

## STUDIES ON PADDY CULTIVATION—VIII

THE EFFECT OF SPACING AND METHOD OF  
PLANTING ON YIELD

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The "village" method of transplanting paddy in Ceylon is to put in bunches of three or four seedlings, about four inches apart; observations made by Mr. K. D. S. S. Nanayakkara, Assistant in Economic Botany, on an experimental area at Peradeniya suggested that, at any rate where soil conditions were good, a better yield might be obtained if the plants were given more room in which to develop. Accordingly an experiment was planned, in which four spacings were compared; they were eighteen, twelve, and eight inches each way, with the normal four by four inches as control. At the same time, the effect was compared of putting a single seedling or three seedlings to a hill. The advantage of putting three seedlings is to create a feeling of confidence that at least one will reach maturity, and from the last paper of this series (10) it would appear that such confidence is well founded; on the other hand, the seed rate is increased, and it is not established that the loss of plants in the seedling stage as a result of single planting, will justify the extra seed required for triple planting. It is also possible that the spacing may determine whether one or three seedlings per hill are better.

Optimum spacing is likely to vary with fertility, and the trials were run in three series, on what were considered to be good, average and poor fields. There were thus twenty-four treatments for comparison, as set out below.

Four spacings (18 in., 12 in., 8 in., and 4 in.) combined with  
Two methods of sowing (single seedlings and three  
seedlings per hill) combined with  
Three soil types (rich, medium and poor).

The trials were further planned to make observations from two points of view—one, that of the development of the individual plant, and two, the effect of spacing on yield per acre. Accordingly, the above twenty-four treatments were sown in duplicate; one set in which each plot had the same number of plants, and in which it was intended to collect data from individual plants (to be called henceforward the plot trials), and another set in which all plots were of the same size, in which plot yields only were to be recorded (to be known as the field trials). In the plot trials, each treatment was to be replicated ten times, and in the field trials six times, and the plots were to be randomized.

The complete trial, of 384 plots, was sown for the *maha* 1935-36 season. The field trials were destroyed by a circumstance completely unconnected with the experiment (or even with agriculture) and the plot trials alone were harvested. The field trials were repeated during the next (*yala* 1936) season, and again during the *maha* 1936-37 season, since different varieties of paddy are sown during the two seasons, and comparison between them is not always reliable. It was not possible to repeat the plot trials, so that comparison between plot and field results is weakened by their being obtained in different seasons; on the other hand, both series of field trials were carried out on the same land that had been used previously for the plot trials, an advantage which may more than compensate for seasonal effect under tropical conditions.

There was one difference of treatment between plot trials and field trials; in the former, grown under experimental conditions, every effort was made to protect plants from being bitten off and destroyed by the land crab (*Paratelphusa Ozitelphusa hydrodromus*) which is the principal enemy of the paddy seedling in Ceylon. In the field trials, grown under agricultural conditions, no special precautions were taken; but counts were made of the gaps in the plots which may serve to indicate the relative importance of crab attack to the young seedling.

#### FIELD TRIALS

The field trials were carried out in plots of 1/200 acre, with borders, randomized and replicated six times. Seed was sown in nurseries and transplanted; at harvest, records were made for each plot, of weight of grain, weight of straw, weight of empty grain and the percentage of plants to reach maturity.

In the *yala* 1936 trial, the variety used was *Vellai-illankalayan* 28061. It was sown in nurseries on March 21, 1936, transplanted on April 21-24 and harvested on September 1-10. Transplanting was done by fields, the poor field being planted first, and the rich field last. Harvesting was done by treatments, each being harvested as it became ripe.

The *maha* 1936-37 trial was sown with *Mawi* B-11, which was put in nurseries on August 24, 1936, transplanted on October 7-13 and harvested between March 10-20, 1937. In both trials, the closely spaced plots (whether threes or singles) were harvested first, followed progressively by the more widely-spaced treatments (Table I.); the effect of wider spacing has been to delay maturity, and the type of soil appears to have had no effect.

TABLE I

## Effect of spacing on age

Measured by Days from sowing to harvest.

*Yala 1936.*

Spacing	Days	Spacing	Days
Single seedlings at 18 in. ..	173	Three seedlings at 18 in. ..	173
„ 12 „ ..	173	„ 12 „ ..	173
„ 8 „ ..	170	„ 8 „ ..	170
„ 4 „ ..	164	„ 4 „ ..	164

*Maha 1936-37.*

Spacing	Days	Spacing	Days
Single seedlings at 18 in. ..	209	Three seedlings at 18 in. ..	209
„ 12 „ ..	204	„ 12 „ ..	204
„ 8 „ ..	202	„ 8 „ ..	202
„ 4 „ ..	199	„ 4 „ ..	199

The *yala* grain results are given in Table II, and the analysis of variance in Table III. The trial is treated as a complex experiment, so that the effect of soil type may be measured.



TABLE III  
Field Trials—Yala 1936

Analysis of Variance for Grain data

	Degrees of Freedom	Sum of Squares	Mean Square	Standard Deviation	loge S. D.	Z	Level of Significance
Blocks	..	395.4017	26.3601	5.134	1.6359	1.2775	.. 1 per cent.
Treatments—							
Methods	1	48.4532	48.4532	6.961	1.9403	1.5819	.. 1
Spacings	3	231.7078	77.2359	8.788	2.1734	1.8150	.. 1
Spacings × Methods	3	21.1473	7.0491	2.655	0.9765	0.6181	..
Fields	2	313.7972	156.8986	12.526	2.5277	2.1693	.. 1 per cent.
Treatments × Fields	14	42.3188	3.0228	1.739	0.5532	0.1948	..
Error	105	214.9203	2.0469	1.431	0.3584		..
Total	..	1267.7463					

Standard deviation of a single plot is 1.431 lb.

Significant differences between groups of plots are : for 6 plots, 14.8 lb.; for 12 plots, 21 lb.; for 18 plots, 25.8 lb.; for 24 plots, 29.6 lb.; for 36 plots, 36.9 lb.; for 48 plots, 42 lb.; and for 72 plots, 51.6 lb.

From the analysis of variance, we may draw the following conclusions :—

1. There is a significant difference between the fertility of the three soil types, as measured by yield of grain obtained on them. The field totals are : Rich 471·06 lb., Medium 374·60 lb., and Poor 297·87 lb. Differences of 42 lb. are significant, so that rich is better than medium and medium than poor. At the same time, the absence of a significant interaction between fields and treatments and the fact that the order of yield is the same for all three soil types, suggest that neither treatment is affected by the differences in fertility, and that corresponding field totals may be grouped for purposes of further comparison.

2. There are significant differences between yields at the different spacings. The totals for all soil types are—

18"	..	..	..	210·00
12"	..	..	..	299·06
8"	..	..	..	302·34
4"	..	..	..	332·13

and differences of 36·4 lb. are significant ; spacing at 18 in. is therefore inferior to all other spacings, which do not differ among themselves, although there is a suggestion that the 4 in. spacing is superior to the 12 in. spacing.

3. There is a significant difference between methods of planting. Grouping for soil types, the totals are—

Single seedlings	..	..	530·00 lb.
Three seedlings	..	..	613·53 ,,

The significant difference is 51·6 lb. so that planting three seedlings to a hill has given a significantly higher yield than planting single seedlings only, irrespective of soil type and of spacing. If, however, we examine the results in more detail, we shall find that the superiority of the three seedlings per hill varies with the spacing ; it is there for all spacings, but its value is only significant at 18 in. Thus, although the yields at the different spacings are not affected by the method of planting, the reverse is not the case, and it is only at the widest spacing that three seedlings per hill appear to be justifiable. The interaction between spacings and methods just fails to be significant, which will account for the inconsistency of the results quoted above.

