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EFFECTS OF WEATHER ON YIELD COMPONENTS OF THE OIL PALM IN A FOREST LOCATION IN NIGERIA

Keywords: *Elaeis guineensis* Jacq., climatic variables, path coefficient analysis.

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Simple linear correlations, stepwise multiple regressions and path coefficient analysis were used to determine the relationship between climatic variables and yield components in the oil palm; i.e. number of bunches (NB), fresh fruit bunch yield (FFB) and mean bunch weight (MBW) over a 13-and 20-year period. Yield could be reliably predicted from minimum relative humidity and sunshine hours 18–24 months prior to harvest.

INTRODUCTION

The environment plays a pronounced effect on vegetative and reproductive phases of plants. In perennial species, consideration should be given to the differences in weather from year to year, otherwise large unexpected errors in yield estimates may become unavoidable. In the oil palm, correlation and regression have been extensively used to study the effect of climatic factors on fresh fruit bunch (FFB) yield. Solar radiation has been implicated as a factor causing major fluctuations in the yield of oil palm (Sparnnaij et *al.*, 1963). Ferwerda (1977) opined that the effect of solar radiation may be due to moisture stress associated with the high temperature resulting from solar radiation. Broekmans (1957) observed that drought two years before harvest led to floral abortion which, in turn, resulted in a reduced sex ratio. There has been a tendency in previous studies on climatic effects on oil palm to relate each climatic factor to yield in isolation without regard to possible overlapping or interaction effects with other climatic factors (Broekmans, 1957; Spamnaij *et al., 1963; Ong,* 1982). Oil palm yields can be complicated by a number of factors (i) the interaction of climatic factors with each other (ii) the oil palm, being a perennial, yields for many years and the climatic influences may be complicated by interbunch competition.

In taking into consideration all these facts, not only correlations were used but also stepwise multiple regression and path coefficient analysis to comprehensively explain climatic influences on oil palm yield. Correlations per se can be biased due to dependency among factors, which lead to multicollinearity and spurious results. However, stepwise multiple regression is effective in considering the influence of each climatic factor on yield without any interactive effect. 'Path coefficient analysis as developed by Wright (1923) further helps to eliminate any spurious effects detected by correlation and regression as it determines the direct effect of the factor through other climatic factors.

In order to have a better understanding of the oil palm, there is need to determine the effect of climatic factors on oil palm yield. This should be investigated at the various stages of production, especially since it has been observed that the oil palm has a distinct juvenile stage during its development and reaches maturity after about six years of field planting, after which its production is affected by a number of factors, one of which is climatic factors. In this study, only climatic factors relevant to a tropical environment such as Nigeria is considered.

EXPERIMENTAL

Analysis in this paper used data from a plantation within NIFOR main station, near Benin City in Southern Nigeria. The palms were planted in 1960, and data recorded on the number of bunches (NB), mean bunch weight (MBW) and fresh fruit bunch (FFB) yield over a 20-year period from 1963 to 1982 were used in this study. The palms were of *dura* and *tenera* varieties. In an earlier study, there was no significant fruit x environment (year) interaction for MBW and FFB (Oboh and Fakorede, 1989). Thus, the relative performances of the *dura* and *tenera* palms were maintained from year to year. However, progeny x environment interaction was observed for the yield traits that showed that performance of the crop varied on a yearly basis. Oboh and Fakorede (1989) concluded that the optimum times for selection and evaluation of oil palm progenies with the best fitting regressions were the 1st to 15th year of production for NB and the 1st to 13th year of production for MBW and FFB. Based on this information, we carried out three sets of analyses: 1st-15th year of production for NB, 1st-13th year of production separately for MBW and FFB and 1st-20th year for each of the three traits. We considered the 1st-13th or 1st-15th year as the linear phase of production.

