International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(2): 1547-1552

Received: 22-01-2019
Accepted: 23-02-2019

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Estimation of heterosis for seedling growth traits in *Bauhinia variegata* L

Tesfaye Ashine and IK Thakur

Abstract
Hybridization plays an important role in tree improvement programme as it enables creation of new recombinants with favorable traits that could be utilized for increased productivity. Aiming at estimating heterosis and identifying superior *Bauhinia variegata* hybrids, ten genotypes involving 6 females (P_3, P_8, P_{16}, P_{24}, P_{27}, and P_{32}) and 4 males (P_{12}, P_{13}, P_{14} and P_{17}) were crossed using Line x Tester Mating Design. The resulting 24 F_1 hybrids along with parents were raised in the mist chamber of the Department of Tree Improvement and Genetic Resources, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2017-2018 in a Randomized Block Design (RBD) with three replications. Percentage mid-parent and better-parent heterosis was estimated for seedling growth traits. Hybrid $P_8 \times P_{12}$ revealed maximum and desirable positive mid parent (19.89%) and better parent (13.07%) heterosis for seedling height and positive desirable mid and better parent heterosis for number of leaves per plant. Hybrid $P_{16} \times P_{13}$ showed maximum positive significant better parent (11.34%) heterosis for collar diameter. Also $T_3 \times T_{17}$ showed maximum positive mid parent heterosis (44.72%) for number of primary branches while $T_{32} \times T_{13}$ had maximum mid parent (169.81%) and better parent (118.91%) heterosis for number of leaves per plant. Hybrid $T_3 \times T_{12}$ had maximum mid parent (35.27%) and better parent (33.14%) heterosis for leaf area while $T_3 \times T_{14}$ exhibited maximum mid parent (12.09%) and better parent (7.52%) heterosis for internodal distance. The hybrids $P_{16} \times P_{14}$, $P_{32} \times P_{17}$ and $P_3 \times P_{17}$ could be used for future breeding program. The present results revealed that hybrids had sustained hybrid vigour both for seedling growth traits when compared with its parents even at nursery stage.

Keywords: Hybridization, recombinants, hybrid vigor, heterosis

1. Introduction

Bauhinia variegata is a medium-sized deciduous tree with a short bole and spreading crown attaining a height of up to 15 m. It is planted in garden, park and roadsides as ornamental plant in many warm temperate and sub-tropical regions. It commonly grows in the sub-Himalayan tract and outer Himalayas from the Indus River eastwards across Assam and also in dry forests of east, central and south India (Anonymous, 1983) [2]. In India it is one of the important fodder species on which farmers bank up during the winter lean period when the grasses are dry, less digestible and unpalatable. Its leaves are rich in mineral and proximate composition which makes it highly nutritious and palatable (Thakur, 2010) [23].

The species grows well in soils of medium fertility that are either droughty or moist. It commands a good reputation of wind firmness, wide adaptability, frost and drought resistance, coppicing and high aesthetic value (Anonymous, 1983) [2]. While the species is most frequently planted for its ornamental qualities the bark is used as an astringent in tanning and dyeing and the leaves and flower buds as a vegetable (Bailey, 1941) [4]. The various parts of the plant viz., flower buds, flowers, stem, stem bark, leaves, seeds and roots are practiced in various indigenous systems of medicine and popular among the various ethnic groups in India for the cure of variety of ailments (Arvind *et al*., 2012) [3].

Genetic improvement of trees can be practiced through many options like traditional breeding, heterosis breeding, mutation breeding, intra/interspecific hybridization and genetic transformation (Divakara *et al*., 2010) [7]. The exploitation of heterosis is a common objective in plant breeding. Heterosis in trees is evident in citrus and oil palm. Commercial exploitation of heterosis has been one of the driving forces behind the rapid and extensive development of the seed industry. Heterosis breeding has allowed yield breakthroughs in several crops including cross-pollinating, often cross-pollinating and self-pollinating species (Soehendi and Srinives, 2005) [20]. Application of heterosis breeding can boost yield in forest trees.

