THE EFFECTS OF SEASON, RAINFALL AND CYCLE ON OIL PALM YIELD IN MALAYSIA

Keywords : Season; Rainfall; Cycle; Palm yeild

CHOW CHEE SING*

Date of Submission : 6 August 1991

* Palm Oil Research Institute of Malaysia (PORIM)

A statistical model incorporating simultaneously the long-term trend, season, rainfall and lagged yield, appears to give a reasonable explanation of the variations in average oil palm yield as expressed by crude palm oil (CPO) production in Peninsular and in East Malaysia.

Variations in CPO production are noted of 53%-57% due to season, being independent of long-term trend, of 12%-24% due to rainfall and of 10%-20% due to lagged yield effects. The seasonality in oil palm yield, being highly significant at the national level, could be quite independent of rainfall though rainfall has apparently interacted with and modified the seasonality pattern to some extent.

Substantial positive correlations of yield with rainfall at lags of 20-24 and 10-11 months (before harvest) clearly relate to the crucial periods of sex differentiation and inflorescence abortion respectively, the effects of which appear to be quite different as between Peninsular and East Malaysia.

The number of negative correlations between palm yield and rainfall may be of interest. A negative correlation at a lag of six months is indicative of some adverse effects of excessive rainfall on anthesis and pollination; those at lags of 30-36 months are probably related to inflorescence initiation. Negative effects of rainfall are also observed at lags of 0-2 months, indicative of the period of oil synthesis. Some significant negative correlations, particularly at a lag of 13 months, and a possible positive correlation *at 17 months, have yet to be explained biologically.*

A marked positive yield effect at a lag of 16 months and a moderate correlation at 21 months seem to suggest major yield cycles with such periods.

INTRODUCTION

The seasonality of palm oil production in Peninsular Malaysia was noted earlier and its effects (accounting for fluctuations in production) were preliminarily estimated (Chow, 1980). The effects of rainfall on palm oil production in Peninsular Malaysia in addition to seasonality were also reported, and the objectives of such a study were stated (Chow, 1987). To recapitulate, it was an attempt to establish a method for month-to-month forecast of Malaysian palm oil production at one to two years ahead, based on four major factors, *viz.* trend, season, climate (so far only rainfall) and yield cycles. Instead of dealing with the method and problems of prediction, this paper attempts to present more details regarding effects of the major factors in Peninsular Malaysia, based on more recent data. Results for East Malaysia are included for comparison.

DATA

Monthly data for total production of crude palm oil (CPO) in the two regions of Malaysia, Peninsular (West) and Sabah and Sarawak (East) were available from the Statistics Department of Malaysia (SDM) from 1968 and 1975 respectively (*Figure 1*).

Monthly rainfall records from 1966 over a total of 200-240 stations (in 1986-1990) from the Malaysian Meteorological Service (MMS) were also employed. In addition, rainfall data published by the Drainage and Irrigation Department and rainfall records from a number of individual estates were used as supplementary sources for the period 1966-70. Mean rainfall (over stations) for each state (excluding Kelantan and Trengganu) was weighted by the area planted with oil palm in the state (from records of the SDM) to arrive at the average rainfall for the two regions (*Figures 2a* and *b*).

METHODS

(A) The model, factors and variables

A basically regression technique was applied to (an extension of) the classical multiplicative model of time series analysis, *viz.*:

Observed production
= Trend x Season x Rainfall x Cycle x Error

or symbolically:

$$Y = T \times S \times R \times C \times E \quad ....(1)$$

where each factor or variable is explained as follows:

(1) Observed production (Y) — the monthly total CPO production in a region (in '000 tonnes), being used as the dependent variable (*Figure 1* for Peninsular Malaysia).

(2) Trend (T) — the shifting of the level of production mainly because of changes (increase) in the area planted with oil palm and the age structure (or distribution) of the mature area. Results from the long-term forecast for Malaysian CPO production (Chow, 1986) were converted to a monthly basis (*Figure 1*).

(3) Season (S) — the seasonal variation is defined in general as the periodic oscillation with a one-year cycle. The monthly seasonal effects can be effectively represented in the regression model by including 12 dummy (binary) variables (or 11 independent variables).

(4) Rainfall (R) — since the initiation of the oil palm inflorescence occurs about three years before harvest (Corley, 1976), lagged average rainfall variables from 0 to 36 months were used. Only variables explaining a substantial amount of variations in the dependent variable were included in the regression.

An alternative to direct rainfall is the use of soil moisture as converted from rainfall. Soil moisture at month t, M(t), may be estimated from average monthly rainfall R(t) by means of a formula originally meant for daily soil moisture based on daily rainfall as follows:

TABLE 1a. SUMMARY OF RAINFALL AND SEASONAL EFFECTS (1968-90)
(t values of regression coefficients)

Lag	Lagged rainfall		Lag	Lagged rainfall		Month	Seasonal variable	
	West Malaysia	East Malaysia		West Malaysia	East Malaysia		West Malaysia	East Malaysia
0	-1.70	-2.17	19	1.93		Jan	-5.05	-1.00
1	-3.57		20	3.31	1.92	Feb	-8.52	-5.92
2	-1.23	-1.11	21	4.43	1.54	Mar	-3.19	-3.95
3			22	1.46	1.01	Apr	-1.24	-1.77
4			23	3.27		May	.62	.80
5			24	2.79		Jun	-2.66	.48
6	-1.81	-2.45	25	2.08	1.55	Jul	-1.26	.80
7	1.74		26	3.25		Aug	.41	-.13
8	2.62		27	1.65		Sep	5.50	1.77
9	1.94	1.26	28	2.36		Oct	8.03	3.44
10	4.92	2.53	29	1.40		Nov	5.61	2.80
11	4.07	2.58	30	-1.07		Dec	—	—
12			31		1.20			
13	-3.68	-1.34	32					
14	-1.68	-1.44	33	-1.58				
15			34	-3.58				
16		-1.28	35		-1.47			
17			36	-2.91				
18								

