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Rubber Cultivation in North East India-An Agrometeorological Perspective

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INTRODUCTION

Rubber cultivation in regions extending from 10°N to 10°S latitude is known as the traditional region and the areas other than its natural climatic origin is termed as the non-traditional region. Northeast India comprises majority of the non-traditional areas in India with major climatic constraints like high seasonal rainfall, excessive precipitation and to some extent dry conditions. These areas extending from 22 to 29°N latitude, holds promise in extending rubber cultivation because of its exceptional climatic make-up and abundant amount of annual precipitation (2000 mm) distributed over a fair period of time.

This perennial crop generally yields latex rubber at the 7th year after planting (with an economic life span of 20 years), although the period (immaturity period) it requires, is higher in the non-traditional region (Rubber Growers Companion, 2006). This immaturity period has also been shown to reduce with water availability in sub-humid climates (Vijayakumar *et al.*, 1998). Harvest of this crop is by tapping. Tapping is a process of controlled wounding during which thin shavings of bark are removed, thus opening the latex vessels which exude latex. Dry rubber yield is obtained after the latex is coagulated and rolled into sheets (about 500gm) which is then smoked and dried.

In the northeast, the alternate daily system of tapping is being presently followed. The general trend of rubber yield in Tripura shows a sudden rise in latex volume from early October, which reaches a peak in mid November and falls to the original level towards the end of January.

One of the important requirements of rubber cultivation is a warm equable climate with not less than 2000 mm of evenly distributed annual rainfall and temperatures ranging from 20 to 35°C. Mean daily air temperature is an important factor controlling growth and yield of rubber (Huang and Zheng, 1985; Rao *et al.*, 1993). The optimum monthly climatic requirements (Vijayakumar et al., 2000) for *Hevea brasiliensis* which are quite characteristic of its place of origin i.e. Brazil is shown in Table 1.

Table 1. Optimum monthly climatic requirement for *Hevea brasiliensis*

Rainfall	≥ 2000 mm evenly distributed with 125-150 rainy days	
Maximum temperature	29 - 34°C	Monthly mean 25 - 28°C
Minimum temperature	≥ 20°C	
Humidity	≥ 80%	
Sunshine	≥ 2000 hours at the rate of 6 hours per day	

None of the areas in the Northeast non-traditional region fully qualifies for the above optimum conditions. However, major areas with moderate level conditions do exist for which rubber can be successfully cultivated. This necessitates the importance of characterizing the crop-weather relations, spatial and temporal variations of the meteorological parameters for the Northeast.

MATERIALS AND METHODS

Studies carried out so far in this region have shown that the day-to-day yield is mainly being controlled by ambient as well as antecedent environmental parameters. A study was undertaken based on the relationship of environmental parameters with latex yield for five clones (RRII203, RRII118, RRIM600, RRII105 and GT1) of *Hevea brasiliensis* in the region of Agartala (Shammi Raj *et al.*, 2005). The dry rubber yield from these trees was studied with the antecedent observed and computed daily meteorological parameters. Regression equations were developed for each of the clone by the forward stepwise procedure for yield. Conducive ranges of the related parameters were identified with daily based above average yield.

On a spatial extent in any geographical region, the importance of rainfall and its variability is the most important to decide the conduciveness of rubber cultivation, more so if it is in a non-traditional region like the Northeast India. Rainfall being the most important parameter for rubber compared to other optimum requirements, its spatial variability was studied over the entire geographical area of the Northeast. Utilizing 139 raingauge stations with more than 30 year individual weekly data sets from the India Meteorological Department, the study was made using horizontal rainfall contours. The Precipitation Concentration Index (PCI) denotes uniformity of monthly distribution in a year over a particular station or the interannual variability. This index (Oliver, 1980) is described as

$$PCI = 100 \times \frac{\sum_{i=1}^{12} p_i^2}{\left(\sum_{i=1}^{12} p_i\right)^2}$$

where, pi is the rainfall amount of the ith month and annually calculated for each of the 139 stations. PCI values below 10 indicate a uniform monthly rainfall distribution in a year. Values from 11 to 20 denote seasonality and values above 20 correspond to climates with substantial monthly variability. Contours of this index were plotted in digital maps prepared for the Northeast (Raj and Dey., 2004).