Yield components are determined sequentially over a period of time. In the oil palm, floral initiation and development start 25 months before mature fruit bunches can be harvested. Thus, it was concluded that the development of harvestable bunches in oil palm lasts over a 30 to 36-month period and the effect of climatic factors during this period was considered. The periods considered for the analysis were based on the sum of monthly or yearly summaries for each climatic variable. Climatic variables considered include total rainfall (TR), mean minimum temperature (T_{min}), mean maximum temperature (T_{max}), total potential evaporation (PE), total number of dry days (DD), mean minimum relative humidity (RH_{min}), mean maximum relative humidity (RH_{max}) and total sunshine hours (SH). Each climatic factor was considered for the following periods:

(i) year of harvest (YH).
(ii) first 12 months before the year of harvest, i.e. for bunches harvested in 1964 climatic variables for 1963 represent the first 12 months before the year of harvest (12 mo.BH).
(iii) second 12 months before harvest (13 to 24 mo. BH).
(iv) 18 mo. BH.
(v) *24* mo. BH.
(vi) *30* mo. BH.
(vii) YH + 12 mo. BH.
(viii) YH + 18 mo. BH.
(ix) dry season preceeding year of harvest, i.e. for bunches harvested in 1964 – dry season is the period in 1963 (October -December) that overlaps till March 1964 (DSBH).

Although, there were overlaps between the periods considered, they corresponded to the floral development stages – sex determination occurring 30 months before harvest, spear enlargement and spikelet initiation 17 to 18 months before harvest, floral abortion 11 months before harvest and bunch failure one to three months before harvest (Corley and Gray, 1976; Hartley, 1977). Each climatic factor for the period under review was considered singly without its interaction/association with other climatic variables by the use of stepwise multiple regression and path coefficient analysis.

RESULTS

Although most of the correlations were not statistically significant, MBW demonstrated significant positive correlations with T_{max} at all lags except in YH and DSBH, while FFB had significant positive correlations only for the period YH + 12 mo. BH and 18 mo. BH (*Table* 1). FFB and MBW were positively correlated with DD at all lags and most of the r – values were significant or highly significant. On the other hand, the two traits had negative correlation with RH,, for all periods and nearly all r – values reached significant levels.

NB had significant positive correlations with RH,, and RH_{min} at 18, 24 and 30 mo. BH as well as YH + 18 mo. BH, SH and DD at periods 13–24, 24 and 30 mo. BH demonstrated significant negative correlations with NB. Similarly, SH showed significant negative correlations with NB in YH + 12 mo. BH and YH + 18 mo. BH.

Regression analyses showed that SH in YH + 18 mo. BH accounted for 79% of the variation in NB during the linear phase (first 15 years) of production (***Table*** 2). TR 30 mo. BH and in the YH + 12 mo. BH, PE in YH + 18 mo. BH and RH_{min} 24 mo. BH accounted for an additional 19% of the variation in NB for the first 15 years. For the 20-year period, SH in YH + 18 mo. BH accounted for only 51% of the variation in NB, while the addition of RH_{min} 24 mo. BH, TR at several lags, T_{min} 24 mo. BH, RH_{max} during DSBH and PE in YH + 18 mo. BH accounted for an additional 41% of the variation in NB.

Path coefficient analysis showed that SH in YH + 18 mo. BH had the largest, though negative, direct effect (P_{1Y}= 0.962) on NB during the first 15 years of production (***Table** 3*) while RH_{min} at 24 mo. BH had the largest direct effect on NB (P_{2Y} = 0.806) for the combined data (***Table*** 4). For the time to peak production (***Table** 3*), RH min at 18 mo. BH gave the largest single indirect effect via SH in YH + 18 mo BH (r_{51} P_{1Y} = 0.688). Total indirect effect of PE in YH + 18 mo. BH was very large (I = 0.9081 with its effect via SH during the same period ($r_{41} P_{1Y}$=-0.550) accounting for the largest proportion of the total indirect effects.

For the 20-year period, RH_{max} in DSBH had the largest total indirect effect (I = 0.702) and this occurred primarily via RH_{min} at 24 mo. BH with r_{52} P_{2y} = 0.473 (***Table*** 4). Although SH in YH + mo. BH gave the largest correlation with NB in the combined data (r = 0.713), its direct effect (P_{14} = -0.6171 was not the highest (***Table** 4*). The two analyses, however, consistently showed that SH during this period had large negative effects on NB.

T_{max} in YH + 18 mo. BH accounted for 58% of the variation in FFB during the linear phase of production (*Table 5*). For the 20-year period, however, DD 12 mo. BH accounted for 70% of the variation in FFB. Three other climatic variables accounted for an additional 36% of the variation in FFB in the first 13 years with SH 12 mo. BH alone accounting for 25%. For the 20-year period, seven climatic variables accounted for an additional 26% of the variation in FFB.

