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Rainfall and crop yields in Madras State — A preliminary study

By

M. B. V. NARASINGA RAO, B. A., B. SC. (AG.), A. I. A. R. I.
(Paddy Specialist)

C. BALASUBRAMANIAM, B. A., B. SC. (AG.)
(Agricultural Meteorologist)

and

M. V. JAYARAMAN, B. SC., B. SC. (AG.)
(Assistant in Agricultural Meteorology)

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It is common knowledge that an intimate relation exists between rainfall and crop production. The quantity of rainfall received is as important as the nature of its distribution. "Unseasonal rain is as bad as untimely food". The unpredictable nature of distribution of rainfall is the reason for the oft-quoted saying that "Agriculture is a gamble with the monsoon."

In considering the influence of rainfall on yield, scientists refer to the "effective rainfall", which means that portion of the total precipation, which gets actually soaked in the soil and thus becomes available for the nutrition of plants. The effective rainfall received at a place affects the texture of the soil, its nitrogen content and its pH value (iii & iv). Again the water-retaining capacity of the soil depends on its slope, internal structure and humus content. The amount and distribution of water in the soil influences not only every phase of soil formation but also the relationship between the soil and the growing plants (ii). Soils vary widely in their capacity to absorb moisture, particularly during rainy seasons. The important points to be borne in mind when we consider soil moisture in connection with crop growth are (i) the depth to which rain water gets soaked into the soil and (ii) its retention in a particular depth of the soil. Briggs and Shantz (i) found that the water required for the formation of one pound of dry plant material may vary from 250 to 1,000 lb., depending upon the crop in question. It becomes evident, therefore, that cultivated crops can give normal yields only when they get sufficient water from the soil to meet their nutritional demands. Lack of water during any portion of crop growth will be reflected in a lowering of yield. Plant tolerance to drought may be both natural and induced, but the basic needs of moisture must be available for the crop if normal yields are to result.

As the main source of supply of moisture in the soil is only rainfall, the study of the inter-relation between the annual rainfall of the Madras State and the yields of different crops was undertaken. The data of annual rainfall for the years 1902–1903 to 1947–1948 and the corresponding

data pertaining to the area and acre yield of different crops were culled from the "Season and Crop Reports", published by the Civil Supplies Branch of the Board of Revenue, Government of Madras. In regard to area, groups of crops like millets and oilseeds were taken into consideration. In the case of majority of crops yield data could be obtained only from 1917 – 1918 onwards.

It is well to remember that the yield per acre as given in the "Season and crop Reports" is based on "Normal yield" and "Anna value". The lack of exactitude of the definition of "Normal yield" (average yield on average soil in a year of average character) and the indefiniteness of the "Anna value", known otherwise as "Seasonal Factor" or "Condition Factor", assessed by eye-judgment by village officials, set a limit to the accuracy of the acre yield data. However it may be expected that the available data of yield per acre would give some indication of the influence of weather. (vi)

Method: Twenty-four total correlations were worked out, nine for areas under different groups of crops or individual crops and rainfall and the rest for acre-yields of individual crops and rainfall. In the case of unirrigated paddy, Malabar and South Kanara were treated separately as the rainfall is very high in these districts. In regard to tenai, the Ceded districts were considered as one unit, as 90 per cent of the total area of tenai in the State is in Ceded districts. All the nine correlations and relevant particulars related to area of unirrigated crops and rainfall are presented in Table I. The remaining fifteen correlations and details pertaining to the influence of rainfall on the yield of crops are also given in Table I.

Four graphs were prepared with rainfall and acre-yield data collected for paddy, millets, oil seeds and cotton.

Interpretation of the correlations and the graphs drawn in this connection:

(I) *Rainfall and area under cultivated crops:* None of the nine correlations worked out in this connection is significant. This apparently shows that the ryots do not anticipate failure of rains but sow the seeds in the available area in anticipation of good seasonal rainfall and are even prepared to take a risk before the season is lost.

(II) *Rainfall and acre-yield of cultivated crops:*— (i) *Paddy:* Separate correlations were worked out for the yield of paddy, irrigated and unirrigated, and the rainfall of the State. The yield of unirrigated paddy in Malabar and South Kanara districts was correlated separately with the annual rainfall of the State.

The yield of irrigated paddy of the State bears a significant correlation with the total rainfall of the State indicating that even irrigated paddy is influenced by rainfall, since our irrigation sources depend on rainfall for their freshes.

The yield of unirrigated paddy has also got a significant correlation with the rainfall of the State, showing that unirrigated paddy is benefited by increased rainfall. Untimely heavy falls do not seem to have any adverse effect as they are confined only to limited areas when compared to the size of the State.

