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Adaptability of prospective mother trees of *Hevea* to the cold climate of Sub-Himalayan West Bengal and Assam

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Abstract

Ortet selection in rubber from polycross mother trees grown in stress prone areas is one of the mandate for developing new generation rubber clones for the non-traditional regions. Aiming at this, experiments were laid out at two Regional Research Stations of Sub-Himalayan range of North Eastern India, *viz.* Nagrakata in Jalpaiguri district of West Bengal and Sarutari in Kamrup district of Assam. The weather of both the stations was different from each other especially on the basis of temperature (T_{max} and T_{min}) and total annual rainfall. Effect of such variations in weather condition had reflected on growth and yield performance of the seedlings. The collective mean yield of trees showing yield above the average block yield every years over eleven years (category I) was much lower at Nagrakata (44.84 g tree^{-1} tap^{-1}) than Sarutari (53.29 g tree^{-1} tap^{-1}) but it was opposite in category II where the trees showed above average yield for ten years over eleven years. In view of the yield performance at Nagrakata, the mother tree NGK 203 was the top ranker (69.79 g tree^{-1} tap^{-1}) followed by NGK 47 (55.40 g tree^{-1} tap^{-1}) with low CV (37.11% and 35.33% respectively) and appreciable winter yield contribution (53.92% and 52.17% respectively); at Sarutari, it was GWH 245 (86.74 g tree^{-1} tap^{-1}) followed by GWH 286 (81.14 g tree^{-1} tap^{-1}) with CV of 55.01 per cent and 40.35 per cent, respectively and winter yield contribution of 48.33 per cent and 43.61 per cent, respectively. Study on adaptation of potential mother trees to two different weather conditions was compared.

Keywords: Adaption, cold, growth, mother ortet, seedling, rubber yield

Introduction

Hevea brasiliensis, a tree crop having wide adaptive potential to adverse climatic conditions when cultivated in non-traditional region not only manages to cope with the abiotic stress *viz.* low winter temperature (cold stress - Priyadarshan *et al.*, 2000; Meenatoor *et al.*, 2000; Reju *et al.*, 2002 and 2007; Mondal *et al.*, 2007b; Das *et al.*, 2010) or high summer temperature (drought stress – Devakumar *et al.*, 1998; Chandrashekar *et al.*, 1998; Gupta and Edathil 2001; BalKrishnan *et al.*, 2007), high or below optimum rainfall (Dea *et al.*,1997), high wind speed (Priyadarshan *et al.*,1998 a and b) but also with the biotic stress like powdery mildew disease (Mondal *et al.*, 2007a). The common practice of propagating rubber plants is through bud grafting – a method where source of stock and scion is different. The question of compatibility/ incompatibility of the bud-grafted trees under the biotic/abiotic stress arise at this point.

High yield, high biomass, disease tolerance *etc*. are the major desirable attributes which are achieved through breeding; however, it is time consuming and success is fortuitous. A more practical approach would be phenotypic selection of offspring(s) raised from naturally occurring polycross seeds at the nurser/juvenile stage and finally, selecting mother trees on the basis of growth and yield performance. Secondary characters like high biomass, disease tolerance, wind-fast *etc*. also carry equal weightage because susceptibility to any one of them would affect the primary character. Final evaluation would be performed in the second generation through budgrafting of the selected

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mother ortets at the nursery level. Keeping this in view, an attempt was made to plant seedlings in two different climatic conditions of Northeast India are in Kamrup district of Assam and the other in Jalpaiguri district of West Bengal to screen region specific planting material.

Materials and Methods

Study was initiated in two different regions *viz*. Nagrakata in Jalpaiguri, district of West Bengal and Sarutari in Kamrup, district of Assam. The terrain of Nagrakata (Table 1) revealed that it is situated more towards northern side (latitude 26°43′ N) of the Sub-Himalayan North East India than from Sarutari (26°35′ N); longitudinally Sarutari is more towards eastern side (90°52′ E) than Nagrakata (88°26′ E). Sarutari has hilly terrain with altitude ranging from 50 to 105 m above MSL whereas, Nagrakata is a flat land at an altitude of 69 m above MSL. Mean of all meteorological data on weekly basis for both the sites were collected from the meteorological observatory situated inside the plantation.

