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IMPACT OF WEATHER PARAMETERS ON SEASONAL AND INTER-YEAR VARIATIONS IN YIELD OF RUBBER

T. SAILAJADEVI, RAMESH B. NAIR,
R. KOTHANDARAMAN and M.R. SETHURAJ

Rubber Research Institute of India
Kottayam - 686009
Kerala

An attempt was made to study the influence of meteorological parameters like temperature, relative humidity, rainfall and sunshine hours on the yield of natural rubber (*Hevea brasiliensis*) in a polyclonal plantation of the Rubber Research Institute of India, Kottayam with a view to develop a predictive model. Among the parameters studied, temperature and rainfall have significant influence on yield. The increase in temperature and reduction in rainfall affects yield through their influence on soil moisture. A predictive model for monthly yield of rubber based on pan evaporation has been developed.

INTRODUCTION

The influence of weather parameters in determining crop yield is a well debated topic. In order to explore the above relationship attempts have been made in the case of coconut (Rao *et al.*, 1984; Vijayakumar *et al.*, 1989), arecanut (Reddy *et al.*, 1993, Vijayakumar *et al.*, 1991) and cocoa (Vijayakumar *et al.*, 1991). The available results on natural rubber (NR) showed a significant positive relationship between low soil moisture levels and reduction in the yield (Sethuraj and Raghavendra,1984). However, no serious scientific attempt has so far been made to establish the relationship between weather parameters and yield of NR. The present study was an attempt to explore the relationship between relevant meteorological parameters and the yield of NR and to develop a model which would be useful for estimating the yield based on meteorological parameters. Although to a great extent yield is determined by clone specific physiological characteristics and age-profile of individual trees, agroclimatic factors play a key role in conditioning and stabilising the yield.

NR production is generally forecasted on the basis of trends in area under cultivation, age-profile of trees and varieties planted. The predictions obtained could further be improved if influential weather parameters are identified and incorporated in the model. Identification of weather parameters having a strong bearing on the yield is also helpful in selecting regions suitable for cultivating rubber.

More than 86 per cent of the total NR production in India is contributed by small holdings. There are about nine lakhs small holdings with an average size less than 0.5 hectare. While estates maintain records related to production and stock, such records are seldom maintained by small holders. Consequently, difficulties are involved in the collection of statistics from this sector. Estimation of monthly production of NR is essential for the assessment of gap between

supply and demand of NR. If the gap is not scientifically assessed, it may lead to import/excess stock resulting in fluctuation in the price having serious implications. In this backdrop, an attempt was made to develop a model capable of estimating monthly production of NR based on meteorological parameters.

MATERIALS AND METHODS

The meteorological parameters used for this study were maximum and minimum temperature, relative humidity (morning and evening), rainfall and sunshine hours. Correlations were worked out between meteorological parameters and yield.

The impact of the rainfall on yield during the dry months was examined by working out the correlations with the yield using the variables *viz.*,

1. Rainfall during current month
2. Total rainfall during current month and the preceding month
3. Total rainfall during current month and two preceding months

In order to assess the influence of meteorological parameters on seasonal variations in yield, twelve months in a year were grouped as four seasons based on the variations in meteorological parameters.

Season 1 - June and July
Season 2 - August, September and October
Season 3 - November, December and January
Season 4 - February, March, April and May

The seasonal changes in yield were correlated with the corresponding changes in meteorological parameters.

In order to examine the impact of defoliation and refoliation on yield, regression analysis was carried out using a dummy variable. Defoliation usually occurs during the months of November and December and refoliation during January and February. The yield increase due to defoliation is maximum during November followed by December. The yield decrease due to refoliation is maximum during February and minimum during January. Since neither defoliation nor defoliation occurs in other months, their effect on yield during the months is considered to be zero. The dummy variable assumes 3, 2, -1 and -3 in November, December, January and February respectively and zero otherwise.

The impact of maximum temperature and relative humidity (evening) on yield was also examined in a different way. From the 132 monthly observations available those having maximum temperature beyond 30°C and relative humidity (evening) below 65% were selected. A proxy variable 'U' is defined as U = - i for each i degree increase in temperature beyond 30°C and another variable 'V' is defined as V = - i for each per cent decrease in relative humidity (evening) below 65 per cent. The relationships of U and V on yield were worked out.

The relationship of pan evaporation and soil temperature on yield was worked out for one year as the data were available only for that period.

RESULTS AND DISCUSSION

The nature and intensity of relationship between meteorological parameters and yield was examined and the results are given in Table 1. Maximum temperature, minimum temperature and sunshine hours were found to have negative significant relationship with yield whereas RH (evening) had a significant positive relationship. Rainfall and RH (morning) were significantly related to yield. The negative relationship is maximum for maximum temperature followed by minimum tem-

perature and sunshine hours. From the results, it is clear that temperature (maximum and minimum) had a crucial role in determining the yield. The drastic reduction in yield during the summer season in certain clones may be due to the high negative influence of temperature on yield. Rainfall had no significant impact on yield when it was examined on annual basis. This may be due to the compensation of positive effect of rainfall during January to May by the negative effect of rainfall during June to August.

