STUDIES ON BIENNIAL BEARING TENDENCY IN COCONUT

1. The Measurement of Bienniality in Coconut

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Most perennial species, according to Pearce (1953), are to some extent biennial in cropping and growth. Explaining the biennial rhythm in fruit trees, Singh (1948) observes that "trees which have acquired this biennial rhythm, carry a heavy crop in one year (called the 'on' year) and little or no crop in the next (the 'off' year). The fruits in the 'on' year tend to be over crowded, small and of poor quality, while the few fruits that are formed in an 'off' year are usually above normal size. The alternation of too much and too little crop in the 'on' and 'off' years respectively, may persist with great regularity, though it may be upset by some major climatic factor".

While this tendency is extensively reported (Singh 1948) to be a common feature of fruit trees in both tropical and sub-tropical regions, its presence in coconut (*Cocos nucifera*) has so far not evoked anything more than passing interest. Webster (1939) has reported biennial tendency in a closely associated species viz. the oil palm (*Elaeis guineensis*), wherein he observes that at least 40% of the palms have a distinct tendency to biennial bearing. Shrikande (1958) and Pankajakshan (1960) have made passing references to the biennial bearing tendency in coconut. According to them "most of the trees exhibit the alternate bearing tendency and there is no well marked pattern for individual trees throughout their life period. The period of the yield cycle also varies from tree to tree during different stages of the productive phase".

The biennial bearing tendency in coconut may not be of such dimensions as to claim so much economic or commercial importance as in horticultural crops. However Haldane (1958) commenting on reported biennial tendency in coconut, feels that "it is important to know if this is a sharply defined character, how it is inherited and whether it can be overcome by the use of fertilizers". Moreover if it were to be established as a sharply defined character, it may call for a reorientation of conventional methods of evaluating experimental data in respect of coconut and accordingly cannot be considered merely of academic interest to research workers on coconut. In this paper, it is proposed to examine this problem more rigorously because the earlier reports seem to give only casual observations. Apart from investigating the biennial bearing tendency in coconut, some methods of measuring this tendency are also discussed — the only available method (Hoblyn & *et al* 1936) now used for orchard crops being, in the author's opinion, not quite adequate for perennial bearers like coconut.

Material and Methods

The data used in this study were obtained from the individual palm nut records of a block of 300 palms maintained under a uniform system of management by the Botanist's Division of the Coconut Research Institute of Ceylon. The data refer to the period 1936–1954, the period subsequent to this has been avoided as some of the trees are being used for "pollination studies" since 1955. The new recruits (younger palms) which have replaced dead palms, have been excluded in the analysis.

Measurement of Biennial Tendency (Existing Method)

(a) Method

Normally the biennial habit in a given tree may be observed by merely examining the trends of the annual yields over the years. Probably the references to biennial bearing in coconut reported earlier, were based on this type of visual examination. However it need not be emphasized that a quantitative estimate is of great value, and apparently the only known numerical standard for specifying biennial tendency in perennials is that devised by Hoblyn *et al* (1936). Singh (1948) reports on these standards as follows:—

"The first expression introduced by these authors, the factor 'B' indicates the extent to which the cropping performance of a tree is regularly annual, biennial or irregular. To determine 'B', crop records for at least 3 years must be available. The yield for each year is considered in relation to that of the previous year. If the second yield exceeds the first, the difference is given a plus sign and if the converse, a minus sign. Thus a series of signs for each consecutive pair of years is obtained. From these, 'B' is calculated by determining the percentage of consecutive pairs of unlike signs over the whole period. A value of 'B' = 100 is obtained when the tree is completely biennial i.e. when plus is followed by minus and *vice versa* throughout the period. On the other hand when 'B' = 0, the tree is regularly increasing (or regularly decreasing) in yield.

The second factor 'I' was employed as a measure of the intensity of degree of crop fluctuations from year to year. The derivation of 'I' may be expressed in the form:

$$I = \frac{\text{Difference between successive yields}}{\text{Sum of successive yields,}}$$

The values of I vary from 0 to 1, where 0 denotes equal crops in successive years and 1 no crop at all in alternate years. Values of 'I' may be averaged for a given number of years and a mean value obtained".

(b) Results

(1) 'B' Factor.