One thousand polyclonal seeds were collected from the *Hevea* Breeding Sub-Station at Kanyakumari district of Tamil Nadu for each of the stations. Three hundred and fourty high vigour seedlings were planted at Sarutari in Kamrup district Assam in 1987 and 290 high vigour seedlings were planted at Nagrakata in Jalpaiguri district of West Bengal in 1990 separately. Completely randomized design with a spacing of 5 m x 5 m was adopted (single tree single plot). The final plant stand at Nagrakata was 178 and that at Sarutari was 270 at the 8th year after planting. Girth data was recorded at 110 cm height for both the experiments at panel opening time after 8 years of planting and final girth data was taken at 12th year after tapping. Timber yield of plants at 20th year of planting was calculated using girth and first branch height following true volume method (Chaturvedi and Khanna, 1982). Biomass was estimated at 20th year of planting from girth following the equation developed by Shorrocks *et al.* (1965). Yield data was recorded since the opening of the panel; however, to get dependable yield data for analysis, eleven consecutive years data were taken after 2nd year of tapping till 12th year at Nagrakata and after 3rd year of tapping till 13th year at Sarutari. The tapping system adopted for the experiment was S/2 d2 6d/7. The average yield of the population/block for each year was calculated and trees showing above population average yield every year (for eleven consecutive years) were selected as the best yielder. This was followed by the trees showing above average yield for ten years over eleven years of tapping. Such a stringent selection procedure was preferred to ensure the consistency of high yield performance/potential of the seedlings throughout the eleven tapping years under the agro-climate of two different regions.

Monthly yield data of each plant was collected on dry rubber yield basis every year. Crop efficiency was calculated considering mean yield (g $tree^{-1}$ tap^{-1}) and mean of tapping panel length (cm). Visual scoring on wind damage, tapping panel dryness (TPD), powdery mildew disease (PMD) was undertaken for the last three consecutive years of tapping. Scoring on PMD incidence was done under

Table 1. Meteorological parameters of two experimental stations (mean of twelve years weather data)

Place		Mean of weekly climatological parameters												Total annual rain fall (mm)	
		T max (°C)		T min (°C)		Sunshine (hr)		Wind speed (m s^{-1})		RH morning IST0625 (%)		RH evening IST1325 (%)			
		NW	W	NW	W	NW	W	NW	W	NW	W	NW	W	NW	W
Nagrakata,	Mean	31.4	27.1	23.2	12.3	4.4	6.5	1.8	1.4	94	94	74	58	3587	226
Jalpaiguri,	Range	25.7	16.3	14.6	04.2	0.0	0.0	0.0	0.0	76	72	37	29	2798	53
West Bengal		to	to	to	to	to	to	to	to	to	to	to	to	to	to
(mean of 1998 - 2009)		34.8	33.2	27.7	24.7	10.2	10.5	3.8	8.9	99	99	98	97	4540	550
Sarutari,	Mean	32.0	27.4	23.2	14.7	4.9	6.6	1.3	2.2	91	86	76	61	1214	134
Kamrup,	Range	23.0	18.5	15.5	08.3	0.0	0.0	0.0	0.0	70	51	41	32	661	20
Assam		to	to	to	to	to	to	to	to	to	to	to	to	to	to
(mean of 1995 - 2006)		36.2	35.2	25.9	22.4	10.2	10.0	8.7	9.4	99	96	98	88	1646	328

Non-winter (NW) = April to September   Winter (W) = October to March sulphur dusted condition. All the experimental plants were rainguarded and routine cultural practices were followed as per the schedule of the Rubber Board. Data were subjected to analysis of variance in Microsoft Excel considering RRIM 600 as the check clone.

Results and Discussion

The meteorological data of the two stations *viz*. Sarutari and Nagrakata was tabulated (Table 1) with the average values of 52 meteorological weeks over 11 years, dividing the weather as non-winter (NW) (April to September) and winter (W) (October to March) period. The temperature data indicated that the fluctuation in T_{min} between NW and W was wider in both the regions compared to that in T_{max}. There was not much variation in morning and evening relative humidity (RH_m and RH_e) except in the RH_e in Nagrakata where, it was lower during W than that in NW period. The sunshine hours was more during W period than that in NW period. The mean total precipitation during NW was more than that during W period because the rainy days are concentrated more during NW period. Thus, in both the regions the trend of weather fluctuation was similar.

While considering the absolute values of weather parameters in both the regions, Nagrakata was found to be cooler than Sarutari. The annual mean T_{min} during NW and W period in Nagrakata was 23.2 °C and 12.3 °C respectively and that of T_{max} was 31.4 °C and 27.1 °C respectively, whereas, in Sarutari T_{min} during NW and W period was 23.2 °C and 14.7 °C, respectively that in T_{max} it was 32.0 °C and 27.4 °C, respectively. Total annual rainfall in Nagrakata was significantly higher than that of Sarutari. The weather parameters of both the stations revealed that the weather at Nagrakata is widely different from that at Sarutari where polycross progenies were cultivated in block. Therefore, comparing the performance of polycross seedlings in these two widely different weathers of North Eastern India is worth investigating.