Path analysis for the two periods (***Tables*** 6 and 7) revealed that climatic variables that had small non-significant correlations were actually important in determining FFB. For the linear phase of production (first 13 years), SH 12 mo. BH accounting for only 25% of the variation in FFB had the highest direct (P_{2Y} = -0.4681 effect (***Table** 6*). For 20-year data (***Table*** 7), RH_{min} 18 mo. BH with r = - 0.166 gave the highest positive direct (P_{3y} = 0.675) and total indirect (I = 0.844) effects on FFB. It seems from the data for the linear phase of production (first 13 years) that T_{max} 30 mo. BH exerted a fairly large positive indirect effect (r_{41} P_{y} = 0.402) on FFB via T_{max} in YH + 18 mo. BH

TABLE 1. CORRELATION COEFFICIENTS OF TRAITS (NB, FFB, MBW) WITH VARIOUS LAP OF CLIMATIC VARIABLES OVER A 20-YEAR PERIOD

Climatic variable		YH	12 mo. BH	13-24 mo. BH	18 mo. BH	24 mo. BH	30 mo. BH	YH+12 mo. BH	YH+18 mo. BH	DSBH
TR	NB	-0.34	-0.06	0.33	0.12	0.18	0.18	0.19	0.31	-0.11
	FFB	-0.19	-0.46'	0.14	-0.29	-0.20	-0.15	-0.44	-0.34	-0.09
	MBW	-0.36	-0.26	-0.07	-0.24	-0.21	-0.20	-0.42	-0.40	0.03
FE		-0.04	-0.05	-0.10	-0.09	-0.11	-0.17	-0.06	-0.09	0.10
		-0.12	0.13	-0.08	0.11	0.04	-0.04	0.01	0.01	0.21
		0.04	0.15	0.06	0.18	0.15	0.10	0.13	0.15	0.24
		-0.27	-0.22	-0.56**	-0.33	-0.46	-0.52	-0.26	-0.38	-0.22
T_{max}		0.40	0.43	0.29	0.44	0.42	0.42	0.49*	0.47*	0.46*
		-0.06	0.34	0.07	0.38	0.30	0.23	0.21	0.34	0.24
T_{min}		-0.35	-0.14	-0.18	-0.11	-0.27	-0.40	-0.37	-0.37	-0.33
		-0.31	-0.41	-0.12	-0.36	-0.42	-0.46*	-0.54*	-0.61**	-0.49"
		-0.31	-0.14	-0.63**	-0.40	-0.45*	-0.47*	-0.26	-0.42	0.04
DD		0.54*	0.84**	0.27	0.72**	0.65**	0.62**	0.78**	0.73**	0.23
		0.70**	0.78**	0.53**	0.80**	0.76**	0.77**	0.84**	0.87**	0.20
		0.41	0.42	0.40	0.46*	0.48	0.45	0.48*	0.47*	0.27
RH_{max}		-0.44	-0.60**	-0.39	-0.61**	-0.58**	-0.61**	-0.60**	-0.61**	-0.48*
		-0.64**	-0.71"	-0.56*	-0.74**	-0.73**	-0.76**	-0.77**	-0.77**	-0.58'
		0.34	0.43	0.59**	0.62**	0.64"	0.61**	0.43	0.55'	0.03
RH_{min}		-0.10	-0.25	-0.03	-0.17	-0.11	-0.15	-0.17	-0.16	-0.23
		-0.33	-0.48*	0.37	-0.51*	-0.49*	-0.52*	-0.42	-0.47*	0.21
SH		-0.35	-0.64**	-0.21	-0.12	-0.55*	-0.49*	-0.67**	-0.71**	0.04
		-0.35	-0.22	-0.15	-0.07	-0.23	-0.18	0.09	0.03	0.15
		0.42	0.14	0.01	0.02	0.09	0.14	0.38	0.40	0.17

*, ** Significant at 0.05 and 0.01 levels of probability. respectively.

