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STUDIES ON HETEROSIS IN SIX *EUCALYPTUS* SPECIES

M. Paramathma, C. Surendran & R.S. Vinaya Rai

Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam - 641 301, India

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PARAMATHMA, M., SURENDRAN, C. & VINAYA RAI, R.S. 1997. Studies on heterosis in six *Eucalyptus* species. Six species of *Eucalyptus* viz. *E. alba, E. camaldulensis, E. microtheca, E. tereticornis, E. polycarpa* and *E. torelliana* were subjected to a complete diallel mating. The cross between *E. polycarpa* and *E. torelliana* was characterised by post-fertilisation abortion. An evaluation of the remaining four parents and their 12 hybrids for heterosis among parents revealed *E. alba* and *E. tereticornis* to record higher than mean performance. Among the hybrids, those of *E. alba* × *E. tereticornis* registered highest heterosis for most characters.

Key words : *Eucalyptus* - combining ability - heterosis - reciprocal cross - relative heterosis - heterobeltiosis - standard heterosis

PARAMATHMA, M., SURENDRAN, C. & VINAYA RAI, R.S. 1997. Kajian heterosis dalam enam spesies *Eucalyptus*. Enam spesies *Eucalyptus* iaitu *E. alba, E. camaldulensis, E.microtheca, E.tereticornis, E. polycarpa* dan *E. torelliana* tertakluk kepada pengawasan kacukan dialel penuh. Silangan antara *E. polycarpa* dan *E. torelliana* dicirikan oleh pengguguran selepas persenyawaan. Penilaian ke atas empat lagi pokok induk serta 12 hibridnya menunjukkan bahawa *E. alba* dan *E. tereticornis* mencatatkan heterosis yang lebih tinggi daripada prestasi purata. Di antara hibrid tersebut, hibrid *E. alba* × *E. tereticornis* mencatatkan heterosis tertinggi bagi kebanyakan ciri.

Introduction

The occurrence of interspecific hybridisation in *Eucalyptus* had been the subject of controversy from the days of the earliest workers (Brett 1937) until the first conclusive evidence was presented (Penfold & Willis 1961). Heterotic effects in *Eucalyptus* have since been reported by several workers (Pryor 1957, Venkatesh & Sharma 1976, 1977a, b, Venkatesh 1981, Surendran 1982). These reports document heterosis for growth characters including wood yield, height, dbh, growth rate, stem volume, number of leaves, girth at base, number of branches, internode length, leaf breadth, leaf length breadth ratio, etc. *Eucalyptus maideni* x *E. bicostata* showed 12% better growth than the *E. maideni* parent while in the reciprocal cross the hybrid was 20% better than the *E. bicostata* parent (Pryor 1957).

With the extensive use of hybrid *Eucalyptus* in Brazil (Chaperon 1976, Campinhos 1980), there has been a resurgence of interest in the use of hybrid. Considering the large number of species in the genus, there is need for more extensive studies in interspecific hybridisation. This paper considers hybrids among six little-investigated species.

Materials and methods

Six species of *Eucalyptus*, viz. *E. alba, E. camaldulensis, E. microtheca, E. tereticornis, E. polycarpa* and *E. torelliana,* were subjected to a full diallel mating (Jinks & Hayman 1953, Mather & Jinks 1971) at the Forest College and Research Institute, Mettupalayam (11° 19'N , 76° 56' E; 300 m a.s.l.; annual rainfall, 830 mm; soil pH 7.1) during 1989-1992. The sources of the six species are given in Table 1.