The yield of rainfed paddy in the West Coast also bears a significant correlation with the rainfall of the State, while that in the other districts of the State bears a highly significant correlation with rainfall at ($P = \cdot 01$ level) even though a few large deviations were found in the "Goodness of fit" test.

The graph reveals that the yields of paddy, irrigated as well as unirrigated, were low in the years 1918–1919, 1920–1921, 1926–1927, 1934–1935, 1938–1939 and 1945–1946, mainly due to the low average rainfall of the State. In 1926–1927 the yields of paddy had not fallen as the "season was better than the previous three years on the West Coast" (v).

In 1934–1935 the yield of irrigated paddy maintained itself at the level of the previous year, in spite of the decrease in the rainfall. In 1945–1946, the yield of unirrigated paddy in Malabar and South Kanara districts and consequently that of the whole State increased in contrast to the rainfall of the State, because "the season was generally fair in South Kanara" (v).

In 1941–1942 even though the rainfall was below the average, the yield of dry paddy showed an increase while the yield of irrigated paddy did not change, but in 1942–1943 an increase in the rainfall of the State has depressed the yield of dry and wet paddy due to "inadequate and ill-distributed rainfall in both the monsoons" (v).

The increase in the yield of paddy was not proportionate to the increase of rainfall in the years 1931–1932, 1939–1940 and 1946–1947. "In 1931–1932 paddy was adversly affected by cyclone in the South-East of Madras". The year 1939–1940 had very ill-distributed rainfall in time as well as in space. In 1946–1947 also crops were affected by heavy rains in November and December.

That rainfall has a very striking effect on the yield of irrigated and unirrigated paddy is beyond question. Though the distribution is also important, it would appear that, if rains are adequate, the distribution also will be fair and the yields will be normal or above normal. Bad yields were mostly attributed to defective rainfall in the "Season and Crop Reports."

To verify the significance of the correlations obtained above, regression equations of the significant correlations were worked out. It is seen that the value of X^2 was somewhat higher due to a few extereme values. If these are not taken into consideration the value of P lies between 0·1 to 0·3 in most of the cases. Thus it may be stated that the linear regression does not fully explain the yield and rainfall correlation and other factors may be at work. Probably by working out correlation between yield and the rainfall during the season of a particular crop and working out partial correlations, taking into account critical periods of rainfall, a better picture of the correlation of yield and rains may be obtained. This will be taken up in subsequent publications.

Millets: (a) *Cholam:* (*Sorghum* spp.) There is no significant correlation between the acre yield of cholam and rainfall of the State. This shows that in years of drought the crop does not fail completely and in years of excess rainfall does not record bumper yields. This millet is sown mostly on black cotton soils after sufficient moisture is received, and hence the amount of rainfall does not interfere, unless there is a very bad drought for months. This is reflected in the absence of significant correlation between annual rainfall and yield of this millet.

(b) *Tenai:* (*Setaria italica*) The correlation of acre yield of *Tenai* with the annual rainfall of the Ceded districts alone, where 90 per cent of the total area of the State under *Tenai* is concentrated, is significant. This may be due to the fact that *Tenai* is raised on lighter types of soil and hence heavier falls benefit the crop immensely.

(c) *Cumbu:* (*Pennisetum typhoides*) The acre yield of *cumbu* bears a significant correlation with the annual rainfall of the State. This indicates that *Cumbu* responds well to higher rainfall.