TABLE 2. MULTIPLE REGRESSION COEFFICIENT (b-values), COEFFICIENTS OF DETERMINATION (R^2) AND R^2 CHANGE (ΔR^2) FROM THE STEPWISE MULTIPLE REGRESSION OF NUMBER OF BUNCHES ON CLIMATIC VARIABLES

Climatic variable	b-Values	R^2	ΔR^2
	Linear phase (first 15 years) of production		
SH in YH + 18 mo. BH	-0.014	0.79**	0.79
TR 30 mo. BH	-0.005	0.88**	0.09
TR in YH + 12 mo. BH	0.015	0.93**	0.05
PE in YH + 18 mo. BH	0.131	0.96"	0.03
Rh_{min} 18 mo. BH	0.409	0.98**	0.02
	First 20 years of production		
SH in YH + 18 mo. BH	-0.008	0.51**	0.51
RH_{min} 24 mo. BH	1.154	0.63**	0.15
TR 30 mo. BH	-0.008	0.76**	0.10
T_{min} 24 mo. BH	0.680	0.83**	0.07
RH_{max} DSBH	-0.368	0.87**	0.04
TR in YH + 18 mo. BH	0.019	0.90**	0.03
PE in YH + 18 mo. BH	0.069	0.91**	0.01
TR 18 mo. BH	-0.016	0.92**	0.01

** Significant F-test at 0.01 level of probability,

(*Table* 6). Although DD in YH + 18 mo. BH was significantly correlated with FFB in the 20-year period (r = 0.734), the correlation was due primarily to its indirect effect via DD 12 mo. BH (r_{61} P_{1y} = 0.533, ***Table 7***).

T_{max} at 30 mo. BH accounted for 83% of the variation in MBW during the linear phase of production ***(Table 8)*** whereas DD in YH + 18 mo. BH accounted for the largest proportion (r^2 = 75%) of the variation for the 20-year period. Four climatic variables accounted for an additional 16% of the variation in MBW in the linear phase of production while seven climatic variables accounted for an additional 24% of the variation in MBW in the 20-year period with TR in YH + 18 mo. BH accounting for half of the 24%.

T_{max} at 30 mo. BH had the highest correlation (r = 0.9121 and the largest direct effect (P_{1y} = 0.820) on MBW during the linear phase of production ***(Table 9).*** The largest individual indirect pathway involved T_{max} in YH via T_{max} at 30 mo. BH. For the 20-year data, DD in YH + 18 mo. BH had the largest direct effect (P_{1y} = 0.866) on MBW ***(Table 10)***. TR in the same period had the largest total indirect effect (I = -0.762) and the largest single direct pathway (r_{21} P_{1y} = -0.63'71 via DD in the same period ***(Table 10)***. If the effect of DD in YH + 18 mo. BH is held constant, TR in the same period exerted the largest direct effect (P_{2y} = 0.634) on MBW although its correlation was negative (r = -0.403).

Correlation of the yield traits (NB, FFB and MBW) with the most important levels of the climatic factors showed that NB and MBW were negatively correlated while significant positive correlations were observed for MBW with FFB ***(Table*** 11). Correlation of NB with FFB was negligible. Significant positive correlations occurred among DD in the YH + 18 mo. BH and DD 12 mo. BH, FFB and MBW and also between the two levels of RH_{min} and NB. Although RH_{min} at 18 mo. BH was negatively correlated with FFB, it had the highest direct (P_{3y} = 0.675) effect ***(Table 7).*** It would seem, therefore, that increased RH_{min} at 18-24 mo. BH increased NB and FFB, while increased DD at 12 - 30 mo. BH increased FFB and MBW. Thus, increased NB would lead to

TABLE 3. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON NUMBER OF BUNCHES FOR FIRST 15 YEARS OF PRODUCTION

Variable (i)	Via variable (j) 1	2	3	4	5	Total indirect effect (I)	Effect *coefficient* (C)	Total correlation (r)	Non-causal correlation (E)
1. SH in YH + 18 MO. BH	-0.962	0.07s	-0.126	0.352	-0.232	0.073	-0.889	-0.890	-0.001
2. TR 30 mo. BH	0.671	-0.113	0.166	-0.483	0.162	0.516	0.403	0.403	0
3. TR in YH + 12 mo. BH	0.367	-0.057	0.330	-0.378	0.160	0.092	0.422	0.423	0.001
4. PE in YH + 18 mo. BH	-0.550	0.089	-0.202	0.616	-0.245	-0.908	-0.292	0.294	-0.002
5. RH_{min} 18 mo. BH	0.688	-0.056	0.162	0.464	0.325	0.330	0.655	0.655	0