Table 1. Details of six *Eucalyptus* species

Species	Notation	CSIRO seed lot number	Locality
E. alba	P_1	12966	South New Guinea
E. camaldulensis	P_2	12479	Pet Ford, Queensland
E. microtheca	P_3	12479	Karnatha, Wales
E. tereticornis	P_4	11889	New Guinea
E. polycarpa	P_5	12012	East Papua
E. torelliana	P_6	12139	South Coast

Six-month-old progenies along with their parents were replicated thrice using a replicated block design (Panse & Suknatme 1961). The seedlings were planted at a spacing of 2 × 2 m in single row (replication) comprising 15 plants. Six months after planting, the following parameters were recorded on ten randomly selected seedlings in each replication: (i) height, (ii) root collar diameter, (iii) internode length, (iv) number of leaves, (v) leaf length, (vi) leaf breadth, (vii) leaf temperature, (viii) photosynthetically active radiation (PAR), (ix) diffusive resistance, and (x) transpiration rate. From the above primary data, the following secondary data were derived: (i) leaf length/breadth ratio (l/b ratio), (ii) sturdiness quotient, (iii) volume index, and (iv) suitability index.

Sturdiness quotient is the ratio of height in cm to root collar diameter in cm, and volume index is diameter squared times height and expressed in cm^3. Suitability index is the summation of height, diameter, and survival, each expressed as percentage of their respective maxima (Ghosh *et al.* 1981).

The physiological parameters described, viz. leaf temperature, diffusion resistance, transpiration rate and PAR were measured on fully expanded leaves using a steady state porometer (Licor 1600, USA) between 1100 h and 1300 h, which coincides with peak physiological activities. PAR was expressed in $\mu mol\ m^{-2} s^{-1}$, diffusive resistance in $s\ cm^{-1}$, transpiration rate in $\mu g\ H_2O\ cm^{-2} s^{-1}$ and leaf temperature in °C.

Heterosis values were estimated as the percentage deviation of the F_1 performance from the midparent, better parent and best parent. The significance of heterosis was tested by *t*-test following Wynne *et al.* (1970). For each character, three scores of +1, 0 and -1 were assigned as follows: if parent/hybrid mean falls above m+s (m=mean, s=standard error of mean) a score of +1 was given; if parent/ hybrid means fall between m+s and m-s, and below m-s, scores of 0 and -1 respectively were given (Rathinaswamy & Jagadesan 1984).

Results and discussion

The direct or reciprocal cross involving the two species, *E. polycarpa* and *E. torelliana,* with others or between themselves failed to set seeds, due possibly to species incompatibility or post-fertilisation abortion (Pryor 1978). This narrowed down the number of species to just four. Among the four parents, *E. alba* showed the highest mean performance for six characters, viz. height, collar diameter, leaf number, leaf breadth, volume index and suitability index (Table 2). Of the species, *E. microtheca* was characterised by poor mean performance. Among the hybrids, those of *E. alba* and *E. tereticornis* recorded the highest mean performance for eight characters, viz. height, collar diameter, internode length, leaf number, leaf length, leaf breadth, volume index and suitability index followed by its reciprocal cross for four characters. Economic traits, e.g. volume index and suitability index were the highest with $P_2 \times P_3$. Hybrid vigour was attributed to enhanced activity of endogenous gibberellin (Rood *et al.* 1983, Rood & Pharis 1987, Bate *et al.* 1988).

Mean performance scores earned by each parent revealed parents P_1 and P_4 to be superior with four and two scores respectively. Parent P_3 earned a score of one and parent P_2 had the negative scores cancelling out the positive (Table 3).

The potential of a parent for use in hybridisation or in a cross for commercial hybrid production may be judged by comparing the mean performance of the parents (Venkateswaralu & Singh 1982). Against this backdrop, *E. alba* and *E. tereticornis* indicate themselves to be ideal candidates.

A knowledge of the extent of the heterosis would help in the choice of the best cross for selection of superior segregants in advanced generations. Although heterosis relative to mid-parent (relative heterosis), better parent (heterobeltiosis) and best parent were all estimated in the present study, the discussion is restricted to the best parent value since several workers have established the superiority of heterosis relative to best parent over other approaches (Kadambavanasundaram 1983, Grakh & Chaudhary 1985). Kadambavanasundaram (1983) also stressed the need for commercial standard heterosis based on the best cultivar for commercial exploitation of hybrid vigour. Given the ever increasing area under man-made plantations of the genus *Eucalyptus,* species developments of commercial cultivars are a distinct possibility.

