RAINFALL AND YIELD IN THE COCONUT *

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Introduction. The yield is the result of the interaction of genetical and environmental factors. The plant-breeder utilizes the genetic variance in evolving superior types; and the agronomist aids the former in adopting the optimum conditions for the growth of the superior type. One of the important functions of the agronomist is to suggest ways and means to reduce to the minimum the variations in the yields.

The yields of any group of coconuts fluctuate from year to year without any regularity, i. e., there is no periodicity. When the trees receive identical treatment every year, and when the age of the plantation does not influence the yields, the yearly variations in the yield must chiefly be attributed to the weather conditions. A consideration, therefore, of the effect of rainfall on the yield is necessary. In the present communication an attempt is made to show how the yields vary according to the rainfall and how the variations incidental to the rainfall can be reduced to the minimum by suitable changes in the agronomic practices.

Materials and Methods. The data utilized in this paper were collected at the Agricultural Research Station, Kasaragod (District: South Kanara) on the West Coast of India. The soil is red loam. The number of rainy days, and the total rainfall for the different seasons and years, are tabulated in Table I. The yield-data utilized in various correlations was collected from 105 regular bearing palms in Block I. The trees are of the ordinary tall type and they were about twenty-five years old in 1919. The plot has been manured and cultivated more or less in the same manner from year to year. The plot has never been irrigated.

In some of these trees, one or two bunches were damaged by beetles. As this would reduce the yield of the trees, the following correction was applied to the particular year's yield, when any damaged bunch would be ready for harvest. The missing yield is

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$y = \frac{x \times a}{a_1}$ were x is equal to the average for the missing month calculated from the rest of the years, a the average yield per month for the remaining months of the same year, and a_1 the average yield per month for the remaining months of the remaining years.

Wishart and Allen's method could not be used as the number of missing bunches was large (300) and would involve laborious calculations. In working out the relationships, ordinary correlation tables have not been prepared. The yearly yields ranged between 10 and 180 nuts per tree per annum. and, therefore, fine grouping makes the number of class intervals unwieldy. Similarly, for the rainfall, the differences are as low as half an inch and this fact causes the inclusion of two or more years' data exclusively into the same row. It was, therefore, thought better to use the simple product-moment method where the correlation coefficient r is given by the formula:

$$\frac{\sum d' \cdot d''}{\sqrt{\sum d'^2 \; d''^2}}$$

As the correlations are worked out in the same manner for all the combinations of the rainfall, the relationships are comparable among themselves. Since, by this method, the effective number of readings dwindles down to 13, which is too inadequate for an analysis of this kind, the relationship between the rain and the yield is considered to be present in cases where r is not less than 0·6; this is enough to lodge the P between 0·02 and 0·01. Before proceeding with the presentation of the data, it must be admitted that the only justification for the departure from the orthodox procedure of dealing with the data spread over a large number of years, is the importance of drawing the attention of the workers to this problem.

Rainfall.—In point of distribution of the rainfall, the coconut areas in India fare very badly when compared to Ceylon and Malaya. On the West Coast, from the middle of December up to the first of April, only a few showers are received. The number of rainy days and the total rainfall for the different seasons and years are tabulated in Table I.

During the south west monsoon very heavy rainfall is received, and the south west monsoon, if at all late, is late only by a few days. The north east monsoon rains are not uniform, but the variations in the early part of the season have very little effect on the yield. That the changes in the quantity of rain received during the south west monsoon and early part of the north east monsoon bear no relation to the yield, is evident from the correlations in Table II, where the value of r is not significant for any of the comparisons. The total rainfall during the calendar year, previous to the year of harvest, does not appear to affect the yield.

Table I.

The Distribution of Rainfall.

