MARDI Res. J. 17(1) (1989): 155–166

Identification of promising materials from a seedling population of cashew based on nut number and nut weight

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Key words: cashew, seedling, population, nut number, nut weight, correlation

Abstrak
Ciri populasi lebih 4 000 asesi gajus yang ditanam di Sg. Baging pada tahun 1967 telah dianalisis. Taburan hasil populasi menunjukkan kepencongan ke arah hasil bilangan kekeras yang rendah dengan bilangan purata populasi hanya 81 biji kekeras setahun. Perbezaan yang amat ketara dalam hasil melonggok kekeras antara asesi menunjukkan variasi yang besar dalam keupayaan pengeluaran hasil. Variasi yang ketara antara tahun menunjukkan tabiat penghasilan gajus yang berselang. Kaedah pemilihan asesi berpotensi berdasarkan hasil purata kekeras dan berat kekeras telah dibuat. Empat asesi berpotensi untuk dimajukan dalam program penyelidikan seterusnya; masing-masing menghasilkan 5.4–7.0 kg/pokok setahun. Korelasi yang negatif wujud di antara bilangan kekeras dan berat kekeras ($r = -0.394$**).

Abstract
A description of over 4 000 seedling population of cashew planted at Sg. Baging in 1967 is given. Yield distribution of the population showed marked skewedness towards small nut number with a mean of only 81 nuts/tree per year. A highly significant difference in cumulative nut number over a 9-year period of production indicates a large variation in yield potential among individuals. The year-to-year variation was also significant suggesting an alternating pattern in bearing habits. A method for selecting potential accessions based on average nut number and nut weight was developed. Four accessions appeared promising for further evaluation work, each producing 5.4–7.0 kg/tree per year. Nut number was negatively correlated with nut weight ($r = -0.394$**).

Introduction

Cashew (*Anacardium occidentale* L.) is a relatively new crop in Malaysian agriculture even though it was probably introduced into this country by the European colonists as early as the 15th century. Sporadic small scale planting initiated by the Department of Agriculture in Terengganu began only in the late 1930s (Mohamad 1936), in

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contrast with rubber and oil palm which by then had already been planted throughout the country. It became apparent from these early plantings that cashew could thrive well and better than most perennials on the sandy bris soils of the east coast. There are about 8 700 ha of the crop in Malaysia (Chai 1982), comprising materials which had been indiscriminately collected from random groves along the coast. Most of these materials possess visibly low genetic potential and lack the good combination of high yield and large nut size. They are capable of producing only 26–346 kg of raw nuts/ha per year (Chai 1982). Production of raw nuts to support a viable cashew nut industry consequently has been dismally low.

A major constraint facing the cashew nut industry in the country, therefore, is the unavailability of superior clones. The need to have a sufficient supply of planting materials consisting of reasonably good clones has been acutely felt. Realizing this necessity, attempts were made to establish an introduction plot in Sg. Baging in 1967. This consisted of a very diverse population whose origins and performance, hitherto, were generally unknown. This paper describes the seedling population in this plot and examines its production pattern over a 9-year period. A method for selecting promising accessions based on nut number and nut weight was developed. A few **elite** accessions which could very well be included in future breeding programmes were identified.

Materials and methods

A total of 4 168 cashew seedlings were planted on the bris soil of Sg. Baging in 1967. The seedlings were raised from seeds randomly collected from unidentified parent plants around Sg. Ular, Balok and Cherating in Kuantan district, Pahang Darul Makmur. Data recording was started in 1972 when about 50% of the cashew population (about 2 041 individuals) began to bear fruit and continued until 1982. However, in 1976 and 1980, no recording was done because the yields were negligible due mainly to dry weather in February, the period of peak flowering *(Appendix 1)*. Effectively, only 9 years of yield data were available for analyses. From the 2 041 plants that started bearing in 1972, only 1 582 individuals continued to bear regularly and have a complete data set for the 9-year period of evaluation. Analyses on nut number were done on the data available for these individuals.

The cumulative yields of the respective individuals were first grouped into eight classes depending on nut production over the 9-year period. Class 1 (the lowest class) was assigned to those individuals bearing less than 1 000 nuts and class 8 (the highest class) was assigned to individuals bearing more than 10 000 nuts, with the respective intermediate classes between the two extremes *(Table 1)*. A frequency bar chart was drawn to show the distribution of individuals according to the various classes.

