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Evaluation of F_1 populations from a 4 x 4 diallel in pineapple and estimation of breeding values of parents

(Penilaian populasi F_1 daripada kacukan 4 x 4 dialel nanas dan penganggaran nilai pembiakbakaan induk)

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Key words: *Ananas comosus* L. (Merr.), pineapple, hybridization, diallel, breeding values, cultivars

Abstrak

Kacukan dialel lengkap pada nanas telah dijalankan dengan menggunakan empat induk daripada tiga kumpulan yang berbeza, iaitu Sarawak (Cayenne), Moris (Queen), Masmerah (Spanish) dan Johor (Spanish). Analisis populasi F_1 yang berdasarkan lapan ciri menunjukkan variasi yang luas, lazimnya melebihi dua kali ganda daripada variasi induk-induknya, dan ini akan memberi skop untuk pemilihan dan mempertingkatkan prestasi. Mengenal pasti induk-induk yang sesuai digunakan bagi menghasilkan progeni F_1 yang baik agak mudah jika hanya satu ciri sahaja yang diambil kira pada satu masa. Bagi setiap ciri, populasi F_1 yang lebih baik mungkin akan terhasil dengan menggunakan induk yang mempunyai min yang terbaik jika tiada interaksi induk jantan x induk betina atau melalui kombinasi induk yang terbaik apabila interaksi didapati ketara. Dalam kajian ini, Sarawak ialah varieti yang terbaik untuk meningkatkan saiz buah, Masmerah berkesan bagi mengurangkan garis pusat empulur, manakala Johor merupakan induk yang lemah bagi meningkatkan toleransi terhadap penyakit mata geguli dan bintik bergabus. Untuk meningkatkan jumlah pepejal larut (TSS%), kacukan terbaik ialah antara Sarawak-Moris, manakala untuk membaiki warna isi, kacukan-kacukan yang baik ialah kombinasi Moris-Masmerah dan salingannya.

Anggaran nilai pembiakbakaan bagi keempat-empat induk itu akan menjadi lebih sukar apabila semua ciri bagi pemilihan diambil kira serentak. Perkiraan nilai pembiakbakaan keseluruhan bagi setiap kultivar telah dihuraikan berasaskan nisbah progeni yang layak untuk dipilih bagi setiap ciri.

Abstract

A complete diallel cross in pineapple was carried out using four parents from three diverse groups, i.e. Sarawak (Cayenne), Moris (Queen), Masmerah (Spanish) and Johor (Spanish). Analyses of the F_1 populations for eight characters showed wide variation, often exceeding twice that of the parents, and this represents scope for selection and improvement. Identifying the parents most likely to generate the best F_1 populations was relatively straight forward when characters were considered one at a time. For each character, more promising F_1 populations may be produced by using the parent with the best mean if there was no female parent x male parent interaction, or by using the best combination of

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parents when interaction was significant. In this study, Sarawak was found to be the best parent for increasing fruit size, Masmerah was effective for reducing core diameter, but Johor was a poor parent in so far as improvement of tolerance to marbling and cork spot diseases was concerned. For increasing TSS content, the best cross was Sarawak-Moris, while the best for improvement of flesh colour were Moris-Masmerah and its reciprocal.

Estimation of breeding values of parents was more complicated when all the characters were considered simultaneously for selection. The computation of an overall breeding value for each cultivar was described. This was based on the product of the proportion of progenies that qualified for selection in each character.

Introduction

The cultivated pineapple is usually self-incompatible but very often sets seed when crosses are made between cultivars. These cultivars are very heterozygous, therefore, progenies derived from such crosses are expected to be very variable. The F_1 population represents a rich source of variation comprising many types of recombinants, some of which may have the potential to be better varieties. Hybridization and clonal selection in the segregating F_1 is a common method used in pineapple breeding (Chan 1986a; Cabot 1987).

In Malaysia, three basic groups of pineapple are cultivated. They are the Smooth Cayenne of which the Sarawak is the best known variety here, the Queen (Moris variety) grown mainly for fresh fruit and the Singapore Spanish (Masmerah variety) fruit of which are mainly used for canning. Most crosses between the groups produce viable seed, although the quantities vary depending on the parents and the direction of the cross (Chan 1986b).