Year.	South west monsoon.	North east monsoon.	Hot weather.	Total.	Calendar year.	South west monsoon rains during 1919 *plus* hot weather rains during 1920 for 1921 yields.	North east monsoon *plus* hot weather rains just preceding the year of harvest.	Two hot weather rains previous to the year of harvest.	Total rains during the calendar year.	No. of rainy days. North east.	No. of rainy days. Hot weather.	No. of rainy days. Total.
1919–20	104·14	20·55	10·39	135 08	...	...	...	...	...	...	...	...
1920–21	115·95	10·57	5·43	131·95	...	...	...	...	130·97	35	12	47
1921–22	115·70	12·51	13·79	142 00	1921	109·57	25·98	15·82	141·55	24	22	46
1922 23	104·56	12·17	15·16	131·89	1922	129·74	24·36	19·22	131·89	18	27	45
1923–24	119·75	3·61	4·25	127·61	1923	130·86	27·67	28·95	127·61	24	8	32
1924–25	117·88	3·75	15·28	136·91	1924	108·83	16·42	19·41	136·91	11	23	34
1925–26	101·42	24·56	24·48	150·46	1925	135·03	18·89	19·53	150·33	14	27	41
1926–27	99·64	10·38	1·42	111·44	1926	142·36	28·23	39·76	111·44	32	6	38
1927–28	91·37	16·47	30·78	138·62	1927	102·84	25·98	25 90	138·10	17	22	39
1928–29	86·49	21·85	16·47	124·81	1928	130·42	41·16	32·20	124 81	20	12	32
1929–30	110·53	26·11	23·34	159 98	1929	107·84	32·94	47·25	159 36	25	22	47
1930–31	88·97	23·49	19 41	131 87	1930	109·83	45·19	39 81	131·87	27	21	48
1931–32	117·71	9·38	20·45	147·54	1931	129 94	45·52	42·75	147 54	30	18	48
1932–33	75·18	26·95	25·06	127·19	1932	109·42	43·94	39 86	127·19	30	25	55
1933–34	102·95	20·50	46·80	170·25	1933	142·77	...	...	...	...	...	...

Table II

Coefficient of correlations between the yield and rains of :—	*r*
South west monsoon during the year previous to the year of harvest.	- 0·3004
One north east monsoon rains previous to the year of harvest.	0·1141
South west monsoon in 1919 *plus* hot weather rains, i. e., for 1921 yields.	0 1790
Total rains during the calendar year previous to the year of harvest.	0·5430

The rains received during the south west monsoon are very heavy, and the variations in the rainfall during this period are large enough to mask the effect of other rains when they are combined with the rains received during the south west monsoon. The rainfall during the south west monsoon has, therefore, to be eliminated in determining the relationship between the rainfall and the yield. For the same reasons, the rainfall during the early part of the north east monsoon is also eliminated. The rains which are most likely to affect the trees are those received during the later part of the north east monsoon and during the hot weather. The rains during the hot weather period—January to April—are most irregular (fig. 1). In the following table the important rains are given from 1919 to 1933. In this tabla, x_1 denotes January to May rains of the year of harvest, x_2 January to May rains during the year previous to the harvest, and x_3 January to May rains during the second year previous to harvest.

Table III.

Important Rains.

Years.	January.	February.	March.	April.	Up to 15th May.	After 16th May.	x_1	x_2	x_3	F + M* of x_1, x_2 and x_3.	Average yield per tree per year.
1919	...	...	0·14	0·11	...	5·14	...	...	...	...	...
1920	0·07	...	...	2·86	...	1·07	...	...	...	..	...
1921	0·98	...	...	1·72	2·07	5·13	0·57	2·93	0·25	0 14	61·13
1922	0·45	...	...	2·61	1·79	5·89	5·14	2·70	2 93	...	66·58
1923	...	...	0·45	0·12	0·08	3·18	2·45	3·06	2·70	0·45	58·45
1924	...	...	2·44	2·70	0 03	3·21	0·62	5·57	3·06	2·89	57·88
1925	...	...	1·20	1·25	3·12	13·31	...	5·12	0·57	4·09	60·30
1926	0·13	0·40	...	0·09	...	0·31	...	2·45	5·14	4·04	78·44
1927	...	...	0·03	2·34	...	11·24	...	0·62	2·45	1·63	51·77
1928	0·52	4·72	3·15	...	0·13	0·27	...	2·37	0·62	8·30	70·49
1929	...	...	0·20	5·39	5·40	5·99	...	8·39	2·37	8·10	86 26
1930	0·02	...	...	4·77	10·71	13·50	...	5·59	8 39	7·80	85·29
1931	...	...	0·02	8·36	1·60	7·74	...	4·79	5·59	0·40	73·98
1932	...	...	...	0·42	1·20	22·65	...	8·38	4·79	0·20	62·09
1933	...	...	0·21	6·19	...	19·51	...	0·42	8·38	0·41	60·10
										Mean	67·14

* x_1 stands for total rains in January, February, March and April during the year of harvest. x_2 stands for total rains in the same months during the year previous to harvest. x_3 stands for total rains in the same months during the second year previous to harvest. F and M stand for February and March rains respectively.

