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Evaluating Soil Characteristics and Weather on Latex Yield of Rubber (*Hevea brasiliensis* Muell. Arg.) in Southern Nigeria by Correlation and Path Co-efficients

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Abstract: Rubber production is influenced by a number of factors. Rubber yield, weather and soil data collected over a total of six-year period from the rubber plantations at the Rubber Research Institute of Nigeria were subjected to correlation and path analysis to determine the direct and indirect contributions of edaphic and environmental factors to the yield of rubber in the humid rainforest ecological zone of Nigeria. Soil total porosity at 0-15 cm and 15-30 cm depths with correlation coefficients of 0.683** and 0.500* respectively positively affected rubber yields while bulk density at 0-15 cm depth negatively affected rubber yield. The weather elements of rainfall and relative humidity at 0900 hours with correlation co-efficients of -0.340** and -0.245** respectively had negative relationships with rubber yield. Path analyses however showed that the influence of bulk density, porosity at 0-15 cm depth and rainfall were indirect thus could have influenced other soil and environmental parameters to affect the yield of rubber. The factors identified in this study could be of practical importance when considering the introduction of rubber into new agro-ecological zones.
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Introduction

Rubber latex yield (dry rubber content) is associated with a number of edaphic and environmental characters, some of which in turn are interrelated. Such interdependence of contributing factors often affect their direct relationship with latex and dry rubber content, thus in selecting indices for the relevant parameters, correlation and regression have been the conventional statistical tools (Wheater and Cook 2003). Usually, stepwise regression is employed and the validity (lack of bias) requires the inclusion of all independent variables that affect the dependent variable, while the reliability (small standard error) of the regression parameters may worsen if some of the independent variables are highly correlated (Wittink, 1988), especially where the primary interest is in the regression coefficients per se to identify “important” variables, the impact of co-linearity on OLS regression is very serious. Stepwise procedures are useful if regression analysis involves a large set of variables and the purpose is prediction. On the other hand, if the purpose is explanation, then adopting some other more logical model-building techniques might be more useful (Howell 1997). As more variables are included in correlation and regression analysis studies, the inherent association becomes complex, hence, the role of path co-efficient analysis becomes important. In such situations, the path coefficient helps to measure the direct influence of one variable upon another and permits the separation of relative contribution of different parameters to the trend of measured interest. Correlation and path analysis, though frequently used in agriculture, have been restricted to selection of desirable characters for breeding of field crops, in recent times it has been successfully applied to tree crops such as rubber, bombax etc. (Gera *et al.,* 1999; Omokhafe, 2001). It was applied in this study to identify the contributing weather and edaphic factors to the yield of rubber. With the recent quest in Nigeria to introduce rubber cultivation into areas hitherto considered marginal for rubber in Kaduna and Taraba States, the knowledge of important edaphic and climatic factors contributing significantly to rubber latex production is important. This study was carried out therefore, to identify the soil and weather parameters that contribute significantly to the yield of rubber. This may be useful in site evaluation and selection for rubber. It may also be helpful in plantation management.

Materials and Methods

Study location

This study was conducted at the Mainstation of the Rubber Research Institute of Nigeria (RRIN). The study area occupies a land area of 2070 hectares about 29 kilometers away from Benin City, Edo State, southern Nigeria. The main access road is through Obaretin Village situated at km 19, Benin- Sapele highway. The Area is located within the co-ordinates of 5º 34'E and 5º 38'E Longitudes; 6º 08'N and 6º 11'N Latitudes. The area lies within the humid rain forest agro-ecological zone. Mean annual rainfall goes above 2000 mm, distributed in a bi-modal pattern with peaks in the month of July and September. The soils of this area are mainly leached Ultisols derived from unconsolidated grits and sand stones containing clay beds of varying proportions. The soils were deep, porous, non-mottled and non-concretionary red soils with textures ranging from loamy sand at the surface to sandy clay in the sub-soils. The detailed characteristics and classification of the soils in this area have been reported (Orimoloye, 2011; Orimoloye and Akinbola, 2013).

