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HETEROSIS FOR YIELD AND GROWTH IN WICKHAM x AMAZONIAN HYBRIDS OF *HEVEA BRASILIENSIS* (Willd. ex A. Juss.) Muell. Arg.

L. Sankariammal, Kavitha K. Mydin, Vinoth Thomas and Y. Annamma Varghese

Rubber Research Institute of India, Kottayam - 686 009, Kerala, India

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The Rubber Research Institute of India has been making efforts on conservation, evaluation and utilization of wild germplasm received from the 1981 IRRDB expedition to Brazil. Accessions showing potential for important secondary traits such as girth, number of latex vessel rows, bark thickness and tolerance to biotic and abiotic stresses have been identified and used in breeding with popular Wickham clones since 1990. This is being done with the intention of broadening the narrow genetic base of cultivated rubber and also to develop location-specific clones for cultivation in the marginal and non-traditional areas in India. This paper summarizes the performance of 26 hybrid clones of *Hevea brasiliensis* resultant of the 1990 hybridization programme in which wild Amazonian germplasm was incorporated for the first time in breeding of *H. brasiliensis* in India.

The study revealed that seven clones, out of which five belonged to the cross RRII 105 x RO 142, were better in yield than the control clone RRII 105. Mean yield of the population ranged from 13.0 to 66.5 g/t/t. The hybrid clone 90/10 recorded the highest yield followed by 90/34. Mean girth at opening of the hybrid clones ranged from 42.3 to 66.2 cm, the highest being recorded in clone 90/29. Girth in the seventh year of tapping ranged from 62.2 to 88.3 cm with the same clone 90/29 recording the highest girth. Girth increment in the immature phase of hybrids ranged from 5.3 to 8.3 cm/year and in the mature phase from 1.9 to 4.8 cm/year. Twenty two clones attained an average girth greater than 50 cm at opening. Bark anatomical studies revealed significant clonal variation with regard to total bark thickness and number of latex vessel rows. Bark thickness and latex vessel rows were high in clone 90/25. Incidence of major diseases and wind damage in general was low.

Estimates of standard heterosis and heterobeltiosis were worked out in respect of the hybrid clones. Standard heterosis for yield ranged from 2.2 to 68.9% and for girth from 4.6 to 63.7%. Estimates of heterobeltiosis for yield ranged from 3.1 to 98.9% and for girth this ranged from 1.3 to 32.9%. Seven clones, *viz.* 90/10, 90/25, 90/29, 90/34, 90/241, 90/170 and 90/271, which showed better yield and other secondary attributes in this preliminary evaluation have been selected for the next phase of evaluation in participatory trials.

Keywords: Biotic/abiotic stresses, Conservation, Girth increment, Heterosis, *Hevea brasiliensis*, Hybrids, Wild germplasm

INTRODUCTION

The Rubber Research Institute of India (RRII) initiated research on genetic improvement in rubber (*Hevea brasiliensis*) by breeding and selection in 1955. Popular Wickham clones were used as parents in

Correspondence: Kavitha K. Mydin (Email: kavitha@rubberboard.org.in)

such crosses and the most popular clone RRII 105 was the result of the first hybridization programme (Nair and George, 1968; Nair *et al*., 1976; Nazeer *et al*., 1986). Subsequent hybridizations have led to the release of 200 series, 300 series and 400 series clones (Premakumari *et al*., 1984; Licy *et al*., 1992, 1993; Mydin *et al*., 2005). The RRII imported wild *Hevea* germplasm accessions during 1984 to 1990 period with the intention of conservation, evaluation and utilization of the genetic resources. Currently, a total of 4548 wild accessions are being conserved along with 215 Wickham clones. By systematic screening, accessions with desirable agro-morphologic traits have been identified (Mercy *et al*., 1995; Abraham *et al*., 2002) for further utilization.

