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Heterosis in Eksotika x Sekaki papaya hybrids

(Heterosis di dalam betik hibrid Eksotika x Sekaki)

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Key words: *Carica papaya* L., papaya, heterosis, hybrid

Abstrak

Dua hibrid yang diperoleh daripada kacukan dua warisan Eksotika (L19 dan L20) dengan Sekaki dinilaikan di dua lokasi iaitu di Serdang (tanah mineral) dan di Pontian (tanah gambut). Pontian ialah lokasi yang lebih baik untuk tanaman betik, dengan purata hasil buah 3.8 kali ganda lebih tinggi dibandingkan dengan Serdang.

Heterosis (dibandingkan dengan induk yang lebih baik) dalam pengeluaran hasil adalah ketara, antara 47.5% bagi L20 x Sekaki hingga 72.5% bagi L19 x Sekaki. Heterosis dalam pengeluaran buah terhasil terutamanya daripada peningkatan berat buah hibrid dan bukan daripada peningkatan bilangan buah. Tiada heterosis didapati bagi bilangan buah, garis pusat batang dan jumlah pepejal larut.

Peningkatan hasil yang dramatik bagi hibrid L19 x Sekaki terjejas oleh kekerapan terjadinya (55%) buah berkarpel 'cat-faced'. Walau bagaimanapun, L20 x Sekaki mempunyai jumlah buah berkarpel yang boleh diterima dan bersama peningkatan hasil yang ketara serta kandungan gula yang lebih tinggi, berpotensi untuk menggantikan kultivar terkini, Sekaki.

Abstract

Two hybrids derived from crossing two Eksotika lines (L19 and L20) with Sekaki were evaluated at two locations i.e Serdang (mineral soil) and Pontian (peat soil). Pontian was the more favourable location for papaya, having a mean yield that was 3.8 times higher than Serdang.

Heterosis (over the better parent) in yield was evident, ranging from 47.5% for L20 x Sekaki to 72.5% for L19 x Sekaki. Heterosis in yield arose mainly from gain in fruit weight of hybrids rather than increase in number of fruits. No heterosis was found for fruit number, stem diameter and total soluble solids (TSS).

The dramatic yield increase in L19 x Sekaki hybrid was negated by the high occurrence (55%) of carpelloid or 'cat-faced' fruit. On the other hand, L20 x Sekaki had acceptable levels of this malady and with significant increase in yield and higher sugar content, may be a potential candidate for replacing the current Sekaki cultivar.

Introduction

Heterosis is the increase in yield, size and vigour of an organism arising from bringing together of unlike gametes to form a hybrid. Heterosis breeding is so significant in agriculture that there are hardly any

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commercial crops that had not included development of hybrids in their breeding programmes at one time or another. Many cereals like corn, sorghum, millet, barley, wheat, rice and horticultural crops like vegetables, fruits, flowers as well as pasture crops and fodder grasses have benefited in increased plant robustness and yield from heterosis breeding. The added advantage in hybrid varieties is the propriety and monopoly in seed production. By maintaining strict security of the inbred parental lines in the production of the hybrid seed, the dissemination and sale of these seeds can be effectively regulated.

In the past, there has been very little interest in F_1 hybrids of papaya with the exception of the work reported by Chang and Wu (1974) and Subramanyam and Iyer (1984) who demonstrated marked heterosis in crosses between varieties, and Mekako and Nakasone (1975) who reported heterosis from interspecific crosses. In the last decade, however, the interest in hybrid papaya seemed to have revived.

Chan (1992) reported heterosis in yield and fruit quality of F_1 hybrids developed from closely related sib crosses. One of such crosses between Line 19 and Line 20 resulted in the development of Eksotika II, the first commercial F_1 hybrid papaya in Malaysia. In later work with wide crosses between unrelated varieties, Chan (1995) reported dramatic hybrid yield increases of 69% in the first season crop compared with the better yielding parent. Many of these hybrids, while having improved vigour, early fruit bearing and much improved yield, however, did not make it as commercial cultivars because of poor eating qualities.

