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Performance of F_1 pineapple hybrids selected for early fruiting

(Prestasi hibrid nanas F_1 yang dipilih untuk pengeluaran buah awal)

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Key words: *Ananas comosus* L. (Merr.), pineapple, breeding, hybrid, variety, early bearing

Abstrak

Prestasi lima hibrid nanas F_1 yang dipilih untuk pengeluaran buah awal telah diuji bersama tiga kultivar kawalan. Hasil daripada kajian menunjukkan bahawa dua hibrid iaitu A25-34 dan A54-47 matang awal dan buahnya boleh dituai 2 minggu lebih awal daripada kultivar kawalan Gandul. Perbezaan utama antara genotip yang awal dan lewat ialah tempoh masa untuk pembentukan buah selepas pengeluaran bunga. Tempoh ini berjulat antara 94–97 hari bagi genotip awal hingga 112–113 hari bagi genotip lewat. Tempoh antara rawatan hormon pembungaan dan pengeluaran bunga tidak banyak berbeza. Semua genotip berbunga pada 30–34 hari selepas rawatan hormon.

Terdapat perhubungan linear antara berat buah dan berat pokok pada semua genotip kecuali A04-16. Genotip ini unik kerana mempunyai buah yang terberat tetapi pokok yang teringan dan ini menghasilkan nisbah berat buah kepada pokok yang tertinggi (0.60). Skop untuk memendekkan tempoh kitar tanaman bagi genotip ini baik. Hal ini disebabkan oleh tempoh pertumbuhan tidak perlu dilanjutkan untuk mendapatkan pokok yang besar bagi menghasilkan saiz buah yang ekonomis. Dua genotip yang lain iaitu A25-34 dan A12-45 yang menunjukkan kecerunan rata bagi regresi antara berat buah dan pokok juga berpotensi untuk pengeluaran buah awal. Peningkatan saiz buah selepas sesuatu tempoh tidak ketara berbanding dengan pertumbuhan pokok. Oleh yang demikian, tempoh pertumbuhan pokok di ladang dapat dipendekkan.

Abstract

The performance of five pineapple F_1 hybrids selected for early bearing were evaluated with three standard cultivars. The results showed that two of the hybrids, viz. A25-34 and A54-47, were early maturing and fruit were harvested 2 weeks ahead of the standard cultivar Gandul. The primary difference between early and late genotypes arose from the period for fruit development after inflorescence emergence (‘red-heart’). This ranged from 94–97 days for early genotypes to 112–113 days for late genotypes. There was not much difference in the time between ‘forcing’ (application of flower hormone) to emergence of inflorescence. All genotypes flowered 30–34 days after hormoning.

There was a linear relationship between fruit weight and plant weight for all, but one of the genotypes – A04-16. This genotype was unique because it had the highest mean fruit weight but the smallest plant resulting in a very high fruit-to-plant weight ratio of 0.60. There is good scope for reduction of crop cycle

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time with this genotype because it was not necessary to extend the growing period to get large plants for production of economic-sized fruit. Two other genotypes, viz. A25-34 and A12-45 that showed a 'flat' gradient in the regression of fruit on plant weights, also appeared to have potential for early harvesting. The increase in fruit size after a certain time was marginal compared with the increase in plant size and therefore, the growing period in the field may be reduced.

Introduction

Many crop breeding programmes have stressed the importance on raising yield on per hectare basis with scant regard for improving yield over time. This is particularly true for fruits like papaya, banana and pineapple where the crop cycle is expected to be over a year (hence they are also sometimes called 'annual fruits'). In perennials such as durian, mangosteen and duku-langsat where maturation period is 6–10 years, there have been some efforts to reduce their juvenile phase. Chong (1992) had suggested using cleft grafting for mangosteen for reducing juvenile phase to 4 years and for producing dwarf trees for high density planting. Use of selected vigorous rootstocks may considerably reduce the time for first fruiting of durian trees in Thailand (Suranant 1993). For annuals, even a small reduction in unproductive gestation time may be an important consideration because of worldwide escalating costs of labour and inputs. A reduction in gestation time would translate into a shorter maintenance period of the crop in the field, less costs and an earlier return on investment.

