Recovering drought-tolerant traits from imported clones of *Hevea brasiliensis* through hybridization

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Abstract


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Clones of *Hevea* exhibit significantly variable response to seasonal factors which is particularly reflected in rubber yield during summer months. In view of the drastic change in climatological variables, development of clones amenable to drier conditions is need of the hour. Previous studies on performance of various clones under varied climates over the years had shown that clones like RRIC 52 and RRIC 104 introduced from Sri Lanka and few other imported clones were capable of performing well in terms of growth and yield, even under drier conditions. During 1993, as a part of breeding for drought tolerance, hybridization was carried out using above clones. After initial assessment for growth and yield at nursery stages, selections were subjected to further small scale evaluation. Sustainable yield of above hybrids during summer months, coupled with previous findings that these hybrids also possessed drought-tolerant traits based on physiological and biochemical studies, suggested that yield during summer months could be used as an indicator of drought tolerance in *Hevea*. Through hybridization, traits for drought tolerance were successfully recovered from imported clones, which established potential use of above drought tolerant clones as parents for conferring tolerance traits to off-springs to otherwise high-yielding clones of *Hevea*. Promising selections from the above breeding programme have already been identified as potential candidates for further long term evaluation in large scale as well as on-farm trials, in traditional and non-traditional regions experiencing drought phases, after which recommendations would be made for large-scale commercial planting.

Key words: *Hevea*, annual yield, summer yield, summer depression, girth, drought tolerance.

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Introduction

Rubber yield in *Hevea* is determined by the genotype of a clone. However, rubber yield is also greatly influenced by various edaphoclimatic variables. Since changes in climate variables adversely affect rubber cultivation, need for developing strategies for management, improvement and protection of crop for sustainable yield in *Hevea* has been stressed (Shammi Raj *et al.*, 2011). There is also increasing trend of shifting rubber cultivation to new areas, particularly those are prone to drastic temperature changes. Hence, evolving clones that are climate-resilient is an important priority for rubber breeders (Satheesh and Jacob, 2011).

Under varied agro-climatic conditions prevailing in India and elsewhere, clones of *Hevea* exhibit significantly variable response to seasonal factors which is particularly reflected in rubber yield during summer months (George *et al.*, 1980; Sethuraj and George, 1976; Sethuraj, 1977). Response to seasonal variations including high moisture stress during summer is determined by structural, physiological and biochemical characteristics of a clone. Clones exhibit variability in yield depression during drought period and it is greatly influenced by latex flow pattern (Sethuraj, 1977). Soil moisture and atmospheric temperature are two main environment variables which influence turgor pressure in laticifers which in turn cause variation in yield during different seasons (George *et al.*, 1980; Sethuraj and George, 1976). Studies were also carried out on the utility of bark anatomical traits in characterization of clones for drought tolerance (Premakumari *et al.*, 1993). The above study showed significant variation in phloic ray width and height width ratio of phloic rays among drought tolerant clones.

In India, few clones, both introduced and indigenous, have been known to show consistent yield largely unaffected by moisture stress during

summer months (Raghavendra *et al.*, 1984; Vijayakumar *et al.*, 1988). Whether yield during summer can be considered as a reliable trait for identifying drought tolerance in *Hevea* is often debated since clones showed varied responses and summer stress is confounded with stress due to refoliation during rainless period of the year. Among imported germplasm, clones RRIC 52, RRIC 104 and RRIM 600 are generally known to be tolerant to drought conditions. During 1993, as a part of breeding for drought tolerance, hybridization was carried out using above imported clones. Based on initial assessment for growth and yield at nursery stage, selections were planted in 1998 in a small scale trial for long-term evaluation. In this paper, variability and recovery of drought tolerant traits among selections from above breeding programme, is discussed

Materials and method

The study was conducted in a small scale trial laid out with the purpose of breeding and selection for drought tolerance. Details of the clones are given in Table 1. The trial, planted in 1998 following a randomized block design (five tree per plot replicated thrice), consisted of fifteen hybrids derived from hybridization in 1993 between high-yielding and drought tolerant clones; seven parental clones have also been planted as checks.

Growth performance of the clones was assessed in terms of girth at 150 cm height in the 7th year of tapping. Dry rubber yield (weighed in grams per tree per tap; $gt^{-1}t^{-1}$) was recorded in all the tress following cup coagulation method based on annual mean of fortnightly recordings every month from January to December during 7th and 8th year of tapping under S/2 d3 6d/7 system without stimulation (Mydin and Saraswathyamma, 2005).

