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HETEROSIS IN YIELD AND FRUIT QUALITY PARAMETERS IN THE PAPAYA HYBRIDS DEVELOPED IN SRI LANKA

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ABSTRACT

Rathna, the only recommended Papaya inbred variety in Sri Lanka and recently developed local inbred Cp-13 were used to exploit heterosis in Papaya. Papaya hybrid Rathna x Cp-13 and it's reciprocal Cp-13 x Rathna derived from the inbred lines (Cp-13 and Rathna) were evaluated with the parental lines and control (Red Lady) in RCBD with three replications in Low country wet zone Sri Lanka at the Fruit Research and Development Institute, Horana from 2011-2013. Heterosis was measured in total number of fruits per tree per year, total fruit weight (kg/tree/year), mean fruit weight (g), percent total soluble solids (TSS) and percent unmarketable fruits. Yield was highest in the hybrid followed by it's reciprocal without significant difference between them. Insignificant difference in the interaction between genotype and year in the characters concerned showed that the consistence in performance of hybrids over two years in Low country wet zone. The heterosis in total fruit yield (kg) in the hybrid (32%) and it's reciprocal (25%) with significant heterosis in percent TSS (26.5 and 24.4%, respectively) and significant decline in percent unmarketable fruits (-3.7 and -7.8 respectively) reflect the hybrid and it's reciprocal might be potential candidates for Low Country Wet Zone, Sri Lanka.

KEYWORDS: Breeding, Fruit quality, Heterosis, Hybrids, Papaya,

INTRODUCTION

Papaya (*Carica Papaya* L.) is native to Tropical America and occupies an important place in global fruit trade including Sri Lanka as it is popular fresh fruit that bring remarkable economical advantages. It earns rapid return to investment due to it's early maturation and heavy yielding nature. Papaya is increasingly becoming more important in commercial plantings in Sri Lanka though all seed requirement of all popular hybrids are imported. This indicates the necessity of developing local Papaya hybrids with high yield potential and better quality. Therefore, Papaya breeding programmes have been initiated to exploit heterosis by developing F_1 hybrids. Heterosis is the increase in such characteristics as size, growth rate, fertility, and yield of a hybrid over those of it's parents. The interest on exploiting hybrid vigour in Papaya was arisen with some genetical and inheritance studies. Hybrid vigour for number of fruit per plant, fruit yield per plant and fruit size was reported by different authors (Hofmeyr, 1938; Nakasone, 1952; Dai, 1972; Ahamad, 1973; Shah and Shanmugavelu, 1975) in certain Papaya cross combinations.

Chang and Wu (1974) and Subramanyam and Lyer (1984) demonstrated marked heterosis in crosses between Papaya varieties, and Mekakao and Nakasone (1975) reported heterosis from interspecific crosses. In the last decade of 20th century, the added interest in hybrid Papaya has been recorded (Chan, 2001). Chan (1992) reported heterosis in yield and fruit quality of F_1 hybrids developed from closely related sib crosses. One of crosses between Line 19 and Line 20 resulted in Eksotica II, the first commercial hybrid Papaya in Malaysia. Chan (1995) reported dramatic yield increase of 69% in hybrids in first season crop compared with the better yielding parent. Though having improved vigour, early fruit bearing and improved yield many of these hybrids were with poor eating qualities (Chan, 1995). There are increasingly more F_1 hybrids in market at present. Papaya Ring Spot Virus (PRSV) resistant 'Red Lady 786' from Thailand and 'Sintha' from Philippines are well known F_1 hybrids grown in Sri Lanka. Tainung 1-3 and 'Golden Maradol' are also superior F_1 hybrids. "Rainbow" the genetically modified (GM) Papaya with PRSV resistance is a F_1 hybrid between the transgenic Sunup and non transgenic commercial cultivar 'Kapoho' (Gonsalves, 1998). The F_1 GM hybrid from Hawaii is the 'Laie Gold' developed from a cross between 'Kamiya' and 'Rainbow' F_2 (Fitch *et al.*, 2002).

Comparatively less effort has been taken in variety development in Papaya in Sri Lanka resulting a very few varieties available. 'Rathna' the only recommended Papaya variety in Sri Lanka, was developed by generation advancement of some introduced seeds from Malaysia and recommended for cultivation (Medagoda, 1998). It produces fruits of convenient size (600-800 g) for domestic market of attractive orange colour flesh with sweet flavor (Brix value 13-15), hard outer peel with longer storability. However, it is susceptible to PRSV (Medagoda, 1998). The inbred Cp-13 was developed by the current Papaya breeding programme at Fruit Research and Development Institute (FRDI), Horana. Although it is a high yielder (40-50 kg/plant/year) with medium to large fruit size (1.2 - 2 kg) with moderate resistance to PRSV, the quality of flesh is undesirable with pale red colour and low brix value (10). It's thin peel has a tendency to occur the diseases like powdery mildew, anthracnose and bumpy fruit production. As both inbreds have the strengths and weaknesses that appear to complement each other, they were used to develop hybrids in Papaya. Therefore, objective of the present study was to evaluate the hybrid (Rathna x Cp-13) with its reciprocal (Cp-13 x Rathna), parents (Rathna and Cp-13) and a control (Red Lady) to exploit heterosis.