Pineapple, depending on variety, requires 15–18 months from planting to harvesting. Under Malaysian conditions, the plant reaches a sizeable mass for flower induction ('forcing') at 10–12 months and fruit may be harvested from 5–6 months after forcing. There is sufficient evidence on the prospects for reducing the gestation period of pineapple through manipulation of planting materials, environmental effects as well as genetic influences. Planting large slips of Singapore Spanish pineapple resulted in more vigorous growth which enabled earlier induction of flowering and harvests compared with plants grown from small slips (Tan and Wee 1973). In Australia, the timing in planting and induction is crucial in influencing the period of fruit development from induction to harvest. This may vary from 185 days when plants are forced in September or October to 283 days when plants are forced in April or May (Sinclair 1993). Therefore, using suitable sized suckers and appropriate timing of induction, the pineapple crop cycle can be considerably reduced. However, there may be better prospects in advancement of early maturation by exploiting genetic influences.

MARDI started a systematic hybridisation programme for pineapple in 1984 using three different groups, viz. Cayenne, Spanish and Queen as parents (Chan 1986). This paper reports the performance of some of the F_1 progenies selected for early bearing and discusses the prospects of using them for reducing the plant crop cycle in pineapple cultivation.

Materials and methods

Ten earliest fruiting progenies were selected from the F_1 hybrid population consisting of 50 000 seedlings derived from crosses between three major groups of pineapple (Chan 1986). After one cycle of evaluation, five promising lines were selected from the original 10 progenies and propagated for further evaluation. The lines selected were A04-16, A12-45, A25-34, A54-47 and C17-33. Lines with an 'A' prefix were derived from Spanish x Cayenne crosses while that with a 'C' was from a Queen x Spanish cross. Three standard cultivars, viz. Gandul, Moris and Tailung, were used for comparison in the experiment. All planting materials in this experiment were propagated by quartering techniques (Lee and Tee 1978) to reduce error due to propagule age and size. The plants were raised to a height of 0.3 m before they were planted in the field.

The experiment was conducted on a peat area at the MARDI station in Pontian, Johor. The eight genotypes were planted on 15 October 1992 in a randomised complete block design with four replicates. In each plot (genotype within replicate), there were 60 plants grown in three double-row beds of 20 plants each. The spacing was 30 cm x 60 cm between plants and 90 cm between beds. Flower induction ('forcing') was done on 22 August 1993 using 400 ppm Ethrel, 4% urea and 0.5% borax.

Data on time to emergence of red heart (young inflorescence) and time to fruit harvest were averaged from plot means. At harvest, the fresh weights of the fruit and plant were recorded, and harvest index was computed from the ratio of fruit to plant weight. Fruit quality data included core diameter, flesh blemish (marbling, cork spot and leathery pocket), total soluble solids (TSS) and acid content. TSS was recorded using a hand refractometer (0–25% Brix) while acid content was determined by titration following the method used by Tay (1972). Flesh blemishes were visually scored from 1 to 10 with higher scores indicating greater disease severity. The data were recorded from 10 sample plants taken at random from the middle bed of each plot.

Results and discussion

Characteristics of genotypes

The analyses of variance are shown in *Table 1*. The mean squares for all the seven characters were not significantly different for replicates but were significantly different between genotypes. The mean values of the eight genotypes for the seven characters are shown in *Table 2*.

- **Fruit weight**
  The genotype with the heaviest fruit was A04-16 (1.73 kg) while Tailung had the smallest fruit (1.03 kg). The fruit weights of the other genotypes were mediocre and ranged from 1.36 kg to 1.51 kg. The fruit weights of all genotypes, with the exception of Tailung, appeared to be acceptable for canning. The small fruit of Tailung may only be suitable for fresh consumption.

