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GENETIC DIVERSITY OF *ARECA CATECHU* L. AND *A. TRIANDRA* ROXB.*

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ABSTRACT

The genetic distances between 13 cultivars of *A. catechu* and four ecotypes of *A. triandra* estimated from 24 characters recorded in the productive phase for two years and the pooled data for both these years were more or less consistent. The cultivars could be grouped into six clusters in both the years and into five for the pooled data. A comparison of the groupings obtained during the two different years showed that the widely divergent clusters remained distinct in both the years whereas in the case of less divergent groups there were slight deviations in the clustering pattern.

It is concluded that detection of genetic divergence is possible in the early years of productive phase. This is of considerable advantage in formulating breeding programmes. The rankings obtained by the different characters for their contribution towards genetic divergence revealed that the importance of nut and kernel characters in differentiation within *A. catechu* group and between *A. catechu* and *A. triandra* types. The results obtained from canonical analysis were also in broad agreement with the clustering pattern found from D^2 analysis. Clustering pattern of cultivars and ecotypes obtained in the present study revealed that geographic diversity need not always be related to genetic diversity in arecanut.

INTRODUCTION

The only reported study of genetic divergence in palms using Mahalanobis D^2 statistic is in coconut (*Cocos nucifera* L.) by Bavappa, Sukumaran and Mathew (1973). This paper reports the intra and interspecific genetic divergence in *A. catechu* and *A. triandra*.

MATERIALS AND METHODS

The 13 cultivars of *Areca catechu* and the four ecotypes of *Areca triandra*, used in this study (Table I) are from the germplasm collection maintained at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka. They were planted in 1960 on a randomised block design, in single tree plots, with four replications. During 1963, observations on six morphological characters were recorded. After the commencement of flowering, during 1966 detailed observations were taken in respect of 40 morphological, anatomical and yield characters. Recording of observations were repeated in respect of 24 out of 40 characters in 1972. The

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data for the years 1963, 1966 and 1972 were analysed independently. The pooled data for the 24 common characters for 1966 and 1972 were also analysed. Separate analysis was also carried out with the 24 characters of 1966 used in pooled analysis. The following were the characters on which observations were recorded in different years:

1963

1. Number of suckers, including main stem. 2. Total height (cm). 3. Girth of collar at fixed mark (cm). 4. Girth below crown (cm). 5. Number of functioning leaves. 6. Number of nodes.

1966 and 1972

1. Height, above fixed mark (cm). 2. Girth at fixed mark (cm). 3 Girth below crown (cm). 4. Internodal distance at fixed mark (cm). 5. Internodal distance at last node (cm). 6. Number of bunches harvested during the year. 7. Number of inflorescence. 8. Number of functioning leaves. 9. Angle of leaf to the stem (degree). 10. Number of leaflets 11. Number of mid-ribs. 12. Length of longest leaflets (cm). 13. Breadth of broadest leaflet (cm). 14. Length of leaf without sheath (cm). 15. Length of leaf sheath (cm). 16. Breadth of leaf sheath (cm). 17. Length of fruit (cm). 18. Breadth of fruit (cm). 19. Weight of nut (gm). 20. Mean volume of nut (cc). 21. Length of kernel (cm). 22. Breadth of kernel (cm). 23. Weight of kernel (gm). 24. Volume of kernel (cc).

1966 only

25. Intensity of selfing or crossing. 26. Number of female flowers produced during the year. 27. Stomatal index. 28. Length of stomatal pore (μ). 29. Length of epidermal cells (μ). 30. Length of guard cells (μ). 31. Breadth of guard cells (μ). 32. Breadth of epidermal cells (μ). 33. Length of spathe (cm). 34. Breadth of spathe (cm). 35. Longevity of leaves (days). 36. Interval between successive leaf fall (days). 37. Duration of male phase (days). 38. Duration of female phase (days). 39. Number of epidermal cells per unit area. 40.Number of stomata per unit area.

Selfing intensity value for a tree was obtained, using the formula:

$$SI = \frac{100}{2n-1}\left\{\sum_{1}^{n} w_b + \sum_{1}^{n} b_b\right\}$$

where w_b and b_b denote the selfing intensity values for within the bunch and between the successive bunches respectively and n the number of bunches in a tree. The epidermal pattern of leaf was studied following the method of Clarke (1960). Stomatal index was calculated using the formula followed by Salisbury (1927).

