

6. SUMMARY

The exploitation of heterosis or hybrid vigour in agricultural crops started seven decades ago with the advent of the hybrid corn. It had, since then, extended to many important cereals such as barley, wheat, sorghum, rice and a host of horticultural crops notably tomatoes, onions, watermelons and a wide variety of vegetables. F_1 hybrids, in general, have better vigour and yield over inbreds and conventional varieties, but the prospects for their cultivation on commercial scales depend to a considerable extent on the economic feasibility in the production of the hybrid seeds.

Production of F_1 seeds requires that the seed-bearing parent be devoid of pollen to prevent production of self-pollinated seeds that would contaminate the purity of the hybrid stock. This can be achieved by hand emasculation and use of gametocides, but by and large, the most successful would be to use male sterility either in the cytoplasmic or gametic form. Production of hybrid seeds using any of these methods would incur additional costs. These added inputs can only be economically justified if the margin of returns of the F_1 hybrids over conventional varieties are higher than the added costs involved in their production. This forms the basis for the present studies on production of F_1 hybrids in papaya.

There are two major parts in the present studies. The first part investigated the seed production behaviour and trends of six inbred lines of papaya using a complete diallel cross system. This part of the study yielded results on the seed production capabilities of the inbreds both as maternal (seed-carrying) or paternal (pollen) parent, and the variation in seed yields as affected by the age of trees, locations and sex of the flowers (hermaphrodite v female). The results from this part of the study allowed an estimation on the pricing of hybrid seeds based on the cost of production of the seeds and the seeding rate for papaya.

The second part evaluated the performance of the F_1 hybrids over six environments. This part of the study provided information on the relative superiority of hybrids over their parents in terms of mean performance (heterosis) and stability. The results will answer the question on the economic justifications for added costs in the production of F_1 hybrids for papaya.

The results from the F_1 seed production study showed that the six inbred parents i.e. Sunrise Solo (So), Ekotika (Ek), Line 19 (19), Paris (Pa), Subang (Su) and Morib (Mo) were all compatible in their crosses and reciprocals, but they differed in their seed production

capabilities. Eksotika and Line 19 produced abundant seeds in excess of 1 000 seeds/fruit while Paris was the least seedy (690). Differences also arose when inbred lines were used as pollen donors, particularly in influencing seed quality. Line 19 was an undesirable male parent because when seeds developed as a result of fertilisation by Line 19 pollen, 27 % of the seeds were found to pre-germinate in the fruit.

Overall, Eksotika, Sunrise Solo and Line 19 were highest in gross seed yield because of the high fruit set and large number of seeds per fruit. The seed yield per 100 pollinations for these three inbreds ranged from 56 000 to 67 000 seeds when female flowers, which obviated emasculation, were used to produce the seeds. When hermaphrodite flowers were used, the seed yields dropped to 25% of the amount because of poor fruit set due to emasculation injury and lower seed number in hermaphrodite fruits. Despite this poor seed yield and increased costs in emasculation, it was still found to be economically feasible to produce hybrid seeds from hermaphrodite flowers for these three inbreds. The lucrative returns arising from a higher proportion of hermaphrodite trees from this seed source appeared to more than compensate for the poor seed yields and added seed costs.

Seed production was found to be also influenced by environments as well as by the age of the trees. Young trees of 9 - 12 months of age, appeared to yield 40% less seeds than older trees (18 - 24 months).

The overall results in the first part of the study showed that papaya is a prolific seed producer and because of the low seeding rate for papaya cultivation (50 - 100 g/ha), the cost of hybrid seeds will not stand in the way in the commercial cultivation of papaya hybrids. The present price of Eksotika II hybrid seed at RM 3 000 per kg means that only RM 150 - RM 300 / ha will be required as seed costs and this works out to be a meagre 1% of the total production cost for papaya cultivation. The price of RM 3 000 per kg is extremely lucrative for seed producers because they are expected to get, after 18 months, a return of RM 4.80 for every RM 1.00 they invest.