**TABLE IV**  
**Field Trials—Maha, 1936-37**  
 Yield of Grain in lb.

	Singles						Threes						Totals		
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	S	T	S+T
<i>Poor Soil Blocks</i>															
18 in.	4.25	4.87	4.38	2.87	3.38	2.62	10.00	5.75	11.00	5.56	5.44	6.75	22.37	44.50	66.87
12 "	6.50	9.19	9.12	6.13	5.37	7.19	9.56	7.75	10.50	10.75	9.00	7.75	43.50	55.31	98.81
8 "	8.88	7.87	7.25	8.38	8.50	10.12	9.75	9.38	9.87	9.88	11.50	11.62	51.00	62.00	113.00
4 "	11.25	14.25	11.00	11.75	12.62	17.50	12.50	8.50	11.13	12.50	13.00	14.87	78.37	72.50	150.87
Total	30.88	36.18	31.75	29.13	29.87	37.43	41.81	31.38	42.50	38.69	38.94	40.99	195.24	234.31	429.55
Block Total	72.69	67.56	74.25	67.82	68.81	78.42									
<i>Medium Soil</i>															
18 in.	7.13	4.81	7.88	5.75	5.25	5.62	5.87	10.87	9.19	13.25	3.25	7.19	36.44	49.62	86.06
12 "	7.56	10.75	9.88	6.87	4.88	9.37	11.25	11.62	13.19	11.19	9.13	6.87	49.31	63.25	112.56
8 "	9.13	9.50	11.63	8.12	8.75	8.31	10.75	11.37	14.00	13.50	6.44	11.25	55.44	67.31	122.75
4 "	12.63	13.81	13.56	14.00	11.87	8.19	12.12	12.25	13.50	7.25	9.63	9.12	74.06	63.87	137.93
Total	36.45	38.87	42.95	34.74	30.75	31.49	39.99	46.11	49.88	45.19	28.45	34.43	215.25	244.05	459.30
Block Total	76.44	84.98	92.83	79.93	59.20	65.92									
<i>Rich Soil</i>															
18 in.	7.31	7.12	4.63	5.25	3.75	3.88	16.12	10.38	8.69	4.87	8.63	11.87	31.94	60.56	92.50
12 "	12.25	9.75	7.75	7.50	9.25	4.87	12.37	12.50	12.50	9.75	11.25	7.13	51.37	65.50	116.87
8 "	10.37	12.63	11.37	8.13	9.62	7.38	13.00	15.37	13.75	10.63	12.87	10.88	59.50	76.50	136.00
4 "	15.50	14.50	13.62	14.88	15.37	12.75	14.00	16.75	14.25	13.50	14.37	13.63	86.62	86.50	173.12
Total	45.43	44.00	37.37	35.76	37.99	28.88	55.49	55.00	49.19	38.75	47.12	43.51	229.43	289.06	518.49
Block Total	100.92	99.00	86.56	74.51	85.11	72.39							Grand Total		1,407.34

**TABLE V**  
**Field Trials—Maha 1936-37**  
 Analysis of Variance for Grain data

	Degrees of Freedom	Sum of Squares	Mean Square	Standard Deviation	loge S. D.	Z	Level of Significance
Blocks	..	195.4509	13.0301	3.6097	1.2837	0.7096	..
Treatments---							
Methods	..	112.8906	112.8906	10.6249	2.3633	1.7892	..
Spacings	..	677.6129	225.8709	15.0290	2.7100	2.1359	..
Methods x Spacings	..	96.2446	32.0815	5.6641	1.7338	1.1597	..
Fields	..	85.4086	42.7043	6.5349	1.8772	1.3031	..
Treatments x Fields	..	50.3600	3.5971	1.8966	0.6402	0.0661	..
Error	..	323.5101	3.0811	1.7553	0.5741	..	..
Total	..	1541.4777					

Standard deviation of a single plot is 1.7553 lb.

Significant differences between groups of plots are: for 6 plots, 18.2 lb.; for 12 plots, 27 lb.; for 18 plots, 31.6 lb.; for 24 plots, 36.5 lb.; for 36 plots, 44.7 lb.; for 48 plots, 54 lb.; and for 72 plots, 63.2 lb.

The *maha* grain results are given in Table IV. and the analysis of variance in Table V., from which we draw the following conclusions :—

1. As in the *yala* results, there is a significant difference between the yields of the three soil types. Further examination reveals, however, that the difference is only partial; the yield totals are: Poor 429·55 lb., Medium 459·30 lb. and Rich 518·49 lb., and significant differences are not less than 51·6 lb. so that the rich soil has given a significantly better yield than either of the others, which do not differ significantly among themselves. As before, there is no significant interaction between fields and treatments, so that results may again be grouped.

2. There are significant differences between the yields of the spacing treatments. The grand totals are :—

18"	..	..	245·43 lb.
12"	..	..	328·24 „
8"	..	..	371·75 „
4"	..	..	461·92 „

and significant differences are not less than 44·7 lb. Thus, 18 in. is again inferior to all other spacings, but in addition, the 4 in. spacing has beaten all others. The significance of these differences is unaffected if the field totals are analysed separately.

3. There is a significant difference between methods of planting. The grand totals are single seedlings 639·92 lb., three seedlings 767·42 lb. and the level of significance is 63 lb. so that three seedlings per hill have given a significantly higher yield than single seedlings.

4. There is a significant interaction between methods and spacings, and these results must be examined in more detail. At 18 in., 12 in., and 8 in., three seedlings give a significantly higher yield than single seedlings, but at 4 in. the single planting has given the higher yield, though the difference is not significant. The figures are given below, for comparison with the level of significance of 31·6 lb.

Spacing			Difference threes—singles
18"	..	..	+ 63·93 lb.
12"	..	..	+ 39·88 „
8"	..	..	+ 39·87 „
4"	..	..	— 16·18 „

The marked superiority of the multiple planting at 18 in. is worthy of notice.

If we examine the effect of method of planting on spacing, we find that where single seedlings were planted, the general result is repeated, *i.e.*, 4 in. is superior to all others, and 18 in. is inferior to all others. Where three seedlings per hill are planted, however, the 4 in. spacing loses its superiority over the

8 in., and the 12 in. just fails to beat the 18 in. These results indicate a general tendency—that where the spacing is as close as 4 in., three seedlings per hill are not necessary, but as the spacing distance increases, they become desirable or even essential, but even then they fail to compensate for the smaller number of hills to the acre.

If we take into consideration that these trials were carried out in different seasons and with different varieties, the results are remarkably consistent. They indicate that a spacing of 18 in. each way is too wide, even when compensated by the planting of three seedlings per hill; that yields increase progressively as the spacing is decreased, and that 4 in. each way is the best spacing tried, though not necessarily the optimum spacing for either variety grown; that at a spacing of 4 in., three seedlings per hill offer little or no advantage over single seedlings. These results were not materially affected by the type of soil in which the plants were growing, although the types used gave significantly-different yields; at the same time, there is a definite tendency for the superiority of the closer spacings to be more pronounced on the poorer soils.

TABLE VI  
Yields of empty grains as percentages by weight of plot yields

	Yala 1936			Maha 1936-37		
	Poor Soil	Me- dium Soil	Rich Soil	Poor Soil	Me- dium Soil	Rich Soil
Single seedlings at 18 in. ..	6.1	8.4	7.2	5.0	6.0	7.4
"      12 " ..	3.8	7.7	6.4	4.7	6.4	5.7
"      8 " ..	6.9	5.7	6.1	5.4	5.8	6.6
"      4 " ..	6.1	6.3	7.5	4.5	4.6	6.5
Three seedlings at 18 in. ..	4.8	6.9	7.9	5.5	7.2	5.9
"      12 " ..	5.7	7.2	8.1	4.8	5.4	5.0
"      8 " ..	6.5	7.7	10.1	4.8	5.3	5.0
"      4 " ..	6.9	6.6	10.8	5.0	6.0	7.3

S. D. = 2.15 per cent.

S. D. = 1.29 per cent.

The records of empty grains are given in Table VI. They are expressed as percentages of the plot yields and are reasonably uniform. In the *maha* figures there is a tendency for the amount of empty grains to decrease as the spacing decreases, but the movement is not regular, and if the figures are considered as a population, no two of them are significantly different. The *yala* figures are more irregular, but there is no indication of a trend of movement in any direction. Considered as a population, two of them (3.8 and 10.8) are significantly different, but the difference has no practical application. There has not been, in these trials, that disproportionate waste of crop in immature tillers that has sometimes been stated to be the result of wide planting.