In hybridization for improvement in pineapple, the choice of parents has usually been based on the strength of one in complementing the weakness of the other. Chan (1989) attempted to improve the flesh colour of Hybrid 36 by crossing it with Gandul, which has attractive golden flesh while Cabot (1987) used the Perolera variety to improve the ascorbic acid content of Cayenne pineapple. These biparental crosses focussed narrowly on the improvement of a single character, with scant attention given to the adverse characters that the donor parent might have inadvertently brought along. Chan (1989) found that improvement of flesh colour had concomitantly reduced fruit size and acid content in the progenies.

Therefore, it should be of immense value to be able to identify the pineapple group as well as the cultivars within a group which could contribute more towards generating a progeny population that has better all-round prospects for selection and development of improved varieties. In other words, their breeding values should be estimated so that one can predict with fair accuracy the overall performance of subsequent F_1 arising from the crosses.

This paper examines the characteristics of all the possible F_1 hybrid populations derived from a complete four parent diallel. The breeding values of these parents will be computed based on their progeny performance in eight important selection criteria.

Materials and methods

The experiment was carried out at the Integrated Peat Research Station at Pontian, Johore.

Four varieties which are representative of the three major groups of pineapple in Malaysia, i.e. Sarawak (Cayenne), Moris (Queen), Johor (Spanish) and Masmerah (Spanish) were crossed in a complete diallel.

However, there was differential seed set (Chan 1986b) and four of the crosses were either incompatible or produced so few seed that they had to be left out of the analysis.

The seed of the remaining eight F_1 populations were sown in sand trays in October 1984 and the plants transplanted to the field in November 1985. Depending on seed availability and viability, the number of plants produced for each of the F_1 populations ranged from about 130 to 300 plants. No prior selection on the progenies was done to avoid genetic drift due to non-random selection. About 200 suckers of the same size as the progeny seedlings from each of the four parents were planted adjacent to the hybrid plots for comparison. The plants were planted in double row beds at a spacing of 30 cm x 60 cm between plants and 90 cm between beds.

Flower initiation was done on 2 April 1987 using 400 ppm ethrel, 4% urea and 0.5% borax. At harvest, the fruit and crown weights, core diameter, number of slips, tolerance to marbling disease (MD) and cork spots (CS), flesh colour and content of total soluble solids (TSS) were recorded on each progeny or parent plant. Core diameter was measured from the centre of the longitudinally dissected half of the fruit and the TSS was recorded using a hand refractometer (0–25° Brix). The intensity of flesh colour and severity of MD and CS were visually scored from 1 to 10, the higher scores indicating more intense colour or greater disease severity. Marbling and cork spot diseases were evaluated on the exposed eyes in the cut peel of the fruit.

An ANOVA was done for each of the eight characters using the fixed effects model:

$$y_{ijk} = u + a_i + b_j + d_{ij} + e_{ijk}$$

where y_{ijk} = effects of the kth plant of the ith female parent crossed with the jth male parent

a_i = effects of the ith female parent

b_j = effects of the jth male parent

d_{ij} = interaction of the ith female with the jth male

e_{ijk} = error term for the kth plant of ith and jth cross

The data were processed by an IBM 4381-11 using the SAS software.

Results and discussion

Description of the F_1 populations

Two statistics that are important for describing the characteristics of the eight F_1 populations in this study are coefficient of variation (C.V.) and mean. F_1 populations that have the best potential for selection of a desirable genotype were those that have a high C.V. (indicating a wider spectrum of recombinants) and a high progeny mean since this would increase their chances of selection. The C.V. and mean values of the parent and hybrids for the eight characters are presented in *Figure 1* to *Figure 8*.