TABLE 1b. 12-MONTH SEASONAL INDEX OF PALM OIL PRODUCTION

Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Peninsular Malaysia													
Unad-justed	0.79	0.78	0.93	0.94	0.95	0.92	1.08	1.16	1.26	1.21	1.09	0.90	12.00
Adjusted	0.84	0.76	0.90	0.95	1.01	0.91	0.95	1.00	1.19	1.29	1.19	1.00	12.00
East Malaysia													
Unad-justed	0.83	0.68	0.78	0.90	1.03	1.04	1.09	1.10	1.20	1.23	1.09	1.02	12.00
Adjusted	0.95	0.75	0.84	0.91	1.03	1.01	1.03	0.99	1.07	1.16	1.13	1.13	12.00

TABLE 1c. MEAN RAINFALL (MR) (in mm) AND RAINFALL INDEX (RI)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean/ Total
Peninsular Malaysia (1966-89)													
MR	149	128	169	209	189	139	144	153	204	240	264	247	186
RI	0.80	0.69	0.91	1.12	1.01	0.75	0.77	0.82	1.10	1.29	1.42	1.33	12.00
East Malaysia (1972-89)													
MR	278	200	149	171	198	211	214	209	254	248	286	297	226
RI	1.23	0.88	0.66	0.76	0.88	0.93	0.95	0.92	1.12	1.10	1.26	1.31	12.00

TABLE 2. REDUCTION IN VARIATION (sum of squares) BY DIFFERENT FACTORS

	West Malaysia		East Malaysia		West Malaysia	East Malaysia
	d.f.	s.s	d.f.	s.s	as % of (R)	
Total observed production	263	196.861	191	77.622		
(1) Due to trend variable	1	186.413	1	67.084		
Residual after fitting trend (R)	262	10.448	190	10.537	100.0	100.0
(2) Due to weevil variable	1	0.165	1	0.106	1.6	1.1
(3) Due to seasonal variables	11	5.909	11	5.611	56.6	53.3
(4) Due to rainfall variables	27	2.476	13	1.235	23.7	11.7
(5) Due to lagged yield variables	+15	1.059	16	2.019	10.0	20.2
Total					91.9	86.3
Residual	208	0.848	149	1.461	8.1	13.7

+ adjusted for three lagged years

TABLE 3a. SUMMARY OF RAINFALL AND LAGGED YIELD VARIABLES FOR PENINSULAR (WEST) AND EAST MALAYSIA
(t values of regression coefficients)

Months Lagged	Lagged rainfall		Lagged yield		Months Lagged	Lagged rainfall		Lagged yield	
	West Malaysia	East Malaysia	West Malaysia	East Malaysia		West Malaysia	East Malaysia	West Malaysia	East Malaysia
0	-2.50				19		-2.22	-1.96	-2.28
1	-1.39	-1.27	12.94	6.83	20	2.28			
2	-1.47			1.92	21			2.17	2.63
3				2.92	22		3.12	-2.19	
4	1.35		-1.09	-1.37	23	3.28		2.53	
5		1.66			24	2.38		-1.10	-1.80
6	-1.69	-2.88		-2.85	25		-2.18	1.90	
7	3.35				26			-1.76	
8	2.28				27			-1.14	
9		1.54		2.36	28	1.45			
10	5.40	3.10			29	1.98	2.54		1.19
11	2.00		4.31	-1.89	30	-1.79			
12	-2.64	-1.49		-1.72	31		1.09		
13	-3.99	-3.78	-2.51		32	-3.26	-1.88		
14					33	-1.68			
15	1.20				34	-3.17		-2.21	-1.51
16			4.09	3.90	35			3.74	
17	3.21	2.22			36	-2.18		-2.22	
18	-1.15		-1.66	-1.93					

TABLE 3b. SUMMARY OF SEASONAL VARIABLES (as seasonal index SI), ADJUSTED FOR RAINFALL AND CYCLE EFFECTS
(with t values of regression coefficients)

	West Malaysia		East Malaysia	
Month	SI	t	SI	t
Jan	0.83	-6.51	0.97	-0.54
Feb	0.72	-11.42	0.78	-6.80
Mar	0.83	-7.16	0.74	-8.38
Apr	0.90	-3.72	0.80	-5.02
May	0.98	-0.25	0.92	-1.79
Jun	0.98	-0.50	1.02	1.00
Jul	1.06	2.54	1.10	3.33
Aug	1.09	3.76	1.11	2.84
Sep	1.22	9.05	1.16	4.03
Oct	1.24	7.98	1.16	4.80
Nov	1.16	5.97	1.10	2.97
Dec	0.98	—	1.15	—