For each year of observation, the D^2 values between any two cultivars were calculated, based on all the characters observed in the respective year. Thus for each year there were 136 values. Based on the D^2 values, clusters were also formed. On the basis of intra and inter-cluster distances, spatial diagrams were drawn. The grouping obtained using D^2 statistic was confirmed by canonical analysis. The analyses were carried out on the electronic computer (IBM-1620 Model II, and IBM 360, 44)

of the Institute of Agricultural Research Statistics and Delhi University, New Delhi, respectively.

RESULTS

During 1963, the D^2 values ranged from 0.29 to 162.00. In 1966, the range of D^2 values for the 40 characters was from 53.88 to 6231.55 while for 24 characters it ranged from 12.42 to 621.67 only. During 1972, the corresponding limits were 24.85 and 822.29. For the pooled data the values ranged only between 8.82 and 309.89. Using Tocher's method, (Rao, 1952) the 17 cultivars could be grouped into 6 clusters each for the independent years 1963, 1966 (24 characters) and 1972. Though the number of clusters were the same, the constituents in the different clusters were slightly different in the different years. For the 40 characters of 1966, the number of clusters increased to seven. In the case of pooled data, there were only five clusters. The pattern of clustering in the different years is given in Table I. The spatial diagram showing the distribution of clusters in 1966 and 1972 (pooled) is given in Fig. 1. The cluster means for the characters under study are presented in Table II and III.

Canonical analysis was also carried out for the data for different years to confirm the clustering obtained from D^2 analysis. The pattern of clustering was more or less in agreement to those obtained from D^2 analysis.

Table I. *Composition of clusters in different years*

Cluster No.	1963 (6 characters)	1966 (40 characters)	1966 (24 characters)	1972 (24 characters)	1966 and 1972 pooled (24 characters)
I.	2, 3, 4, 9	3, 6, 7, 8, 9, 12	7, 8, 9	7, 8, 9, 12	7, 8, 9
II.	13, 14, 15	14, 15	13, 14, 15, 16	13, 14, 16	13, 14, 15, 16
III.	1, 5, 6, 7	4, 5, 11, 17	4, 5, 6, 11	1, 3, 4, 5, 6, 11, 17	1, 3, 4, 5, 6, 11, 17
IV.	10, 11, 12, 17	1, 10	1, 3, 10, 12	10	10, 12
V.	8	2	2	2	2
VI.	16	16	17	15	
VII.		13			

Details of the cultivars :

1. Ceylon-1	6. Saigon-3	11. Singapore	16. Ceylon–3
2. Ceylon-2	7. Br. Sol. Islands-1	12. Fiji	17. Local
3. Indonesia-6	8. Br. Sol. Islands-2	13. Indonesia-1	
4. Saigon-1	9. Br. Sol. Islands-3	14. Indonesia-2	
5. Saigon-2	10. China	15. Mauritius	

Note : Numbers 1 to 12 and 17 .. *A. catechu*
Numbers 13 to 16 .. *A. triandra*

FIG. 1. SPATIAL DIAGRAM SHOWING THE DISTRIBUTION OF CLUSTERS (1966 AND 1972 POOLED)