In the present study, selection of outstanding performers was done on the basis of yearly average rubber yield. Data on yearly mean yield of each year was calculated and trees showing yield above / below the average population yield for each year was considered for the study. At Nagrakata, out of 178 tapping plants only four trees *viz.* NGK 43, NGK 224, NGK 136 and NGK 55 (Table 2a) showed above the average block yield every year for eleven consecutive years (category I). The coefficient of variance (CV) per cent of yield over years of NGK 224 and NGK 136 trees were high (above 40) except in NGK 43 (5.51) and in NGK 55 (32.13). Crop efficiency in the high yielding mother trees *viz.* NGK 55 and NGK 136 was 1.4 g $tree^{-1}$ tap^{-1} cm^{-1} and 1.1 g $tree^{-1}$ tap^{-1} cm^{-1} respectively, whereas, for the other two it was less than one. In general, the contribution of BO2 panel was more (57.64 g $tree^{-1}$ tap^{-1}) than BO1 panel (40.12 g $tree^{-1}$ tap^{-1}) except for NGK 136 where, the difference was narrow. Winter yield contribution ranged from 42 to 54 per cent that indicated less variation between the NW and W yield. A second group (category II) of high yielding mother trees was selected at Nagrakata based on above average yield for consecutive ten years over eleven years of tapping (Table 2a). Out of 178 tapping plants, eleven trees were found to be in this category. The yield of these trees ranged from 35.05 g $tree^{-1}$ tap^{-1} to 69.78 g $tree^{-1}$ tap^{-1}. The CV per cent of the second group varied from 29.89 to 41.95 with crop efficiency ranging from 1.0 g $tree^{-1}$ $tap^{-1}$$cm^{-1}$ to 1.9 g $tree^{-1}$ tap^{-1} cm^{-1}. The overall yield of BO2 panel of this group was lower than the category I. Winter yield contribution ranged from 45.34 to 60.84 per cent with an exception of NGK 146 where it was 37 per cent only. The best performer in this category was NGK 203 with 69.79 g $tree^{-1}$ tap^{-1} yield with a crop efficiency of 1.87 g $tree^{-1}$ tap^{-1} cm^{-1} and low CV (37.11%).

Out of 270 seedlings at Sarutari, fourteen mother trees (Table 2b) showed above average yield for eleven consecutive years (category I). Annual average yield of these fourteen plants ranged from 32.55 g $tree^{-1}$ tap^{-1} to 86.74 g $tree^{-1}$ tap^{-1} with collective mean of 53.29 g $tree^{-1}$ tap^{-1}. Highest yield was found in GWH 245 (86.74 g $tree^{-1}$ tap^{-1}) followed by GWH 286 (81.14 g $tree^{-1}$ tap^{-1}). The CV per cent of this category varied from 18.20 to 55.01 and the mean crop efficiency of the category I was 1.51 g $tree^{-1}$ tap^{-1} cm^{-1}. Yield performance of BO1 panel (population average 43.02 g $tree^{-1}$ tap^{-1}) was lower than that of the BO2 panel (64.35 g $tree^{-1}$

Table 2 (a). Pattern of yield in selected mother trees at Nagrakata showing above average block yield from polyclonal block compared to RRIM 600

Name of mother plants	Annual average yield over eleven years (g tree^{-1} tap^{-1})	CV of annual average yield (%)	Crop efficiency (g tree^{-1} tap^{-1} cm^{-1} panel)	Average yield of BO1 panel (g tree^{-1} tap^{-1})	Average yield of BO2 panel (g tree^{-1} tap^{-1})	Winter yield contribution (%)
Category I: Mother trees showing above average block yield over consecutive eleven years						
NGK43	36.26	5.51 **	0.90	31.41	61.24 **	42.09
NGK224	46.13 **	42.87 **	0.97	39.92 **	60.66 **	53.59
NGK136	47.02 **	41.05 *	1.11	42.28 **	48.46 **	52.70
NGK55	49.92 **	32.13	1.43	46.87 **	60.20 **	53.58
Collective mean	44.84	40.39	1.08	40.12	57.64	50.49
Category II: Mother trees showing above average block yield for ten years over eleven years of tapping						
NGK15	43.85 **	33.02	0.99	40.64 **	53.85 **	50.69
NGK114	50.32 **	41.95 **	1.01	42.89 **	62.87 **	53.26
NGK22	48.45 **	31.09	1.01	43.41 **	60.88 **	60.84
NGK11	38.40	31.26	1.03	34.56 *	43.14	48.87
NGK147	35.08	29.89	1.12	36.39 **	40.21	45.34
NGK47	55.40 **	35.33	1.14	45.14 **	72.96 **	52.17
NGK78	43.80 **	36.65	1.16	44.69 **	48.21 **	57.15
NGK146	47.29 **	34.02	1.16	48.84 **	50.23 **	36.69
NGK69	49.45 **	31.46	1.33	53.67 **	51.92 **	51.11
NGK91	43.34 **	35.66	1.35	39.73 **	52.68 **	55.09
NGK203	69.79 **	37.11	1.87	62.04 **	86.81 **	53.92
Collective mean	45.04	34.17	1.13	41.10	54.59	52.62
RRIM 600	36.51	35.55	1.10	32.50	43.90	60.81
CD (P=0.05)	2.95	4.77	NS	1.73	2.45	NS