Generally, it can be seen that the C.V. of the F_1 populations were very large. The variation of the hybrids was usually at least twice that of the parents. Similar findings were reported in an earlier study of a biparental cross between two Spanish cultivars (Chan 1989). The wide variation provides good opportunities for selection of improved recombinants. There was an exception, however, in marbling disease (*Figure 3*) in which the C.V. of several parents exceeded those of the hybrids. This was under unusual circumstances because the tolerant parents were generally rated 0, but when occasional severe disease incidence occurred in some fruit, very high C.V. resulted.

The parental means for most of the characters were very different from one another, indicating the diversity of the parents from the different groups of pineapple. The distribution of the hybrid means in fruit weight, core diameter, marbling disease and slip number appeared to be clearly influenced by the parents. The relationship of the parents and the hybrids will be dealt in greater detail later, after examining the ANOVA for each character.

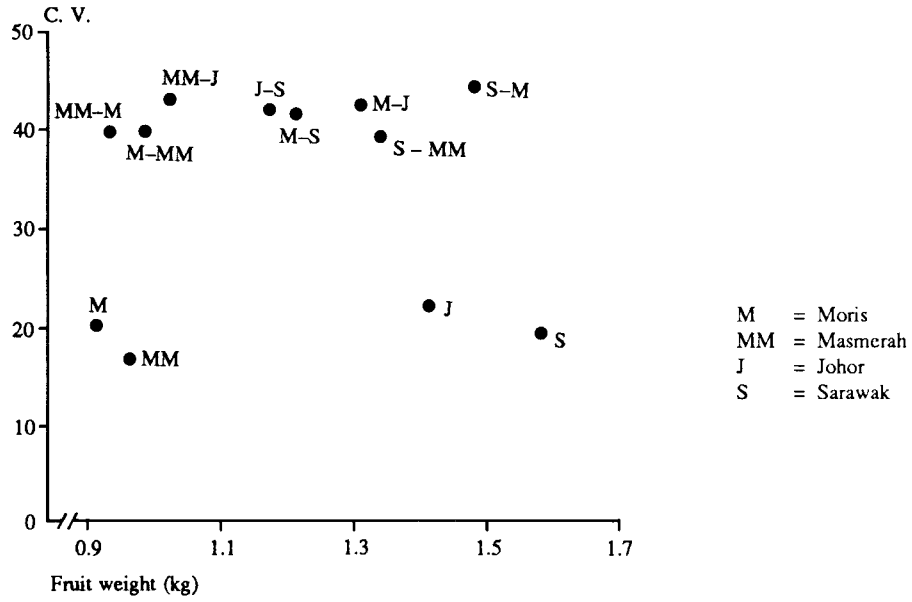

Figure 1. C. V. and means of fruit weight of parents and hybrids