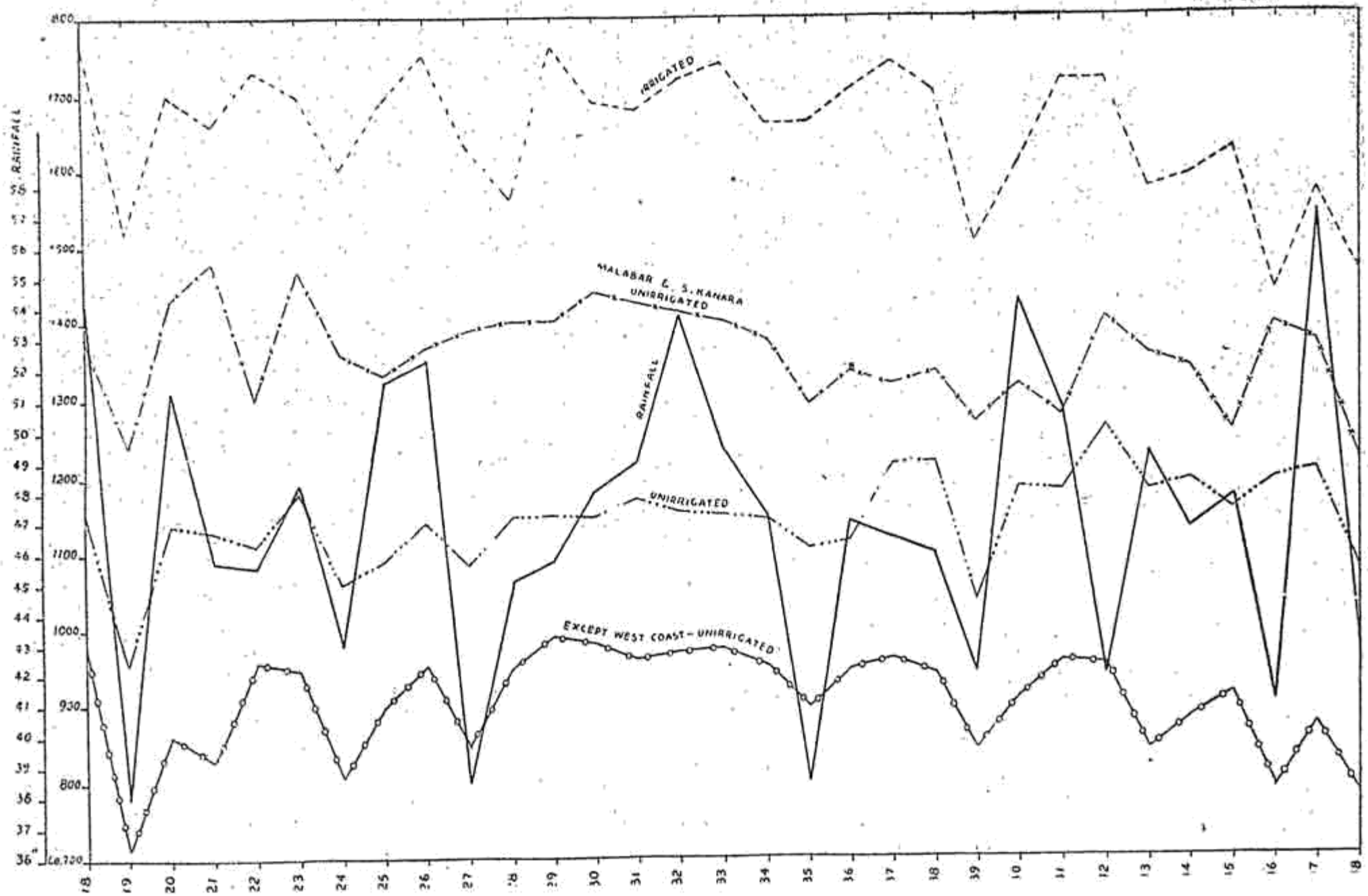
(d) *Ragi:* (*Eleusine coracana*) *Ragi* is generally grown under irrigated conditions in rich soils. But it is grown also under unirrigated conditions to the tune of about eight lakhs of acres in this State. The yield of *Ragi* has got a significant correlation with rainfall, indicating thereby that *Ragi* is benefited by higher rainfalls.

Incidentally the following observations may be recorded. The normal yield of *Ragi* (unirrigated) is 678 lbs. per acre while that of *cumbu* is only 498 lbs. per acre. Therefore, in portions of Chittoor and Salem districts where nearly 1,46,000 and 2,79,000 acres are grown under rainfed *cumbu*, it may be advisable to substitute *ragi* for *cumbu*, taking into consideration soil fertility factors. As a matter of fact, certain ryots in Chittoor district have already taken to this change over.

The graph reveals that there is a general fall in the yield of all the crops in the years 1918–1919, 1923–1924, 1926–1927, 1934–1935, 1941–1942, 1942–1943 and 1945–1946. In all these years except

