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Effect of foliar arrangement on the leaf epidermal structures in Areca palm (*Areca catechu* Linn.)

M. GHOSE, KAUSHIK BHATTACHARYA, S. S. GHOSH, K. ROYCHOUDHURY and A. DATEY

Indian Statistical Institute, 203, Barrackpore Trunk Road, Calcutta 700 035, India

SUMMARY

The Areca palm (*Areca catechu* Linn.) shows alternate phyllotaxy with angular deflection of about 143° between two consecutive leaves, which leads to a spiral mechanism. Foliar spirality of the plant may either be left (FSL) or right (FSR). Analysis of data on five consecutive leaves of 10 FSR and 10 FSL seedlings of *Areca catechu* reveals that the former plants possess a significantly ($P \leqslant 0{\cdot}01$) higher number of stomata and stomatal indices over the latter ones. However, sides of each individual leaf have no effect in determining stomatal frequency, number of epidermal cells and their length. Sides of individual leaf vary significantly ($P \leqslant 0{\cdot}05$) only in respect of number of epidermal cells and their width. The foliar spirality of a plant, therefore, has a significant role in determining number of stomata per unit area.

Key-words: Areca catechu, foliar spirality, leaf epidermis, stomata.

INTRODUCTION

The phyllotoxy of palms is always alternate, i.e. a single leaf is produced at each node. In *Areca catechu*, two consecutive leaves are placed at an angular deflection of about 143°. The leaves in this case are seen to be spirally arranged. If an imaginary line is drawn from the base of any leaf, and this line is passed through the bases of the successive leaves, it is seen that the spiral line moves either clockwise (left-spiralled) or counter-clockwise (right-spiralled) around the stem. Although this asymmetry is not genetically determined (Compton 1910; Davis 1962; Kundu & Sharma 1965), it has been reported that fruit yield is associated with the foliar arrangement in some palms including *Areca catechu* and other plants (Davis 1972).

In view of this, the objective of the present study is to determine (i) whether the observations in the FSL and FSR plants are significantly different, (ii) whether the observations obtained from the right side of the leaf and those obtained from left side are significantly different and (iii) whether the spirality of the plants and side of the leaves are correlated.

MATERIALS AND METHODS

Ripe seeds (fruits) of *Areca catechu*, collected from a local plant, were sown in a nursery bed within the campus of Indian Statistical Institute. After about 6 months of germination when the plants bore three laminate leaves, 10 FSL and 10 FSR seedlings of more or less uniform size were selected and tagged for sampling. Leaf samples of about 5 mm^2 were collected from each leaf approximately half-way between the base and apex of a sector from both left and right halves of the lamina. Similar samples were also collected from later grown fourth and fifth leaves when the plant attained the age of about 8 months. The samples were fixed in FAA. Epidermal peelings of lamina were prepared by treatment with 30% nitric acid and 1% chromic acid, details of which have been described elsewhere (Ghose & Davis 1973). As the stomata are almost absent on the adaxial epidermis, peelings from abaxial epidermis only were mounted in phenol-glycerine. In this way a total of 200 slides (10 slides per plant) were prepared. Ten observations from each slide were made, and thus 2000 observations were taken for each characteristic under an Olympus Research microscope using 7×40 magnification, which covered an area of 0·17 mm^2. This area was then converted into 1 mm^2.

Statistical analysis

A suitable linear model was considered, where factors such as spirality and side have been treated as 'fixed' effects and leaf effects have been treated as 'random' effects. For fixed effects we are interested in estimating the average values of characters; and for random effects the variances of the effects are relevant. Further, interaction effects which are in terms of 'differences of differences' when only fixed effects are involved and in terms of variances when a random effect is involved are also useful parameters to be estimated. The theory underlying the model is fairly standard and described, for instance, in Hand & Taylor (1987).

