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IMPACT OF COLD WEATHER CONDITION ON THE GROWTH OF *HEVEA BRASILIENSIS* CLONES IN NORTHERN WEST BENGAL

Shankar Meti, Rajeswari Meenattoor, G.C. Mondal and D. Chaudhuri

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In an experiment to study the response of 12 different clones of *Hevea brasiliensis* to cold weather in the early stages of establishment in the northern part of West Bengal, cold injury symptoms like wilting and withering of leaves, black discoloration of bark with occasional oozing of latex and dieback of shoots were observed by the end of the cold season (February). Clonal differences were observed with significantly higher number of cold injured plants in RRIC 100 followed by RRII 422. The clone RRII 429, a selection from a cross of RRII 105 and RRIC 100 did not show any injury. Other clones showed a low intensity of cold injury. In the experimental area, the plants were exposed to sub optimal temperatures of below 10°C for 8 to 9 hours daily for 9 to 10 weeks. Leaf photosynthesis was low during the cold season, which resulted in poor biomass increment and relative growth rate during the winter. Cold susceptible and resistant clones differed mainly in their photosynthetic activity and growth under sub optimal temperatures. However, there were some exceptions like RRII 105 and PB 217, which failed to show such relations.

Key words: Biomass, Cold injury, *Hevea brasiliensis*, Photosynthesis

Shankar Meti (for correspondence), Rajeswari Meenattoor, Rubber Research Institute of India, Rubber Board, Kottayam - 686 009, Kerala, India; G.C. Mondal and D. Chaudhuri, Regional Research Station, Rubber Board, Guwahati – 781 024, Assam, India.

INTRODUCTION

Rubber (*Hevea brasiliensis*) is indigenous to the Amazon basin situated within 5° latitude of the equator and below 200 m altitude. Hence the species has developed an ecological preference for wet, equatorial type, warm, bright, humid climate and fertile soil characteristic of the region. The optimum climatic requirement for rubber includes a maximum temperature of about 29 – 34° C, minimum temperature of about 20° C or more and bright sunshine of about 2000 hours annually at a rate of nearly 6 hours per day in all the months (Rao and Vijayakumar, 1992). Northern part of West Bengal has been identified as one of the non-traditional areas suitable for rubber cultivation in India. This region receives an average rainfall of 3200 mm. During winter the minimum temperature goes down to as low as 5°C for 3-4 weeks. Hence this region is classified as hydro-thermally marginally suitable for rubber cultivation (Rao *et al.*, 1993). Rubber plants suffer from cold stress when exposed to low winter temperature during the early stages of establishment (Ailiang, 1984). Cold injury during the early stage of establishment of *Hevea* has been reported from the northern West Bengal (Meenattoor *et al.*, 2000). The present paper is an attempt to study cold injury in *Hevea* clones under the agro-climatic conditions observed in the northern part of West Bengal.

MATERIALS AND METHODS

The study was taken up at the Regional Experiment Station of Rubber Research Institute of India, located at Nagrakata, northern West Bengal (26° N, 88° E and 69 m above msl) with the objective of studying the response of different clones to the cold weather in the early growth phase. Soil is acidic (pH 4.4) sandy loam with high organic carbon (2.3%), low available P (0.2 mg/100 g) and K (4.2 mg/100 g) content. Materials consisted of 12 clones, of which five were selections from a cross between RRII 105 and RRIC 100 (Table 1). Field planting was done in 1996

Table 1. **No. of cold injured trees during winter**

Clones and their origin	No. of plants showing cold injury		
	Winter 1996-97	Winter 1997-98	Mean
Indian			
RRII 51	4	4	4.0 (3.7)
RRII 105	7	1	4.0 (3.7)
RRII 176	6	3	4.5 (4.2)
RRII 203	1	0	0.5 (0.5)
RRII 414*	1	0	0.5 (0.5)
RRII 417*	2	0	1.0 (0.9)
RRII 422*	26	44	35.0 (32.4)
RRII 429*	0	0	0.0 (0.0)
RRII 430*	1	2	1.5 (1.4)
Sri Lankan			
RRIC 100	67	64	65.5 (60.6)
Malaysian			
RRIM 600	0	3	1.5 (1.4)
PB 217	10	6	8.0 (7.4)
Total	125	127	126 (9.7)
Mean	3.47	3.53	3.47
S.Em.	2.42	1.92	1.45
C.D ($P \leq 0.05$)	5.03	3.98	3.01

Figures in parentheses are percentage to the total population of the clone

* Hybrids selected from RRII 105 x RRIC 100

using polybag plants at a spacing of 5x5 m with gross plot size of 36 plants. Treatments were laid out in randomised block design with 3 replications. *Mucuna bracteata* was grown as cover crop from the first year. During the initial two years (Winter 1996-97 and winter 1997-98) only the number of plants showing cold injury symptoms were recorded clonewise. During the third year (winter 1998-99) the cold injury symptoms were categorised and clones showing the symptoms were grouped accordingly after visual observation of the canopy. During the three years, the number of casualties due to cold stress were also recorded at the end of each winter season.