Summer yield or yield during stress was computed from annual yield based on yield during dry months of February - May. Summer depression or yield depression which reflects decreasing trend in

Table 1. Growth and yield performance of hybrids in the small scale trial

Clone	Pedigree	Annual mean yield (g/t/t)	Summer yield (g/t/t)	Summer depression (%)	Girth (cm)
55	RRII 105 X AVT 73	54.8	32.0	38.02	68.3
53	RRII 105 X AVT 73	56.2	29.2	49.17	72.1
80	RRII 105 X PB 86	57.1	38.0	31.78	65.6
84	RRII 105 X PB 86	33.7	25.7	24.90	64.0
88	RRII 105 X PB 86	66.8	41.1	37.85	64.9
270	RRII 105 X RRIC 52	56.3	38.6	31.81	75.9
216	RRII 105 X RRIC 52	68.5	57.2	16.17	78.9
214	RRII 105 X RRIC 52	90.5	45.4	49.21	73.4
105	RRIM 600 X RRIC 104	52.5	37.5	30.26	76.9
225	RRIM 600 X RRIC 104	43.9	25.8	40.15	60.7
112	RRIM 600 X RRIC 104	59.4	40.1	32.47	77.7
145	RRIM 600 X RRIC 52	61.6	45.6	26.74	71.7
184	RRIM 600 X RRIC 52	51.4	36.7	29.05	75.3
188	RRIM 600 X RRIC 52	21.6	19.3	10.43	50.1
286	PB 217 X AVT 73	49.2	31.5	35.51	71.1
RRII 105	Tjir 1 x Gl 1	57.7	36.5	35.8	60.6
RRIC 104	RRIC 52 x Tjir 1	61.7	38.3	37.7	76.7
AVT 73	Estate selection	39.1	25.7	32.4	63.2
RRIC 52	Ortet selection	43.3	36.7	15.2	82.5
PB 217	PB 5/51 x PB 6/9	80.6	45.8	42.5	62.6
PB 260	PB 5/51 x PB 49	76.9	41.4	44.9	70.9
RRIM 600	Tjir 1 x PB 86	54.0	32.0	40.5	60.8
CD		18.8	14.8	14.5	11.7

summer yield was computed as percentage drop in yield during summer months over the annual mean value. Data was subjected to statistical analysis using standard procedures. Genetic parameters and standard heterosis for various traits were computed to assess the potential for high genetic gain through breeding for drought tolerance (Hays *et al.*, 1955; Fonseca *et al.*, 1968).

Results and discussion

The study revealed significant variation for annual yield, summer yield, summer depression and growth among the hybrids (Table 1). Annual mean yield ranged from 21.6 $gt^{-1}t^{-1}$ in HP 188 to 90.5 $gt^{-1}t^{-1}$ in HP 214. In general, the hybrids, from families involving RRIC 52 and RRIC 104 exhibited high mean yield compared to other families. Annual mean yield ranged from 56.3 $gt^{-1}t^{-1}$ in HP 270 of family RRII 105 x RRIC 52 to 90.5 $gt^{-1}t^{-1}$ in HP 214 of the same family. Hybrids of the family RRII 105 x RRIC 52 had an average yield of 71.8 $gt^{-1}t^{-1}$ while those from the family RRIM 600 x RRIC 52 showed average yield of 44.8 $gt^{-1}t^{-1}$. Among the check clones annual mean yield ranged from 43.3 $gt^{-1}t^{-1}$ in RRIC 52 to 80.6 g/t/t in PB 217.

Regarding summer yield, HP 216 of family RRII 105 x RRIC 52 showed maximum yield with 57.2 $gt^{-1}t^{-1}$ while clone 188 from family RRIM 600 x RRIC 52 showed minimum yield (19.3 $gt^{-1}t^{-1}$) as in Table 1. With reference to summer yield in different families, hybrids of family RRII 105 x RRIC 52 showed an average of 47.1 $gt^{-1}t^{-1}$ while those of family RRII 105 x AVT 73 showed an average of 30.1 $gt^{-1}t^{-1}$. In the check clones summer yield ranged from 25.7 in AVT 73 to 45.8 $gt^{-1}t^{-1}$ in PB 217. There was significant variation for summer depression among the hybrids (Table 1). Summer depression ranged from 10% in HP 188 to 49% in HPs 53 and 214. Among the families, hybrids of family RRIM 600 x RRIC 52 showed an average of 22.1% while those of family RRII 105 x AVT 73 showed an average of 43.6%. Summer depression ranged from 15.2 % in RRIC 52 to 44.9 in PB 260 %. With reference to summer depression also, family RRII 105 x RRIC 52 showed superior performance with an average of 32.4%.