These formulae have been applied on our data and the proportion of palms showing varying degrees of bienniality as per 'B' factor is obtained (Table 1).

TABLE 1. Biennial Tendency (Factor 'B') in Coconut

Factor 'B'		*No. of*	*Percentage*	*Cumulative*
ratio	*per cent*	*palms*	*of palms*	*percentage*
0–7/17	47.1	*nil*	*nil*	*nil*
8/17	47.1	2	0.7	100.0
9/17	52.9	10	3.6	99.3
10/17	58.8	28	10.2	95.7
11/17	64.7	53	19.3	85.5
12/17	70.6	76	27.7	66.2
13/17	76.5	60	21.8	38.5
14/17	82.4	31	11.3	16.7
15/17	88.2	13	4.7	5.4
16/17	94.1	0	—	0.7
17/17	100.0	2	0.7	0.7
all palms		275	100.0	

The data analysed covered a period of 19 years. The 'B' factor is accordingly based on 17 pairs of successive signs. On the basis of an equiprobable hypothesis, the probability of unlike signs in any pair of consecutive years is 0.5. Therefore a test of significance for bienniality can be obtained by calculating the Binomial probabilities given by,

$$Pr(x) = {}^{17}C_x \left(\tfrac{1}{2}\right)^x \left(\tfrac{1}{2}\right)^{17-x}$$

where x is the number of pairs of unlike signs (x= 0, 1, 2, ...17).

Based on the above probabilities, we observe that any value of x=13 or above is a significant departure from an equiprobable hypothesis. Therefore we can consider a palm showing a 'B' factor equal to or higher than 13/17 as significantly biennial in bearing; and on this basis we find that 38.5% of the palms are significantly biennial in bearing.

(2) 'I' Factor.

The 'I' factor has been worked out on a percentage basis for each of the palms and the distribution is shown in Table 2.

TABLE 2. Biennial Tendency (Factor 'I') in Coconut

Factor "I"	*No. of palms*	*percentage of palms*	*cumulative percentage*
Less than 5%	1	0.4	0.4
Less than 10%	48	17.4	17.8
Less than 15%	123	44.7	62.5
Less than 20%	63	22.9	85.4
Less than 25%	21	7.6	93.0
Less than 30%	10	3.6	96.6
Less than 35%	4	1.5	98.1
Less than 40%	1	0.4	98.5
Less than 45%	3	1.1	99.6
Less than 50%	1	0.4	100.0
Total	275		

It is observed that nearly two-thirds of the palms show an 'I' factor less than 15%, compared to a mean 'I' value ranging from 45% –70% for apples (Preston 1956). Another noteworthy point arising from above is that the distribution of 'I' shows a significant departure from normality — β_1 being equal to 3.22 and significant (P=< 0.001) and β_2 being equal to 7.92 and significant (P=< 0.001).

(3) Covariance of 'B' and 'I' factors.

The joint-distribution of 'B' and 'I' factors in coconut is shown by the bivariate frequency table (Table 3) and its bivariate surface is shown by the stereogram (Fig. 1).

TABLE 3. Joint Frequency Distribution of 'B' and 'I' Factors in Coconut

'B'/'I'	5%	−9.9%	−14.9%	−19.9%	−24.9%	−29.9%	−34.9%	−39.9%	−44.9%	49.9	*All 'I's*
47.1	—	—	—	—	—	—	—	—	—	—	*nil*
47.1	—	2	—	—	—	—	—	—	—	—	2
52.9	—	5	2	3	—	—	—	—	—	—	10
58.8	1	7	14	4	1	1	—	—	—	—	28
64.7	—	10	27	9	2	4	1	—	—	—	53
70.6	—	11	35	17	7	2	2	—	1	—	75
76.5	—	8	25	17	6	2	1	—	1	1	61
82.4	—	3	14	8	3	1	—	1	1	—	31
88.2	—	2	6	4	1	—	—	—	—	—	13
94.1	—	—	—	—	—	—	—	—	—	—	*nil*
100.0	—	—	—	1	1	—	—	—	—	—	2
All 'B's	1	48	123	63	21	10	4	1	3	1	275

