

SEASONAL VARIATION OF COCONUT CROPS

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The seasonal variation of coconut crops in relation to variations in the climatic environment (or weather) has engaged the attention of several research workers in coconut over the last two to three decades. However, as evidenced by the literature cited in the "references" to this paper, it does not appear that, apart from casual and piecemeal investigations, there has been anything like a projected attempt to correlate crop fluctuations with the weather.

While most workers stress the elusiveness of this problem on the grounds that "weather" is a very complex variable—being the result of a combination or interaction of several meteorological components—apparently very few workers, so far as this problem is concerned, have viewed the coconut crop too as an equally or more complex variable. The coconut palm normally delivers one mature bunch or crop each month. Each such crop is the final outcome of several crop components which are conditioned at different phases of a long cycle of development which lasts about $3\frac{1}{2}$ years. "The primordium of the inflorescence is formed about 32 months prior to its opening, that of the spikes about 15 months before and of female flowers about 12 months before" (Marar and Pandalai 1957). After the spathe opens, it takes about 12 months for the female flowers to develop into fully ripe nuts.

Now what are the crop components that decide the final crop? First it is the number of female flowers formed in the inflorescence about two years prior to the crop—each one of them constituting a potential nut. Within about four weeks of the opening of the spathe, these female flowers (a fraction of them) get successfully pollinated to form nuts and the unpollinated flowers fall off. This phenomenon, commonly known as setting constitute the second crop component and is quantitatively expressed as a percentage of the total number of female flowers, to be termed "percentage setting". From among these formed nuts, a certain number fall off within the early months of nut development due to some cause or other—the more so in the early ages. Such nutfall, commonly termed immature nutfall, constitutes the third crop component. After a lapse of about 12 months from the opening of the spathe, the bunch is ripe and ready for plucking. From among these mature nuts, we may still find some nuts which are either without kernal or with imperfectly developed kernal. Such nuts usually termed, "empties" or "barren nuts", constitute a further debit on the final crop and therefore could be considered a fourth crop component. Further if what we mean by the final crop is the weight of copra, then the size of nuts (or the copra weight per nut) will constitute a fifth crop component deciding the final crop.

It will therefore be appreciated that the magnitude of a particular crop is the final outcome of the variations of these crop components and any attempt to treat the final yield as a single entity to be correlated with one or more weather factors will not be a hopeful proposition. This is especially

so, because unlike in orchard crops, the phenomena associated with these crop components occur at widely spaced intervals of time and hence have to face the vagaries of the weather in all its extreme manifestations. The obviously sound approach will be to think of a crop as the nett result of these crop components, each of which owes its variations to one or more weather factors specific to itself and with a specific effective period and intensity.

Some aspects of this problem have received the attention of this Institute (as and when time permitted) and it is intended to publish some of the results of our investigations in due course. In this preliminary paper, however, we intend discussing some trends in the seasonal variations of coconut crops and their crop components. As insinuated earlier, published work do not seem to indicate any serious attempt to view the seasonal variation of crops as an integral of the variations of their crop components. The studies of Menon and Pandalai (1958) and Marar and Pandalai (1957)—probably the only work in this direction—valuable though in their own way, appear to be yet inadequate. For one reason, they have not considered all the crop components and secondly their statistical examination of the data has not been extended sufficiently to command confident acceptance of the repeatability of the seasonal trends given by them in respect of the different crop characteristics. Herein we hope to give indices of the repeatability of the seasonal patterns of each of the crop components, and also explain (in a note given by the senior author in the appendix) for the benefit of future workers, the purely biometrical aspects of such indices which we have adapted to suit similar problems.

MATERIAL AND METHODS

The data for this study were taken from the 972 palms of the N.P.K. trial conducted at Bandirippuwa Estate by the Soil Chemist's Division of the Coconut Research Institute of Ceylon. The first five years of this experiment have been excluded in order to allow for the treatment effects to stabilise, because any time trends possible during this period may to a certain extent vitiate the assessment of seasonal variability envisaged herein. Ten years data have been used.

It will be pertinent to mention that although it was stated in the introduction that each bunch is considered a coconut crop, it is not possible with our data to consider a crop as such. In Ceylon, the practice is to harvest nuts bimonthly. This will permit us to talk only in terms of bimonthly crops. Therefore the seasonal patterns presented herein will be bimonthly seasonal patterns. This will incidentally entail a sixth crop component as well viz. the number of bunches harvested. This too has a certain seasonal pattern. In fact it is common knowledge among planters in Ceylon that in the Wesak Pick (May-June) there are more bunches ready for harvesting. It is however not clearly known whether this phenomenon of a higher number of bunches in one season and a lower number in another, is due to the presence of a seasonal pattern in the initiation of inflorescences in the primordial phase $3\frac{1}{2}$ years prior to the harvest or a seasonal feature in the emergence of spathes or a variation in the period from the opening of the spathe to maturation of nuts.

