THE POSSIBILITIES OF AN INDIRECT ESTIMATION OF PADDY YIELD FROM AUXILIARY PLANT CHARACTERS

By J. M. SEN GUPTA

Indian Statistical Institute

SUMMARY. The importance of obtaining an estimation of paddy yield, even though very approximate, on the basis of some suitable auxiliary characters well in advance of the actual harvest, cannot be over-emphasized because final and revised estimates could then be obtained subsequently by carrying out actual crop-cutting experiments.

Of the several physical characters of a paddy plant examined here, the height of a plant is found to possess a fair degree of correlation with yield, but other factors like weather conditions and incidence of pests and animals may influence the yield to a considerable extent. It, therefore, seems that, in addition to objective measurements, enumerations on somewhat subjective grounds of the condition of plants in their respective stages of development may prove helpful.

1. Introduction

1.1. *Objects.* A number of crop-cutting experiments on winter paddy were conducted at Giridih (Bihar) in December 1952. One of the objects was to evolve a technique for an early prediction of the yield rate of paddy by a quick (and cheaper) survey of one or more concomitant variates related to yield without recourse to actual crop-cutting work. One great advantage of such a scheme, is that the enumeration work involves very little time and therefore the size of sample could be made considerably large. The final estimates could then be built up at a subsequent stage when the plants were mature, by taking a smaller number of sample cuts. With this object, the variabilities of a number of physical characters of the paddy plant and their correlations with the corresponding yield rates have been worked out from this experimental material. It may be noted here that for the winter variety of paddy in this area, normal sowing is over by the end of July and harvesting is completed by the end of November extending sometimes up to the first week of December. To be of any value for purposes of planning and control of the food supplies, it is essential that the forecasts, however rough, should be available well in advance.

1.2. *Experimental procedure.* The sample points were located unistage over a compact patch of paddy land (comprising a number of small fields) cultivated under the Institute's direct management. At every point, the following plant characters were enumerated :

(i) number of plants, (ii) number of tillers, (iii) length of specified tillers along with the length of ears and the number of earlets in them, and finally, (iv) number of paddy grains in one specified earlet from each of these tillers.

These were observed for all plants contained within each of the two concentric circles of radii 6" and 12". The data was collected in the form of five independent samples of equal size and within each, every alternate sample unit or circle was enumerated twice over, i.e., duplicated by two independent parties. Around the same points as centres circular cuts of 4' radius (with a concentric sub-cut of 12" radius in sample 1 and of 2' radius in samples 2-5) were ultimately taken and the weights of green and dry paddy were recorded. The concentric circular cuts were taken by a special instrument devised by the Institute, which consists of a vertical screw and a horizontal arm with telescoped tubes of varying length. The vertical screw is driven into the ground, while the horizontal arm is rotated around and all plants covered in the sweep are harvested.

1.3. The enumeration was done by a batch of 12 investigators who were assigned groups of sample units allocated at random. The investigators counted up all the plants and tillers within a sample enclosure of 6" and 12" radius. The bunch of tillers sprouting from the same point on the ground where one or more seedlings were initially planted was defined as constituting a plant. In counting the number of plants contained within a circle, border plants, major section of which (at ground level) fell inside the circle were also included, and all tillers belonging to them were counted. The measurement of height was confined to the tallest and the shortest tiller of each individual plants. This measurement was taken as the total length between the tip of the tiller and the ground when the tiller was held fully stretched. Height of the tallest tiller represented the overall plant height. From each of these two tillers in a plant, length of the whole ear was measured and the total number of earlets (i.e. minute branchings emerging from the ear) and the number of paddy grains in the *top-most* earlet were counted up.

1.4. Harvesting was done for two concentric circles of radius 12" and 4' in sample 1 and for 2' and 4' circles in samples 2-5. Thus, the physical characters relating to the 6" and 12" circle could each be correlated with yield obtained from 12" circle and 4' circle in sample 1, and from 2' circle and 4' circle in samples 2-5. In the course of this experiment, it was found that the measurement of height and the counting of plants and tillers take up a good deal of time and identification of individual plants becomes extremely difficult for circles with a radius of more than 2'.