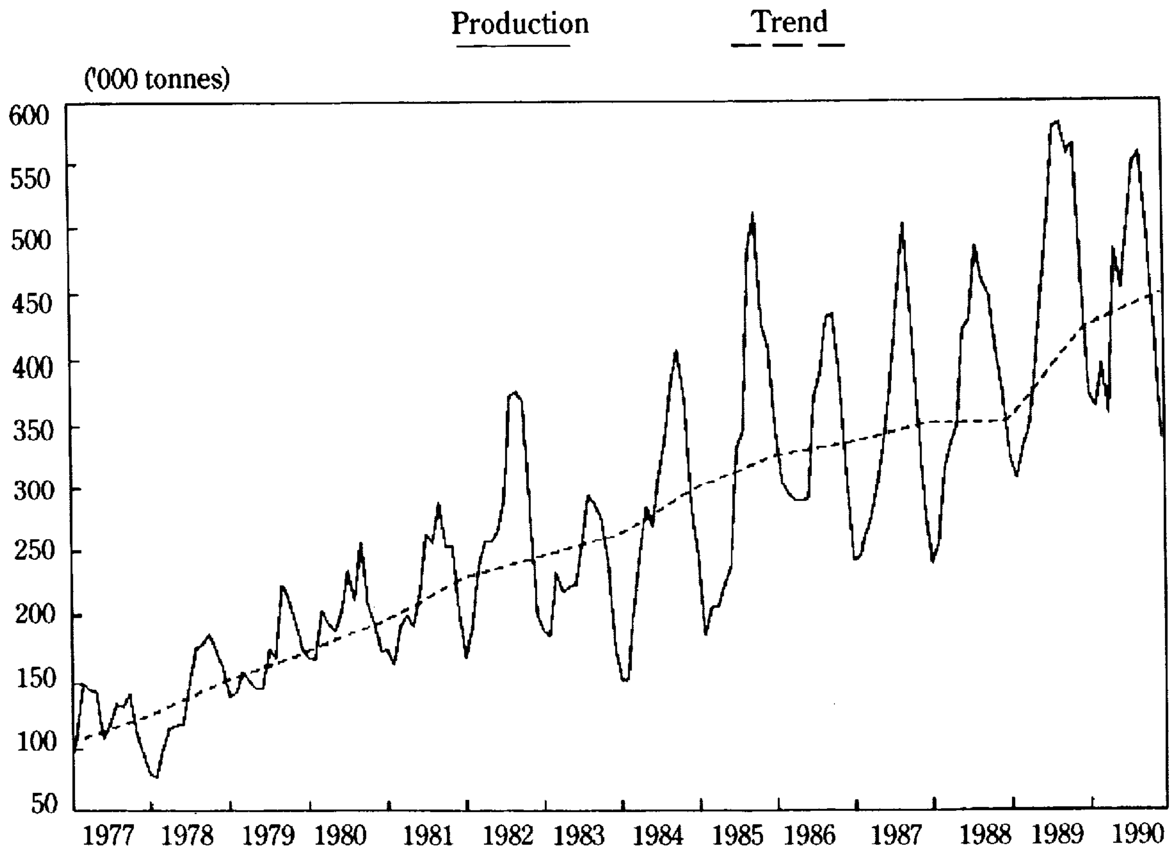

Figure 1. Total Monthly Palm Oil Production in Peninsular Malaysia 1977-1990

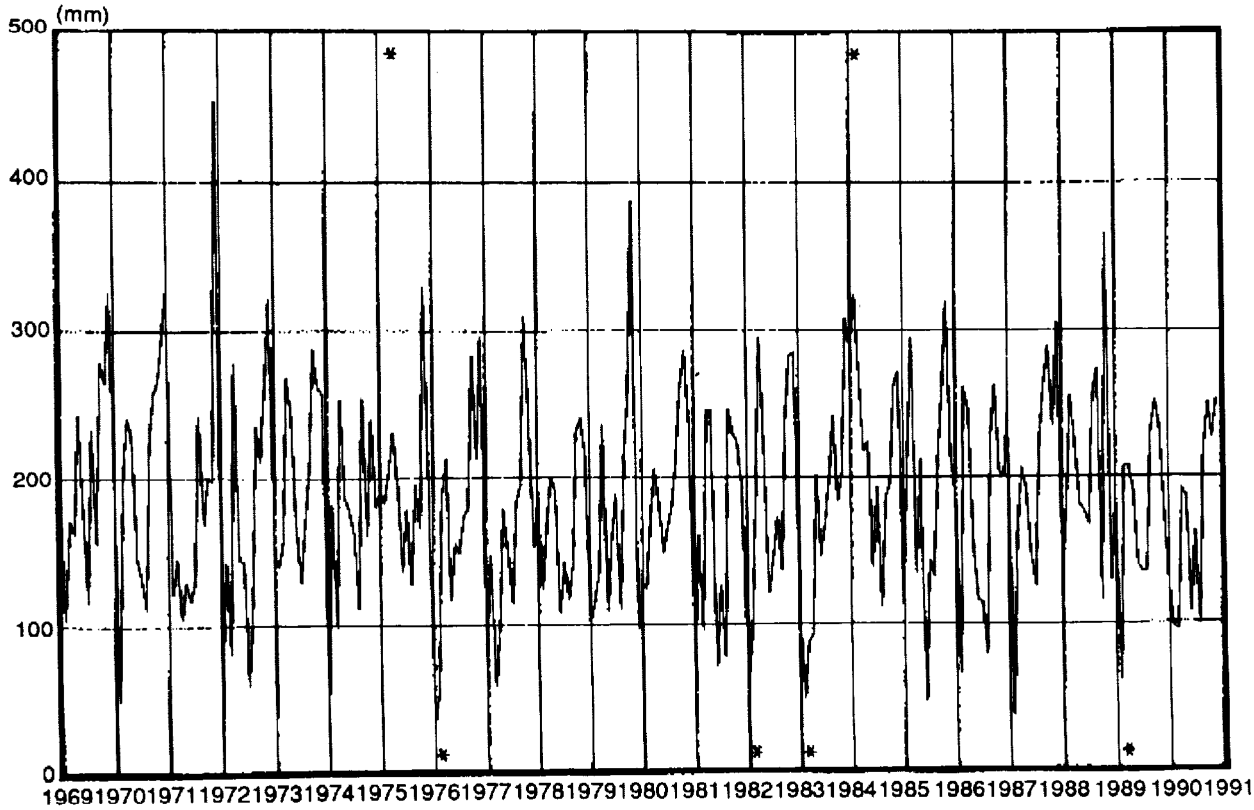

Figure 2a. Weighted Average of Monthly Rainfall in Peninsular Malaysia

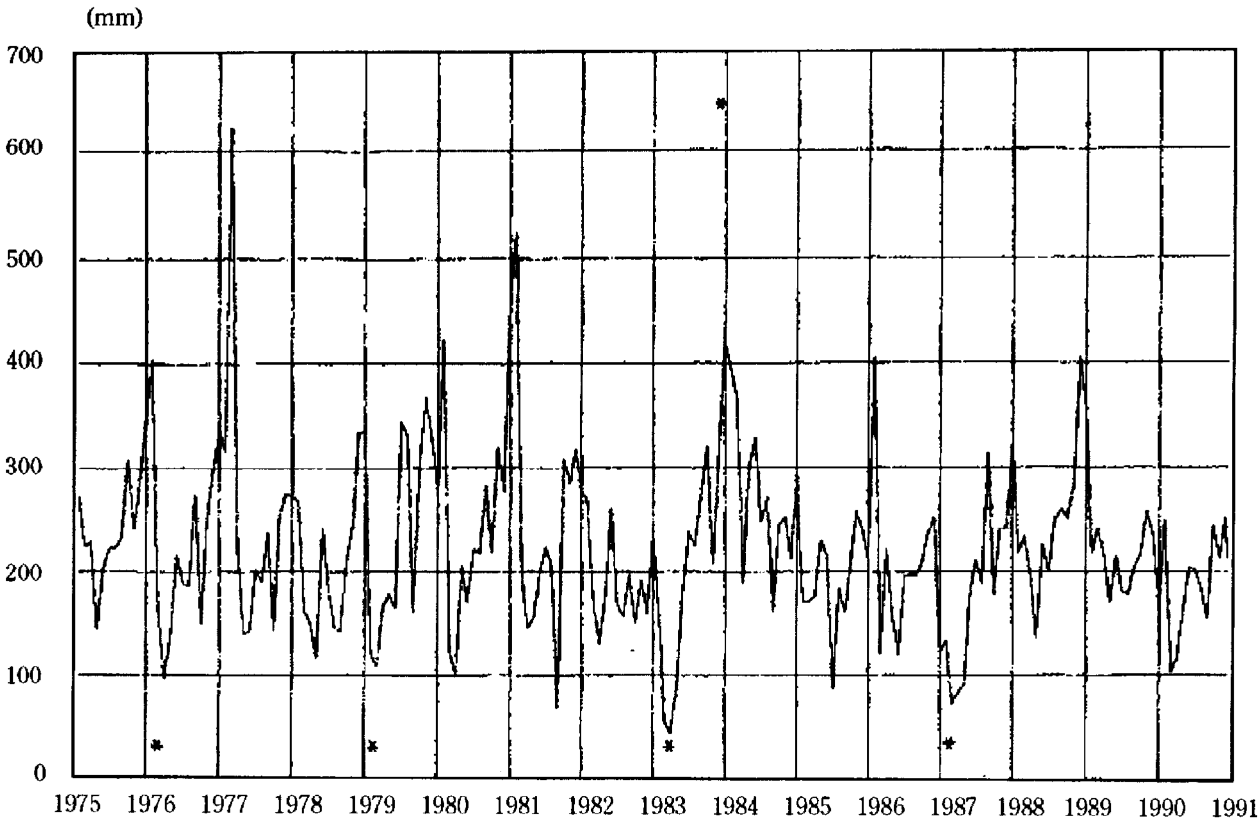

Figure 2b. Weighted Average of Monthly Rainfall in East Malaysia

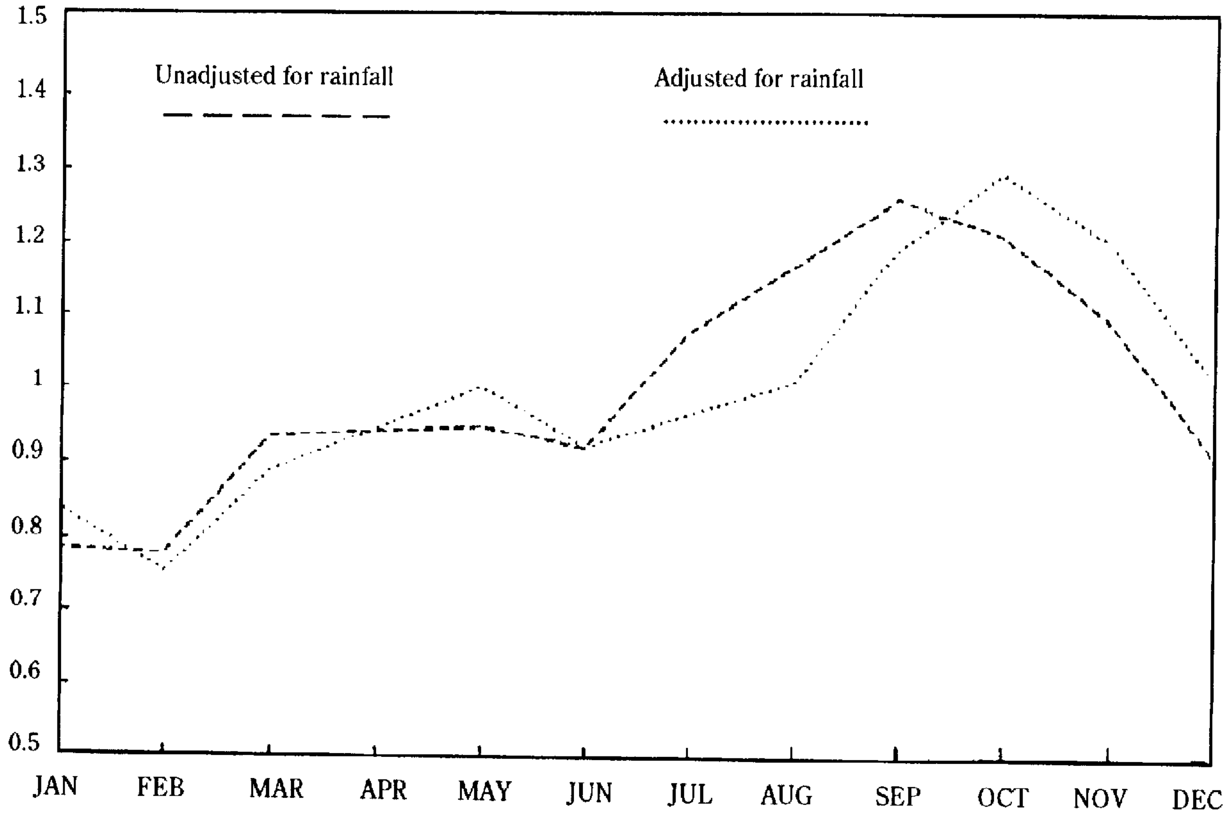

Figure 3a. Seasonal Index of CPO Production, Peninsular Malaysia

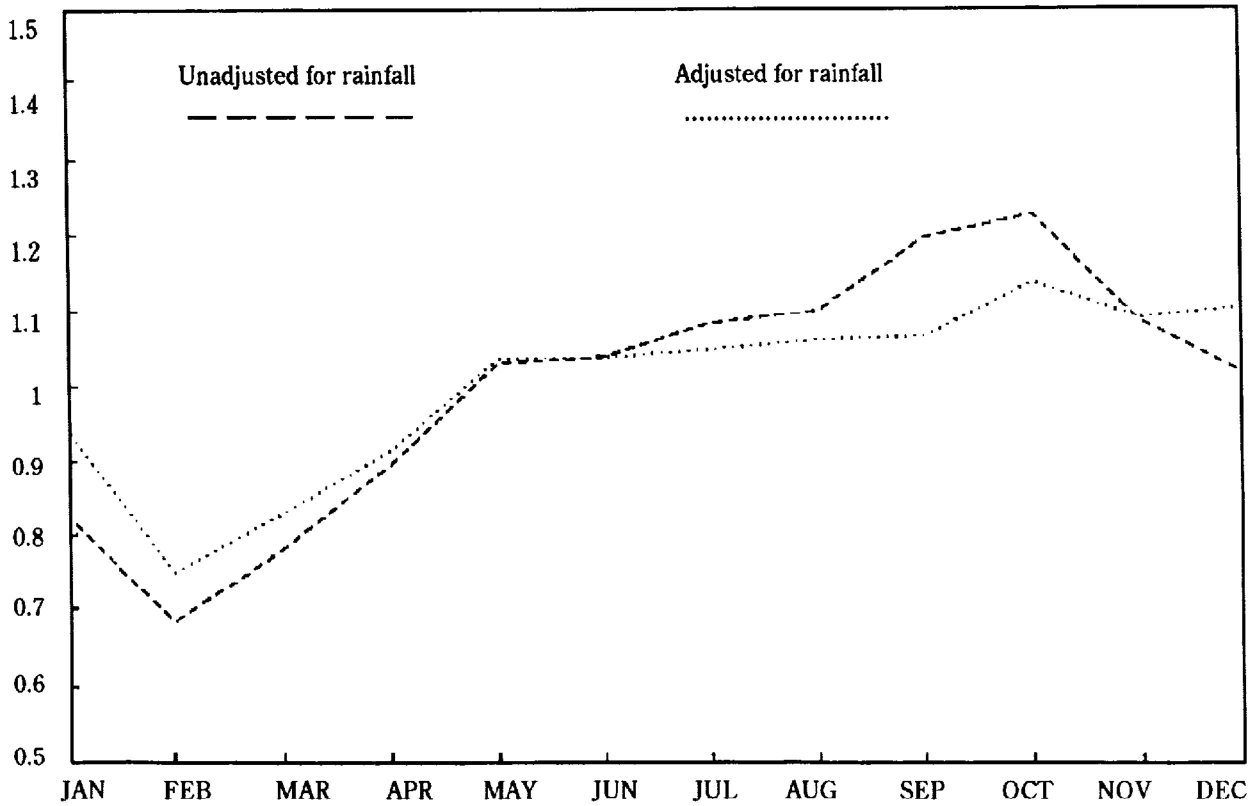

Figure 3b. Seasonal Index of CPO Production, East Malaysia

$$M(t) = M(t\text{-}1) + R(t) - EV(t) \quad \text{for } M(t) < SWHC \text{ or}$$
$$= SWHC \quad \text{if } M(t) > SWHC \quad \text{..........(2)}$$