**TABLE VII**  
**Field Trials—Yala 1936**  
 Yield of Straw in lb.

	Singles						Threes						Totals			
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	S	T	S+T	
<i>Poor Soil</i>																
18 in.	2	2	8	6	10	6	3	3	7	10	15	12	34	50	84	
12 "	9	5	7	11	8	8	8	11	15	15	15	12	48	66	114	
8 "	4	5	7	11	15	11	5	7	10	11	10	10	53	53	106	
4 "	8	8	9	12	10	10	10	10	15	12	10	10	57	69	126	
Total	23	20	31	40	43	35	26	30	35	50	53	44	192	238	430	
Block Total	49	50	66	90	96	79										
<i>Medium Soil</i>																
18 in.	12	14	13	13	3	7	15	18	11	15	8	9	62	76	138	
12 "	14	15	19	25	8	16	15	17	23	16	16	12	97	99	196	
8 "	13	13	10	14	7	10	10	12	13	16	9	14	67	74	141	
4 "	10	13	14	14	11	16	15	15	16	18	10	12	78	86	164	
Total	49	55	56	66	29	49	55	62	63	65	43	47	304	335	639	
Block Total	104	117	119	131	72	96										
<i>Rich Soil</i>																
18 in.	10	14	8	9	12	20	21	22	10	8	20	20	73	101	174	
12 "	26	16	12	16	15	12	26	25	18	20	14	12	97	115	212	
8 "	18	16	12	6	10	11	20	20	11	12	10	11	73	84	157	
4 "	18	15	16	9	14	9	22	22	15	15	12	12	81	98	179	
Total	72	61	48	40	51	52	89	89	54	55	56	55	324	398	722	
Block Total	161	150	102	95	107	107										
Grand Total	.. 1,791															

**TABLE VIII**

**Field Trials—Yala 1936**

Analysis of Variance for Straw data

	Degrees of Freedom	Sum of Squares	Mean Square	Standard Deviation	loge S. D.	Z	Level of Significance
Blocks	..	1004.7708	66.9847	8.184	2.1022	1.0289	.. 1 per cent.
Treatments—							
Methods	..	158.3403	158.3403	12.583	2.5323	1.4590	.. 1 "
Spacings	..	293.2431	97.7477	9.887	2.2912	1.2179	.. 1 "
Methods × Spacings	..	22.2430	7.4143	..	..	..	..
Fields	..	943.2917	471.6459	21.717	3.0781	2.0048	.. 1 per cent.
Treatments × Fields	..	129.4861	9.2490	3.041	1.1122	0.0389	..
Error	..	898.0625	8.5530	2.925	1.0733	..	..
Total	..	3449.4375					

Standard deviation of a single plot is 2.925 lb.

Significant differences between groups of plots are: for 6 plots, 30.39; for 12 plots, 43 lb.; for 18 plots, 52.6 lb.; for 24 plots, 60.8 lb.; for 36 plots 74.5 lb.; for 48 plots, 86 lb.; and for 72 plots, 105.3 lb.

The *yala* straw weights are given in Table VII. and the analysis of variance in Table VIII. The following conclusions are drawn from the data.

1. The results are identical with the corresponding figures for grain, with the exception of the order of merit at different spacings. If the yields are summarized, we have the following result.

18"	..	..	396 lb.
12"	..	..	522 "
8"	..	..	404 "
4"	..	..	469 "

The level of significance of differences for groups of 36 plots is 74.5 lb., and from the data, the 12 in. spacing has given a higher straw yield than either the 8 in. or the 18 in. Further analysis shows that the superiority of the 12 in. spacing is confined to the medium and rich soils, and that in the poor series, the 4 in. spacing gives the highest straw yield, with the 12 in. spacing second. A comparison of spacing and methods of planting shows that the 12 in. spacing leads whether one or three seedlings are planted; otherwise, the 18 in. spacing has the poorest straw yield for single seedlings but the 8 in. spacing is poorest where three seedlings per hill were planted. These results bear no relation to the corresponding grain weights.

2. On the total yields, three seedlings per hill are superior to a single seedling. The totals are 971 lb. and 820 lb. respectively and the level of significance is 105 lb. A detailed examination shows that this significant superiority is built up from a series, of which no member is itself significant. In each group of twelve plots, the six planted with three seedlings per hill have given a bigger yield than the six planted with single seedlings, but the differences are nowhere significant, and the superiority decreases as the spacing becomes less. If we compare methods of planting with spacing, we find that only at 18 in. have the three seedlings given a significantly higher yield than the single seedling. Nevertheless, the analysis of variance indicates that there is no interaction between spacing and methods.

The *maha* straw results are given in Table IX. and the analysis of variance in Table X. There are significant differences between fields, between spacings and between methods. The spacing totals are 18 in., 387.50 lb.; 12 in., 473.50 lb. 8 in., 493.25 lb.; and 4 in., 547.75 lb. The order of merit agrees with that for the grain weights, but the differences do not have the same significance. The 18 in. spacing is again inferior to all others, but the 4 in. spacing has not yielded a significantly greater amount of straw than the 8 in. spacing. The general agreement is, however, the same.

**TABLE IX**  
**Field Trials—Maha 1936-37**

Yield of Straw in lb.

	Singles						Threes						Totals		
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	S	T	S+T
<i>Poor Soil Blocks</i>															
18 in.	6.50	7.25	8.50	4.00	4.00	3.50	11.25	9.50	15.50	9.00	6.50	9.50	33.75	61.25	95.00
12 "	9.00	12.50	11.75	7.50	7.00	8.25	10.50	9.00	11.00	13.75	11.75	13.00	56.00	69.00	125.00
8 "	10.50	11.00	8.00	9.50	9.50	15.75	10.00	11.50	9.50	11.75	14.00	14.00	64.25	70.75	135.00
4 "	11.25	15.25	9.25	10.00	15.00	14.50	14.00	10.25	19.00	14.50	14.75	19.00	75.25	91.50	166.75
Total	37.25	46.00	37.50	31.00	35.50	42.00	45.75	40.25	55.00	49.00	47.00	55.50	229.25	292.50	521.75
Block Total	83.00	86.25	92.50	80.00	82.50	97.50									
<i>Medium Soil</i>															
18 in.	12.50	10.25	12.00	10.50	13.00	12.25	12.00	20.00	14.25	16.00	12.00	13.50	70.50	87.75	158.25
12 "	11.25	16.50	15.00	10.00	13.00	14.00	16.00	15.75	21.00	17.00	13.50	12.50	79.75	95.75	175.50
8 "	10.50	12.50	16.50	13.50	12.50	15.00	12.00	16.50	23.50	14.25	16.50	16.00	80.50	98.75	179.25
4 "	12.75	15.00	17.00	15.00	15.50	13.50	15.50	16.25	12.75	11.00	12.50	13.00	88.75	81.00	169.75
Total	4.700	54.25	60.50	49.00	54.00	54.75	55.50	68.50	75.50	58.25	54.50	55.00	319.50	363.25	682.75
Block Total	10.250	122.75	132.00	107.25	108.50	109.75									
<i>Rich Soil</i>															
18 in.	14.00	14.25	6.00	7.50	6.50	7.00	21.25	16.50	10.00	7.25	9.00	15.00	55.25	79.00	134.25
12 "	16.50	13.00	9.50	12.00	13.50	12.00	15.00	20.50	14.50	18.00	14.50	14.00	76.50	96.50	173.00
8 "	16.50	16.25	14.50	9.50	11.50	10.50	18.00	21.00	18.00	11.00	18.75	13.50	78.75	100.25	179.00
4 "	18.00	19.00	16.00	14.50	16.75	15.00	21.50	19.00	15.50	18.00	20.00	18.00	99.25	112.00	211.25
Total	65.00	62.50	46.00	43.50	48.25	44.50	75.75	77.00	58.00	54.25	62.25	60.50	309.75	387.75	697.50
Block Total	140.75	139.50	104.00	97.75	110.50	105.00									
														Grand Total	1902.00

**TABLE X**  
**Field Trials—Maha 1936-37**

Analysis of Variance for Straw data

	Degrees of Freedom	Sum of Squares	Mean Square	Standard Deviation	loge S. D.	Z	Level of Significance
Blocks	..	330.6849	..	4.695	1.5465	0.6729	..
Treatments—							
Methods	..	237.6736	..	15.417	2.7354	1.8618	..
Spacings	..	368.9757	..	11.090	2.4057	1.5321	..
Methods x Spacings	..	31.3229	..	3.179	1.1566	0.2830	..
Fields	..	396.0182	..	14.072	2.6439	1.7703	..
Treatments x Fields	..	165.1138	..	3.434	1.2338	0.3602	..
Error	..	602.4609	..	2.395	0.8736	..	..
<b>Total</b>	<b>..</b>	<b>2132.2500</b>					

Standard deviation of a single plot is 2.4 lb.

Significant differences between groups of plots are, for 6 plots, 25 lb.; for 12 plots, 35.2 lb.; for 18 plots, 43.1 lb.; for 24 plots, 50 lb.; for 36 plots, 16 lb.; for 48 plots, 70.4 lb.; and for 72 plots, 86.2 lb.

2. Three seedlings per hill are better than a single seedling. The total yields are: threes, 1,043·50 lb.; singles, 858·50 lb.; and the level of significance is 86·2 lb. The superiority again decreases with spacing, but is significant for all but the narrowest.

The straw weights, while in general agreement with the corresponding grain weights, are much less uniform, both with them and with one another.