From a perusal of the heterosis values (Table 4), the following crosses among a total of 12 were characterised by positive heterosis for the characters noted (Table 5).

Table 2. Mean performance of parents and hybrids-6 MAP in a 4 x 4 diallel mating in *Eucalyptus*

Parent/ hybrid	Height (cm)	Collar diameter (cm)	Internode length (cm)	Leaf number	Leaf length (cm)	Leaf breadth (cm)	Leaf l/b ratio	Leaf temperature (°C)	PAR (µmol $m^{-2}s^{-1}$)	Diffusive resistance ($s cm^{-1}$)	Transpiration rate (µg.H_2O $cm^{-2} s^{-1}$)	Volume index	Sturdiness quotient	Suitability index
Parent														
P_1	58.4	0.72	3.5	43.7	11.3	5.2	2.2	30.7	1655.0	6.7	2.4	30.6	80.8	194.5
P_2	51.4	0.62	3.1	29.3	12.4	3.5	3.5	32.4	1609.0	6.2	2.5	19.9	83.0	165.1
P_3	50.3	0.54	2.9	38.4	16.8	1.2	14.2	33.0	1645.3	8.0	1.9	15.1	93.0	177.7
P_4	51.8	0.66	4.0	40.3	12.7	2.8	4.4	33.2	1669.0	7.7	2.3	23.2	78.5	174.1
Hybrid														
$P_1 \times P_2$	58.1	0.88	4.3	55.3	13.5	4.5	2.9	32.6	1526.3	5.8	2.3	45.9	66.1	209.9
$P_1 \times P_3$	67.6	0.90	3.4	47.2	14.8	4.8	3.1	32.7	1626.3	6.0	2.2	55.6	74.7	203.2
$P_1 \times P_4$	101.8	1.36	4.7	91.0	18.0	6.5	2.7	33.5	1559.9	7.3	2.8	190.6	74.7	285.3
$P_2 \times P_1$	74.3	1.04	4.4	55.4	15.3	5.5	2.9	31.7	1681.3	6.0	2.3	84.6	73.4	235.7
$P_2 \times P_3$	87.8	1.13	4.3	80.9	16.0	4.3	3.7	31.9	1714.3	7.1	2.3	111.7	78.4	247.1
$P_2 \times P_4$	90.3	1.19	3.9	74.2	14.6	4.7	3.1	30.7	1766.3	4.9	2.8	119.2	75.9	251.5
$P_3 \times P_1$	57.8	0.76	4.0	37.3	11.3	5.4	2.1	32.8	1254.6	8.2	2.2	33.8	76.0	194.4
$P_3 \times P_2$	71.6	1.00	4.0	67.3	13.2	3.9	3.4	31.2	1689.3	7.1	2.3	75.8	70.1	206.1
$P_3 \times P_4$	64.1	0.84	3.5	38.0	14.2	5.0	2.8	32.8	1741.3	8.8	2.2	46.3	76.1	216.5
$P_4 \times P_1$	87.3	1.16	4.6	79.3	16.9	5.7	2.9	32.7	1672.3	7.2	2.3	120.0	75.6	251.6
$P_4 \times P_2$	82.5	1.01	3.7	64.1	14.4	4.2	3.5	32.7	1663.0	7.4	2.3	88.0	82.7	233.6
$P_4 \times P_3$	67.7	0.85	3.7	59.9	17.3	1.5	11.6	33.6	1632.0	8.7	2.1	56.3	78.5	215.5
Parent mean	53.0	0.63	3.5	37.9	12.3	3.2	6.1	32.4	1644.5	6.9	2.3	22.2	83.8	172.8
SE_d	2.6	0.03	0.1	3.6	0.4	0.3	0.4	0.4	33.0	0.5	0.1	7.6	2.8	4.7
CD 5%	5.4	0.07	0.3	7.3	0.8	0.5	0.8	0.9	67.4	1.1	0.1	15.6	5.6	9.7
Hybrid mean	75.6	1.01	4.0	62.5	15.0	4.7	3.7	32.4	1659.5	7.0	2.3	85.7	75.2	229.2
SE_d	4.6	0.06	0.3	6.2	0.7	0.4	0.7	0.7	52.2	0.8	0.1	13.2	4.8	18.2
CD 5%	13.5	0.18	0.7	17.9	1.9	1.3	2.1	1.2	165.3	1.7	0.3	38.2	13.8	23.7
Grand mean	70.2	0.91	3.9	56.4	14.5	4.3	4.3	32.4	1656.4	7.1	2.3	69.8	77.3	215.2
SEd	3.1	0.04	0.2	4.2	0.5	0.3	0.5	0.5	44.1	0.6	0.1	10.4	3.1	10.5
CD 5%	8.8	0.11	0.5	11.6	1.3	0.8	1.0	0.9	106.3	1.3	0.2	24.1	9.0	15.7