With reference to growth performance of the clones, girth ranged from 50.1 cm in HP 188 to 78.9 cm in HP 216 (Table 1). Among the families, hybrids RRII 105 x RRIC 52 showed an average girth of 76.1 cm while those of family RRII 105

x PB 86 showed an average girth of 64.8 cm. Hybrids produced using RRIC 52 and RRIC 104 were able to attain high girthing compared to check clone RRII 105.

Clonal variations for response to drought in terms of yield and associated physiological parameters have been observed earlier in Wickham clones and germplasm accessions of *Hevea* and breeding and selection for drought tolerance have already been initiated in India and elsewhere (RRII, 2004; Varghese *et al*., 2006; Mercy *et al*., 2011). An earlier study showed significant clonal difference in yield during dry season (Jan-May); GT 1 could sustain yield trend even during drought and the yield drop was low (36 %) compared to Tjir 1 (61%) suggesting existence of drought-tolerant traits in GT 1 (Vijayakumar *et al*., 1988). Summer yield is considered as a clonal trait and has been used to categorize clones either as drought-tolerant or drought-susceptible (Premakumari *et al*., 1993). Based on chlorophyll traits, membrane stability and epicuticular wax content, clones have been categorised as drought-tolerant or drought-susceptible (RRII, 2004; Varghese *et al*., 2006). In the above study, Sri Lankan clones viz. RRIC 52 and RRIC 104, and a Malaysian clone RRIM 600, along with HP 225, HP 105 and HP 184 (hybrids which are also under long-term evaluation in the small scale trial), were shown to possess drought tolerant traits which commensurate with observation from the present study.

In the present study, clones like RRIC 52 and RRIC 104, which are known to be drought tolerant, have been used as parents in breeding for tolerance to drought. Hybrid clones derived from the cross using RRIC 104, RRIC 52 and RRIM 600 were able to inherit drought-tolerant traits as clearly evident from their overall pattern of high annual mean yield, summer yield, low yield depression, and girth. It is worthwhile to note that, based on chlorophyll flourescence, chlorophyll stability, membrane stability and epicuticular wax content, which are considered as traits conferring drought tolerance in *Hevea*, hybrids HP 225, HP 105 and

HP 184 of the present population, have already been identified as drought tolerant clones (RRII, 2004). Based on standard heterosis for traits under consideration, families involving RRIC 52 and RRIC 104 showed better heterosis compared to other families indicating potential for achieving significant levels of genetic gain through breeding for drought tolerance using these clones as parents (Table 2).

Details of genetic parameters are given in Table 3. Among the traits, annual mean yield and summer depression (%) showed high heritability. Summer yield and girth exhibited moderate heritability. With reference to correlation among various traits, summer yield was strongly correlated with annual mean yield and girth implying that high-yielding clones in general presented high rubber yield during summer months also (Table 4). Summer depression was correlated with annual mean yield indicating that high-yielding clones showed

Table 2. Standard heterosis for growth and yield of hybrids

Clone	Pedigree	Standard heterosis (%)			
		Annual mean yield	Summer yield	Summer depression	Girth
55	RRII 105 X AVT 73	-5.1	-12.3	6.2	12.7
53	RRII 105 X AVT 73	-2.6	-19.9	37.4	19.0
80	RRII 105 X PB 86	-1.0	4.1	-11.2	8.3
84	RRII 105 X PB 86	-41.6	-29.6	-30.4	5.7
88	RRII 105 X PB 86	15.9	12.5	5.7	7.0
270	RRII 105 X RRIC 52	-2.4	5.6	-11.1	25.2
216	RRII 105 X RRIC 52	18.6	56.6	-54.8	30.1
214	RRII 105 X RRIC 52	56.9	24.5	37.4	21.1
105	RRIM 600 X RRIC 104	-9.0	2.7	-15.5	26.8
225	RRIM 600 X RRIC 104	-24.0	-29.4	12.1	0.2
112	RRIM 600 X RRIC 104	2.9	9.9	-9.3	28.2
145	RRIM 600 X RRIC 52	6.7	24.9	-25.3	18.3
184	RRIM 600 X RRIC 52	-11.0	0.6	-18.9	24.3
188	RRIM 600 X RRIC 52	-62.6	-47.0	-70.9	-17.3
286	PB 217 X AVT 73	-14.7	-13.6	-0.8	17.3