Since the original genetic base of cultivated *H. brasiliensis* is narrow, incorporation of wild germplasm in breeding assumes great significance. Greater genetic variability is essential for further genetic advance and for attaining stability in yield by incorporating genes resistant to various biotic and abiotic stresses. With this intention, superior wild accessions have been incorporated as one of the parents in hybridization programmes. The first such crossing (Wickham x Amazonian) in India was done at RRII, Kottayam in 1990. This paper summarises the performance of 26 selected hybrid clones of Wickham x Amazonian crosses together with the parents and control RRII 105, in a small-scale trial over a period of 14 years.

MATERIALS AND METHODS

The materials used in this study included 26 hybrid clones, the selected progenies of Wickham x Amazonian hybridization programme taken up in 1990, along with the parents and the control clone RRII 105. The clones were evaluated in a small-scale trial laid out in 1995 employing randomized block design with three replications and four plants per plot at the Central Experiment Station of RRII at

Table 1. **Parentage of clones evaluated**

Sl. no.	Clone	Parentage	Sl. no.	Clone	Parentage
1.	90/3	RRII 105 x RO 142	14.	90/341	RRIM 600 x RO 142
2.	90/4	RRII 105 x RO 142	15.	90/168	RRIM 600 x RO 87
3.	90/6	RRII 105 x RO 142	16.	90/170	RRIM 600 x RO 87
4.	90/10	RRII 105 x RO 142	17.	90/171	RRIM 600 x RO 87
5.	90/19	RRII 105 x RO 142	18.	90/174	RRIM 600 x RO 87
6.	90/21	RRII 105 x RO 142	19.	90/176	RRIM 600 x RO 87
7.	90/25	RRII 105 x RO 142	20.	90/177	RRIM 600 x RO 87
8.	90/29	RRII 105 x RO 142	21.	90/184	RRIM 600 x RO 87
9.	90/34	RRII 105 x RO 142	22.	90/185	RRIM 600 x RO 87
10.	90/241	RRII 105 x RO 142	23.	90/193	RRIM 600 x RO 87
11.	90/321	RRIM 600 x RO 142	24.	90/352	RRIM 600 x RO 87
12.	90/322	RRIM 600 x RO 142	25.	90/265	RRIM 600 x RO 87
13.	90/340	RRIM 600 x RO 142	26.	90/271	RRIM 600 x RO 87

Chethackal, Ranni in Central Kerala. The clones and the parentage are given in Table 1. Two popular Wickham clones, RRII 105 and RRIM 600, which served as the female parents, and two accessions from wild germplasm, RO 87 and RO 142, the male parents, were also planted. The trees were opened for tapping in 2003. The tapping system followed was S/2 d3 6d/7 and yield was recorded at fortnightly intervals by cup coagulation method. Mean annual dry rubber yield and dry rubber yield during the stress period (February – May) and peak yielding period (October – January) were computed separately in the seventh year of tapping. Yield depression under stress was computed as percentage over the annual mean value. The girth of the trees was recorded annually from the third year of planting and was used to determine the tappability of clones and girth increment rate during the pre-tapping and tapping phases. Bark samples were collected at the time of opening at a height of 150 cm and the number of latex vessel rows was counted by microscopic observation of thin sections stained with Sudan IV. Incidence of diseases and damage caused by wind were assessed. The data on yield, girth, bark thickness and latex vessel rows were statistically analysed.