Data on total yield were plotted against years to show any year-to-year variation and to trace any biennial trends in the fruiting pattern. An analysis of variance was done to ascertain significance due to seasons and individual trees.

Table 1. Classification of individuals according to classes of nut production over a 9-year period

Class	Nut production (no. of nuts)	No. of plants	%
1	< 1 000	1 271	80.3
2	1 001–2 000	170	10.7
3	2 001–3 000	53	3.4
4	3 001–4 000	30	1.9
5	4 001–5 000	27	1.7
6	5 001–7 500	18	1.1
7	7 501–10 000	8	0.5
8	> 10 000	5	0.3

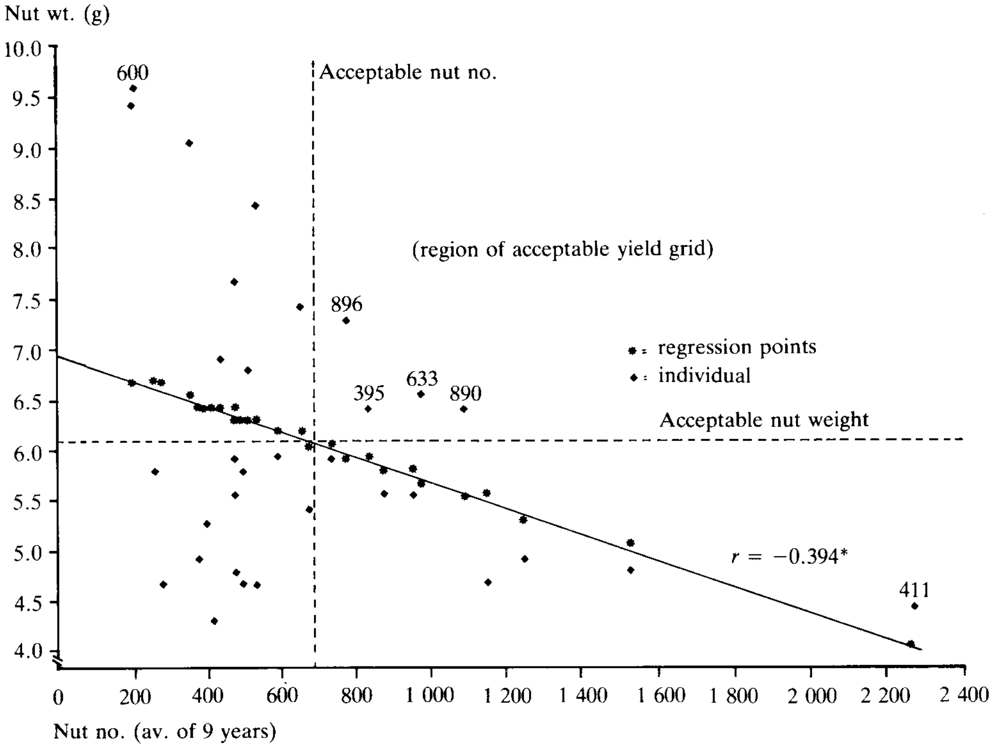

Figure 1. Regression of nut weight against nut number for 33 accessions of cashew bearing more than 1 000 nuts in 1981

In 1983, 33 accessions bearing more than 1 000 nuts were identified and their nut characteristics were determined. One hundred nuts from each of these accessions were randomly taken and the average nut weight and other attributes were recorded. Correlation studies were done to show the relationship between these components.

In selecting promising accessions, a regression of nut weight from the 1981 data against average nut number for 9 years was done. An acceptable limit of nut weight and nut number was then demarcated on the regression line. The acceptable nut weight taken (6.05 g) was the average nut weight of all the 33 accessions. A horizontal line demarcating this acceptable limit was then drawn *(Figure 1)*. An acceptable nut number was set at 700 nuts/year. This modest figure was obtained by rounding up the 9-year average nut number to the nearest hundred. A vertical line was then drawn to demarcate this acceptable limit of nut number *(Figure 1)*. Any point located within the acceptable yield grids (i.e., the intersection of the vertical and horizontal lines) represents a promising accession in the population.