1.5. A small experiment was also carried out in order to study the changes in yield rate at progressive stages of maturity. Harvesting of sample cuts was started a fortnight before the normal date of harvesting and the same was continued for three weeks. The study was confined to two selected paddy plots, random cuts of radius 4' being taken in a number of sub-samples representing different periods of time at equal intervals. The results were expected to indicate firstly as to how much ahead of normal maturity, gross weight of paddy grains becomes steady. Secondly, it would give an idea about the extent of losses in delaying the harvest beyond the normal date.

2. Results of the experiment

2.1. *Mean and variability of certain auxiliary characters.* Table 1 gives the mean and coefficient of variation of a number of auxiliary characters in concentric circles of radii 6" and 12", based on the total material. The same computed for each of the five samples separately has been given in Table A.1 in the Appendix.

TABLE 1. MEAN AND COEFFICIENTS OF VARIATION FOR A NUMBER OF AUXILIARY CHARACTERS OF THE PADDY PLANT BASED ON SAMPLE UNITS IN THE SHAPE OF CONCENTRIC CIRCLES OF RADII 6" AND 12" (n=238)

auxiliary characters		mean		coefficient of variation	
		6" circle	12" circle	6" circle	12" circle
(1)		(2)	(3)	(4)	(5)
x_1	number of plants/sq. ft.	2.54	2.25	48.8	31.3
x_2	number of 'gross' tillers/sq. ft.	20.39	17.73	56.1	32.6
x_3	number of grain bearing tillers/sq. ft.	18.73	16.37	58.3	34.2
x_4	mean height of plant in inches	33.76	35.09	28.9	19.6
x_5	mean length of ear in inches	7.00	7.98	25.0	12.1
x_6	number of 'gross' tillers per plant	8.07	8.21	48.2	31.5
x_7	number of earlets per tillers	7.86	7.96	29.7	12.7
x_8	number of grains per earlet	10.07	8.23	30.7	17.8
x_9	number of grains per sq. ft.	917.66	815.48	72.1	45.2
x_{10}	number of earlets per sq. ft.	115.09	100.44	64.5	39.2
x_{11}	running inches of plant height	87.66	78.10	48.1	33.4
x_{12}	running inches of tiller height	592.20	508.87	67.0	41.0
x_{13}	yield (tolas) in one plant nearest to centre	0.66	0.06	74.0	74.0

2.1.1. The number of tillers (x_2) given in this table represent all tillers constituting a plant, some of which may not bear paddy grains. In the present sample, 92.3% of total tillers, as observed in the circles of 12" radius, were found to be fruitful ones, i.e., bearing grains. It may be noted here that the fate of an individual tiller, as to whether it would ultimately develop into a grain bearing one or not, may be known at a very late stage only after the flowering stages are over. The total (gross) number of tillers inclusive of the grainless ones may therefore be considered to be more relevant for purposes of prediction.

2.1.2. The variates x_4-x_{13} represent the observed averages of these characters in respect of the individual sample units of radius 6" or 12" based on the few readings taken from each. For instance, the total number of grains per sq. ft. in a circle of radius r' plot was computed as

$$\sum_{i=1}^{n} \frac{l_i(O_iE_i+g_ie_i)}{2\pi r^2}$$

where

G_i = number of grains in the top most earlet in the tallest tiller with E_i earlets in the i-th plant;

g_i = number of grains in the top most earlet in the shortest tiller with e_i earlets in the i-th plant;

t_i = total tillers in the i-th plant;

p = total plants in the circle of radius r' ft.

Similarly, the running length of tiller heights (variate x_{12}) was computed for each individual sample unit as

$$\sum_{i=1}^{p} \frac{t_i(H_i+h_i)}{2}$$

where

H_i = height of the tallest tiller in the i-th plant in ft.;

h_i = height of the shortest tiller in the i-th plant in ft.

Running length of plant height in a circle was computed as $\sum_{i}^{p} H_i$, height of the tallest tiller in a plant being considered as the effective plant height.