In Hawaii, the first transgenic papaya called 'Rainbow' with resistance to ringspot virus is an F_1 hybrid between the conventional Kapoho and the transformed SunUp (Gonsalves 1998). The evident heterosis in vigour and yield of the hybrids has spurred further hybridization work particularly with local, diverse varieties.

This study reports the performance of hybrids developed from crosses between Sekaki and Eksotika (Line 19 and Line 20). Sekaki and Eksotika are currently the most important papaya cultivars in the country. Sekaki with larger fruits is mainly grown for domestic consumption while Eksotika forms the backbone of the papaya export industry amounting to RM60 million annually. Both cultivars have the strengths and weaknesses that appear to complement each other. Further, with their diversely different genetic backgrounds, hybridization between the two appears logical for the development of improved hybrids.

Materials and methods

Sekaki pollen was collected and pollinated onto stigmas of emasculated hermaphrodite flowers of two Eksotika lines i.e. Line 19 and Line 20. The seeds of the hybrids L19 x Sekaki and L20 x Sekaki, together with the three parents were grown at two locations i.e. Serdang (mineral soil) on 8 April 1999 and at Pontian (peat soil) on 4 August 1999. The plants were grown in a randomized complete block design in four replicates and with ten plants per plot. The plants were spaced at 1.8 m within rows and 2.7 m between rows. Cultural practices followed the recommendations of Chan et al. (1991).

The number of fruits produced and the number of carpelloid fruits (malformed 'cat-faced' fruits) were counted over a period from first fruiting till 12 months after seed sowing (season 1) and from 13–18 months after seed sowing (season 2). Carpelloid fruits occur when stamens fuse to the ovary tissues of the flower. On development of the fruit, the areas of fusion show up as unsightly scars. Fruit weight and total soluble solids (taken with a hand refractometer) of each tree were derived from the means of ten randomly sampled fruits taken from the tree. Yields at season 1 and season 2 were computed from the product of fruit number and mean fruit weight. Trunk diameter was used as an indicator of tree vigour and was measured

15 cm from ground level, 6 months after seed sowing.

Heterosis was measured by the percentage of the hybrid performance that exceeded its better parent i.e.

$Hp = [(F_1 - BP)/BP] * 100$,

where Hp = (%) heterosis estimate, F_1 = hybrid mean, BP = better parent mean. Combined analysis of variance over the two locations were carried out for each character with genotypes taken as fixed effects while effects from locations and replicates within locations were considered random.

Results and discussion

Effects of location and genotype were significant for all characters (*Table 1).* However the interaction between genotype and location (G x L) were also all significant with the exception of stem diameter. This implies that while genotypes may differ from location to location, these differences were not always expressed in the same, equal proportions among the genotypes.

Examining the performance of genotypes over each location in *Table 2* gives a clearer picture of the nature of this G x L interaction. In the case of carpellody percentage, the occurrence of G x L was quite evident because genotypes did not behave in a predictable trend over the two locations. While the mean for location indicated that Serdang (14.24%) had the higher occurrence than Pontian (7.08%), genotypes like L19 and L20 deviated from this trend and in fact, showed higher incidence in Pontian *(Table 2).*

For the other characters that showed significance in G x L interaction such as fruit number, fruit weight, yield and TSS, pinpointing the cause of the interaction was more difficult. In the case of fruit number, weight and yield, all genotypes consistently showed higher mean values in Pontian than Serdang. In the case of TSS, again all genotypes without exception showed higher mean values at Serdang compared with Pontian. There seemed to be no discrepancies in the trend of genotypes behaviour over locations yet significance in G x L interaction was detected. The likely explanation is that although there was a set trend of genotypes over locations, the differences in genotypic means over locations were disproportionate among genotypes. This is also sometimes described as a 'change-in-rate' interaction.