Table 3. Mean performance score tally

Parent/ hybrid	Height	Collar diameter	Internode lenght	Leaf number	Leaf length	Leaf breadth	Leaf l/b ratio	Leaf temperature	PAR	Diffusive resistance	Transpiration rate	Volume index	Sturdiness quotient	Suitability index	Total score
P_1	+1	+1	0	+1	-1	+1	-1	-1	0	0	+1	+1	0	+1	+4
P_2	0	0	0	0	0	+1	-1	0	0	0	+1	-1	0	0	0
P_3	0	-1	-1	0	+1	-1	+1	+1	0	+1	-1	-1	+1	+1	+1
P_4	0	+1	+1	0	+1	0	-1	+1	0	0	0	0	-1	0	+2
$P_1 \times P_2$	-1	0	+1	-1	-1	0	-1	0	-1	-1	0	-1	+1	0	-5
$P_1 \times P_3$	-1	0	-1	-1	0	0	0	0	0	-1	0	-1	0	0	-5
$P_1 \times P_4$	+1	+1	+1	+1	+1	+1	-1	+1	-1	0	+1	+1	0	+1	+8
$P_2 \times P_1$	0	+1	+1	-1	0	+1	-1	0	0	-1	0	0	0	0	0
$P_2 \times P_3$	+1	+1	+1	+1	+1	0	0	0	+1	0	0	+1	0	0	+7
$P_2 \times P_4$	+1	+1	0	+1	0	0	0	-1	+1	-1	+1	+1	0	+1	+5
$P_3 \times P_1$	-1	-1	0	-1	-1	+1	-1	0	0	+1	0	-1	0	-1	-5
$P_3 \times P_2$	0	0	0	0	-1	-1	0	-1	0	0	0	0	+1	0	-2
$P_3 \times P_4$	-1	-1	-1	-1	-1	0	-1	0	+1	+1	0	-1	0	0	-5
$P_4 \times P_1$	+1	+1	+1	+1	+1	+1	-1	0	0	0	0	+1	0	+1	+7
$P_4 \times P_2$	+1	0	-1	0	0	0	0	0	0	0	0	0	-1	0	-1
$P_4 \times P_3$	-1	-1	-1	0	+1	-1	+1	+1	0	+1	-1	-1	0	0	-2

Table 4. Expression of heterosis in sets of 4 x 4 diallel crosses in *Eucalyptus* (%)