The objective of the current study was to determine the heterotic response of major growth characters in *Bauhina variegata* for improved fodder production. The results can be used in guidelines for plant breeders to commercially produce F_1 hybrids for establishing *Bauhinia* plantations under Agroforestry systems.

Materials and Methods

Six parental genotypes [P_3 (Kathua), P_8 (Giripul), P_{16} (Solan), P_{24} (Narag), P_{27} (Dhaulakuan) and P_{32} (Sahastradhara)] were used as female parents (lines). Each was hand-pollinated by pollen from four genotypes [P_{12} (Mandi), P_{13} (Nahan), P_{14} (Kunihar) and P_{17} (Paonta Sahib)] that were used as male parents (teters). The study was conducted in the mist chamber of the Department of Tree Improvement and Genetic Resources, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) India during 2017-2018. The study site is located at an elevation of 1200 m above mean sea level in north-west of Himalayas and lies between 30º51' N latitude and 76°11' E longitude. The experimental area is hilly, marked with elevations, depressions and has a gentle slope towards the southeastern aspect. The area experiences a wide range of temperature with a minimum of 2 ^{0}C in winters to a maximum of 32.6 ^{0}C in the summers. Hand pollination was done by taking pollen from matured male flowers of the male parent to pollinate the receptive stigma of the chosen female flower of the female parent to generate a 6x4 line x tester hybrid seeds. The F_1 seeds and seeds from the ten parental genotypes were sown in polybags containing potting mixture of sand, clay and FYM (2:1:1). The sown seeds were watered regularly till seedlings got good vigor. The seedling growth traits *viz*: seedling height, collar diameter, number of primary branches, number of leaves per plant, leaf area, intermodal length and petiole length were measured monthly starting from one month after sowing for up to six months.

Analysis of variance was performed to test the significance of difference among the genotypes for the characters studied as suggested by Panse and Sukhatme (1957). The percent increase or decrease of F_1 hybrids over mid parent as well as better parent was calculated to estimate possible heterotic effects for above mentioned parameters as below

$$\text{Better-parent heterosis} = \frac{F_1 - B_P}{B_P} \times 100$$

$$\text{Mid-parent heterosis} = \frac{F_1 - M_P}{M_P} \times 100$$

Where, F1 = Mean performance of hybrid

B_P = Mean performance of better-parent

M_P = Mean of mid- parent

The't' test was manifested to determine whether F1 hybrid means were statistically different from mid parent and better parent means. The heterosis was tested by critical difference at 5 per cent level of significance for error degrees of freedom as follows, For testing heterosis over mid parent; SE (M_P) = $\sqrt{3Me/2r}$

For testing heterosis over better parent; SE (B_P) = $\sqrt{\frac{2\ Me}{r}}$

Where, M_e = error variance

r = replication

Results

The analysis for seedling height, collar diameter, number of primary branches, number of leaves per plant, leaf area, internodal distance and petiole length are presented in Table 1. The mean squares due to genotypes were highly significant ($P<0.05$) for all traits indicating that the genotypes under study were highly variable.

Table 1: Mean squares for seedling growth traits in *Bauhinia variegate*

Source of Variation	DF	Seedling height	Collar diameter	No. of primary branches	No. of leaves per plant	Leaf area	Petiole length	Internodal length
Replication	2	71.43	0.15	0.28	0.66	18.01	0.74	0.37
Genotypes	33	85.95*	0.50*	1.76*	92.35*	48.72*	1.13*	0.78*
Error	66	16.25	0.28	0.12	1.41	13.95	0.05	0.30

The mean performance of parental genotypes and their hybrids for seedlings growth traits are presented in Table 2. Parents P_{16} (Solan) and P_{32} (Sahastradhara) though statistically comparable had tallest seedlings compared to rest of the parents. Parents P_3 (Kathua) and P_{24} (Narag) recorded the largest collar diameter. P_{24} (Narag) and P_{32} (Sahastradhara) though statistically comparable gave the highest number of primary branches compared to others. Parents P_{27} (Dhaulakuan) and P_{24} (Narag) recorded the highest number of leaves per plant. Parent P_{14} (Kunihar) exhibited the highest value for leaf area and petiole length while P_{17} (Paonta Sahib) recorded the highest internodal distance (Table 2).