2.1.3. The fall in the coefficients of variation, when the size of the sample cut is increased so far as the auxiliary plant characters are concerned, is considerable as will be seen from columns (4) and (5) of Table 1. These coefficients are usually small in circles of 12" radius, except for the estimated number of grains per sq. ft. which has been obtained as 45.2%. Variability in the total yield of the 'central' plant is of course still higher being 74.0%. It may be noted here that the plots under investigation, although in a compact area, represent a highly varied cultivation in respect of varieties, manuring, spacing and the modes of cultivation. The area had changing slopes and many of the plots were under terraced cultivation.

2.1.4. Table 2 will show how far the counting and measurement of these characters were consistent and dependable. A comparison between the two different observations first and second returned by two different enumerators, has been made and the mean differences and the values of student's t have been worked out. As already mentioned, every alternate sample unit was to be re-enumerated by another worker by a fresh allocation of the work. In actual practice, more than 50% (132 out of 238) was re-enumerated and the whole material, not strictly a "sub-sample" on this account, has been analysed and the results given in Table 2. It will be seen that estimates A and B are very close and that except for one character, namely, the estimated number of grains per earlet (x_8) none of the differences comes out as significant. The significant but a small difference in character x_8 may have been due to considerable trampling during the first enumeration by batch A resulting in loss of grains, which is reflected in the second enumeration by B batch.

TABLE 2. COMPARISON BETWEEN THE TWO ESTIMATES OBTAINED FROM A DUPLICATED SURVEY OF IDENTICAL SAMPLE UNITS IN THE SHAPE OF CIRCLES OF RADIUS 12" (n = 132)

auxiliary characters		mean		difference (A − B)	
		1st survey (A)	2nd survey (B)	mean ± s.e.	student's t
	(1)	(2)	(3)	(4)	(5)
x_1	number of plants	2.22	2.21	.01 ± .01	0.58
x_3	number of 'gross' tillers	18.07	17.97	0.10 ± .09	1.34
x_4	mean height of plant in inches	35.41	35.43	−.02 ± .11	−0.20
x_5	mean length of ear in inches	7.95	7.92	.03 ± .04	0.84
x_7	number of earlets per tiller	8.33	8.25	.08 ± .04	1.90
x_8	number of grains per earlet	10.64	10.42	.22 ± .07	3.20*

*significant at 1% level.

2.2. *Correlation of the different plant characters with final yield.* Correlation coefficients of the final yield of green paddy obtained from cuts of 12" and 4' radius with a number of variates based on the physical characters observed in circles of radius 6" and 12" have been given in Table 3. These were also computed for each sample separately and the results are given in Table A.3 in the Appendix.

TABLE 3. CORRELATION COEFFICIENTS OF (PADDY) YIELD IN CIRCLES OF RADIUS 12" (n = 40) AND 4' (n = 238) WITH THE AUXILIARY PLANT CHARACTERS AND INDEPENDENT VARIATES, BASED ON THE CONCENTRIC CIRCLES OF RADIUS 6" AND 12"

auxiliary plant characters (derived) as independent variates (x_i)		correlation coefficient of			
		yield in 12" circles (y_1) with independent variates (x_i) $\bar{y}_1 = 18.2$ mds./acre c.v. $(y_1) = 42.6\%$		yield in 4' circles (y_4) with independent variates (x_i) $\bar{y}_4 = 21.4$ mds/acre c.v. $(y_4) = 43.3\%$	
		in 6" circle	in 12" circle	in 6" circle	in 12" circle
	(1)	(2)	(3)	(4)	(5)
x_1	number of plants/sq. ft.	.242	.365	.016	−.123
x_3	number of 'gross' tillers	.285	.418	.270	.235
x_4	mean height of plant in inches	.449	.564	.512	.708
x_5	mean length of ear in inches	.318	.514	.299	.631
x_6	number of 'gross' tillers per plant	−.019	.114	.336	.450
x_7	number of earlets per tiller	.435	.541	.302	.589
x_8	number of grains per earlet	.169	.237	.168	.341
x_9	number of grains/sq. ft.	.547	.731	.551	.713
x_{10}	number of earlets/sq. ft.	.506	.698	.514	.648
x_{11}	running inches of plant height	.467	.604	.331	.302
x_{12}	running inches of tiller height	.428	.439	.489	.583
x_{13}	yield (tolas) in one plant nearest to centre	—	.582	—	.511

2.2.1. From Table 3, it will be seen that the correlation of yield rate with the number of plants as also with the number of tillers is rather small. A correlation coefficient of 0.768 has been obtained between yield rate and the mean height of paddy plants. Table A.4 in the Appendix gives the two way frequency distribution of the same cuts between yield rates and the corresponding plant heights. The correlation coefficient between average plants height and the overall yield-rate (based on a complete harvest of each plot) relating to the 40 individual plots that constitute our total "field", has again come out as 0.677. This indicates the presence of considerable correlation even at the level of "field" units.