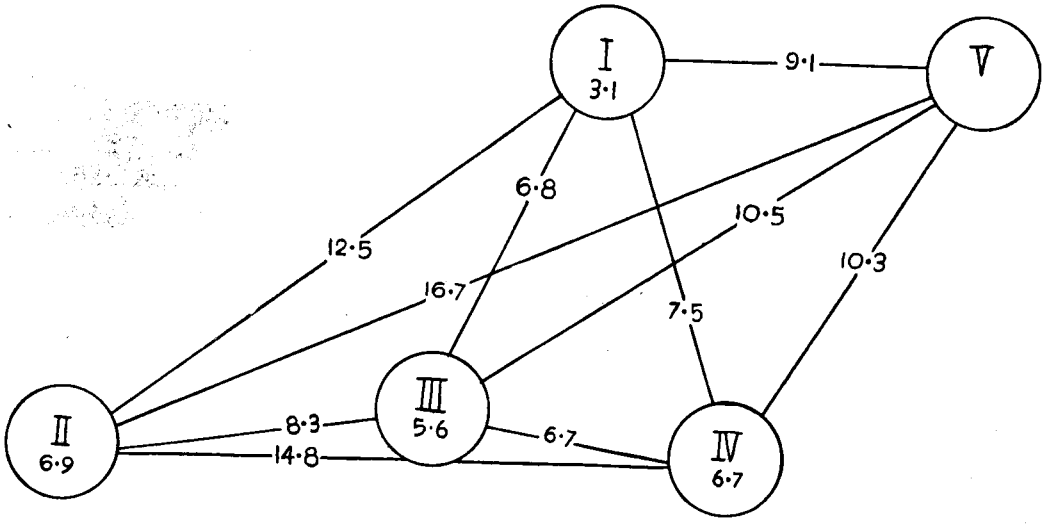

Table II. *Cluster means for different characters (1963)*

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Total number of suckers	1.00	1.00	4.00	1.00	1.00	4.00
Height	62.66	77.85	33.90	72.03	31.05	0.00
Girth of collar at fixed mark	47.75	55.43	28.52	48.78	41.20	10.13
Girth below crown	32.96	34.61	22.67	32.73	32.18	0.00
Number of leaves	8.19	9.06	7.08	8.50	7.25	5.00
Number of nodes	7.38	9.50	4.58	8.50	5.75	0.00

DISCUSSION

The 13 cultivars and four ecotypes from nine countries fell into six clusters in 1966 and 1972, when 24 characters were considered (Table I). The number of clusters and pattern of clustering were more or less similar for these years. During 1966, the four ecotypes of *A. triandra* were found to be in the same cluster (cluster II) and the divergence of this cluster from the others was of a high order. This was because of the fact that the ecotypes included in the above cluster were conspicuous for their thin stem, low angle of leaf to the stem, short leaves, short and narrow leaf sheath and small size and weight of the fruit and kernel. The divergence of Ceylon–2 which is the only constituent of cluster V was also high due to its short stature, low internodal distance, broad leaflets and large size of fruit and kernel (Table II).

When the analysis was repeated with the observations recorded for the same set of characters, six years later, the group constellations were found to be more or less similar (Table I). The maximum divergence was between

Table III. *Cluster means for different characters (1966–'72)*

Characters*	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
1 a	167 50	72.63	264.75	112.75	58.00	80 00	88.50
b	140.25	78.44	250.25	138.25	58.00	314.75	
c	485.43	368.75	763.14	413.00	389.25	600.50	
d	319.25	252.56	500.40	266.25	223.62		
2 a	43.83	25.13	44.81	42.38	43.25	18.50	16.25
b	42.33	21.25	44.50	43.63	43.25	47.50	
c	47.81	19.50	46.86	39.95	46.75	26.00	
d	44.25	21.19	45.60	45.50	45.00		
3 a	39.42	26.38	43.31	40.88	40.75	17.00	16.00
b	37.58	21.44	42.56	41.75	40.75	41.50	
c	33.63	17.42	37.18	36.50	34.00	22.25	
d	34.29	20.03	39.71	40.25	37.37		
4 a	9.71	12.50	11 94	7.00	6.25	12.00	9.50
b	9.83	11.62	10.31	8.31	6.25	16.00	
c	10.31	11.17	11.54	8.00	8.75	17.50	
d	9.87	12.19	11.25	8.31	7.50		
5 a	12.21	14.25	12.75	6.50	6.00	15.00	7.25
b	14.17	12.69	13.00	7.19	6.00	14 00	
c	7.19	6.92	6.89	5.00	4.75	11.00	
d	10.96	10.31	9.41	5.44	5.37		
6 a	1.96	3.08	3.19	4.50	3.50	0.00	2.00
b	1.33	2.06	3.38	3.31	3.50	2.75	
c	2.75	7.50	4.32	2.25	4.00	11.50	
d	2.17	5.28	3.91	2.31	3.75		
7 a	3.42	4.00	4.31	5.75	4.50	0.75	4.25
b	2.50	3.25	4.25	5.00	4.50	4.75	
c	5.31	22.53	5.96	2.75	5.00	13.75	
d	4.12	11.78	5.30	4.00	4.75		
8 a	9.59	9.13	10.06	10.00	7.95	8.50	8.75
b	9.50	8.88	10.00	9.88	7.75	9.75	
c	9.63	8.00	10.50	10.00	9.25	8.50	
d	9.54	8.50	10.25	9.75	8.50		
9 a	51.22	35.41	61.68	49.99	42.75	46.75	32.75
b	64.04	37.58	53.85	43 97	42 75	70.60	
c	55.87	48.42	59.57	61.90	58.47	44.70	
d	60.93	42.53	56.13	57.23	50.70		
10 a	28.31	17.20	36.82	34.59	19.37	24.02	18.42
b	18.85	19.21	38.31	35.47	19.37	34.65	
c	23.56	20.26	24.54	35.05	20.60	17.87	
d	18.42	19.43	35.22	37.69	19.98		