* Significant at (P≤0.05); ** Significant at (P≤0.01)

tap^{-1}) in this group. Winter yield contribution varied from 41.01 to 66.71 per cent with collective mean of 52.78 per cent. In the second category fourteen trees were found (Table 2b) collective mean of which was 34.07 g tree^{-1} tap^{-1} with a range from 27.46 g tree^{-1} tap^{-1} to 50.83 g tree^{-1} tap^{-1}. The CV of this group of mother trees varied from 20.12 to 37.84 per cent indicating that fluctuation in yield over years in this category was less compared to the first category. Crop efficiency ranged from 1.03 g tree^{-1} tap^{-1} cm^{-1} to 1.62 g tree^{-1} tap^{-1} cm^{-1}. Difference between the yield in BO1 and BO2 panel was low. All the trees showed 50 per cent or above winter yield contribution except GWH 181 (49.13%). The best performer in this category was GWH 191 with 50.83 g tree^{-1} tap^{-1} mean yield, 31.94 per cent CV and crop efficiency of 1.59 g tree^{-1} tap^{-1} cm^{-1}.

While considering the secondary attributes of the fifteen potential polycross mother trees of Nagrakata (Table 3a), it was observed that the highest girth at panel opening was achieved by NGK 136 (64.3 cm) followed by NGK 55 and NGK 47 both showing the girth of 58.6 cm. The collective mean of girth at tapping of category I in Nagrakata was higher (58.5 cm) than that of the category II (50.5 cm). Girth increment rate was similar (84.7 cm and 86.8 cm respectively) in both the categories except NGK 114 where, it was high (101.4 cm). The highest clear bole volume was found in NGK 47 (0.35 m^3) followed by NGK 15 (0.29 m^3) with an annual average yield of 55.4 g tree^{-1} tap^{-1} and 43.9 g tree^{-1} tap^{-1} (Table 2a) respectively. The girth of promising mother trees *viz.* NGK 55, NGK 69, NGK 22, NGK 203, NGK 47, and NGK 114 ranged from 72.0 cm to 101.4 cm with bole volume varying from 0.1 m^3 to 0.15 m^3 and biomass ranging from 284 kg tree^{-1} to 995 kg tree^{-1}. The data on powdery mildew disease intensity revealed that all the selected trees were moderately tolerant. The check clone RRIM 600 showed 51.7 cm girth at panel opening time that increased upto 68.5 cm after 11 years of tapping. Bole volume of this clone was as low as 0.08 m^3 with moderate tolerance to powdery mildew disease. At Nagrakata, 87 per cent trees showed significantly higher girth than the check clone and bole volume

Table 2 (b). Pattern of yield in selected mother trees showing above average block yield from polyclonal block compared to RRIM 600 at Sarutari, Assam

Name of mother plants	Annual yield over eleven years (g tree^{-1} tap^{-1})	CV of average yield (%)	Crop efficiency (g tree^{-1} tap^{-1} cm^{-1})	Average yield of BO1 panel (g tree^{-1} tap^{-1})	Average yield of BO2 panel (g tree^{-1} tap^{-1})	Winter yield contribution (%)
Category I: Mother trees showing above average block yield over eleven consecutive years						
GWH37	32.55	38.93	0.84	25.10	39.76	41.01
GWH41	43.74	31.73	1.38	34.92 **	54.32	49.73
GWH57	34.03	18.20	1.87	32.13 **	31.25	46.24
GWH65	59.83 **	36.55	1.64	48.16 **	69.25 **	54.54
GWH86	47.33	41.99	1.13	45.46 **	46.34	56.65
GWH132	55.26 **	31.33	1.76	43.69 **	64.50 **	52.01
GWH165	46.39	27.94	1.66	41.44 **	47.65	66.71 **
GWH206	31.73	29.11	1.09	29.08	34.79	53.37
GWH245	86.74 **	55.01 **	1.58	57.75 **	120.74 **	48.33
GWH260	55.00 **	35.42	1.55	43.45 **	68.36 **	53.42
GWH286	81.14 **	40.35	2.01	67.32 **	98.17 **	43.61
GWH293	53.50 **	49.84 *	1.07	34.40 **	77.97 **	56.41
GWH173	64.54 **	33.56	1.92	51.48 **	76.10 **	60.30 **
GWH248	54.30 **	33.02	1.64	47.95 **	71.69 **	56.62
Collective mean	53.29	35.93	1.51	43.02	64.35	52.78
Category II: Mother trees showing above average block yield for ten years over eleven years of tapping						
GWH25	32.21	31.32	1.03	30.57 **	43.94	66.04 **
GWH107	29.95	25.13	1.19	26.33	33.99	52.74
GWH113	40.76	32.13	1.27	39.31 **	46.56	56.43
GWH161	36.46	23.76	1.53	29.77 *	43.47	58.29
GWH179	36.18	23.37	1.55	39.37 **	34.19	52.19
GWH185	31.84	25.49	1.25	25.35	39.36	50.92
GWH191	50.83 **	31.94	1.59	49.92 **	43.49	53.19
GWH235	40.62	37.84	1.07	31.91 **	51.68	62.24 **
GWH258	27.46	24.58	1.12	25.09	32.95	61.58 **
GWH90	29.18	22.62	1.29	27.44	34.62	63.81 **
GWH127	29.49	29.19	1.01	28.68	31.51	59.61 **
GWH177	29.57	25.62	1.15	32.59 **	29.42	59.78 **
GWH181	29.89	23.04	1.30	27.89	34.31	49.13
GWH203	32.59	20.12	1.62	35.17 **	34.84	59.55 **
Collective mean	34.07	26.87	1.28	32.10	38.17	57.53
RRIM 600	43.82	44.73	NS	25.67	52.27	56.13
CD(P=0.05)	4.66	3.24	2.26	3.66	6.21	2.80

