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A BIOMETRICAL APPROACH TO EVOLVING A SELECTION INDEX FOR SEED PARENTS IN COCONUT *(COCOS NUCIFERA L.)*

V. ABEYWARDENA* and D. T. MATHES

Coconut Research Institute, Lunuwila, Sri Lanka

ABSTRACT

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An efficient selection index for mother palms in coconut is evolved through the technique of Principal Component Analysis.

This index helps to select the superior genotypes through characters in the palm that can be measured at a given instant as against the present questionable system of selecting the superior phenotypes as mother palms and that too through yield data gathered over a period of as long as four years.

The use of this index as a calibrating variate for field experiments on coconut is also recommended in order to improve experimental precision.

INTRODUCTION

Elite seed parents (or mother palms as they are commonly known) are generally selected on the basis of their yield performance – perhaps with some additional guidance from the characters of the crown of the palm. In Sri Lanka the more important criteria for selection of mother palms, (CRI advisory Leaflet No. 1) are as follows.

1. Stem stout with leaf scars close to each other,
2. Large number of leaves well disposed on the crown,
3. Bunches well stocked with nuts in all stages of development and
4. Mean yield of at least 75 nuts per palm per annum.

While the above criteria cover both vegetative and reproductive characters, it is apparent that except in the case of the character yield, judgement based on the other characters is very subjective. This is because they are not quantified and, as a result, no critical minima can be laid down. Further, even in the case of the character yield, where a certain minimum is specified, if it is to be at all precise, one would need yield data averaged over a period of at least four successive years. This would be necessary in order to (1) nullify the biennial rythm (Abeywardena, 1963) and (2) average out fluctuations due to the weather – both of which phenomena can render the laying down of an absolute critical yield level based on a single years' yield meaningless.

* *Present address: Agroskills, Asoka garden, Colombo 4, Sri Lanka.*

At any rate, even if one is prepared to record yields for four years, laying down of an absolute minimum yield to define a mother palm regardless of its environment is itself questionable. The phenotypic yield of a palm is controlled by two factors, namely, the environmental factor and the genetical factor. As such, the selection of a mother palm on the basis of an absolute yield level regardless of the environment may not help us to a precise identification of the superior genotypes. A more meaningful approach (perhaps now accepted by most plant breeders) would be to select the best 5% or best 10% (or whatever other selection intensity) within a given homogeneous environment.

In this paper, we are proposing a selection index for mother palms which would avoid the objections discussed above - one that would not necessitate keeping yield records for four years and further would ensure more precise genotypic selection unbiassed by the environment.

METERIALS AND METHODS

The data for this study were obtained from the "Calibration trial" conducted at Ratmalagara Estate by the Biometry Unit of the Coconut Research Institute of Sri Lanka.

The mean individual palm yields and measurements of vegetative and reproductive characters (1967 - 1970) were used in the analysis.

A solution to the first problem of avoiding keeping yield records for four years rests on (1) how far we can identify certain vegetative and/or reproductive characters that can be measured at any given instant and which would singly or in combination reflect the four-year mean yield and (2) if it is a number of characters involved, how we can efficiently integrate these measurements into a single numerical index precisely reflecting the four-year mean yield. A solution to the other problem of the index ensuring the selection of the better genotypes regardless of the environment has also to be found.

A previous study based on data from this same "Calibration trial" (Abeywardena, 1973) shows the relationships between certain vegetative and reproductive characters on the one hand and the mean yield on the other (Table 1).

It is apparent that there are four characters in the palm that can be measured at a given instant and these characters are related to the mean yield to some extent or other. These are :

x_1 : Trunk girth just below the crown (mean of two measurements taken one foot apart).

x_2 : Number of opened inflorescences including mature bunches.

x_3 : Number of nuts per bunch (averaged over all opened inflorescences and mature bunches).

x_4 : Number of green fronds present at a given time.