RESULTS AND DISCUSSION

Yield of clones

The performance of hybrid clones together with the control in respect of yield is given in Table 2. Mean yield over seven years ranged from 13.0 to 66.5 g/t/t. Clone 90/10 exhibited the highest yield followed by clone 90/34 (47.7 g/t/t). The control clone RRII 105 showed an yield of 40.1 g/t/t. Of the other parental clones, RRIM 600 gave 22.7 g/t/t, the wild parents RO 142 and RO 87 gave 16.3 g/t/t and 17.2 g/t/t, respectively. Clone 90/10 (66.5 g/t/t) was the significantly superior yielder and others, *viz*. 90/34 (47.7 g/t/t), 90/271 (45.0 g/t/t), 90/25 (43.5 g/t/t), 90/29 (41.8 g/t/t), 90/241 (41.3 g/t/t) and 90/170 (40.9 g/t/t), were at par with RRII 105. In the peak yielding period, clone 90/10 exhibited the highest yield (139.4 g/t/t) followed by clone 90/193 (78.7 g/t/t). The control (RRII 105) showed 65.3 g/t/t in the peak period. The wild parent RO 142 showed 25.0 g/t/t and RO 87 showed 26.7 g/t/t in the peak yielding period. Yield during the stress period of the hybrids ranged from 13.7 in 90/176 to 78.5 g/t/t in 90/10. The summer yield depression ranged from 7.6 to 43.3% and was the highest in RRII 105 (43.3%).

Among the three cross combinations, progenies of RRII 105 x RO 142 recorded superior yield. Of the seven high yielding hybrids, five clones, including clone 90/10, were the progenies of the above cross. The superiority of these hybrids may be due to the genetic effect of the maternal parent, RRII 105, which is a proven high yielder and a prepotent parent (Mydin *et al*., 1996). In the second cross combination (RRIM 600 x RO 142), one clone *viz.* 90/340 showed yield (39.7 g/t/t) that was on par with the control RRII 105 (40.1 g/t/t) and in the third cross (RRIM 600 x RO 87) two clones, *viz.* 90/170 and 90/271, showed yield (40.9 and 45.0 g/t/t) that was on par with the control. The wild accessions were low yielders compared to the popular Wickham clones, as expected.

Growth parameters

The growth parameters are given in Table 3. There was clonal variation with respect to girth at opening and girth increment in the immature and mature

Table 2. **Yield performance (g/t/t) of clones**

Sl. no.	Clone	Mean yield over 7 years	Yield (peak period) (7th year)	Yield (stress period) (7th year)	Summer yield depression (%) (7th year)
1.	90/3	30.3	49.9	42.4	10.9
2.	90/4	26.3	41.8	23.9	33.1
3.	90/6	26.7	40.7	29.7	25.6
4.	90/10	66.5	139.4	78.5	35.1
5.	90/19	16.0	37.8	25.3	27.1
6.	90/21	37.3	58.6	50.2	10.9
7.	90/25	43.5	69.0	46.0	19.9
8.	90/29	41.8	61.4	41.8	25.4
9.	90/34	47.7	73.4	44.9	33.5
10.	90/241	41.3	67.3	52.2	23.5
11.	90/321	21.1	24.4	22.9	14.0
12.	90/322	31.2	45.5	41.0	17.1
13.	90/340	39.7	69.5	50.1	20.7
14.	90/341	17.9	25.7	18.9	16.0
15.	90/168	21.8	29.7	27.1	27.1
16.	90/170	40.9	66.7	48.1	24.4
17.	90/171	32.7	59.8	47.2	12.0
18.	90/174	29.1	52.9	44.3	13.9
19.	90/176	16.3	20.0	13.7	13.7
20.	90/177	14.3	17.6	13.7	27.3
21.	90/184	13.0	27.7	21.2	17.3
22.	90/185	26.4	47.3	36.0	7.6
23.	90/193	36.0	78.7	72.9	10.1
24.	90/352	30.4	53.7	43.2	19.6
25.	90/265	26.9	34.7	36.0	11.0
26.	90/271	45.0	76.1	63.1	14.1
27.	RRII 105	40.1	65.3	33.2	43.3
28.	RRIM 600	22.7	44.4	19.6	27.4
29.	RO 142	16.3	25.0	22.2	16.7
30.	RO 87	17.2	26.7	19.0	19.0
	CD (P=0.05)	10.47	9.85	8.43	7.62

phases. Mean girth at opening ranged from 42.3 to 66.2 cm. The highest girth was observed in clone 90/29 (66.2 cm) followed by clone 90/10 (65.1 cm). In all the clones, except clones 90/25 and 90/352, more than 50% of the trees attained tappable girth at opening. Mean girth in the seventh year of tapping ranged from 58.8 to 88.3 cm.

