RICE EXPERIMENTS: 1931

(1) RICE VARIETAL TRIAL

(2) STUDIES IN SPACING OF TRANSPLANTED RICE.

Dissertation presented in part
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by

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RICE VARIETY TRIAL 1931.

Introduction.

The immediate possibilities of pure line selection in rice are nowhere near exhausted. In the past selections have been made at the I.C.T.A. farm from the popular local variety - Kalyaman, the three outstanding pure line selections being No.29, No.38 and No.11. The present experiment was designed by Prof. Wood and Mr. Paterson to test the performance of these three pure lines, the original variety Kalyaman and two other varieties No. 4 and No.7.

Description of Pure Lines and Varieties.

Kalyaman Special - a very popular variety. White - Relatively long, thin cylindrical grain. Has a tendency to break on husking. The average dimensions of the paddy run to $10\frac{1}{2}$ - 11 m.m. in length, $2\frac{3}{4}$ - 3 mm in width and about 2 m.m. in thickness. There is no dark red pigment either in the husk or the cuticle surrounding the kernel.

No.29 - White rice. Very much like Kalyaman, though not quite so long. Doesn't break. As paddy it is $9\frac{3}{4}$ - 10 m.m. long, 3 m.m. wide and $2\frac{1}{4}$ - $2\frac{1}{2}$ m.m. thick. The husk is a shade darker and a very small percentage of the grains have red cuticle, indicating that the selection is by no means quite pure. It is early maturing and yields well. Its performance in previous years has been reported very favourably (vide the cultivation sheets).

No.38 - White rice. Same colour as Kalyaman but a shade longer and wider. 11 to $11\frac{1}{2}$ m.m. by $3\frac{1}{2}$ m.m. by $2\frac{1}{2}$ m.m.

No.11 - Has a very distinct appearance. Much shorter and stouter than Kalyaman. The average dimensions of the paddy run to 8 m.m. in length, $3\frac{1}{2}$ m.m. in width and 2 m.m. in thickness. Dark red pigment is contained only in the husk and not in the cuticle surrounding the kernel. This selection is supposed to have originated from a solitary short plant in a field of Kalyaman rice.

No.4 - Very much like No.38. It appears to be a mixture of different strains. Some have white husks and white grains, some white husks and red grains and a very small proportion red husks and red grains. The white paddy is about 11-11½ mm long, 3 m.m.wide and 2½ m.m. thick. The red paddy on the other hand is about 9 m.m. long, 3 m.m. wide and 2 m.m.thick.

No.7 - An awned variety with red cuticle covering the kernel. Very late maturing. Grows to a considerable height, about 6½ feet. Has all the undesirable qualities. Worthless from the millers point of view. The dimensions are 8 m.m. long, 4 m.m. wide and 3 m.m. thick. The awn is on the average 25 m.m. long but there is a great deal of variation.

Design of the Experiment.

The Randomised Blocks layout was adopted. Each variety was replicated three times and therefore there were five blocks with six plots on each Block.

Location. Rice Beds Nos. 10, 11, 17, 18, and 19. Each bed was treated as one Block. The beds were all approximately of the same width namely 50' but their lengths varied between 82' and 90'. It was decided to start planting at the eastern end in each Block and to fill the extra space available after the 6 plots were marked out, with the same variety planted in the adjoining plots (on the Eastern side).

Two plants were set per hole one foot apart in rows one foot wide. After allowing the necessary discards at harvest to eliminate border effects, the ultimate size of plots for yield purposes worked out exactly 25' by 25' or approximately 1/70th of an acre.

Manuring. 5 lbs. of Leunophos was broadcasted per Block after first flooding and another 5 lbs. when the water was first drawn off after planting.

DATE OF PLANTING

BEDS 17, 18 & 19th ON 9th JULY 1931
" 10 & 11 ON 8th JULY - 1931

Harvesting.

Harvesting commenced on 11th Nov. 1931. No.38 had to be discarded along with the discard rows because at the time of planting it got mixed up in some places with the variety on the adjoining plots (on the eastern side).

No.7 was not even in flower at the time of harvest and so it had to be left standing. It ripened about a month later but by the time it was harvested half the grain on the plots was consumed by birds. The yield was therefore not taken into account.

The rest of the field was harvested in the usual way by hand under ideal conditions. Threshing was done almost immediately and the grain weighed when quite dry.

Yield in lbs.

Yield in lbs.

Varieties.

Blocks.	4	Kal. sp.	11	29	Total	Average
A	56	62	51	56	225	56.25
B	56.5	64	53	51.5	225	56.25
C	49	60	53	61	223	55.75
D	50	73	51	53	227	56.75
E	64	70	54	57	245	61.25
Total	275.5	329	262	278.5	1145.0	
Average	55.1	65.8	52.4	55.7		
Yield per acre (in lbs.)	3857	4606	3668	3899		

The Analysis of Variance.

	D.F.	S.S.	Variance	S.D.	Log e	Z
Blocks	4	82.0	20.50			
Treatments	3	518.25	172.75	13.153	2.57411	1.06384
Error	12	246.00	20.50	4.528	1.51027	Significant beyond 1% pt.
Total	19	846.25				

From Fisher's Table 5% pt = .6250

$n_1 = 3.$ $n_2 = 12$ 1% pt.= .8919

The Standard Error expressed as a percentage of mean = 7.91%

Variance due to error of 1 plot = 20.50

" " " " " 5 plots = $\frac{20.50}{5}$

" " " difference of 5 plots - $\frac{20.50}{5} \times 2$

$\therefore$ Standard deviation $= \sqrt{\frac{20.50}{5} \times 2} = \sqrt{8.2} = \pm 2.864$

$\frac{\text{Diff.}}{\text{its S.E.}} = t = 3.055$ when $p = .01$ & $n = 12.$

$\frac{\text{Diff.}}{\pm 2.864} = 3.055$

i.e. Mean Diff. must be ± 8.75 to be significant.