#### PLOT TRIALS

The plot trial was carried out in the *maha* 1935-36 season. The plots of each series were together in one banded field; eighty plots formed a series, consisting of ten replications of each of eighty treatments; thus the complete trial comprised two hundred and forty plots. Each plot consisted of twenty five plants transplanted in the form of a square, of which the border row (of sixteen plants) was harvested separately, and only the inner nine plants were counted in the trial. Since the object of the trial was to determine the effect of treatment on the individual plant, it was necessary that each plant harvested should fulfil the conditions of the trial: accordingly at harvest, any plant that was not completely surrounded by other plants at the correct spacing was discarded. This precaution was responsible for a further one. The smallness of individual plots (whose size was determined by the condition that a complete series should be enclosed within one banded field) made it desirable that as many plants as possible should reach maturity, and special measures were taken to prevent the attacks of the land crab (*Paratelphusa Ozioatelphusa hydrodromus*) which is the chief enemy of the paddy plant in the seedling stage. Losses did occur, but to a less degree than under field conditions; at the same time, the eradication of weeds was more thorough than it would be under field conditions, and the calculated yields per acre were in consequence disproportionately high.

At harvest, the following data were recorded:—

- (1) Number of plants harvested per plot.
- (2) Number of mature earheads per plot.
- (3) Number of immature earheads per plot.
- (4) Number of grains per plot.
- (5) Weight of grains per plot.

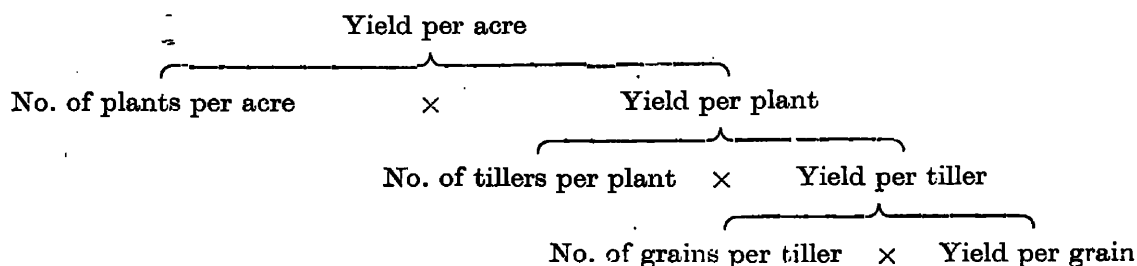
From these data, the following means were calculated.

- (1) Mean number of mature ears per plant.
- (2) Mean number of immature ears per plant.

- (3) Mean number of grains per plant.
- (4) Mean number of grains per tiller.
- (5) Weight of grain per plant.
- (6) Weight of grain per tiller.
- (7) Weight of a single grain.
- (8) Calculated yield per acre.

Because gaps in the plots did occur, which resulted in different numbers of plants being harvested from different plots, and because the gaps were not the result of the treatments under examination, it was not possible to treat the plot data by the method of the analysis of variance. Means were calculated for each plot, and from them for each treatment, with an estimate of the standard deviation of each mean so that they could be compared. The data are presented in Table XI.

We may analyse the quantity 'yield per acre' according to the following diagram :—



From the data which have been collected, it is proposed to examine this analysis in detail, to discover if possible whether any stage in it is of paramount importance. Our data in this part of the examination take us upwards only so far as yield per plant; the number of plants per acre is taken as the theoretical maximum, and the yield per acre is consequently a calculated one, which we may hope will give indications of comparative performance but on the actual figures of which we can place no reliance. The field trials will provide more reasonable estimates of yield per acre.

#### YIELD PER PLANT

The data calculated for yield per plant should more correctly be designated yield per hill, since we are comparing treatments in which different members of plants comprise a hill. The data

TABLE XI  
Plot Trials, Maha 1935-36—Means

Treatment	1 Mature ears per plant	2 Immature ears per plant	3 Grains per ear	4 Weight per grain in gms.	5 Yield per earhead in gms.	6 Yield per plant in gms.	7 Yield per sq. yd. in gms.	8 Plants per sq. yd.
<i>Poor</i>								
18" Single	12.55±0.38..	1.01±0.13..	96.74±3.23..	0.0303±0.0006..	2.90±0.064..	36.27±1.28..	145.08..	4
12" "	9.00±0.35..	0.31±0.07..	100.38±2.10..	0.0295±0.0002..	2.84±0.073..	26.68±1.22..	240.12..	9
8" "	4.82±0.19..	0.17±0.05..	99.48±2.34..	0.0323±0.0009..	3.21±0.097..	15.31±0.58..	310.03..	20.25
4" "	2.65±0.12..	0.04±0.016..	92.61±3.20..	0.0307±0.0003..	2.85±0.109..	7.51±1.23..	608.31..	81
18" Threes	16.79±0.48..	0.64±0.11..	107.23±2.22..	0.0292±0.0001..	3.13±0.070..	52.22±1.55..	208.88..	4
12" "	9.23±0.31..	0.52±0.11..	105.95±2.29..	0.0299±0.0003..	3.18±0.060..	29.43±1.33..	264.87..	9
8" "	6.09±0.11..	0.29±0.06..	94.43±2.07..	0.0301±0.0002..	2.84±0.066..	17.37±0.64..	351.74..	20.25
4" "	3.10±0.10..	0.03±0.01..	62.64±2.64..	0.0309±0.0003..	1.94±0.087..	6.07±0.35..	491.67..	81
<i>Medium</i>								
18" Single	10.19±0.19..	1.00±0.13..	118.52±2.69..	0.0288±0.0006..	3.41±0.115..	34.88±1.48..	139.52..	4
12" "	8.02±0.12..	0.42±0.08..	121.30±1.78..	0.0300±0.0003..	3.64±0.057..	29.18±0.63..	262.62..	9
8" "	4.52±0.10..	0.39±0.08..	116.60±2.83..	0.0317±0.0004..	3.68±0.089..	16.68±0.53..	337.77..	20.25
4" "	2.37±0.08..	0.27±0.07..	107.48±2.18..	0.0312±0.0002..	3.35±0.067..	7.97±0.28..	645.57..	81
18" Threes	13.87±0.47..	1.19±0.13..	117.08±1.58..	0.0299±0.0001..	3.50±0.052..	48.72±1.97..	194.88..	4
12" "	9.38±0.13..	0.29±0.09..	116.33±2.42..	0.0306±0.0003..	3.54±0.058..	32.09±1.43..	288.81..	9
8" "	6.19±0.14..	0.40±0.07..	100.86±1.40..	0.0310±0.0001..	3.10±0.048..	19.13±0.50..	387.38..	20.25
4" "	3.36±0.07..	0.12±0.03..	78.50±1.63..	0.0304±0.0003..	2.39±0.051..	8.04±0.28..	651.24..	81
<i>Rich</i>								
18" Single	21.08±0.42..	2.37±0.16..	122.60±1.81..	0.0289±0.0004..	3.54±0.055..	74.66±1.78..	298.64..	4
12" "	11.99±0.39..	1.64±0.21..	129.17±3.11..	0.0296±0.0004..	3.84±0.093..	45.57±1.28..	410.13..	9
8" "	6.37±0.22..	0.48±0.08..	131.98±2.75..	0.0305±0.0001..	4.02±0.093..	25.59±1.02..	518.20..	20.25
4" "	3.31±0.12..	0.26±0.08..	114.25±3.51..	0.0306±0.0003..	3.50±0.107..	11.46±0.48..	928.26..	81
18" Threes	22.62±0.35..	2.20±0.21..	132.25±2.78..	0.0284±0.0005..	3.77±0.122..	84.79±2.27..	339.16..	4
12" "	12.00±0.22..	1.58±0.25..	126.58±0.91..	0.0305±0.0004..	3.86±0.023..	46.37±0.85..	417.33..	9
8" "	6.52±0.18..	0.43±0.09..	112.67±1.60..	0.0306±0.0001..	3.44±0.051..	23.00±0.83..	465.75..	20.25
4" "	3.67±0.19..	0.29±0.07..	69.79±1.95..	0.0296±0.0003..	1.97±0.120..	7.53±0.43..	609.93..	81

are set out in Table XI. Col. 6. and indicate a regular progression from the widest spacing, which is the best, to the narrowest. The order is the same in all soil types and it is the same whether a hill is made up of one or of three plants. Differences are in all cases significant, and if we assume that, as in field trials, differences in fertility are not sufficient to affect the results of treatment, we may group the three series together to find a new set of means.

18" Single	..	..	48·60	±	0·88	gms.
12" "	..	..	33·81	±	0·63	"
8" "	..	..	19·19	±	0·43	"
4" "	..	..	8·98	±	0·44	"
18" Threes	..	..	61·91	±	1·13	"
12" "	..	..	35·96	±	0·71	"
8" "	..	..	19·83	±	0·39	"
4" "	..	..	7·21	±	0·21	"

It should be noted that here, as in the field trials the advantage of planting in groups of three decreases as the spacing decreases ; in fact, it is significant only at 18 in.

The order of merit is still the same and differences between treatments are still significant, with a single exception. The rich soil series shows a greater advantage in favour of the wider spacings, as may be expected.