- **Plant weight**
  The most vigorous genotype was A25-34, which had a mean plant weight of 5.35 kg. This variety had been selected based on rapid vegetative growth and early bearing, and was released as 'Josapine' in 1996. The standard cultivar Gandul (3.55 kg) has smaller plant mass, but the smallest plants were from A04-16 (3.13 kg). This is surprising because A04-16 had the largest fruit and this suggests that this variety is very efficient in partitioning dry matter between plant and fruit. It also contradicts some earlier reports that fruit size is correlated to plant mass (Bartholomew and Kadzimin 1977). It appears that correlation between these two characters may vary according to different varieties as suggested by Williams and Fleisch (1993).

- **Fruit-to-plant weight ratio**
  Examining further the relationship between plant and fruit size, the ratios of fruit weight to plant weight of all the genotypes were computed. It was found that A04-16 indeed had the highest fruit-to-plant weight ratio (0.60) while ratios for standard cultivars like Moris and Gandul ranged from 0.37 to 0.44. High fruit-to-plant weight ratio is desirable because it implies that the partitioning of photosynthates favoured fruit development rather than vegetative growth. The least efficient genotypes for fruit production were Tailung, A25-34 and A12-45, all of which produced fruit that weighed less than a third of their plant mass. These genotypes have typically large plants weighing over 5 kg and rather small fruit *(Table 2).*

Table 1. Analyses of variance: mean squares for seven characters

Source	df	Fruit wt.	Plant wt.	Fruit: plant wt.	Blemish	Core diameter	TSS	Acid
Replicate	3	0.0163ns	0.3051ns	0.0029ns	0.3067ns	0.9625ns	0.4801ns	0.0009ns
Genotype	7	0.1551**	3.5838**	0.0600**	7.0484**	40.7186**	17.8987**	0.0295**
Error	21	0.0099	0.5610	0.0059	0.4541	1.0658	0.2036	0.0010
Total	31							

Table 2. Mean values of eight pineapple genotypes for seven characters

Genotype	Fruit wt. (kg)	Plant wt. (kg)	Fruit: plant wt.	Blemish	Core diameter (mm)	TSS (%)	Acid (%)
A04-16	1.73a	3.13c	0.60a	4.78a	30.43a	13.35c	0.57de
A12-45	1.43b	5.14ab	0.28cd	2.35b	23.15c	13.47bc	0.63bcd
A25-34	1.38b	5.35a	0.28cd	1.15bc	27.68b	16.95a	0.68ab
A54-47	1.51b	4.45abc	0.35cd	0.98bc	23.90c	16.15a	0.70a
C17-33	1.36b	3.13c	0.50ab	1.12bc	22.50c	11.24d	0.56e
Gandul	1.51b	3.55bc	0.44bc	1.25bc	23.00c	10.85d	0.61cde
Moris	1.38b	3.86abc	0.37bcd	1.17bc	26.13b	14.35b	0.67abc
Tailung	1.03c	5.29a	0.22d	0.80c	29.88a	14.02bc	0.44f

Mean values in each column with the same letter are not significantly different at $p = 0.01$ according to the DMRT

- **Blemishes**
  It is rather evident that despite the high harvest index for A04-16, this variety currently has a few shortcomings that need to be redressed before it can be accepted by the industry. One of the most glaring is its susceptibility to blemishes in the flesh caused mainly by brown spots and marbling *(Table 2)*. A ranking of 1 or 2 would have been permissible, but for A04-16 the ranking of 4.78 would definitely result in high rejection rates at the cannery. On the other hand, Tailung was exceptionally tolerant to such blemishes and has excellent cosmetics when served as a dessert fruit.

- **Core diameter**
  Another setback of A04-16 is the large core of the fruit (30.4 mm). The cannery is unlikely to accept fruit with cores more than 25 mm because the coring knife would not be able to remove the core completely. Remnants of the core in the slices are fibrous and unsightly, and may cause products to be rejected. The standard canning variety Gandul produced fruit with an acceptable core size of 23 mm. Moris and A25-34 (Josapine) have rather large cores ranging between 26 and 27 mm. However, these cores are crunchy or crispy in texture and are quite acceptable when the fruit are consumed fresh.