2.2.2. It may be noted however, that the correlation with mean plant height as obtained here, may have been merely a local feature, that applies to an area where sowing is done by transplantation. In other localities with broadcast sowing, or with other varieties of paddy, mean height of plants may assume quite different levels. The area to be sampled has therefore to be adequately stratified to take advantage of this correlation.

2.2.3. As expected, the correlation coefficients of yield in circles with a given radius, are usually higher with the physical measurements relating to the 12' circles than with the same of 6' circles. From the practical point of view it is essential that the enumeration of the physical characters is confined to the smallest unit, from considerations of cost as also of accuracy in field enumeration. The correlation is liable to become less however if this unit is very much smaller in size than the sample cut itself.

2.2.4. Among the derived characters, correlation of yield is highest with the number of grains per sq. ft. (as computed from the number of paddy grains in the top-most earlet of the tallest and of the smallest tiller of each individual plant in the circle) which is found to be considerable. This is however of a doubtful practical value, in as much as the prediction is likely to be required at a time, when most of the tillers will not shoot out their ear in full. At a time much before the normal harvesting time, specially before the flowering stages, it is the number of plants, height attained by the plants and the number of tillers emerging, that will have to be observed and prediction formulae could make use of these characters alone.

2.2.5. Correlation of the paddy weight obtained from one single plant situated nearest to the located sample point with the yield obtained by harvesting a circle of 4' radius is also fairly high being 0.511. But this is a character which we can enumerate only after the crop is mature. Nevertheless, this suggests that harvesting of one or two plants only and counting up the plants contained within the circle may economise the crop cutting operations. A random selection of a few individual plants from within a sample enclosure, would however present a lot of practical difficulties.

2.2.6. It would be worthwhile to study also the multiple correlation coefficients that exist between the more effective characters with yield. The correlation coefficients of yield in cuts of 4' radius with physical characters in 12' cuts in various combinations have been obtained as given in Table 4.

TABLE 4. MULTIPLE CORRELATION COEFFICIENTS OF YIELD IN 4' CIRCLE WITH PHYSICAL CHARACTERS RELATING TO 12' CIRCLE

Independent variates from circles of 12' radius	correlation coefficient of y_4 with independent variates (x)	p.c. of variation explained
(1)	(2)	(3)
1. mean height of plant (x_4)	.708	50.1
2. mean height of plant (x_4) and number of 'gross' tillers (x_2)	.772	59.7
1. mean number of earlets per tiller (x_7)	.589	34.7
2. mean number of earlets per tiller (x_7) and number of 'gross' tillers (x_2)	.642	41.2
3. mean number of 'gross' tillers (x_2), earlets per tiller (x_7) and grains per earlet (x_8)	.713	50.8

It will be seen that the highest correlation of 0.708 is obtained from a single character, namely the mean height of plants. The gain in having multiple correlation with one or two additional characters is negligible as will be evident from the respective percentages of variances due to regression given in Column (3). Coefficients of mutual correlation for seven independent characters have been given in Table 5.

TABLE 5. COEFFICIENTS OF MUTUAL CORRELATION BETWEEN DIFFERENT PLANT CHARACTERS AS DERIVED FROM 12' CIRCLES ($n = 238$)

plant characters (derived)	plant characters						
	x_1	x_2	x_4	x_5	x_6	x_7	x_8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
x_1 number of plants	—	.593	—.215	—.355	—.418	—.362	—.203
x_2 number of 'gross' tillers	.593	—	.214	—.059	.411	—.003	—.181
x_4 mean height of plant	—.215	.214	—	.723	.507	.810	.338
x_5 mean length of ear	—.355	—.059	.723	—	.360	.708	.636
x_6 number of 'gross' tillers per plant	—.418	.411	.507	.360	—	.435	.043
x_7 number of earlets per tiller	—.362	—.003	.810	.708	.435	—	.447
x_8 number of grains per earlet	—.203	—.181	.338	.636	.043	.447	—