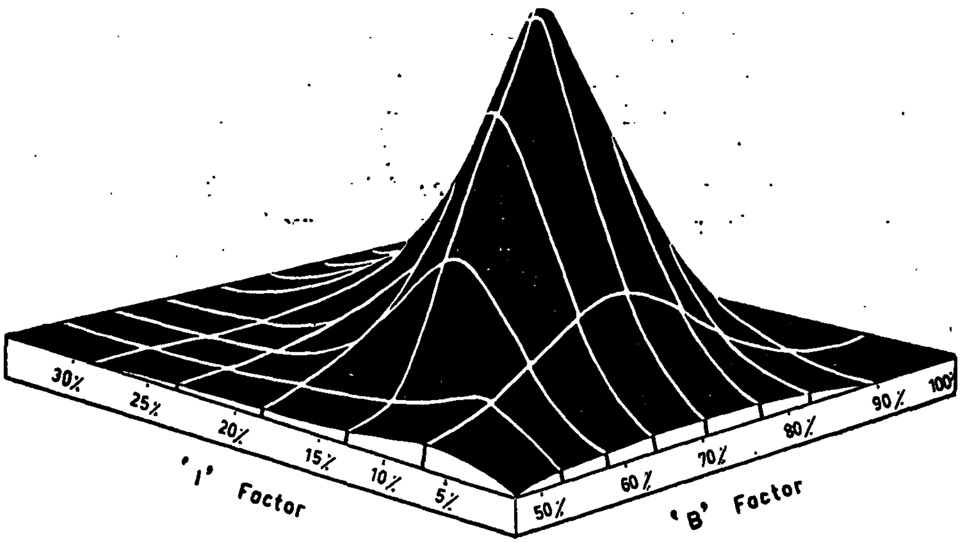

Fig. 1 BIENNIALITY in COCONUT

The moment correlation (r) is found to be + 0.1898 (P = 0.01 — 0.001) and the correlation ratio (η) is 0.2335, showing that a high 'I' factor in a palm is to a certain extent associated with a high 'B' factor. However this correlation though significant is not very high and understandably so because the 'I' factor in coconuts is controlled to an appreciable degree by the random fluctuations and also large fluctuations due to the weather. A comparison of r and η (supra) indicates that the relationship between 'B' and 'I' is more or less linear.

Measurement of Biennial Tendency (Alternate Method 1)

(a) Method.

Given a stable form of management and ignoring any long term trends for whatever reason it may be, the annual individual tree fluctuations in perennial crops are controlled mainly by three factors, *viz.* (1) random fluctuations, (2) biennial rhythm (if any) and (3) weather fluctuations.

In the case of coconut, (probably more than in other perennial crops) it is known that the annual fluctuations due to the weather are appreciably high and in fact one could pretty closely predict a year's coconut crop from the previous year's rainfall data (Abeywardena 1962). Due to this superimposition of a sizeable weather effect, one is left wondering how far the measures of biennial tendency given by factors 'B' and 'I' of Hoblyn *et al* are applicable to this crop. These indices may be validly used in the case of orchard crops for which it had been specifically derived, because the latter although perennial in growth, are mostly seasonal in cropping and therefore the influence of weather fluctuations on these crops may not be of such a magnitude as on coconut which is a perennial bearer. Each coconut crop (i.e. a bunch) has a developmental period of about three years and at any particular time, there are at least 12 over-lapping crops (or bunches) at equally spaced stages of development, with the result that the occurrence of unfavourable weather at any time of the year can affect two to three crops at least. Therefore unlike in orchard crops, the influence of the weather on the annual fluctuations of coconut crops can be appreciably high. For these reasons Hoblyn's indices, if used on coconut, may not reflect the true biennial rhythm, being invariably masked by the large fluctuations due to weather alone. Some modified method should be derived whereby the biennial rhythm is assessed barring the fluctuations due to the weather. For this purpose the following approximate method is proposed.

Generally the biennial rhythm reported in coconut is such that in a particular year there are some trees in the 'on' phase and some in the 'off' phase. Really when a large number of palms is considered, one could expect as many trees in the 'on' phase as in the 'off' phase. However, when one examines the observed yield data, this equiprobability will not be indicated (Table 4). The phase attributable to the biennial rhythm is masked by the weather effect. In a particular year which shows a favourable crop due to good weather, even the trees that are in the 'off' phase by virtue of bienniality will show a rise in yield and therefore will indicate a false 'on' phase, while the trees that are in the 'on' phase will continue to be 'on'. The years 1943, 1946, and 1950 are cases in point. A similar spurious reversal of the biennial phase accrues to trees in the 'on' phase in an un-favourable year, such as 1939 or 1945.