If we calculate the yield per acre by multiplying the data given above by the theoretical number of plants per acre, we find that the order of merit is exactly reversed ; the close-placed plants give the highest yield per acre, and the widely spaced plants the poorest. The figures given below are in grams per square yard, which differ from the yield in bushels per acre only by a factor which is constant.

18" Single	..	..	194·41	gms/sq. yard
12" "	..	..	304·29	" "
8" "	..	..	388·67	" "
4" "	..	..	727·38	" "
18" Threes	..	..	247·64	" "
12" "	..	..	323·67	" "
8" "	..	..	401·62	" "
4" "	..	..	584·01	" "

These figures have no significance of their own, because they are calculated on a theoretical number of plants per acre but, because they reproduce the order of merit found in the field trials, they become of great importance, and indicate that number of plants per acre (*i.e.*, spacing) is an important determiner of yield per acre, and perhaps the most important of all.

### NUMBER OF TILLERS PER PLANT

It is seen that in every group of four treatments, any one treatment is better than all those below it, which is the result already obtained for yield per plant. In fact, of all the factors which go to make up the quantity 'yield per plant', this is the only one in which the order of merit is consistently the same as in the final product. The product of the remaining factors, which together give the quantity 'yield per tiller' does not remain constant, but its fluctuation is not sufficient to upset the influence of the number of tillers; it is therefore suggested that number of tillers matured is a limiting factor in the determination of the yield of the individual plant. The same conclusion was formed by Biffen and Engledow (6), working with wheat.

The influence of soil fertility is shown at the wider spacings, as will be seen from the table below.

Single	Threes
18" Rich > Poor > Medium	.. Rich > Poor > Medium
12" Rich > Poor or Medium	.. Rich > Poor or Medium
8" Rich > Poor or Medium	.. No differences
4" Rich > Poor or Medium	.. No differences

The so-called poor soil has given better results than the average soil, but the effect of the rich soil is seen to fall off as more plants are put into a given area. Except in the rich series, any spacing gives a better result where there are three plants to a hill than where there is only one.

### YIELD PER TILLER

In the remaining quantities, the order of merit varies from that found for yield per plant, and the variation is not in a constant direction. For example, in those sets of treatments in which three plants per hill are found, the heaviest tiller is produced at the 12 in. spacing, followed by 18 in., 8 in., and 4 in. If the corresponding treatments on different soil types are averaged, the order is still the same. In those sets of treatments in which one plant per hill was sown, the treatments do not agree among themselves. All have the heaviest earhead at 8 in., but thereafter the order of merit is 12 in., 18 in., and 4 in. for the medium and rich series, and 18 in., 4 in., and 12 in. for the poor series, the mean of the three series agreeing with the majority. In all sets but one, the 4 in. spacing has the lowest result, *i.e.*, the least number of tillers per plant is associated with the smallest earhead, but there the association stops. The largest earheads are produced by the intermediate spacings, and the widely spaced, many tillered plants have to be content to take second or third place.

### NUMBER OF GRAINS PER EAR

Again there is diversity of result. All the three-plant treatments agree with the data for yield per plant and tillers per plant in giving the largest earhead at the 18 in. spacing and the smallest at the 4 in., but they cannot be held to influence these quantities, since they do not influence yield per tiller. The single plant treatments, on the other hand, agree with nothing nor do they agree among themselves. It is true that the order of merit in the series on rich soil agrees with that for yield per ear, but the agreement must be regarded as a coincidence. The three-plant series agree with the results obtained with wheat, *i.e.*, that there is correlation between size and number of earheads, but the agreement is confined to the number of grains, and does not apply to their weight. The single plant series tend to produce the largest earhead at 12 in.

### YIELD PER GRAIN

In no case does the mean yield per grain show the same grading as either the number of grains per ear nor the weight of the earhead, but there is a tendency for large grains and small earheads to be associated. On the whole, the heaviest grain is produced at the 8 in. spacing, with 4 in. next, and the wide spacings last.

The general conclusions to be drawn from these analyses are, that number of tillers is the prime factor in the determination of plant yield, and that number of plants per acre (spacing) is the prime factor in the determination of acre yield. The wider the spacing, the more productive the plant because the more tillers it produces; but the gain in plant yield is not compensated for by the loss of plants per acre, and the yield per unit area falls. The optimum yield per acre will be obtained when both factors have their maximum value.

The results also suggest that superiority of close spacing is more pronounced on poor soils. Examination of yield versus spacing in three series (Plot, Field *maha* and, Field *yala*) suggests that where yields are lower, the wider spacings have an advantage, or rather, that the optimum spacing increases. It appears as though weed competition is of much more importance than at least, the soil differences, between series in this trial. The difference in condition between Plot and Field *maha* was probably largely one of weed control, and with the weeds removed there is room for so many more plants to develop earheads.

### THE OPTIMUM SPACING

A comparison of the yield figures in column 6 of Table XI. with the corresponding spacings shows a relationship that may

be expressed graphically by a hyperbolic curve, and that appears to be governed by the general formula—

$$y = ax^b + c$$

where  $y$  = yield per hill.

$x$  = spacing, expressed as number of hills per unit area ;  $a$ ,  $b$ , and  $c$  = constants.

The plot weights were measured in grams and the spacing in inches; accordingly in the calculations that follow  $y$  has been expressed throughout in grams and  $x$  in hills per square yard. The use of units other than these will alter the constants, but they will not affect the general relationship nor the form of the curve which expresses that relationship.

The curves of  $y$  vs.  $x$  have been plotted for all three trials and samples are reproduced on Fig. I. They show a rapid initial decrease in yield per hill as the number of hills per unit area increases, but the loss soon falls off, and a stage is soon reached where closer spacing produces only a slight decrease in yield per hill, whereas the increasing number of plants per unit area should produce a larger and larger acre yield. By inspection of these curves, therefore, we might deduce that the optimum spacing is somewhat to the right of (*i.e.* greater than) the value of  $x$  at the point at which the curve flattens.

We have a more accurate means of determination. If  $y$  represents the yield per hill and  $x$  the number of hills per unit area, then the greatest acre yield will correspond with the maximum value of  $xy$ , and the optimum spacing will be the value of  $x$  when  $xy$  is a maximum. Therefore, since—

$$y = ax^b + c$$

$xy = ax^{(b+1)} + cx$ , and  $xy$  will be a maximum when  $ax^{(b+1)} + cx$  is a maximum.