Results and discussion

In the analysis of variance *(Table 2)*, a log transformation of the data was done because the nut number covers a wide range of values and there is a strong positive linear relationship between the variance and the mean (r = 0.87**). The effects of year and seedling were tested against their interaction term (error) because there was no replication of seedling to permit separation of the year-seedling interaction.

Table 2. ANOVA on log transformed data of nut number for 1 582 accessions in a cashew seedling population

Source	df	SS	MS
Year	8	1 825.61	228.20**
Between seedling	1 581	5 735.50	3.63**
Year x seedling	12 648	7 499.03	0.59

**significant at 1% level

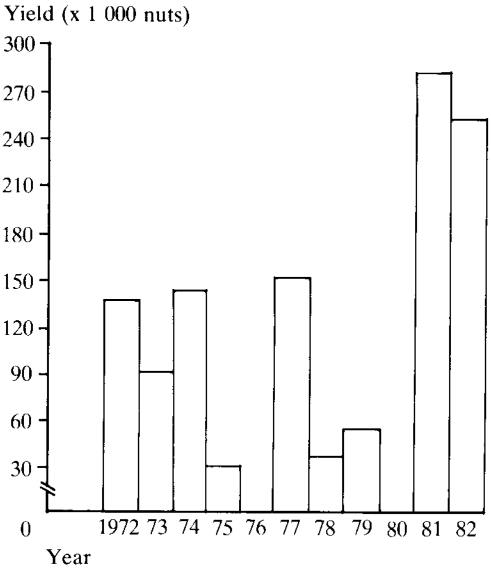

Figure 2. The nine-year cumulative yield for 1 582 individuals in a cashew seedling population

Production pattern

The significant difference for years *(Table 2)* is explained by the alternate bearing patterns as influenced by climate, the physiology of the tree regarding carbohydrate storage and utilization, and plant age. Favourable weather is conducive to good flowering, fruit setting and subsequently fruit production. Ohler (1979) mentioned that wet weather and high humidity could have drastic effects in reducing floral development and fruit setting in cashew. Similarly, extremely dry weather during the period of floral initiation may wither the flowers and cause considerable loss in yield (Ohler 1979).

The yield variation between years is clearly seen by the alternate bearing pattern shown in *Figure 2* where a high yield in one year is preceded by a trough in the previous year. This phenomenon followed a definite sequence in the years 1972–75. The trough year in 1975 fell below that of 1973 probably because of a very wet spell recorded during the flowering and fruit setting period of that year. There was excessively high rainfall during January–March of 1975 *(Appendix 1)* and this could have encouraged the widespread incidence of floral blight (anthracnose) and insect pests such as leaf miner, beetles and leaf mosquitoes.

In the alternate pattern of bearing, a trough year signifies the time when a plant is 'off-season' and accumulating storage reserves for fruit production in the following year. Theoretically, a trough in 1975 should be followed by a high in 1976. However, the expected high did not materialize in 1976. Nut production in 1976, on the contrary, was negligible and the alternate bearing pattern was broken. This was probably due to the very dry weather when negligible rainfall was recorded in February 1976, which is generally the period of peak flower formation for cashew in Sg. Baging. The accumulation of reserves in two consecutive years in 1975 and 1976 resulted in a high nut production in 1977. Thereafter a clear pattern of alternate bearing was reestablished *(Figure 2)*. Negligible yield, perhaps attributable to floral blight and its associated factors, was again recorded in 1980. For the same physiological reason given earlier, the high yield in 1981 was due to abundant carbohydrate reserves stored in 1980. Furthermore, the plants were now older and possessed higher bearing capacity.

The phenomenon of alternate bearing in cashew has been reported in Jamaica (Anon. 1960) with the tendency being more apparent in trees yielding larger nuts. Similarly, Northwood (1966) also recorded a tendency towards alternate bearing in cashew in Tanzania, and added that this might possibly increase as the trees get older. Because of the phenomenon of alternate bearing, Northwood (1966) suggested that yield records of apparently superior trees should be taken over at least 6 years or more before using them in breeding programmes.

Yield potential

Yield potential preferably should also include a discussion on yield in terms of nut weight. However, data on nut weight were not available except for in 1981. Hence, yield potential is confined only to nut number production.