Table 3. **Important growth parameters of clones**

Sl. no.	Clone	Mean girth at opening (cm)	Girth in the 7th year of tapping (cm)	Girth increment in the immature phase (cm/year)	Girth increment in the mature phase (cm/year)
1.	90/3	55.7	74.7	7.0	3.2
2.	90/4	50.3	69.7	6.3	3.2
3.	90/6	54.4	77.2	6.8	3.8
4.	90/10	65.1	81.7	8.1	2.8
5.	90/19	42.3	58.8	5.3	2.8
6.	90/21	52.0	80.8	6.5	4.8
7.	90/25	50.4	63.4	6.3	2.2
8.	90/29	66.2	88.3	8.3	3.7
9.	90/34	54.9	74.9	6.9	3.3
10.	90/241	56.7	75.0	7.1	3.0
11.	90/321	58.1	79.0	7.3	3.5
12.	90/322	55.2	74.0	6.9	3.1
13.	90/340	50.8	62.2	6.3	1.9
14.	90/341	49.4	66.1	6.2	2.8
15.	90/168	51.3	64.6	6.4	2.2
16.	90/170	57.3	71.8	7.2	2.4
17.	90/171	53.2	83.8	6.7	5.1
18.	90/174	57.3	81.5	7.2	4.0
19.	90/176	49.0	62.4	6.1	2.2
20.	90/177	55.0	77.2	6.9	3.7
21.	90/184	49.9	65.4	6.2	2.6
22.	90/185	55.2	73.8	6.9	3.1
23.	90/193	53.3	73.9	6.7	3.4
24.	90/352	54.8	69.6	6.8	2.5
25.	90/265	52.6	66.2	6.6	2.3
26.	90/271	58.7	78.9	7.3	3.4
27.	RRII 105	40.4	55.7	5.1	2.5
28.	RO 142	49.8	63.1	6.2	2.2
29.	RO 87	53.6	81.4	6.7	4.6
30.	RRIM 600	38.9	46.9	4.9	1.3
	CD (P=0.05)	8.03	10.15	1.04	0.78

Clone 90/29 showed the highest girth (88.3 cm) followed by clone 90/171 (83.9 cm). Girth increment rate in the immature phase ranged from 5.3 to 8.3 cm/year, the highest rate was exhibited by clone 90/29 (8.3 cm) followed by clone 90/10 (8.1 cm). In the mature phase, this ranged from 1.9 cm in clone 90/340 to 4.8 cm in clone 90/21.

Estimates of standard heterosis and heterobeltiosis are given in Table 4. Standard heterosis for yield ranged from 2.2 to 68.9%, the highest being in clone 90/10 (68.9%), followed by clone 90/34 (19.0%). Standard heterosis for girth at opening ranged from 4.6 to 63.7%, the highest being exhibited by clone 90/29 (63.7%) followed by clone 90/10 (61.1%). Estimates of heterobeltiosis for yield in the first cross (RRII 105 x RO 142) ranged from 3.1 to 68.9%, in the second cross (RRIM 600 x RO 142) this ranged from 37.6 to 75.3% and in the third cross (RRIM 600 x RO 87) this ranged from 16.4 to 98.9%. Based on girth at opening, in the first cross, heterobeltiosis ranged from 1.3 to 32.9%, in the second cross, from 2.0 to 16.7% and from 2.1 to 9.4% in the third cross. The presence of heterobeltiosis *i.e.* heterosis over the better parent points to transgressive seggregants occurring in the progeny of crosses between Wickham clones and wild Amazonian accessions.