$$\text{Let } ax^{(b+1)} + cx = z.$$

Then  $z$  is a maximum or a minimum when  $\frac{dz}{dx} = 0$

$$\frac{dz}{dx} = a(b+1)x^b + c$$

when  $\frac{dz}{dx} = 0$ ,  $a(b+1)x^b + c = 0$

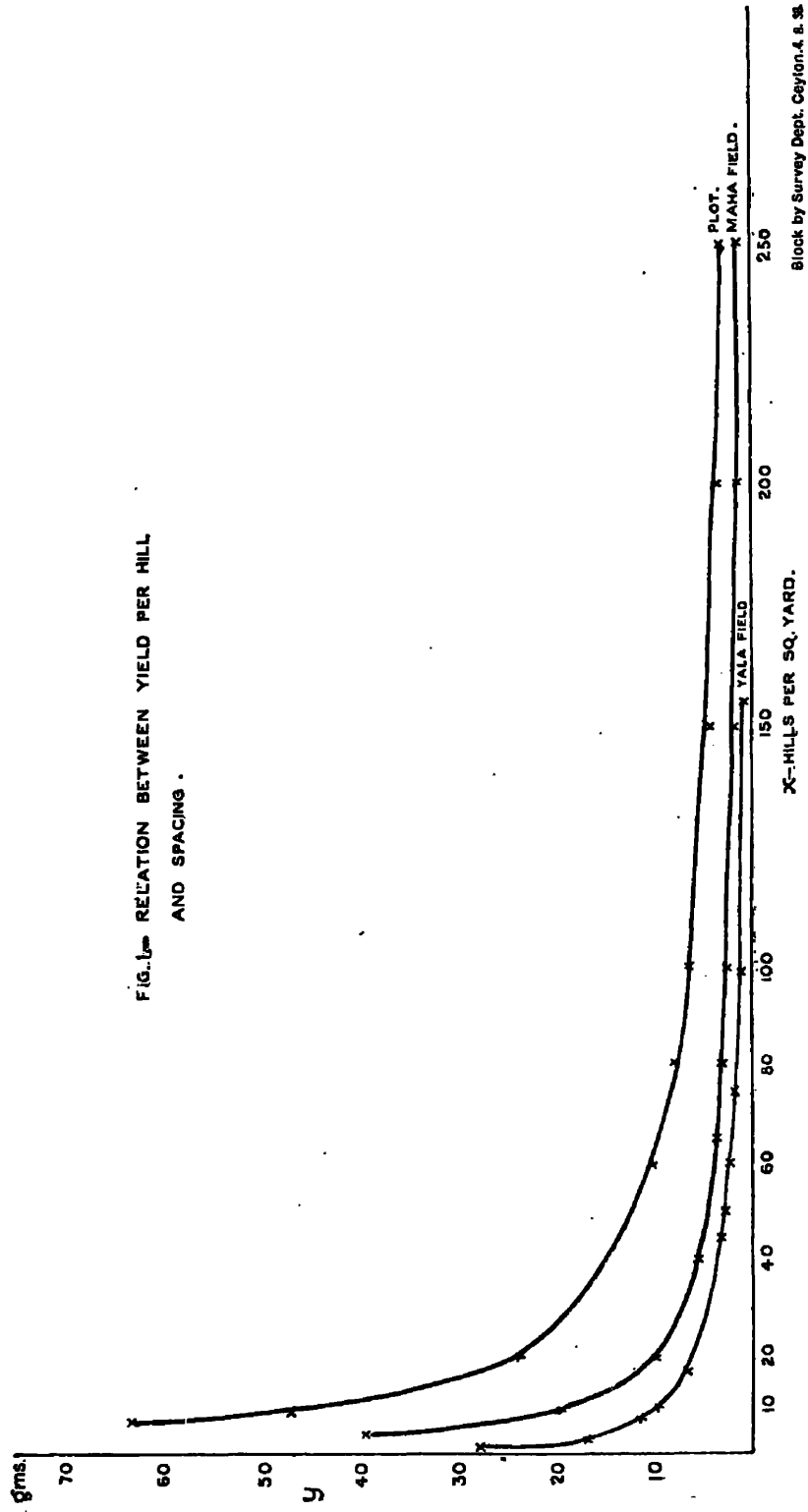
whence  $x^b = \frac{-c}{a(b+1)}$

and  $x = \left( \frac{-c}{a(b+1)} \right)^{\frac{1}{b}}$

This will be a maximum, as opposed to a minimum, value, if  $\frac{d^2z}{dx^2}$  is negative.

Now  $\frac{d^2z}{dx^2} = ab(b+1)x^{b-1}$ , and it has been found in every case examined, that  $a$  is positive and  $b$  negative and less than unity. In the expression above, therefore  $a \cdot b + 1$  and

FIG. 1.—RELATION BETWEEN YIELD PER HILL  
AND SPACING.



Block by Survey Dept. Ceylon. 4. 8. 38

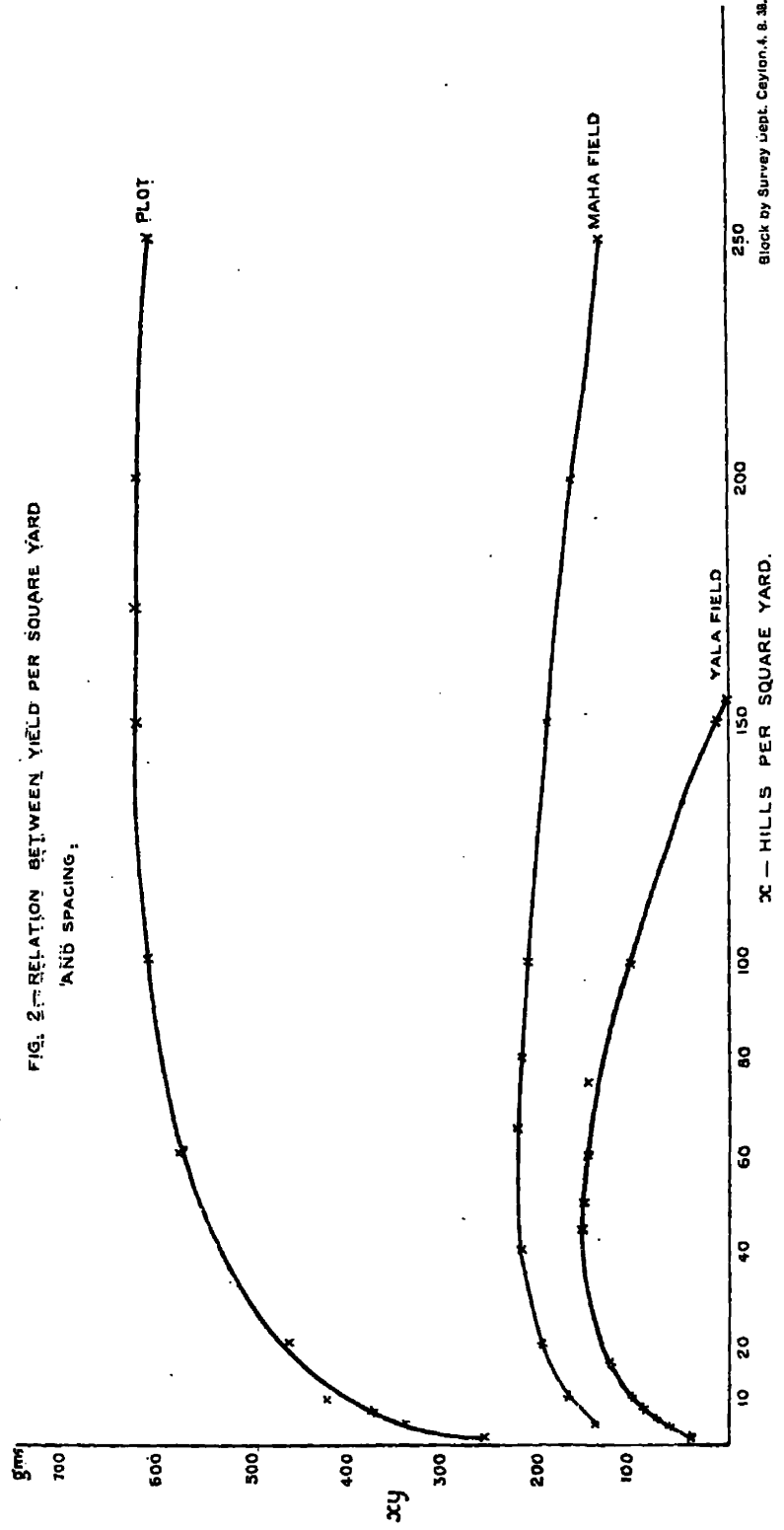


FIG. 2 - RELATION BETWEEN YIELD PER SQUARE YARD AND SPACING:

Block by Survey Dept. Ceylon, 4. 8. 35.

and  $x^b - 1$  are positive,  $b$  is negative and the product is negative. Accordingly the value  $x = \left( -\frac{c}{a(b+1)} \right)^{\frac{1}{b}}$  represents a maximum value of  $xy$ , and will correspond with a maximum yield.

The constants  $a$ ,  $b$  and  $c$  have been determined for the plot data from the records in Table XI (columns 6 and 8). The formula  $y = ax^b + c$  reduces to  $\log(y - c) = \log a + b \log x$  and values of  $c$  were found which gave straight lines when  $\log(y - c)$  was plotted against  $\log x$ . The other constants were then determined by substitution of known values of  $x$  and  $y$  in the logarithmic equation given above. The values of the constants, together with that value of  $x$  which corresponds to a maximum value of  $xy$ , are given in Table XII. With one exception, they form a uniform series, and suggest that under the conditions of the experiment, closer planting could be adopted with advantage. There is also a suggestion where single seedlings are planted, that the spacing may be wider on good soils than on poorer ones; with three seedlings to a hill, the soil differences in the areas used for the experiment are not sufficiently great to warrant any difference in spacing.

The determination of the relationship between yield and spacing in the field trials was not such an easy matter. The data available were mean yields per plot in pounds (from Tables II. and IV.) and a count of the vacancies in each plot (Tables XIII. and XIV.); from these figures have been estimated (1) mean number of hills per square yard and (2) mean yield per hill in grams, to conform with the corresponding figures from the plot trials. Admittedly these values of  $y$  and  $x$  are only estimations, but it was felt that the conditions under which the plot trials were carried out were artificial in that more than normal care had been taken to control the attack of pests and the competition from weeds; that the increased development of the plants as a result of these precautions, would probably be reflected in the estimate obtained for the optimum spacing; and that some attempt should be made to obtain a similar estimate for the field trials, for purposes of comparison.

The estimated means for the *maha* field trial are given in Table XV. They are found to be related to one another by the same general formula as the plot data, as will be seen from the curves on Fig. I, but with lower values for yield per hill, no doubt as a result of the less favourable conditions under which the plants were growing. The constants and the optimum values of  $x$  appear in Table XII; they are reasonably uniform, and suggest that a spacing, very similar to that now in popular use, may be expected to give optimum results. It is surprising to find that the care used in experimental cultivation will make such a difference as to allow of the number of plants per square

yard to be doubled, and suggests that caution should be used in interpreting the results of small scale trials carried out under artificial conditions.