We shall be giving, in the results, the seasonal patterns of (1) the number of bunches (2) the number of female flowers per bunch (3) the percentage setting (4) immature nutfall (5) barren nuts and (6) weight per husked nut (which is a constant multiple of the copra content).

A point to be borne in mind in the interpretation of the patterns of the crop components given in this paper is that the seasonal values given in respect of a particular crop component should not be related to their respective periods, but to the respective crops. For instance if in the pattern for immature nutfall, the highest nutfall is shown for period November-December, it does not mean that the highest nutfall occurs during the period November-December. What it does indicate is that the crop harvested in November-December, suffers relatively heaviest nutfall.

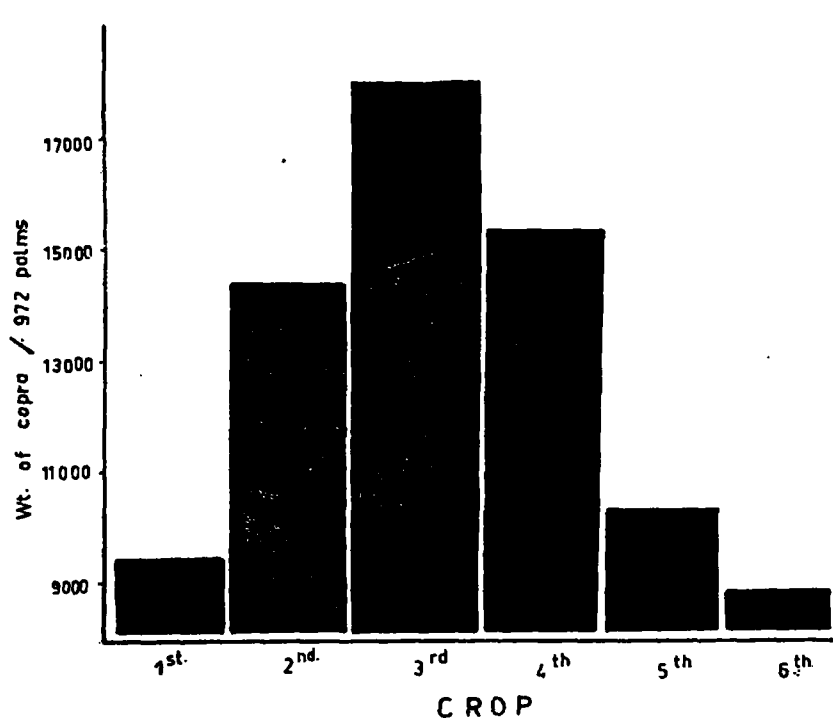
RESULTS

1. Seasonal variation of crops and crop components

The seasonal variation of the various crop components are shown in the tables and histograms given below under each heading. The intra-class correlations (vide appendix) showing the repeatability of the seasonal patterns are given—with asterisks to indicate the significance. X^2 values (vide appendix) are also given as a further test of the repeatability of the patterns.

(a) Weight of Copra (i.e. crop)

Fig. 1



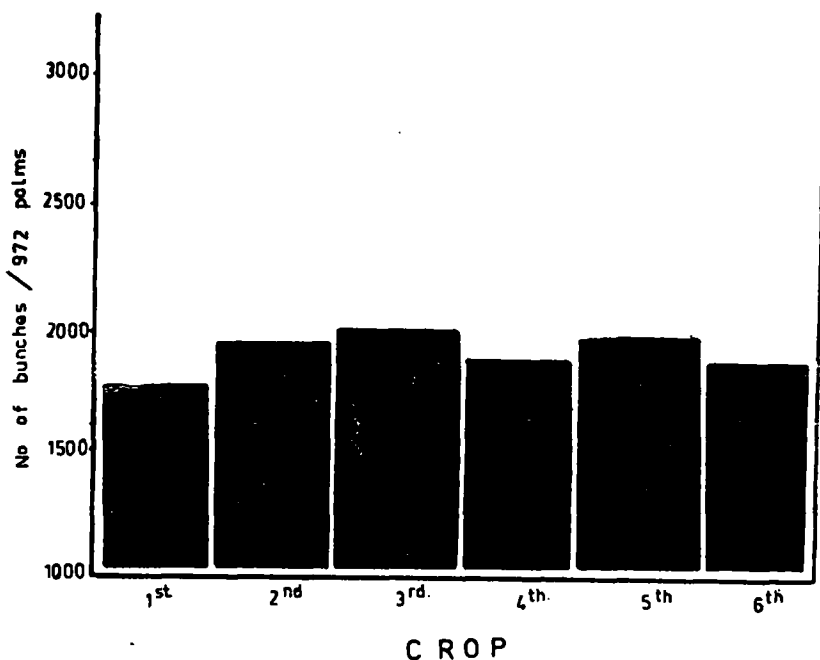
		1st Crop Jan.-Feb.	2nd Crop Mar-April	3rd Crop May-June	4th Crop July-Aug.	5th Crop Sept.-Oct.	6th Crop Nov.-Dec.
Weight of Copra (lbs.) 972 palms	Mean	9,314	14,479	18,061	15,397	10,223	8,759
	Median	7,741	13,581	18,459	17,373	10,456	7,599
	% of T	12.2	19.0	23.7	20.2	13.4	11.5