Rainfall availability varies from place to place depending mainly on the topography (Raj and Dey, 2004). Information on chances of a wet week and wet spell in a season would clearly characterize the seasonal rainfall variability in a region. This could also be precisely utilized by the rubber based farming community in the Northeast for planning timely farming operations like application of fertilizers, pesticides and other agromanagement practices needed for the crop. Probability studies adopting the first order Markov Chain model were conducted in ten selected stations in the rubber growing tracts of the Northeast. Here, a week is designated as wet if the weekly total rainfall is higher than the specified amount of the cumulative weekly evaporative demand of 28 mm (Raj *et al.*, 2005) for rubber. Otherwise it is known as a dry week. The initial probabilities (%) of dry weeks P(D), wet weeks P(W), and conditional probabilities (%) of a wet week following a wet week P(W/W), a dry week following a wet week P(W/D), a wet week following a dry week P(D/W), and a dry week following a dry week P(D/D) have been calculated for all respective four seasons for every stations considered in the study using the following equations (Raj and Dey, 2005). For every season, the probability of continuation of dry/wet spells of different lengths (2 to 6 weeks) has been calculated. Probability analysis of monthly rainfall data was carried out using the Gringorten's Plotting Position method (Chow *et al.*, 1988). The minimum rainfall expected for various probability percentages have been computed, but only the important levels of 50 and 90% were discussed for brevity sake. This dependability depicts the true nature of rainfall, even when the distribution is highly skewed.

Table 2. Regression equations for yield (Y) of clones for the non-winter and winter tapping periods using environmental variables.

Clone	Non-Winter Tapping Period	Winter Tapping Period
$Y_{RRII203}$	-7.638 + 0.147 ST-1 (8.64)* - 2.055 T_n-0 (2.93) + 1.823 T_x-2 (2.61) - 1.133 VP_{f-a}-1 (2.55) + 0.694 VD_a-1 (2.31) (R^2=0.72)	-123.353 + 0.269 ST-3 (11.65) + 5.869 T_{20a}-1 (6.84) - 2.029 T_n-1 (3.46) - 1.964 $T_{10}D$-3 (4.04) - 2.120 $T_{10-20f}D$-1 (3.36) - 1.166 VP_{f-a}-3 (2.88) (R^2=0.94)
$Y_{RRII118}$	18.378 + 0.048 ST-1 (4.14) - 2.486 V_f-1 (4.42) + 1.708 T_{10f}-0 (3.39) - 2.201 PE-2 (2.38) + 2.760 T_{10f}-1 (3.28) - 0.748 T_{5a}-3 (2.25) (R^2=0.55)	43.307 + 0.137 ST-3 (5.54) + 0.243 RD_{f-a}-1 (3.52) - 5.483 E-2 (3.50) + 0.975 VD_a-1 (3.94) - 1.531 T_5D-3 (5.31) (R^2=0.86)
$Y_{RRIM600}$	91.104 - 3.065 AT-1 (2.95) + 0.117 ST-1 (4.70) + 23.220 $T_{5-10f}D$-2 (3.86) + 3.471 $T_{10}D$-2 (2.42) + 1.810 S-1 (2.20) (R^2=0.55)	46.034 + 0.139 ST-3 (3.27) + 1.255 VD_a-2 (8.93) + 1.139 T_{5a}-3 (2.97) + 0.555 R_a-3 (3.50) + 0.396 RD_{f-a}-3 (3.08) - 6.167 E-2 (2.63) (R^2=0.86)
Y_{RRI105}	40.879 - 5.050 AT-1 (4.31) + 0.115 ST-1 (4.28) + 1.735 S-1 (2.23) + 6.214 T_{20a}-3 (3.57) - 6.082 PE-2 (2.14) - 3.000 T_n-3 (2.01) (R^2=0.62)	-95.658 + 0.417 ST-3 (10.51) + 3.518 T_{10f}-0 (3.13) - 15.069 SI-2 (3.58) + 4.516 VP_{f-a}-3 (4.09) - 3.856 V_f-1 (2.84) [illegible] 3.265 T_{20a}-1 (1.89) (R^2=0.83)
Y_{GT1}	-7.930 + 0.434 ST-1 (2.69) - 0.422 ST-2 (2.62) - 2.208 T_n-0 (2.75) + 1.891 $T_{10}D$-3 (2.06) - 0.153 PE-2 (1.43) - 0.673 T_{5a}-2 (1.93) (R^2=0.37)	23.556 - 15.758 E-2 (4.13) - 0.449 R_a-2 (4.11) + 3.154 T_n-3 (4.73) + 0.839 RD_{f-a}-3 (6.41) - 1.956 VD_{f-a}-3 (2.51) + 0.108 ST-3 (3.89) (R^2=0.83)