The plant effect was assumed to be 'random' and nested within type of spirality (fixed effect). The 'leaf' effect was also assumed to be random and nested within the plant type. Other effects were treated as fixed. We felt that the nesting assumptions incorporated the dependence structure present among the observations. The randomness of 'plant' and 'leaf' was incorporated to embody the fact that the plants chosen for the experiment were a representative random sample from the population of all plants of the same species. A similar logic applies to the leaf effect. The model considered can thus be written as:

$$Y(i, j, k, l, m) = m + t(i) + b(i, J) + l(i, j, k) + s(m) + ts(i, m) + e(i, j, k, l, m).$$

Where: $Y(i, j, k, l, m)$ represents a single observation (on a particular variable), m: is the overall mean effect; $t(i)$: the effect due to the i-th type of spirality, i=1(FSL), 2(FSR); $b(i, j)$: the effect due to the j-th plant of the i-th type of spirality; for j=1 to 10 are assumed to be identically distributed as N $(0, \sigma_b^2)$. This is denoted as $b(i, j)$ are i. i. d. N $(0, \sigma_b^2)$; j=1 to 10.

Similarly, $l(i, j, k)$: the effect due to the k-th leaf in the j-th plant of the i-th type of spirality are assumed to be i. i. d. N $(0, \sigma_l^2)$; k=1 to 5. $S(m)$: the effect due to the m-th side of leaf. m=1(left side), 2(right side), $ts(i, m)$: the interaction between i-th type of spirality and m-th side of leaf. $e(i, j, k, l, m)$: error in the i, j, k, l, m-th observation are assumed to be i. i. d. N$(0, \sigma_e^2)$.

The analysis was carried out on a VAX-8650 computer using relevant sections from the BMDP package at the ISI Computer Centre.

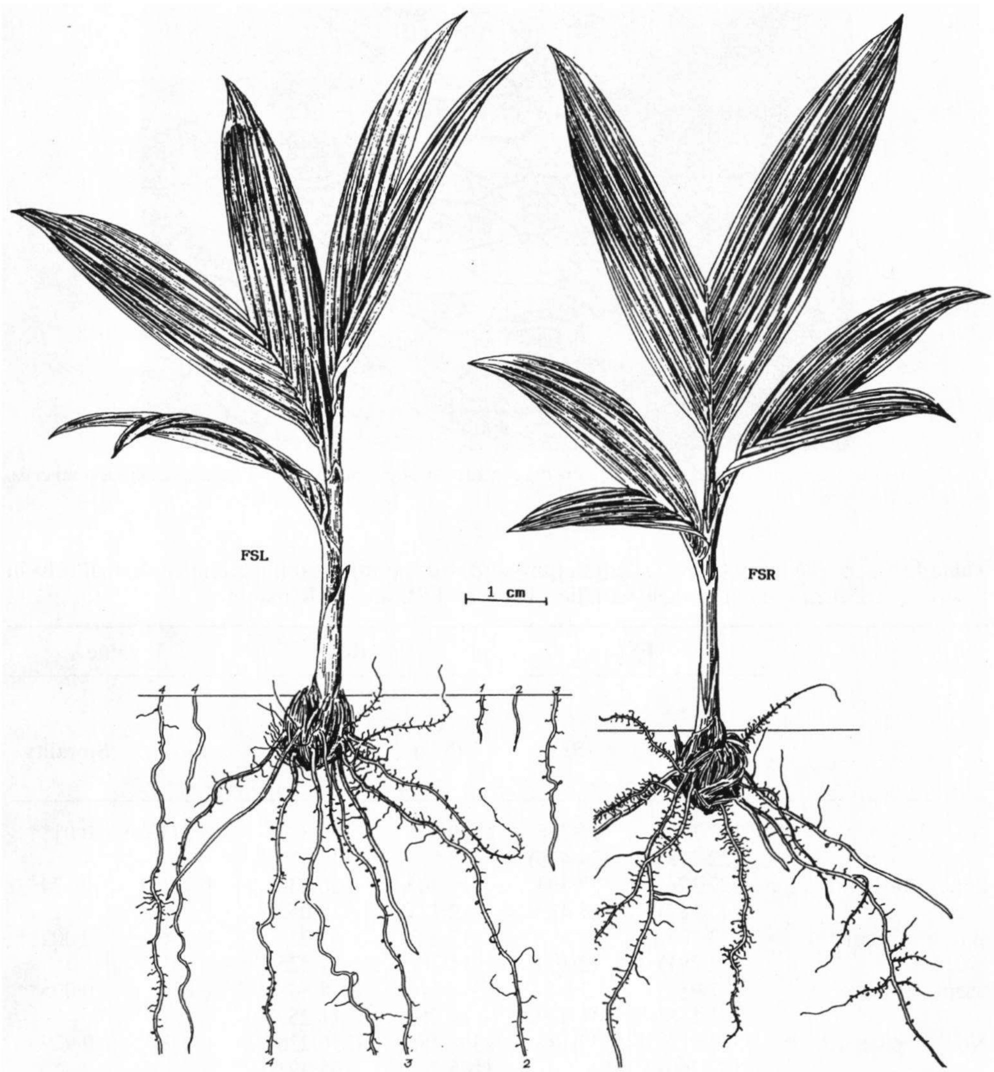

Fig. 1. Six-month-old left-spiralled (FSL) and right-spiralled (FSR) seedlings of *Areca catechu.*