Hybrid	Height			Collar diameter			Internode length			Leaf number			Leaf length		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
$P_1 \times P_2$	5.7	- 0.5	- 0.5	31.1*	22.1	22.1	31.1*	22.1	7.4	31.5	26.5	26.5	13.7	8.8	- 19.9
$P_1 \times P_3$	24.4*	15.8	15.8	42.6*	24.8	24.8	5.5	- 2.4	- 14.2	15.1	8.1	8.1	5.2	- 12.1	- 12.0
$P_1 \times P_4$	84.7**	74.2**	74.2**	96.6**	88.4**	88.4**	25.4*	17.8	17.8	149.2**	108.2**	108.2**	50.9**	43.5**	6.8
$P_2 \times P_1$	35.2*	27.1	27.1	54.9**	44.2*	44.2*	35.5*	26.2	11.0	31.8	26.8	26.8	29.1**	23.5*	9.2
$P_2 \times P_3$	72.5**	70.5**	50.2*	93.7**	81.2**	56.2*	44.9**	43.6*	8.9	105.5**	100.0**	85.2*	9.7	- 4.7	- 4.7
$P_2 \times P_4$	74.9**	74.3**	54.6**	84.9**	79.3**	64.5**	10.9	- 2.5	- 2.5	112.9**	83.8*	69.7*	17.2*	16.4	13.2
$P_3 \times P_1$	6.4	0.9	0.9	20.0	5.1	5.1	23.7*	14.3	0.4	9.3	- 14.6	- 14.6	- 19.3*	- 32.6**	- 32.6**
$P_3 \times P_2$	40.8*	39.2*	22.6	74.8**	63.6*	41.1*	34.8*	33.6*	1.3	70.8*	66.7*	54.0*	- 9.2	- 21.2*	- 21.2*
$P_3 \times P_4$	25.6*	23.7	9.8	39.2*	26.6	16.1	0.2	- 12.5	- 12.5	12.3	- 0.9	- 12.9	- 3.5	- 15.8*	- 15.8*
$P_4 \times P_1$	58.4**	49.5*	49.5*	67.7**	60.8*	60.8*	23.3*	15.9	15.9	117.1**	81.5*	81.4*	42.0**	35.0*	0.5
$P_4 \times P_2$	59.7*	59.1**	41.1*	56.9**	52.2*	39.6*	5.7	- 7.0	- 7.0	84.1*	58.9**	46.8	15.3	14.5	- 14.6
$P_4 \times P_3$	32.6*	30.6	15.9	41.4*	28.6	17.9	6.5	- 7.0	- 7.0	76.9*	56.1	37.1	17.7*	2.7	- 2.7

* = significant at 5% level ; ** = signification at 1% level;
di = relative heterosis ; dii = heterobeltiosis ; diii = heterosis over best parent.

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Table 4. Expression of heterosis in sets of 4 x 4 diallel crosses in *Eucalyptus* (%) (cont.)