Having decided on these four characters, our next step would be to derive an integrated index (incorporating these four measurements) to which, subjectively though, we can attach some biological significance. If we consider the concept of "plant vigour", it would be reasonable to expect that more often than not a more vigorous palm will have a larger trunk girth (x_1), more bunches (x_2), more nuts per bunch (x_3) and more fronds (x_4). Then, if we are to express palm vigour through these four characters, we have to pose ourselves the question : "What function of these four characters will discriminate best between more vigorously growing palms and less vigorously growing palms?"

Table 1. *Growth Characteristics of high and Low Yielding palms*

Yield Group nuts/palm/year		*Height (m)*	*Trunk girth below the crown (cm)*	*No. of fronds (no.)*	*No. of bunches with nuts per annum*	*No. of FF per bunch*	*No. of mature nuts per bunch*	*No. of mature nuts per annum*	*wt. per husked nut (kg)*
< 25	..	5.85	57.91	22.4	7.1	6.3	2.2	15.6	0.58
25 — 44	..	8.93	55.63	23.4	11.0	9.6	3.6	39.9	0.58
45 — 64	..	11.79	60.96	26.3	12.4	14.8	5.1	63.5	0.67
65 — 84	..	12.07	62.99	27.1	12.8	16.7	6.3	80.5	0.62
85 — 104	..	12.59	66.04	28.6	13.5	19.2	7.5	100.6	0.63
105 and over	..	11.79	75.95	31.1	14.1	20.9	8.2	115.3	0.62

In order to derive such a multivariate function, we would suggest a Principal Component Analysis of the correlation matrix derived from the four variables and select the Eigen vector wherein the vector elements, corresponding to the four variables, all show positive signs and are nearly of equal dimension. In this case, the vector elements should approximate to 0.5, 0.5, 0.5, 0.5 if plant vigour is reflected in equal measure by all four characters. Such a vector would be an expression indicating that there is some correspondence between the four characters, which may be interpreted as general plant vigour. Further, if this vector explains away a sizeable proportion (say over 60%) of the total variation in these four variables, we can expect that whatever differences that exist between palms are mostly general vigour differences – at least so far as these four characters are concerned.

If such a vector is found, one could calculate the standardized vector scores for each palm in respect of this vector and the selection index for mother palms will be some critical level of these scores (depending on the desired selection intensity) provided of course that these vector scores are related to the four-year average yield. This latter proviso would be the decisive criterion of the efficiency of the proposed selection index.

RESULTS

1. Principal Component Analysis

The Principal Component Analysis of the correlation matrix of the four vegetative and reproductive characters (x_1 to x_4) mentioned under "Materials and Methods" gave rise to the Eigen vectors and Eigen roots shown in Table 2.

Table 2. *Eigen vectors of the four characters and Eigen values of the vectors*

	Vector elements (aj)					
Vector	*Trunk girth* (a_1)	*No. of bunches* (a_2)	*No. of nuts/ bunch* (a_3)	*No. of green fonds* (a_4)	*Eigen value*	*Proportion of variance accounted for by vector*
V_1	0.5593	0.4743	0.3553	0.5796	2.4271	60.7 %
V_2	0.0563	0.4678	−0.8764	0.1001	0.8349	20.9 %
V_3	0.5355	−0.7291	−0.3230	0.2780	0.4992	12.4 %
V_4	0.6303	0.1568	0.0374	−0.7595	0.2388	6.0 %
					4.0000	100.0 %

The first vector (V_1) has the vector elements all positive and each approximating to 0.5 and this vector explains away 60.7% of the total variance. Therefore, for all intents and purposes, this vector reasonably fulfils the requirements of an integrated expression of the correspondence between these four characters and may be construed as an index of "plant vigour"

2. Selection Index

The standardized vector scores for each palm in respect of the vector described above would indicate how "vigorous" a given palm is – a high value indicating a more vigorous palm and vice versa.