Table 2: Mean performance of parents and their hybrids for seedling growth traits in *B. variegate*

WS	Seedling height (cm)	Collar diameter (mm)	No. of primary branches	No. of leaves per plant	Leaf area (cm^2)	Petiole length (mm)	Internodal distance (cm)
P_3 (Female)	83.56	5.83	2.50	17.66	38.10	2.93	8.38
P_8 (Female)	79.59	4.43	2.49	10.00	35.47	2.77	8.49
P_{16} (Female)	86.52	3.82	2.97	11.56	40.58	3.27	8.18
P_{24} (Female)	77.92	4.79	4.21	23.22	40.05	2.87	8.19
P_{27} (Female)	83.40	4.72	2.52	25.83	46.74	3.53	7.13
P_{32} (Female)	85.04	4.41	3.37	11.78	41.19	3.50	8.78
P_{12} (Male)	71.60	4.38	2.67	12.00	39.34	3.07	7.96
P_{13} (Male)	75.69	3.88	2.98	7.33	45.93	3.23	8.96
P_{14} (Male)	80.87	3.84	2.56	13.33	48.76	3.70	7.69
P_{17} (Male)	84.44	4.39	3.33	16.89	36.20	2.70	9.37

Hybrids							
$P_3 \times P_{12}$	87.04	4.40	2.31	10.22	52.38	3.53	9.10
$P_3 \times P_{13}$	82.77	4.37	2.56	9.17	45.66	2.93	7.91
$P_3 \times P_{14}$	89.25	4.71	3.33	14.83	41.57	2.60	9.01
$P_3 \times P_{17}$	88.31	4.58	4.22	15.33	49.35	3.52	8.10
$P_8 \times P_{12}$	89.99	4.70	2.00	16.72	47.85	3.03	7.97
$P_8 \times P_{13}$	71.60	3.77	2.03	8.22	48.39	4.00	7.29
$P_8 \times P_{14}$	91.52	4.26	1.99	12.11	44.39	3.10	8.62
$P_8 \times P_{17}$	77.63	3.70	3.78	17.11	40.12	2.60	7.07
$P_{16} \times P_{12}$	85.50	4.17	3.55	16.00	41.74	3.53	8.08
$P_{16} \times P_{13}$	90.37	4.29	3.58	23.45	44.37	3.20	8.13
$P_{16} \times P_{14}$	84.69	4.21	3.34	18.89	49.44	4.20	7.37
$P_{16} \times P_{17}$	86.25	4.11	3.56	15.33	46.72	3.50	7.88
$P_{24} \times P_{12}$	82.35	3.96	2.17	9.67	52.99	2.77	8.12
$P_{24} \times P_{13}$	79.07	2.98	1.97	8.83	48.00	2.70	7.33
$P_{24} \times P_{14}$	77.59	3.82	2.21	20.56	50.27	3.57	7.84
$P_{24} \times P_{17}$	75.83	3.44	2.33	9.56	43.77	2.43	7.68
$P_{27} \times P_{12}$	85.23	4.33	2.25	22.22	45.80	3.27	7.45
$P_{27} \times P_{13}$	88.43	4.15	2.67	13.78	51.49	2.87	7.94
$P_{27} \times P_{14}$	84.81	3.76	3.45	15.72	38.24	2.57	7.83
$P_{27} \times P_{17}$	81.80	3.60	4.21	23.33	47.41	2.80	7.59
$P_{32} \times P_{12}$	87.18	3.94	2.78	14.00	46.22	4.70	7.87
$P_{32} \times P_{13}$	80.02	3.78	2.24	25.78	51.44	4.33	7.99
$P_{32} \times P_{14}$	85.34	4.20	2.67	11.17	51.90	3.93	8.42
$P_{32} \times P_{17}$	93.03	4.29	4.00	26.56	43.78	3.60	7.34
Mean	83.36	4.18	2.91	15.53	45.17	3.26	8.03
$CD_{0.05}$	7.52	0.79	0.53	1.75	5.33	0.48	0.98
CV (%)	5.52	11.68	11.15	6.91	7.22	9.00	7.46