From this it is evident that only Kalyaman spacial gave significantly higher yield than all the others.

General Statement of Results.

VARIETIES	MEAN YIELD in ozs.	DIFFERENCES FROM		
		Tr (1)	Tr (2)	Tr (3)
(1) No: 11	52.4	-	-	-
(2) No: 4	55.1	+ 2.7	-	-
(3) No: 29	55.7	+ 3.3	+ 0.6	-
(4) Kaly. Sp.	65.8	+ 13.4	+ 10.7	+ 10.1

Area of each plot is approximately 1/70th of an acre. Statistically significant differences are marked in red.

Discussion.

From the results it is obvious that the pure line selections have failed to yield as much as the original variety Kalyaman. The variety with strains of different habits of growth appears to have been able to exploit the resources much more efficiently. The yield differences per acre in its favour are 938 lbs. over No.11, 749 lbs. over No.4 and 707 lbs. over No.29. These figures are high and statistically significant. They also indicate that the variety might include one or more high yielding strains. It is unfortunate that No.38 had to be scrapped, for it may have been the high yielding strain.

However, from the field records of previous years, it may be stated definitely that No. 29 and No.38 are two very promising pure lines which can be tried in the future.

STUDIES IN SPACING OF TRANSPLANTED RICE.

INTRODUCTION.

There is perhaps no other crop in the tropics whose cultivation is so largely influenced by native practice and tradition as the rice crop, which for centuries has provided the staff of life of millions of inhabitants of the vast regions in the Eastern Hemisphere.

Grown as a food crop by a peasantry for the most part in debt and usually unable to adopt improved methods of tillage even when fully convinced of their value, its production today has reached a level which due to inelasticity of demand and inadequate marketing facilties has lowered the price immensely. The problem therefore is to find all possible means of increasing the monetary return per acre. In attempts to solve this problem so far, the line of least resistance has been taken by providing the cultivator at moderate rates with seed of better yielding strains, but there is reason to infer that certain modifications in cultural practice may without impairing its efficiency effect a reduction in expenses and even increase the yield per acre without proportionately increasing the cost.

A common practice in transplanting both here in Trinidad and in most other tropical countries is to set clumps of seedlings varying in number from 2 to 20 or even more, at distances generally considered to be suitable for the locality. Such distances may vary from 6" as in Ceylon - where actually the advantages of transplanting are not fully appreciated - to a much wider spacing of 15" by 18" advocated in Malaya.(1) While the spacing and the number of plants set per hill may happen to prove adequate in some countries , there is no indication that here in Trinidad the practice of planting a varying number in the hill at a mean distance of 12" is sound.

The popular idea that setting out more than one plant per hill is an insurance against complete failure in case of onset of unfavourable conditions does not appear to be well founded, for eye observations of the actual field practice suggest that it is largely a matter of convenience in that less trouble and delay are involved by setting out the plants as they come into the hand where pulled from the bunch rather than by separating the individuals from an entangled mass of roots and foliage. Consequently there is the possibility that this procedure may induce incidence of interplant competition in the hills at an earlier date to the detriment to growth of all the plants and if tillering is taken as an index to growth, the effect will be reflected in fewer number of ears per plant at harvest. In fact, as far as planting six or more per hill is concerned, i.e. in a case where interplant competition is serious, the investigations of various workers have brought to light the futility of the procedure from the point of view of increased tillering or yield per hill. With a fewer number of plants however, there is difference of opinion, for some have found it in practice to work quite satisfactorily on fertile soils. This may be due to the fact that by restricting the tiller number per plant in the hills a more conservative type of growth is maintained which results in the production of heavier ears all maturing uniformly. And since there are more than one plant per hill, the output of grain ought to compare favourably with that from a hill with a single plant in which tillering though profuse has progressed in stages with a corresponding gradient in ear size. Thus Summers (1) has recognised three tillering phases in the case of a transplanted seedling grown under normal conditions. Shortly after transplanting when the plant is about five weeks old, 3 or 4 main shoots are thrown out which at maturity bear ears slightly larger than those borne by the shoots of the second phase. The latter in turn are larger than those of the third phase developing as late as the seventh week after transplanting. If however, when nearing maturity, the plant received excess of water either artificially or in consequence of excessive precipitation two or three smaller tillers are produced which bear ears that don't ripen with the rest. This unevenness of flowering and maturing which may also be brought about by wider spacing is of particular importance in countries where the paddy fly is a serious pest, for it prolongs the period when the paddy fly can find grains in the milk stage to feed upon. In addition there is the danger that the panicles of main culms will begin to shed their grains if the harvesting is delayed to allow the late tillers to mature. For these reasons heavy tillering is deliberately discouraged in Ceylon by adopting a high seed rate and closer spacing.

Although tillering as measured by the number, size and vigour of shoots produced is recognised to be a hereditary character by many including Summers who says "Within small limits each variety has a specific tillering capacity for the same habitat whatever its origin", its expression is greatly modified by those external conditions which check or assist vegetative growth in general. They may be height of water supply, spacing, the rate of flow of water, etc. Of these spacing is of particular importance because of its dual influence on yield. To start with spacing determines the number of plants per unit area and therefore the number of contributions to yield from that area: and since it implies a specific combination of environmental conditions which influences tillering and ear production, its role in determining the actual amount of each contribution is equally important. Thus on poor soils where tillering and ear production are not likely to be enhanced by wider spacing, the usual practice is to adopt a high seed rate to ensure a good stand, while on more fertile soils the policy is to exploit tillering by allowing enough space for maximum development. Also it is recognised that profuse tillering will not be associated with high plant numbers. Therefore in deciding upon the optimum spacing for ordinary soils on any locality one has to strike a happy medium between these two factors which will not only allow for satisfactory tillering and ear development under favourable environmental conditions, but also provide for sufficient number of plants per unit area as an insurance against poor yields in case adverse conditions retard growth and reduce the amount of contribution from each individual plant. In this connection it may be well to emphasise the danger of lodging if a weak type of growth is induced by very close planting.