2.3. *Correlation of the different plant characters with straw yield.* It was expected that the yield of dry straw show a higher correlation with certain plant characters like height and the number of plants or tillers, than in the case of paddy yield. Correlation coefficients with four different characters have been worked out on all the five samples taken together, and the results are shown in Table 6. The highest correlation has been obtained as 0.745 with mean height of plants. Correlation with the running length of tillers is also fairly high being 0.653 while the same with number of plants and number of tillers is quite small.

TABLE 6. CORRELATION COEFFICIENTS BETWEEN YIELD OF STRAW IN CIRCLES OF 4' RADIUS AND CERTAIN PLANT CHARACTERS IN CIRCLES OF 12' RADIUS

mean yield of straw = 31.18 mds. per acre
coefficient of variation = 61.5%

	plant characters with yield of straw	correlation coefficient ($n = 220$)
	(1)	(2)
x_1	number of plants	—.019
x_3	number of 'gross' tillers	.347
x_4	mean height of plant	.745
x_{11}	running inches of tiller height	.653

2.4. *Cost of enumerating the physical characters.* A study of the time spent in enumerating the different characters has not however been attempted in these experiments. It is obvious that to be of any practical use, such characters as are easy to enumerate and highly correlated with yield will have to be selected and utilised. Further experiments are obviously necessary in order to ascertain the relative merits of each character in predicting the yield rate, when cost and correlation are both taken into account.

2.4.1. Apart from the question of relative costs, the importance of obtaining a prediction of outturn, even though very approximate, need not be over-emphasised. It should be quite useful if such provisional forecasts could be arrived at on the basis of some suitable auxiliary characters, well in advance of the actual harvest. Final and revised estimates could then be obtained subsequently by carrying out actual crop cutting experiments. There is one distinct advantage in this two-phase procedure. In taking physical measurements alone, the time of arriving at the spot at the right moment is not so critical as in actual crop cutting and for this purpose securing the cultivator's permission is hardly necessary.

2.5. *Progressive estimates of yield rate by successive dates of harvesting.* As already discussed, two plots were chosen for this study and samples of 20 cuts were taken at intervals of 5 days, starting from a date 10 days ahead of the normal harvesting time. The material is however much too meagre for drawing general conclusions and it is unfortunate that the experiment could not be started sufficiently early so as to obtain the yield estimates for paddy in its very immature stages. It may be noted here that for purposes of estimating the expected yield, it does not matter, if the kernel has not duly formed and not yet in the edible stage. As our estimate of the yield rate refers to the final weight of paddy grains, it would suffice if the apparent weight of paddy capsules, irrespective of the quality of its inner contents at the time of observation, assumed a stable relation with the final yield.

2.5.1. Table 7 gives the rates of mean yield with their standard errors in the successive 'time' samples in each of the two plots. It may be noticed that the yield rate had not reached its maximum until the 23rd of November. According to the local cultivators, the period 21st to 25th of November was the most appropriate time of harvesting. It appears therefore that the cultivator's judgement is fairly good and that the yield rate subsequently goes on falling, due to pilferage, shedding of grains or destruction by birds and animals. The experiment was continued upto one full month beyond the normal date of harvesting when the yield rate was found to go down very rapidly.

TABLE 7. PROGRESSIVE ESTIMATES OF YIELD RATE BASED ON SUB-SAMPLES ON 2 CUTS OF 4' RADIUS TAKEN AT INTERVALS OF 5 DAYS FROM TWO PADDY PLOTS (1952)