$$\text{Repeatability} \begin{cases} x^2 & = 25.5^{***} \\ \text{Intra } r & = 0.4886^{***} \end{cases}$$

The crop pattern is highly repeatable. The highest crop is obtained very often in May-June and the lowest in November-December. The pattern is very regular with a maximum midway in the calendar year and tapering down to the two extremes.

(b) *Number of Bunches*

Fig. 2



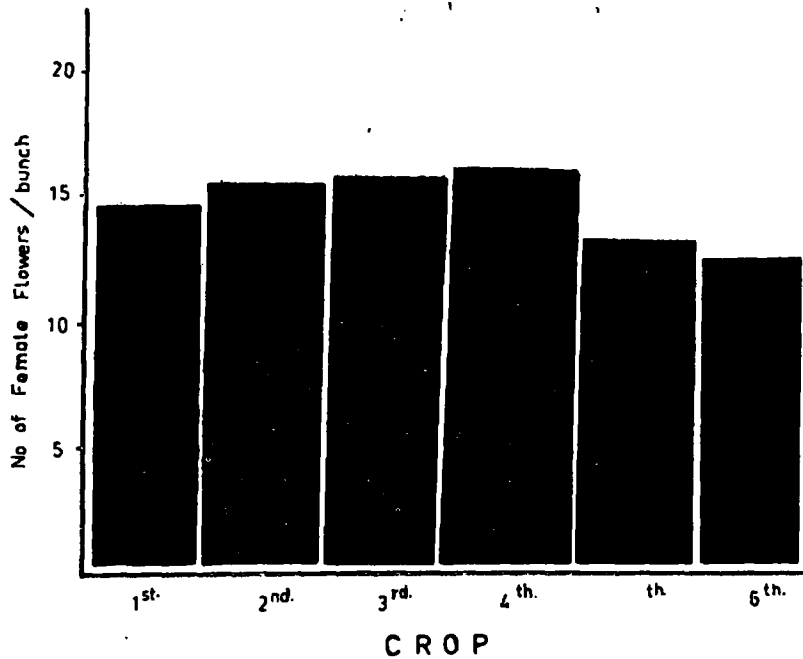
		1st Crop Jan.-Feb.	2nd Crop Mar.-Apr.	3rd Crop May-June	4th Crop July-Aug.	5th Crop Sept.-Oct.	6th Crop Nov.-Dec.
Number of Bunches (972 palms)	Mean	1,773	1,956	2,009	1,931	1,996	1,932
	Median	1,844	1,988	1,967	1,980	1,985	1,900

$$\text{Repeatability} \begin{cases} x^2 & = 11.86^* \\ \text{Intra } r & = 0.1826^* \end{cases}$$

The seasonal pattern of the number of bunches harvested is fairly repeatable. However the intra-class correlation is pretty low. Normally more bunches are harvested during May-June season. The second highest is normally in September-October, and the lowest is in the period January-February.