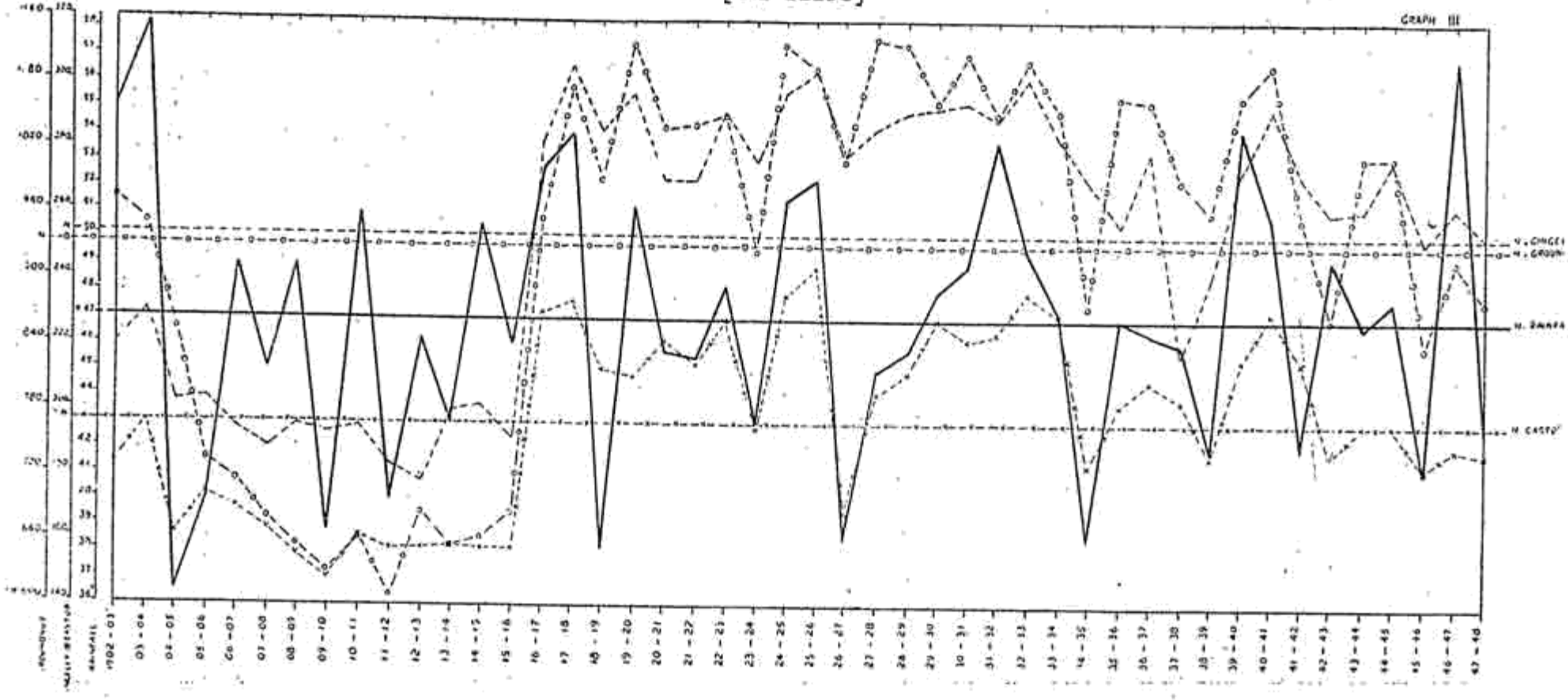
[PADDY]