Table IV

Correlations of yield with important rainfalls.

(*Note:*—J, F and M stand for January, February and March rains respectively.)

		Value of r
1	x_1 = total rains in January, February, March and April during the year of harvest.	0·3400
2	x_2 = total rains in the same months during the year previous to harvest.	0·4598
3	x_3 = total rains in the same months during the second year previous to harvest.	0·3393
4	$(x_1 + x_2)$	0·6428
5	$(x_2 + x_3)$	0·6273
6	$(x_1 + x_2 + x_3)$	0·6767
7	J + F + M of $(x_1 + x_2 + x_3)$	0·7211
8	$(x_2 + x_3)$ + (J + F of x_1)	0·6995
9	J + F + M of x_2 and x_3	0·8104
10	J + F + M of x_2 + (J + F of x_1)	0·5589
11	F + M of (x_1, x_2 and x_3)	0·6656
12	x_2 + (F + M of x_1)	0·4628
13	x_2 + (J + M of x_1)	0·5199
14	J + F + M of x_2 and F + M of x_1	0·4170
15	J + F + M of x_1 and x_2	0·4587
16	J + F + M of x_2 and J + M of x_1	0·3723
17	x_2 + (J + F of x_1)	0·5669
18	April of x_3 + (J + F + M of x_2) (J + F of x_1) ...	0·3989
19	x up to the 15th May + (J + F of x_1)	0 6409
20	x_2 and x_3 up to the 15th May	0·3391

Note:—All values of r above 0·6000 are clearly significant. P is less than 0·02 The differences between these significants are not significant.

In table IV the coefficients of correlations for twenty different combinations of rainfall are tabulated. The magnitude of the r is the largest for the combination (9) —i. e., January to April rains for two years previous to the harvest. The coefficients for seven other combinations are also significant.

The values of the total correlations, viz., ryx_1, ryx_2 and ryx_3 are utilized in finding out the partial correlations (y = yield). The values of the partial correlations are given below:—

Particulars.	Correlation coefficient. Total.	Partial.
$ryx_1 - x_2x_3$	0·3400	0·2769
$ryx_2 - x_3x_1$	0·4598	0·3466
$ryx_3 - x_1x_2$	0·3393	0·2133

For these data partial regression will be more appropriate and therefore the following relationship has been calculated for the deviations of yield y in terms of the deviations of the respective rainfall totals from their means :—

$$y = 2{\cdot}3427x_1 + 3{\cdot}9907x_2 + 0{\cdot}8538x_3$$

A multiple correlation where $R = 0{\cdot}798$ was also obtained. The multiple correlation value is very close to the coefficient of correlation for the total rains in three years during January to April. The total as well as the partial correlations are not significant, thereby, indicating that the rainfall of one year is not related to the rainfall of another year for the observations made, and that total correlations, wherever significant, are not spurious.

Significance of the partial regression coefficients.

Regression coefficient.	Value of b.	Value of P.
b_1	2·3407±0·84	< 0·02
b_2	3·9907±1·01	< 0·01
b_3	0·8538±0·78	> 0·90

The regression coefficients, given above, show that the rainfall of the year previous to the year of the harvest are significantly correlated to the yield. Though the regression coefficient, for the rainfall of the second year previous to the harvest, is not significant, the importance of this rainfall is derived from the fact that multiple correlation is significant.

Variance due to	Degrees of freedom.	Sum of squares.	Mean square.	Z
Linear regression	3	907·30	302 43	
Deviation from linear regression.	9	542·89	60·32	
Total.	12	1450·19		0·8059

The figures given above show a slightly significant deviation from linear regression, indicating that the curve of the relationship between the rainfall and the yield does not follow a straight line. The points appear to be distributed along a parabola.