An ideal rubber clone would be one which maintains both high rubber yield as well as vigorous growth so as to sustain a high yield trend for many years (Mydin *et al*., 2005). In the present study, the high yielders were also vigorous (Fig. 1). The five high yielders, *viz*. 90/10, 90/25, 90/29, 90/34 and 90/241, were the hybrids of the cross between RRII 105 and RO 142. The girth of these clones ranged from 65.1 to 56.7 cm at the time of opening the trees for tapping which was significantly greater than that of the control. The growth vigour of these hybrid clones was very high when compared

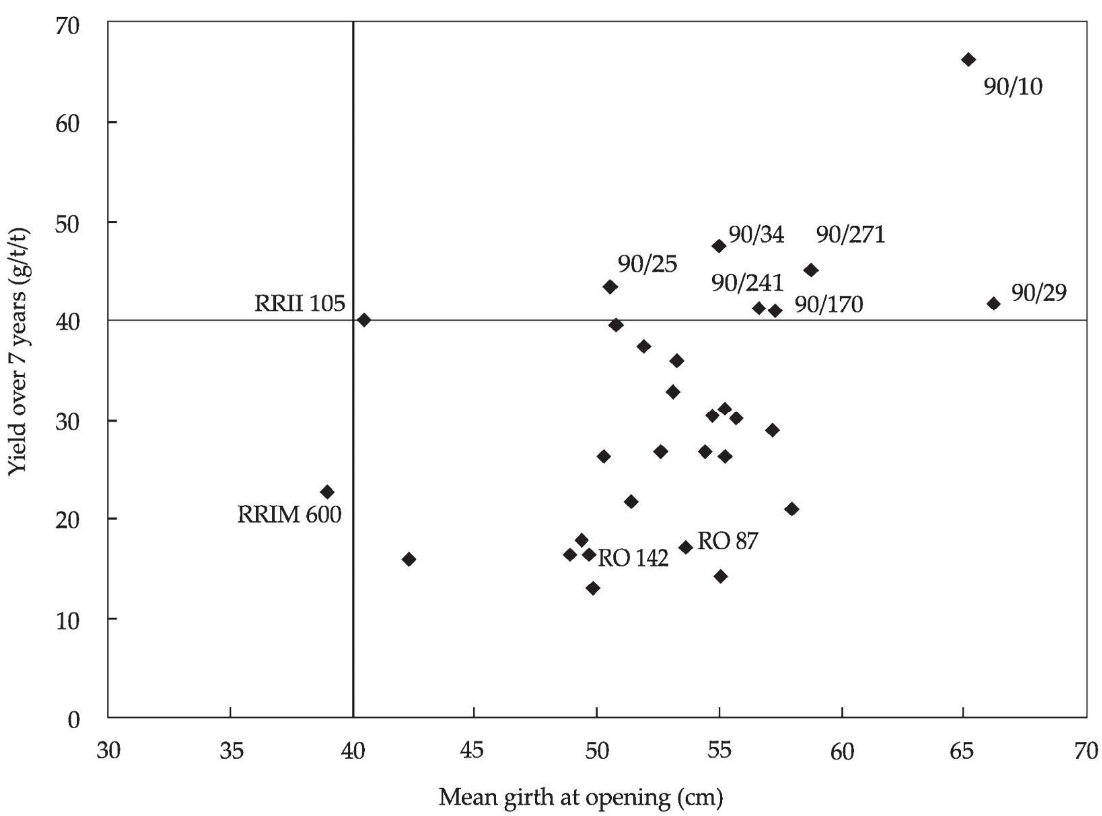

Fig. 1. Girth vs. yield in the hybrid clones

Table 4. **Estimates of heterosis**

Sl. no.	Parentage	Clone	Standard heterosis (%) – Girth at opening	Standard heterosis (%) – Yield over seven years	Heterobeltiosis (%) – Girth at opening	Heterobeltiosis (%) – Yield over seven years
1.	RRII 105 x RO 142	90/3	37.7	_	11.87	_
2.	″	90/4	24.3	_	0.9	_
3.	″	90/6	34.6	_	9.3	_
4.	″	90/10	61.1	68.9	30.9	68.9
5.	″	90/19	4.6	_	_	_
6.	″	90/21	28.6	_	4.5	_
7.	″	90/25	24.8	8.6	1.3	8.6
8.	″	90/29	63.7	4.2	32.9	4.4
9.	″	90/34	35.9	19.0	10.4	19.0
10.	″	90/241	40.3	3.1	13.9	3.1
11.	RRIM 600 x RO 142	90/321	43.7	_	16.7	_
12.	″	90/322	36.5	_	10.8	37.6
13.	″	90/340	25.5	_	2.0	75.3
14.	″	90/341	22.2	_	_	-
15.	RRIM 600 x RO 87	90/168	27.0	_	_	-
16.	″	90/170	41.6	2.2	6.8	80.7
17.	″	90/171	31.5	_	_	44.6
18.	″	90/174	41.6	_	6.8	28.3
19.	″	90/176	21.2	_	_	-
20.	″	90/177	36.0	_	2.6	-
21.	″	90/184	23.5	_	_	-
22.	″	90/185	36.5	_	3.0	16.4
23.	″	90/193	31.9	_	_	58.9
24.	″	90/352	35.4	_	2.1	34.4