Hybrids $P_{32} \times P_{17}$ and $P_8 \times P_{14}$ though statistically at par recorded the tallest seedlings compared to the rest of the hybrids which were statistically comparable. Hybrids $P_3 \times P_{14}$ followed by $P_{32} \times P_{17}$ showed the largest collar diameter while $P_{24} \times P_{13}$ and $P_8 \times P_{14}$ exhibited the smallest. Statistically higher number of primary branches was recorded for hybrids $P_3 \times P_{17}$, $P_{27} \times P_{17}$, $P_{32} \times P_{17}$, $P_8 \times P_{17}$ and $P_{16} \times P_{13}$ compared to rest of the hybrids. Hybrids $P_{32} \times P_{17}$ and $P_{32} \times P_{13}$ though statistically comparable with most of the hybrids exhibited the highest number of leaves per plant compared to $P_8 \times P_{13}$ and $P_{24} \times P_{13}$ that recorded the least number of leaves.

Hybrids $P_{24} \times P_{12}$, $P_3 \times P_{12}$, $P_{32} \times P_{14}$, $P_{27} \times P_{13}$ and $P_{24} \times P_{14}$ had higher leaf area compared to rest of the hybrids. Hybrids $P_{32} \times P_{12}$, $P_{32} \times P_{13}$ and $P_{16} \times P_{14}$ showed the highest mean values for petiole length while $P_{24} \times P_{17}$, $P_8 \times P_{17}$ and $P_{24} \times P_{12}$ recorded the lowest mean values compared to the rest of the hybrids that had similar petiole length. Hybrids $P_3 \times P_{12}$, $P_3 \times P_{14}$ and $P_8 \times P_{14}$ exhibited the highest mean values for intermodal distance whereas $P_8 \times P_{17}$, $P_8 \times P_{13}$ and $P_{24} \times P_{13}$ recorded the lowest internodal distance.

The coefficient of variation (CV) estimates were highest for collar diameter (11.68%), followed by number of primary branches (11.15%), petiole length (9.00%), internodal distance (7.46%), leaf area (7.22%), number of leaves per plant (6.91%) and the lowest was recorded for seedling height (5.52%). The estimates of percentage heterosis for 24 F_1 hybrids over mid and better-parent for seedling growth traits are presented in Table 3.

Seedling height: Out of 24 hybrids 13 expressed significant positive mid parent heterosis for seedling height while only 3 hybrids $P_8 \times P_{13}$, $P_8 \times P_{17}$ and $P_{24} \times P_{17}$ expressed significant negative heterosis for the trait. Eleven crosses $P_3 \times P_{12}$, $P_3 \times P_{14}$, $P_3 \times P_{17}$, $P_8 \times P_{12}$, $P_8 \times P_{14}$, $P_{16} \times P_{13}$, $P_{24} \times P_{12}$, $P_{27} \times P_{12}$, $P_{27} \times P_{13}$, $P_{32} \times P_{12}$ and $P_{32} \times P_{17}$ recorded positive significant better parent heterosis while 7 crosses exhibited significant negative better parent heterosis for this trait (Table 3). The significant positive better parent heterosis for seedling height ranged from 2.20 % to 13.17% (Table 3).

Collar diameter: Mid parent heterosis for collar diameter revealed only one significant positive hybrid ($P_{16} \times P_{13}$) and ten significant negative hybrids (Table 3). No significant positive better parent heterosis was recorded for collar diameter while 15 hybrids showed significant negative better parent heterosis. However better parent heterosis for collar diameter ranged from (-37.77%) in cross $P_{24} \times P_{13}$ to (10.46%) in $P_{16} \times P_{13}$ (Table 3).