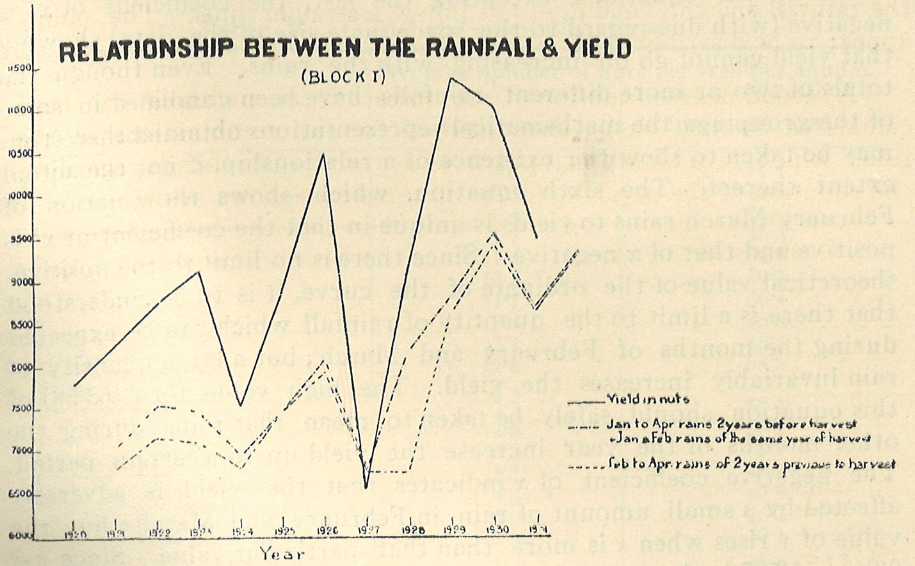
A second degree function of the closest fit of parabola has been calculated by the least square method for the combinations of the rains which give highly significant values of *r*. The details regarding the equation of the parabola of the closest fit are given below:—

Particulars of rains.	Equation of parabola.
(1) x_2	$y = 54{\cdot}489 + 5{\cdot}227x - 0{\cdot}3x^2$
(2) $x_3 + x_2$ + January and February rains of the year of harvest.	$y = 44{\cdot}795 + 4{\cdot}336x - 0{\cdot}149x^2$
(3) January, February and March rains of (x_2 and x_3)	$y = 57{\cdot}2 + 4{\cdot}521x - 0{\cdot}13x^2$
(4) January, February and March rains of ($x_1 + x_2 + x_3$)	$y = 56{\cdot}556 + 3{\cdot}564x - 0\ 098x^2$
(5) $x_1 + x_2 + x_3$	$y = 44{\cdot}5 + 1{\cdot}734x - 0{\cdot}009x^2$
(6) February and March rains of $x_1 + x_2 + x_3$	$y = 63{\cdot}658 - 1{\cdot}795 + 0{\cdot}48x^2$

In all the above equations, *y* denotes the yield in nuts per tree and *x* represents the quantity of rain in inches during the respective periods. All the equations show, as expected, that the yield does not go below a certain minimum even if *x* becomes zero. The minimum yield that can be expected, per tree, even if January to April rains for the two years prior to harvest and for the year of the harvest are nil, is about 44 nuts per tree.

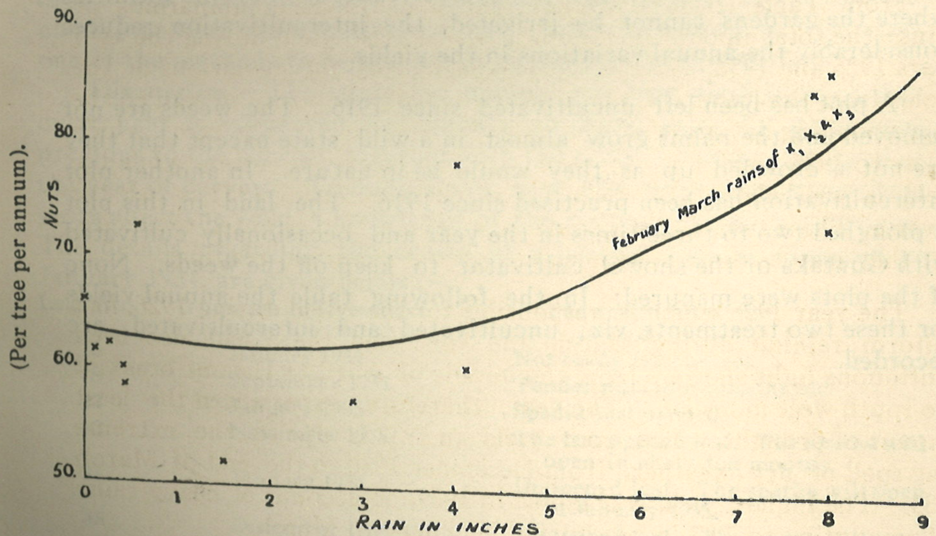
From Table III, it is evident that none of the combinations of rains—the total amount of rainfall—explain the yield during the two years 1926 and 1932. Contrary to expectations, the deviations of the yields from the mean are, for these two years, opposite in sign to the corresponding deviations of the rains for the mean. The rains which relate to 1926 yield, *i. e.*, those of 1925 are below the mean, while the yield is well above the mean. The position during 1932 is just the reverse. These two, out of 13 readings, cannot be attributed to chance, but they may be more appropriately termed abnormal readings.