where EV(t) denotes evapotranspiration and SWHC average soil water holding capacity. The monthly evapotranspiration EV was obtained by averaging observations given by Scarf (1976) for the stations all over the Peninsular (except those above a certain altitude).

(5) Cycle (C) — this may be more appropriately termed 'lagged yield' effect, since empirically it is the effect of high yield at one period causing low yield at another and vice versa. But statistically it also includes (positive) correlations between yield in successive time intervals (months). Biologically the lagged yield effect is referred to the innate cycles of the palm yield, resulting from interaction between the endogenous cycle of palm flowering and the environmental cycle (Haines, 1959). The variables used are the lagged dependent (production) variable with trend and season removed; lags of 1-36 months were used.

(6) Error (E) — the error term, and in fact all other variables besides the trend that appear in the present multiplicative model imply proportionality of these effects to trend over time, as seen in *Figure 1.*

In addition, the abrupt increase in production in 1982 (from about April to October), due to the initial effect of the weevil (*E. kamerunicus*) as pollinator, is explained by a (dummy) variable.

A stepwise regression was adopted for selecting variables into the regression from a total of 86 variables (1 for trend, 11 for the season, 37 for rainfall, 36 for lagged yield and 1 for the weevil). The criterion for variable inclusion into or exclusion from the equation was whether the t value of the regression coefficient was at least or less than 1.