MATERIAL AND METHODS

Hybrid seeds were produced by reciprocal crosses made on stigmas of female flowers of two parental lines Rathna and Cp-13. Hybridization using female flowers will obviate emasculation and the seed production is also four times higher compared with using hermaphrodites (Chan and Mac, 1993) Pollen was collected from opposed hermaphrodite flowers of each parent. Pollinated flowers were covered with oil paper bags. The seeds of parental inbred lines were produced by self pollination by covering hermaphrodite flowers with oil paper bags. The most important Papaya inbred lines in world today are propagated from generation to generation from seeds obtained by selfing hermaphrodite flowers (Chan 2009). Flowers were bagged one day before flower opens. The bags secured over the flowers by tying up them using a thread. Generally, anther burst and self pollination occur within the flower and the resultant fruit inside the bag comes out by bursting the bag (Chan, 2009).

Fruits of both cross pollinated and self pollinated were harvested when the yellow patches started to develop. The sarcotesta of extracted seeds were removed and dried in room temperature. Removal of sarcotesta promotes germination (Yahiro, 1979). Method for drying Papaya seeds are either under sun or air drying in the shade (Chan, 2001). Seed count of ten randomly selected fruits which were used to produce hybrid seeds was taken to find the seed setting efficiency of both cross combinations. The seedlings were raised in black polythene pots. One month old seedlings of the hybrid (Rathna x CP-13), its reciprocal (CP-13 x Rathna), parents (Rathna and Cp-13) and control (Red Lady) were planted in a field at FRDI, Horana during July 2011and continued up to 2013.

Ten plants of each genotype were replicated three times in Randomized Complete Block Design. The plants were spaced at 2.5 m within and between rows and maintained as Department of Agriculture (DOA) recommendations. Total number of fruits per tree, total yield per tree (kg), fruit weight (g), TSS and per cent unmarketable fruit was recorded over a period from first fruiting to 12 months (year one) and subsequent twelve months (year two). TSS was measured using hand held refractometer of ten randomly sampled fruits taken from each treatment. The number of fruits produced and the number of fruits malformed were counted to work out the percent unmarketable fruits. The experiment was repeated over two years and data was analyzed as repeated measures using ANOVA followed by F test. Significant differences of genotypes were detected by mean comparison using LSD.

Heterosis was measured by the percentage of the hybrid performance that exceeded its better parent (heterobeltosis):

$$Hp = [(F1 - BP) / BP] \times 100$$

Where Hp= Heterosis estimate (%), F_1 = hybrid mean, BP= Better parent mean. Cp-13 was considered as better parent for calculating percent heterosis.

RESULTS AND DISCUSSION

Analysis of variance showed that the effect of genotype was significant for all characters while the effect of year was only significant for yield traits. The mean weight of fruit, TSS (%) and unmarketable fruits (%) were not significantly varied from year to year. All yield traits, the number of fruits per plant, total fruit weight per plant and mean fruit weight were highest in two hybrids without significant difference between them (Table 1). Field trials of F_1 hybrid 'Frangi' and its reciprocal cross which developed by the Malaysian Agrifood Corporation Berhad (MAFC) from hybridization between 2 inbred parents '(LSGC1' and 'LSGC2) showed that there were no significant differences in performance (Adina, 2014).

Table 1. Comparison of genotypic means of hybrids of papaya with parents.

Variety/ Hybrid	Number of fruits/tree/year	Total fruit weight (kg/tree/year)	Mean fruit weight (g)	TSS (%)	Unmarketable fruit (%)
Rathna	30 b	25.6 c	791 d	13.4 a	7.7 a
Cp-13	33 ab	39.4 b	1212 b	9.8 c	3.8 b
Rathna x Cp-13	36 a	52.1 a	1501 a	12.4 b	3.7 b
Cp-13 x Rathna	38 a	49.3 a	1451 a	12.2 b	3.5 b
Red Lady	17 c	19.1 d	1128 c	13.0 a	3.0 b
LSD	5.00	4.52	79.13	0.589	1.48
CV (%)	9.41	8.4	3.49	1.97	16.4

The hybrids recorded intermediate TSS values between parents while significantly higher than Cp-13 (Table 1). TSS is largely controlled by additive genes and hybrids tend to have intermediate values between the parents (Chan, 1995). One of the parents 'Rathna' produced significantly higher number of unmarketable fruits (Table 1). At cooler temperatures Solo Papaya have a great number of pentandria and carpelloid fruits that are not marketable (Awed, 1958). However, the hybrid, it's reciprocal and the

better parent (Cp-13) produced fruits with uniform shape and size resulted lower percentage of unmarketable fruits (Table 1). According to variance and mean of genotypes the hybrid and it's reciprocal are probable to select as promising. In one of the Papaya trials, two parameters the variance and mean of genotype were used as criteria for selection (Chan and Ooi, 1975). The best parameters would be genotypes with low variance (high uniformity) and the most desirable mean value (Chan, 2009).