The year 1925 which is responsible for the yield during 1926, had uniform rainfall during March and April and there had also been continuous light showers from the middle of April to the out-break of the south west monsoon. The year, therefore, experienced the least amount of drought. The poor yield in 1932 is due to the extreme long spell of dry weather, from December 1930 to the end of March 1931. The highest yield is obtained in 1929, on account of heavy rainfall amounting to 7·87 inches during February to March.



GRAPH I

GRAPH II



In all the equations, excepting the last, the coefficient of x^2 is negative (with due regard to the inadequate size of the data) showing that yield cannot go on increasing with the rains. Even though the totals of two or more different rainfalls have been combined in some of the groupings, the mathematical representations obtained therefrom may be taken to show the existence of a relationship, if not the actual extent thereof. The sixth equation, which shows the relation of February-March rains to yields is unique in that the coefficient of x^2 is positive and that of x negative. Since there is no limit to the positive, theoretical value of the ordinate of the curve, it is to be understood that there is a limit to the quantity of rainfall which can be expected during the months of February and March; but a large quantity of rain invariably increases the yield. The high value for c (63·58) of this equation should safely be taken to mean that rains during the other months of the year increase the yield up to a certain period. The negative coefficient of x indicates that the yield is adversely affected by a small amount of rain in February and March; but the value of y rises when x is more than that particular value. Since $y = 0·96\,x - 1·795$ is the equation of the gradient of the provisional curve of the sixth equation, it means that the yield is minimum when x (the rainfall) is 1·85 inches. It may, therefore, be inferred that a substantial amount of rainfall, *i. e.*, more than 1·85 inches during February to March is important.

The observed and expected value of yield for the sixth equation are shown in graph II.

Rainfall and intercultivation. It is pertinent for a planter to question as to how the variations in the yield consequent to the fluctuations in the rainfall can be avoided or reduced. For the localities where the gardens cannot be irrigated, the intercultivation reduces considerably the annual variations in the yields.

A plot has been left uncultivated since 1916. The weeds are not removed and the palms grow almost in a wild state except that they are not as crowded up as they would be in nature. In another plot intercultivation has been practised since 1916. The land in this plot is ploughed two to three times in the year and occasionally cultivated with Guntaka or the showel cultivator to keep off the weeds. None of the plots were manured. In the following table the annual yields for these two treatments, viz., uncultivated and intercultivated, are recorded.

Table V. *Yield and intercultivation.*

Years.	Average number of nuts per tree per annum.	
	Uncultivated.	Intercultivated.
1917	4·0	14·4
1918	8·3	23·5
1919	6·4	44·4
1920	1·7	46·3
1921	1·6	54·5
1922	13·1	59·3
1923	11·7	56·4
1924	7·4	46·0
1925	2·7	48·4
1926	11·6	65·6
1927	2·4	30·4
1928	2·3	59·1
1929	12·6	58·1
1930	0·3	59·1
1931	1·7	45·3
1932	4·6	47·9
1933	11·0	46·1
1934	3·8	37·1
Average per year—1917 and 1918	6·2	19·0
Average per year—1919 to 1934	5·9	50·3
Percentage increase in the average of 1919 to 1934 over the average of 1917 to 1918	- 4·8	164·7

The yield in the cultivated plot has increased suddenly in 1919 by 134 per cent. of the average of 1917-18. The increase in the yield after 1919 has been gradual. Annual variations in the yields of the cultivated plot are very low when compared with those of the plot left uncultivated. The coefficient of variability for the cultivated plot is 16·6 per cent., but for the uncultivated plot it is as much as 76·2 per cent. The cultivated plot is decidedly less subject to the seasonal conditions than the uncultivated plot. Intercultivation is, therefore, one of the methods to be utilized in regulating the production.