TABLE 4. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON NUMBER OF BUNCHES FOR FIRST 20 YEARS OF PRODUCTION

Variable (i)	Via variables (j) 1	2	3	4	5	6	7	8	Total indirect effect (I)	Effect coefficient (C)	Total correlation (r)	Non-causal correlation (E)
1. SH in YH + 18 mo. BH	-0.617	-0.223	0.133	-0.035	0.139	-0.137	-0.003	0.127	0.001	-0.616	-0.713	-0.097
2. RH_{min} 24 mo. BH	0.171	0.806	-0.056	0.007	-0.251	0.244	-0.219	-0.126	-0.230	0.567	0.636	-0.060
3. TR 30 mo. BH	0.369	0.203	-0.222	0.045	-0.072	0.315	-0.157	-0.301	0.402	0.180	0.179	-0.001
4. T_{min} 24 mo. BH	0.136	-0.034	-0.062	**0.159**	0.001	0.212	-0.028	-0.083	0.142	0.301	0.301	0
5. RH,, DSBH	0.201	0.473	-0.038	0.001	0.274	0.205	-0.048	-0.092	0.702	0.275	0.274	-0.001
6. TR in YH + 18 mo. BH	0.162	0.377	-0.134	0.065	-0.168	0.521	-0.227	-0.287	0.212	0.309	0.308	-0.001
7. PE in YH + 18 mo. BH	0.006	0.460	0.091	-0.012	0.054	-0.307	0.384	0.153	-0.475	-0.091	-0.092	-0.001
8. TR 18 mo. BH	0.215	0.279	-0.184	0.036	-0.108	0.411	-0.161	-0.364	0.488	0,124	0.125	0.001

TABLE 5. MULTIPLE REGRESSION COEFFICIENT (b-values), COEFFICIENTS OF DETERMINATION (R^2) AND R^2 CHANGE (ΔR^2) FROM THE STEPWISE MULTIPLE REGRESSION OF FRESH FRUIT BUNCH YIELD ON CLIMATIC VARIABLES

Climatic variable	b-Values	R^2	ΔR^2
	Linear phase (first 13 years) of production		
T_{max} in YH + 18 mo. BH	14.459	0.58**	0.58
SH 12 mo. BH	-0.133	0.83**	0.25
TR 13-24 mo. BH	0.214	0.90**	0.07
T_{max} 30 mo. BH	12.410	0.94**	0.04
	First 20 years of production		
DD 12 mo. BH	1.059	0.70**	0.70
TR 18 mo. BH	0.163	0.78**	0.08
RH_{min} 18 mo. BH	11.065	0.85**	0.07
RH_{max} 12 mo. BH	-8.735	0.88**	0.03
SH 30 mo. BH	-0.059	0.91”	0.03
DD in YH + 18 mo. BH	0.288	0.94**	0.03
RH_{min} 30 mo. BH	-5.702	0.95**	0.01
T_{min} DSBH	2.355	0.96**	0.01

** Significant F-test at 0.01 level of probability.

TABLE 6. MULTIPLE REGRESSION COEFFICIENT (b-values), COEFFICIENTS OF DETERMINATION (R^2) AND R^2 CHANGE (ΔR^2) FROM THE STEPWISE MULTIPLE REGRESSION OF MEAN BUNCH WEIGHT ON CLIMATIC VARIABLES

Climatic variable	b-Values	R^2	ΔR^2
	Linear phase (first 13 years) of production		
T_{max} 30 mo. BH	4.725	0.83**	0.83
T_{min} 12 mo. BH	-3.254	0.91**	0.08
TR 18 mo. BH	0.022	0.96**	0.05
T_{max} in YH	1.460	0.98**	0.02
T_{min} 18 mo. BH	1.999	0.99**	0.01
	First 20 years of production		
DD in YH + 18 mo. BH	0.168	0.75**	0.75
TR in YH + 18 mo. BH	0.051	0.87**	0.12
TR DSBH	0.046	0.94**	0.07
SH 18 mo. BH	0.006	0.96**	0.02
RH_{min} in YH	0.712	0.97”	0.01
TR 12 mo. BH	0.015	0.98**	0.01
T_{max} 24 mo. BH	1.821	0.98**	0.005
T_{min} 24 mo. BH	-1.815	0.99**	0.005