Assuming soil heterogeneity was not a critical factor, the significant difference in nut number among seedlings *(Table 2)* was to be expected because of the heterogeneity of the population arising from random selections of seed materials from farmers' fields. A population mean of only 81 nuts/year was obtained and this reflected the generally low yield potential of the mother plants from which the seeds were collected. The low yield potential is further shown by the frequency bar chart which shows intense skewedness towards Class 1 and Class 2 *(Figure 3)*. The total number of accessions falling into these classes (1 441 trees) accounted for more than 91% of the total number of individuals on which records were kept. From the point of view of raw nut production capability, all the plants in these two classes do not merit further consideration in selection.

Accessions falling into Class 3 to Class 6 generally possessed mediocre yield potential. Even assuming that they bear nuts about the same size as that of C11 (i.e. 5.62 g/nut), the clone currently recommended by MARDI, those in Class 5 (with a maximum cumulative yield of 5 000 nuts) potentially could yield only

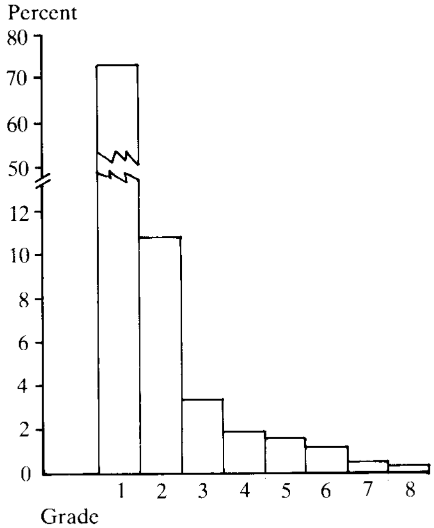

Figure 3. Various 'classes' of cumulative yield for 1 582 individuals in a cashew seedling population

555 nuts/tree per year, or approximately 3.12 kg/tree per year which is far below that of C11 (5.6 kg/tree per year) as reported by Chai and Samad (1980). As far as nut number is concerned, it is best to ignore accessions in these classes in future selection work.

The number of accessions falling into Class 7 and Class 8 (13 accessions) represent only 0.5% and 0.3% respectively, of the total number of individuals studied. Those in Class 8 (five accessions) could be regarded as elites with Accession 411 outyielding the others by a wide margin, giving a 9-year mean yield of 2 270 nuts/year *(Table 3)*. Mean nut number of three of these accessions (410, 411 and 413) exceeded the highest yield of 1 524 nuts/year recorded in Tanzania (Northwood 1966). Their potential in nut number production could be best used to improve yield capacity in future cashew breeding programmes.

Relationship between nut number and nut weight

There was a wide variation in the mean nut weight of the accessions *(Table 4)*. The biggest nut (9.47 g) was recorded in

Table 3. Yields of 13 cashew accessions producing more than 7 500 nuts within a 9-year period

Accession	Yield (no. of nuts)											Class
	1972	1973	1974	1975	1977	1978	1979	1981	1982	Total	Mean	
192	1 591	1 079	2 164	765	489	69	150	473	806	7 586	843	7
196	587	811	1 511	1 263	1 064	290	700	616	1 116	7 958	884	7
200	223	429	1 764	1 016	1 100	20	80	1 597	1 606	7 835	871	7
395	252	576	2 180	125	79	100	100	1 691	2 458	7 561	840	7
423	1 118	928	2 185	450	881	25	350	1 662	1 018	8 617	957	7
633	1 094	1 405	1 258	0	483	308	220	1 443	3 049	9 260	1 029	7
890	1 574	961	818	70	190	150	120	2 654	3 310	9 847	1 094	7
1608	527	374	1 336	485	125	505	505	2 525	1 721	8 103	900	7
379	1 062	1 188	1 158	610	83	1 216	705	2 677	2 646	11 345	1 261	8
410	863	1 686	3 244	780	3 115	160	1 273	2 435	1 454	15 010	1 668	8
411	941	3 730	3 089	520	2 734	52	1 460	4 503	3 404	20 433	2 270	8
412	886	1 341	2 238	232	1 176	155	1 255	1 438	1 645	10 366	1 152	8
413	429	1 111	1 514	346	1 481	1 060	1 645	3 118	3 180	13 884	1 543	8

Accession 600 while the smallest nut (4.27 g) was observed in Accession 89, with a standard deviation of 1.44 units. The highest yielding accession (Accession 411) with a 9-year mean of 2 270 nuts/year produced the second smallest nut, and conversely, the accession producing the biggest nut (Accession 600) gave the second lowest yield among the 33 accessions listed. There was apparently a negative correlation between the two characters, a fact commonly recognized in all cashew-growing regions (Ohler 1979).