Discussion:—The study has pointed out that yield in any particular year is influenced by January to April rains for two years previous to the harvest, together with the rains in January to April of the year of harvest. To understand, how the rains during the three years affect the yield, a knowledge of the coconut crown is necessary. The details regarding the crown of a bearing tree as observed in January 1934, are given below:—

Leaf No.	When the inflorescence will be harvested.	The condition of the inflorescence.
10	January 1934	Not ready for harvest
18	September 1934	Tender nuts four months old.
22	January 1935	Spadix just opened.
32	November 1935	The last opened leaf. The spathe will open in about ten months.
34	January 1936	Unopened leaf. The spathe will open in January 1935.
45	December 1936	Unopened leaf. The spathe will open in December 1935.

On the dissection of the crown, it is found that in the axils of leaves, 23 to 45 there are developing spadices, at various stages of the growth. The rains during January 1934, would, therefore, affect these developing spadices, which would come up for harvest during 1935 and 1936. It would also affect the shedding of buttons from the spadix which opened during January 1934. In a similar manner, the rainfall in each of the months during 1934 would affect the setting of the crop to be harvested in 1935. Thus the rainfall during 1934 would affect the yields in 1934, 1935 and 1936.

The development of the inflorescence is a slow process taking about thirty-four months from the time of the differentiation of the flower primordium to the opening of the spathe. The maximum elongation of the spathe occurs during the period of six months prior to the opening of the spathe. The branches of the inflorescence begin to form about sixteen months prior to the opening of the spathe; and severe drought occuring at this period kills the growing points and the spathe aborts. Park (1934) has found that the drought affected the yields for a period of about thirty-two months after the commencement of drought. Thus there is support for the view that the effect of rainfall lasts for about three years after the incidence of the rainfall.

Park (1934) found that severe drought experienced in Puttalam (Ceylon) in 1931, decreased the copra per nut production for a period of one year with the maximum effect approximately six months after the drought. Shepherd's (1926) investigations, in Trinidad, have revealed a positive and significant correlation of $0{\cdot}733 \pm 0{\cdot}072$ between the rainfall over a six month period and the size of the nut one year later. The findings of Shepherd, and Park are in agreement since the size of the nut and copra per nut production are correlated. Patel (1934) has found that the size of the nut and its copra content are correlated. He found the following coefficients of correlations:—

(i) Between the volume of the unhusked nut and its yield of copra $0{\cdot}659 \pm 0{\cdot}013$,

(ii) Between the volume of the husked nut and its yield of copra $0{\cdot}680 \pm 0{\cdot}0127$.

The authors have, however, not attempted the study of the effect of rainfall on the size of the nut or on the yield of copra per nut. From the point of view of the practical agriculturists, the most important finding is the utility in minimizing considerably the effect of rainfall on yield.

Summary and conclusions. The study has pointed out that yield in any particular year is influenced by January to April rains for two years previous to harvest, together with the rains in January to April of the year of harvest. The study of the crown has shown how the rainfall in a particular year affects the yields during that year and the succeeding two years. On the West Coast of India, the critical rains are those which are received during January to April. Annual variations in the yields of nuts are much more for the uncultivated plot than for the cultivated plot. The vagaries of seasons have less effect on the trees in a cultivated garden, than on those in a plot left uncultivated.

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MULTIPLE SEEDEDNESS IN SORGHUM AND CONSEQUENT REPERCUSSIONS

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The occurrence of double seeds in cereals is frequently reported. The presence of double seedeed varieties in sorghum is on record. In a previous article (G. N. R. Ayyangar and M. A. S. Ayyar, 1929)[1] the stray occurrence of double seeds in a variety of sorghum (*S. Roxb* var *hians.*) has been reported and the possibility of accentuating this double grained condition by continued selection over a period of years indicated. Such selection work was done but resulted in no appreciable increase in doubleness. The range of occurrence proved to be of about the same degree of fluctuation.

While this selection work was in progress further fresh material was obtained from various sources and led to a detailed and careful examination of this doubleness. The material represents varieties from Madras, Central Provinces, and Bihar in India and Nigeria, Rhodesia and Tanganyika in Africa. The incidence of doubleness varied according to the variety. This variation was from head to head in the variety and in the incidence within the earhead. In six varieties (mostly *S. Durra*) all the earheads produced double grains. In the others the incidence was from 1 to 70 per cent of the population. This wide range of material from the various parts of the world representing varying degrees of manifestation of doubleness afforded very good material for the study of this character.