TABLE 4. No. of palms showing 'on' and 'off' phase.

Year	*'On' Phase*	*'Off' Phase*	*%'On' Phase*	*Year*	*'On' Phase*	*'Off' Phase*	*%'On' Phase*
1937	192	83	69.8	1947	35	240	12.7
1938	156	119	56.7	1948	156	119	56.7
1939	8	267	2.9	1949	35	240	12.7
1940	211	64	76.7	1950	238	37	86.5
1941	176	99	64.0	1951	111	164	40.4
1942	38	237	13.8	1952	161	114	58.5
1943	239	36	86.9	1953	62	113	22.5
1944	35	240	12.7	1954	172	103	62.5
1945	16	259	5.8				
1946	273	2	99.3	*All Years*	2314	2536	47.7

Generally although the annual yield fluctuations of individual trees can be attributed as mentioned earlier, to three factors *viz.* random causes, biennial rhythm and the weather, the yield fluctuations of a whole block of trees taken in a cluster can be attributed almost wholly to the weather the biennial rhythm and the random factor, averaging out over a large number of trees.

The annual fluctuations of the individual tree yields can accordingly be corrected for the weather factor, by regressing on the annual yields of the block as a whole. Such corrections, incidentally, will eliminate any other disturbing factors common to the whole block. The yearly individual tree yields obtained thereby (to be termed adjusted yields herein-after) will contain only fluctuations due to random causes and the biennial rhythm.

Having thus eliminated the weather factor, we are in a less questionable position to estimate bienniality in coconut using the 'B' and 'I' factors of Hoblyn *et al.*

(*b*) *Results.*

(1) 'B' Factor (adjusted yields).

The incidence of bienniality in the adjusted yields hardly differs from what it was prior to adjustment (Table 5). This may be due to the fact that the variation of the block totals, for which the adjustments have been made, has been more or less random; and this is confirmed by the non-significant serial correlation coefficient (with lag 1) of –0.2909 in respect of the annual yields of the blocks. However when considering individual palms, a few palms which were strongly biennial earlier turned out to be less so and *vice versa.*

TABLE 5. "B" Factor in adjusted yields.

'B' Factor ratio	'B' Factor per cent	No. of palms	percentage of palms	cumulative percentage
(0–7)/17	47.1	nil	nil	nil
8/17	47.1	6	2.2	100.0
9/17	52.9	15	5.5	97.8
10/17	58.8	20	7.3	92.3
11/17	64.7	64	23.3	85.0
12/17	70.6	52	18.9	61.7
13/17	76.5	51	18.5	42.8
14/17	82.4	40	14.5	24.3
15/17	88.2	18	6.5	9.8
16/17	94.1	5	1.8	3.3
17/17	100.0	4	1.5	1.5
		275	100.0	

It is found that, after adjustment 42.8% of the palms show significant bienniality.

(2) 'I' Factor (adjusted yields).

The intensity factor for adjusted yields shows a substantial reduction (Table 6) — the mean 'I' value being 9.4% for adjusted yields as compared with 14.9% for unadjusted yields.

TABLE 6. 'I' Factor in Adjusted Yields

'I' *Factor* %	*No. of palms*	*percentage of palms*	*cumulative percentage*
2— 3.9	4	1.4	1.4
4— 5.9	34	12.4	13.8
6— 7.9	82	29.8	43.6
8— 9.9	71	25.8	69.4
10—11.9	30	10.9	80.3
12—13.9	23	8.4	88.7
14—15.9	14	5.1	93.8
16—17.9	4	1.4	95.2
18—19.9	3	1.1	96.3
20—21.9	3	1.1	97.4
22—23.9	1	0.4	97.8
24 & *above*	6	2.2	100.0
Total	275	100.0	

The positive skewness in the 'I' factor observed in respect of the unadjusted yields is present in the adjusted data too — β_1 being 2.83 and significant ($P = < 0.001$) and β_2 being 6.52 and significant ($P = < 0.001$).