During winter 1996-97 and winter 1997-98, girth was recorded before and after the cold period, biomass estimated using Shorrocks formula (Shorrock *et al.*, 1965) and relative growth rate (RGR) (g/kg/month) calculated. Leaf photosynthesis was recorded in December 1997 using LICOR-600 portable photosynthesis system. Photosynthesis was recorded between 10 and 11am from the mature middle leaflet of the second whorl from the top. Photosynthetically active radiation (PAR) was 120-1500 µmoles/sec and air temperature was 26-27°C.

Daily weather parameters were recorded from the agro-meteorological observatory located close to the experimental plot. Mean diurnal temperature profile for winter 1997-98 was worked out from the daily thermo hygrograph charts. Samples from cold injured plants were examined for the presence of any pathogen. Vacancy filling of cold injured plants was done during July 1997 using polybag plants. Data were subjected to analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Cold injury is the result of interaction between climate and genotype. Among the climatic factors, temperature is the key factor followed by sunshine hours. In the northern West Bengal, mean temperature ranges between 13 to 17°C during winter (Nov-Feb) (Fig. 1). The minimum temperature went below 10°C, as low as 4 to 5°C during the 48th or 49th standard meteorological week of 1997 and this continued up to 6th meteorological week of 1998. The atmospheric temperature went below 10°C by midnight and was the lowest early in the morning (5-7 am) (Fig. 2). Cold period at Nagrakata is also characterised by bright sunshine (PAR 120-1500 µmol/sec) and moderately high temperature during daytime resulting in tem-

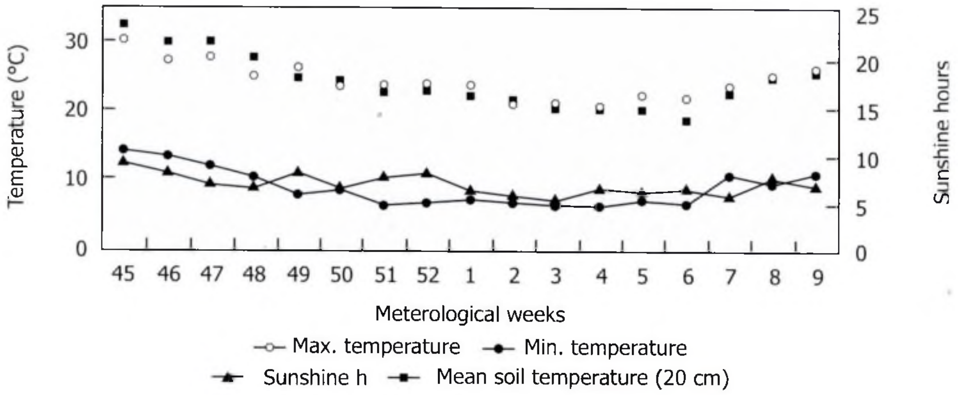

Fig. 1. Weekly weather parameters during 1997-98

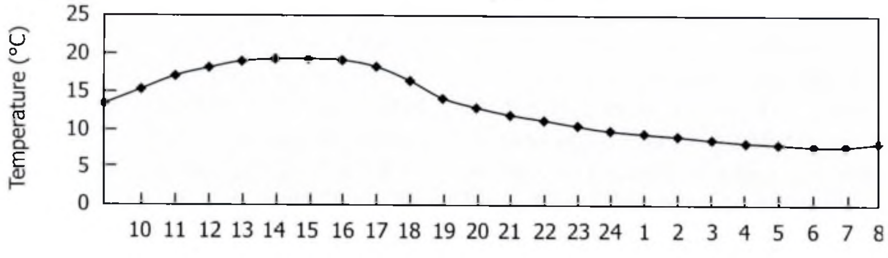

Fig. 2. Diurnal temperature profile during winter season (1997-98)

Fig. 3. Wilting and yellowing of leaves with black discolouration of green bark

Fig. 4. Oozing of latex from bark

perature range of 10 to 12° C (Fig. 1). Changes in atmospheric temperature influenced the rhizosphere environment, particularly soil temperature in the top 20 cm soil, which was below 14°C during winter.