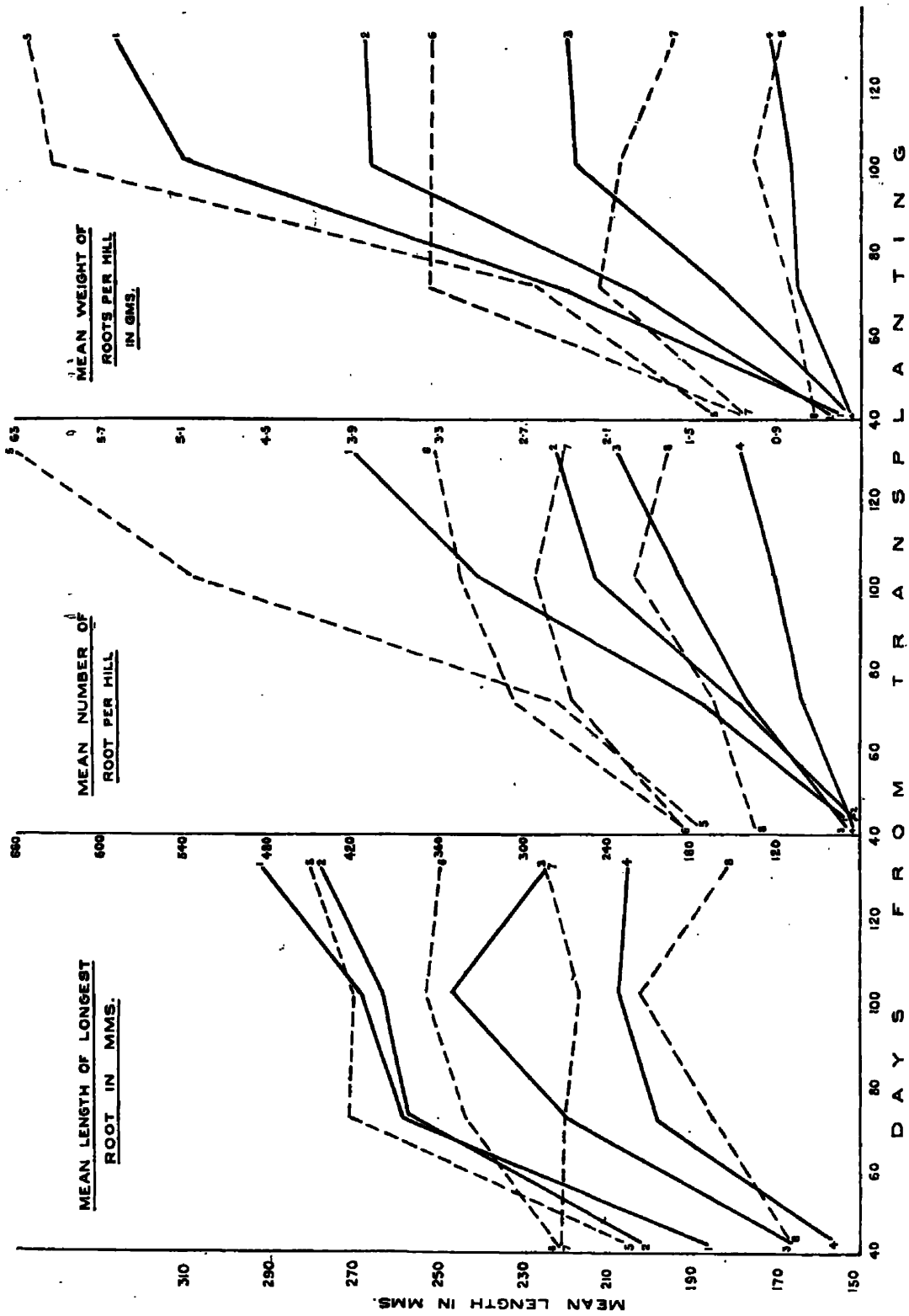
The corresponding estimates of means for the *yala* field trials are given in Table XV., and show again the same general relationship; yields per hill are still lower in this series, corresponding to the use of a shorter-aged paddy. The constants and optimum values of  $x$  appear in Table XII., and suggest that the optimum spacing is somewhat wider than 4 in. It almost appears as though the shorter growing-period of a *yala* crop demands that each plant should have more space than is required by a longer-aged variety, in order that the plant may develop as much as possible in the short space of time between sowing and flowering. Does it also suggest a tendency for yield per plant to increase relatively in importance and the number of plants per acre to become less important?

The optimum spacings obtained in the field trials are correlated with the corresponding yield figures, in that the *maha* trial showed a superiority of the 4 in. spacing over all others, and the optimum spacing appears to be about 4 in.; whereas the *yala* trial shows the 4 in. spacing to be superior to the 18 in., doubtfully superior to the 12 in., but not significantly better than the 8 in.; and the optimum spacing is found to be somewhat between 4 in. and 8 in.

#### ROOT DEVELOPMENT

Additional small plots of each treatment were planted from which samples could be taken in order to observe the general root development under different treatments. Sample plants were removed and examined by the method described in an earlier paper (10) and data were collected on the length, number and weight of roots produced. It is not proposed to present those data in full, for the results obtained under different soil conditions confirm one another. A summary represented by means, is given in Table XVI. and is reproduced diagrammatically in Fig. III. The results were to be expected, that the wider spacings (Nos. 1 and 5) have the greatest root development, followed progressively by the more closely-spaced treatments. It is further seen that in mean length of root, each "Single" treatment (1-4) has beaten the corresponding "Threes" treatment (5-8) due no doubt to less competition—but in mean number of roots, the reverse is the case; there the "Threes" had an initial advantage that they never lost, although with the exception of the 18 in. spacing, the singles gained on the corresponding threes in the period during which the observations were made. It is perhaps surprising to find the singles treatment superior in the factor for mean weight of roots,

FIG. 3.—ROOT DEVELOPMENT AT DIFFERENT SPACINGS.



but it suggests that the singles treatments produced a smaller number of long roots, whereas many of the roots of the threes were short, and contributed little to the weight.

#### DISCUSSION

The relationship between yield and spacing in paddy has been investigated by a number of workers, and their results are in general agreement with those of the experiments described in this paper. Jacobson (2), (3), Rodrigo (5), Dionisio (7) and Ramiah (9), all agree that the number of tillers per plant increases with the spacing, but that the yield per unit area decreases, and Bhide and Balerao (8) agree that tillering is the most important component of plant yield. Dionisio further agrees that the number of tillers per hill increases as the number of seedlings per hill is increased but that the number of fruiting culms per plant decreases; Jacobson agrees that varieties with a large number of grains per panicle have small grains, and *vice versa*; further, that single seedlings are not good at planting distances greater than 4 in. and that the closer spacings show a higher death rate among seedlings. He finds, however, that spacing has no effect on age, whereas the present trial showed that wider spacing tended to increase the period between sowing and maturity.

Summers (4) quotes Thompstone (1) as saying that the average yield per tiller decreases with an increasing number of tillers per plant, and agrees with his finding. We do not, nor do Thompstone's figures appear to support his own statement.

It was suggested in a former paper on paddy cultivation (10) that three seedlings per hill were to be preferred to single ones. The suggestion was made rather from observation than from actual comparison, and is not supported by the results of the experiments now described; the previous trials were planted at 4 in. by 4 in., which is the one spacing at which three seedlings cannot be said to have the advantage. In the same paper, the question was asked "what effect single seedlings would have on subsequent tillering." Some evidence on this point is provided by the plot data in Table XI.; in column 1 it is seen that the single seedlings produce more tillers per seedling planted, but always less per hill; the increased rate of tillering in the singles is not sufficient to compete against the initial advantage of three seedlings per hill.

From the same data, another point of interest emerges. Each "Three" is superior to its corresponding "Single" in the factor "mature ears per plant", which we have decided to be the most important factor in the composition of plant yield; yet in the data of plant yield (Col. 6.) it is seen that the superiority of the "Three" decreases as the spacing becomes closer, and is actually lost on two soil types out of three at the 4 in. spacing.

The change is apparently brought about by the "grains per ear" factor (Col. 3.) which at the 18 in. spacing, is in favour of the "Threes", but decreases with the spacing until, at 4 in., the "Single" earhead is definitely the larger. Thus, although the single seedling fails to produce the same number of tillers per hill as the three seedlings, yet it compensates in part for that failure by producing a larger earhead at the closer spacings. It is this size of ear factor which is responsible for the superior performance of the singles treatment at the 4 in. spacing, and it thus becomes temporarily at least, an important determiner of yield.

