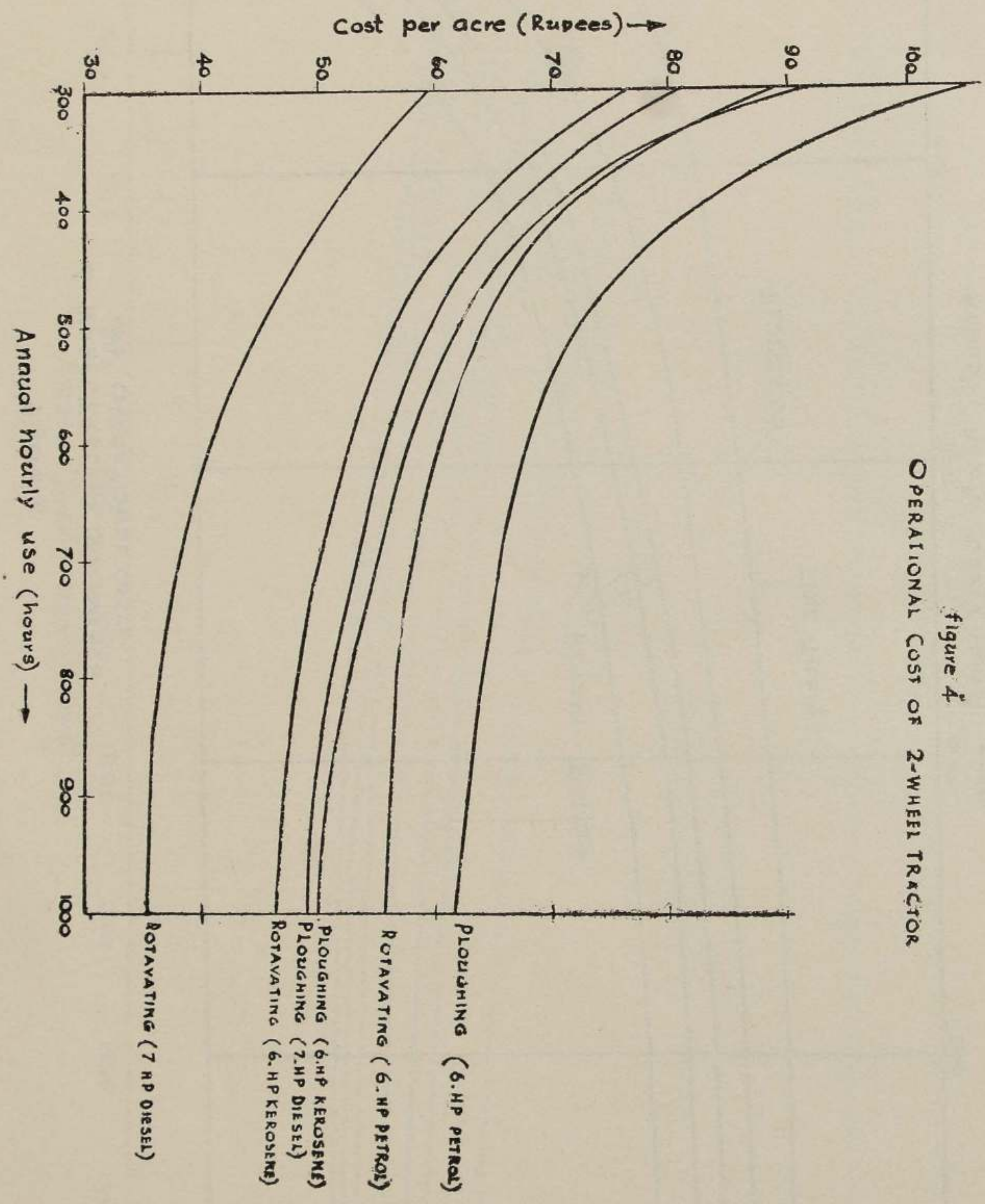

figure 4
Operational Cost of 2-Wheel Tractor

RESEARCH NOTE

Botryodiplodia stem-end rot of lime fruits A new disease in India

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Botryodiplodia and *Diplodia* spp. are known to infect several crops of economic importance. While *Diplodia natalensis* has been reported on lime fruits by Patel *et al.* (1949) from India, no report of the incidence of *Botryodiplodia* stem-end rot could be traced from the available literature. The disease was observed in a severe form in the fruit markets of Jaipur in 1969. The disease was reproduced in healthy fruits by stem-end inoculation of 48 hours old monoconidial culture of the fungus.