Table III contd.—

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
11 a	55.76	49.23	62.01	62.98	55.80	51.80	38.45
b	48.42	47.18	66.00	63.14	55.80	52.75	
c	54.43	44.54	65.13	63 45	55.62	48.37	
d	49.11	46 34	64.32	64.25	55.71		
12 a	82.52	80.40	89.22	86.53	91.30	61.15	137.15
b	86.86	89.77	84.04	86.78	91.30	81.22	
c	93.82	70.66	88.58	92.10	96.10	83.22	
d	90.32	81.79	86.33	90.51	93.70		
13 a	11.30	12.89	10.65	10.74	16.67	8.32	8.50
b	12.00	10.65	10.39	10.67	16.67	11.62	
c	12.05	9.82	11.21	9.37	15.77	12.97	
d	12.44	10.63	11.13	9.37	16.22		
14 a	164.00	115.88	180.88	175.50	137.25	142.50	124.00
b	151.25	124.56	186.44	179.19	137.25	142.25	
c	176.81	164.67	197.12	216.50	183.75	202.50	
d	163.12	149.34	188.39	186.44	160.50		
15 a	82.25	67.25	89.56	83.38	87.00	55.75	51.50
b	80.08	60.44	87.13	85 50	87.00	87.75	
c	88.56	62.50	91.07	91.25	73.75	66.00	
d	85.04	61.90	89.73	83.75	80.37		
16 a	34.46	23.75	34.19	37.13	34.00	17.25	18.75
b	27.50	20.88	35.38	39.75	34.00	34.75	
c	44.38	33.92	51.54	49.00	33.00	42.75	
d	34.21	28.50	44.11	45.56	33.50		
17 a	5.32	2.96	5.30	5.50	6.65	2.72	3.02
b	5.31	2.92	5.58	5.35	6.65	4.65	
c	5.00	2.86	5.17	5.60	5.87	2.80	
d	5.17	2.88	5.29	5.-6	6.26		
18 a	3.64	1.40	4.28	4.13	4.62	1.45	1.47
b	3.63	1.43	4.30	3.82	4.62	3.82	
c	3.44	1.59	3.98	4.30	4.20	1.25	
d	3.53	1.46	4.01	3.92	4.41		
19 a	30.93	4.28	39.47	48.20	55.02	3.52	4.70
b	33.04	4.19	39.97	38.37	55.02	27.37	
c	28.04	4.21	38.42	43.70	47.73	3.02	
d	30.49	4.04	38.32	36.30	51.40		
20 a	37.44	4.25	52.41	51.11	68.27	3.57	4.80
b	36.91	4.22	54.36	43.26	68.27	35.27	
c	30.88	4.06	43.93	48.10	55.02	2.42	
d	33.89	3.43	45.87	42.52	61.65		
21 a	2.48	1.95	2.69	2.55	3.05	1.62	1.70
b	2.52	1.81	2.72	2.49	3.05	2.30	
c	2.33	1.81	2.47	2.45	2.90	2.45	
d	2.39	1.79	2.53	2.49	2.97		