25.	″	90/265	30.1	_	_	18.6
26.	″	90/271	45.1	12.4	9.4	98.9

to the parental clones which was 40.4 cm in RRII 105 and 49.8 cm in clone RO 142. The clone 90/10, having the second highest girth was the top yielder as well. Among the four hybrid clones in the second cross (RRIM 600 x RO 142) the highest girth observed was in clone 90/321 (58.1 cm); but the yield of this clone was very low (21.1 g/t/t). In the same cross, clone 90/340 showed average girth (50.8 cm) and moderate yield (39.7 g/t/t). In the third cross (RRIM 600 x RO 87) among the 12 clones, six showed girth higher than the vigorous male parent, RO 87. The clone 90/271 showed the highest girth (58.7 cm)

Table 5. **Anatomical parameters of the clones**

Sl. no.	Clone	TBT(mm)	LVR
1.	90/3	7.4	11.8
2.	90/4	6.7	10.3
3.	90/6	7.3	11.4
4.	90/10	6.4	9.0
5.	90/19	6.0	8.4
6.	90/21	7.4	12.2
7.	90/25	7.8	18.3
8.	90/29	7.1	10.6
9.	90/34	6.8	8.2
10.	90/241	6.6	13.5
11.	90/321	7.7	8.5
12.	90/322	5.7	5.7
13.	90/340	6.0	9.3
14.	90/341	6.3	6.6
15.	90/168	5.6	8.2
16.	90/170	6.4	8.4
17.	90/171	5.8	9.0
18.	90/174	6.2	8.1
19.	90/176	5.6	6.7
20.	90/177	6.1	7.3
21.	90/184	6.0	9.0
22.	90/185	5.4	6.8
23.	90/193	6.6	12.6
24.	90/352	6.2	10.1
25.	90/265	7.0	12.4
26.	90/271	6.3	10.2
27.	RRII 105	7.4	15.2
28.	RRIM 600	6.3	12.5
29.	RO 142	7.1	8.1
30.	RO 87	6.9	9.6
	GM	6.52	9.92
	CV (%)	10.76	22.86

as well as the highest yield of 45.0 g/t/t in this set of hybrids. The female parent RRIM 600 had a girth of 38.9 cm and the male parent RO 87 had 53.6 cm girth at opening. The vigour of the hybrids appears to be contributed by the wild parent.