- **TSS and acid**
  A balance of high TSS and acid would impart the good taste of pineapple. The most prominent feature of two of the new hybrids, viz. A25-34 (Josapine) and A54-47, is the very high TSS in the range of 16–17% which was significantly higher than the standard fresh eating cultivar Moris (14.4%) *(Table 2)*. The other genotypes have acceptable TSS with the exception of Gandul (10.8%) which is a canning variety whose low TSS can be rectified by addition of sugar during processing. For acid, the majority has a fairly high content ranging from 0.56% to 0.70%

with the exception of Tailung (0.44%). The low acid content and fairly high TSS makes Tailung a sweet but rather bland tasting variety. On the other hand, the balance of high TSS and high acid of A25-34 (Josapine) and A54-47 gives these fruit their excellent aroma and taste.

Flowering and fruiting characteristics

In the study on earliness of fruiting, the development period of the fruit was divided into the period required for flower emergence after hormoning and the period required for maturation of fruit after emergence of flower *(Table 3)*.

The earliest maturing genotypes were A25-34 and A54-47 whose fruit can be harvested at 438–439 days after planting. Compared with these, the latest maturing varieties like Gandul and C17-33 were delayed by at least 2 weeks. The difference in harvesting time between the early and late varieties was due primarily to the time taken for the inflorescence to form the fruit, which in the case of early varieties took 94–97 days while late varieties took 112–113 days. There was little difference in the time taken for the inflorescence to emerge after hormone application. All genotypes flowered 30–34 days after hormoning *(Table 3)*.

The difference of just 2 weeks is hardly significant in reduction of juvenility in pineapple. There appears to be little scope in selection of early varieties based on telescoping the period for inflorescence emergence or the time for fruit development. Other avenues for reduction of the crop maturation period must be sought. In this trial, all genotypes were hormoned at 311 days after planting. It appeared that during this time period, some of the varieties have already developed quite enormous plants and it may be questioned whether such large plants may be necessary for optimal fruit production. If not, then perhaps the plants may be hormoned earlier and more significant saving in time for crop maturation may be realised. To have a clearer understanding, the relationship of fruit size and plant mass for each genotype need to be examined.

Correlation and linear regression between fruit weight and plant weight

Correlations between fruit weight and plant weight were carried out for each genotype to establish their relationship. The results indicated that the correlations were positive and significant in seven of the genotypes with the exception of A04-16. The correlation coefficients ranged from 0.41* to 0.86**. For A04-16, however, no correlation was detected, implying that fruit weights cannot be predicted from the size of the plants. It was interesting to notice that A04-16 had the largest fruit but the smallest plant in this trial.

A more detailed linear regression of fruit weight with plant weight was performed individually for all genotypes.

Table 3. Flowering and fruit development characteristics of eight pineapple genotypes

Genotype	Hormone to flower (days)		Flower to fruit (days)		Planting to fruit (days)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
A04-16	31.75	1.50	105.25	2.87	448.00	2.00
A12-45	31.00	0.00	107.00	2.31	449.00	2.31
A25-34	30.25	0.50	97.00	0.00	438.25	0.50
A54-47	34.24	1.26	93.75	6.65	439.00	5.66
C17-33	31.00	0.00	113.25	2.50	455.25	2.50
Gandul	31.00	0.00	112.00	0.00	454.00	0.00
Moris	32.00	1.15	105.75	4.27	448.75	3.50
Tailung	33.50	0.58	101.75	0.50	446.25	0.50