Table III contd.—

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
22 a	2.51	1.11	3.10	2.69	3.10	1.10	0.97
b	2.48	1.07	3.11	2.52	3.10	2.87	
c	2.20	1.03	2.79	3.25	3.70	0.98	
d	2.33	1.04	2.83	2.70	2.90		
23 a	11.68	2.96	13.34	11.19	22.75	1.40	2.02
b	12.61	2.34	13.74	10.46	22.75	11.25	
c	7.92	1.26	13.34	11.10	16.80	1.17	
d	10.29	1.78	12.99	9.58	19.77		
24 a	10.56	2.24	13 21	11.75	26.87	4.12	2.17
b	11.52	2.60	13.29	10.15	26.87	11.35	
c	6.88	1.29	11.65	10.45	14.50	1.00	
d	9.25	1.95	11.92	9.20	20.73		
25 a	25.31	54.50	24.06	32.64	35.56	37.61	26.73
26 a	1006.75	4038.62	902.31	2272.25	636.00	906.25	1299.15
27 a	9.75	9.55	8.82	8.90	7.54	8.14	7.79
28 a	1.46	1.96	1.62	1.52	1.49	1.79	1.54
29 a	3.12	5 82	5.52	3.05	3.17	5.72	4.88
30 a	2.91	3.65	3.05	2.93	2.71	3.38	3.11
31 a	2.00	1.31	2.08	2.05	1.87	0.99	1.23
32 a	1.77	2.12	1.72	1.76	1.75	1.89	1.92
33 a	54.10	36.84	61.03	62.02	39.57	38.00	34.30
34 a	13.76	11.31	15.33	21.17	11.22	8.00	8.77
35 a	429.61	496.16	404.65	394.89	351.42	467 50	445.32
36 a	44.13	59.30	38.59	35.79	46.35	55.22	62.82
37 a	23.99	44.14	22.09	21.33	32.07	69.52	21.17
38 a	14.02	50.77	12.92	13.83	19.40	17.75	18.92
39 a	188.14	110.06	191.71	185.75	190 00	116.25	115.87
40 a	20.49	11.56	18.49	18.56	18.50	10.25	9.75

(Note: For composition of clusters in individual years, refer Table II)
a = 1966 (40 characters) b = 1966 (24 characters)
c = 1972 (24 characters) d = 1966 & 1972 (pooled)

* 1. Height, above fixed mark (cm). 2. Girth at fixed mark (cm). 3. Girth below crown (cm). 4. Internodal distance at fixed mark (cm). 5. Internodal distance at last node (cm). 6. Number of bunches harvested during the year. 7. Number of inflorescence. 8. Number of functioning leaves. 9. Angle of leaf to the stem (degree). 10. Number of leaflets. 11. Number of mid-ribs. 12. Length of longest leaflet (cm). 13. Breadth of broadest leaflet (cm). 14. Length of leaf without sheath (cm). 15. Length of leaf sheath (cm). 16. Breadth of leaf sheath (cm). 17. Length of fruit (cm). 18. Breadth of fruit (cm). 19. Weight of nut (gm). 20. Mean volume of nut (cc). 21. Length of kernel (cm). 22. Breadth of kernel (cm). 23. Weight of kernel (gm). 24. Volume of kernel (cc). 25. Intensity of selfing or crossing. 26. Number of female flowers produced during the year. 27. Stomatal index. 28. Length of stomatal pore (μ). 29. Length of epidermal cells (μ). 30. Length of guard cells (μ). 31. Breadth of guard cells (μ). 32. Breadth of epidermal cells (μ). 33. Length of spathe (cm). 34. Breadth of spathe (cm). 35. Longevity of leaves (days). 36. Interval between successive leaf fall (days). 37. Duration of male phase (days). 38. Duration of female phase (days). 39. Number of epidermal cells per unit area. 40. Number of stomata per unit area.

clusters IV and VI, which can be attributed to the differences in girth and internodal distance, number of leaflets, breadth of leaf sheath and size and weight of nut and kernel between *A. catechu* China and *A. triandra* Mauritius. Clusters II and IV also differed between them for all the above characters in addition to the length of leaf and leaf sheath (Table III).