RESULTS AND DISCUSSION

Regression equations between latex production and weather parameters for different clones of rubber were worked out and data are presented in Table 2.The explained variance (Table 2) for the regression equations over five clones, based on parameters from the day of tapping up to three days prior to it, varied from 37 to 72% during the non-winter tapping period and 83 to 94% during the winter tapping period.

Estimated soil moisture storage values one day and three days prior to tapping were found to be the primary parameters affecting yield for these two periods respectively. RRIM600 and RRII105 being high yielding clones were found to be fairly dependent on the average temperature of the day prior to tapping. It was also observed (Table 3), that the clone RRII105, with a comparatively lower yield to that of RRIM600, was more susceptible to daily water deficit conditions during the non-winter season.

Table 3. Values of environmental parameters associated with above average yield for five different clones in *Hevea brasiliensis* during the non-winter tapping period.

Variables	RRII203	RRII118	RRIM600	RRII105	GT1
ST-1 (mm)	124 to 320	227 to 320	149 to 289	226 to 320	129 to 320
PE-2 (mm)		1.4 to 3.6		2.1 to 3.6	3.6 to 6.2
AT-1 (°C)			15 to 31	15 to 29	
T_n-0 (°C)	21 to 27				19 to 27
T_n-3 (°C)				20 to 26	
T_x-2 (°C)	26 to 35				
T_{5f}-1 (°C)		25 to 27			
T_{5a}-2 (°C)					29 to 42
T_{5a}-3 (°C)		25 to 35			
T_{10}D-0 (°C)					
T_{10}D-2 (°C)			-1.1 to 9.5		
T_{10}D-3 (°C)		2.5 to 11.0			-3.4 to 4.0
T_{20}a-3 (°C)				28 to 33	
T_{5-10f}D-2 (°C)			-1.8 to 1.7		
V_f-1 (mm of Hg)		19.2 to 23.3			
VP_{f-a}-1(mm of Hg)	-5.3 to 1.7				
VD_a-1 (mm of Hg)	0.0 to 16.0				
S-1 (Hours)			0.2 to 10.6	1.6 to 10.6	

Contribution to the above-average yield for all the five clones was found to be the highest during October-January period (40-60%). The effect of solar radiation is more pronounced in the high yielding varieties, especially during the non-winter period. Antecedent soil and air temperature also affects the daily yield of rubber. This study also confirms that varied responses of yield with the environmental factors in the non-traditional region depend on clonal characteristics (Raj *et al.,* 2005).

Studies on the spatial heterogeneity of rainfall conducted in the northeast revealed that on an average, about 62% of the annual rainfall is accounted for the monsoon season. Generally, December, January and February months comprise the lowest rainfall period. The mean annual precipitation along the entire northeastern states, ranged from >10,000 mm along the Jaintia Hills of Meghalaya to <1500mm along the east Assam, South of Nagaland and Northern Manipur. Mean annual rainfall amounts greater than 4000 mm were seen to be concentrated in large areas in the northwestern portion of Assam, and the Jaintia Hills.