A regression of mean nut weight for the 1981 data plotted against the 9-year average yield showed this inverse relationship *(Figure 1)*. Taking 700 nuts as the lowest acceptable nut number and 6.05 g as the minimum acceptable nut weight, only four accessions fell within the range of acceptable yield grids *(Table 5)*. They are identified by closely examining the data on nut weight and average nut number in *Table 4* and cross-checking with *Figure 1*. By the same calculation, Accession 600, which produced the biggest nuts, gave only 1.9 kg/tree per year or 279 kg/ha per year. On the other hand, Accession 411 which was the highest yielder, gave 9.89 kg/tree per year or 1.41 t/ha per year. However, it has a serious disadvantage of having very small nut size (4.36 g). For practical purposes of processing and marketing, nut sizes below 5.0 g are considered uneconomical. Nevertheless, Accession 411 is perhaps a very good parent for improving yield in terms of nut number.

In 1981 Accession 890 recorded higher yield than the other four including C11 *(Table 5)*. All four accessions produced bigger nuts than C11. However, the small nut size of C11 is well compensated for by its large nut number. Hence, its yield for 1981 was higher than three of the accessions listed in the table. Similarly, its calculated yield per hectare appears to be the highest *(Table 5)*. This probably suggests that the annual yields of the four accessions are somewhat erratic while that of C11 is more stable giving a consistently high average. A detailed comparison is given in a separate paper (Salleh et al. 1988). The works of several cashew workers in different countries were reported by Ohler (1979) as shown in *Table 6*. The nut sizes were generally less than 5.0 g except in Jamaica.

It is clear that even though the nut size and potential yield of the four accessions do not fully meet the most demanding breeding goals, their

Table 4. Nut number and nut weight of 33 cashew accessions producing more than 1 000 nuts in 1981

Accession	Nut wt.* (g)	Nut no.	Nut no. for 9 years	
			Total	Average
89	4.27	1 034	3 741	416
155	5.79	1 001	2 391	265
200	5.56	1 597	7 835	871
203	5.86	1 470	6 574	730
216	4.66	1 173	2 441	271
219	5.70	1 206	4 451	495
222	5.89	1 556	5 344	594
237	5.28	2 042	3 642	405
286	4.65	1 130	5 554	617
379	4.87	2.677	11 345	1 261
395	**6.43**	**1 691**	**7 561**	**840**
407	4.59	1 772	4 779	531
408	5.49	1 054	4 376	486
411	4.36	4 503	20 433	2 270
412	4.67	1 438	10 366	1 154
413	4.77	3 118	13 884	1 543
423	5.48	1 662	8 617	957
436	7.37	1 442	5 978	664
439	5.37	2 111	6 086	696
600	9.47	1 107	1 868	208
623	8.32	1 202	4 855	539
626	6.71	1 057	4 734	526
633	**6.45**	**1 443**	**8 900**	**988**
843	5.70	1 025	4 421	491
848	7.58	1 454	4 370	486
890	**6.37**	**2 654**	**9 847**	**1 094**
896	**7.19**	**1 120**	**7 000**	**778**
1214	9.02	1 184	3 266	363
1241	9.41	1 097	1 717	191
1460	6.83	1 506	3 942	438
1527	5.82	1 536	4 371	486
1591	4.75	1 363	4 230	470
1930	4.89	1 595	3 463	385
Mean	6.05	1 607	6 133	682
C11	5.62	2 846	10 743⁺	1 534‡

*based on sample of 100 nuts from 1981 yield
⁺total of 7-year (1977–83) yield data
‡average of 7-year yield data

performance, nevertheless, merits consideration in future breeding programmes.