The economic aspect of the problem has to be considered next. It is evident from the investigations of various workers that substantial saving in seed and cultural expenses can be effected by setting out single plants per hill fairly wide apart. How far this will be practicable under local conditions and whether one is justified in taking risks are questions which can be answered only on the results of experiments conducted over a period of years.

OTHER WORKERS AND THEIR CONCLUSIONS.

It is generally known that within limits under favourable conditions, the rice plant exhibits remarkable capacity for tillering and ear production with increase in spacing,and so yield per unit area is not necessarily very dependent on the plant population density. On very poor soils however, yield per unit area may be highly correlated with plant population density since the effect of the prevailing unfavourable environmental conditions on growth will be to reduce the number and size of ears. In extreme cases such adverse conditions may also reduce the number of plants surviving, and in addition prevent the survivors from responding to the increased space at their disposal. Hence the general practice is to plant more closely on poor soils: thus Thompstone ([3]) in his article on some observations on Upper Burma paddy reports "no doubt the custom of reducing the distance and increasing the number of seedlings according to the conditions of poverty of the soil or to lateness of transplanting has been formed by generations of experience but at the same time one can meet many cultivators who have a very shrewd idea of the resaons for these practices". Similarly Jack (9) recommends planting 12" each way on "hard medium soils" in Malaya. The optimum distance on the extremely fertile soils in the Krian district being 20" x 18". Also in Ceylon where heavy tillering does not seem to be desirable for reasons previously stated, the plant population density is of particular importance in determining yield, and so the usual practice is to set the hills 6" apart with 3 vigorous seedlings per hill.

On normal soils however, favourable early growth conditions, and particularly varietal capacity may accelerate tillering and vigour of growth to such an extent as to probably cause a clash of interests between neighbouring plants for essentials of plant life - light, plant nutrients, etc. Assuming there is one plant per hill, this will result in early incidence of interplant competition involving growth control by spacing. Now tillering as measured by the number, size and vigour of shoots produced is generally recognised to be an index to growth and so any influence of spacing on growth will be reflected on the extent of tillering. Thus Parr (4) states that leaving out the quality of the soil and the seed, the amount of space allowed to each plant is the limiting factor of the plant's ability to tiller and produce grain, and that the number of tillers produced per plant varies up to a certain limit directly with the space allowed to the individual plant. Also tillering is known to be positively correlated with yield.- According to Sethi (5) this is what is to be expected since yield is generally determined more by the number of fertile tillers rather than by any other factor. However, as pointed out by Parr, there is the danger of too wide spacing which leads to excessive vegetative development with few and imperfectly formed grains and to uneven ripening which naturally interferes with harvesting.

The effect of spacing on tillering and yield of transplanted rice has been studied in detail by Rodrigo (6) in the Philippines. Working with three varieties of lowland paddy, he attempted to compare the effect of planting one seedling per hill at distances of 10 cm. x 10 cm., 15 cm. x 15 cm., 20 cm. x 20 cm., 25 cm. x 25 cm., 30 cm. x 30 cm., and 40 cm. x 40 cm. with the normal practice of planting three in a hill 20 cm. apart each way. He found that with any of the three varieties studied the greater the space allowed to each plant the greater was the number of fruiting culms produced. The yield however increased only up to a certain point as the distance at which the hills were set was increased - the optimum distance being 25 cm. x 25 cm. for one

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One serious criticism which has been put forward by Lord (8) in connection with a similar type of lay out adopted by Calvo a couple of years later in the same locality, and which applies equally well to the experiment under review, is that unless fields in the Philippines are remarkably uniform, the absence of replications has introduced what may easily be a very large error due to soil heterogeneity. In spite of this drawback it seems worthwhile to consider the results of tiller counts since statistically adequate numbers were taken, and they agree strikingly with those published by Calvo and with those made on the cut ends in the stubble of the two out of five blocks on the I.C.T.A. farm while supervising harvest operations.

variety, and 30 cm. x 30 cm. for the other two. Examination of the number of ear bearing tillers per square metre showed that the spacing which gave the highest production of grain had a smaller number compared to the closer spacings, which incidentally showed the smaller production. Therefore he inferred that the increase in yield was due to increase in average size of panicles effected by the production of either larger number of grains, bigger sized grains, or both.

Similarly Calvo[7] working with the variety Apostol in the same locality a couple of years later found that as the distance between hills varied the number of ear bearing tillers per hill also directly varied, but the increase however, was not in proportion to the increase in spacing. This he found to be in agreement with the observations of Rodrigo.

The number of plants to be set per hill is the next consideration which is of particular importance. Experimental evidence indicates that there is no justification for the practice of planting ten or more plants per hill. Even with five plants per hill, with hills spaces at an optimum distance of 17" x 15" on first class land in the Krian district in Malaya, Jack found that interplant competition is so severe that tillering shows a definite tendency to decline. However, in spite of this gradual reduction in the average number of tillers per plant, there is an increase in number of tillers per hill as the number of plants in the hill is raised up to five. But the yields per hill and per acre show a definite tendency to decline when there are more than 2 plants per hill. So that Jack points out that it makes little difference as far as tillering and yield are concerned whether 1 or 3 plants are set in each hill.

Grist,[10] also working in Malaya, but under an entirely different set of conditions in Kuala Pilah with no irrigation facilities, finds that the total number of tillers per hill increases with the planting distance almost irrespective of the number of plants frequently planted per hill, and therefore there is no advantage in planting a large number of seedlings per hill. When, however, one seedling was planted per hill spaced 1 ft. apart in all subsequent paddy experiments, the practice worked unsatisfactorily since on the death of one plant, there was a large gap which apparently could not be fully utilised by the neighbouring plants. Therefore the practice of planting two seedlings per hill was adopted. In this connection it is of particular interest to note the relationship between lodging and high plant production. Very close planting resulted in early lodging of the crop.