** Significant F-test at 0.01 level of probability.

TABLE 7. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON FRESH FRUIT YIELD FOR FIRST 13 YEARS OF PRODUCTION

Variable (i)	Via variables (j) 1	2	3	4	Total indirect effect (I)	Effect coefficient (C)	Total correlation (r)	Non-causal correlation (E)
1. RH_{max} in YH + 18 mo. BH	0.459	-0.073	0.006	0.367	0.302	0.761	0.761	0
2. SH12 mo. BH	0.072	-0.468	-0.049	0.066	0.089	-0.379	-0.379	0
3. TR 13-24 mo. BH	0.012	0.074	0.306	-0.033	0.053	0.361	0.362	0
4. T_{max} 30 mo. BH	0.402	-0.074	-0.024	0.419	0.304	0.723	0.723	0

TABLE 8. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON FRESH FRUIT BUNCH YIELD FOR FIRST 20 YEARS OF PRODUCTION

Variable (i)	Via variable (j) 1	2	3	4	5	6	7	8	Total indirect effect (I)	Effect coefficient (C)	Total correlation (r)	Non-causal correlation (E)
1. DD mo. BH	0.639	-0.177	-0.328	0.293	0.001	0.320	0.131	-0.043	0.197	0.836	0.835	-0.001
2. TR 18 mo. BH	-0.398	0.246	0.234	-0.151	0.040	-0.204	-0.113	0.022	-0.570	-0.286	-0.290	-0.004
3. RH_{min} 13 mo. BH	-0.311	0.098	0.675	-0.261	0.091	-0.221	-0.265	0.025	-0.844	-0.169	0.166	0.003
4. RH,, 12 mo. BH	0.415	0.095	0.391	-0.450	0.149	-0.257	-0.163	0.047	-0.153	-0.603	-0.603	0
5. SH 30 mo. BH	-0.001	-0.028	-0.164	-0.179	-0.375	0.084	-0.130	-0.001	0.199	-0.176	-0.175	0.001
6. DD in YH + 18 mo. BH	0.553	-0.157	-0.402	0.313	-0.086	0.370	0.174	-0.031	0.364	0.734	0.734	0
7. RH_{min} 30 mo. BH	-0.277	0.107	0.592	-0.243	-0.162	-0.213	-0.302	0.028	0.156	-0.146	-0.147	-0.001
8. T_{min} DSBH	-0.267	0.061	0.163	0.202	0.003	0.111	-0.082	0.104	-0.438	-0.334	-0.332	0.002

TABLE 9. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON MEAN BUNCH WEIGHT FOR FIRST 13 YEARS OF PRODUCTION

Variable (i)	Via variable (j)					Total indirect effect	Effect coefficient	Total correlation	Non-causal correlation
	1	2	3	4	5	(I)	(C)	(r)	(E)
1. SH in YH + 18 mo. BH	**0.820**	-0.010	-0.079	0.133	0.048	0.092	0.912	0.912	0
2. T_{min} 12 mo. BH	0.017	**-0.471**	0.035	0.030	0.184	0.206	-0.265	-0.265	0
3. TR 18 mo. BH	-0.326	-0.083	**0.200**	-0.030	0.022	-0.417	-0.217	-0.216	0.001
4. T_{max} in YH	0.422	0.056	-0.023	**0.258**	-0.070	-0.358	0.643	0.644	0.001
5. T_{min} 18 mo. BH	0.170	-0.374	0.019	-0.078	**0.232**	-0.263	-0.031	-0.031	0

TABLE 10. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF CLIMATIC VARIABLES ON MEAN BUNCH WEIGHT FOR FI

Variable (i)	Via variable (j)								Total indirect effect	Effect coefficient	Total correlation	Non-causal correlation
	1	2	3	4	5	6	7	8	(I)	(C)	(r)	(E)
1. DD in YH + 18 mo. BH	**0.866**	-0.467	-0.021	0.012	-0.119	-0.054	0.196	-0.081	-0.534	0.332	0.866	0.534
2. TR in YH + 18 mo. YH	-0.637	**0.634**	0.009	-0.101	0.030	0.073	-0.060	-0.076	-0.762	-0.128	-0.403	-0.275
3. TR DSBH	-0.187	0.056	**0.098**	0.054	0.145	0.007	-0.138	0.073	0.010	0.108	0.029	-0.079
4. SH 18 mo. BH	0.038	-0.238	0.020	**0.268**	-0.004	-0.042	-0.029	-0.008	-0.263	0.005	0.023	-0.018
5. RH_{min} in YH	-0.362	0.067	0.050	-0.004	**0.284**	-0.011	-0.192	-0.005	-0.457	0.173	-0.328	-0.155
6. TR 12 mo. BH	-0.421	0.414	0.006	-0.099	-0.027	**0.112**	-0.054	0.005	-0.176	-0.064	-0.255	-0.191
7. T_{max} 24 mo. BH	0.558	-0.125	-0.044	-0.025	-0.179	-0.020	**0.305**	-0.039	0.126	0.431	0.669	0.238
8. T_{min} 24 mo. BH	-0.375	0.257	-0.038	0.012	0.008	0.003	0.063	**-0.188**	-0.070	0.258	-0.419	-0.161