(3) Covariance of 'B' and 'I' factors in adjusted yields.

The joint-distribution of 'B' and 'I' factors in adjusted yields is shown by the bivariate frequency table (Table 7) and the stereogram (Fig. 2).

TABLE 7. Joint Frequency Distribution of 'B' and 'I' Factors in Adjusted Yields

'B'/'I'	–1.9%	–3.9%	–5.9%	–7.9%	–9.9%	–11.9%	–13.9%	–15.9%	–17.9%	–19.9%	–21.9%	–23.9%	–24 & *ab*:	*All 'I's*
47.1	—	—	—	—	—	—	—	—	—	—	—	—	—	*nil*
47.1	—	—	2	4	—	—	—	—	—	—	—	—	—	06
52.9	—	—	3	5	2	3	1	—	—	—	—	—	1	15
58.8	—	1	3	8	3	2	2	1	—	—	—	—	—	20
64.7	—	1	7	20	20	5	5	2	—	1	1	—	2	64
70.6	—	1	6	20	14	3	2	5	—	1	—	—	—	52
76.5	—	—	8	10	15	5	5	4	2	—	1	—	1	51
82.4	—	1	4	11	7	8	3	2	1	—	—	1	2	40
82.2	—	—	—	4	8	1	3	—	1	—	1	—	—	18
94.1	—	—	1	—	1	2	1	—	—	—	—	—	—	—
100.0	—	—	—	—	1	1	1	—	—	1	—	—	—	04
All 'B's	—	04	34	82	71	30	23	14	04	03	03	01	06	275

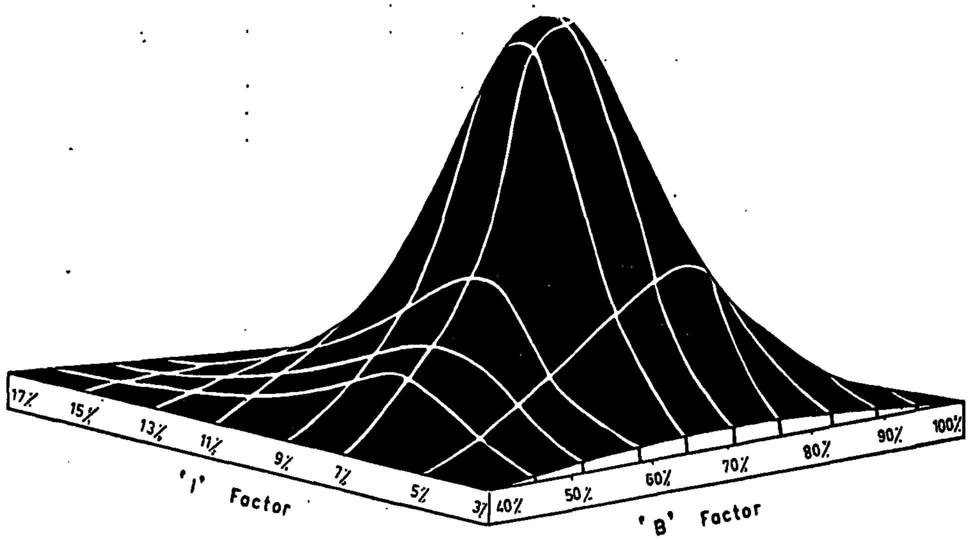

Fig. 2 BIENNIALITY in COCONUT

(ADJUSTED YIELDS)

The correlation coefficient (r) is + 0.1733 (P= 0.01– 0.001) and the correlation ratio (η) is 0.2195. The association between 'I' and 'B' factors is still appreciably low although significant, showing that in spite of the elimination of the weather factor, the intensity of crop fluctuations is only slightly influenced by the biennial rhythm.

Measurement of Biennial Tendency (Alternative Method II).

(*a*) *Method.*

The presence of the biennial bearing tendency has been examined through another method especially suited to this type of crop. This method makes no assumptions whatsoever and could be employed on observed data in spite of the superimposition of fluctuations due to weather.

