Jl. Rubb. Res. Inst. Sri Lanka (1977) **54**, 299—305

THE EFFECT OF WEATHER ON *HEVEA* PLANT GROWTH

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SUMMARY

Girth and height measurements of a number of young rubber plants of several clones were recorded for a period of over six months. The effect of weather factors ; rain, humidity, pressure, wind, sunshine and temperature on the growth parameters were investigated using regression methods. Seasonal changes in girth and height were also studied.

INTRODUCTION

Hevea brasiliensis was indigenous to wet, tropical areas of the Amazon river in Brazil (Collier, 1968). After its introduction to Sri Lanka one hundred years ago, during a period of nearly twenty years of lost identity, it was named the " water absorbing tree ", due to the observed characteristics of drying up the soil and growing fast in swamps (Anon, 1934). A scientific study of the climatic requirements of the rubber tree is not known, but the effect of weather on growth is not an uncommon investigation among plant scientists. Carr (1972) has reviewed over sixty papers on the climatic requirements of the tea plant. Amongst the vast literature on the subject are the studies of the effect of meteorological conditions on beech (Fritts, 1956, 1958, 1959) birch (Millar, 1965), pasture (Alcock *et al.*, 1968), plantation forest structure (Fraser, 1971), Corsican pines (Fourt *et al.*, 1971 ; Hiley & Cunliffe, 1923), Scots pine, birch and rowan (White, 1971). Apart from the addition to scientific knowledge, a similar study on rubber would be beneficial in deciding on suitable geographical regions and seasons for planting, subjected to the accuracy of the quantitative estimates of the effects.

MATERIALS AND METHODS

Thirty plants in a polyclonal nursery bud at the Rubber Research Institute (Sri Lanka) premises in a soil of the Agalawatta series were selected for the study. In the nursery, the distance between plant rows averaged 70 cm, and that between plants within a row was approximately 60 cm. The selected plants were randomly distributed. There were not more than two plants per clone. At the commencement of the field work, in October 1975, the plants were nearly three months old. Recording was continued for six months.

All meteorological measurements were taken from the Institute's Agri-meteorological station. This was situated about hunderd meters away from the nursery at a slight elevation. Here, screen and soil temperatures were recorded using liquid-in-glass type thermometers. The Stevenson screen was 1·3 m high. Angle thermometers were buried with bulbs at depths of 5, 10, 20 and 30 cm, and a sheathed thermometer was inserted 122 cm deep in a steel tube sunk into the earth. Wind was quantified as the number of revolutions of an annemometer fixed at a height of 6·5 m. The sun-shine recorder was mounted on a pillar 2 m tall. The amount and time of rain was marked on a self-recording pluviograph kept at ground level. All meter readings were recorded in metric units.

As growth parameters, the height along the main stem and the diameter 20 cm above the bud-union were selected. Heights were measured using a flexible tape and the diameters with a micrometer screw gauge, recording to an accuracy of 1/400th cm. Throughout the measurement period diameters in one direction and as far as possible at the same hour of the day were recorded. Intervals of measurement were often five days with extremes of one and eleven days. The mean rate of growth for each period was calculated and expressed as growth per day (cm).

Weather data recorded daily were :

screen minimum temperature	soil temperature 20 cm depth 8·30 a.m.
screen temperature 8·30 a.m.	soil temperature 30 cm depth 8·30 a.m.
screen maximum temperature	soil temperature 122 cm depth 8·30 a.m.
screen wet – bulb min. temp.	rainfall
grass min. temperature	wind
soil temp. 5 cm depth 8·30 a.m.	sunshine
soil temp. 10 cm depth 8·30 a.m.	atmospheric pressure

Based on these, several expressions were calculated for the periods between successive measurements of plants. Along with these computed meteorological variable given below the age of the plants was also considered as an independent variable, for the purpose of eliminating trend.

1	screen min. temp.
2	screen mean temp. 8·30 a.m.
3	screen max. temp.
4	grass mean min. temp.
5 – 7	soil 5 cm, min. mean & max. temp. 8·30 a.m.
8 – 10	soil 10 cm, min. mean & max. temp. 8·30 a.m.
11 – 13	soil 20 cm min. mean & max. temp. 8·30 a.m.
14 – 16	soil 30 cm min. mean & max. temp. 8·30 a.m.
17 – 19	soil 122 cm min. mean & max. temp. 8·30 a.m.
20	min. relative humidity (RH) 8·30 a.m.
21	mean RH 8·30 a.m.
22	max. RH 8·30 a.m.
23	rainfall per day
24	previous 24 hour rainfall
25	sunshine per day
26	mean atm. pressure 8·30 a.m.
27	wind per day

It would certainly be unnecessary to use all these as explanatory variables as there are close relationships between many of them. For example, all of the fifteen earth temperatures were highly correlated with each other; the mean 8·30 a.m. screen temperature was significantly correlated with some of the earth temperatures and the mean minimum on grass and the maximum screen temperature was significantly correlated with the screen minimum, grass mean minimum and some of the earth temperatures.