Table 3: Estimates of percentage mid parent heterosis (MPH) and better-parent heterosis (BPH) for seedling growth traits in *B. variegata*

	SDHT (cm)		CDM (mm)		NPB (no.)		NLP (no.)	
F_1 hybrids	**MPH**	**BPH**	**MPH**	**BPH**	**MPH**	**BPH**	**MPH**	**BPH**
$P_3 \times P_{12}$	12.96*	4.16*	-13.75*	-24.47*	-10.69*	-13.48*	-31.09*	-42.14*
$P_3 \times P_{13}$	3.94*	-0.95	-10.02*	-25.04*	-6.80	-14.30*	-26.66*	-48.10*
$P_3 \times P_{14}$	8.55*	6.80*	-2.55	-19.21*	31.75*	30.38*	-4.29	-16.02*
$P_3 \times P_{17}$	5.12*	4.58*	-10.44*	-21.50*	44.72*	26.70*	-11.25*	-13.19*
$P_8 \times P_{12}$	19.89*	13.07*	6.66	5.98	-22.53*	-25.09*	52.03*	39.36*
$P_8 \times P_{13}$	-7.78*	-11.39*	-9.34	-14.96*	-25.75*	-31.84*	-5.15	-17.80*
$P_8 \times P_{14}$	14.08*	13.17*	3.10	-3.86	-21.06*	-22.03*	3.80	-9.18*
$P_8 \times P_{17}$	-5.34*	-8.07*	-16.21*	-16.62*	29.75*	13.40*	27.26*	1.30
$P_{16} \times P_{12}$	8.89*	-1.18	1.75	-4.72	25.81*	19.40*	35.81*	33.31*
$P_{16} \times P_{13}$	11.42*	4.45*	11.34*	10.46	20.09*	19.89*	148.24*	102.88*

$P_{16} \times P_{14}$	1.19	-2.12*	10.11	9.81	20.79*	12.33*	51.76*	41.65*
$P_{16} \times P_{17}$	0.89	-0.32	0.08	-6.53	12.79*	6.70	7.80*	-9.22*
$P_{24} \times P_{12}$	10.94*	5.68*	-13.63*	-17.31*	-37.05*	-48.58*	-45.11*	-58.38*
$P_{24} \times P_{13}$	2.95	1.48	-31.28*	-37.77*	-45.35*	-53.32*	-42.18*	-61.96*
$P_{24} \times P_{14}$	-2.28	-4.06*	-11.52*	-20.32*	-34.81*	-47.63*	12.46*	-11.48*
$P_{24} \times P_{17}$	-6.59*	-10.20*	-25.13*	-28.28*	-38.16*	-44.62*	-52.35*	-58.85*
$P_{27} \times P_{12}$	10.75*	2.20*	-4.87	-8.29	-13.42*	-15.86*	17.48*	-13.97*
$P_{27} \times P_{13}$	11.17*	6.03*	-3.56	-12.08*	-2.967	-10.50*	-16.90*	-46.66*
$P_{27} \times P_{14}$	3.26	1.70	-12.07*	-20.27*	35.78*	34.81*	-19.71*	-39.14*
$P_{27} \times P_{17}$	-2.53	-3.13*	-20.92*	-23.68*	43.96*	26.40*	9.23*	-9.68*
$P_{32} \times P_{12}$	12.08*	2.52*	-10.39	-10.79*	-7.99	-17.59*	17.76*	16.67*
$P_{32} \times P_{13}$	-0.44	-5.91*	-8.81	-14.24*	-29.42*	-33.50*	169.81*	118.91*
$P_{32} \times P_{14}$	2.87	0.35	1.98	-4.74	-10.06*	-20.95*	-11.06*	-16.25*
$P_{32} \times P_{17}$	9.78*	9.40*	-2.39	-2.62	19.28*	18.58*	85.28*	57.23*