Anatomical parameters

Clonal variation was evident for total bark thickness and number of latex vessel rows (Table 5). Fourteen clones recorded higher value for bark thickness (TBT) and 13 clones had more latex vessel rows (LVR) than the general mean (GM). The virgin bark thickness in the fifth year ranged from 5.4 mm to 7.8 mm. Clone 90/25 exhibited the highest bark thickness followed by clone 90/321 (7.7 mm). The total number of LVR ranged from 5.7 to 18.3, the highest being in clone 90/25. The control clone RRII 105 showed the second highest LVR (15.2) followed by clone 90/241 (13.5).

Clone 90/29 showed high girth both at opening and also in the seventh year of tapping, *i.e.* 66.2 and 88.3 cm, respectively. The TBT and LVRs of this clone were higher than the general mean and this clone showed a promising yield of 41.8 g/t/t. Clone 90/10, the highest yielder (66.7 g/t/t) showed high girth (81.7 cm) but the structural components such as bark thickness and number of LVR were comparatively low (6.4 and 8.9 mm, respectively). In clone 90/25, even though the girth was not very high (63.4 cm), bark thickness (7.8 cm) and LVR (18.3 cm) were very high and yield was moderately high (43.5 g/t/t). According to Gomez *et al*. (1972) and Napitupulu (1973), girth shows a higher association with yield in certain clones and latex vessel rows showed stronger association with yield in certain others, as observed in the present study. Hamzah and Gomez (1982) observed that girth, bark thickness, latex vessel rows and vessel volume in the tapping panel were all inter-related and these properties were in turn related to the total yield.

Reaction to biotic and abiotic stresses

Tolerance to various biotic and abiotic stresses is of great significance in the performance of different clones. Incidence of tapping panel dryness was observed in a few clones, *viz.* 90/3, 90/4, 90/168, 90/185, 90/265 and 90/341 in which one tree per clone was affected. Pink disease was detected in clones 90/21, 90/241, 90/184, 90/185, 90/352, 90/340, 90/168 and 90/271 with low to moderate intensity. Powdery mildew was observed in a few clones with low intensity. Four clones, *viz.* 90/185, 90/177, 90/34 and 90/6 were affected by wind, one tree per clone was damaged. Incidence of major diseases and wind damage in general were low. It may be noted that these results need confirmation from large-scale on-farm evaluation for several years.

CONCLUSION

Wild germplasm accessions were used as parents in breeding of *H. brasiliensis* in India for the first time. Among the promising offsprings, clone 90/10 was the highest yielder. Five out of seven promising yielders were the progenies of RRII 105 x RO 142. In general, crosses in which RRII 105 was one of the parents showed better yield than the other crosses. Wild germplasm is known to be a reservoir of variability and desirable genes. They are not generally expected to give direct selection. Instead, they provide genes for enhancing yield, resistance to biotic/abiotic stresses or for quality enhancement through hybridization. Since the genetic base of rubber is narrow, the main aim of incorporating wild accessions in breeding is to broaden the genetic base. Breeding of location-specific clones capable of withstanding different constraints prevalent in non-traditional areas, like extremes of temperature in winter and summer, prolonged drought, high velocity wind, high altitudes, diseases, *etc*. requires a wide array of genes which only the wild germplasm can provide. Incorporation of these desirable wild genes in the cultivars by hand pollination and marker assisted selection will improve yield and simultaneously broaden the genetic base of the crop. Aziz (2003) emphasized that while yield of rubber is a major consideration of improved clones, characters such as girth and other desirable secondary attributes are equally important in ensuring stability of yield and thereby enhancing the value of the rubber tree. Among the 26 Wickham x Amazonian hybrids, seven clones, *viz*. 90/10, 90/25, 90/29, 90/34, 90/241, 90/170 and 90/271 exhibited high yield combined with high vigour (Fig. 1) when compared to the controls. These clones, showing high yield, good vigour and other secondary attributes are now in the pipeline for the next phase of evaluation in participatory trials.

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