There are different methods of solving this problem of selecting a reduced set of variables which conveys approximately the same amount of information expressed by the original variables (Hocking, 1976). Here, the method of principal component analysis (Kendall, 1957) is employed to reduce the number of temperature variables. Principal components are hypothetical variables obtained as weighted combinations of the observed variables and having the property of being uncorrelated with one another. A component analysis on the 19 temperature variables showed that the first five components accounted for 92% of the variation amongst the set of temperature measurements. Those variables having the maximum weightage in the eigenvectors for each one of the first five components, namely ;

screen minimum temp.
mean 8·30 a.m. soil temp. at 20 cm depth
mean 8·30 a.m. soil temp. at 5 cm depth
maximum soil temp. at 5 cm depth and
mean minimum temp. on grass

were selected for the subsequent analysis along with the other weather variables and the age factor. A summary of the combined variables is given in Table 1.

TABLE 1 : SUMMARY OF MERGED VARIABLES

No.	Variable Name	Minimum	Mean	Maximum	Std. deviation	Coeff. of variation
1.	screen min. temp. (°C)	14·00	18·28	20·80	1·51	8·28
2.	soil 20 cm mean temp. 8·30 a.m. (°C)	25·54	27·11	30·25	1·23	4·55
3.	soil 5 cm max. temp. 8·30 a.m. (°C)	24·36	25·80	27·83	0·89	3·46
4.	soil 5 cm max. temp. 8·30 a.m. (°C)	25·40	26·66	28·90	1·02	3·82
5.	grass mean min. temp. a.m. (°C)	17·33	19·57	21·55	1·06	5·40
6.	mean RH 8·30 a.m.	79·33	85·78	93·60	3·67	4·28
7.	max. RH 8·30 a.m.	88·00	93·67	99·99	2·87	3·06
8.	min. RH 8·30 a.m.	64·00	78·35	87·00	4·98	6·38
9.	rainfall per day (mm)	0·00	12·21	40·50	14·52	118·69
10.	previous 24 h rainfall (mm)	0·00	20·20	124·10	35·54	175·67
11.	wind per day (no. of revolutions)	1393·0	2698·0	4160·0	745·64	27·63
12.	mean atm. preasure 8·30 a.m. (mm of mercury)	756·44	758·19	759·17	0·67	1·15
13.	sunshine per day (h)	1·10	5·15	8·82	2·34	45·45
14.	age (days)	86·0	161·96	255·0	50·91	31·42

Since the plants belonged to a number of clones, between plant differences in diameter increments and also in height increments were scrutinized by the analysis of variance technique applied separately to the two sets of data. It showed non-significant differences between diameter increments and a 0·05 level significance for the height increments. However, the differential effects were eliminated by averaging the diameter and height increments over the thirty plants.

There were a few missing points in the pressure data. These were estimated by a regression method (Buck, 1960). Then the mean height increments and mean diameter increments were regressed separately on the set of merged meteorological variables. A packaged computer programme was used to obtain best equations with varying numbers of variables as described by Beale *et al.* (1967).

An analysis was also carried out to determine months with significantly higher growth rates (Sverdrup, 1975).

RESULTS AND DISCUSSION

During the period of the field work, irregular increases in height were observed. On certain days, plants were seen to have attained appreciable height increments, sometimes as much as 5 cm. The tender shoots continued to mature for some days without any further noticeable increase in height. Normally, after maturing to a stage of getting a dark green colour, another sudden elongation occurred. But sometimes, a further increase was seen before complete maturing. This could be due to the occurrence of a conducive environment for height increments. This process was observed in almost all the plants. In certain instances, when such prematured height increments were apparent, measurements were carried out, on consecutive days. Calculations did not indicate any dependence between the height increment and the length of the period since the previous increment. It is possible that there was a similar but off-phase behaviour in girthing, making the plant grow either in height or diameter at a given time (Chowdhury & Tandau, 1950 ; Wareing, 1950). This may not have been observed due to the very small magnitude of the measurement (the mean diameter increment of a tree for a day was 0·00255 cm.) and/or a deficit on the observation periods such as being relatively too lengthy. The correlations between height and diameter increments were calculated for each of the 30 plants. Only 9 plants showed significant correlations, six of which were high ($P < 0{\cdot}01$). It could be inferred that heights and diameters do not necessarily increase simultaneously. These 9 plants belonged to the clones RRIC 104, RRIC 38, RRIC 99, RRIC 108, 2473 and RRIM 609. From these, clones RRIC 108 and RRIM 609 were represented in the uncorrelated group as well. This debars an inference that the above phenomenon is a clonal effect. Perhaps, a different picture would have been shown, if total shoot lengths of the plants were measured instead of heights alone.