In the Philippines Calvo[7] has observed that there is a fairly regular increase in number of ear bearing tillers per hill as the number of seedlings per hill is increased. The increase however, is not in proportion to the increase in number of seedlings. Thus instead of showing a 100% increase when the number of seedlings is raised from 1 to 2, only 14.25% increase is shown. With seedling number raised from 2-3, 12.8% increase is shown, and from 3-4, 12.54% increase is shown. But as far as the individual plants are concerned, their tillering power is reduced by 43% when the number is raised from 1 to 2, by 12% when raised from 2-3, and by 8% when raised from 3-4, so that he advocates planting 1 seedling per hill. No mention is made of the relative yields.

In fact the plant number per hill is also determined by the type of seedling used for transplanting and to some extent by the personal element.

According to Jack, the number must also vary according to soil conditions for if the seedlings are thin and weak, planter cannot afford to waste time separating them when 3-4 can be picked up more quickly.

The economic aspect of the problem is bound up with the question of saving in seed, reduction in cost of planting and in cost of harvesting. Lonsdale (11) in S. India has proved conclusively that the amount of seed used per acre can be enormously reduced without in any way diminishing the yield by transplanting single seedlings instead of bunches containing from two even up to twenty seedlings. He also recommends a lower seed rate for the seedbed so that the roots of the seedlings will not be closely matted together when pulled for transplanting. But there is the possibility that this procedure may entail extra expense in preparing a bigger area for the seed bed in spite of the reduction made in the number of seedlings to be planted per hill.

Similarly Rodrigo has given figures to show the substantial saving in seed effected by planting one seedling per hill compared to the normal practice in the Philippines of planting three. He has also found that the labour saving in transplanting at the optimum spacing of 30 cm. x 30 cm. is 56% over the usual 20 cm. x 20 cm. planting distance.

Observations made when harvesting the plots in the present experiment indicate that more ground can be covered within the same period of time if the hills are further apart than if they were closely packed; since the size of the plant in the hill does not appear to make much difference in cutting. In one minute, on the average 10 hills were cut by a man on the 8" x 8" spacing plots, and 33 hills on the 16" x 16" spacing plots. Since unit area on the 8' x 8" spacing contains in theory four times the number of hills as same area in the 16" x 16" spacing, it is obvious that at this rate more time will be taken to harvest the closer spaced area.

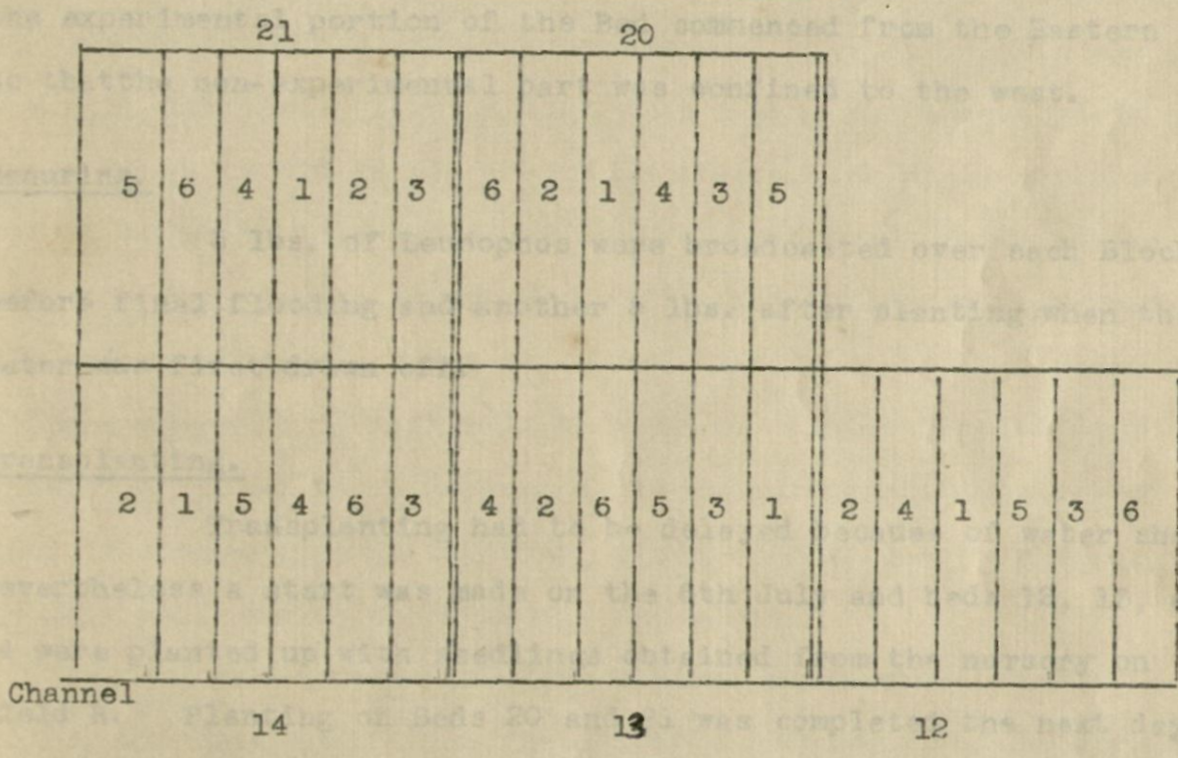
LAY OUT OF PRESENT EXPERIMENT AND RESULTS.

Plan of Experiment.

Site. The land selected for the Experiment was a low lying swamp which had carried crops of rice in previous years. The only drawback was the inefficient control of water supply. Water could not be had when it was most needed nor could it be drained off easily when not wanted.