RESULTS

Before the full model was fitted, it was intended to see how rainfall alone could have affected seasonality of palm yield. This was done by selecting only the (37) rainfall variables into the equation, after the (11) seasonal variables (together necessarily with trend and weevil variable) being forced (*i.e.* without selection) into the equation. The results summarized in *Tables 1a* and *1b* were obtained.

The seasonal effects in terms of index numbers unadjusted for rainfall (*Table 1b*) represent average monthly variations over 22 years (1968-90) for Peninsular Malaysia and 15 years (1975-90) for East Malaysia. The results show that CPO production in the Peninsular is, under normal conditions, about 21%-26% above average during September and October but only 78% of the average in February. In East Malaysia the peak is 20%-23% above average in September-October and only 68% of the average in February. A second significant 'trough' in June with about 92% of the average is usually observed in the Peninsular but is less obvious in East Malaysia. It is remarkable that despite the large variations in climatic and other conditions, including differences among soil types, age distribution of the palms, planting materials and management, the seasonal factor is nevertheless highly significant at the national level.

By the partial model with lagged yield variables excluded (*Table 1a*), some similarities in the effects of rainfall as between Peninsular and East Malaysia may be noted, *e.g.* the correlations at lags of 9-11 months (before harvest) and the negative effects at 6 and 13-14 months. Substantial positive correlations may be noted in the Peninsular at lags of 20-28 months, and negative correlations between 33 and 36 months. These will be discussed further under the full model below.

Table 1a also shows that the seasonal variables remain significant when adjusted for rainfall, although modified to some extent, as compared with those estimated without including rainfall (unadjusted). For comparison, the seasonal variables before removing (or unadjusted for) rainfall effects and those after removing (or adjusted for) rainfall effects are given in terms of seasonal index (SI) in *Table 1b* and shown in *Figures 3a* and *3b*. The monthly averages of rainfall (and indices) are given in *Table 1c*.

It can be seen in *Table 1b* and *Figure 3a* that the difference between peak and trough is slightly greater in the adjusted SI than in the unadjusted SI, in the case of the Peninsular. In fact rainfall adjustment lowered the February index from 0.78 to 0.76 and shifted the peak of 1.26 in September to 1.29 in October. However, in East Malaysia where the peak remained unshifted in October, the difference between peak and trough was less in the adjusted SI than in the unadjusted (*Figure 3b*). This may also imply that the more moderate rainfall in the Peninsular tends to reduce seasonal fluctuations, whereas the more drastic rainfall in the East (*Table 1c*) increases these variations.

Table 2 shows the reduction in variations in terms of sum of squares (SS) in the observed production by fitting variables of each factor.

The major reduction in SS (for both East and West Malaysia) by removing the trend was rather expected in view of the rapid increase in planted area. However, the explanation of 56.6% (and 53.3%) due to average seasonal effects, 24% (and 12%) due to rainfall, and 10% (and 20%) due to lagged yield (cycle) effects may be noteworthy. Apart from trend variations, the three main factors (plus the weevil variable) are able to account for about 87%-92% of the fluctuations in production.

The effects of the rainfall and lagged yield obtained by fitting the full model are summarized in *Table 3a*. Compared with *Table 1a*, substantial positive correlations in the Peninsular remain in *Table 3a* at lags of 7-8 months (before harvest), 10-11, 19-20, 23-24 and 28-29 months, and in addition at 17 months. It is interesting to note the equally numerous negative correlations of rainfall with production in the Peninsular (*Table 3a*). As in *Table 1a*, negative correlations remain at lags of 0-2 months, and at 6, 13, 30, 33-34 and 36 months. Other lagged months may be noted. *Table 3a* also shows some similarities and differences in the rainfall effects between West and East Malaysia, for example substantial positive correlations for both regions at lags of 10, 17 and 29 months, but more negative correlations at 1 month and at 6, 12, 13 and 32 months.

Sex differentiation generally occurs 16-24 months before anthesis (m.b.a.) or 21-30 months