*Significant at 0.05 level

Table 3: continued

	LA (cm^2)		PTL (mm)		INTD (no.)	
F_1 hybrids	**MPH**	**BPH**	**MPH**	**BPH**	**MPH**	**BPH**
$P_3 \times P_{12}$	35.27*	33.14*	17.78*	15.22*	11.47*	8.68*
$P_3 \times P_{13}$	8.66*	-0.60	-4.86*	-9.28*	-8.69*	-11.65*
$P_3 \times P_{14}$	-4.29	-14.75*	-21.61	-29.73*	12.09*	7.52*
$P_3 \times P_{17}$	32.82*	29.51*	24.85*	19.89*	-8.66*	-13.49*
$P_8 \times P_{12}$	27.91*	21.62*	4.00*	-1.09	-3.12	-6.16*
$P_8 \times P_{13}$	18.88*	5.34	33.33*	23.71*	-16.39*	-18.57*
$P_8 \times P_{14}$	5.39	-8.97*	-4.12	-16.22*	6.49*	1.49
$P_8 \times P_{17}$	11.94*	10.81*	-4.88*	-6.02*	-20.78*	-24.48*
$P_{16} \times P_{12}$	4.45	2.86	11.58*	8.16*	0.12	-1.22
$P_{16} \times P_{13}$	2.56	-3.41	-1.54*	-2.04	-5.06*	-9.19*
$P_{16} \times P_{14}$	10.67*	1.40	20.57	13.51*	-7.16*	-9.91*
$P_{16} \times P_{17}$	21.678*	15.11*	17.32*	7.14*	-10.16*	-15.87*
$P_{24} \times P_{12}$	33.48*	32.31*	-6.74*	-9.78*	0.54	-0.90
$P_{24} \times P_{13}$	11.65*	4.50	-11.47*	-16.50*	-14.46*	-18.12*
$P_{24} \times P_{14}$	13.21*	3.09	8.63	-3.60	-1.24	-4.23
$P_{24} \times P_{17}$	14.82*	9.31*	-12.57*	-15.12*	-12.51*	-18.01*
$P_{27} \times P_{12}$	6.41	-2.01	-1.01	-7.55*	-1.19	-6.33*
$P_{27} \times P_{13}$	11.13*	10.18*	-15.27	-18.87*	-1.28	-11.35*
$P_{27} \times P_{14}$	-19.92*	-21.58*	-29.03	-30.63*	5.64*	1.78
$P_{27} \times P_{17}$	14.33*	1.45	-10.16	-20.76*	-8.02*	-19.00*
$P_{32} \times P_{12}$	14.79*	12.22*	43.15	34.29*	-5.99*	-10.40*
$P_{32} \times P_{13}$	18.09*	11.99*	28.71	23.81*	-9.87*	-10.76*
$P_{32} \times P_{14}$	15.39*	6.43*	9.26	6.31*	2.27	-4.06
$P_{32} \times P_{17}$	13.13*	6.29*	16.13	2.86	-19.10*	-21.64*

*Significant at 0.05 level

SDHT= Seedling height, CDM= Collar diameter, NPB= Number of primary branches, NLP= Number of leaves per plant, LA= Leaf area, PTL= Petiole length and INTD= Internodal distance

Number of primary branches: Out of 24 hybrids 10 hybrids viz; $P_3 \times P_{14}$, $P_3 \times P_{17}$, $P_8 \times P_{17}$, $P_{16} \times P_{12}$, $P_{16} \times P_{13}$, $P_{16} \times P_{14}$, $P_{16} \times P_{17}$, $P_{27} \times P_{14}$, $P_{27} \times P_{17}$ and $P_{32} \times P_{117}$ showed positive significant mid parent heterosis (Table 3). Nine hybrids $P_3 \times P_{14}$, $P_3 \times P_{17}$, $P_8 \times P_{17}$, $P_{16} \times P_{12}$, $P_{16} \times P_{13}$, $P_{16} \times P_{14}$, $P_{27} \times P_{14}$, $P_{27} \times P_{17}$ and $P_{32} \times P_{17}$ exhibited significant positive better parent heterosis whereas 14 hybrids showed significant negative heterosis (Table 3).