The Experiment was located on the five rice beds - Nos. 20, 21, 12, 13 and 14. The Beds were of the same width namely 50' but their lengths varied from 82' to 90'.

Design of the Experiment.



Each bed was treated as one Block of the Randomised Block layout and the 6 plots each 14' wide and of the same length and area (approx. 1/62 acre) were marked out as strips running N. and S. across the Block. The following six treatments were randomised over the strips in each of the five Blocks. The resulting number of rows per plot are also given.

TREATMENTS.

		Rows per plot.
(1)	Single plant per hill 8" apart in 8" wide rows	21 rows
(2)	" " " " 12" " " 12" " "	14 "
(3)	" " " " 16" " " 16" " "	10 "
(4)	Double plants per hill 8" apart in 8" wide rows	21 "
(5)	" " " " 12" " " 12" " "	14 "
(6)	" " " " 16" " " 16" " "	10 "

The extra land not included in the Blocks was planted up with the same variety of rice - No.29 - as used in the Experiment at a spacing distance of 1' by 1' with 2 plants per hill. In all cases the experimental portion of the Bed commenced from the Eastern side, so thatthe non-experimental part was confined to the west.

Manuring.

5 lbs. of Leunophos were broadcasted over each Block before final flooding and another 5 lbs. after planting when the water was first drawn off.

Transplanting.

Transplanting had to be delayed because of water shortage Nevertheless a start was made on the 6th July and beds 12, 13, and 14 were planted up with seedlings obtained from the nursery on field H. Planting on Beds 20 and 21 was completed the next day.

From the reports appearing in the cultivation sheets for the Rice Lands, it is to be gathered that water shortage was just beginning to be felt on the 6th August. The following, also taken from the cultivation sheets is a description of the condition of the plots on the 26th August:-

Block 12. Very good. Dry. Weeds showing here and there.

Block 13. Very good.

Block 14. Fair.

Block 20. A little patchy.

Block 21. A few blanks here and there. Otherwise good.

Harvesting.

The whole experimental area was harvested on the 5th November under rather wet conditions due to intermittent showers of rain. Blocks 12, 13 and 14 adjoining the channel were flooded and there was no way of draining the water. Block 14 was particularly bad; the sheaves were thoroughly soaked with water. Blocks 20 and 21 were, on the other hand, comparatively dry and showed patches of weeds here and there. Apparently the blanks noticed on these two blocks in August must have encouraged growth of weeds under the dry conditions then prevalent. Their effect on yield was not very striking. The northern end of the two adjoining plots under treatments 3 and 5 respectively in Block 20 was particularly weedy, but little difference was to be noticed in the yield from the two plots, for although plot 3 gave the lowest yield for Block 20 as it did in all the other blocks, the yield difference was by no means aggravated; while the yield from plot 5 in all the other Blocks was too irregular to draw any inference as regards the effect of weeds. Yet it is but fair to state that under conditions where it is difficult to keep the fields flooded weed growth is likely to be serious if the plants are widely spaced than if they are close together, since they will not even be able to grow well enough to choke out the weeds.

The sheaves from the various plots were labelled separately and kept apart from the discards belonging to the non-experimental area. The carting was done on the same day - two lots of sheaves belonging to different plots being loaded each time. On arrival at the farm buildings, the sheaves from each plot were stacked together. There was enough room for only a few in the shed, the rest had to be kept out on the yard.

Threshing was started on the 9th November, 4 days after harvest, when the sheaves were sufficiently dry, but unfortunately in the meantime some of the grain in the sheaves belonging to Block 14 which were particularly wet when stacked and which in addition happened to lie in a depression on the far end of the yard, got thoroughly soaked in a few more showers of rain and began to sprout. The yields on the plots from this Block were therefore considerably reduced. The technique devised for threshing out the grain was simlar to that adopted by the Tamils in Malaya - a large rectangular deal-wood box with a sack screen round the three sides was used. The procedure was to take a handful from the sheaf and lash the ears against a miniature ladder resting against the unscreened end in the box.

The grain from each plot was weighed periodically till it was thoroughly dry and showed no reduction in weight. The straw weight was not considered necessary since the straw is not of any value in this country.

The yields (in lbs.) fromthe various plots are given below together with the analysis of variance.

Treatments	(1)	(2)	(3)	(4)	(5)	(6)	Block Total
Block 21 A	65	58	49½	70	56½	51½	350½
20 B	55	56	53½	77	72	45	358½
14 C	52	36½	44	59½	53	47	292
13 D	64	63	56	59	63	66½	371½
12 E	58	74	52	51	67½	62	364½
	294	287½	255	316½	312	272	1737
	Single plant 8"x 8"	Single plant 12"x12"	Single plant 16"x16"	Double plant 8"x8"	Double plant 12"x12"	Double plant 16"x16"	

Analysis of Variance.

	D.F.	S.S.	Variance	S.D.	Log e	Z
Blocks	4	679.20	169.800	13.038		
Between Spacings	1	411.65	205.825	14.352	2.66372	.31133
1 plant 2 plants	1	136.53	136.530	11.704	2.45960	.10821
Interaction between Spacing & No. of plants	2	3.02	1.510			
Error	20	1291.30	64.565	8.035	2.35139	
Total	29	2521.70				