Note: All genotypes were hormoned at 311 days after planting

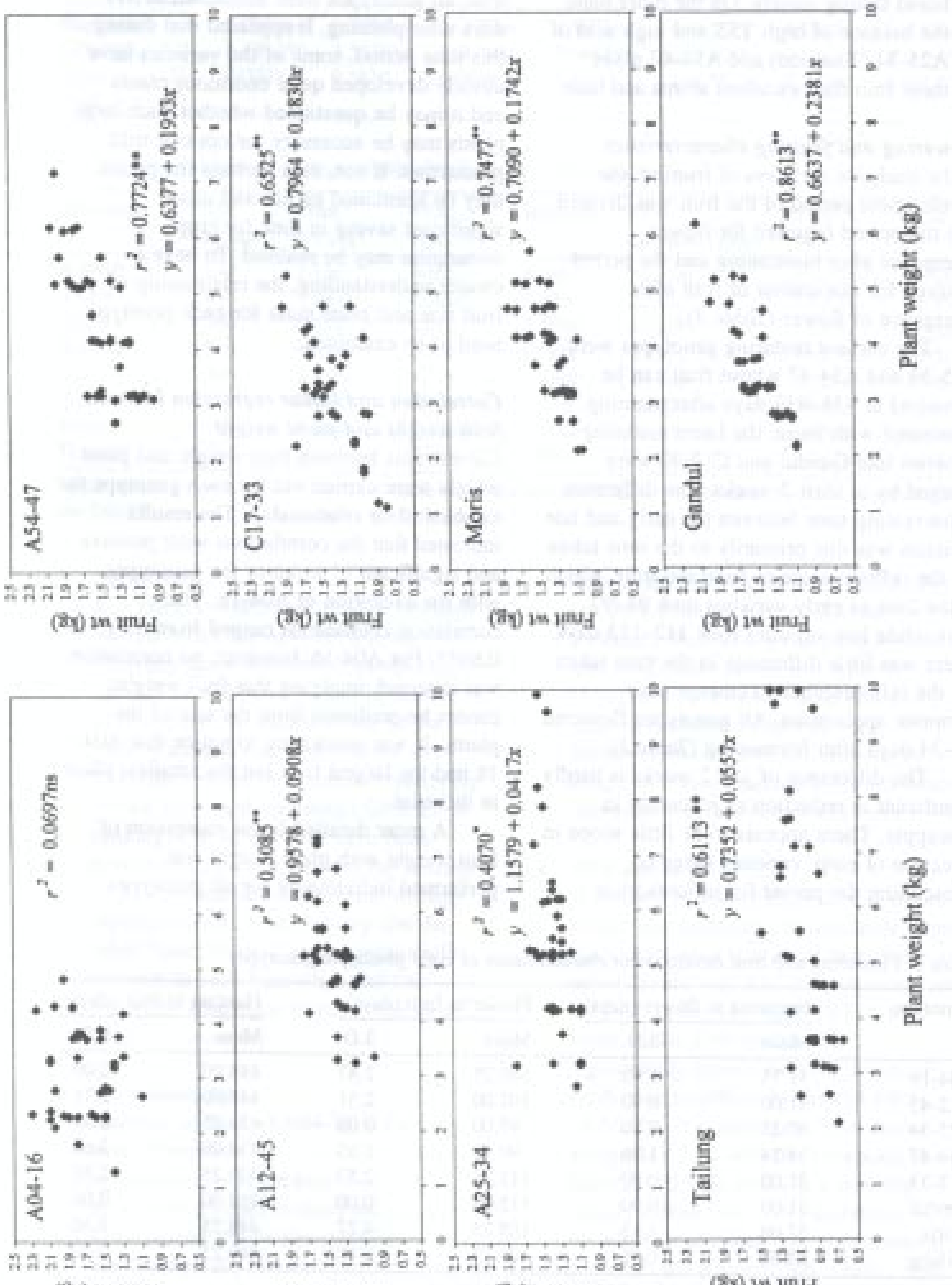

Figure 1. Relationship between fruit and plant weights for eight pineapple genotypes

The results *(Figure 1)* may be categorised into three types of regression responses:

1. Random: There were no correlations and the points were scattered in random distribution. This is clearly illustrated by A04-16 in *Figure 1* in which the regression cannot be used to predict the fruit weight from a certain plant mass.
2. Weak correlation: The correlation coefficients were around 0.41–0.61 and the gradients (b) of the regression lines were rather 'flat' and less than 0.1, i.e. for every kilogram increase in plant weight, the corresponding increase in fruit weight was no more that 10%. Genotypes A12-45, A25-34 and Tailung represent this group.
3. Strong correlation: The correlation coefficients were from 0.65 to 0.86 and the gradients (b) of the regression lines were steeper – ranging from 0.17 to 0.24. This implies that the fruit weight is strongly dependent on plant mass and each kilogram increase in plant mass would bring about a concomitant 17–24% increase in fruit weight. The varieties in this group are A54-47, C17-33, Moris and Gandul.

The behavior in fruiting and its implication on early maturation can be seen in further examination of these three groups. It is rather obvious that the Group 1 sole representative, viz. A04-16, had the capability of producing an economic-sized fruit even with very small plants, and that plant mass increase after a certain point was not effective in increasing fruit weight further. This would explain the absence of correlation between fruit and plant size for this genotype. It would be interesting to carry out further trials to 'force' A04-16 much earlier to see if the correlation exists when plant size is much smaller, say in the region of 1–2 kg. Right now, plant weights of 2–3 kg appeared to have the capacity to bear 1.5–2 kg fruit – not very different from fruit carried on plants twice their size. The correlation and linear association may begin to be evident perhaps at the younger age and smaller size of the plants. In this case, there seemed to be very good potential for breeding of early maturing varieties using A04-16 as the parent.

For genotypes with the 'flat' regression slopes such as A12-45, A25-34 and Tailung, it appears that there is also good potential for improving early maturation. The small gradient of the regression slope suggests that there is not much justification in keeping these genotypes in the field for a time longer than is necessary to get an acceptable fruit size. This is because the size increase was very slow in relation to the plant development. For A25-34 (Josapine) for example, it did not matter too much if the plants were 5 kg or 9 kg, the fruit weight would have still hovered around 1.3–1.5 kg. For these genotypes, the prospects of getting early bearing is promising because fruit size is more or less set at a certain plant mass and this can be achieved quite early in the case of A12-45 or A25-34. It would appear that a 3–4 kg plant might be sufficient for supporting an economic-sized dessert fruit of 1.3 kg.

For the third group, however, the steeper regression slopes reflect that there was clear dependency of fruit weight on plant mass. For these varieties, fruit size can be manipulated by timing of flowering hormone, the later it is done, the larger would be the plant size resulting in a concomitantly larger fruit. This is particularly true for the established cultivars like Gandul and Moris which are currently hormoned at 10–12 months or so after planting depending on the size that is required. In the case of Moris, some growers deliberately delay hormoning to obtain fruit that are larger than 2 kg. Studies on Smooth Cayenne in Cote D'Ivoire by Maléieux (1993) indicated that this variety could also be classified in this group which showed strong dependency of fruit weight on plant mass. For genotypes in this group, there is little likelihood in improving earliness in fruit bearing.

Conclusion

There are three phases in the crop cycle of the pineapple, i.e. planting to hormoning, hormoning to inflorescence emergence, and inflorescence emergence to fruit harvest. For improving early fruit bearing, there seemed to be limited prospects in telescoping the periods for inflorescence emergence and fruit maturation. The best avenue for obtaining early fruit bearing appeared to be in shortening the period of plant growth for hormoning. This requires the selection of genotypes with high fruit-to-plant weight ratio, i.e. genotypes that are more competent in channeling photosynthates to fruit rather than to vegetative growth. Such genotypes can be hormoned very early since they have the capability of bearing economic-sized fruit on very small plants. Indeed, with early bearing varieties, it may be possible to cultivate pineapples strictly on an annual cycle rather than over 15–18 months as in the present practice.

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