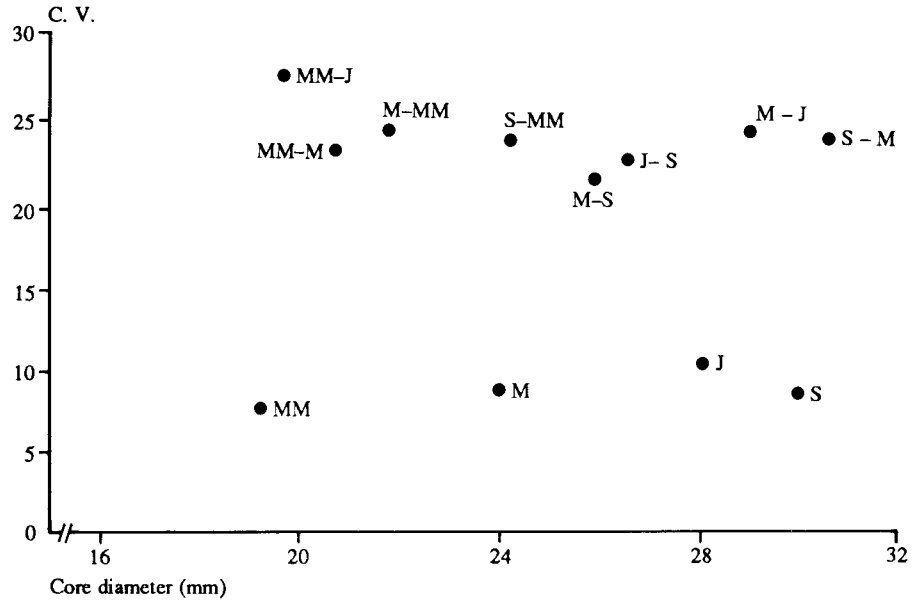

Figure 2. C. V. and means of core diameter of parents and hybrids

Analysis of variance of characters

The 4 x 4 diallel gave three degrees of freedom each for the female and male parents in the ANOVA. The general conclusion that can be drawn from *Table 1* was that the four cultivars used either as the female or male parent produced F_1 populations that were significantly different from each other. There were, however, two exceptions, namely responses to cork spot and marbling diseases, where the four cultivars when used as the female parent did not produce progenies that were significantly different. This had arisen because of the incomplete hybrid sets in the diallel. For example, the susceptible parent

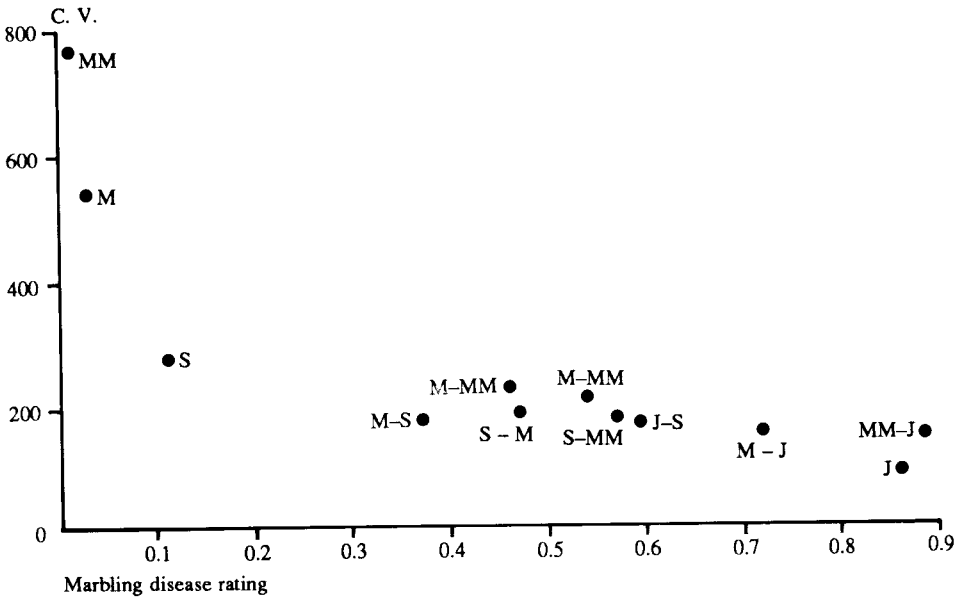

Figure 3. C. V. and means of marbling disease of parents and hybrids

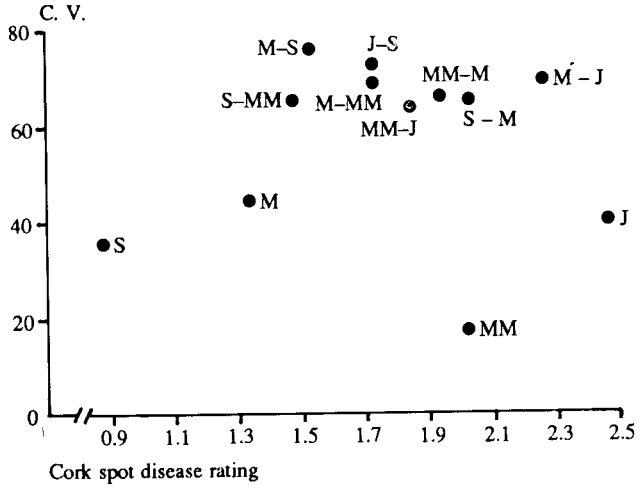

Figure 4. C. V. and means of cork spot disease of parents and hybrids

(Johor) appeared more often in the male set of crosses (thereby causing significance in F_1 progenies) but because of incompatibility when used as a female parent, had less representation in the female set (hybrid populations therefore tended to be more similar in response).