The results also indicated that Pontian, on peat soil, was a better environment for growing papaya. Trees were generally more robust with higher yields. However, the fruit quality in terms of sugar content (TSS) may be compromised. The superior yield performance of papaya on peat has also been previously reported (Chan 1985, 1995). The mean yield at Pontian was an astonishing 3.8 times higher than at Serdang, most of the difference accounted for by the higher number of fruits and to a smaller extent, due to an increase in fruit size. The high water table and continuous moist, friable peat are conducive to vigorous growth and high yields. However, because of the heavy crop load and soft peat conditions, staking of trees is necessary to prevent tree lodging.

Heterosis estimates in *Table 3* show that hybrids were not as vigorous as the better parent as indicated by the negative values (–4.0% to –5.6%) for stem diameter. This is contrary to findings of previous studies (Chan 1995) where hybrids showed clear heterosis in stem diameter ranging from 9.4% to 11.2%. It appears therefore, heterosis in plant vigour is dependent on the genotypes used in the crosses. In this study, the Sekaki was rather weak in vegetative growth and hybrids derived from this parent were also not very robust.

Heterosis was evident in yield ranging from 47.5% to 72.5%, L19 being the parent with better combining ability due to higher number of fruits and heavier fruit weight. Heterosis in yield apparently arose from the fruit weight component rather than from fruit number. Heterosis in fruit weight was 2.2% to 13.5% while for fruit number, both

Table 1. Analysis of variance mean square values

	df	Stem diameter	TSS	Fruit number	Fruit weight	Carpelloid percentage	Yield 1	Total yield
Location (L)	1	499.8**	83.54**	38 506**	1 624 573**	512.8**	14 863**	83 698**
Replicate	3	324.0 ns	0.18 ns	105 ns	9 145 ns	22.9 ns	119 ns	287 ns
Genotype (G)	4	2 274.2**	9.58**	2 078**	1 392 227**	1 548.1**	1 691**	4 725**
G x L	4	130.2 ns	0.61**	622**	118 972**	448.5**	612**	2 696**
Error	27	63.0	0.10	33	7 973	18.0	37	57
Total	39							

* = significantly different at $p < 0.05$
** = significantly different at $p < 0.01$
ns = not significantly different

hybrids recorded negative estimates (–17.2% to –26.0%). Heterosis estimates for carpellody were extremely high, from 175% to 727%. This of course, is undesirable and would probably be detrimental to the recommendation of these hybrids as commercial varieties. This is particularly true for L19 x Sekaki hybrid where 35% of the fruits may be unmarketable because of this malady. Hybrids did not show heterosis for TSS. This is because TSS is largely controlled by additive genes and hybrids

Table 2. Genotypic means over two locations

	Stem diameter (cm)		Fruit number		Fruit weight (g)		Yield (kg)		Carpellody (%)		TSS (%)	
	SER	PON	SER	PON	SER	PON	SER	PON	SER	PON	SER	PON
L19	118.95	122.35	49.05	128.15	598.0	771.0	29.48	98.36	1.08	6.24	14.28	11.94
L20	112.00	124.37	38.90	113.17	593.4	723.6	23.02	85.78	0.78	1.63	13.66	10.21
Sekaki	96.30	102.25	27.60	62.90	1115.0	1584.2	31.22	98.04	5.11	1.08	11.26	9.03
L19 x Sekaki	110.95	116.75	32.45	98.90	1202.6	1861.1	38.56	184.37	51.55	17.81	13.08	9.89
L20 x Sekaki	111.10	117.30	35.90	90.50	1082.6	1675.7	38.67	152.09	12.44	6.25	12.64	9.49
Mean	109.86	116.93	36.78	98.83	918.32	1321.4	32.19	123.68	14.24	7.08	12.98	10.11