Grouping the frequencies of PCI values associated with the mean distribution of the number of dry months in a year, three distinct ranges (Fig.1) were identified in the Northeast as <14.9, 15.0-19.9 and >20.0. The <14.9 category showed more than 50% of the contributions without any dry periods per year. The >20.0 PCI range showed 7 and 10 % years with 4 and 5 dry months per year respectively.

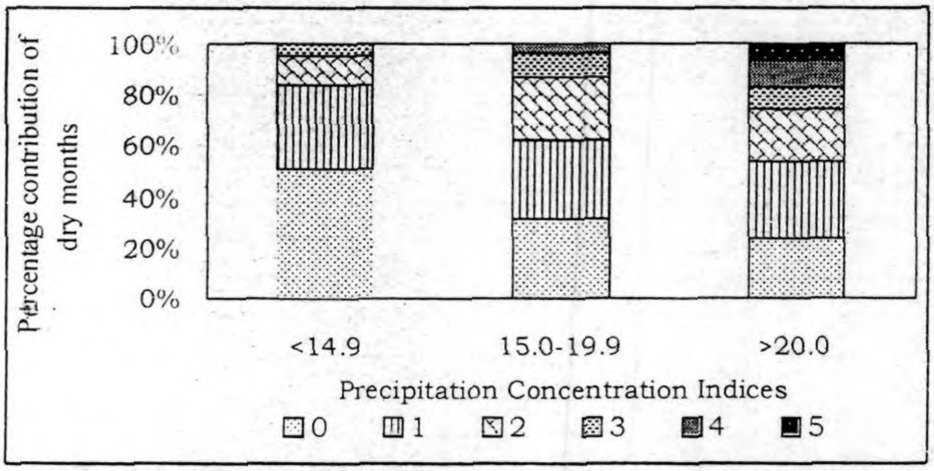

Fig. 1. Percentage contribution of dry months for the three ranges of Precipitation Concentration Indices

Superimposing the gridded base maps of the 1500-4000 mm rainfall contours with that of the PCI contours, three separate areas of suitability could be demarcated. These were designated as Optimal (< 14.9), Sub-optimal (15.0 to 19.9), and Moderate (>20.0) (Fig 2). Marginal areas in terms of rainfall suitability considered here were areas with rainfall >4000mm and <1500mm irrespective of the PCI values. The regions of Optimal, Sub-optimal, Moderate and Marginal identified comprises of 14.5, 26.9, 46.4 and 12.2 % of the total area in the Northeast.