These scores can be calculated as shown below :

Step 1- Calculate for each variable the mean and the standard deviation, which for the j^{th} variable would be

$$\bar{x}_j \text{ and } \delta_{x_j}$$

Step 2- Calculate for each plam the standardized normal deviate in respect of each variable (x_j)

The standardized normal deviate for the i^{th} palm in respect of the j^{th} variable would be

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\delta_{x_j}}$$

Step 3- The vector elements are aj (j = 1 to 4) subject to the condition that

$$\sum_{j=1}^{4} a_j^2 = 1$$

The standardized vector score (I) for a given palm is given by :

$$I_i = \sum_{j=1}^{4} a_j z_{ij}$$

In this particular case, if the variables are x_1 to x_4 and the vector elements of V_1 are as shown in Table 2, the vector score for the i^{th} palm would be :

$$I_i = \left(\frac{X_{i1} - \bar{X}_1}{\delta_{X_1}}\right)\left(0.5593\right) \left(\frac{X_{i2} - \bar{X}_2}{\delta_{X_2}}\right)\left(0.4743\right) + \left(\frac{X_{i3} - \bar{X}_3}{\delta_{X_3}}\right)\left(0.3553\right) + \left(\frac{X_{i4} - \bar{X}_4}{\delta_{X_4}}\right)\left(0.5796\right)$$

It can be proved that the vector score (Ii) too follows the standardized normal distribution.

Therefore, a particular value of the Index (I) intended to meet a given selection intensity will be independent of the mean yield of the block of palms from which selection is done. For instance, if we fix the critical level of the selection index (I) at 1.28 which (according to Table II_1 of Fisher and Yates' Tables) selects the best 10% of the palms, this value will select the best 10% of palms regardless of whether selection is done in a high yielding block or low-yielding block. Thereby one would be selecting the superior genotypes unbiassed by the environment.

3. Efficiency of Selection Index

The efficiency of this selection index (I) which is expected to select the superior genotypes will, as stated earlier, depend on the degree to which it reflects the 4-year mean yield.

The correlation coefficient between the vector scores (I) and the 4-year mean yield in respect of the data under consideration is found to be $r = 0.76^{***}$ ($P = .001$). This is evidence that the selection index proposed by us reflects the mean yield closely and is, therefore efficient.

Further evidence is supplied in Table 3, which gives (1) the critical level of the selection index corresponding to certain intensities of selection and (2) the mean yield of the palms selected based on such critical levels.

Table 3. *Relationship between vector score and mean yield*

Critical level of vector score (selection Index 1)	*Group of palms selected*	*Mean yield of group nuts/palm*
1.28 and over	Best 10%	90.7
0.84 to < 1.28	next 10% — 20%	80.0
0.52 to < 0.84	next 20% — 30%	73.6
0.25 to < 0.52	next 30% — 40%	70.8
0.00 to < 0.25	next 40% — 50%	66.2
<0.00	Below average	Below average

It is evident that when the selection index is high, the yield too is high. If the selection index is negative, the corresponding palms will be below average yield.

DISCUSSION

The present system of selecting mother palms based on a given minimum phenotypic yield is questionable as the phenotype is essentially an expression incorporating a genetic effect and an environmental effect. A mother palm selected on this basis need not necessarily be a good seed parent. Further, the efficient selection of even such phenotypes for whatever they are worth necessitates the keeping of yield records for a period of about four years.

The proposed selection index has dual advantages. Firstly, it eliminates the problem of keeping yield records for a period of four years. The second and the decisive advantage of this index is its ability to fix any desired selection intensity regardless of the environment – thereby helping to select the superior genotypes and not the superior phenotypes which are of dubious value as seed parents.

It has to be remembered that these vector elements (a_i) obtained through the Principal Component Analysis, which are the relative weightages applicable to the four characters, may not necessarily be identical for all conditions. These weightages may apply to the North-Western Province of Sri Lanka, but not necessarily in the wet zone southern belt and other different agro-climatic zones. Perhaps fresh vectors will have to be calculated for each agro-climatic zone.

This index can also be used as a calibrating variate for field experiments. It eliminates the need to keep pre-experimental yield data for about two years as is generally done, as all the characters incorporated in the proposed index can be measured at a given instant. Through this approach a reduction of the experimental error by about 50% can be expected.

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