Number of leaves per plant: Among the 24 hybrids 12 viz; $P_8 \times P_{12}$, $P_8 \times P_{17}$, $P_{16} \times P_{12}$, $P_{16} \times P_{13}$, $P_{16} \times P_{14}$, $P_{16} \times P_{17}$, $P_{24} \times P_{14}$, $P_{27} \times P_{12}$, $P_{27} \times P_{17}$, $P_{32} \times P_{12}$, $P_{32} \times P_{13}$ and $P_{32} \times P_{17}$ recorded positive significant mid parent heterosis whereas 9 hybrids showed negative significant mid parent heterosis (Table 3). Seven hybrids viz; $P_8 \times P_{12}$, $P_{16} \times P_{12}$, $P_{16} \times P_{13}$, $P_{16} \times P_{14}$, $P_{32} \times P_{12}$, $P_{32} \times P_{13}$ and $P_{32} \times P_{17}$ showed significant positive better parent heterosis whereas 16 hybrids exhibited significant negative better parent heterosis (Table 3).

Leaf area: It was observed that among the 24 hybrids 18 showed significant positive mid parent heterosis while only one hybrid $P_{27} \times P_{14}$ showed significant negative mid parent heterosis for leaf area (Table 3). Twelve hybrids namely; $P_3 \times P_{12}$, $P_3 \times P_{17}$, $P_8 \times P_{12}$, $P_8 \times P_{17}$, $P_{16} \times P_{17}$, $P_{24} \times P_{12}$, $P_{24} \times P_{17}$, $P_{27} \times P_{13}$, $P_{32} \times P_{12}$, $P_{32} \times P_{13}$, $P_{32} \times P_{14}$ and $P_{32} \times P_{17}$ exhibited significant positive heterosis over better parent while only 3 crosses $P_3 \times P_{14}$, $P_8 \times P_{14}$ and $P_{27} \times P_{14}$ showed significant negative heterosis over better parent (Table 3).

Petiole length: Only six hybrids viz; $P_3 \times P_{12}$, $P_3 \times P_{17}$, $P_8 \times P_{12}$, $P_8 \times P_{13}$, $P_{16} \times P_{12}$ and $P_{16} \times P_{17}$ exhibited significant positive mid parent heterosis for petiole length while 11 hybrids showed significant negative mid parent heterosis for this trait (Table 3). Nine hybrids showed positive significant better parent heterosis for petiole length whereas 10 hybrids exhibited negative significant better parent heterosis (Table 3).

Internodal distance: Out of 24 crosses **o**nly four hybrids $P_3 \times P_{12}$, $P_3 \times P_{14}$, $P_8 \times P_{14}$ and $P_{27} \times P_{14}$ showed significant positive mid parent heterosis while 14 hybrids exhibited significant negative mid parent heterosis for internodal distance (Table 3). Only two crosses $P_3 \times P_{12}$ and $P_3 \times P_{14}$ showed positive significant better parent heterosis while 14 crosses exhibited negative significant better parent heterosis for this trait. However, heterobeltosis ranged from (-24.48%) in cross $P_8 \times P_{17}$ to (8.68%) in $P_3 \times P_{12}$ (Table 3).

Discussion

The analysis of variance suggested that parental genotypes were highly variable and therefore would likely respond to selection. The comparative mean performance of the parents and hybrids indicated superiority for some of the genotypes over others. Good potential existed for P_{16} (Solan) in terms height. Seedling height is an important trait to select for early maturity. Parent P_3 (Kathua) showed the largest collar diameter. The superior growth traits of these genotypes is a good indicator for volume and biomass production in the species.