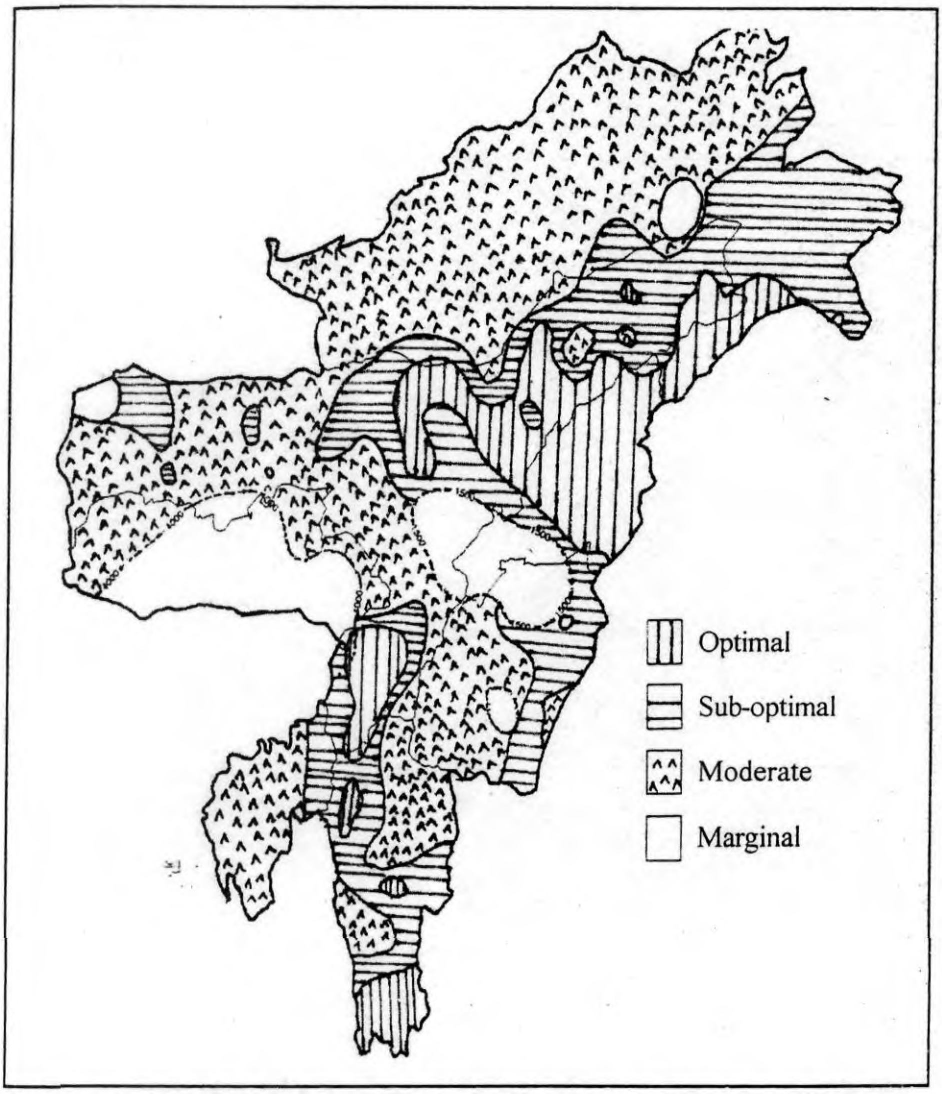

Fig. 2. Areawise suitability of rubber cultivation in north eastern states of India

Table 4. Initial and conditional probabilities of ten rubber growing places in different seasons

Rubber growing places	W	D	W/W	D/W	W/D	D/D	W/W	D/W
Winter season								
Silchar	9	91	30	70	10	90	9	91
Tezpur	2	98	0	100	3	97	2	98
Guwahati	2	98	0	100	3	97	2	98
North Lakhimpur	12	88	22	78	13	87	12	88
Lumding	2	98	10	90	3	97	2	98
Amguri	9	91	20	80	10	90	9	91
Imphal	6	94	21	79	7	93	6	94
Tura	4	96	28	72	4	96	4	96
Kolasib	9	91	22	78	10	90	9	91
Agartala	2	98	0	100	3	97	2	98
Hot-weather season								
Silchar	61	39	71	29	54	46	61	39
Tezpur	47	53	62	38	42	58	47	53
Guwahati	43	57	59	41	41	59	43	57
North Lakhimpur	57	43	75	25	44	56	57	43
Lumding	29	71	47	53	29	71	29	71
Amguri	61	39	76	24	50	50	61	39
Imphal	33	67	51	49	34	66	33	67
Tura	47	53	81	19	31	69	47	53
Kolasib	57	43	79	21	46	54	57	43
Agartala	44	56	66	34	38	62	44	56
Monsoon season								
Silchar	89	11	90	10	1	99	89	11
Tezpur	72	28	72	28	3	97	72	28
Guwahati	68	32	73	27	1	99	68	32
North Lakhimpur	87	13	90	10	1	99	87	13
Lumding	57	43	61	39	5	95	57	43
Amguri	87	13	88	12	1	99	87	13
Imphal	63	37	66	34	1	99	63	37
Tura	80	20	88	12	1	99	80	20
Kolasib	88	12	93	7	1	99	88	12
Agartala	65	35	74	26	1	99	65	35
Post-monsoon season								
Silchar	21	79	36	64	18	82	21	79
Tezpur	12	83	30	70	19	81	12	88
Guwahati	9	91	16	84	9	91	9	91
North Lakhimpur	19	81	28	72	18	82	19	81
Lumding	13	87	21	79	16	84	13	87
Amguri	18	82	26	74	15	85	18	82
Imphal	15	85	20	80	15	85	15	85
Tura	17	83	42	58	14	86	17	83
Kolasib	25	75	40	60	11	89	25	75