GRAPH

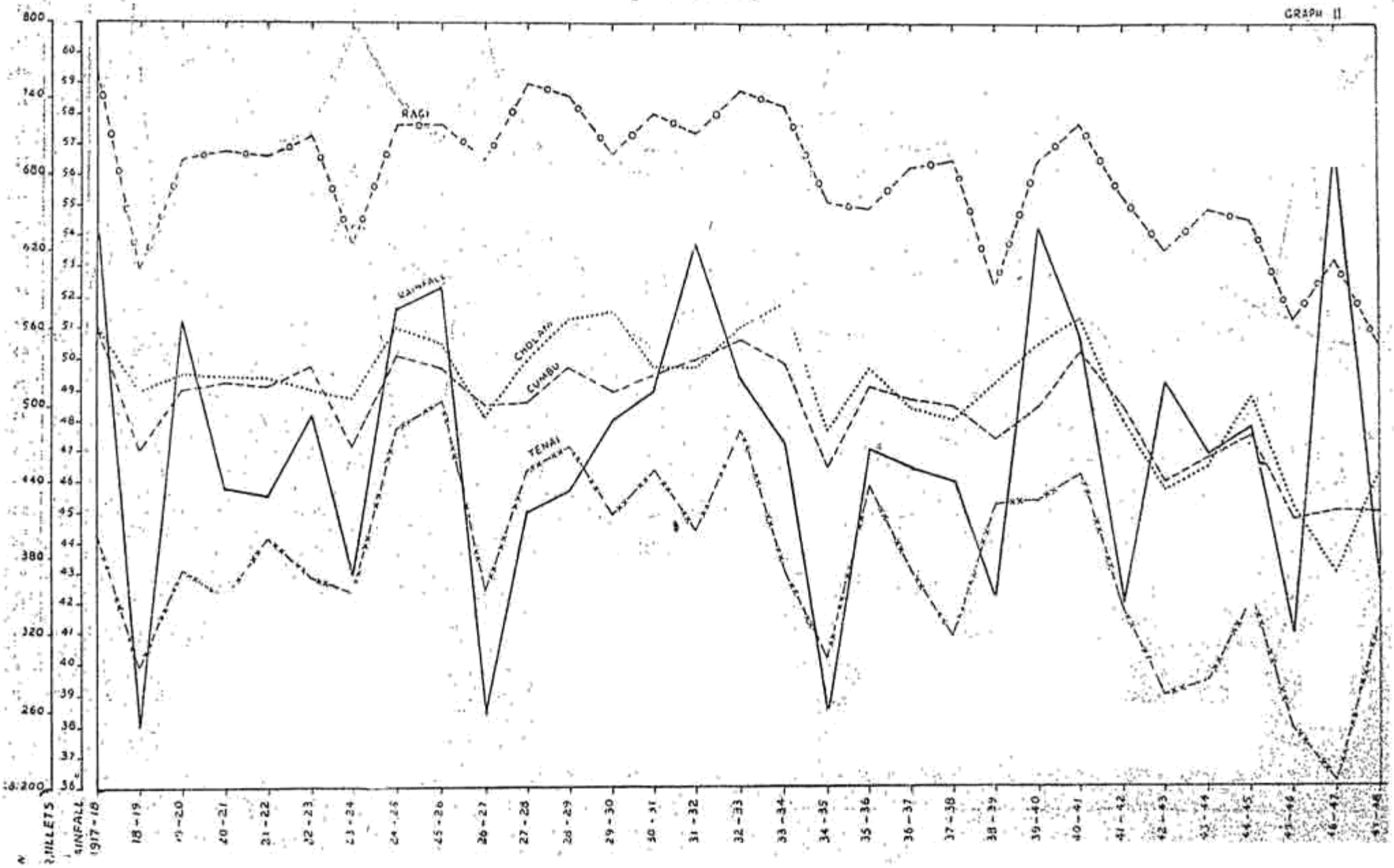

IRRIGATED
MALABAR & S. KANARA
UNIRRIGATED
RAINFALL
UNIRRIGATED
EXCEPT WEST COAST - UNIRRIGATED
RAINFALL

MADRAS PROVINCE — RAINFALL AND ACRE YIELD

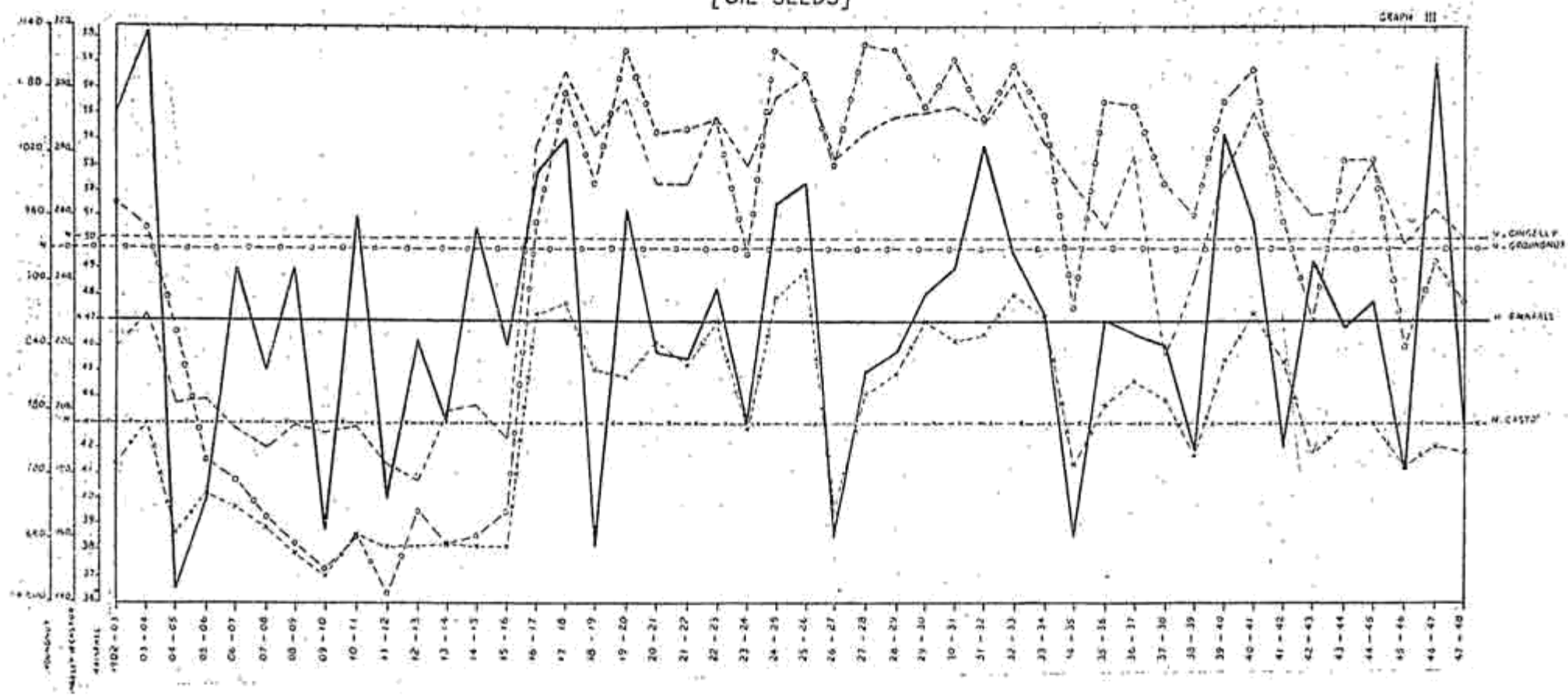
[OIL SEEDS]