Typical symptoms of the disease are the softening and light brown colouration of the peel tissues around the stem-end. The colour gradually changes to dark brown and the rot rapidly spreads downwards engulfing the whole fruit within three to four days. (Fig. 1).

The morphological characters of the fungus are as follows : Pycnidia, brown to black, globose to sub-globose on the surface of culture media, usually in groups of 3 to 6 (Fig. 2 A). Shape of pycnidia varies from sub-globose to pyriform and their size varies from 135—180 $\times$ 216—480 μ. The fungus produces two types of conidia. Conidia in early stages are hyaline, thin walled, single-celled and round to oval in shape (Fig. 2 B). With the advance in age the spores become olive-brown, thick-walled and bicelled. Both cells are almost equal or one cell slightly smaller than the other. Shape of these spores is ovate to elliptical. Bicelled conidia have longitudinal striations on their surface which vary from 4 to 6. Size of single and bicelled conidia (Fig 2 C) are 12—15 $\times$ 17—28 μ and 13—15 $\times$ 20.5—32 μ respectively.

On the basis of morphological characters of pycnidia, presence of stroma, size and shape of spores and presence of longitudinal striations on bicelled spores, the pathogen under study was identified as *Botryodiplodia theobromae* Pat. The identification of the fungus was confirmed by CMI Kew, Surrey (IMI 141578).

REFERENCES

PATEL, M. K., M. N. KAMAT AND V. P. BHIDE (1949—Fungi of Bombay, Supplement 1. *Indian Phytopath* 2 : 142—155.

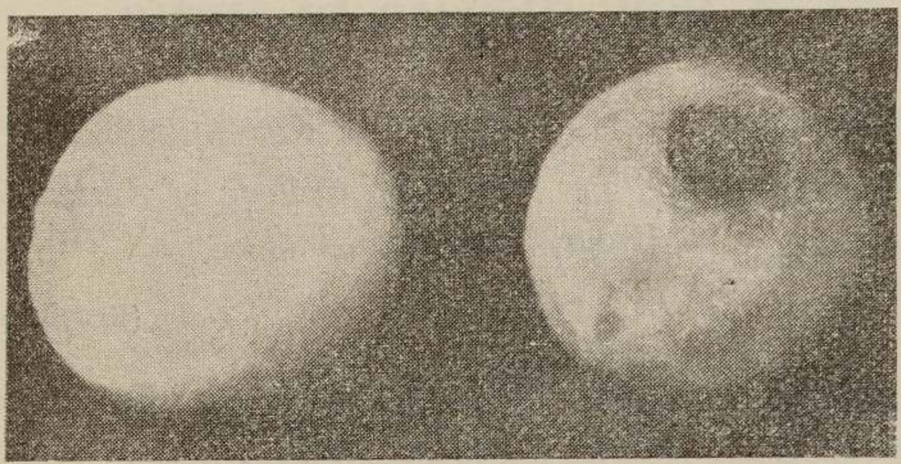

Fig. 1—Healthy and diseased lime fruits.