Probability estimates explained the nature of variability of rainfall at different places in the NE region. Probability or chances of occurrence of 76% was noted for wet weeks in general during the monsoon season. Probability of obtaining dry weeks (Table 4) in winter is more than 90%. A high value of 12% probability for a wet week was noted in the case of North Lakhimpur. The stations of Tezpur, Guwahati and Agartala showed similar characteristics of not receiving any two consecutive wet weeks during the winter season at all, while Silchar showed a high of 30%. Percentage occurrence of wet spells is higher for North Lakhimpur and Amguri during the winter season.

Table 5. Seasonwise probabilities (%) of consecutive dry and wet week spells of different lengths

	Consecutive dry spells (no of weeks)					Consecutive wet spells (no of weeks)				
	2	3	4	5	6	2	3	4	5	6
Winter season										
Silchar	79	66	53	42	33	13	7	0	0	0
Tezpur	92	86	77	68	59	0	0	0	0	0
Guwahati	94	89	82	75	66	0	0	0	0	0
North Lakhimpur	76	64	52	43	35	3	2	2	0	0
Lumding	94	89	83	76	69	0	0	0	0	0
Amguri	80	70	58	47	37	8	0	0	0	0
Imphal	87	79	69	59	50	3	0	0	0	0
Tura	92	86	78	70	62	11	0	0	0	0
Kolasib	81	70	60	50	40	4	0	0	0	0
Agartala	93	86	78	69	59	0	0	0	0	0
Hot-weather season										
Silchar	20	9	3	1	0	53	42	36	0	0
Tezpur	34	19	11	6	2	42	31	26	0	0
Guwahati	35	21	12	6	3	33	22	16	1	0
North Lakhimpur	30	16	7	2	0	61	51	46	0	0
Lumding	52	38	28	20	14	25	14	7	1	0
Amguri	27	12	6	3	0	59	51	43	0	0

Contd...

Table 5 Contd...

Monsoon season										
Silchar	8	3	0	0	0		80	70	61	0	0
Tezpur	18	11	9	7	5		50	34	24	0	0
Guwahati	22	14	10	9	9		51	37	26	0	0
North Lakhimpur	19	17	17	16	15		78	69	59	0	0
Lumding	21	11	6	4	3		33	18	10	1	0
Amguri	8	3	0	0	0		75	64	54	1	0
Imphal	19	10	8	6	5		40	24	13	0	0
Tura	34	28	24	21	20		72	61	50	0	0
Kolasib	14	8	5	5	5		81	71	63	0	0
Agartala	18	8	4	2	2		49	34	22	1	0
Post-monsoon season											
Silchar	84	80	76	74	71		14	6	1	0	0
Tezpur	89	87	85	84	83		7	1	0	0	0
Guwahati	92	90	89	88	87		0	0	0	0	0
North Lakhimpur	82	77	72	67	60		8	1	0	0	0
Lumding	88	85	83	82	81		5	1	0	0	0
Amguri	82	79	75	72	68		6	0	0	0	0
Imphal	84	79	75	72	69		4	0	0	0	0
Tura	91	88	86	84	82		16	4	0	0	0
Kolasib	83	79	76	73	70		19	7	2	0	0
Agartala	86	83	82	81	80		0	0	0	0	0