MADRAS PROVINCE - RAINFALL AND ACRE YIELD
[MILLETS]

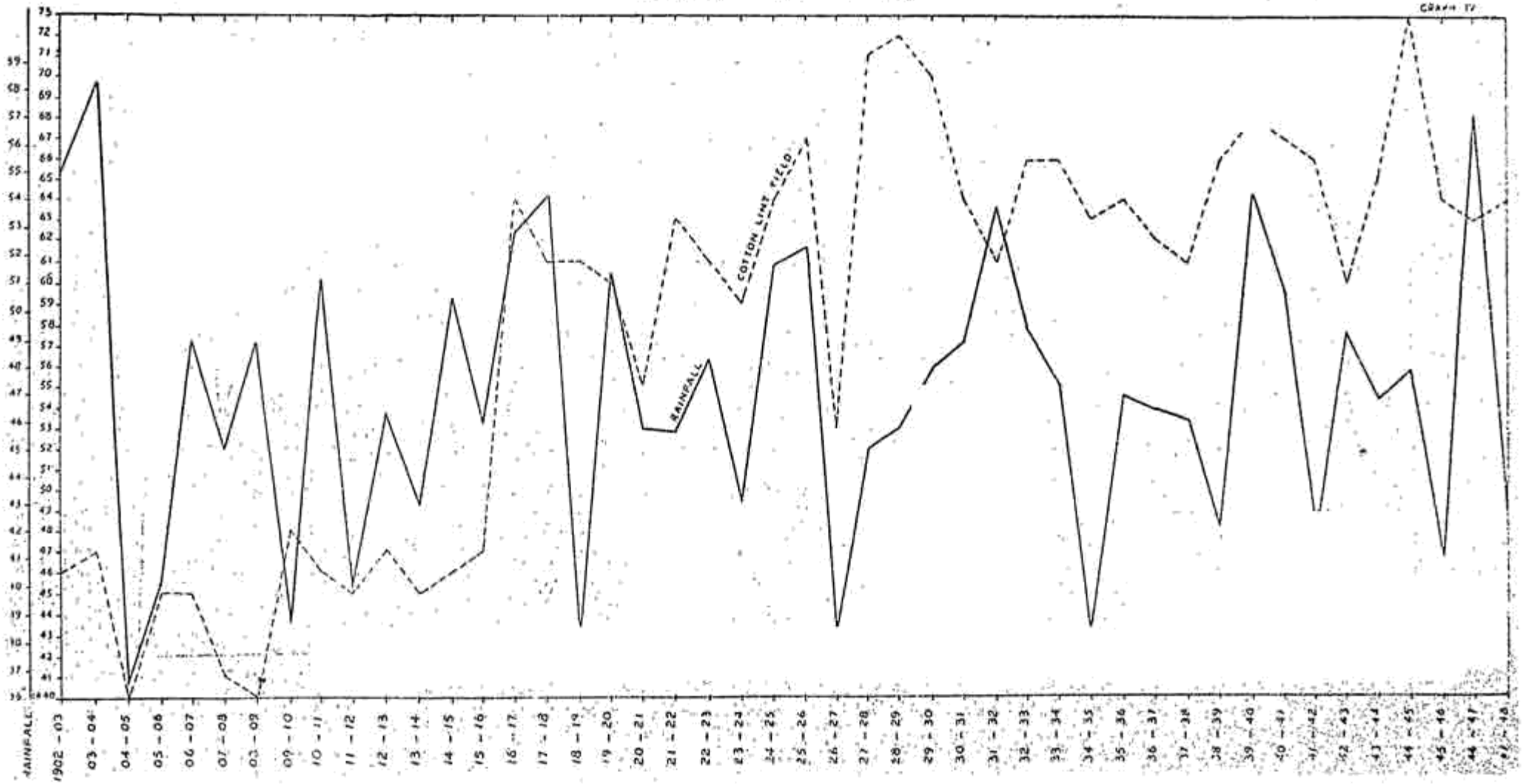


MADRAS PROVINCE – RAINFALL AND ACRE YIELD
[OIL SEEDS]



MADRAS PROVINCE - RAINFALL AND ACRE YIELD

[COTTON - LINT YIELD]



1942–1943 the fall in the yield may be due to low rain-fall of the State. In the year 1942–1943, even though the rainfall of the State was above normal by 2 inches, the yields of millets were low. This has been attributed, in the Season and Crop Report of that year, to the untimely rainfall which affected *cumbu* in Madhurai, Ramanathapuram and Tirunelveli districts.