* Significant at ($P \leq 0.05$); ** Significant at ($P \leq 0.01$)

of all the trees were at par with the check clone; biomass of nine trees were found to be superior to the check clone. Percentage of PMD incidence in NGK 47, NGK 69 and NGK 91 was significantly higher than RRIM 600.

The collective mean girth at tapping of the first category at Sarutari was 53.5 cm with a range of 47.4 cm to 60.9 cm (Table 3b). The mean girth was 94.5 cm with a range from 76.8 cm to 119 cm and an annual girth increment ranging from 1.9 cm yr^{-1} to 4.9 cm yr^{-1}. The clear bole volume ranged from 0.10 m^3 to 0.37 m^3 with annual average of 0.23 m^3. Powdery mildew disease intensity varied from moderately tolerant to susceptible range. In the second category, the mean girth at panel opening was 50.4 cm and the best scorer was GWH 191 (58.8 cm). The highest girth was achieved by GWH 235 (104.5 cm). Girth increment after tapping varied from 1.7 cm yr^{-1} to 4.7 cm yr^{-1}. Three mother trees showed above 0.40 m^3 bole volume *viz.* GWH 107, GWH 235 (0.44 m^3) and GWH 258 (0.42 m^3). The girth of RRIM 600 at tapping was 52.5 cm which attained 74.4 cm after 11 years of tapping with bole volume being as low as 1.2 m^3; the clone was moderately tolerant to powdery mildew disease.

Table 3 (a). Secondary characteristics of selected mother trees showing above average block yield from polyclonal block compared to RRIM 600 at Nagrakata, West Bengal

Name of mother plants	Girth at tapping (cm)	Girth at 12th year after tapping (cm)	Girth increment after tapping (cm year^{-1})	Bole volume at 12th year after tapping (m^3)	Biomass at 12th year after tapping (kg tree^{-1})	Powdery mildew disease intensity (%)#
Category I: Mother trees showing above average block yield over eleven years						
NGK43	56.7 **	82.7 **	2.2	0.12	564 *	50
NGK224	54.5	85.1 **	3.9	0.15	611 **	54
NGK136	64.3 **	99.1 **	1.1	0.20	933 **	50
NGK55	58.6 **	72.0 **	2.9	0.10	384	47
Collective mean	58.5	84.7	2.5	0.14	623	51
Category II: Mother trees showing above average block yield for ten years over eleven years of tapping						
NGK15	51.0	90.5 **	3.3	0.29	725 **	48
NGK114	45.1	101.4 **	4.7	0.15	995 **	53
NGK22	58.2 **	97.5 **	3.3	0.16	892 **	51
NGK11	45.4	76.3 **	2.6	0.09	451	49
NGK147	53.8	64.6	0.9	0.07	944 **	45
NGK47	58.6 **	99.5 **	3.4	0.35	284	57 **
NGK78	50.2	77.8 **	2.3	0.13	944 **	43
NGK146	44.7	83.7 **	3.3	0.14	476	52
NGK69	53.2	76.1 **	1.9	0.11	583 *	63 **
NGK91	55.9 *	66.1	0.9	0.07	448	55 **
NGK203	56.1 **	76.7 **	1.7	0.13	302	51
Collective mean	50.5	86.8	2.6	0.18	625	52
RRIM 600	51.7	68.5	3.3	0.08	334	50
CD (P≤0.05)	3.54	2.43	NS	NS	197.71	4.65

#Disease index data: 0 to 30 = Tolerant; 31 to 50 = Moderately tolerant; > 51 = Susceptible
*Significant at (P≤0.05); **Significant at (P≤0.01)

Sixty four percent trees showed significantly higher girth than the check clone RRIM 600 at Sarutari; however, none of the trees showed higher bole volume than RRIM 600.