Consecutive wet weeks were obtained at more than 70% probability for Silchar, N.Lakhimpur, Amguri and Kolasib during the Hot-weather season. About 50% chance occurence was seen for a dry week following a wet week (W/D) in the case of Silchar and Amguri. Although, the nature of wet spell occurrences (Table 5) were similar for the hot-weather and monsoon seasons, relative percentages were higher during monsoon. High percentages of dry spells (75%) were noted for even the sixth week during post-monsoon followed by the winter season (51%). More than 10% dry spells of > 5 weeks were also experienced for Lumding, Tura, Kolasib and Agartala during the post-monsoon season. It was also observed that over all seasons, wet spells lasted only up to the fourth week beyond which chances were negligible, especially during the hot-weather and monsoon seasons. However during the five months comprising the winter and post-monsoon periods, very little chances for consecutive 3 wet week spells were seen. In the case of Guwahati and Agartala, no chance occurrence, were noted after the first week.

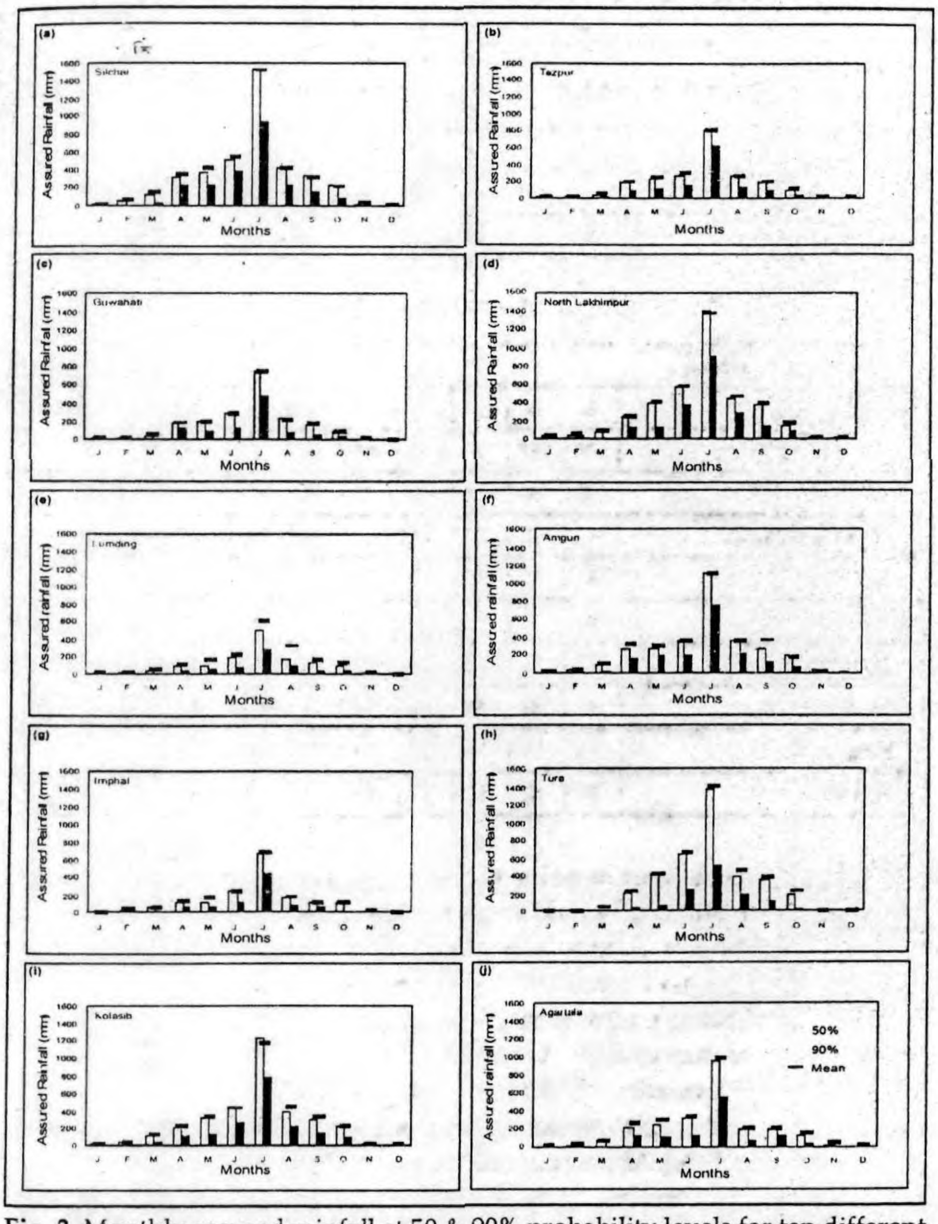

Fig. 3. Monthly assured rainfall at 50 & 90% probability levels for ten different rubber growing stations in the Northeast

The minimum amount of rainfall at a given level of probability, rather known as the dependable rainfall (mm) is expressed at the 50 and 90% probability levels (Fig.3 (a-j)). Silchar & North Lakhimpur received a more satisfactory distribution of monthly rainfall followed by Amguri and Kolasib.

Tura in Meghalaya showed the lowest assured rainfall at 90% in comparison with its 50% probability level, showing the high level of erratic behaviour of rainfall in this region. The dependable amount at 50% probability was the lowest for Lumding. It can also be seen from (Fig.3 (h)) that Tura is characterized with the highest skewness during the hot-weather period, due to high differences between the 90% level and the mean monthly rainfall. However, experiencing a high annual rainfall, the low annual value at the 90% level is quite comparable to that of Agartala. This can be corroborated by the fact that the high yielding RRIM 600 variety is more stable and adaptable to the northeastern regions of India (Meenatoor *et. al.*, 1991) and stability of this clone is comparable to Agartala in Tripura in terms of growth and yield (Reju *et al*,. 2001; Reju *et al.*, 2003).