Hybrid	Leaf breadth			Leaf l/b ratio			Leaf temperature			PAR			Diffusive resistance		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
$P_1 \times P_2$	4.8	- 12.2	- 12.2	2.7	- 16.9	- 79.2**	3.4	0.7	- 1.6	- 0.9	- 2.3	- 3.7	- 3.5	- 13.2	- 17.2
$P_1 \times P_3$	50.4*	- 6.9	- 6.8	- 62.0*	- 78.1**	- 24.8**	2.8	- 0.7	- 1.2	- 14.5*	- 5.2	- 5.2	- 18.3	- 25.0*	- 25.0*
$P_1 \times P_4$	63.1**	26.3	26.3	- 17.0	- 37.9	- 80.7**	4.8	0.9	0.9	- 3.1	- 3.9	- 5.3	1.4	- 5.4	- 8.7
$P_2 \times P_1$	28.2	7.3	7.3	2.1	- 17.4	- 79.3**	0.4	- 2.2	- 4.5	5.1	3.6	2.1	0.2	- 10.3	- 25.0*
$P_2 \times P_3$	80.5*	22.1	17.6	- 57.8**	- 73.6**	- 73.6**	- 2.3	- 3.2	- 3.7	6.4	4.1	4.1	- 3.4	- 11.2	- 11.2
$P_2 \times P_4$	48.0*	34.2	9.4	- 21.8	- 29.3	- 78.1**	- 6.3	- 7.5	- 7.4	5.0	4.4	1.2	- 24.2	- 35.9*	- 38.7*
$P_3 \times P_1$	69.1**	4.6	4.6	- 73.8**	- 84.9*	- 84.9*	3.1	- 0.5	- 1.0	1.2	0.5	0.5	11.5	2.5	2.5
$P_3 \times P_2$	68.3*	13.8	- 23.2	- 61.7**	- 76.1**	- 76.1**	4.6	- 5.5	- 6.0	4.8	2.6	2.6	5.6	11.2	- 11.2
$P_3 \times P_4$	147.5**	77.3*	- 2.6	- 69.7**	- 80.1**	- 80.1	0.8	- 1.1	- 1.1	17.4*	15.8*	15.8	12.1	10.0	10.0
$P_4 \times P_1$	44.1*	11.5	11.6	- 11.2	- 33.5	- 79.4**	2.2	- 1.6	- 1.5	3.9	3.1	1.6	0.5	- 6.3	- 10.0
$P_4 \times P_2$	31.4	19.2	- 19.5	- 12.2	- 20.6	- 75.4**	- 0.2	- 1.4	- 1.3	4.8	4.2	1.0	12.9	- 4.5	- 7.5
$P_4 \times P_3$	23.5	- 45.3*	- 70.0**	24.5	- 18.2	- 18.4	1.6	1.3	1.4	0.7	- 0.8	- 0.8	10.8	- 8.7	8.7

* = significant at 5% level; ** = signification at 1% level;
di = relative heterosis; dii = heterobeltiosis; diii = heterosis over best parent.

Table 4. Expression of heterosis in sets of 4 × 4 diallel crosses in *Eucalyptus* (%) (cont.)

Hybrid	Transpiration rate			Volume index			Sturdiness quotient			Suitability index		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
$P_1 \times P_2$	- 6.5	- 8.4	- 8.4	81.5	49.8	49.8	- 19.2*	- 18.1*	- 15.7*	16.7*	7.8	7.8
$P_1 \times P_3$	2.8	- 6.7	- 10.5	143.6	81.6	81.6	- 13.9	- 19.6	- 4.8	9.1	4.4	4.4
$P_1 \times P_4$	19.4*	16.6*	12.0	607.9**	522.8**	522.8**	- 6.1	- 4.8	- 4.8	63.6**	46.6**	46.6**
$P_2 \times P_1$	- 3.9	- 5.9	- 5.9	234.6*	176.1*	176.1*	- 10.3	- 9.1	- 6.4	31.1**	21.1*	21.1*
$P_2 \times P_3$	5.2	- 6.3	- 6.3	539.0**	460.7**	264.6*	- 10.8	- 5.5	0	44.1**	38.9**	26.9*
$P_2 \times P_4$	16.6*	12.0	12.0	452.5**	413.4**	288.9**	- 5.9	- 3.3	- 3.3	57.6**	52.3**	29.2**
$P_3 \times P_1$	0.3	- 9.0	- 12.7	48.2	10.5	10.5	- 2.5	- 5.9	- 3.1	4.4	- 0.1	- 0.1
$P_3 \times P_2$	6.4	- 5.2	- 5.2	338.8*	280.6*	147.5	- 20.3*	- 15.5	- 10.7	20.4*	16.2	6.1
$P_3 \times P_4$	1.9	- 6.7	- 12.2	142.1	99.5	51.1	- 11.2	- 3.0	- 3.0	30.5**	21.7*	11.2
$P_4 \times P_1$	- 2.6	- 3.5	- 7.5	345.6**	291.5**	291.5**	- 5.0	- 3.6	- 3.6	44.3**	29.3**	29.3**
$P_4 \times P_2$	- 5.3	- 8.1	- 8.1	308.0**	279.1*	187.2*	2.4	- 5.3	- 5.3	46.4**	41.4**	20.1*
$P_4 \times P_3$	- 1.9	- 10.3	- 15.6	194.2*	142.5	83.7	- 8.4	0	0	29.8**	21.1*	10.6

* = significant at 5% level; ** = signification at 1% level;
di = relative heterosis; dii = heterobeltiosis; diii = heterosis over best parent.