The incidence of tapping panel dryness (TPD) in the selected mother trees at both the stations was found to be either negligible or below 25 per cent except in GWH 248 (above 70%) which was highly susceptible to TPD. Low incidence of panel dryness by polyclonal population was reported in Tripura (Sasikumar *et al.*, 2001). Such a low incidence of panel dryness in polyclonal trees compared to the budgrafted elite clones was reported to be due to low yielding potential of the seedling population (Dey, 2006). A seasonal variation in TPD was observed in rubber trees under tapping, grown in cold climatic condition (Das *et al.*, 2006) with severe invasion during winter. Reduction in TPD with tapping rest in North Eastern India was observed (Das *et al.*, 2006 and 2008) which may be due to optimum reconstitution of cellular damage (Jacob *et al.*, 1994).

Trees that showed low winter yield potential were presumed to be susceptible to the climatic condition of the respective region. It was felt necessary to get contrasting groups while focusing on the efficiency of polycross trees grown under the low winter temperature. At Nagrakata 4.5 per cent trees and at Sarutari 3.3 per cent trees showed yield below the average yield of the population every year for eleven consecutive tapping years (Table 4). Mean yield of this lowest group at Nagrakata was 17.0 g tree^{-1} tap^{-1}, with mean crop efficiency of 0.65 g tree^{-1} tap^{-1} cm^{-1} and winter yield contribution of 52.0 per cent respectively. At Sarutari, the mean yield of the 3.3 per cent selected lowest group was 12.3 g tree^{-1} tap^{-1} with mean crop efficiency of 0.38 g tree^{-1} tap^{-1} cm^{-1} panel length and 52.7 per cent average winter yield contribution. The yield performance of low yielding group was better at Nagrakata than Sarutari. The mean girth at panel opening time in the lowest yield group at Nagrakata was 45.4 cm that attained 54.4 cm girth at 12th year with average clear bole volume of 0.07m^3 and biomass of 179 kg tree^{-1}.

Table 3 (b). Secondary characteristics of selected mother trees showing above average block yield from polyclonal block compared to RRIM 600 at Sarutari, Assam

Name of mother plants	Girth at tapping (cm)	Girth at 12th year after tapping (cm)	Girth increment after tapping (cm year^{-1})	Bole volume at 12th year after tapping (m^3)	Biomass at 12th year after tapping (kg tree^{-1})	Powdery mildew disease intensity (%)#
Category I: Mother trees showing above average block yield for eleven years of tapping						
GWH37	48.8	70.50	3.1	0.28	362	60.1
GWH41	47.9	66.10	2.6	0.12	302	52.3
GWH57	57.0**	56.40	1.9	0.10	194	60.3
GWH65	60.9**	81.50 *	4.6 *	0.21	542**	27.5
GWH86	59.5**	103.40**	4.0	0.31	1050**	45.0
GWH132	52.2	78.50 *	3.1	0.37	488	40.4
GWH165	54.9	103.40**	4.4 *	0.31	1050**	45.0
GWH206	47.4	44.50	2.5	0.16	101	53.4
GWH245	57.3**	52.20	5.6**	0.33	157	40.5
GWH260	52.2	85.00**	3.6	0.24	609**	78.0
GWH286	51.2	104.30**	3.2	0.19	1076**	35.5
GWH293	52.8	33.40	4.9**	0.19	45	38.7
GWH173	52.9	46.70	3.9	0.14	115	43.7
GWH248	53.6	56.90	4.6 *	0.30	199	30.0
Collective mean	53.5	70.20	3.7	0.23	449	46.5
Category II: Mother trees showing above average block yield for ten years over eleven years of tapping						
GWH25	45.8	74.20	2.2	0.08	417	52.4
GWH107	47.1	50.40	3.9	0.44	142	55.1
GWH113	49.4	83.00**	3.1	0.08	570**	51.0
GWH161	45.5	63.00	2.1	0.20	265	62.9
GWH179	55.7**	75.40	1.7	0.12	436	58.1
GWH185	47.4	69.00	2.3	0.29	341	52.0
GWH191	58.8**	75.40	2.5	0.14	436	49.5
GWH235	53.3	82.20**	4.7**	0.44	555**	71.0
GWH258	53.7	91.50**	3.4	0.42	747**	66.9
GWH90	51.2	73.70	1.8	0.11	409	61.2
GWH127	47.1	94.00**	2.1	0.16	806**	66.1
GWH177	51.5	67.80	1.7	0.25	325	68.0
GWH181	46.0	73.50	2.2	0.13	406	65.1
GWH203	53.0	74.10	3.2	0.22	416	61.0
Collective mean	50.4	74.80	2.6	0.22	448	60.0
RRIM 600	52.5	68.50	1.9	0.12	334	80.0
CD(P≤0.05)	2.52	9.69	2.28	NS	153.60	NS

#Disease index data: 0 to 30 = Tolerant; 31 to 50 = Moderately tolerant; > 51 = Susceptible
* Significant at (P≤0.05); ** Significant at (P≤0.01)

Table 4. Characteristics of group of plants showing below average yield for eleven consecutive tapping years