Soil Sampling and analysis

Bulk soil samples were collected at both wet and dry seasons of the year over a six year period from 2005 to 2010 at depths of 0-30 cm from six poly clonal rubber plantations measuring four hectares each of ages 12 to 20 years in the rubber Research Institute of Nigeria. Undisturbed core samples were also collected for bulk density, porosity and soil hydraulic conductivity determinations. The soil samples were subjected to laboratory analysis using the methods described in the IITA (1978) Manual.

Collection of weather data

The daily weather parameters of the study area namely: rainfall, evaporation, wind speed, minimum and maximum temperature, and Relative humidity (at 0900 and 1500 hours) over a 10 year period obtained from the Benin Airport Meteorological Station (2003-2005) and the Automated Weather Station at RRIN Mainstation, Iyanomo (2006-2012) were computed to obtain monthly conditions. However, monthly weather parameters of the four years for which yield was monitored were used in correlation analysis with monthly rubber yields from the rubber plantations.

Collection of rubber yield data

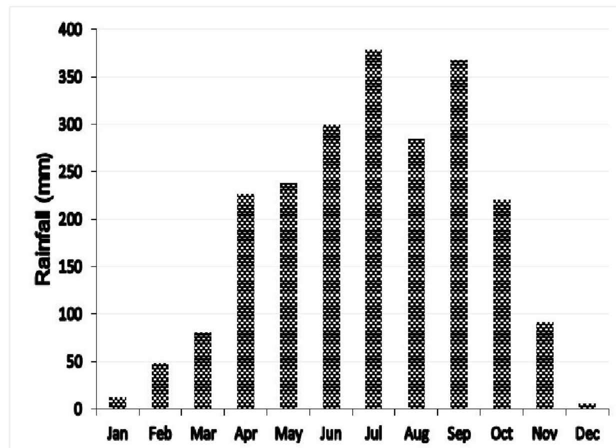
Twenty (20) rubber trees that are being actively tapped by half spiral/alternating days tapping method (without stimulation) were tagged in each of the six poly clonal fields. The latex yield records of the tagged trees were monitored over a four year period from 2005-2008. Dry rubber yield were estimated using the metrolach hydrometer method and yield per hectare were calculated based on the planting population of 450 trees per hectare.

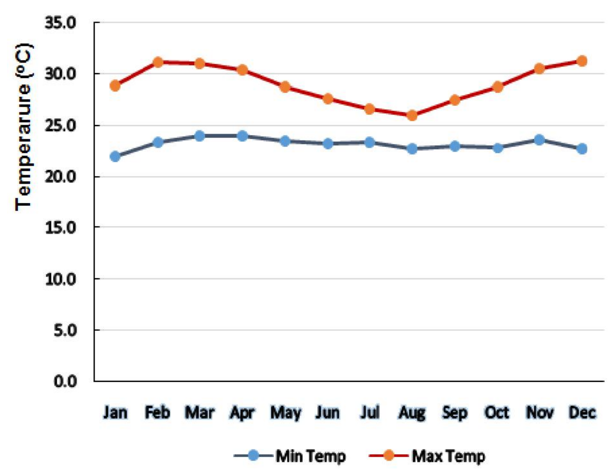
Assessment of weather and soil parameters on rubber yield

The soil parameters obtained from laboratory analysis of soil samples and the rubber yields from the fields were subjected to correlation analysis. Based on the significance, the relevant soil parameters were selected for further analysis. Average monthly weather parameters were also correlated with the monthly yield of rubber. The direct and indirect contributions of the soil and weather parameters to rubber yield were evaluated using Path Analysis (Gera *et al*., 1999).

Results and Discussion

Relationship between soil parameters and rubber yield





B

Fig. 1: Rainfall (A) and temperature charts (B) of the the study area from 2003 to 2012 obtained from NIMET and Rubber Research Institute of Nigeria (RRIN)

The correlation analysis of soil parameters and rubber yields are presented in Table 1. Surface bulk density and potassium (K) significantly affected rubber yield negatively (r = -.679 ** and -.506 * respectively) at 0.01 and 0.05 probability levels. On the other hand, surface Porosity (0-15 cm) and subsoil porosity (15-30 cm) positively affected the yield of rubber (r =.683 ** and.500* respectively). This scenario led to the determination by path analysis the direct and indirect contributions of the individual parameters to the observed relationship. FELDA (1989) observed that poor plant growth might be brought about as a result of inappropriate choice of planting location. Opeke (1987), noted that rubber does well on deep, porous, red-clay sub soil with a relatively sandy top soil. It could therefore be inferred that the productivity level of rubber is influenced by interactive effects of genetic and soil fertility status.