#### SUMMARY

1. Trials have been made with transplanted paddy at four different spacings, and using two methods of planting.

2. In order to be able to analyse the data collected, the trials were in two series.

(a) field trials, in which performance per unit area was measured,

(b) plot trials, in which performance per plant was observed.

3. For each series, an optimum spacing has been calculated. The difference between the optima for the corresponding field and plot trials suggest that considerable caution should be exercised in interpreting the results of plot experiments, which are usually treated horticulturally rather than agriculturally.

4. The spacing of 4 in. by 4 in. usually employed in Ceylon is somewhere near the optimum for long-aged paddies under field conditions. At that spacing, there appears to be little advantage to be gained by planting three seedlings to a hill, although at wider spacings there is a definite advantage.

5. The most important determiner of plant yield is number of fertile tillers, which increases with spacing. The most important determiner of acre yield is spacing, which overshadows individual plant performance, so that a bigger crop is produced from a large number of small plants than from a small number of large ones.

6. Yield per plant ( $y$ ) and number of plants per unit area ( $x$ ) appear to be related by an expression of the form  $y = ax^b + c$ , where  $a$ ,  $b$  &  $c$  are constants, and  $b$  is  $< 0 > - 1$

7. Root development is a function of plant performance.

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TABLE XII

Values of constants in equation

$$y = ax^b + c$$

*Plot Trial*

	a	b	c	Value of x corresponding to a maximum value of xy.	
Poor Singles	.. 78.77..	— 0.45..	— 4..	199	} Mean of 5 values = 169, or a spacing of about 4 in. by 2 in.
Medium Singles	..100.8 ..	— 0.72..	+ 4..	—15	
Rich Singles	..166.8 ..	— 0.53..	— 6..	125	
Poor Threes	..126.5 ..	— 0.62..	— 2..	169	
Medium Threes	..107.4 ..	— 0.50..	— 4..	180	
Rich Threes	..257.2 ..	— 0.78..	— 1..	173	

*Field Trial—Maha Season.*

Poor Singles	.. 45.14..	— 0.43..	— 4..	73	} Mean = 58 or a spacing of about 4 in. by 5 in.
Medium Singles	.. 76.81..	— 0.64..	— 2..	61	
Rich Singles	.. 60.73..	— 0.44..	— 6..	52	
Poor Threes	..107.5 ..	— 0.77..	— 1..	64	
Medium Threes	..115.1 ..	— 0.71..	— 3..	30	
Rich Threes	..140.5 ..	— 0.79..	— 1..	68	

*Field Trial—Yala Season.*

Poor Singles	.. 35.46..	— 0.35..	— 6..	45	} Mean = 32 or a spacing of about 4 in. by 10 in. (or 6 in. by 6½ in.)
Medium Singles	.. 57.86..	— 0.47..	— 6..	33	
Rich Singles	.. 87.11..	— 0.47..	—10..	27	
Poor Threes	.. 70.76..	— 0.67..	— 2..	36	
Medium Threes	.. 89.80..	— 0.63..	— 4..	28	
Rich Threes	..156.6 ..	— 0.89..	— 1..	25	

**TABLE XIII**  
**Field Trials—Yala 1936**

Percentage vacancies in field plots and estimates of number of plants per square yard (x)

Spacing	Poor Soil		Medium Soil		Rich Soil		Theoretical value of x
	Vacancies	Estimated x	Vacancies	Estimated x	Vacancies	Estimated x	
Single 18"	..	3.3	..	3.2	..	3.4	4
12"	..	7.6	..	8.1	..	7.5	9
8"	..	16.7	..	17.4	..	17.5	20.25
4"	..	74.6	..	72.7	..	75.8	81
Threes 18"	..	10.2	..	3.7	..	3.8	4
12"	..	3.9	..	8.3	..	8.8	9
8"	..	4.9	..	19.5	..	19.6	20.25
4"	..	3.0	..	77.1	..	79.1	81

Note that (1) there are less vacancies in the threes than in the singles.

(2) there are less vacancies in the closer spacings, although the decrease is not regular.

**TABLE XIV**  
**Field Trials—Maha 1936-37**

Percentage vacancies in field plots and estimates of number of plants per square yard (x)

Spacing	Poor Soil		Medium Soil		Rich Soil		Theoretical value of x
	Vacancies	Estimated x	Vacancies	Estimated x	Vacancies	Estimated x	
Single 18"	..	3.5	..	3.8	..	3.7	4
12"	..	8.7	..	8.2	..	8.4	9
8"	..	19.4	..	18.3	..	19.3	20.25
4"	..	76.5	..	70.7	..	77.3	81
Threes 18"	..	11.0	..	9.5	..	3.8	4
12"	..	0.7	..	3.8	..	8.8	9
8"	..	0.9	..	2.4	..	19.6	20.25
4"	..	1.7	..	3.9	..	79.5	81

Note that (1) there are less vacancies in the threes than in the singles (one exception).  
(2) there are less vacancies at the closer spacings.

**TABLE XV**  
**Estimated yields of grain per hill in field trials**  
 Yields in grams

Spacing	Yala 1936			Maha 1936-37		
	Poor Soil	Medium Soil	Rich Soil	Poor Soil	Medium Soil	Rich Soil
Single 18"	16.38	26.39	35.83	19.80	29.71	26.73
12"	12.08	16.62	26.60	15.50	18.64	18.95
8"	6.70	8.84	10.97	8.15	9.38	9.56
4"	2.06	2.03	2.60	3.11	3.18	3.47
Threes 18"	26.90	32.98	45.14	38.32	42.72	49.38
12"	14.97	20.90	22.56	19.26	22.53	23.07
8"	6.92	8.19	9.49	9.51	10.53	12.09
4"	1.94	2.40	2.44	2.77	2.49	3.37

**TABLE XVI**  
**Records of root development—Means**

No.	Treatment	Mean length of longest root in mm.			Mean number of roots			Mean weight of roots in gms.						
		42..	72..	132..	42..	72..	132..	42..	72..	132..				
1.	18" Single	186..	258..	268..	292..	292..	66..	173..	330..	419..	0.473..	2.445..	5.138..	5.642
2.	12" "	202..	257..	263..	278..	278..	61..	148..	250..	275..	0.531..	1.937..	3.793..	3.832
3.	8" "	166..	220..	247..	225..	225..	68..	140..	188..	234..	0.402..	1.292..	2.337..	2.398
4.	4" "	155..	198..	207..	205..	205..	67..	103..	119..	148..	0.386..	0.753..	0.800..	0.932
5.	18" Threes	204..	270..	270..	280..	280..	175..	272..	538..	664..	1.378..	2.607..	6.058..	6.227
6.	12" "	222..	243..	253..	250..	250..	185..	305..	345..	364..	1.217..	3.373..	3.361..	3.367
7.	8" "	221..	220..	217..	225..	225..	186..	266..	291..	274..	1.197..	2.158..	2.010..	1.638
8.	4" "	166..	185..	202..	182..	182..	137..	165..	218..	199..	0.622..	0.805..	1.057..	0.882

## REFERENCES

1. Thompstone, E.—Some observations in Upper Burmah paddy (grown under irrigation). *Agric. Jl. Ind.* X. 1915, p. 26.
2. Jacobson, H. O.—Observations on the influence of area per plant on yield of grain in rice culture. *Philipp. Agric. Review.* VIII. 1915, p. 252.
3. Jacobson, H. O.—Correlative characters of the rice plant. *Philipp. Agric. Review.* IX. 1916, p. 74.
4. Summers, F.—The tillering of Ceylon rices. *The Tropical Agriculturist* LVI. 1921, p. 67.
5. Rodrigo, P. A.—The effect of spacing on tillering and production of three varieties of rice. *Philipp. Agric. & Forester* XIII. 1924, p. 5.
6. Biffen, Sir R. H. & Engledow, F. L.—Wheat breeding Investigations at the Plant Breeding Institute, Cambridge. *Min. Agric. & Fisheries Research Monograph No. 4. London 1926.*
7. Dionisio, C.—Tillering of rice. *Philipp. Agric.* XVI. 1927, p. 89.
8. Bhide, R. K. & Balerao, S. G.—The Kolamba rice of the North Konkan and its improvement by selection. *Mem. Dept. Agric. Ind.* XIV. 1927, p. 199.
9. Ramiah, K.—Some recent manurial experiments in rice. *Madras Agric. Jl.* XXIII. 1935, p. 363.
10. Haigh, J. C.—Studies on Paddy Cultivation—VII. The effect of Cultivation on Root Development and Ear Formation. *The Tropical Agriculturist* I.XXXVII. 1936, p. 213.