Place	Percentage of plants showing below average yield	Collective mean									
		Mean yield over 11 years (g tree^{-1} tap^{-1})	CV of annual average yield (%)	Crop efficiency (g tree^{-1} tap^{-1} cm^{-1} panel)	Winter yield contribution (%)	Girth at tapping (cm)	Girth at 12th year after tapping (cm)	Girth increment after tapping (cm year^{-1})	Bole volume at 12th year after tapping (m^3)	Biomass at 12th year after tapping (kg tree^{-1})	Powdery mildew disease (PDI)
Nagrakata, Jalpaiguri	4.5	17.00	47.61	0.65	51.99	45.4	54.4	0.7	0.07	179	62.9
Sarutari, Assam	3.3	12.26	36.73	0.38	52.66	44.5	65.8	1.9	0.15	311	57.8

Plants with 80-100 per cent incidence TPD were negligible and the intensity of powdery mildew disease was high. At Sarutari, the average girth of lowest group at panel opening time was 44.5 cm that attained to 65.8 cm girth at 12th year after tapping with an annual girth increment of 4.0 cm, clear bole volume of 0.15 m^3 and biomass of 311 kg $tree^{-1}$. Trees with 80-100 per cent TPD incidence were negligible (0.5%) with varied intensity of powdery mildew disease.

On the basis of the weather parameters studied for both the regions, it revealed that the weather in Sarutari is different from that in Nagrakata (Table 1). Effect of such variations in climatic condition had reflected on growth and yield performance of the seedlings also. The mean yield of category I was much lower at Nagrakata than Sarutari but it was similar in category II of both the regions. Among the trees in category I and II, thirteen trees showed CV of below 30 per cent at Sarutari (46%) but at Nagrakata it was two trees (13%) indicating that yield over eleven years was more stable at Sarutari than at Nagrakata.

Three plants out of four plants at Nagrakata in category I and nine plants out of eleven plants in category II showed significantly higher yield than that of RRIM 600. The superiority of these trees were maintained in BO1 and BO2 panels also. Eight plants out of fourteen plants in category I at Sarutari and one plant out of fourteen plants in category II showed significantly higher yield than RRIM 600. These mother plants were preserved in source bush nursery and are being under further evaluation trial. The mother tree *viz.* NGK 203 was the top ranker (69.8 g $tree^{-1}$ tap^{-1}) at Nagrakata followed by NGK 47 (55.4 g $tree^{-1}$ tap^{-1}) among the lot with low CV (37.1% and 35.3% respectively) and good winter yield contribution (53.9% and 52.2% respectively); it was GWH 245 (86.74 g $tree^{-1}$ tap^{-1}) at Sarutari followed by GWH 286 (81.14 g $tree^{-1}$ tap^{-1}) with CV of 55.01 per cent and 40.35 per cent respectively and winter yield contribution of 48.33 per cent and 43.61 per cent, respectively.

Plants showing better yield during winter period were presumed to be well adapted to the cold climatic extremes of the region. Consequently, among the selected mother trees at Sarutari, nine plants showed 60 per cent or more winter yield contribution, whereas, it was only one at Nagrakata. The data indicated that the selected mother trees were better adapted to the climatic shifts of Sarutari than that of Nagrakata which may be because of the pronounced/extreme weather change (*viz.* low winter temperature, high rainfall) at Nagrakata within the year and over years than that at Sarutari.

References

Bal Krishnan, Rao, K.N. and Nazeer, M.A. 2007. Growth performance of *Hevea brasiliensis* in a dry sub-humid climate of Bastar region of central eastern India. *Indian Journal of Natural Rubber Research* **20**(1&2): 56-60.

Chandrashekar, T.R., Nazeer, M.A., Marattaukalam, J.G., Prakash, G.P., Annamalainathan, K. and Thomas, J. 1998. An analysis of growth and drought tolerance in rubber during the immature phase in a dry sub-humid climate. *Experimental Agriculture* **34**: 1-14.

Chathurvedi, A.N. and Khanna, L.S. 1982. *Forest Mensuration*. International Book Distributors, Dehradun, pp. 310.

Das, G., Raj, S. and Dey, S.K. 2006. Seasonal variation in occurrence of TPD in the agroclimatic condition of Tripura. In: *Tapping Panel Dryness of Rubber Trees*. (Eds.) J. Jacob, R. Krishnakumar and N.M. Mathew. Rubber Research Institute of India, Kottayam, Kerala, India, pp. 68-73.

Das, G. Raj, S., Dey, S.K. and Chaudhuri, D. 2008. Low winter temperature rest based tapping system for Tripura and north Bengal. *Indian Journal of Natural Rubber Research* **21**(1&2): 84-91.

Das, G., Chaudhuri, D. and Varghese, Y.A. 2010. Evaluation of *Hevea* clones in the mature phase under the agroclimate of Sub-Himalayan West Bengal. *Journal of Plantation Crops* **38**(2): 105-110.