(c) *Number of female flowers per bunch*

Fig. 3



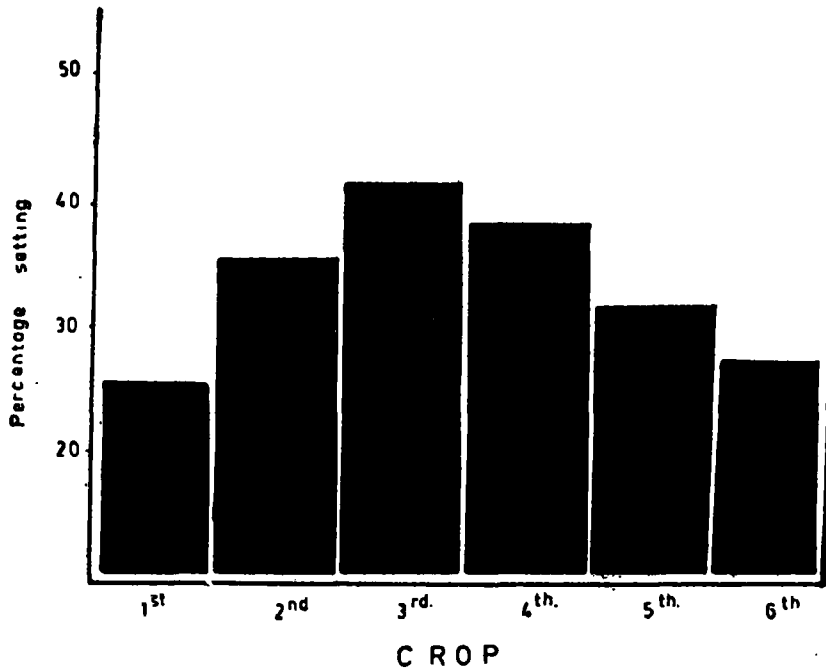
		<i>1st Crop Jan.-Feb.</i>	<i>2nd Crop Mar.-Apr.</i>	<i>3rd Crop May-June</i>	<i>4th Crop July-Aug.</i>	<i>5th Crop Sept.-Oct.</i>	<i>6th Crop Nov.-Dec.</i>
Number of Female Flowers per bunch	Mean	14.77	15.47	15.59	16.33	13.85	13.41
	Median	13.87	15.80	15.52	17.36	12.80	12.51

$$\text{Repeatability} \begin{cases} x^2 & = 9.31 \\ \text{Intra } r & = 0.1297^* \end{cases}$$

The incidence of female flowers in a bunch hardly follows a typical pattern as such—the repeatability being low and barely significant. However there is some regularity in the pattern of variation to be taken cognizance of; the highest is in respect of the crop harvested in the period July-August and the lowest in November-December. The low repeatability does not necessarily lead us to suggest that the number of female flowers per bunch has no control over the seasonal variation of the final crop. It may and in fact it must have some influence.

(d) Percentage Setting

Fig 4



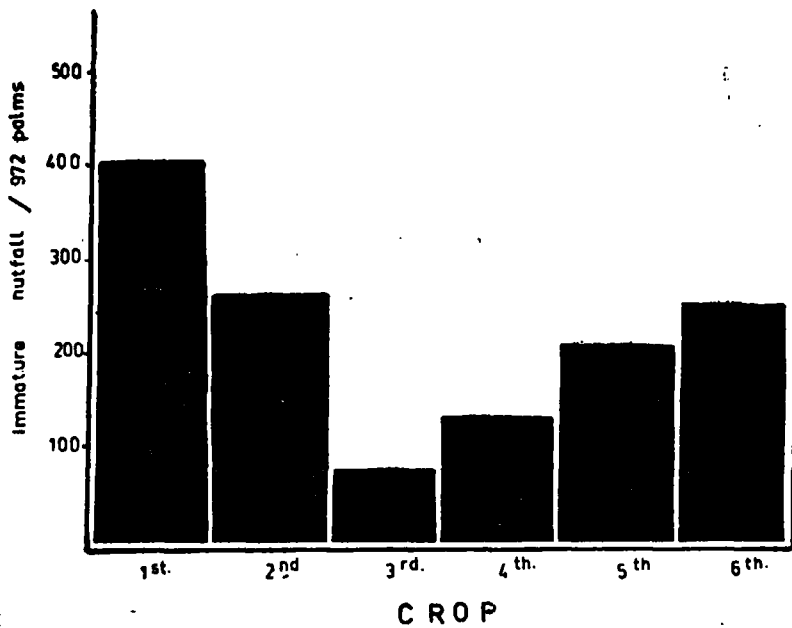
		1st Crop Jan.-Feb.	2nd Crop Mar.-Apr.	3rd Crop May-June	4th Crop July-Aug.	5th Crop Sept.-Oct.	6th Crop Nov.-Dec.
Percentage Setting	Mean	25.77	35.05	41.81	38.17	31.60	27.36
	Median	26.61	37.52	41.24	38.48	31.22	27.83

$$\text{Repeatability} \begin{cases} x^2 & = 22.10^{***} \\ \text{Intra } r & = 0.4382^{***} \end{cases}$$

The percentage setting has a highly repeatable seasonal pattern following closely the pattern of variation of the final crop—the highest being in respect of the crop harvested in May-June, second highest in July-August and lowest in November-December. Moreover as in the case of the final crop it has a very regular and symmetrical pattern within the calendar year with the maximum in May-June and tapering down on either side.