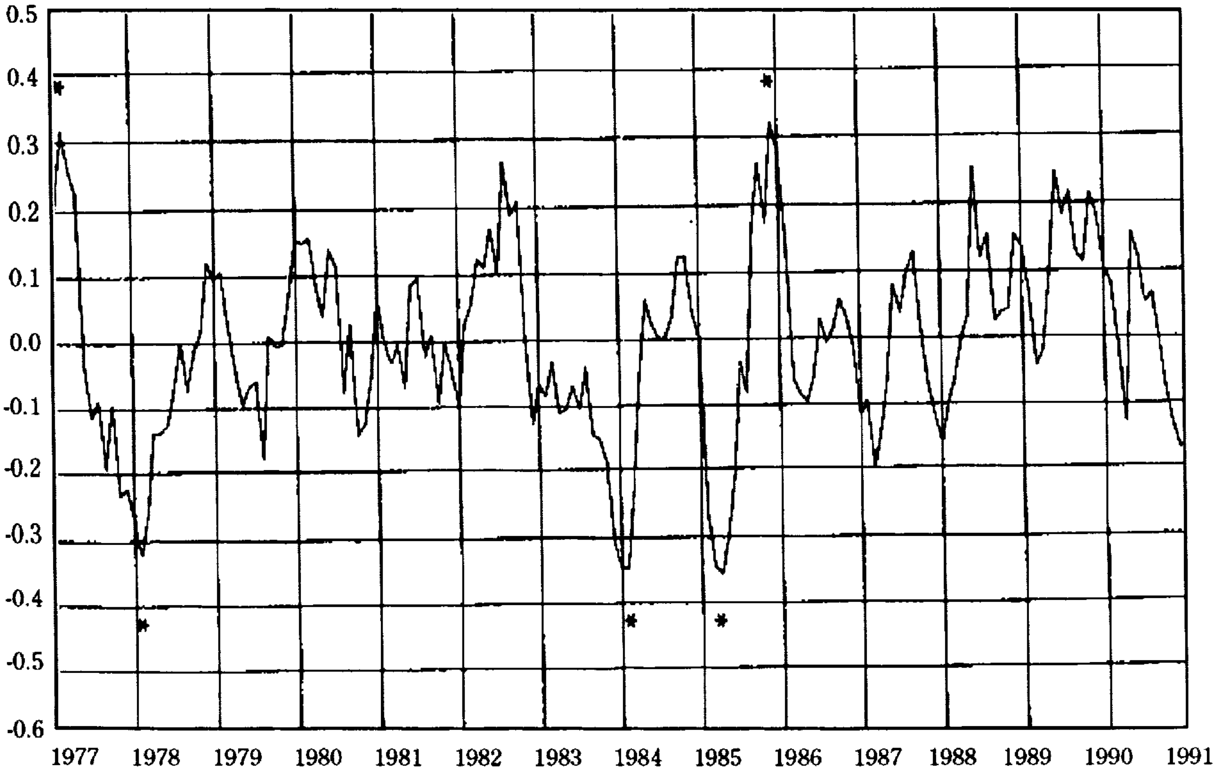

Figure 4a. Deviations of Production from Trend And Seosonal Variations, Peninsular Malaysia

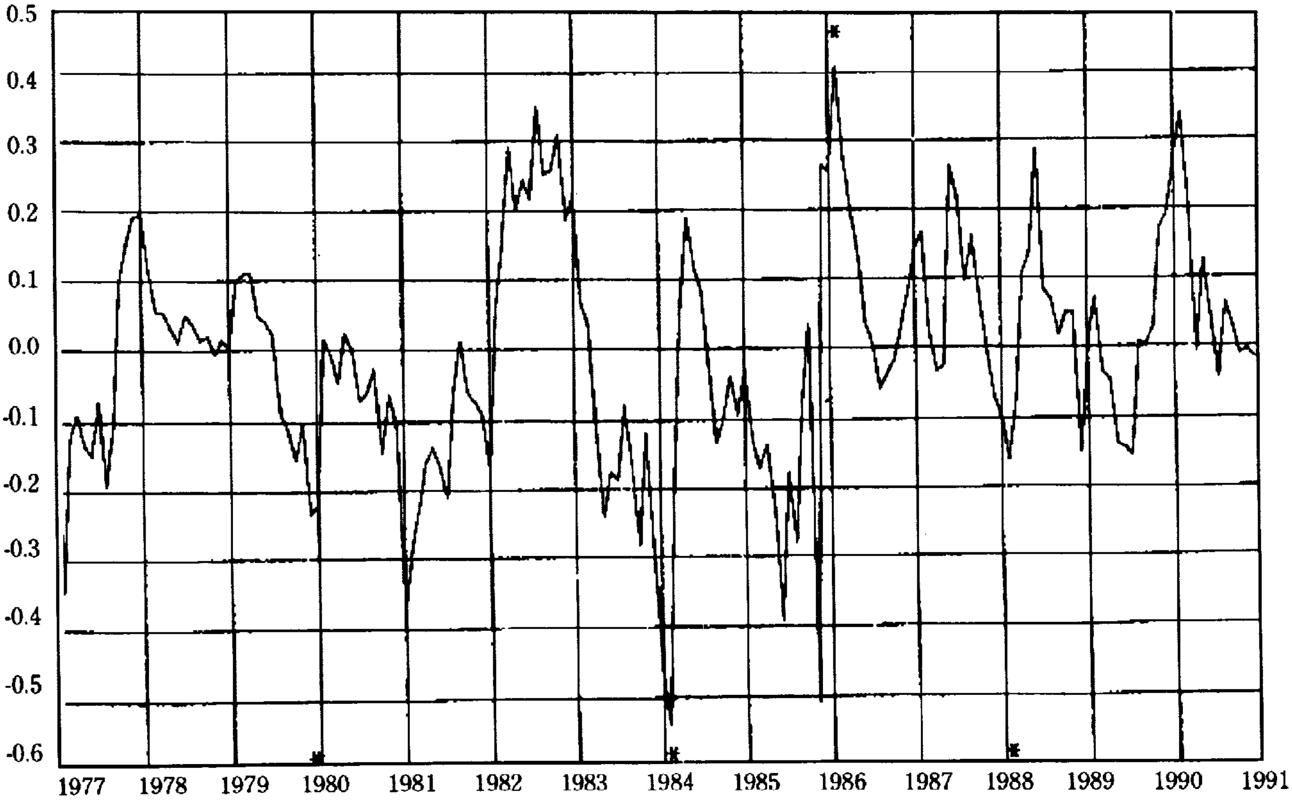

Figure 4b. Deviations of Production from Trend and Seasonal Variations, East Malaysia

before harvest (m.b.h.) (Corley, 1976a). The positive correlations with rainfall at lags of 20-24 months, particularly at 23 months for Peninsularr Malaysia and at 22 months for East Malaysia (*Table 3a*) apparently correspond to this very important period.

The positive correlations at lags of 7-11 months, particularly at 10 months, very likely indicate inflorescence abortion, which normally occurs 4-5.5 m.b.a. or 9-11.5 m.b.h. (Broekmans, 1957; Corley, 1976a).

By removing trend and seasonal variations in the production series, the deviations (*Figures 4a* and *4b*), which indicate mainly effects of rainfall and cycle may be matched with the average rainfall (*Figures 2a* and *2b*) at certain troughs and peak corresponding to dry spells and wet periods respectively. The more conspicuous matches may be observed between the 1976 drought (*Figure 2a*) and the 1978 production trough (*Figure 4a*) (both marked *) and likewise between 1982 and 1984, 1983 and 1985, and 1989 and 1991, being all at lags of about 24 months. The year-end high peaks in 1977 and 1985 are suspected to be due to the unusually wet months at the beginning (about January to March) of 1975 and of 1984, with rainfall effects at a lag of about 18 months.