Interaction between female and male parents existed for flesh colour, TSS, crown weight and slip number. Significance in only the male or female effect and not in their interaction as encountered in fruit weight, core diameter, cork spot and marbling disease implied that the differences in

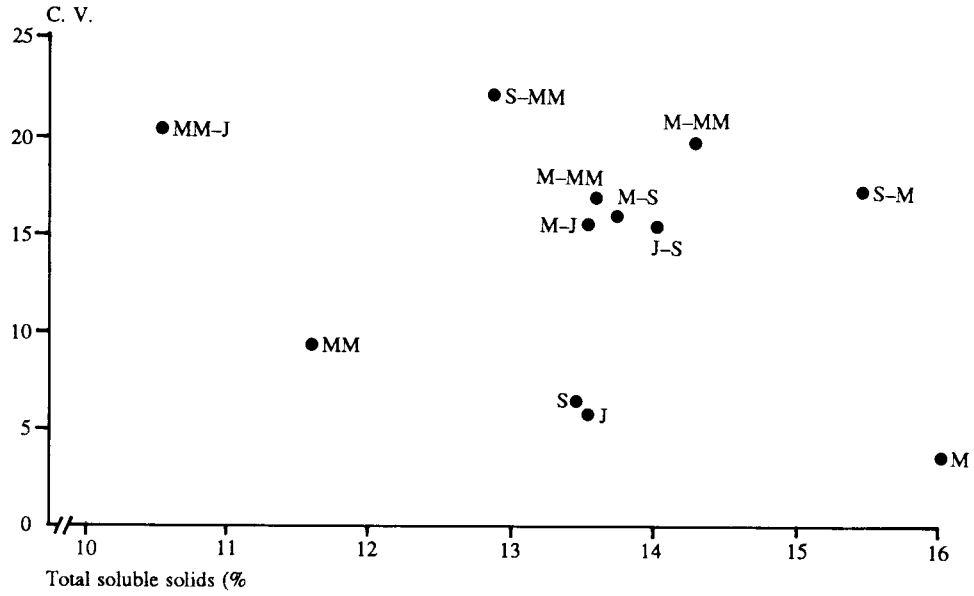

Figure 5. C. V. and means of total soluble solids of parents and hybrids

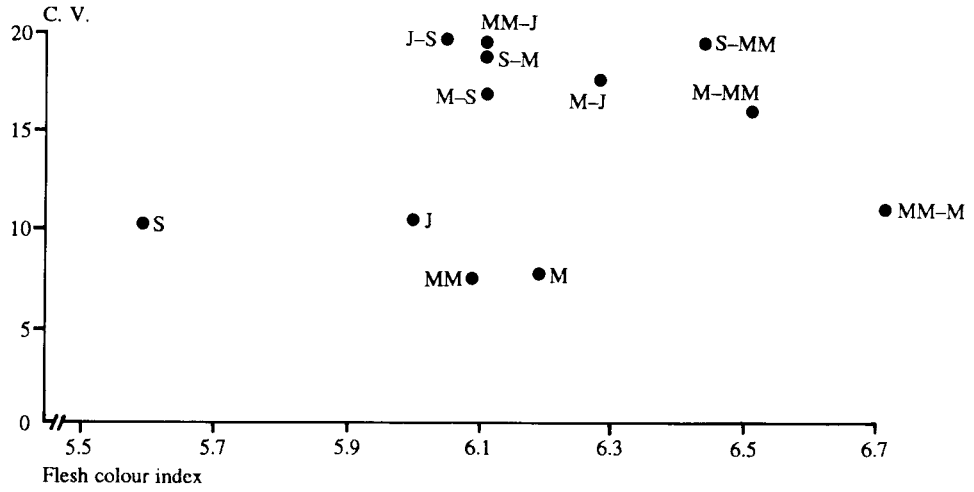

Figure 6. C. V. and means of flesh colour of parents and hybrids

progeny populations could be mostly accounted for by the contribution of the parents used either as males or females. These effects constitute the general combining ability of the parent. In this case, the parent with the highest or best means would be adjudged the most suitable for use in crosses for improving these four characters. Where interaction effects between female and male were significant, the superiority of the parents either as male or female in generating the best progeny populations cannot be as easily decided. In this case, the specific combining ability of the parents should be considered and the hybrid with the highest mean would be