(e) *Immature Nutfall*

Fig. 5



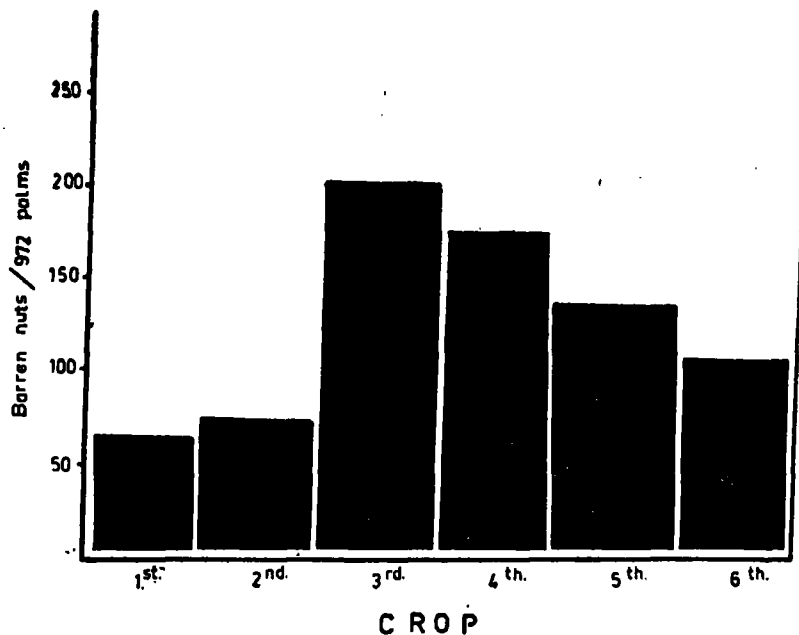
		1st Crop Jan.-Feb.	2nd Crop Mar.-Apr.	3rd Crop May-June	4th Crop July-Aug.	5th Crop Sept.-Oct.	6th Crop Nov.-Dec.
Immature nut fall	Mean (972 palms	401	271	74	132	209	252
	Median (972 palms)	211	131	62	87	194	204
	% of for- med nuts	5.59	2.57	0.58	1.10	2.57	3.96

$$\text{Repeatability} \begin{cases} \chi^2 & = 21.54^{***} \\ \text{Intra } r & = 0.4101^{***} \end{cases}$$

The immature nutfall too has a highly repeatable seasonal pattern, following as it were a pattern completely inverse to the crop. Whatever crop gave a high yield has had a relative low immature nutfall.

(f) Empty Nuts

Fig. 6



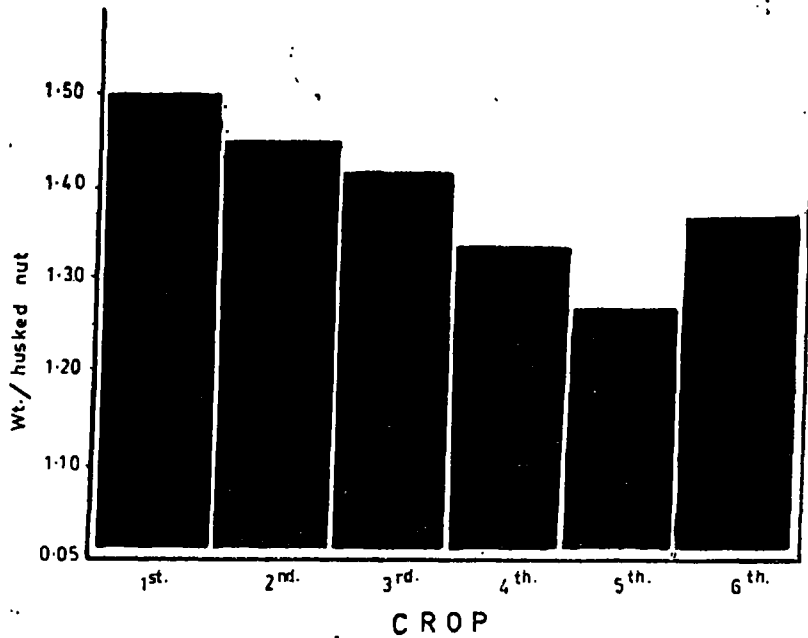
		1st Crop Jan.-Feb.	2nd Crop Mar.-Apr.	3rd Crop May-June	4th Crop July-Aug.	5th Crop Sept.-Oct.	6th Crop Nov.-Dec.
Empty nuts	Mean (972 palms)	65	78	204	181	141	111
	Median (972 palms)	54	79	195	172	116	113
	% of nuts after nutfall	1.01	0.76	1.53	1.57	1.81	1.84

$$\text{Repeatability} \begin{cases} x^2 & = 28.40^{***} \\ \text{Intra } r & = 0.5543^{***} \end{cases}$$