5% pt. $n_1 = 2.$ $n_2 = 20$ 5% pt. = .8831

$n_1 = 1.$ $n_2 = 20$ 5% pt. = 1.0457

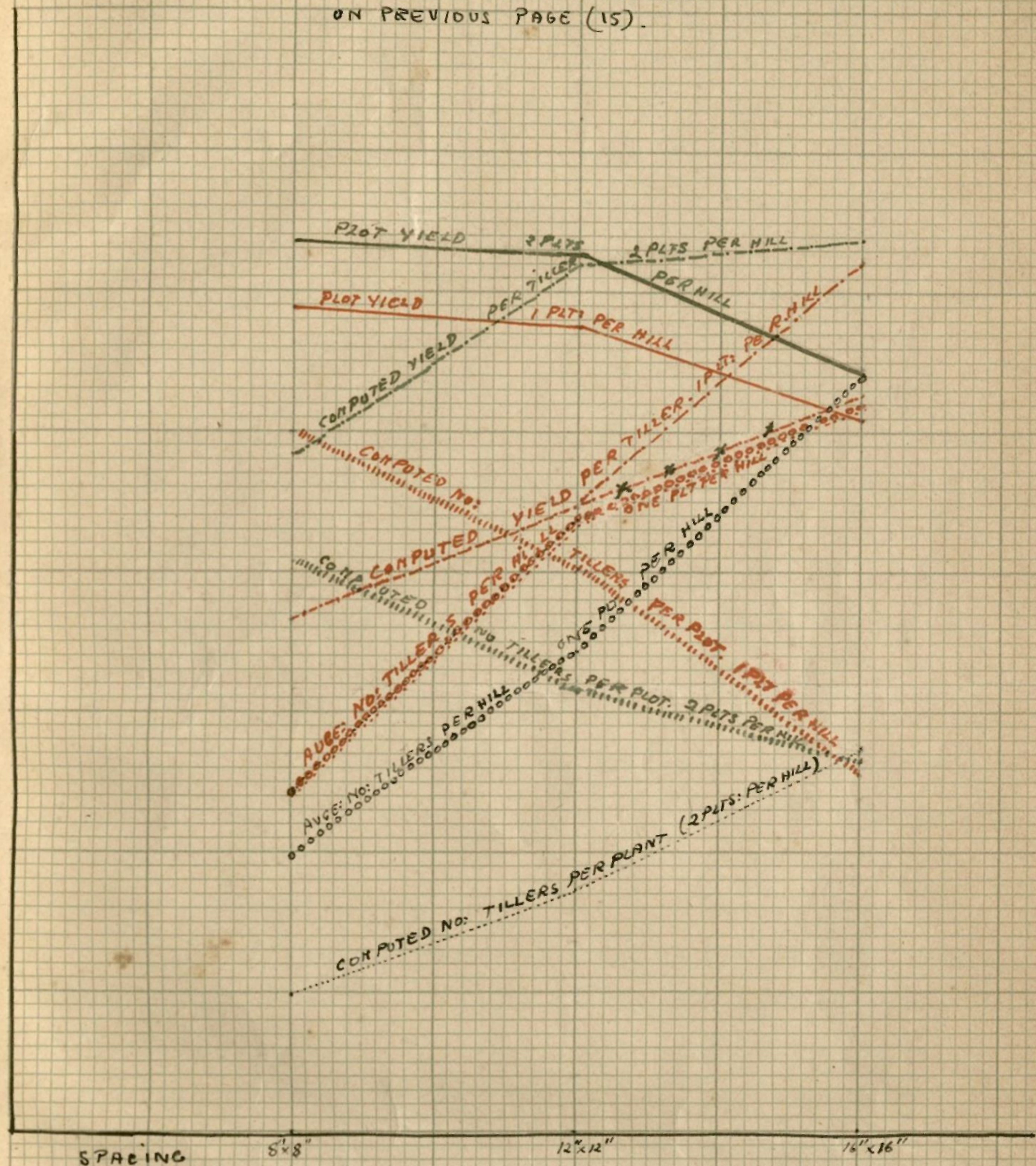
Discussion.

None of the treatments showed any significant effect on final yield. There is, however, a curious downward gradient in yield from the closer spacing to the wider spacing for both single plant in the hill and the double number per hill.

Consideration of the counts taken on the cut ends of the stubble ~~in~~ which incidentally, may also include barren tillers, reveals an interesting state of affairs. The procedure in taking the counts was to throw a stick at random on to the plot and count in a predetermined direction the tillers or rather the cut ends of 10 successive hills in row nearest the stick. If the stick happened to fall halfway between two rows, the final choice was made by the toss of a coin. 30 hills were thus counted per plot and in all 12 plots constituting two blocks were gone over by the time they were ready for ploughing. In every case the increase in number of tillers per plant with increase in spacing was found to be significant. But the computed number of tillers per unit area was decidedly small for the wider spacing, as shown by the following table. The yields however were practically the same at all spacings, there being no significant differences.

VARIETY 29.	One Plant per hill at spacing distance:-			Two Plants per Hill at Spacing Distance		
	8" x 8"	12" x 12"	16" x 16"	8" x 8"	12" x 12"	16" x 16"
Average No. tillers per hill	12.10 .651	21.83 .831	26.00 1.14	9.90 .649	17.13 .646	27.03 .972
Computed No. tillers per plant	12.10	21.83	26.00	4.95	8.57	13.52
Computed No. tillers per plot	32016.60	25672.08	16380.00	26195.40	20144.88	17028.90
Relative No. tillers per plot	100	80.18	51.16	81.82	62.92	53.19
Average yield per plot in lbs.	58.8	57.5	51.0	63.3	62.4	54.4
Computed Yield per tiller in lbs.	.001837	.002240	.003144	.002417	.003098	.003195

DIAGRAMATIC REPRESENTATION OF FIGURES
ON PREVIOUS PAGE (15).