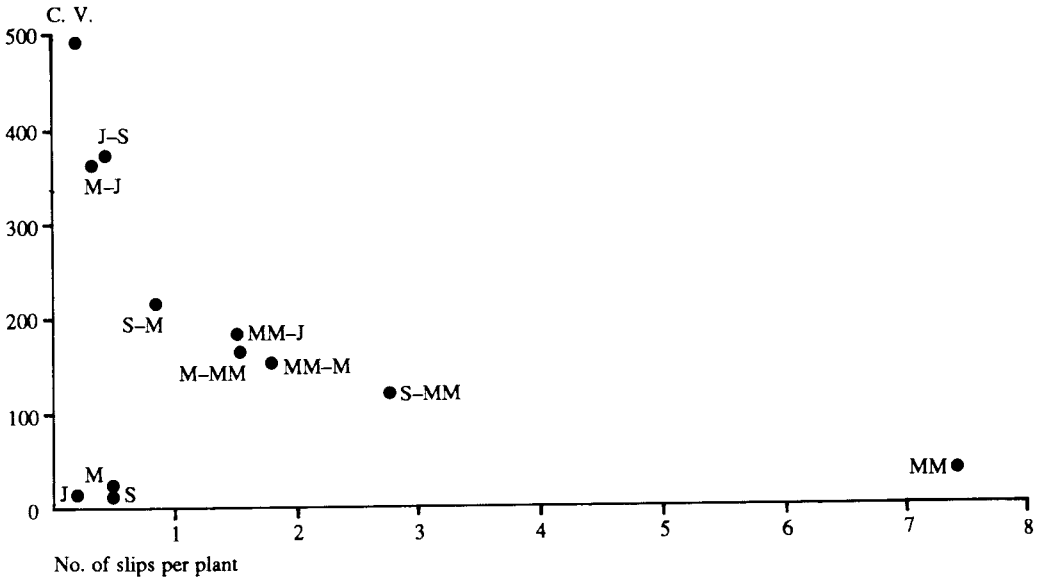

Figure 7. C. V. and means of number of slips per plant of parents and hybrids

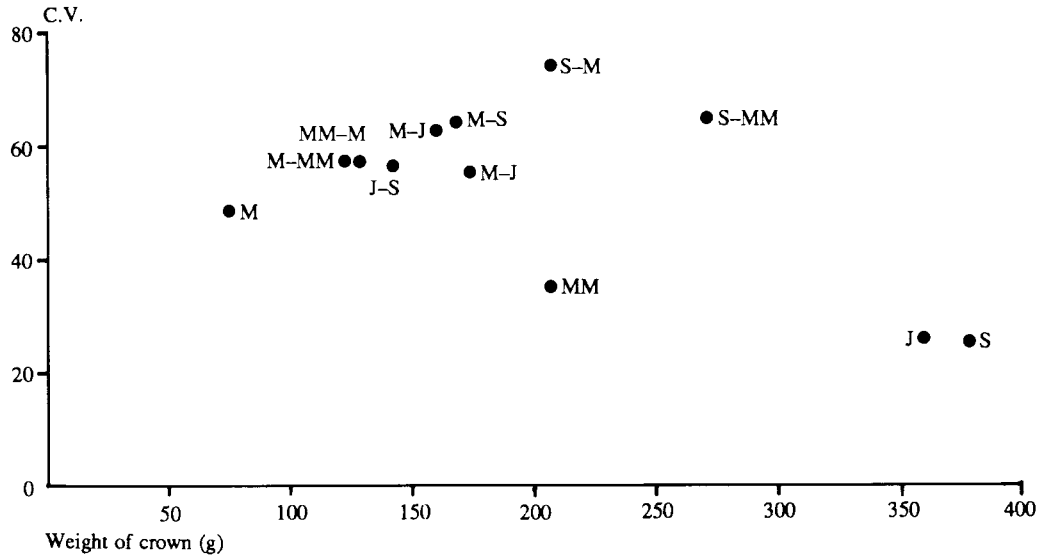

Figure 8. C.V. and means of crown weight of parents and hybrids

adjudged as the specific cross that would be best for improving the population. Let us examine each of the characters in turn and the relationship of the parents with the hybrids (*Figure 1* to *Figure 8*).