The pattern of incidence of empty nuts or barren nuts is also highly repeatable. When we consider absolute values, it appears as if heavy final crops are associated with a higher incidence of empties and *vice versa*. But from another angle, one notes that in crops where immature nutfall has been high, there are less empties and *vice versa*. Incidentally does this indicate that both the nuts that fall prematurely and the empties are due to the same cause? It may be that when there is heavy immature nutfall, a major portion of the inferior nuts falls off, leaving hardly any to be identified as empties at the time of harvesting and when the immature nutfall is low due probably to some favourable seasonal factor, the inferior nuts remain and develop to give rise to a high incidence of empties at time of harvesting.

(g) *Weight per Husked Nut*

Fig. 7



		<i>1st Crop Jan.-Feb.</i>	<i>2nd Crop Mar.-Apr.</i>	<i>3rd Crop May-June</i>	<i>4th Crop July-Aug.</i>	<i>5th Crop Sept.-Oct.</i>	<i>6th Crop Nov.-Dec.</i>
Weight per husked nut (lbs.)	Mean	1.50	1.46	1.42	1.33	1.27	1.37
	Median	1.53	1.48	1.43	1.38	1.24	1.40

$$\text{Repeatability} \begin{cases} \chi^2 & = 19.31^{***} \\ \text{Intra } r & = 0.3828^{***} \end{cases}$$

The seasonal pattern of nut size (i.e. out-turn) is highly repeatable. The maximum nut size is given in respect of the crop harvested in January-February (i.e. 1st Pick). The nut size becomes less and less progressively to reach the lowest in September-October (i.e. 5th Crop). The sixth pick (i.e. November-December) again records a slight improvement.

2. Fluctuations of individual crops and the contributory fluctuations of the individual crop components

Due to the fact that different crop components are themselves interrelated, a correct appraisal of the relative contribution by these components to make the final crops what they are, can be obtained only through multiple regression techniques. Presently we are in the process of applying such techniques to assess the status of the various crop components in the between-year and within-year variations of coconut crops and also in the between palm variations.

However in the context of the seasonal fluctuations of crops and crop components studied herein it will be useful to get an approximate and interim picture of the relative contributions by each of the components towards the variations of the final crops.

A particular crop is expressed as a percentage increase or decrease over the mean of all the six crops. Similarly each of the six components in respect of each crop is expressed as a percentage increase or decrease over its corresponding mean (Table 1). In the case of immature nutfall and empties whose absolute values were given earlier, the corresponding percentage increases or decreases are calculated on the proportion surviving after nutfall and empties—the idea being to make them comparable from the contributory aspect.

TABLE 1

Percentage increase or decrease in crop in relation to percentage increases or decreases in their crop components

<i>Crop</i>	<i>Bunches</i>	<i>F. Flowers per bunch</i>	<i>Percentage setting</i>	<i>Immature nutfall</i>	<i>Empty nuts</i>	<i>Wt./nut</i>	<i>Final Crop Wt. of Copra</i>
1st Crop							
Jan.-Feb.	-8.3	- 0.9	-22.6	-2.9	+0.4	+7.9	-26.7
2nd Crop							
March-April	+1.2	+ 3.8	+ 5.3	+0.2	+0.7	+5.0	+14.0
3rd Crop							
May-June	+4.0	+ 4.6	+25.6	+2.2	-0.1	+2.2	+42.1
4th Crop							
July-August	-0.1	+ 9.6	+14.7	+1.7	-0.2	-4.3	+21.2
5th Crop							
Sept.-Oct.	+3.3	- 7.0	- 5.1	+ 0.2	-0.4	-8.6	-19.5
6th Crop							
Nov.-Dec.	-0.0	-10.0	-17.8	-1.3	-0.4	-1.4	-31.1

With these values we may be able to associate a percentage increase or decrease of a particular crop, with certain percentage increases or decreases in its components. For instance, we may be in a position to say that the 1st crop for the year (i.e. January-February) is normally 26.7% below the average for the 6 picks and that this 26.7% drop in the final crop is occasioned by an 8.3% drop in the number of bunches, 0.9% drop in the number of female flowers per bunch, 22.6% drop in the percentage setting, 2.9% increase in the immature nutfall, 0.4% decrease of empties and 7.9% increase in nut size etc.