During initial two years clonal differences were not apparent. The cold injury symptoms were observed (Fig. 3 & 4) included wilting of leaves followed by their withering without abscission, cccasional inter-venal chlorosis, black discoloration of green bark and its dying off extending downward, occasional oozing of latex from the green bark and die-back of shoots. Similar symptoms have been reported for cold injury from China (Huan and Pan, 1992; Watson, 1989). However, during the third year (winter 1998-99) clonal variations for cold symptoms could be categorised as (a) purple/yellow discoloration of canopy and shedding of leaves, (b) wilting and dieback of small and tertiary shoots, (c) yellowing, wilting and dieback of whole primary branch or plant, or (d) no injury (healthy canopy).

In general, cold injury symptoms were observed at the fag end of the cold season (February). Watering of cold injured plants did not bring them to normal condition indicating lack of moisture stress. Some cold injured plants re-sprouted from the base after the cold season, but during the subsequent cold season they again showed injury. Samples collected from cold injured plants did not show any pathogen infection.

During the experimental period an average of 95 plants dried every year (Table 2). There were significant differences between the clones for cold injury (Table 1). RRIC 100 recorded significantly higher mean number of injured plants (66) followed by RRII 422 (35). RRII 429 did not show any dieback. Other clones also showed cold injury but intensity was very low and the mean number of affected plants ranged from 0.5 to 8.0. Similarly the number of casualties due to cold was higher in RRIC 100 (51) followed by RRII 422 (30) (Table 2). Among the clones, RRII 429 did not show any cold injury. It is interesting to note that clonal response to cold during winter 1998-99 season was different from winter 1996-97 and winter 1997-98 seasons. Only RRIC 100 and RRII 422 showed casualties during all the three years under observation (Table 2&3). Most of the other clones except RRII 429 showed casualties only during initial two years of estab-

Table 2. **Number of casualties due to cold injury**

Clones and their origin	Winter 1996-97	Winter 1997-98	Winter 1998-99	Mean
Indian				
RRII 51	4(3.7)	2(1.9)	0(0.0)	2(1.9)
RRII 105	7(6.5)	0(0.0)	0(0.0)	2.3(2.2)
RRII 176	6(5.6)	2(1.9)	0(0.0)	2.7(2.5)
RRII 203	1(0.9)	0(0.0)	0(0.0)	0.3(0.3)
RRII 414	1(0.9)	0(0.0)	0(0.0)	0.3(0.3)
RRII 417	2(1.8)	0(0.0)	0(0.0)	0.7(0.6)
RRII 422	26(24.7)	9(8.3)	56(51.9)	30.3(28.3)
RRII 429	0(0.0)	0(0.0)	0(0.0)	0.0(0.0)
RRII 430	1(0.9)	1(0.9)	0(0.0)	0.7(0.6)
Sri Lankan				
RRIC 100	67(62.0)	43(39.8)	44(40.7)	51.3(49.5)
Malaysian				
RRIM 600	0(0.0)	2(1.9)	0(0.0)	0.7(0.6)
PB 217	10(9.0)	2(1.9)	0(0.0)	4.0(3.6)
Total	125	61	100	95.3(7.4)

Figures in parentheses are percentage to the total population of the clone lishment (1997-98). During the third year RRII 176, RRII 114, RRIM 600 and RRII 51 showed purple discoloration and shedding of leaves, RRII 430 showed no injury, while PB 217 and RRII 203 showed only mild injury (wilting and dieback of few young or tertiary shoots only) (Table 3). Among the 12 clones RRIC 100 and RRII 422 were susceptible to cold whereas RRII 429, RRII 414, RRII 203, RRII 417, RRII 430 and RRIM 600 showed more endurance to cold.

Table 3. **Clone-wise cold injury symptoms observed during winter 1998-99**

Clones and their origin	A	B	C	D
Indian				
RRII 51	—	✓	—	—
RRII 105	✓	—	—	—
RRII 176	—	✓	—	—
RRII 203	—	—	✓	—
RRII 414	—	✓	—	—
RRII 417	✓	—	—	—
RRII 422	—	—	—	✓
RRII 429	✓	—	—	—
RRII 430	✓	—	—	—
Sri Lankan				
RRIC 100	—	—	—	✓
Malaysian				
RRIM 600	—	✓	—	—
PB 217	—	—	✓	—

A: No injury; B: Purple discolourtion and shedding of leaves; C: Wilting and dieback of small and tertiary branches; D: Wilting and dieback of primary branch or whole plant

This indicates the development of resistance to cold with the age. Initial higher survival of plants is essential for better establishment of plantation. Among the clones RRIC 100 and RRII 422 showed poor establishment due to casualty from cold injury. Hence these clones may not be suitable for cultivation in the northern parts of West Bengal.