Best parents and crosses for improving a specific character

There was no interaction of female x male for this character so that the best parent for improving fruit size would be Sarawak (*Figure 1*). This was reflected by the fact that of the five heaviest hybrids, four of them involved Sarawak.

Table 1. Analysis of variance: mean squares for eight characters

Source	df	Fruit weight	Core diameter	Marble disease	Cork spot	TSS	Flesh colour	No. slip	Crown weight
Female parent	3	11.68**	3 447**	1.6ns	3.59ns	72.6**	10.3**	232.7**	834 084**
Male parent	3	5.49**	3 403**	8.1**	30.70**	595.1**	14.3**	188.0**	185 882**
Male x female	1	0.35ns	101ns	0.1ns	0.25ns	39.3**	13.9**	30.3*	116 514**
Error	1 823	0.24	34	1.1	1.60	5.8	1.2	4.9	12 599

**Significant at $p < 0.01$
*Significant at $p < 0.05$

Table 2. Progeny selection based on set criteria and estimation of breeding values

Variety	Progenies (%) qualified for selection								
	Fruit wt. >1.2 kg	Core diameter <25 mm	Marble disease 0	Cork spots <2	TSS content >13	Flesh colour >6	No. slip <3	Crown wt. >300 g	Breeding value (x 10^2)
Johor	39.3	41.7	60.9	47.5	46.9	38.1	88.3	90.3	6.76
Masmerah	22.5	81.1	64.5	45.0	46.8	51.2	46.8	94.9	8.17
Moris	36.8	52.3	68.9	48.3	59.4	45.1	80.9	90.9	12.62
Sarawak	48.3	40.7	67.9	56.7	55.9	38.9	81.4	84.5	11.30

In the case of core diameter, since again no interaction was detected, the best parent for reducing core size would be Masmerah. This cultivar had a small core of less than 20 mm and all the hybrids that involved Masmerah either as male or female had considerably reduced cores of <25 mm (*Figure 2*).

For marbling disease and cork spot, it was difficult to point out the best parent, but much easier to identify the worst one i.e. Johor. The susceptibility of this cultivar to marbling disease or 'mata geguli' is in agreement with the findings of Lim (1989) who reported that up to 48% of fruit of Johor cultivar was infected with this bacterial disease in one trial. For both diseases, all progenies derived from Johor also had relatively higher incidence than the others (*Figure 3* and *Figure 4*).

For the four remaining characters, i.e. TSS, flesh colour, number of slips and crown weight, the interaction terms were significant and therefore we have to consider the best combinations, rather than parents *per se*, for improving the progeny population.

For TSS, shown in *Figure 5*, the best combination would be Sarawak with Moris which gave a high population mean of 15.4%. For some reason, this appeared better than its reciprocal whose mean was only 13.7%. In practice, however, there may be a problem with this cross because Sarawak or Smooth Cayenne generally do not set seed easily (Chan 1986b).

There was no disagreement regarding the best crosses for improving flesh colour. Both Masmerah and Moris were reputed to have the most attractive golden yellow flesh colour among Malaysian pineapples, and their hybrids including reciprocals were easily the best combinations for flesh colour improvement (*Figure 6*).

Slips were produced in fair abundance by Masmerah, but not in the other parents. Such propagules are desired only to the extent of fulfilling replanting needs. Excessive slip number of >2 significantly compete with the fruit development. As indicated in *Figure 7*, the best crosses were those that precluded Masmerah. This character appeared highly heritable.