Relationship between weather parameters and rubber yield

The correlation between soil and weather variables with rubber yield over the study period are as shown in Tables 1 and 2 respectively. Most of the weather parameters showed a negative correlation with rubber yield. With rainfall having the highest negative correlation (r = - 340**). This might have been a result of the many tapping days that are usually lost during heavy rains, the high moisture content of latex during the raining months and latex wash-off during the years of heavy rainfall. Vijayakumar, *et al,* (2000) observed that higher dry rubber yields are obtained around October and November when the dry season has set in. Other weather factors such as relative humidity (RH) at 0900 and 1500 hours also correlated negatively with yield obviously because of the intimate relationship between rainfall and RH. Mokwunye *et al.* (2007), also observed that irregular and deficient rainfall pattern adversely affects the growth and productivity of natural rubber. Changes in rainfall pattern triggers fungal infection of leaves, which adversely affects productivity, while rainstorms can also bring about a lot of wind damage in rubber plantations. The path analysis however reveals that Maximum temperature had the highest direct effect (0.666) with relative humidity also having positive direct effects. Devi *et al.* (1998) investigated the impact of weather variables on the rubber yield of a polyclonal rubber seedling population and concluded that both temperature and evaporation influenced yield. In another study, Priyadarshan *et al.* (2000) found that minimum temperature; evaporation and wind velocities were negatively correlated with dry rubber yield under the conditions found in Tripura state.

Path coefficients of soil and weather on rubber yield

Table 1: Correlations matrix of selected relevant soil parameters to rubber yield

	Sand	B/density 0-15 cm	B/ density 15-30 cm	Porosity 0-15 cm	Porosity 15-30cm	K	Base saturation	Rubber Yield
Sand	1.000	-.163	-.001	.150	-.012	-.551*	.324	.303
B/ density 0-15 cm		1.000	.882**	-.998**	-.881**	.031	-.127	-.679**
B/ density 15-30 cm			1.000	-.884**	-.994**	-.137	-.019	-.490
Porosity 0-15 Cm				1.000	.884**	-.026	.142	.683**
Porosity 15-30					1.000	.140	-.017	.500*
K						1.000	-.027	-.506*
Base saturation							1.000	.216

* Significant at the 0.05 level, ** Significant at the 0.01 level

Table 2: Correlations matrix of selected weather variables to rubber yield over a ten year period at Iyanomo

	Rainfall	Evaporation	Wind Speed	Max temp	Min temp	RH 09§	RH 15§§	Rubber Yield
Rainfall	1.000	-.436**	.103	-.708**	-.372**	.668**	.790**	-.340**
Evaporation		1.000	.388**	.697**	.519**	-.466**	-.541**	.081
Wind Speed			1.000	.232*	.346**	-.059	-.005	-.139
Max temp				1.000	.665**	-.806**	-.883**	.167
Min temp					1.000	-.202*	-.332**	-.195
RH 09						1.000	.915**	-.245**
RH 15							1.000	-.261*

§ RH 09 = relative humidity at 0900 hrs, §§ RH 15 = relative humidity at 1500 hours
** Correlation is significant at the 0.01 level * Correlation is significant at the 0.05 level

Simple correlations measures interrelationships between characters, whereas, path coefficient analysis partitions the total correlation between direct and indirect effects of other characters. The Path coefficient analysis of soil parameters on rubber yield is presented in Table 3. It is interesting to note that though the correlation between subsoil bulk density and yield was not significant, the direct effect of subsoil bulk density (1.482) is higher than all other variables but it was affected by the negative indirect effects that subsoil porosity (-1.409) and surface porosity (- 0.346). Among the variables considered, subsoil porosity, surface porosity, subsurface bulk density and base saturation had direct positive influences on the yield or other variables while sand, surface bulk density and K had negative direct effects. The current study corroborates the earlier observations of Ugwa et al (2006) and Orimoloye (2011) which pointed out relative poor K status of this area and attributed this to the sandy nature of the soils arising from the inherently sandy nature of the parent materials.