Table 1. Correlation coefficient of yield with meteorological parameters

Meteorological parameter	Correlation coefficient
Maximum temperature	–0.4055**
Minimum temperature	–0.2599**
Relative humidity(mor)	0.1117
Relative humidity(eve)	0.2860**
Rainfall	0.0969
Sunshine hours	–0.2061*

* Significant at 5% level
** Significant at 1% level

The results of stepwise regression analysis of the selected meteorological parameters and yield are given in Table 2. The R^2 value is significant. The t- value of the regression coefficient (-ve) is maximum for maximum temperature followed by sunshine hours and RH (evening). Here also, the maximum temperature emerged to be the most significant factor. Sunshine hours had a highly significant positive role on yield. The yield drop during June-July as compared to August to December in rainguarded plantations can be attributed to low sunshine hours in June-July.

Table 2. Influence of meteorological parameters on yield

Meteorological	Regression parameter coefficient	SE	t value
Maximum temperature	-9.32	1.67	-5.58**
Relative humidity(eve)	0.730	0.323	2.26*
Sunshine hours	0.2699	0.063	4.28**
Constant term	254.34	R^2	0.16**

* Significant at 5% level
** Significant at 1% level

February to May is a period characterised by scattered rain. The analysis of the effect of rainfall (Table 3) showed that the impact of rainfall on yield would be more pronounced when the cumulative rainfall for current and one or two preceding months rather than the current months rainfall alone. From the analysis it was clear that cumulative rainfall upto three months has a positive influence on the yield of rubber. Therefore, it is possible to conclude that there may not be any reduction in the yield for a dry spell upto two or three months after a sufficient rainfall.

Table 3. Influence of rainfall on yield

Variable	Correlation coefficient
Rainfall during current month	0.48**
Rainfall during current month + preceeding one month	0.62**
Rainfall during current month + preceeding 2 months	0.62**

** Significant at 1% level

When the cumulative rainfall and other meteorological parameters were stepwise regressed for the period February to May and (Table 4) the R^2 value was found to be significant. The t- value was maximum and positive for cumulative rainfall and negative for maximum temperature. From the results, it was clear that maximum temperature had a crucial role in determining the yield. The lower temperature and scattered rainfall are ideal for rubber.

Table 4. Regression analysis for yield

Meteorological parameter	Regression coefficient	SE	t value
Maximum temperature	-7.72	3.70	-2.08*
Cumulative rainfall -	0.075	0.015	4.95**
R^2	0.45**		

* Significant at 5% level
** Significant at 1% level

The seasonal changes in yield was correlated with the corresponding changes in the meteorological parameters. The analysis revealed that maximum temperature and minimum temperature had significant negative relationship with yield whereas RH (evening), RH (morning), rainfall and sunshine were insignificantly related to yield (Table 5). The negative relationship was maximum for maximum temperature. The yield increased proportionally with the reduction in minimum temperature. The yield increase during November and December is attributed to lower night temperature. The analysis of seasonal variations complemented the results obtained in analysing the monthly data.

Table 5. Correlation coefficient of seasonal variations in yield with meteorological parameters

Variable	Correlation coefficient
Maximum temperature	–0.3966**
Minimum temperature	–0.6639**
Relative humidity (mor)	–0.0667
Relative humidity (eve)	0.111
Rainfall	–0.0868
Sunshine	–0.1188

** Significant at 1% level

The effect of defoliation and refoliation when studied using a dummy variable is presented in Table 6. The analysis revealed that the defoliation and refoliation has a significant influence on the yield of rubber. R^2 was also significant. The increase in the yield during November was not only due to the effect of lower night temperature but was the cumulative effect of lower night temperature and defoliation. The drastic reduction in yield during February was the cumulative effect of refoliation, meteorological and other parameters.

Table 6. Regression analysis for defoliation

Variable	Regression coefficient	SE	t value
Dummy variable	5.69	1.41	4.02**
R^2	0.11**		

** Significant at 1% level

The effect of maximum temperature and RH (evening) when examined using a proxy variable is presented in Table 7. The results indicated that the effect of maximum temperature was found to be significant and the RH (evening) insignificant. R^2 was also significant. The result also supports that yield reduces drastically when the ambient temperature rises.

Table 7. Regression analysis for yield using proxy variables

Proxy variable	Regression coefficient	SE	t value
U	–11.76	2.84	4.14**
V	0.24	0.44	0.54
Constant term	93.79		
R^2	0.26**		

** Significant at 1% level

The influence of pan evaporation and soil temperature on yield examined by using the available monthly observations is presented in Table 8. The results of the analysis indicated negative and highly significant relationship of yield with soil temperature of all depths and pan evaporation. From the result it was clear that the temperature below a certain range and soil moisture in the root zone are the essential requirements of rubber.

Table 8. Influence of soil temperature and pan evaporation on yield

Variable	Correlation coefficient
1) Soil temperature (FN) 5 cm depth	–0.90**
2) Soil temperature (FN) 15 cm depth	–0.89**
3) Soil temperature (AN) 5 cm depth	–0.74**
4) Soil temperature (AN) 15 cm depth	–0.81**
5) Pan evaporation	–0.91**

** Significant at 1% level

A predictive model explaining the relationship between pan evaporation and yield has been established (Table 9).

Since the R^2 was very high and significant, the model can be used for estimating monthly production of rubber based on pan

evaporation. When the predictions were made using the model it was found that the deviation between the actual and predicted values was only less than 6 per cent. The model is capable of forecasting monthly yield of rubber provided data on pan evaporation are available.

Table 9. Regression equation for estimating yield

Variable	Regression coefficient	SE	t value
Pan evaporation	–9.56	1.38	–6.94**
Constant term	84.68		
R^2	0.83		

** Significant at 1% level

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