RESULTS

Notation and terminology

L: left side of leaf.
R: right side of leaf.
FSL: foliar spirality left (Fig. 1).
FSR: foliar spirality right (Fig. 1).
In all cases the interaction between spirality and side was insignificant. Hence the significance of the main effects were tested. Results are given below.

The structure of mature stomata in the leaves of *Areca catechu* is of the tetracytic type (Fig. 2). Each stoma is surrounded by four subsidiary cells, two terminal cells and two

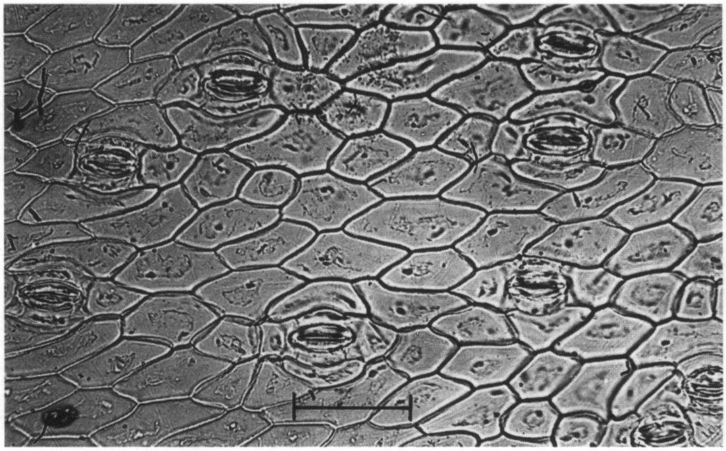

Fig. 2. Abaxial epidermis of *Areca catechu* showing mature tetracytic stomata and hexagonal epidermal cells Scale bar is 50 μm.

Table 1. Mean frequency (mm^{-2}), length (μm) and width (μm) of stomata and epidermal cells in leaves of *Areca catechu*, and their variation between FSL and FSR plants

	FSL		FSR		P value	
	L (SD)	R (SD)	L (SD)	R SD)	Side	Spirality
No. of stomata	117·132 (22·278)	116·368 (24·455)	130·866 (18·006)	130·384 (16·113)	0·311	0·01**
Length of guard cells	27·326 (3·155)	27·494 (3·439)	26·345 (2·123)	26·430 (2·053)	0·175	0·174
Width of guard cells	13·707 (2·291)	13·695 (2·140)	12·282 (1·256)	12·334 (1·225)	0·756	0·002**
Stomatal index	7·958 (1·518)	7·940 (1·629)	8·814 (1·250)	8·848 (1·259)	0·849	0·005**
No. of epidermal cells	1359·910 (142·760)	1352·144 (136·341)	1364·286 (165·295)	1356·236 (165·993)	0·038*	0·927
Length of epidermal cells	57·473 (13·418)	57·776 (12·608)	57·017 (10·404)	57·543 (10·294)	0·413	0·758
Width of epidermal cells	17·604 (3·248)	18·043 (3·232)	17·707 (3·080)	17·922 (3·416)	0·015**	0·982

*Significant at 5% level; **significant at 1% level. FSL=foliar spirality left; FSR=foliar spirality right; L=left side of leaf; R=right side of leaf.

lateral cells. Terminal subsidiary cells are short and wide, while lateral ones are long and narrow, and lie parallel to guard cells. Each guard cell has two cutinized ledges.

Frequency of stomata

The number of stomata per unit area of 1 mm^2 is presented in Table 1. It shows that FSR plants, on average, possess 130·87 and 130·38 stomata and FSL plants 117·13 and

116·37 stomata per unit area on the left and right sides of lamina, respectively. It also reveals that the overall difference between FSR and FSL plants is 11·88%, which is highly significant ($P \leqslant 0{\cdot}01$). However, the difference (0·51%) in stomatal frequency between left side and right side of each lamina is not statistically significant at a 5% level, and there is no interaction between sides of lamina and spirality of the plant.