As in the case of paddy, in millets also, there was a downward trend of yield after 1940–1941 owing to unfavourable seasons in 1941–1942, 1945–1946 and 1947–1948 and untimely heavy and ill-distributed rainfall, favouring incidence of insect pests and diseases in the rest of the years.

(III) *Oilseeds.:* The annual rainfall of the State was correlated separately with the yields per acre of gingelly, groundnut and castor, for forty-one years from 1902–1903 to 1947–1948.

(a) *Gingelly:* The yield of gingelly has no significant correlation with the total annual rainfall. This, in part, may be due to the fact that the gingelly crop requires very limited moisture, and that too only at particular periods. Correlation of yield with seasonal rainfall may show some significance. This will be attempted in a later paper.

(b) *Groundnut:* The yield per acre of groundnut has got a positive significant correlation of $0{\cdot}3116 \pm 0{\cdot}1432$, showing that, inspite of its being a weak one, the yield of groundnut is influenced by the rainfall received during the year. This is because groundnut is grown generally from July–August to November–December when the South-West monsoon and North-East monsoon are active. Further, the soils in which groundnut is grown are of a light type and this makes it all the more obvious, that groundnut requires rainfall in abundance during its growing season and for the successful penetration of the gynophore into the soil.

Though untimely heavy fall, such as the one received soon after sowing and during the flowering phase may adversely affect the yield, such incidence is negligible when the whole State is taken into consideration.

(c) *Castor:* The acre yield of castor also has got a positive significant correlation with the rainfall of the State. This may be explained by the fact that as castor is generally grown in poor soils and occupies the ground for almost the whole year, it gets the full benefit of rainfall received during the year.

The graph reveals that there was a progressive deterioration in the yield per acre of groundnut from 1902–1903 to 1909–1910 irrespective of the fluctuations of rainfall during the same period. From 1916–1917 onwards there was a general increase in yield of all the crops viz. gingelly, castor and groundnut. This was mainly due to a revision of policy by the

Board of Revenue in estimating crop yields. The yield of groundnut, thereafter, fluctuates almost in the same manner as rainfall except in the years 1929–1930, 1931–1932 and 1942.

(IV) *Cotton:* The yield of lint per acre of rainfed cotton was correlated with the rainfall of the State for the period of 46 years from 1902–1903 to 1947–1948. The yield has a positive correation with rainfall but it is not significant. This indicates that the yield of cotton is influenced also by factors other than the rainfall of the State. Cotton is very easily susceptible to pests and diseases.

The study of the graph reveals that depressions in rainfall have caused similar reductions in cotton yields in the years 1904–1905, 1911–1912, 1923–1924, 1926–1927, 1934–1935 and 1945–1946. In 1934–1935 the yield of cotton did not fall so low as the rainfall of the year. There had been an increase in the yield of cotton in the years 1909–1910 and 1918–1919 in spite of low rainfall. There had also been decrease of yields in the years 1931–1932, 1942–1943 and 1947–1948 in contrast to the increase of rainfall, mainly due to adverse weather conditions.

V. *Sugarcane:* The acre yield of jaggery from sugarcane, was correlated with the rainfall of the State for 46 years. The correlation, though positive, is not significant. This is because sugarcane is mainly grown under irrigated conditions and the yield is also more influenced by manuring, cultural operations and varieties than by rainfall.

Summary and Conclusions

(a) *Paddy:* Though in paddy fields water stands always to a depth of 2 inches the crop responds well to timely monsoonic showers. Paddy, which is by nature a water-loving plant, is significantly influenced by rainfall, when raised under purely rainfed conditions.

(b) *Millets:* (i) Cholam: In years of drought the crop does not fail completely and in years of excess rainfall does not give a bumper yield. It requires only optimum amount of timely rains.

(ii) *Tenai:* The total rainfall influences the yield of *Tenai* of the Ceded districts.

(iii) *Cumbu:* It responds well to higher rainfall and requires more soil moisture than cholam.

(iv) *Ragi:* In heavy rainfall years *ragi* records higher yields.

(c) *Oilseeds:* (i) *Gingelly:* In view of its varying sowing seasons in different districts in the State, its short life-period in the field, high

susceptibility to pests and diseases and sensitiveness to adverse weather conditions, it is not possible to record from the available data, as to whether the crop responds well or ill to the rainfall received.

(ii) *Groundnut:* The yield of groundnut is directly proportional to the rainfall received during its growth period. Yield depends on the successful penetration of the gynophore, which, in turn, mainly depends on optimum soil moisture condititions.

(iii) *Castor:* Though drought-resistant by nature, this crop responds well to higher rainfall. By virtue of its long span of life in the field of nearly one year, it gets the maximum benefit from the rainfall received in any year.