Dea, G.B., Keli, Z.J., Eschbach, J.M., Omont, H., and Canh, T. 1997. Rubber tree (*Hevea brasiliensis*) behaviour in marginal climatic zones of Côte d' Ivoire: assessment of ten years observations. In: *IRRDB Symposium on Agronomical Aspects of the Cultivation of Natural Rubber* (*Hevea brasiliensis*) (Ed.) M.E. Cronin IRRDB, Hertford, UK. pp. 44-53.

Devakumar, A.S., Sathik M., Jacob J., Annamalainathan K., Prakash G.P. and Vijayakumar K.R. 1998. Effects of atmospheric and soil drought on growth and development of *Hevea brasiliensis*. *Journal of Rubber Research* **1**: 190-198.

Dey, S.K. 2006. Incidence of tapping panel dryness in *Hevea brasiliensis* trees in Tripura. In: *Tapping Panel Dryness of Rubber Trees*. (Eds.) J. Jacob, R. Krishnakumar and N.M. Mathew. Rubber Research Institute of India, Kottayam, Kerala. pp. 74-78.

Gupta, C.K. and Edathil, T.T. 2001. Growth performance during the immature phase of a few rubber (*Hevea brasiliensis*) clones in Orissa. *Indian Journal of Natural Rubber Research* **14**(2): 159-164.

Jacob, J.L., Prevot, J.C. and Lacrotte, R. 1994. Tapping panel dryness in *Hevea brasiliensis*. *Plantations Recherche Development* **1**(3): 22-24.

Meenatoor, R.J., Sasikumar, B., Soman, T.A., Gupta, C.K., Meti, S., Meenakumari, T., Nair, B.R., Licy, J., Saraswathyamma, C.K. and Brahman, M. 2000. Genotype x Environment interaction in *Hevea* in diverse agroclimatic condition in India: Preliminary growth results. *Proceedings of International Planters Conference*, Kuala Lumpur, Malayasia, pp. 183-195.

Mondal, G.C., Das, K., Chaudhuri, D. and Varghese, Y.A. 2006. Performance of ten selections from a polyclonal seedling block of natural rubber (*Hevea brasiliensis*) in Assam. *Journal of Plantation Crops* **34**(3): 181-185.

Mondal, G.C., Deka, H.K. and Chaudhuri, D. 2007a. Reaction of *Hevea brasiliensis* clones against powdery mildew disease in North Eastern region of India. *Natural Rubber Research* **20**(1&2): 90-93.

Mondal, G.C., Singh, R.P., Mondal D., Gupta, C., Gohain, T., Cahudhuri, D., Nazeer, M.A. and Nair, B.R. 2007b. Evaluation of yield potential of *Hevea brasiliensis* clones over ten years of tapping in Assam. *Natural Rubber Research* **20**(1&2): 32-38.

Priyadarshan, P.M., Sudhdaowmyalatha, M.K., Sasikumar, S.,Varghese, Y.A. and Dey, S.K. 1998a. Relative performance of six *Hevea brasiliensis* clones during two yielding regimes in Tripura. *Indian Journal of Natural Rubber Research* **11**: 67-72.

Priyadarshan P.M.,Vinod K.K., Rajeswari M.R., Pothen J., Sudhdasowmyalatha M.K. and Sasikumar S. 1998b. Breeding *Hevea*. *brasiliensis* Muell. Arg. in Tripura (N.E.India). Performance of few stress tolerant clones in the early phase. In: *Developments in Plantation Crops Research* (Eds.) Mathew N.M. and Kuruvilla Jacob C. Allied Publishers, New Delhi, pp. 63-65.

Priyadarshan, P.M., Sudhdaowmyalatha, M.K., Sasikumar, S., Dey, S.K. and Varghese, Y.A. 2000. Evaluation of *Hevea brasiliensis* clones for yielding trends in Tripura. *Indian Journal of Natural Rubber Research* **13**: 56-63.

Reju, M.J., Thapliyal, A.P., Gopalakrishnan, J., Deka, H.K. and Soman, T.A. 2002. First panel yield of eight *Hevea* clones in Sub-tropical Meghalaya. *Indian Journal of Natural Rubber Research* **15**(1): 190-193.

Reju, M.J., Thapliyal, A.P., Singh, R.P., Soman, T.A., Nazeer, M.A, and Varghese, Y.A. 2007. Promising *Hevea brasiliensis* clones for the Sub-tropical climate of Meghalaya. *Indian Journal of Natural Rubber Research* **20**(1&2): 50-55.

Sasikumar, S., Priyadarshan, P.M., Dey, S.K. and Varghese, Y.A. 2001. Evaluation of polyclonal seedling block of *Hevea brasiliensis* (Willd. Ex. Adr. DeJuss.) Muell. Arg. in Tripura. *Indian Journal of Natural Rubber Research* **14**(2): 125-130.

Shorrocks, V.M., Templeton, J.K. and Iyer, G.C. 1965. Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis*: 3. Relationship between girth and shoot dry weight. *Journal of Rubber Research Institute of Malaya* **19**: 85-92.