The individual tree yields are ranked in either descending order or ascending order, but in the same order for all the years. Whatever effect the weather has on a particular year's crops, will necessarily operate in the same direction on all the palms, though not necessarily to the same extent due to a possible interaction between the yield capacity of a palm and its responsiveness to a particular stimulus. This latter interaction, if present, is only slight and may be ignored. Therefore, if a biennial rhythm is present, one can expect the ranks to agree more in alternate years than in adjacent years because a tree that is in the 'on' phase in a particular year will be in the 'off' phase in the adjacent year and again in the 'on' phase in the subsequent year. If then we calculate the rank correlation coefficients (Spearman's) for every pair of adjacent years and every pair of alternate years, the coefficients for the alternate years should generally be higher than those for the adjacent years.

(b) Results.

These coefficients have been worked out for the present data (Table 8).

TABLE 8. Rank Correlation Coefficients for Adjacent and Alternate Years

Rank Correlation Coefficients	
Adjacent years	*Alternate years*
0.6295	0.7904
0.7866	0.8177
0.8085	0.7834
0.7798	0.7982
0.7058	0.8121
0.6461	0.8035
0.6129	0.7611
0.7420	0.8093
0.7807	0.8110
0.7786	0.7950
0.7646	0.7688
0.6595	0.7538
0.5983	0.7084
0.4917	0.7552
0.5714	0.6969
0.6539	0.7446
0.6650	0.7700
0.6917	—

A simple test of significance that may be used for testing whether the rank correlation coefficients for the alternate years are higher than for adjacent years, is the "Rank Sum test" (Sibuya 1961), sometimes referred to as Wilcoxon's test.

Suppose there are m coefficients $(x_1, x_2, \ldots\ldots x_m)$ for alternate years and n coefficients $(y_1, y_2, \ldots\ldots y_n)$ for adjacent years. These coefficients are combined into a single ordered series and ranked from 1 (the lowest) to m+n (the highest). For reasonably high values of m and n, (as in this particular case where m=17 and n=18) T may be assumed to be distributed approximately Normally with expectation

$$= \frac{m(m+n+1)}{2} \text{ and the variance } = \frac{mn(m+n+1)}{12}.$$

To put it in mathematical notation:—

$$T \sim \text{(approx) } N \left(\mu = \frac{mm(+n+1)}{2},\ \delta^2 = \frac{mn(m+n+1)}{12} \right)$$

On this basis, when m = 17 and n=18, we observe that any value of T outside the critical range 247—365 is statistically significant (P=0.05).

The value of T based on the correlations in Table 8, is found to be 404, which is highly significant. Therefore we conclude that biennial bearing tendency is a significant feature in coconut.

Discussion

Due to the fact that coconut is a perennial bearer, with its crop fluctuations controlled to an appreciable extent by the weather, the detection of bienniality in its yields, calls for a modification of the methods devised by Hoblyn *et al* for orchard crops. However the alternate method (suggested in this paper) of eliminating the weather factor by adjusting for the block totals and using Hoblyn's indices on the adjusted yields, do not show any marked differences in bienniality apart from reducing the intensity of fluctuations. This is not surprising as the weather fluctuations have been almost at random during the period under consideration. Therefore the objections raised by the author regarding the direct use of Hoblyn's indices on coconut should still remain valid. Apart from giving a more precise estimate for a particular area, this modified method ensures comparability of estimates for different areas of different weather patterns. On the other hand, the second alternative method of comparing the rank correlation coefficients of adjacent and alternative years is available for use on the observed data and will be a sensitive index of bienniality whatever the weather pattern.

All the three methods employed in the present study indicate the presence of a biennial rhythm in coconut. But the intensity of biennial fluctuations is pretty low and therefore should cause the least concern in economic and commercial circles. But as suggested earlier, its importance to research workers from the biometrical angle, is yet to be examined. In the statistical evaluation of experimental data, a knowledge of some factor that contributes to variation in the data and also the extent of such variation will always be considered a step forward in scientific experimentation.

These problems are now being examined and the results will appear in a subsequent publication.

Summary

The incidence of the biennial rhythm in coconut yields has been examined, on a quantitative basis. Two alternative methods for detecting bienniality in perennial bearers such as coconut are discussed, in addition to the methods currently used for orchard crops.

Bienniality is shown to be a significant feature in coconut yields. However the intensity of biennial fluctuations is found to be low and therefore of no immediate concern to commercial circles, although its importance to research workers on coconut is not to be underestimated.

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