Table 5. Hybrids with positive heterosis

Crosses	Character
$P_1 \times P_4$, $P_2 \times P_1$, $P_2 \times P_3$, $P_2 \times P_4$, $P_4 \times P_1$, $P_4 \times P_2$	Suitability index
$P_1 \times P_4$, $P_2 \times P_3$, $P_2 \times P_4$, $P_4 \times P_1$, $P_4 \times P_2$,	Height
$P_1 \times P_4$, $P_2 \times P_1$, $P_2 \times P_3$, $P_2 \times P_4$, $P_3 \times P_2$, $P_4 \times P_1$ $P_4 \times P_2$	Collar diameter
$P_1 \times P_4$, $P_2 \times P_3$, $P_2 \times P_4$, $P_3 \times P_2$, $P_4 \times P_1$, $P_4 \times P_2$	Leaf number
$P_1 \times P_4$, $P_2 \times P_1$, $P_2 \times P_3$, $P_2 \times P_4$, $P_4 \times P_1$, $P_4 \times P_2$	Volume index

But in respect of characters like internode length, leaf length, leaf breadth, leaf length/breadth ratio, PAR, diffusive resistance, transpiration rate, leaf temperature and sturdiness quotient, negative heterosis was evident in most crosses.

This negative expression of heterosis may be attributed to the existence of non-allelic interactions (Hayman 1957, 1958). Such crosses could be exploited to throw up transgressive segregations for improvement of *Eucalyptus* (Tilak Raj Gupta 1981, Venkateswaralu & Singh 1982).

The scope for exploitation of hybrid vigour will depend on (i) the magnitude of heterosis, (ii) the high mean performance of hybrids over the best parent, and (iii) the biological feasibility of large scale production of hybrid seed. Among the twelve crosses, the cross $P_1 \times P_4$ (*E. alba* × *E. tereticornis*) registered heterosis for most of the characters like volume index (522.8%), leaf number (108.2%), collar diameter (88.4%), height (74.2%) and suitability index (46.6%) (Table 4). This cross also registered the highest cumulative score of 8 (Table 3).

It was further observed that crosses involving parents of high mean performance, viz. *E. alba* and *E. tereticornis,* resulted in high heterosis. High heterotic expression of hybrids was directly related to high mean performance of hybrids and such results were earlier reported (Dhanakodi 1990). The hybrids of *E. alba* x *E. tereticornis* are worthy of commercial exploitation.

Heterosis is dependent on the mean of the concerned parents. Obviously, there is every possibility of getting a cross with high mean performance but with low heterosis if parental performance is also high. On the contrary, there can also be a cross with poor mean performance but high heterotic response if the parental performance is poor. For instance, the hybrid $P_4 \times P_3$ had positive heterotic expression for height (15.9%), collar diameter (17.9%), leaf number (37.1%), volume index (83.7%) and suitability index (10.6%) but the mean performance was less than the hybrid mean.

The high degree of natural cross pollination (Pryor 1961, Moran & Bell 1983, Griffin & Cotterill 1988) can be exploited to promote unaided crosses in these four species through suitable orchard designs. The possibility of a rapid emasculation and availability of abundant pollen will also facilitate controlled pollination.

A large number of seeds resulting from each act of low seed rate, and successful vegetative propagation methods, especially in hybrids (Campinhos & Ikemori 1977, Campinhos, 1980, Destremau *et al.* 1980, Zoblel & Talbert 1984, Mascarenhas *et al.* 1988, Mascarenhas & Muralidharan 1989) are some of the biological advantages that will result from the exploitation of hybrid vigour in this genus.

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