CONCLUSION

Studies pertaining to larger proportions of yield (areawise) will help in precisely understanding the suitability of clones within an agroclimate. As a forerunner, implications of these studies can be considered for assessing development of clones for the non-traditional regions where rubber is not normally grown. Improper estimation of production of Natural Rubber (NR) within a framework of supply and demand, not only leads to import/excess stock, but also results in serious price fluctuations. Therefore, better resource management can be inducted in this non-traditional rubber growing area with identification of weather parameters having a regional influence on yield.

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ABBREVIATIONS

Observed Parameters

T_x-Maximum Temperature; T_n-Minimum Temperature; S-Sunshine Hours; P-Rainfall; E-Evaporation; R-Relative Humidity; V-Vapour Pressure; T5, T10, T20 - Soil Temperatures at 5, 10 & 15 cm depths respectively; Subscripts 'f '-forenoon & 'a'-afternoon.

Computed Parameters

SI-Sine of the day of year; PE-Potential Evapotranspiration; ST-Soil Storage; WS-Water Surplus; WD-Water Deficit; AT-Average Temperature; DT-Difference between maximum (previous day) and minimum temperature (succeeding day), VD-Vapour Pressure deficit; RD_{f-a}-difference in Relative Humidity values between succeeding day morning and previous day afternoon; VP_{f-a}-difference in Vapour Pressure values between succeeding day morning and previous day afternoon; T_{5-10}D-Difference of Soil Temperature between 5cm and 10 cm depth; T_{10-20}D-Difference of Soil Temperature between 10cm and 20 cm depth; T_5D, T_{10}D & T_{20}D-decrease in respective Soil Temperature of 5, 10 and 20 cm depths of the previous day afternoon to that of the succeeding day morning.

Rainfall Probabilities

W-Wet week; D-Dry week; W/W-Wet week following a wet week; W/D-Dry week following a wet week; D/W-Wet week following a dry week; D/D-Dry week following a dry week.

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