date of harvest		mean yield ± se			index of col. (7) base = yield rate as on 23.11.52
		plot no. 20	plot no. 21	pooled	
(1)		(2)	(3)	(4)	(5)
November	13	4.54 ± .32	6.51 ± .40	5.52 ± .34	75.5
	18	5.88 ± .48	6.57 ± .74	6.22 ± .44	75.1
	23	7.12 ± .27	7.50 ± .63	7.31 ± .34	100.0
	28	5.47 ± .31	7.54 ± .67	6.50 ± .43	88.0
December	3	5.75 ± .60	6.00 ± .66	5.88 ± .43	80.4
	8	5.23 ± .63	4.89 ± .67	5.06 ± .41	69.2
	13	5.04 ± .63	4.56 ± .42	4.80 ± .37	65.7
	16	4.40 ± .31	2.90 ± .38	3.65 ± .29	49.9
	19	1.13 ± .23	0.45 ± .10	0.79 ± .15	10.8
	22	0.16 ± .00	0.24 ± .01	0.20 ± .04	2.7

2.5.2. The object of this experiment was to ascertain the range, i.e., the number of days before and after the normal date of harvesting within which the yield would remain for all practical purposes stationary. The wider this range, the greater would be the latitude for sampling operations, and for advance crop cutting experiments on the premature crop. The present experiments have however been quite inadequate for achieving this object.

3. Conclusions

3.1. Of the several physical characters of a paddy plant examined here, the height of plant is found to possess a fair degree of correlation with yield. It seems however that an efficient production of paddy yield from a physical measurement of the plant characters is difficult of achievement. Other factors like the weather conditions, incidence of pests and animals, influence the yield to such an extent, that predictions on the basis of physical characters alone may deviate widely from the real yield. Thus it seems, that in addition to such objective measurements, enumerations on somewhat subjective grounds of the condition of plants in their respective stages of development, may prove to be helpful. If such observations are continued from year to year, a series of data will eventually be thrown up, from which the relations between actual yield and these subjective enumerations may be studied and results utilised for provisional forecasts. The possibilities for the prediction of final yield from crop-cutting experiments on immature paddy, two or three weeks ahead of full maturity, should be explored further.

Appendix

TABLE A.1. MEAN AND COEFFICIENTS OF VARIATION OF A NUMBER OF PHYSICAL CHARACTERS OF PADDY PLANT BASED ON SAMPLE UNITS IN THE SHAPE OF CONCENTRIC CIRCLES OF RADII 6" AND 12" (TOTAL n=238)

(i) sample units of 6" circle

auxiliary plant character	sample 1 n=46	sample 2 n=49	sample 3 n=48	sample 4 n=47	sample 5 n=48	total n=238
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mean values						
1. number of plants/sq. ft.	2.35	2.49	2.84	2.65	2.33	2.54
2. number of 'gross' tillers/sq. ft.	18.88	22.01	22.07	19.64	19.23	20.39
3. number of grain bearing tillers/sq. ft.	17.41	20.40	19.97	17.61	18.14	18.73
4. mean height of plants in inches	35.30	33.96	33.59	31.44	34.44	33.76
5. mean length of ear in inches	7.77	7.67	7.72	7.09	7.74	7.80
6. mean number of 'gross' tillers per plant	8.37	8.59	7.73	7.00	8.64	8.07
7. mean number of earlets per tiller	8.10	8.10	7.86	7.21	8.01	7.86
8. mean number of grains per earlet	10.41	10.18	10.26	9.14	10.33	10.07
9. number of grains/sq. ft.	814.34	1074.46	998.69	818.00	873.18	917.66
10. number of earlets/sq. ft.	106.27	131.61	121.26	105.11	110.38	115.09
11. running inches of plant height	82.03	88.97	98.32	98.72	80.00	87.66
12. running inches of tiller height	555.77	670.77	642.50	548.00	539.85	592.20
13. yield (tolas) in one plant nearest to centre	0.60	0.75	0.69	0.47	0.76	0.66
coefficients of variation						
1. number of plants/sq. ft.	45.8	44.4	52.4	53.0	45.8	48.8
2. number of 'gross' tillers/sq. ft.	48.8	56.3	60.8	61.1	49.7	56.1
3. number of grain bearing tillers/sq. ft.	51.7	57.2	64.6	62.4	52.9	58.3
4. mean height of plants in inches	19.0	32.0	29.3	35.7	25.2	28.9
5. mean length of ear in inches	15.8	27.0	26.1	32.7	21.7	25.0
6. mean number of 'gross' tiller per plant	37.2	54.9	46.8	47.0	40.8	48.2
7. mean number of earlets per tiller	21.4	31.1	31.7	36.8	24.7	29.7
8. mean number of grains per earlet	24.0	30.0	29.2	37.5	30.5	30.7
9. number of grains/sq. ft.	61.6	70.7	69.7	80.3	63.3	72.1
10. number of earlets/sq. ft.	55.5	65.9	63.5	74.4	60.0	64.5
11. running inches of plant height	46.6	50.7	37.0	58.4	45.5	48.1
12. running inches of tiller height	56.1	70.8	67.2	72.2	62.7	67.0
13. yield (tolas) in one plant nearest to centre	54.6	56.0	94.5	68.9	77.7	74.0