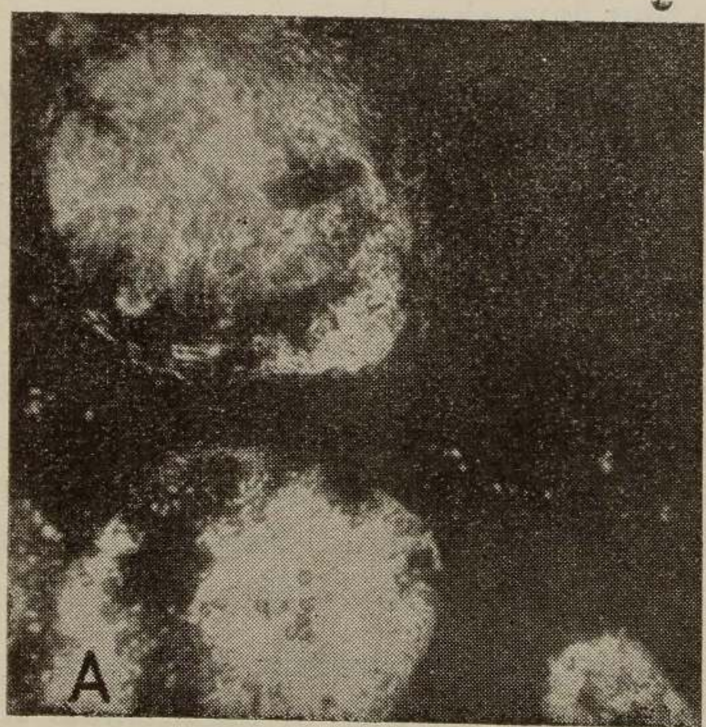

Fig. 2(A)—T. S. of stroma showing group of pycnidia

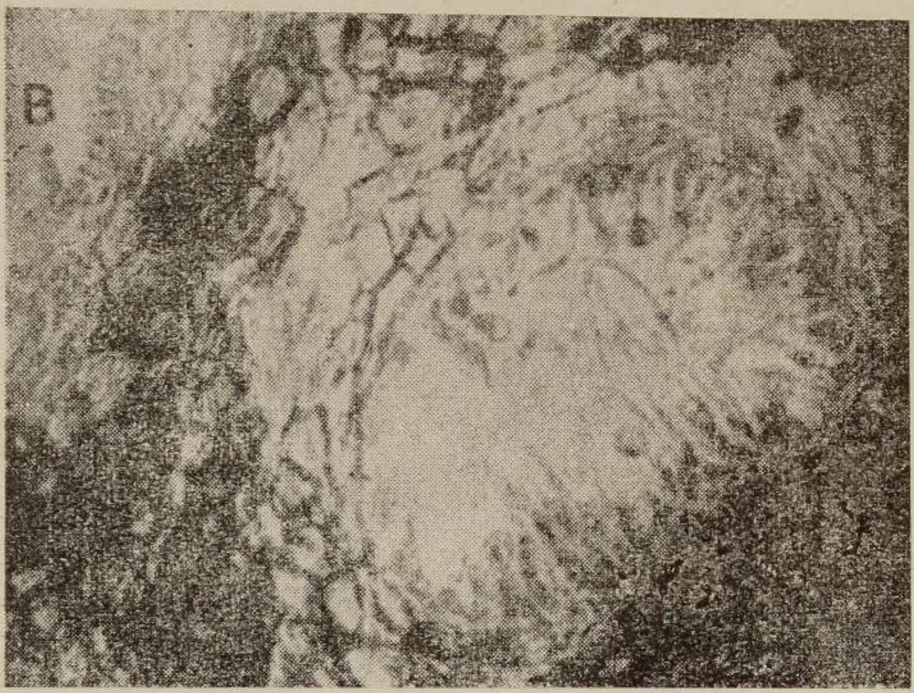

Fig. 2(B)—L. S. of a pycnidium

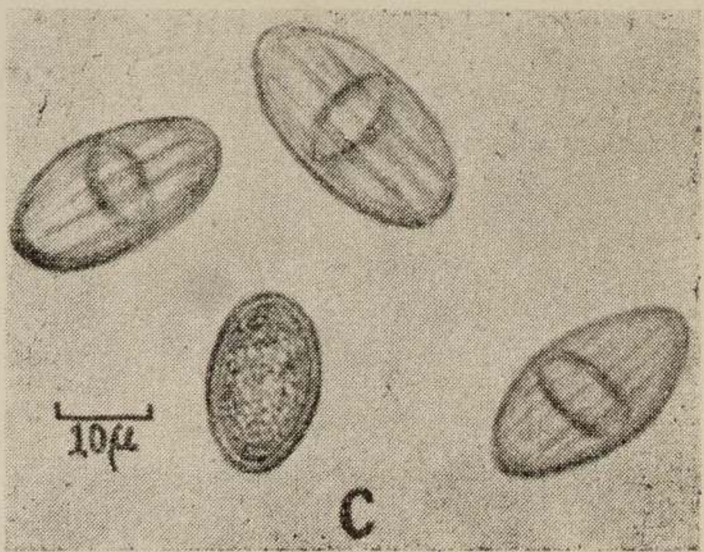

Fig. 2.(C)—Pycnidiospores of *Botryodiplodia theobromae*