Table 3. Heritability (H^2)for different traits among hybrids

	Phenotypic coefficient of variation	Genotypic coefficient of variation	H^2
Annual mean yield	31.9	24.6	0.60
Summer Yield	30.8	18.4	0.36
Summer Depression (%)	35.8	27.7	0.60
Girth	14.1	9.7	0.47

Table 4. Phenotypic correlation for growth and yield traits

	Annual mean yield	Summer yield	Summer depression	Girth
Annual mean yield	1			
Summer Yield	0.809**	1		
Summer Depression (%)	0.601**	0.069	1	
Girth	0.362	0.573**	-0.031	1

**significant at 1% level

significant drop in yield but still maintained better yield levels compared to rest of the clones. However, the extent of drop in yield was not correlated with summer yield *per se*. Girth was not correlated with annual mean yield and similar trends have been reported earlier (Narayanan and Kavitha, 2011).

Hybrids derived from drought-tolerant clones were able to sustain rubber yield during summer months when moisture stress is present, without considerable yield depression. This observation on sustainable yield during summer months from the present study, coupled with the previous finding that these hybrids possess other intrinsic drought-tolerant traits not only suggested that yield during summer months could be used as an indicator of drought tolerance in *Hevea* but also indicated potential use of drought tolerant clones as male parents for conferring tolerance traits to off-springs to otherwise high-yielding clones. Whether drought-tolerance is a paternally transmitted trait, however, needs further genetical analysis through systematic progeny testing. Nevertheless, more detailed investigation in above hybrids using physiological, biochemical and molecular markers could be of immense application in validating the summer resilience of clones as well as identification of markers for early selection for the above traits.

Through hybridization, traits for drought tolerance were successfully recovered from imported clones, as indicated by the superior performance of their hybrid progenies under summer period. Promising selections from the above breeding programme have already been identified as potential candidates for further long-term evaluation in large-scale as well as on-farm trials, in traditional and non-traditional regions experiencing drought phases, after which recommendations would be made for large-scale commercial planting.

References

Alika, J. E. (1985) Heritability and genotypic gain from selection in rubber (*Hevea brasiliensis*). *Silvae Genetica* 34: 1-4.

Fonseca, S. and F.L. Patterson (1968). Hybrid vigor in a seven-parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Science* 8: 85-88.

George, M. J. Sethuraj, M. R., Rao, G. G., Krishnaswamy, N. P. and George, P. J. (1980) Effect of environmental factors on yield and yield components in *Hevea brasiliensis*. International Rubber Conference, 1980, India.

Hays, H.K., Immer, F.R. and Smith, D.C. (1955) *Methods of Plant Breeding*. McGraw Hill Book Co. Inc., New York, pp. 52-65.

Mercy, M. A., Kavitha K. Mydin, Meenakumari . T. and Nair, D. B. (2011) Juvenile growth response of selected wild Amazonian accessions and hybrid *Hevea* clones of Wickham origin in a drought stressed environment. *Natural Rubber Research* 24(1): 76-83.

Narayanan, C. and Kavitha K. Mydin (2011) Heritability of yield and secondary traits in two populations of Para rubber tree (*Hevea brasiliensis*). *Silvae Geneitca* 60 (3-4): 132-139.

Premakumari, D., Panikkar, A.O.N., Marattukulam, J.G. and Sethuraj, M.R. (1993) Comparative bark anatomy of drought tolerant and susceptible clones of *Hevea brasiliensis*. *Indian Journal of Rubber Research* 6(1&2): 10-14.

Raghavendra, A. S., Sulochanamma, S., Rao G. G., Mathew, S., Satheesan, K. V., Sethuraj, M. R. (1984) The pattern of latex flow in relation to clonal variation, plugging and drought tolerance. *In* Proceedings of the IRRDB Symposium "Exploitation, Physiology and Improvement of *Hevea*." Montpellier, France. IRRDB, Kuala Lumpur, Malaysia, pp. 205–226.

Rubber Research Institute of India (2004) RRII Annual Report 2002-2003, pp. 204.

Satheesh, P. R. and James Jacob (2011) Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research* 24(1): 1-9.