TABLE A.2. MEAN AND COEFFICIENTS OF VARIATION FOR A NUMBER OF PHYSICAL CHARACTERS OF THE PADDY PLANT BASED ON SAMPLE UNITS IN THE SHAPE OF CONCENTRIC CIRCLES OF RADII 6" AND 12" (TOTAL n = 238)

(ii) sample units of 12" circle

auxiliary plant character	sample 1 n = 46	sample 2 n = 49	sample 3 n = 48	sample 4 n = 47	sample 5 n = 48	total n = 238
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mean values						
1. number of plants/ sq. ft.	2.18	2.20	2.47	2.19	2.21	2.25
2. number of gross tillor /sq. ft.	17.60	17.66	18.64	16.79	17.94	17.73
3. number of grain bearing tiller/sq. ft.	15.98	16.64	17.10	15.24	16.84	16.37
4. mean height of plants in inches	35.36	35.12	35.45	34.30	35.17	35.09
5. mean length of ear in inches	7.94	8.01	8.11	7.88	7.93	7.98
6. mean number of 'gross' tillor per plant	8.30	8.47	7.91	7.85	8.49	8.21
7. mean number of earlet per tillor	7.98	7.90	8.05	7.86	7.93	7.96
8. mean number of grains per earlet	8.18	8.31	8.32	8.10	8.24	8.23
9. number of grains/sq. ft.	767.92	870.30	896.06	718.97	819.00	815.48
10. number of earlets/sq. ft.	96.26	104.88	108.92	90.64	101.02	100.44
11. running inches of plant height	77.15	76.73	86.89	74.14	75.79	78.10
12. running inches of tillor height	510.60	514.76	550.70	461.36	505.89	508.87
13. yield (tolas) in one plant nearest to centre	0.60	0.75	0.69	0.47	0.76	0.66
coefficients of variation						
1. number of plants/sq. ft.	27.0	29.5	34.1	28.7	34.3	31.3
2. number of 'gross' tiller/sq. ft.	31.8	30.7	32.3	37.8	30.6	33.6
3. number of grains bearing tiller/sq. ft.	33.4	32.9	33.7	30.1	32.3	34.2
4. mean height of plant in inches	18.2	21.2	19.2	20.6	20.4	19.8
5. mean length of ear in inches	10.6	14.6	11.3	12.8	12.4	12.1
6. mean number of (gross) tillers per plant	28.0	37.8	33.0	30.4	27.7	31.5
7. mean number of earlets per tiller	11.1	14.5	11.9	13.8	12.3	12.7
8. mean number of grains per earlet	15.1	19.0	17.7	19.6	18.0	17.8
9. number of grains/sq. ft.	43.2	48.3	43.1	44.8	43.5	45.3
10. number of earlets/sq. ft.	38.5	42.4	37.0	39.2	37.2	39.2
11. running inches of plant height	32.6	37.1	35.0	27.0	31.8	33.4
12. running inches of tiller height	43.2	45.3	40.4	35.4	38.3	41.0
13. yield (tolas) in one plant nearest to centre	54.6	56.0	94.5	68.9	77.7	74.0