TABLE 11. CORRELATION COEFFICIENTS OF MOST IMPORTANT LEVEL OF CLIMATIC VARIABLES WITH YIELD (NB, MBW AND FFB) OVER A 20-YEAR PERIOD

Variable	NE3	FFB	MBW	DD in YH	RH min 24 mo. BH	DD 12 mo. BH
FFB	0.08					
MBW	-0.46*	0.79**				
DD in YH + 18 mo. BH	-0.42	0.73**	0.87**			
RH_{min} 24 mo. BH	0.64**	-0.11	-0.49	-0.52*		
DD 12 mo. BH	-0.14	0.84**	0.78**	-0.87**	-0.41	
RH_{min} 18 mo. BH	0.62**	-0.17	-0.51*	-0.60**	0.92**	-0.49*

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

decrease MBW with relatively stable FFB since both RH_{min} and DD favoured the production of FFB.

DISCUSSION

NB and MBW are negatively correlated because climatic factors deterimental to the expression of NB favour MBW (Corley et al., 1971; Ooi et al., 1973; Van der Vossen, 1974; Hartley, 1977; Obisesan, 1981). Negative correlations among yield components may also be caused by genetically independent components which develop in a sequential pattern and vary in response to a limited input of metabolities, thereby limiting input at critical stages in the developmental sequence (Adams, 1967). Since NB is determined earlier than MBW during ontogeny, the correlation may be developmental rather than genetic per se.

Total SH and RH_{min} at about 18-24 mo. BH (time of spear development and enlargement, and spikelet initiation) demonstrated the strongest association with bunch yields as measured by NB and FFB. Increased total SH at this time favoured production of male flowers. It can be deduced from these studies that although sex differentiation occurred earlier than 18-24 months before harvest, unfavourable conditions during this period can lead to sex reversal from femaleness to maleness. Hartley (1977) suggested that the cause of such a transition may be genetic, physiological or a combination of both and would depend on environmental, nutritional and hormonal factors. A low relative humidity 18-24 months before harvest was favourable to NB and FFB production. Thus, cool nights and wet conditions two years before harvest favoured (development of sexually differentiating tissues, thereby dominating sex determination), spear development and enlargement and spikelet initiation.

The use of correlations, stepwise multiple regression and path coefficient analysis has helped to critically examine the associations of NB, FFB and MBW with each climatic factor covering a lag from 30 months preceding the year of harvest to the year of harvest. In a study on yield variation from year to year, Jackson (1967) concluded that yield variation is largely determined by some stages of growth which are controlled by complex environmental variables and these are related to simple meteorological factors. The significance of the regression was measured by the percentage of yield variation (R^2) accounted for by the meteorological factors and the slope of the regression (b). These parameters were determined in this study using stepwise multiple regression analysis. Path analysis was further used to separate cause and effect relationships. It was shown that each stage of growth was affected by one climatic factor or the other. Also, the traits identified in the stepwise multiple regression in most cases had high direct effects on the yield traits, i.e. NB, MBW and FFB. However, path analysis helped to determine the most important critical factors affecting yield and also determines the factors which effects are exerted through other climatic factors.

Obisesan (1981) suggested that tree crops experience a residual effect of climatic factors from a year into future years. Our study provides some empirical results to substantiate these hypotheses. The cumulative effects of climatic factors in pre-harvest and harvest years affected yield traits in this study. Reductions in yield during these periods suggest that a critical level for each climatic factor is either being exceeded or not attained and this may be one of the reasons for 'bunch failure' occurring one to three months before harvest,

We conclude from these studies that minimum relative humidity and sunshine hours 18-24 months prior to the year of harvest could serve as indicators to the yield pattern and that the use of path coefficient analysis along with correlations and regression analyses would give a better understanding of the relationship between yield and weather factors in oil palm plantation.

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