Similarly some hybrids expressed superiority with respect to some of the traits. Hybrids $P_8 \times P_{12}$ and $P_8 \times P_{14}$ were distinct for seedling height while the hybrid $P_{16} \times P_{13}$ recorded superior collar diameter. Hybrids $P_3 \times P_{17}$ and $P_{27} \times P_{17}$ also had the highest number of primary branches whereas $P_{32} \times P_{13}$ and $P_{16} \times P_{13}$ recorded the highest number leaves per plant. Hybrids $P_3 \times P_{12}$ and $P_{24} \times P_{12}$ were superior for leaf area while $P_8 \times P_{13}$ recorded the longest petiole length. Hybrids $P_3 \times P_{14}$ and $P_3 \times P_{12}$ exhibited the widest internodal length. Depending on the breeding objectives there are wide variety of parental genotypes and hybrids to choose from. Most tree breeding projects utilize the selection of the best performing seedlings concerning agriculturally important traits (Emanuel and Eli, 1995) [9].

Height is an essential trait to determine early maturity to produce maximum leaf fodder yield in *B. variegata* trees. Hybrids $P_8 \times P_{12}$ and $P_8 \times P_{14}$ expressed highly significant positive mid parent and better parent heterosis for seedling height with values of 19.89% and 13.07%; 14.08% and 13.17%, respectively which could be exploited for early maturity for leaf yield. Ghosh *et al.* (2009) [10] tested eight mulberry (*Morus* sp.) hybrids viz., C-2036, S-1908, C-2037, C-2038, C-2039, C-2040, C-2041 and C- 2042 against S-1635. Heterosis for leaf yield and its attributing characters in 8 hybrids were significantly positive ranging from 5.95 to 159.31% over better parent, 13.92 to 159.31% over mid parent and 1.50 to 27.79% over standard variety (S-1635) among the crosses for leaf yield.

Collar diameter along with height is an important factor for tree growth which determines the volume of wood produced. However no hybrids recorded significant positive heterosis for stem diameter in the nursery except $P_{16} \times P_{13}$ which showed mid parent heterosis value of 11.34%. This might be an indicative of the naturally cross pollinated species whose hybrids performance could be unpredictable most probably due to the decrease in effectiveness of the alleles when they are combined together in one genotype. These decreases provide cases of negative heterosis due to heterozygosity at a single locus (Sukartini *et al*., 2012) [22] or the traits may be under additive gene control as suggested by Johnsen *et al.* (1998) [11].

Hybrids $P_{27} \times P_{14}$ $P_3 \times P_{14}$, $P_3 \times P_{17}$ and $P_{27} \times P_{17}$ showed significant heterotic response for number of primary branches. Also $P_{27} \times P_{17}$ had mid parent heterosis of 9.23% for number of leaves. Heterosis has been documented in branch habit of *Populus* (Brandshaw and Stettler, 1995) [5]. In the light of this the combined mid provenance and better-provenance heterosis achieved by $P_{27} \times P_{14}$ $P_3 \times P_{14}$, $P_3 \times P_{17}$ and $P_{27} \times P_{17}$ could be utilized for fodder yield improvement.

Superiority of intra-specific hybrids in trees has been demonstrated by several workers (Hathaway, 1977 [12]; Krstinic, 1979 [13]; Ronnberg and Gulberg, 1999 [17]; Smart *et al*., 2005 [19]; Cameron *et al.*, 2008 [6]; in willows, Dongsen *et al*., 1992 [8]; Li and Wu, 1996 [14]; Singh and Singh 2004 [18], Ozel *et al*., 2010 [15] in Poplars.

Conclusion

It can be concluded from present study that the heterotic values for plant height, collar diameter, number of primary branches, number of leaves per plant, leaf area, petiole length and internodal distance in relation to mid and better parent indicated increase. Thus, dominance genetic control was able to influence these traits in *B. variegata* seedlings. The hybrids $P_8 \times P_{12}$, $P_3 \times P_{17}$, $P_{16} \times P_{12}$ and $P_{32} \times P_{17}$ could further be evaluated for early seedling growth due to their high heterotic values for seedling height, collar diameter,number of primary branches, number of leaves and leaf area.

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