Correlation among traits

Correlation studies were done to enable further assessment of the accessions. This was necessary because in addition to nut weight and nut number, other components of the nut *(Appendix 2)* could also be used as criteria in a selection programme. Of interest among the correlation coefficients presented in *Table 7* are the relationships among four components, namely nut number, nut weight, shell weight and kernel

Table 5. Comparison between four promising accessions[+] from a cashew seedling population and C 11 clone

Accession/ clone	Yield (kg/tree)*	Av. nut wt. (g)[‡]	Av. nut no.[§]	Cal. yield (kg/ha)[@]
Acc. 890	16.9	6.37	1 094	988.1
Acc. 633	9.3	6.45	989	905.7
Acc. 395	10.8	6.43	840	767.4
Acc. 896	8.1	7.19	778	794.1
C 11	15.9	5.62	1 534[#]	1 224.2

[+]those that fall within the acceptable yield grid (having nut weight more than 6.05 g and nut no. exceeding 700 nuts)
* actual yield of 1981 (from *Table 4*)
‡ calculated based on 100 nuts from 1981 yield
§ average of 9-year yield data
#average of 7-year yield data
@calculated based on 142 plants/ha

Table 6. Average nut size and yield from various countries (after Ohler 1979)

Source	Country	Age of plants	Av. nut size (g)	Yield (kg/tree)
Anon. (1960)	Jamaica	Mature tree	2.3–16.5	–
Mutter and Bigger (1962)	Tanzania	Mature tree 5 years	– –	9.5 3.6
Correia (1963)	Mozambique	Mature tree	5.0	–
Lefebvre (1963)	Madagascar	Mature tree	3.9–4.6	–
Northwood (1966)	Tanzania	Mature tree	4.9	–
Rocchetti and Mosselle (1967)	Tanzania	Mature tree	4.8	–
Raghavan (1976)	India	Mature tree	–	15–70

Table 7. Correlation coefficients among nut components in 33 cashew accessions

Nut component	Nut weight	Nut length	Shell width	Shell thickness	Shell weight	Kernel length	Kernel percent
Nut no.	−0.394*	−0.398*	−0.344*	−0.116*	−0.394*	−0.318	0.016
Nut weight		0.938*	0.932**	0.604**	0.990**	0.793**	−0.274*
Nut length			0.808**	0.560**	0.917**	0.905**	−0.234*
Shell width				0.662**	0.930**	0.651**	−0.247*
Shell thickness					0.602**	0.406*	−0.234*
Shell weight						0.737**	−0.386*
Kernel length							0.016

**significant at 1% level
*significant at 5% level

percentage. Nut number was negatively correlated with nut weight. Thus, accessions with large nut number such as Accession 411 tended to have smaller nuts. This was already demonstrated in the relationship between nut weight and average nut number shown in *Figure 1.*

Nut weight is positively correlated with shell weight but negatively correlated with kernel percentage. This means that the bigger the nut, the heavier is the shell while the percentage of kernel recovered would be correspondingly lower. This further indicates that thick or large nuts need not necessarily have relatively heavy kernels. The reason for this is because a large or heavy nut tends to have a larger cavity between the kernel and its shell and also between the two cotyledons. Such nuts, therefore, have low densities. Smaller nuts, on the other hand, tend to be completely filled and have high densities. Ohler (1979) argues that for the processing industry, which pays for the nuts by total weight, the kernel percentage is the most important characteristic of the nut, as the kernel is the most valuable part of it. A small difference in percentage could be crucial between profit and loss.

The results suggest that in terms of nut number production, from 4 168 cashew seedlings, only five individuals (Class 8) showed good potential and merit further consideration in a breeding programme. One would probably exercise caution in selecting Accession 410 because of its rather erratic yield pattern, which gave less than 1 000 nuts in 1981. The list could also include a few accessions in Class 7 (e.g. Accession 395, Accession 633 and Accession 890). Some of these accessions have moderately large nuts. They are definitely better choices than those with exceptionally large nuts but which are hampered by low yield potential and other disadvantages as shown by analyses of their nut components *(Appendix 2)*. In conclusion, apart from nut number and nut weight, other attributes must be considered in selecting promising cashew accessions. Because of character association, only a few accessions finally stand out as promising individuals.