Results for East Malaysia appear to differ slightly. For example, the production troughs in 1977, 1980, 1981, 1984 and 1988 (*Figure 4b*) seem to match with dry spells in 1976, 1979, 1980, 1983 and 1987 (*Figure 2b*) respectively, being all at lags of 12 months or less, and unlike cases in the Peninsular, are more likely related to the effects of inflorescence abortion. Despite the rain effects in many other lags (and certainly some degree of interaction with season and cycle), the sex differentiation and inflorescence abortion periods appear to be crucial in relation to rainfall.

The relatively moderate negative correlation at a lag of six months (apparently reducing in recent years, particularly in the Peninsular) may indicate some effects of (excessive) rainfall on anthesis and pollination. But the need for sufficient rainfall in the following months (7-8) is also indicated. The negative effects of rainfall observed at lags of 0-2 months in the Peninsular are probably related to the maximum rate of increase in bunch dry matter during the period of oil synthesis 4-6 months after anthesis (Corley, 1976). The negative correlations could possibly be explained by the negative correlation between rainfall and sunshine. The negative correlations at lags of 30-36 months (which are less evident for East Malaysia) are probably related to the period of inflorescence initiation, as Corley (1976) observed that oil palm leaf initiation occurs at about 32 m.b.a. or 37-38 m.b.h. and inflorescence initiation probably two months later (35-36 m.b.h., or within the range from 30 to 43 m.b.h.). The negative correlations, consistent in both East and West Malaysia, at lags of 12 and 13 months, and the positive correlations at 17 months, have yet to be explained biologically.

Lagged yield effects in the Peninsular are observed at lags of 1, 11, 13, 16, 18-19, 21-23, 25-26 and 34-36 months. Rather different results were obtained in East Malaysia with only the lags of 1, 16, 18-19, 21 and 34 months in common with the Peninsular. Of particular interest are the positive correlations, marked at a lag of 16 months and moderate at 21 months, for both regions. These seem to suggest major yield cycles of 16 and 21 months. In practice, the cycle effects are rarely clear-cut as the cycles have more than one component which could also interact with the season and climate to some extent.

The seasonal variables remained highly significant in the full model regression. A summary of the seasonal effects after removing rainfall and cycle effects (in terms of SI) is given in *Table 3b*. It is noted that the troughs and peaks in the seasonal index adjusted for rainfall and cycle are of comparable magnitude to those given in *Table 1b*.

The traditional view attributes the 12-month periodical movement mainly to climatic factors, particularly rainfall. Theoretically, should seasonality be determined mainly by rainfall, it would be expected to reduce to statistical insignificance when rainfall variables are also present in the same regression. The results indicate that the seasonality of oil palm yield could be quite independent of rainfall (*Table 1a*) but the influence of rainfall on oil palm yield is certainly substantial. Foster (1985) suggested that seasonal yield variation is largely due to the operation of two cycles, an annual abortion cycle and an annual sex cycle maintained by seasonal variation in the weather two years earlier. Besides weather, Foster suggested also that the lagged yield effects were the main cause for seasonal yield variations. But by a similar argument to that above, the results in *Table 3b* suggest that the seasonality of palm yield should also be quite independent of lagged yield.

CONCLUSION

By using data on monthly CPO production and rainfall, and incorporating an available trend together with two other factors, *viz.* the season and lagged yield, a regression model with a stepwise variable selection procedure appears to give a reasonable explanation for the variations in oil palm yield in Peninsular and East Malaysia.

Results regarding production or yield variations in relation to season, rainfall and cycle may be of some biological and economic interest. It is hoped that some of the observations will throw light on, or raise questions about certain aspects that are probably as yet less understood. It may be remarked that apart from its original objective in establishing a basis for prediction, an analysis by the present approach may be useful in supplementing studies on physiological and agronomic aspects of oil palm, probably more at the macro level.

ACKNOWLEDGEMENT

The author wishes to thank the Director-General of PORIM, Dr Yusof Basiron for his permission to publish this paper which has been adapted from one originally presented to the Second National Seminar on Agrometeorology, 1991. He also thanks Pn. Jamaliah bt. Mohamed for her assistance in preparing the paper.

REFERENCES

BROEKMANS, A F M (1957). Growth, flowering and yield of the oil palm in Nigeria. *J. W. Afr. Inst. Oil Palm Res., 2.* pp. 187-220.

CHOW, C S (1980). A note on the seasonal and related variabilities of the palm oil production in West Malaysia. *PORIM Bulletin No. 1.*

CHOW, C S (1986). Forecast of Malaysian palm oil production up to year 2000, (revised) (PORIM) Report, unpublished).

CHOW, C S (1987). The seasonal and rainfall effects on palm oil production in Peninsular Malaysia. *Proceedings of the 1987 International Oil Palm Conference,* Kuala Lumpur, pp. 46-52.

CORLEY, R H V (1976). Oil palm yield components and yield cycles. *Proceedings of Malaysian International Agricultural Oil Palm Conference, 1976,* pp. 116-129.

CORLEY, R H V (1976a). Inflorescence abortion and sex differentiation. Oil palm research (eds. R. H. V. Corley, J. J. Hardon and B. J. Wood), pp. 37-54. Amsterdam: Elsevier.

FOSTER, H L (1985). Seasonal variation in oil palm yield. *Malaysian Oil Palm Growers' Council Briefing Paper No. 4.*

HAINES, W B (1959). The significance of cycle peak yield in Nigerian oil palm. *Empire J. Exp. Agric.,* 27, pp. 1-9.

SCARF, F (1976). Evaporation in Peninsular Malaysia. *Water Resources Pub. No. 5,* 1976, Drainage and Irrigation Department, Ministry of Agriculture, Malaysia.