A point to note is that the algebraic sum of the percentages for the components need not necessarily be equal to the percentage in respect of the final crop this being due to a certain amount of inaccuracy arising from the averaging out of rates and percentages used in the specification of these components.

As evidenced in Table 1, the worst crop (i.e. November-December) which is 31.1% below the mean, is better than the second worst crop (i.e. 1st crop) from the point of view of the number bunches and also from the point of view of setting. But the lowest number of female flowers per bunch, and nut size which too is slightly below average, have made it the worst crop.

The first crop (January-February) the second worst, is 26.7% below average. It has the lowest percentage setting and the lowest number of bunches. But it makes up for it to a certain extent due to the best nut size viz. 7.9% above average.

The second crop (i.e. March-April) is 14.0% above average and is occasioned by slightly above average values in all the components. This crop is also to be noted for its good nut size i.e. 5.0% above average.

The 3rd crop (i.e. May-June) has the highest crop within the year i.e. 42.1% above the average. This is brought about primarily by the very heavy setting i.e. 25.6% above average. Even the number of bunches is at a maximum for this crop. The number of female flowers per bunch is also relatively well above average though not the best. It also records relatively the lowest immature nutfall. The nut size too is a little above average although third best. A noteworthy point is that the incidence of empties on an absolute basis is at a maximum in this crop, although when expressed as a proportion it is not so high.

The 4th crop (July-August) constitutes the second best crop with an increase of 21.2% above average. Its percentage setting and number of bunches is appreciably lower than the best crop (i.e. 3rd); and nut size itself is very low. But this is to a certain extent compensated for by a higher number of female flowers per bunch of 9.6% above average, which is the highest for all picks. The incidence of immature nutfall is also low although there is still a higher number of barren nuts.

The 5th crop (September-October) is a pretty low crop (19.5% below average). The percentage setting is slightly below normal. The number of female flowers per bunch is relatively very low. From the point of view of nut size it is the lowest. However from the point of view of the number of bunches, it is very favourable being 3.3% above average.

The sixth crop (November-December) records a drop of 31.1% from the average and is the worst. All the crop components operate unfavourably towards this crop. It is the worst from the point of view of the number of female flowers per bunch. Setting is poor. Immature nutfall and empties are high and nut size also poor.

Generally, apart from the individuality maintained by different crops from the point of view of the relative importance of the contributory crop components, it is observed from a rough estimate that as far as the within year fluctuations of crops are concerned, the percentage setting seems to control about 50% of the fluctuations, with female flowers per bunch about 20%. The nutsize and number of bunches come next in importance. Immature nutfall and empties together do not account for more than 2-3% of the crop variations within the year.

DISCUSSION AND SUMMARY

In any attempt to study the influence of climate and weather on coconut crops, it would be futile to consider the crop as a single entity. Emphasis has to be laid on the more meaningful crop philosophy of viewing a coconut crop as the outcome of several crop components, whose magnitudes are fixed at different phases of a cycle of development lasting about three and half years between the initiation of flower primordia and realisation of the final crop; and therefore any fluctuations of the final crop must be related to the fluctuations of its components, each of which in turn may have its own specific weather factors with specific periods and specific intensities controlling such fluctuations.

A study is made of the pattern of the within-year variations of coconut crops in this region vis a vis the patterns of variation of the crop components. The variations of the different crop components have been utilized to explain why a particular crop is typically low or high. Further the repeatability of the patterns of variation is tested in order to verify how typical they are. The final crop pattern and that of all the components except the number of bunches and the number of female flowers per bunch are highly repeatable. The number of bunches is significantly repeatable but not quite high and the number of female flowers per bunch, just borders on significance and one can hardly consider it to have a typical pattern.

An interim estimate shows that as far as the within-year crop pattern is concerned, the percentage setting is the predominant factor controlling the fluctuations, accounting for about 50% of the total contribution; the number of female flowers per bunch accounts for about 20%; the nut size and the number of bunches are next in importance; immature nutfall and barren nuts do not so much control the crop fluctuations.

The possible influence of weather factors on these crop components is now being investigated by us. However, we are conscious of the fact that our data do not permit a definitive assessment as such, because the data available are restricted to bi-monthly crops where we are really handling totals of two bunches on an average.

To fill this gap, we have recently commenced some multi-purpose yield recordings in the field. Originally intended to be a "calibration" trial, it is now extended to provide material for the elucidation of various other biometrical problems as well as crop-weather relationships. In these recordings, every bunch is followed up regularly from the opening of the spathe to maturity and it is proposed to keep such records in a block of about 175 palms and for several years.