SER = Serdang, PON = Pontian

Table 3. Heterosis in hybrids compared with the better parent

		L19	L19 x SEKAKI	SEKAKI	L20 x SEKAKI	L20
Stem	Mean	120.6	113.8	99.3	114.2	119.0
	Heterosis (%)		(–5.6)		(–4.0)	
Fruit number	Mean	88.6	65.6	45.2	63.2	76.3
	Heterosis (%)		(–26.0)		(–17.2)	
Fruit weight	Mean	684.5	1 531.8	1 349.6	1 379.1	654.2
	Heterosis (%)		13.5		2.2	
Yield	Mean	63.9	111.4	64.6	95.3	54.2
	Heterosis (%)		72.5		47.5	
Carpellody	Mean	4.2	34.9	3.5	9.52	1.2
	Heterosis (%)		727.9		175.1	
TSS	Mean	13.1	11.4	10.1	11.06	11.9
	Heterosis (%)		(–12.4)		(–7.3)	

Negative heterosis is indicated in parenthesis

Table 4. Heterosis in yield over seasons and locations

		L19	L19 x SEKAKI	SEKAKI	L20 x SEKAKI	L20
SEASON 1	Serdang	16.70	26.77	20.83	25.85	12.42
	Heterosis (%)		28.50		24.10	
	Pontian	43.18	89.86	50.97	76.48	34.92
	Heterosis (%)		76.30		50.00	
SEASON 2	Serdang	12.78	11.79	10.39	12.82	10.60
	Heterosis (%)		(–7.7)		20.90	
	Pontian	55.18	94.51	47.07	75.61	50.86
	Heterosis (%)		71.30		48.70	
TOTAL YIELD	Serdang	29.48	38.56	31.22	38.67	23.02
	Heterosis (%)		23.50		23.90	
	Pontian	98.36	184.37	98.04	152.09	85.78
	Heterosis (%)		87.40		55.10	

Negative heterosis is indicated in parenthesis

tend to have intermediate values between the parents (Chan 1995).

Examining the heterosis of yield in greater detail, the effects of season and location were elucidated in *Table 4.* Results of yield in season 1 which represented the first six months of harvest and season 2, the harvest in the following six months showed that heterosis was more marked in the first season harvest compared with the second. For L19 x Sekaki, heterosis was 76.3% in season 1 and 71.3% in season 2 while for L20 x Sekaki, it was 50.0% and 48.7% respectively. In the extreme case at Serdang, heterosis for L19 x Sekaki was 28.5% in the first season and declined to a negative value of –7.7% in the second season. Differential heterosis over seasons was generally more pronounced (74.8% vs 32.6%) in previous trials involving wide crosses (Chan 1995). The higher heterosis in the first season harvest is due to the precocious fruiting habit of hybrids.

Differential heterosis over locations was evident with Pontian, the better environment consistently expressing higher heterosis than Serdang over the two seasons of harvest. Overall, hybrids at Pontian showed heterosis in total yield ranging from 55.1% to 87.4% compared with 38% at Serdang. Hybrids tend to respond proportionately to favourable changes in environment in which case, they have the Type II or agronomic stability (Lin et al. 1986).

The question finally asked on completion of this study is the prospect of the F_1 hybrid being used as commercial cultivars. The most evident advantage of the hybrids is of course, the dramatic leap in yield which in the case of L19 x Sekaki was a spectacular 72.5%. Weighed against this, however, is the high percentage of carpelloid fruits of hybrids, particularly L19 x Sekaki which can climb as high as 55%. Such high occurrence would negate any favourable yield increases and immediately precludes it from being a candidate for release. The other hybrid L20 x Sekaki, while exhibiting lower heterosis in yield, has acceptable levels of carpellody between 6.25% to 12.44%. Its fruit size and appearance are quite similar to Sekaki and its sugar content (TSS 12.6%) is also a definite improvement. All things considered, therefore, L20 x Sekaki, with a definite edge in yield and taste over Sekaki, may be a suitable candidate to replace this cultivar.

Conclusion

The hybrids derived from crossing two lines of Eksotika and Sekaki showed dramatic increase in yield. One of the hybrids i.e. L19 x Sekaki cannot be recommended as a commercial cultivar because of severe carpellody problem. L20 x Sekaki, on the other hand, has acceptable levels of carpellody and improved yield and sugar content which make it a potential candidate to replace the current Sekaki cultivar.

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