In the pooled analysis for 1966 and 1972, the number of clusters got reduced from six to five. However, it was interesting to note that the pattern of clustering was more or less in conformity with the groups obtained for the individual years (Table I). The groups obtained for 1972 and the pooled data were similar except in the case of cultivars China, Fiji and Mauritius. The pooled data showed that cultivars Ceylon–1, Indonesia–6, Saigon–1, 2, 3, Singapore and Local were in a single cluster whereas in 1966 they were in three different clusters. All the four ecotypes of *A. triandra* were in cluster II in the pooled analysis and this cluster continued to show maximum divergence from the rest. A comparison of the groups obtained during 1966 and 1972 showed that the deviations observed were in respect of China, Fiji, Mauritius and Local. A closer study of the deviations revealed that the instability was restricted to those, the divergence between which was quite low, whereas the widely divergent clusters remained distinct in both the years (Table I). It was also observed that the D^2 values slightly increased during 1972. Due to the perennial nature of the crop and consequent changes in the morphological characteristics of the population, such variation in the D^2 values could be expected. However, such variation has not materially affected the classification. Since the detection of genetic divergence in the early years of productive phase is of considerable advantage in formulating breeding programmes, groupings obtained in 1966, five years after planting, can be preferred over later years.

The rankings obtained by the different characters during 1966 for their contribution towards overall genetic divergence showed that the mean volume of nut and breadth of kernel were the characters of primary importance. When the differentiation within *A. catechu* cultivar alone was considered, height of the palm above the fixed mark, was also found to assume importance. For divergence between *A. triandra* and *A. catechu* mean length of fruit was found to be second in importance, next only to volume of nut. Ranking of characters for 1972 and the pooled data also revealed the importance of nut and kernel characters in differentiation within *A. catechu* cultivars and between *A. catechu* and *A. triandra* types. It was also evident that characters such as length of the longest leaflet and number of leaves on the palm do not contribute to any appreciable extent to the divergence. When the 40 characters were considered together, it was observed that the characters such as duration of male phase, number of stomata and number of epidermal cells were gaining importance. It therefore appears that there is scope for appropriate choice of characters in such divergent studies.

The grouping obtained for 1963 (juvenile phase) showed considerable difference as compared to that obtained in 1966 and 1972 (productive phase) (Table I). Though in a perennial crop identification of the genetic divergence in the early years has tremendous advantage in planning breeding programmes the results of the present study indicate that identification of genetic divergence in the juvenile phase in arecanut may not give the correct picture.

The groupings obtained in the present study revealed that the three cultivars each from Saigon and British Solomon Islands, and the two ecotypes of *A. triandra* from Indonesia were invariably in one cluster each. As against this, close similarity between the cultivars from different countries has also been observed. The cultivars from Singapore got grouped with the three cultivars from Saigon in one cluster. A similar affinity between the two geographically distant cultivars is shown by Ceylon–1 and Indonesia–6, both always coming within the same cluster. The local cultivar (17) has been found to be invariably associated with the cultivar from Singapore in forming the cluster. Of the two cultivars of *A. catechu* from Ceylon, Ceylon–2 was always forming a separate cluster indicating its distinct nature of divergence. Murthy and Anand (1966) in linseed, Arunachalam and Jawahar Ram (1967) in *Sorghum*, Singh and Bains (1968) in cotton and Gupta and Singh (1970) in green gram found that there was no relationship between geographic and genetic diversity. However, a definite relationship between the above two has been reported in *Pennisetum typhoides* (Upadhyay and Murthy, 1970) and in *Linum usitatissimum* (Jeswani, Murthy and Mehra, 1970). The clustering pattern of cultivars and ecotypes obtained in the present study revealed that geographic diversity need not always be related to genetic diversity.

CONCLUSION

Studies of the inter cluster divergence showed that the genetic distance between *A. triandra* and *A. catechu* Local is wide. The interspecific hybrids between *A. catechu* and *A. triandra* showed high sterility and hybrid vigour for different characters as can be expected in an interspecific cross involving genetically divergent parents. Since it has been possible to backcross the hybrids to *A. catechu*, the possibilities of transferring the high fruit set reported in *A. triandra* (Bavappa, 1966 a, b) to *A. catechu*, are bright. As the sterility observed in the hybrids appears to be due to the meiotic abnormalities in *A. triandra* and the disharmonious interaction between the genotype and cytoplasm of the parents, restoration of fertility through repeated backcrosses with *A. catechu* may be feasible. Among the *A. catechu* cultivars, cluster IV and VI were highly divergent from cluster V. Crosses of Ceylon–1, Indonesia–6, China, Fiji and Local with Ceylon–2 (which fall under the above mentioned groups) should prove useful. It may be mentioned in this context that a natural hybrid of China and Ceylon–2 has shown hybrid vigour for different characters.

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