While it may not be fair to associate the tiller counts taken on only 2 of the 5 Blocks in the Experiment with the total yield, it does not seem unreasonable to infer by analogy from the results of others, that the smaller number of tillers per unit area shown at the wider spacing must have all borne bigger sized ears on the average. That is an increase in number of tillers per plant was followed by an increase in average ear size - an apparent contradiction to the existence of a negative correlation in most cases between tillering and ear size (Sethi)[57]. It is, however, possible to reconcile the one with the other when viewed from a different angle. If on a field tillering within limits is encouraged by means other than wider spacing, the average ear size per tiller will tend to decline, but the average number of tillers and average yield per unit area will show an increase. On the other hand, when tillering is encouraged by wider spacing, here again within limits, the average number of tillers per plant does not increase in proportion to the increase in spacing and therefore the average number of tillers per unit area is comparatively small. Also since the yield per unit area is practically the same if not higher, the indications are that the average ear size is considerably enhanced. That is in spite of the increase in number of tillers per plant the total number of tillers per unit area remains comparatively small and therefore with more space for development, the tillers produce on the average heavier ears. The practical significance of this point brought out by developmental studies is that to obtain best results with wider spacing it will be necessary to maintain favourable conditions for ear development at the time of flowering. For adverse conditions as water shortage may not only reduce the number of grains setting but also prevent the developing grains from attaining their maximum size. In fact there is a strong suspicion that water shortage which was experienced on the rice lands at the I.C.T.A. farm last season may have prevented the ear bearing tillers at the wider spacing from tapping the resources of the extra space at their disposal.

At the same time it has to be remembered that there is a limit to wider spacing beyond which the increase in tillering or ear development may not compensate for paucity of plants and this limit can be determined only by a process of trial and error guided to a certain extent by experience. In practice it may not be advisable to adopt the extreme limit of spacing since vagaries of weather at the time of grain formation may introduce an element of risk which will prove too serious if the ear number per unit area is not adequate enough. The best policy would therefore be to select a spacing for the locality which will not only allow for satisfactory tillering and ear development under favourable conditions, but also provide for sufficient number of plants per unit area as an insurance against poor yields in case of onset of adverse environmental conditions.

As regards the number of plants per hill, it is evident from these counts, that setting two plants per hill compared to setting only one per hill has significantly lowered the total number of tillers per hill for all three spacing distances.

At the wider spacing of 16" however, there is little difference in tiller number between the two treatments. In fact the double plant number per hill has given a shade higher tiller number which is not significantly different. There is of course no evidence to prove that both plants have survived or one has succumbed and the other pulled through. Yet it is not unreasonable to infer tentatively that the rice land was not particularly fertile, or that some condition like water supply was not adequate enough to encourage tillering when two seedlings are planted in hills at the comparatively closer spacing distance of either 8" by 8" or 12" by 12". But as emphasised previously the effect of limiting the tiller number per plant in the hills will be to produce on the average much heavier ears at harvest. Hence it is perhaps more than mere coincidence that the final yield in each case for the plots with double number of plants per hill should be practically the same if not significantly higher than the yield from plots with one plant per hill. Thus once more the important role played by average ear size in determining yield is brought out.

On the strength of these findings one might conclude that where high plant population density is essential - i.e. with a low tillering variety on poor soils - the policy will be to plant more closely rather than to plant more seedlings in the hill, since on such soils interplant competition will be so serious that even with two plants per hill neither will both develop nor will one overcome the other and get well away. Also any gap that occurs because of plant mortality will not be big and may in fact stimulate growth of neighbouring plants, though to a very small extent on account of the infertile condition of the soil. On rich soils however with rather wide spacing, 3-4 plants may be necessary per hill to check rank growth, and on ordinary soils of normal fertility one plant per hill a foot apart each way will be adequate. Nevertheless as an insurance against total loss of hills due to plant mortality under accidental circumstances two seedlings may be planted per hill, provided favourable conditions are maintained for grain formation.

SUMMARY AND CONCLUSIONS.

Between Spacings.

(1) The differences in yields of single plants per hill spaced 8", 12" and 16" each way were not significant.

(2) The differences in yields of two plants per hill spaced 8", 12" and 16" each way were also not significant.

(3) The average number of tillers per hill increased - though not in proportion - with increase in spacing.

(4) The average number of tillers per unit area, however, declined with increase in spacing.

(5) Since the yields were practically the same at all spacings, it was inferred that the comparatively small number of tillers at the wider spacing must have all borne heavier ears on the average.

(6) There was a marked tendency for the crop to lodge at the closer spacing.

One plant Versus 2 plants.

(1) The yield differences between one plant per hill and two plants per hill at the above spacings, were also not significant.

(2) With two plants per hill, the average number of tillers per plant and per hill showed a tendency to decline at the spacing 8" x 8" and 12" x 12".

(3) Reduction in amount of seed paddy required, labour saving in transplanting and harvesting are some of the other advantages to be had by setting one seedling per hill at the comparatively wide spacing.

Recommendations.

(1) One plant per hill, one foot apart each way appears to be quite suitable under local conditions.

(2) The nursery to be sown thinly in order to facilitate separation of single seedlings, when transplanting.

(3) Optimum conditions to be maintained at the time of flowering to encourage grain formation.

PROBABILITY OF RESULT.

Investigations by Lord,[12] indicate that rice fields are far from being uniform in fertility. They exhibit characteristic interfield and intrafield variations. Thus in Malaya yield appears to increase as the bunds are approached. In Burma yields of plots next to irrigation channels and drains are higher than normal and the recommendations are:- to lay the plots at right angles to the channels. In Ceylon results of uniformity trial with pure strains of paddy revealed appreciable variations, in one case well over 50% within the same bunded field, where in view of smallness of size one would not suspect the existence of such marked soil heterogeneity. By increasing the size of plots however, the standard error per plot can be reduced and in Ceylon this reduction becomes small as the plots are made larger than $^1/87$th of an acre. In fact Lord considers this size of plot to be the most practicable for field trials and it is satisfactory to note that the size of plots used in the present Experiment at St. Augustine was approximately $^1/62$nd of an acre - a figure well above that recommended in Ceylon. He also considers the Randomised Blocks layout to be the most suitable under present conditions of rice growing - especially if enough replications are made and if each field is treated as one block - as was done in the present Experiment. The use of a Latin Square extending over more than one field does not appear to produce a more accurate experiment than the use of Randomised Blocks layout in spite of its adaptability to control soil heterogeneity in two directions.