In the second part of the study, i.e. on evaluation of performance of hybrids over six environments, it was found that hybrids showed better performance than inbreds, particularly in characters related to vigour, precocity (earliness to flower) and yield. With regards to these characters, there was no question about the superiority of hybrids over the inbreds and sibs. In the combined yield over two harvests, the hybrids were 51.0% higher yielding than the better inbred parent. Even the sibs which were actually narrow cross hybrids, were about 2.5% better

yielding than the better inbred parent. The bulk in the difference in yield appeared to arise from the first harvest (9 - 12 months) where hybrids outyielded the better inbred parents by 90%. In the second harvest (13 -18 months), however, while there was still significant difference between hybrids and inbreds (41.5%), the gap was considerably reduced compared with the first harvest. The reason for the dramatic heterosis in yield appeared to stem from the fact that hybrids were vigorous and precocious and these factors translated to very early harvests for hybrids.

Heterosis for other characters such as fruit weight, height of fruiting, total soluble solids and fruit number was generally unimpressive. These characters apparently were strongly influenced by additive gene action and usually hybrids in these cases have mean values intermediate between the parents.

Significant GxE interactions were obtained in the majority of the 14 characters evaluated. Three methods were used in the analysis of GxE and estimation of the genotypes' stability. They were: distribution of means and CV (Francis and Kannenberg, 1978), non parametric ranking (Hühn, 1979) and rank sum and rank product (Kang, 1988; Schuster and Zschoche, 1981). The results showed that the stability exhibited by inbreds was more inclined towards the Type 1 (biological or static) while the hybrids have stability that was more of Type 2 (agronomic or dynamic). This implied that while inbreds enjoyed a good measure of uniformity (low CV) within the genotype, they were incapable of responding readily to favourable changes to the environment. The hybrids, on the other hand, were more plastic to the environmental changes and appeared to be able to exploit the favourable conditions to become better performers. This was reflected by the fact that performance of hybrids were not very different from the inbreds in poor environments, but under mediocre to favourable environments, the superiority of hybrids was very clear cut. It was estimated that the ceiling yield of papaya would be 298 t/ha over a full year of harvest. At the best environment, Pontian, the most prolific hybrid Mo x So, was estimated to have achieved 88% of the ceiling.

Simultaneous selection of mean and stability on the basis of scores accumulated from the three methods of GxE analysis showed that the majority of genotypes selected for vegetative vigour, earliness in flowering and high yield, came as expected, from the hybrids. However, for total soluble solids which reflected fruit quality, none of the hybrids were selected.

Recommendation of high yielding hybrids may be made based on their general and specific adaptabilities. Mo x So appeared to have good general adaptability, and can be recommended for most environments. Su x Pa appeared to be specifically adapted for poor environments and Mo x 19 was found to be specifically adapted for good environments. A mixture of Su x Pa and Mo x 19 may also be recommended to exploit the high yields of Mo x 19 under favourable environments and to reduce crop loss with Su x Pa in situations when environments turned adverse.

The prospects of F_1 hybrids for papaya did not appear to be restricted by the constraints in seed production which seemed to be the case for many other crops especially cereals. Their prospects were dimmed more by the fact that none of the hybrids in this study have high TSS % and good eating qualities. As a dessert variety, these hybrids will not be expected to be well received because they cannot compete with the better established Eksotika variety. There are however, two current areas in which they can be of potential use.

Their exceedingly high yields will be a definite advantage for the less fastidious downstream markets for purée, juice and canned products. An economic analysis using Mo x So (best hybrid) compared with Pa x Pa (best inbred) showed that farmers would stand to gain 57% higher income when the hybrid was cultivated for the processing industry.

The hybrids also appear to be good candidates for beating the papaya ringspot virus disease which is presently growing in importance in this country. Since they have the vigour and the early high yields, they can be cultivated on an annual basis in infected areas. An early economic harvest may be obtained before the trees are debilitated by the disease.

Although the prospects of the present set of F_1 hybrids as dessert varieties appeared bleak, there is great potential for improvement of fruit quality in hybrids. It is necessary for breeders to develop more inbred lines that are genetically diverse and have good eating qualities, so that F_1 progenies will show heterosis in vigour and yield while retaining their high fruit qualities.