It follows therefore that soil texture, porosity, bulk density and K reserve are soil parameters that directly impact on rubber yield. The residual effect showed that 24.36 % variables were not accounted for by the Path coefficient (Table 3). Wycherley (1963) stated that soil constitutes the major aspects of the environment that greatly affect the growth and productivity of rubber trees. The direct and indirect effects of weather variables on rubber yield by path co-efficient analysis are shown in Table 4. The direct effect of rainfall is negative and is higher than the correlation values. Maximum temperature had the highest positive direct effect on rubber yield (0.666) though the correlation co-efficient (r = 0.169) was not significant, the total correlation values were reduced by a higher negative indirect value of Relative humidity at 1500 hours. Similarly, a high negative direct influence (-0.542) was exerted by Minimum Temperature which had a lower and insignificant correlation (r= -0.195). Relative humidity at 0900 and at 1500 hours have positive direct effects though their correlation co-efficients were significantly negative. These were brought about by a highly negative indirect effects of maximum temperature and relative humidity in both cases. High value of residual effect (42.67%) indicated that there could be other weather parameter, which were not included in the present study, contributing to the variability in latex yield.

Conclusion

From the analysis of the interrelationships, direct and indirect effects of soil characteristics and weather parameters on rubber yield using correlation and path co-efficients; soil texture, porosity, bulk density and K reserve are soil parameters while rainfall, maximum temperature and relative humidity are the weather elements that directly impact on rubber yield in the humid rainforest Zone of Southern Nigeria. Though, 24.2 % of soil characteristics and 46.67 of weather parameters were not accounted for in this study, the consideration of these parameters could improve the suitability criteria for site selection for rubber cultivation in this zone. It may also be a guide while introducing rubber into new environments.

Table 3: Direct (Diagonal) and indirect effects of relevant soil characteristics to rubber latex yield (kg/ha).

Soil Characteristics	Sand	B/density 0-15 cm	B/ density 15-30 cm	Porosity 0-15 cm	Porosity 15-30cm	K	Base Saturation
Sand	**-0.175**	0.028	0.0001	-0.026	0.002	0.096	-0.057
B/ density 0-15 cm	0.050	**-0.330**	-0.291	0.330	0.291	-0.01	0.042
B/ density 15-30 cm	-0.001	1.31	**1.482**	-1.310	-1.470	-0.20	-0.028
Porosity 0-15 Cm	0.058	-0.39	-0.346	**0.392**	0.346	-0.010	0.056
Porosity 15-30	-0.017	-1.24	-1.409	1.253	**1.418**	0.198	-0.024
K	0.314	-0.02	0.078	0.015	-0.08	**-0.571**	0.015
Base saturation	0.068	-0.03	0.004	0.030	-0.004	0.006	**0.212**
‘r’ with yield	0.303	-0.679**	-0.49	0.683**	0.500*	-.506*	0.216

Residual effect = 24.36, ** significant at the 0.01 level * significant at the 0.05 level

Table 4: Direct (Diagonal) and indirect effects of weather variables to rubber latex yield (kg/ha)

Weather parameters	Rainfall	Evaporation	Wind speed	Max temp	Min temp	RH 09	RH 15
Rainfall	**-0.466**	0.203	-0.048	0.330	0.173	-0.311	-0.368
Evaporation	0.008	**-0.020**	-0.008	-0.014	-0.101	0.009	0.011
Wind speed	-0.004	-0.016	**-0.041**	-0.009	-0.014	0.002	0.0002
Max temp	-0.411	0.464	0.154	**0.666**	0.443	-0.537	-0.588
Min Temp	0.102	-0.281	-0.187	-0.360	**-0.542**	0.109	0.180
RH 09	0.074	-0.059	-0.007	-0.101	-0.025	**0.126**	0.115
RH 15	0.347	-0.210	-0.002	-0.343	-0.129	0.356	**0.389**
‘r’ of rubber yield	-0.340**	0.081	-0.139	0.167	-0.195	-0.245**	-0.261*

Residual effect = 42.67, * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

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