The interaction between genotype and year (G x Y) was not significant for all characters except mean fruit weight shows the consistence in performance of hybrids over two years in Low Country Wet Zone environment. A stable genotype is one that shows a very small GE interaction in the character concerned namely the genotype is consistence in performance regardless of the changes in a set of environment (Chan, 2009).

Heterosis in yield in hybrid and it's reciprocal was ranging from 32.2 to 25.1% (Table 2). In an experiment to study the hybrid vigour in Papaya, three crosses showed more than 22% positive heterosis over better parent (Mansha *et al.*, 1999). Positive heterosis for fruit yield was also reported by several authors (Hofmeyr, 1938; Nakasone, 1952; Dai, 1972; Ahamad, 1973; Shah and Shanmugavelu, 1975; Chang and Wu, 1974; Subramanyam and Lyer, 1984 and Chan, 1992). These results showed occurrence of over dominance for fruit yield (Mansha *et al.*, 1999).

Table 2. Heterosis in hybrids of papaya compared with better parent.

Character		Rathna	Cp-13	Rathna x Cp-13	Cp 13 x Rathna	Red Lady
Number of fruits /tree/year	Mean	30	33	36	38	17
	Heterosis (%)			9.1	15.1	
Total fruit weight (kg /tree/year)	Mean	25.6	39.4	52.1	49.3	19.1
	Heterosis (%)			32.2	25.1	
Mean Fruit weight (g)	Mean	791	1,212	1,501	1,451	1,128
	Heterosis (%)			23.8	19.7	
TSS (%)	Mean	13.4	9.8	12.4	12.2	13.0
	Heterosis (%)			26.5	24.4	
Unmarketable fruit (%)	Mean	7.68	3.81	3.67	3.51	3.03
	Heterosis (%)			(-3.7)	(-7.8)	

Note: Negative heterosis is indicated in parenthesis

Heterosis in number of fruits per tree was lower in the hybrid and it's reciprocal (9.1 and 15.1%, respectively) when comparing heterosis in total fruit weight per tree (kg)

(Table 2). Thus, heterosis in yield is apparently arisen from the component of fruit weight rather than from number of fruits. Similar observation was reported previously (Chan, 2001). TSS of the hybrid and it's reciprocal showed that significant heterosis over better parent (Table 2). Heterosis estimates for unmarketable fruits were negative in the hybrid and it's reciprocal indicating that they produce better quality fruits (Table 2).

When considering heterosis in detail, the effects of the season were elucidated in Table 3. The yield in year one and year two showed that heterosis was more expressed in first year harvest than that of the second year. Heterosis was 34.2 in year one and 29.5 in year two in the hybrid (Rathna x Cp-13), while for it's reciprocal (Cp 13 x Rathna), it was 27.2 and 22.2, respectively. Chan (1995) reported dramatic hybrid yield increases of 69% in first season crop compared with the better yielding parent. The higher heterosis in the first season harvest is due to precocious fruiting habit of hybrids (Chan, 2009).

Table 3. Heterosis in yield of papaya hybrids over two years.

		Rathna	Cp-13	Rathna x Cp-13	Cp 13 x Rathna	Red Lady
Year 1	Mean	29.9	43.6	58.5	55.5	24.3
	Heterosis (%)			34.1	27.2	
Year 2	Mean	21.2	35.2	45.6	43.0	13.9
	Heterosis (%)			29.5	22.2	

Seed setting was 650 per fruit when Rathna was used as the maternal parent while it was 222 when Cp-13 was used. Although two hybrids performed comparable to each other based on fruit yield and fruit quality, Rathna x Cp- 13 was selected as the most suitable candidate for commercial papaya cultivation considering the feasibility of its hybrid seed production.

CONCLUSIONS

The hybrid Rathna x Cp-13 showed the highest yield followed by it's reciprocal without significant difference between them. Insignificant difference in the interaction between genotype and year in the characters concerned showed that the consistence in performance of hybrids over two years in the Low Country Wet Zone. The heterosis in total fruit yield (kg) in the hybrid (32%) and it's reciprocal (25%) with significant heterosis in TSS (26.5 and 24.4%, respectively) and significant decline in percent unmarketable fruits (-3.7 and -7.8 respectively) reflect the hybrid and it's reciprocal might be potential candidates for the Low Country Wet Zone, Sri Lanka. Since the seed production of the cross Rathna x Cp-13 was 3 times higher than in Cp-13 x Rathna, it will be the ideal candidate to meet the seed requirement for commercial cultivation.

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