Sethuraj, M.R. (1977) Studies on the physiological factors influencing yield in *Hevea brasiliensis* Muell. Arg. Ph D. Thesis, Banarus Hindu University, U.P. India, 184 p.

Sethuraj, M. R. and George, M. J. (1976) Drainage area of the bark and soil moisture content as factors influencing latex flow in *Hevea brasiliensis*. *Indian Journal of Plant Physiology* 19 : 12-15.

Shammi Raj, P.R., Satheesh and James Jacob (2011) Evidence for climate warming in some natural rubber growing regions of south India. *Natural Rubber Research* 24(1): 10-17.

Varghese, Annamma, Kavitha K. Mydin and Alice John (2006) Genetic improvement of *Hevea brasiliensis* in India. International Rubber Conference, 2006, Vietnam, pp. 325 - 341.

Vijayakumar, K. R., Rao, G. G., Rao, P. S., Devakumar, A. S., Rajagopal, R., George, M. J. and Sethuraj, M. R. (1988) Physiology of drought tolerance of *Hevea*. *Compte-Render du Colloque Exploitation Physiologie et Amelioratım de l'Hevea*, 1988. Paris, France, pp. 269 - 281.

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References

Alika, J. E. (1985) Heritability and genotypic gain from selection in rubber (*Hevea brasiliensis*). *Silvae Genetica* 34: 1-4.

Fonseca, S. and F.L. Patterson (1968). Hybrid vigor in a seven-parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Science* 8: 85-88.

George, M. J. Sethuraj, M. R., Rao, G. G., Krishnaswamy, N. P. and George, P. J. (1980) Effect of environmental factors on yield and yield components in *Hevea brasiliensis*. International Rubber Conference, 1980, India.

Hays, H.K., Immer, F.R. and Smith, D.C. (1955) *Methods of Plant Breeding*. McGraw Hill Book Co. Inc., New York, pp. 52-65.

Mercy, M. A., Kavitha K. Mydin, Meenakumari , T. and Nair, D. B. (2011) Juvenile growth response of selected wild Amazonian accessions and hybrid *Hevea* clones of Wickham origin in a drought stressed environment. *Natural Rubber Research* 24(1): 76-83.

Narayanan, C. and Kavitha K. Mydin (2011) Heritability of yield and secondary traits in two populations of Para rubber tree (*Hevea brasiliensis*). *Silvae Geneitca* 60 (3-4): 132-139.

Premakumari, D., Panikkar, A.O.N., Marattukulam, J.G. and Sethuraj, M.R. (1993) Comparative bark anatomy of drought tolerant and susceptible clones of *Hevea brasiliensis*. *Indian Journal of Rubber Research* 6 (1&2): 10-14.

Raghavendra, A. S., Sulochanamma, S., Rao G. G., Mathew, S., Satheesan, K. V., Sethuraj, M. R. (1984) The pattern of latex flow in relation to clonal variation, plugging and drought tolerance. *In* Proceedings of the IRRDB Symposium "Exploitation, Physiology and Improvement of *Hevea*," Montpellier, France. IRRDB, Kuala Lumpur, Malaysia, pp. 205–226.

Rubber Research Institute of India (2004) RRII Annual Report 2002-2003, pp. 204.

Satheesh, P. R. and James Jacob (2011) Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research* 24(1): 1-9

Sethuraj, M.R. (1977) Studies on the physiological factors influencing yield in *Hevea brasiliensis* Muell. Arg. Ph D. Thesis, Banarus Hindu University, U.P. India, 184 p.

Sethuraj, M. R. and George, M. J. (1976) Drainage area of the bark and soil moisture content as factors influencing latex flow in *Hevea brasiliensis*. *Indian Journal of Plant Physiology* 19 : 12-15.

Shammi Raj, P.R., Satheesh and James Jacob (2011) Evidence for climate warming in some natural rubber growing regions of south India. *Natural Rubber Research* 24(1): 10-17.

Varghese, Annamma, Kavitha K. Mydin and Alice John (2006) Genetic improvement of *Hevea brasiliensis* in India. International Rubber Conference, 2006, Vietnam, pp. 325 - 341.

Vijayakumar, K. R., Rao, G. G., Rao, P. S., Devakumar, A. S., Rajagopal, R., George, M. J. and Sethuraj, M. R. (1988) Physiology of drought tolerance of *Hevea*. *Compte-Render du Colloque Exploitation Physiologie et Amelioratim de l'Hevea*, 1988. Paris, France, pp. 269 - 281.