Characteristics of the regression coefficients of the equations selected from the multiple regression analysis are given in Table 2, separately for height and diameter,

TABLE 2 : REGRESSION-COEFFICIENT-PROPERTIES OF BEST EQUATIONS

Variable		Height		Diameter	
No.	Name	sign	significance	sign	significance
1.	Soil 20 cm mean temp. 8·30 a.m.	—	***	—	**
2.	Soil 5 cm mean temp. 8·30 a.m.			+	*
3.	Soil 5 cm max. Temp. 8·30 a.m.	+	***		
4.	Grass mean min. temp.	+	***	+	***
5.	Mean relative humidity 8·30 a.m.	+	***	+	**
6.	Min. relative humidity 8·30 a.m.	—	***	—	*
7.	Rainfall per day			—	**
8.	Previous 24 h rain	—	***		
9.	Wind per day	+	*		
10.	Mean at pressure 8·30 a.m.	+	***	+	**
11.	Sunshine	+	***	+	**
	Number of variables	9		8	
	Degrees of freedom	17		16	
	Multiple correlation	0·909		0·817	

* denotes 0·05 level significance
** denotes 0·01 level significance
*** denotes 0·001 level significance

An increase in the mean 8·30 a.m. soil temperature at 20 cm depth depresses both height and diameter increments while the variables on 5 cm depth soil temperatures show that higher temperatures at 5 cm depth enhance growth. A higher grass mean minimum temperature is in favour of growth. A contrast is seen between the variables on relative humidity. The correlation between the mean humidity and the minimum humidity at 8·30 a.m. is 0·877. Inconsistent results due to this relationship is unlikely. An increase in the mean humidity and a decrease in the minimum humidity is possible if the maximum relative humidity increases. Fluctuating humidities would bring about this suitable situation. Rainfall, in the form found in this study, does not favour higher growth rates. More wind is significantly favourable to height increments. Higher atmospheric pressures, a characteristic of lower elevations, and longer hours of sunshine are conducive to growth.

An examination of the pattern of the residuals showed that no important variables have been omitted. The coefficients of determination which are the squares of the multiple correlation coefficients show that 83% of the variability in height increments and 67% of the variability in diameter increments are accounted for by meteorological variables.

It has been found by other workers that the proportion of variability in growth accounted for by meteorological variables differ from year to year (Hiley & Cunliffe 1923 ; Fritts, 1960). Fraser (1971) in his investigation on climate and forest structure, states the necessity to study the microclimate in some detail to explain the differential effect on neighbouring trees. Hence, further studies should be carried out on this aspect.

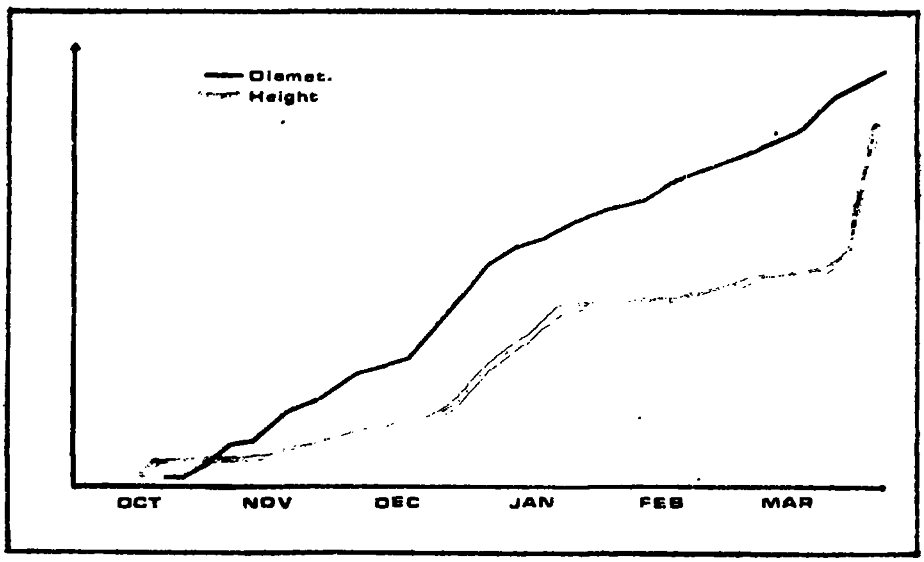

Fig. 1. Monthly increments in heights and diameters

Fig. 1 shows the patterns of increment rates for heights and diameters over the observed period. No significant difference is present in diameter increments over the months considered here. Diameter increments were highest in November followed by April. In the case of height increments, those in April were significantly higher than all other months. There was no significant difference between January and March, but these were significantly higher than October, November, December and February which did not differ significantly among themselves.

ACKNOWLEDGEMENTS

I am thankful to Dr. O. S. Peiris, Director, RRISL for useful suggestions on the manuscript and to Dr. A. de S. Liyanage, Head, Plant Pathology Department of the RRISL for allowing his experimental material to be used in this study. Thanks are also due to Dr. K. S. E. Jayatillaka of the Central Bank for the advice on the technical aspects of the paper, to Messrs. R. B. Ekanayake of the State Engineering Corporation and S. Wijewansa of Peradeniya Campus for their assistance in computer analysis and to Mr. M. D. H. Goonatillake of the Dept. of Census and Statistics for his co-operation in obtaining library facilities.

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