For reduction of crown weight, the best crosses were Masmerah with Moris or their reciprocal (*Figure 8*).

Estimation of overall breeding values of parents

What had been discussed so far was the effectiveness of the parents in generating progenies with favourable high means and high probability for selection, considering a single character at a time. In practice, however, one has to select for recombinants with all the desired characteristics within one genotype. The parents used in this experiment have been shown to produce progenies that excelled in some, but not all, characters. There must be a way to evaluate their overall worth or breeding value as parents in crosses to improve a certain set of characters.

Table 2 gives the percentage of progenies from each parent that qualified for selection based on meeting a set of conditions in each character. Very strict conditions cannot be imposed for all characters, otherwise there may not be any individuals meeting all these conditions later. A differential selection weightage was applied, based on the relative economic importance of the character, much like the weightage practised for derivation of usual selection indices. For example, flesh colour in Malaysian canned pineapple is renowned, and no compromise is acceptable in this criterion. Therefore our selection pressure will have to be high too. Only 38–51% of the progenies were selected from each parent. On the other hand, characters like crown weight which, within reason, is less likely to influence the marketability or production of fruit, will enjoy a more laxed selection pressure allowing more than 80% of the progenies through.

If each character is considered at a time, it can be seen that the percentage of progenies selected from each parent differed. This was expected because the worth or effectiveness of the parent in generating a population with favourable means would differ as was seen earlier. For fruit size, it can be seen that Masmerah crosses generally produced smaller fruit, therefore imposing a fruit size of at least 1.2 kg quickly forced out a good number of Masmerah progenies. For core diameter, the reverse was true, over 80% of Masmerah progenies were selected when small cores of <24 mm were required. Just for these two characters, there appeared to be a balance-up for Masmerah. What it lost out in fruit size, it made up with small core. Therefore, using the same argument, the overall breeding value of each parent for this set of eight characters would be the product of the portion of selected progenies from each character. It would have a theoretical value of 1 if all progenies of the parent are selected for all characters.

Considering a population of 1 000 progenies, the breeding values would be the number of progenies that would meet all selection conditions and qualify for selection. In this case, twice as many potential progenies can be expected by using Moris as parents compared with Johor. A note of caution in this interpretation is that the model was regarded as fixed, and conclusions may only be drawn from these four parents, albeit they covered the major pineapple groups. If Moris and Johor were used for crossing with cultivars other than those used in this experiment, or if the selection pressure or the set of selection criteria had been different, the results would have most certainly come out differently.

Conclusion

The analysis of F_1 populations generated from crosses among four cultivars showed that there was wide variation in the F_1, providing a potential source of recombinants for selection of improved genotypes. Examining the relationship of the means of parents and progenies for each character revealed, however, that each parent had its pros and cons in generating suitable F_1 populations for clonal selections. Because of this, there is danger in choosing parents for crosses based on one or two outstanding

characters. The attendant adverse effects of the donor parents may far outweigh the benefits that it may bring. Therefore, the more effective approach would be to consider a set of agronomic characters and choose the overall best parents based on computation of their breeding values as outlined in this study.

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References

Cabot, C. (1987). Practice of pineapple breeding. *Acta Horticulturae 196:* 25–36

Chan, Y. K. (1986a). Hybridization and selection in F_1 as a methodology for improvement of pineapple [*Ananas comosus* L.(Merr.)]. *Prosid. Simp. Buah-buahan Keb.* 8–9 Apr. 1986, Serdang (Chan, Y. K., Raveendranathan, P. and Zabedah, M., ed.) p. 307–14. Serdang: MARDI

——— (1986b). Differential compatibility in a diallel cross involving three major groups of pineapple [*Ananas comosus* L.(Merr.)]. *MARDI Res. Bull. 14(1):* 23–7

——— (1989). F_1 variation from hybridization of two 'Spanish' pineapple cultivars. *MARDI Res. Bull. 17(2):* 172–7

Lim, W. H. (1988). Penyakit geguli buah pada 'Nanas Johor'. *Teknol. Buah-buahan, MARDI 4(1):* 25–32

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