Length and width of guard cells

Data on the length of guard cells, presented in Table 1, indicate that neither sides of lamina nor spirality of plants differ significantly. However, the difference in width of guard cells is quite significant ($P \leqslant 0{\cdot}01$) between FSR and FSL plants. Widest stomata (13·71 μm) occur in FSL plants and narrowest (12·28 μm) in FSR plants. There is no interaction between sides of lamina and spirality.

By comparison, it is evident that FSL plants possess the widest but minimum number of stomata and FSR plants possess the narrowest but maximum number of stomata.

Stomatal index

Stomatal index (I) was calculated by the formula $I = S/(S+E) \times 100$ where S=number of stomata per unit area and E=number of epidermal cells per unit area (Salisbury 1928). The data are presented in Table 1. The maximum index (8·85) occurs in FSR plants and minimum (7·94) in FSL plants. The difference is statistically significant ($P \leqslant 0{\cdot}01$). However, there is no statistically significant difference between left and right sides of the lamina. This indicates that spirality of the plant has effect on the stomatal index.

Frequency of epidermal cells

The epidermal cells are more or less hexagonal (Fig. 2). The number of cells per unit area does not differ much between FSR and FSL plants but differ significantly ($P \leqslant 0{\cdot}05$) between left and right sides of the lamina. On an average, 0·58% more cells are present on the left side of the lamina over the right side. Maximum number of cells (1364·29) occurs on the left side of the lamina in FSR plants and minimum (1352·14) on the right side of the lamina in FSL plants. However, there is no interaction between sides of lamina and spirality of plants.

Length and width of epidermal cells

Data presented in Table 1 show that there is practically no difference of cells between FSR and FSL plants, and also between left and right sides of the lamina. The average length of cells is about 57 μm. The maximum width (18·04 μm) of epidermal cells is observed on the right side of the lamina and minimum (17·60 μm) on the left side of the lamina of FSL plants. The difference between FSR and FSL plants is not significant but it is significant ($P \leqslant 0{\cdot}01$) between sides of the lamina. Hence, the side of lamina has an effect in determining width of epidermal cells.

It is interesting to note that, if we compare data, they reveal that the number of cells per unit area increases when width of cells decreases and vice versa, but length of cells remains constant everywhere.

DISCUSSION

The foregoing results reveal that right-spiralled (FSR) plants possess on an average 11·88% more stomata than left-spiralled (FSL) plants, which is statistically significant.

However, there is no significant difference in respect of epidermal cell frequency. It indicates that the spirality of the plant has a significant role in determining number of stomata in leaves. Stomata act as portals for CO_2 into the leaf for photosynthesis and exit of water vapour, i.e. transpiration. Photosynthesis is an important factor in dry matter accumulation, hence somata are of major importance in controlling crop yield. Davis (1972) reported that fruit yield is associated with the foliar arrangement in *Areca catechu* and *Cosos nucifera.* He showed that right-spiralled plants produced 38·67% and 24·01% fruits in excess of the left in *Areca catechu* and *Cocos nucifera,* respectively, which conform with the results of the present study on stomatal frequency.

Bahadur *et al.* (1980) reported that right-spiralled plants of *Cajanus cajan* showed higher stomatal indices and higher yield of pods. In the present study, also, significantly higher stomatal indices were observed in the right-spiralled palms.

The differences between left and right sides of the lamina in respect of all the parameters studied were insignificant except in the cases of number of epidermal cells and their width. The number of epidermal cells was more on the left side and, on the contrary, width of cells was higher on the right side, which is logical, as the number of cells per unit area was more due to narrowness of cells. A similar situation was also noticed in cases of frequency of stomata and width of guard cells. Here FSL plants possess the widest but minimum number of stomata and FSR plants possess the narrowest but maximum number of stomata per unit area. Length and width of trichomes (not shown in Table 1) do not vary significantly between FSR and FSL plants and also between sides of the lamina, which indicate that spirality and sides have no effect in determining dimension of trichomes.

Hence, in conclusion it may be said that although foliar spirality does not follow Mendelian inheritance (Compton 1910; Davis 1962, 1972; Rao 1980) it has a significant role in determining stomatal frequency in leaves which might have correlation with fruit yield.

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