TABLE A.3. CORRELATION COEFFICIENTS OF YIELD IN CIRCLES OF RADII 2' AND 4' WITH THE CORRESPONDING AUXILIARY PLANT CHARACTERS TREATED AS INDEPENDENT VARIATES OBTAINED FROM CONCENTRIC CIRCLES OF RADII 6' AND 12' (TOTAL $n=238$)

auxiliary plant characters as independent variates (x_i)	correlation coefficients of the auxiliary character with yield rate based on						
	1' circle (Y_1) in sample 1 only $n=46$	4' circle (Y_4) in sample 1 $n=46$	sample 2 $n=49$	sample 3 $n=48$	sample 4 $n=48$	sample 5 $n=48$	total $n=238$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(i) independent variates for 6' circle							
x_1 number of plants/sq. ft.	.242	.202	.130	.156	.089	.157	.016
x_3 number of 'gross' tillers/sq. ft.	.285	.306	.391	.129	.294	.211	.270
x_4 mean height of plant in inches	.440	.576	.681	.469	.328	.571	.512
x_5 mean length of ear in inches	.318	.376	.622	.216	.115	.310	.299
x_6 number of 'gross' tillers per plant	.019	.060	.443	.482	.167	.404	.336
x_7 number of earlets per tiller	.435	.492	.573	.301	.267	.344	.362
x_8 number of grains per earlet	.159	.154	.257	.143	.120	.121	.168
x_9 number of grains/sq. ft.	.547	.500	.071	.455	.582	.485	.551
x_{10} number of earlets /sq. ft.	.506	.529	.636	.359	.551	.461	.514
x_{11} running inches of plant height	.467	.476	.474	.112	.392	.130	.331
x_{12} running inches of tillor height	.426	.519	.626	.334	.510	.426	.489
x_{13} yield (tolas) in one plant nearest to centre	.582	.347	.403	.531	.657	.454	.511
(ii) independent variates for 12' circle							
x_1 number of plants/sq. ft.	.365	.138	.154	—.301	—.299	—.272	—.123
x_2 number of tillers/sq. ft.	.418	.210	.544	.137	.196	.043	.235
x_4 mean height of plants in inches	.564	.670	.830	.762	.821	.755	.768
x_5 mean length of ear in inches	.514	.540	.770	.622	.620	.557	.631
x_6 number of tillers per plant	.114	.080	.494	.588	.622	.430	.450
x_7 number of earlets per tiller	.541	.473	.621	.582	.670	.558	.589
x_8 number of grains per earlet	.237	.102	.386	.318	.283	.483	.341
x_9 number of grains/sq. ft.	.731	.856	.829	.718	.720	.607	.713
x_{10} number of earlets/sq. ft.	.608	.586	.823	.633	.644	.494	.648
x_{11} running inches of plant height	.604	.495	.565	.076	.205	.138	.302
x_{12} running inches of tillor height	.439	.526	.772	.531	.615	.453	.583
x_{13} yield (tolas) in one plant nearest to centre	.582	.347	.403	.531	.657	.454	.511

TABLE A.4. TWO WAY FREQUENCY DISTRIBUTION OF CUTS BY MEAN HEIGHT OF PLANTS IN 1' (x) CIRCLE AND YIELD IN TOLAS PER CUT OF 4' RADIUS (y)

yield in tolas per cut of 4' radius	mean height of plant (inches) in circle of 1' radius																				total
	19 –20–	21 22–	23 24–	25 26–	27 28–	29 30–	31 32–	33 34–	35 36–	37 38–	39 40–	41 42–	43 44–	45 46–	47 48–	49 50–	51 52–	53 54–	55 56		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	
171—180													1				1	1			3
161—170																1					1
151—160								1		1			1		2	2	2	1	1	1	11
141—150									1					1	1		1				4
131—140												1	2		1	1					5
121—130							1			2	1		1	1	2	1	1				10
111—120							1		2	1	1	1									6
101—110							4	2	1	3	1	1	1								13
91—100					1	3	1	3	4	4											16
81— 90						4	6	4	5	2	1				1						23
71— 80				1	2	10	10	9	6		2	1					1				42
61— 70				3	3	9	9	3	1			1	1								30
51— 60			2	3	9	7	2	4	2	1											30
41— 50			3	4	2	1	1	3	2	3	2										21
31— 40			2		4	3		1	1	1											12
21— 30	1		1		1					1											4
11— 20	1	1	3		1	1															7
1— 10																					–
total	2	1	11	11	23	38	35	30	25	19	6	5	7	2	7	5	6	2	1		233

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