Acknowledgements

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APPENDIX

THE MEASUREMENT OF REPEATABILITY OF SEASONAL PATTERNS

By

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A very common problem in agricultural research is to ascertain the association of individuals within groups. For instance, we may be interested in ascertaining the homogeneity of crop yields of a number of plots within a block, or the resemblance of leaves within a tree or the similarity of the performance of progenies within a parent or the consistency of the seasonal distribution of rainfall over the years. In all such problems, it is customary to calculate an index which is generally termed "the intra-class correlation coefficient".

But quite often, we meet with similar problems, wherein we may be tempted to use an intra-class correlation coefficient, only to end up with a highly unacceptable result—sometimes one that denies what is even obvious on a cursory visual examination of the data.

Let us take a hypothetical example of the seasonal variation of some yield character such as (say) immature nutfall. We have the records of the seasonal immature nutfall for different seasons over a number of years (Table 1).

TABLE 2
Hypothetical data on seasonal immature nutfall

<i>Year</i>	<i>IMMATURE NUTFALL</i>					
	<i>Jan.-Feb.</i>	<i>Mar.-Apr.</i>	<i>May-June</i>	<i>July-Aug.</i>	<i>Sept.-Oct.</i>	<i>Nov.-Dec.</i>
1941	350	325	290	360	370	385
1942	300	200	180	330	340	380
1943	160	40	30	180	190	200
1944	230	220	200	260	280	350
1945	420	400	380	480	500	725
Mean/Year	292	237	216	322	336	408

The problem here is to determine whether the seasonal pattern of nutfall is repeatable over the years. That is, can we expect that the seasonal pattern, as evidenced by the seasonal totals (or means) over the years, is typical of this character and if so to what extent?

In a two-way classification of this type (Table 2) where the between year variation is large, the intra-class correlation fails to give us the correct answer. The intra-class correlation coefficient for the above data (where the seasons are reckoned to be the classes) is found to be 0.0654. This value is extremely low and on the strength of it, we would not hesitate to conclude that the seasonal pattern of immature nutfall obtained by averaging seasonal values over the years is not typical.

But this result is certainly unacceptable because even a visual examination of the data shows clearly that the pattern is very consistent. In fact in each year, May-June season gives the lowest nutfall, November-December season gave the highest nutfall and similarly for each of the seasons which carry intermediate values. Therefore, the intra-class correlation has failed to answer our problem.

In such situations, it is preferable to avoid metrical values and resort to statistical methods based on "order statistics". Two methods to be used to ascertain the repeatability of seasonal patterns, when the yearly variation is large and itself variable for the different seasons, are given below.

(a) Rank sum test in a two-way classification (adapted from Sibuya 1961).

TABLE 3

Years \ Seasons	Seasons						Sum
	1	2	j	c	
1							
2							
.							
.							
i							
.							
.							
r							
Sum	T ₁	T ₂	T _j	T _c	rc(c+1)/2

r years are considered with c seasons in each. The observations are ranked by their order within the year (based on their metrical values). For example, the lowest value for the year may be marked 1, the second lowest 2, . . . and the highest c and similarly for all the years. The results may be summarized in a 2-way table with r rows and c columns (Table 3). Each row contains rank orders 1, 2, c. The sum of all the ranks in the table is equal to rc(c + 1)/2.

On the basis of a null hypothesis that the seasonal pattern is not repeatable, the ranks 1, 2, c would be distributed randomly in a row. Therefore the expected value of columnwise sums is equal to r(c + 1)/2.

A suitable test for any departure from this null hypothesis is given by:—

$$x^2 = \frac{12}{rc(c+1)} \sum_{j=1}^c \left\{ T_j - \frac{r(c+1)}{2} \right\}^2$$

(c - 1)d.f

If the calculated value of x² exceeds the significant level for (c - 1) degrees of freedom, we dismiss the null hypothesis and accept that the seasonal pattern is repeatable.

(b) Intra-class correlation for ranks.

If in addition to a test of significance of repeatability, one needs also an index of the degree of repeatability, one may calculate an intra-class correlation coefficient for the rank orders in the same 2-way table used for the x² test. However prior to the calculation of the coefficient it would be necessary to convert such ranks into "normal scores" using Table XX of the Statistical Tables for Biological, Agricultural and Medical Research by Fisher and Yates.

This coefficient may be tested for significance at the analysis of variance stage which precedes the calculation of the coefficient. Once this is done, the x² test may be dispensed with.