The statistical technique adopted for working out the Randomised Block layout is known as the "Analysis of Variance" devised by R. A. Fisher.[13]

PLAN OF EXPT: p. 10

Yields in lbs.

Treatments	(1)	(2)	(3)	(4)	(5)	(6)	Block Totals.
Block 21 A	65	58	49½	70	56½	51½	350½
20 B	55	56	53½	77	72	45	358½
14 C	52	36½	44	50½	53	47	292
13 D	64	63	56	59	63	66½	371½
12 E	58	74	52	51	67½	62	364½
Total	294	287½	255	316½	312	272	1737.0
Average	58.8	57.5	51.0	63.3	62.4	54.4	
	Single plant 8"x 8"	Single plant 12"x12"	Single plant 16"x16"	Double plant 8"x 8"	Double plant 12"x12"	Double plant 16"x16"	

$$\text{SS Total} = \left\{(65^2 + 55^2 + \ldots 66.5^2 + 62^2) - 30\ \frac{(1737.0)^2}{30}\right\}$$

$$= \underline{2521.70}$$

$$\text{SS. Blocks} = {}^1/_6 \left\{(350.5^2 + 358.5^2 + \ldots 364.5^2) - 5\frac{(1737.0)^2}{5}\right\}$$

$$= \underline{697.20}$$

$$\text{SS. Treatments} = {}^1/_5 \left\{(294^2 + 287.5^2 + \ldots 272^2) - 6(\underline{1737.0})^2\right\}$$

$$= \underline{551.20}$$

	8" x 8"	12"x 12"	16"x 16"	Total
One plant per hill	294.0	287.5	255.0	836.5
Two plants per hill	316.5	312.0	272.0	900.5
Total	610.5	599.5	527.0	1737.0

One plant Versus 2 plants. SS $= {}^1/2 \times {}^1/15\ (836.5-900.5)^2$

$= 136.53$ (one degree of freedom).

Between Spacings SS $= {}^1/10 \left\{(610.5^2 + 599.5^2 + 527.0^2) - 3(1737.0)^2\right\}$

$= 411.65$ (Two degrees of Freedom).

Total SS for Treatments = 551.20 (5 Degrees of Freedom).

∴ Interaction SS = 551.20 - (411.65 + 136.53) = 3.02 (TWO DEGREES OF FREEDOM)

Analysis of Variance.

	D.F.	S.S.	Variance	S.D.	Log e	Z
Blocks	4	679.20	169.800	13.038		
Between Spacings	2	411.65	205.825	14.352	2.66372	.31133 Not.signif
1 plant v 2 plants	1	136.53	136.530	11.704	2.45960	.10821 Not Signif
Interaction	2	3.02	1.510	Not signif.		
Error	20	1291.30	64.565	8.035	2.35139	
Total	29	2521.70				

From Fisher's Tables $n_1 = 2$. $n_2 = 20$ 5% pt. = .8831

$n_1 = 1$. $n_2 = 20$ 5% pt. = 1.0457

∴ Treatments have not given a significant increase in yield.

The following table gives the average number of tillers - or rather cut ends of stubble - per hill for the various spacings.

30 hills picked at random were counted per plot in Blocks 20 and 21, so that the average number of tillers per hill for each treatment is based on the counts of 66 hills.

Mean No. stems	for	Single	Plant	8"	apart	=	$12.10 \pm .651$	Difference is significant
"	"	Double	"	8"	"	=	$9.90 \pm .649$	
"	"	Single	"	12"	"	=	$21.83 \pm .831$	Difference is significant
"	"	Double	"	12"	"	=	$17.13 \pm .646$	
"	"	Single	"	16"	"	=	26.00 ± 1.14	Difference is not significant
"	"	Double	"	16"	"	=	$27.03 \pm .972$	

Single plant 8" apart $M = 12.10 \pm .651$

" " 12" " $M = 21.83 \pm .831$

$$\frac{\text{Diff.}}{\text{Its S.E.}} = \frac{9.73}{\sqrt{(.651)^2 + (.831)^2}} = \frac{9.73}{\sqrt{1.14}} = \frac{9.73}{1.06}$$

$= 9.18$ Significant

Single plant 8" apart $M = 12.10 \pm .651$)
" " 16" " $M = 26.00 \pm 1.14$) Diff. is significant

Single plant 12" apart $M = 21.83 \pm .831$)
" " 16" " $M = 26.00 \pm 1.14$)

$$\frac{\text{Diff.}}{\text{Its S,E.}} = \frac{4.17}{\sqrt{(.831)^2 + (1.14)^2}} = \frac{4.17}{\sqrt{1.99}} = \frac{4.17}{1.41}$$

$= 2.95$ significant.

Similarly

Double plant 8" apart $M = 9.90 \pm .649$)
" " 12" " $M = 17.13 \pm .646$) Diff. is significant.

Double plant 8" apart $M = 9.90 \pm .649$)
" " 16" " $M = 27.03 \pm .972$) Diff. is significant

Double plant 12" apart $M = 17.13 \pm .646$)
" " 16" " $M = 27.03 \pm .972$) Diff. is significant

The number of rows per plot for the three different spacings:-

Treatments 1 & 4 have 21 rows per plot

" 2 & 5 " 14 " " "

" 3 & 6 " 10 " " "

Since the rows are all of the same length namely 84'. the number of hills per row for each of the treatments works out to be:-

for Treatments 1 & 4 with hills 8" x 8" - the total no. hills per row $= \frac{84 \times 12}{8} = 126$ hills

for Treatments 2 & 5 with hills 12" x 12" - the total no. hills per row $= \frac{84 \times 12}{12} = 84$ hills

for Treatments 3 & 6 with hills 16" x 16" - the total no. hills per row $= \frac{84 \times 12}{16} = 63$ hills

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Thanks are due to Professor Wood and Mr. Paterson - who initiated the problem - for valuable assistance and helpful suggestions.

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