(d) *Cotton:* Besides rainfall, there are other factors also that determine the yield of cotton. Rainfall has an appreciable, though not a decisive influence on cotton yields.

(e) *Sugarcane:* Nothing definite can be said in regard to this crop since it is seldom cultivated under purely rainfed conditions, except perhaps in South Kanara where it is grown under very favourable rainfall conditions,

Conclusion: It is to be mentioned that more revealing information of the effects of rainfall on the yield of crops will be obtained if multiple correlations between rainfall at different periods and the yields are worked out. As yield is also dependent upon other climatic factors such as sunshine, humidity etc., partial correlations between yield and different elements of weather may throw more light on the problem of yield. It is hoped that these aspects will be dealt with in later publications.

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TABLE I.

S. No.	Details of Correlation	Correlation Co-efficient r.	Significant or not	Regression equations for significant correlations *Where Y is the expected yield in lbs. and X is annual rainfall for the State
1.	Rainfall and area under paddy (unirrigated) in Malabar and South Kanara ...	− 0·0612 ± 0·1505	Not	...
2.	Rainfall and area under (unirrigated) paddy in the whole State ...	+ 0·0002 ± 0·1857	Not	...
3.	Rainfall and area of *Cholam* (unirrigated) in the whole State ...	− 0·1181 ± 0·1497	Not	...
4.	Rainfall and area of *Ragi* (unirrigated) in the whole State ...	+ 0·0086 ± 0·1857	Not	...
5.	Rainfall and area of *Tenai* (unirrigated) in the Ceded districts ...	+ 0·2412 ± 0·1802	Not	...
6.	Rainfall and area of *Tenai* in the whole State ...	+ 0·0350 ± 0·1856	Not	...
7.	Rainfall and area of *Cumbu* (unirrigated) in the whole State ...	+ 0·1213 ± 0·1844	Not	...
8.	Rainfall and area under Oil Seeds (Castor, Groundnut, and gingelly) in the whole State ...	+ 0·0835 ± 0·1502	Not	...
9.	Rainfall and area under Cotton (unirrigated) in the whole State ...	+ 0·0188 ± 0·1856	Not	...
10.	Rainfall and acre yield of Paddy (irrigated) in the whole State ...	+ 0·4011 ± 0·1701	Significant	Y = 7·2804 X + 1309
11.	Rainfall and acre yield of Paddy (unirrigated) in the whole State ...	+ 0·4281 ± 0·1678	Significant	Y = 5·3830 X + 889
12.	Rainfall and acre yield of Paddy in Malabar and South Kanara for thirty one years ...	+ 0·2486 ± 0·1799	Not	

S. No.	Details of Correlation	Correlation Co-efficient r.	Significant or not	Regression equations for significant correlations *Where Y is the expected yield in lbs. and X is annual rainfall for the State
13.	Rainfall and acre yield of Paddy in Malabar and South Kanara for forty six years ...	+ 0·3324 ± 0·1422	Significant	Y = 6·5504 X + 1000
14.	Rainfall and acre yield of paddy (unirrigated) in the whole State except Malabar and South Kanara Districts ...	+ 0·4892 ± 0·1620	Significant	Y = 7·1284 X + 569
15.	Rainfall and acre yield of Cholam (unirrigated) in the whole State ...	+ 0·1900 ± 0·1824	Not	...
16.	Rainfall and acre yield of *Cumbu* (unirrigated) in the whole State ...	+ 0·3779 ± 0·1719	Significant	Y = 3·1733 X + 349
17.	Rainfall and acre yield of Ragi (unirrigated) in the whole State ...	+ 0·4174 ± 0·1688	Significant	Y = 4·8053 X + 452
18.	Rainfall and acre yield of *Tenai* (unirrigated) in the whole State ...	+ 0·2962 ± 0·1773	Not	...
19.	Rainfall in Ceded districts alone and acre yield of *tenai* in Ceded districts ...	+ 0·4764 ± 0·1633	Significant	*Y = 8·0684 X + 146
20.	Rainfall and acre yield of gingelly in the whole State ...	+ 0·2471 ± 0·1461	Not	...
21.	Rainfall and acre yield of castor in the whole State ...	+ 0·4072 ± 0·1377	Significant	Y = 2·1223 X + 96
22.	Rainfall and acre yield of groundnut in the whole State ...	+ 0·3116 ± 0·1432	Significant	Y = 9·7133 X + 473
23.	Rainfall and acre yield of sugarcane (irrigated) in the whole State ...	+ 0·1615 ± 0·1488	Not	...
24.	Rainfall and acre yield of cotton (unirrigated) in the whole State ...	+ 0·1481 ± 0·1491	Not	...

Note:— *Rainfall of Ceded districts alone to be taken as value of (X)