Cold susceptible and resistant clones mainly differed in their ability to carry out photosynthetic activity and put up more growth during sub-optimal temperature conditions (Tables 4 & 5). Leaf photosynthesis during cold season was very low (0.97 - 2.68 μmol/m^2 /sec). Among the clones PB 217, RRIC 100 and RRII 422 recorded significantly low photosynthesis while RRII 429 recorded high (2.68 μmols/m^2 /sec). Among the clones, RRIC 100 and PB 217 showed significantly lower RGR and biomass increment

Table 4. **Relative growth rate (RGR) and photosynthesis during winter, 1996-97**

Clones and their origin	RGR (g/kg/month) during 1997		Photosynthesis (μmol m^{-2}/sec) (December 1997)
	Winter	Non-winter	
Indian			
RRII 51	81.7	140.4	2.37
RRII 105	111.0	111.2	1.64
RRII 176	75.0	136.6	1.73
RRII 203	92.3	162.7	1.12
RRII 414	94.6	115.0	1.60
RRII 417	80.2	124.6	2.07
RRII 422	77.1	128.5	1.37
RRII 429	110.8	143.5	2.68
RRII 430	88.9	136.4	1.32
Sri Lankan			
RRIC 100	11.9	111.7	1.47
Malaysian			
RRIM 600	83.0	133.7	2.20
PB 217	54.6	155.3	0.97
Mean	80.2	133.3	1.71
S.Em	12.9	10.1	0.29
CD ($p \leq 0.05$)	37.7	29.5	0.60

Table 5. **Mean biomass increment (g/month) during winter and non-winter seasons, 1996-97**

Clones and their origin	Winter (Nov 1996-Feb 1997)	Non-Winter (Feb-Nov 1997)
Indian		
RRII 51	18.4	73.0
RRII 105	31.5	68.0
RRII 176	21.0	81.0
RRII 203	30.8	135.0
RRII 414	25.1	58.3
RRII 417	27.7	89.7
RRII 422	24.5	86.5
RRII 429	34.6	108.9
RRII 430	23.0	79.1
Sri Lankan		
RRIC 100	3.0	51.9
Malaysian		
RRIM 600	26.0	92.5
PB 217	14.9	99.7
Mean	23.38	85.3
S.Em	4.6	12.8
CD (P=0.05)	13.1	36.6

during winter compared to RRII 429 and RRII 105. Cold resistant clones like RRII 429, RRII 203, RRII 414 and RRIM 600 showed significantly higher biomass increment and RGR during winter.

The cold injury observed in northern West Bengal is due to cumulative effect of prolonged exposure to sub-optimal temperature and not due to abrupt cold condition like frost observed in high altitudes of China (Ailiang, 1984). Hence cold injury symptoms were observed at the fag end of the winter season. Moderately high temperature and bright sunshine during day time concomitant with repeated and prolonged exposure to cold at night resulted in damage to the photosynthetic machinery triggering senescence of leaves (Mc Kersie and Leshem, 1994). This is clearly evident from the yellowing and wilting of leaves in cold injured plants. Since rubber is a surface feeder, changes in atmospheric temperature might have influenced the rhizosphere temperature, affecting the normal root functioning and thus compounding the effect of cold injury on above ground plant parts.

Photosynthesis is one of the physiological processes inhibited by cold stress (Baker, 1996). Cold stress reduces the light use efficiency and CO_2 assimilation in mature *Hevea* leaves (Jacob *et al.*, 1999). Cold period in northern West Bengal has bright sunshine also. In a cold stressed plant such bright sunshine may aggravate the stress (Oquist *et al.*, 1987). There are reports of high light intensity induced inhibition of photosynthesis in rubber plants experiencing abiotic stress like low temperature and drought (Sathik *et al.*, 1998; Devakumar *et al.*, 1999). This could be the reason for low leaf photosynthesis during cold season (0.97 to 2.68 µmoles/m^2/sec) compared to 13 to 16 µmoles/m^2/sec recorded during stress free season in NorthEast India (Sathik *et al.*, 1998). Poor RGR and biomass during winter compared to non-winter season can be attributed to poor photosynthetic efficiency per leaf coupled with loss of the photosynthetically active loci caused by discoloration and wilting of leaves due to cold stress. Girth increment during winter season is reported to be very poor (Meenattoor *et al.*, 1991; Priyadarshan *et al.* 1998). Significant clonal differences were observed with respect to leaf photosynthesis, RGR and biomass production during the winter season. In general cold resistant clones like RRII 429 showed significantly higher biomass, leaf photosynthesis and RGR compared to cold susceptible clones like RRIC 100. However, there were some exceptions like PB 217, which showed less cold injury even though the biomass production, RGR and photosynthesis were low. On the contrary, RRII 422 showed more cold injury even though the its biomass production, RGR and photosynthesis were comparatively better. This suggests that there are different factors in clones, which aid in adaptation to adverse low temperature. This needs to be probed further. Clones with wide adaptability and stable growth habit in different environments are ideal for extensive rubber cultivation in non-traditional region.

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