The overall results of this study seem to point towards the mediocrity of the accessions present in the population and the mother plants from which the materials were originally collected. They indicate the low genetic potential in terms of nut number and nut weight of the materials present in the population as well as in the areas where the collection was undertaken. Thus, while the establishment of a collection comprising largely seedling populations could theoretically enhance the preservation of genetic resources, the usefulness and economics of maintaining mainly unselected seedling materials may be questionable. A more practical approach would be first, to identify reasonably good individuals in the farmers' groves. These materials should then be observed for a few seasons. Those that show consistent high yields and good potential in other characters are then collected and conserved in a germplasm plot before incorporating them in replicated trials.

Acknowledgements
The authors are grateful to Mr Chan Ying Kwok for technical discussions in the preparation of this report, Mr Abdullah Hasim Budin and Mr Ahmad Ishak of MARDI Sg. Baging for access to the data, and to Ms Zaharah Hj. Talib for her assistance in the statistical analyses.

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Accepted for publication on 16 August 1988

Appendix 1. Rainfall (mm) in Sg. Baging from January–March (1972–1982)

	Jan.	Feb.	Mar.
Good year (peak)			
1972	45.2	21.0	89.1
1974	11.3	174.2	81.3
1977	53.9	170.2	96.6
1981	58.8	220.0	115.7
1982	30.1	63.3	290.2
Total	199.3	648.7	672.9
Mean	39.9	129.7	134.6
Off year (trough)			
1973	429.8	34.7	297.7
1975	717.7	540.7	117.0
1976	41.3	0	61.2
1978	143.2	104.1	75.4
1979	149.9	63.7	151.3
1980	165.5	46.1	107.7
Total	1 647.4	789.3	810.3
Mean	274.6	131.3	135.1
Grand total	1 846.7	1 438.6	1 483.2
Mean	167.9	130.5	134.8

Appendix 2. Nut components of 33 cashew accessions yielding more than 1 000 nuts in 1981

Accession	Nut length (mm)	Shell width (mm)	Shell thickness (mm)	Shell wt. (g)	Kernel length (mm)	Percentage recovery
89	25.4	16.6	2.7	2.7	22.1	33
155	29.2	17.3	3.1	4.0	33.2	26
200	27.1	18.4	3.3	3.8	21.9	27
203	27.8	20.0	3.6	4.0	21.3	27
216	26.2	16.9	3.1	3.4	19.8	25
219	28.9	18.2	2.9	3.8	23.4	29
222	29.0	18.3	3.4	4.2	21.9	26
237	26.9	17.1	2.9	3.6	20.9	29
286	27.4	15.3	3.0	3.5	20.5	22
379	26.0	18.1	3.3	3.5	18.6	25
395	**29.8**	**18.2**	**3.3**	**4.5**	**22.2**	**25**
407	27.1	17.1	3.2	3.4	20.5	24
408	27.9	18.8	2.9	3.9	21.5	27
411	26.4	16.3	3.1	3.0	20.1	27
412	27.2	16.0	2.8	3.3	21.2	25
413	26.7	17.5	3.1	3.5	21.5	24
423	27.3	18.5	3.4	3.9	20.3	26
436	30.0	19.1	3.5	5.0	24.8	29
439	28.1	17.7	3.7	3.8	20.1	26
600	32.9	23.3	3.6	7.1	24.9	23
623	31.6	23.2	4.0	6.3	23.7	25
626	30.6	18.5	3.6	4.6	24.3	28
633	**30.6**	**18.4**	**3.1**	**4.4**	**24.4**	**29**
843	28.4	19.3	4.0	4.0	21.6	28
848	31.3	21.2	3.3	5.2	24.5	27
890	**29.0**	**20.1**	**3.7**	**4.4**	**23.1**	**28**
896	**30.6**	**21.0**	**3.6**	**4.9**	**24.2**	**27**
1214	31.4	23.8	3.4	6.7	22.7	23
1241	32.7	23.1	3.7	6.9	24.6	23
1460	30.6	19.7	3.7	4.8	24.1	25
1527	28.5	18.9	3.0	4.0	22.0	29
1930	28.6	17.3	3.0	3.5	22.3	26
1951	27.0	16.4	3.2	3.4	20.2	26
Mean	28.7	18.8	3.3	4.3	22.5	26
SD	2.0	2.2	0.3	1.1	1.7	2.3
C 11	27.4	18.2	3.4	3.6	22.0	29