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ANALYSIS OF OIL PALM PRODUCTIVITY. I. THE ESTIMATION OF SEASONAL TRENDS IN BUNCH DRY MATTER PRODUCTION

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When assessing oil palm productivity over periods of less than a year, the direct use of bunch harvest data, normally available as monthly totals of FFB yield, is inadequate as much of the dry matter in a bunch may be formed prior to the month of harvest. Also, as is widely recognized, the higher energy content of bunches compared with vegetative tissue needs to be allowed for. To take account of these factors, a simple model was constructed based on monthly FFB yields, final bunch composition, growth curves of bunch components and component energy contents, to allow the bunch 'non-oil equivalent' dry matter production (BDMP) achieved each month to be calculated.*

The model was applied to data from two sites over several seasons. BDMP estimates from the model showed similar, but displaced, cyclic patterns to FFB, and gave smoother curves with lower CVs. Although based on a fixed bunch growth rate throughout the year, the results proved insensitive to growth duration and were similar for growth periods ranging from 130 to 190 days.*

INTRODUCTION

Bunch production is the most important component of oil palm dry matter production (DMP) with the annual bunch index (bunch/total above-ground DMP) of the most productive sites ranging from 0.4 to 0.6 (Corley *et al.*, 1971; Corley and Breure, 1981) and being as high as 0.73 as a function of total energy content (Corley, 1983). In most oil palm trials, productivity is assessed from the yield of fresh

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fruit bunches (FFB) converted to dry weight assuming a dry matter content of around 53 per cent and, if desired, then allowing for the higher energy content of the mesocarp oil in the bunch (*e.g* Squire, 1985). This approach is satisfactory only if yearly or longer periods of assessment are involved. There is, however, increasing interest in examining and explaining within-year variations in productivity which may be quite large, even in the relatively uniformly wet climates of Southeast Asia. These are usually evident as annual peaks and troughs of FFB production and serve to complicate both estate and milling operations.

For short-term (*e.g.* monthly) assessments of the dry matter or energy incorporated into bunches, the current FFB yield serves only as an approximation. This is because only part of the dry matter energy equivalent of individual bunches harvested in a particular month will have been produced during that month. Also, the FFB yield in a particular month will be influenced by the timing of harvesting rounds. While the latter problem can be overcome by careful control of harvesting and/or use of running means, a more 'mechanistic' approach is required to overcome the former limitation.

This paper describes the development of a simple model which permits calculation of monthly bunch non-oil equivalent dry matter production (BDMP*) from monthly FFB yield after taking account of:

i) bunch composition (bunch component ratios, bunch percentage dry weight)
ii) energy content of bunch components
iii) bunch component growth curves

The model was then used to plot the seasonal changes in BDMP* for a coastal and an inland site.

METHODS

Sites

Data used were from two sites, both in West Malaysia, which were selected to represent the two main oil palm 'environments' found in the central west coastal area. Both sites were subject to normal commercial management by large plantation agencies.

The 'coastal' site was near Banting, Selangor on a flat, fertile, alluvial soil (Selangor/Carey series). The 94 hectare field was planted in late 1983 with 136 palms/hectare. (For further details see Henson, 1991 and 1993). Annual rainfall in 1992-5 varied from 1700mm to 2228 mm, while monthly rainfall varied from as little as 42mm up to 446 mm. However, due to the presence of a permanent water table and regulation of water level by a system of field drains, no serious soil water deficit at the site was experienced.

The 'inland' site near Nilai, Negeri Sembilan was on slightly undulating terrain with a free draining Rengam series soil. The field of 102 hectare was planted in 1985 with 148 palms/hectare. Annual rainfalls in 1994 and 1995 were 2486 and 2571mm respectively but monthly variations were large (from 9 mm to 443 mm) and sufficient to result in occasional periods of water deficit. The lower fertility of the site, as indicated by its lower soil organic matter content (data not presented), may also have contributed to its lower yields compared with those of the coastal site.

Bunch composition

At the coastal site, five randomly sampled mature bunches were gathered each month from each of five 20 palm sample plots laid out in different sectors of the field (Henson, 1991). Bunches harvested had fewer than 10 detached fruits per bunch and were weighed and dispatched the same day to the laboratory for analysis. Sampling was done for 22 months beginning April 1993, giving a total of 550 bunches.

Bunches were collected from the inland site in a similar way but only three harvests were made monthly, starting February 1995. The data, being based on a mean of only 75 bunches, may therefore be less reliable for this site.

Bunch analysis was performed using standard subsampling techniques based on the method of Blaak *et al.* (1963).

The bunch analysis gave the proportions, on a fresh weight basis, in the harvested bunch of the frame (stalk plus empty spikelets), mesocarp (M), mesocarp (palm) oil (PO), shell

(S) and kernel (K). It also gave the mesocarp water content. The kernel oil content (KO) was not determined and was taken as 0.38 of the fresh and 0.532 of the dry weight of the kernel based on the data of Crombie (1956), Mollegaard (1970), Tan *et al.* (1985) and Tang (1991). From these data, the water and fibre contents of the kernel were deduced. The shell water content assumed was that given for tenera fruits by Mollegaard (1970). Dry matter content of the frame was calculated as a residual after subtracting other components from the total bunch dry matter.

The overall percentage dry weight (%DW) of bunches was calculated from the fruit/bunch (F/B) ratio using the formula of Corley *et al.* (1971) as given by Corley and Breure (1981):

$$\%DW = 0.37 \times F/B(\%) + 29 \qquad (1)$$

This did not take into account possible seasonal changes but was used due to the absence of direct dry weight measurements.

Energy contents of bunch components

Energy contents used to calculate 'non-oil equivalent dry mass' (Squire, 1985) were those given by Corley and Lee (1992) and Wood and Corley (1993) and are shown in *Table 1*. The standard value for 'vegetative' dry matter (VDM) for purposes of comparing with BDM* was taken as 19.3 kJ/g; somewhat higher than the values of 18.8 and 19.0 kJ/g used by Squire (1985) and Corley (1983) respectively, but in line with the value adopted by Wood and Corley (1993) for empty fruit bunches.

TABLE 1. ASSUMED ENERGY CONTENTS OF BUNCH COMPONENTS

Component	Energy content (kJ/g)
Frame, mesocarp fibre, kernel fibre	19.3
Shell	25.0
Kernel oil	38.2
Mesocarp oil	39.0

Bunch component growth curves

For constructing the model it is necessary to know the bunch composition at each stage of bunch growth from anthesis to maturity. The only data this author is aware of are those given in graphical form by Corley (1986) who illustrated changes in dry weight of the frame, kernel, mesocarp plus endocarp and PO from anthesis to harvest over a 160 day period. Using these curves and the measured bunch composition at harvest, the relative proportions of bunch components were calculated at five day intervals from anthesis. Corley's graph does not distinguish between mesocarp non-oil dry matter ('fibre') and endocarp (shell) or between kernel fibre and KO. Temporal changes in these components were calculated on the basis of the final ratios being constant throughout growth of the bunch. This may not strictly hold but the errors are not considered critical given the small proportions of tissues involved.

The BDMP* model

From the dry matter curves and energy contents, non-oil equivalent DM (BDM*) curves were produced for the 160 day growth period. Curves for periods shorter or longer than this were produced by proportionally adjusting the 160 day curves.

The proportion of the total BDM* formed in each 30 day period preceding harvest, working back to anthesis, was then calculated. These fractions were then used to calculate BDMP* in a given month (month n) from FFB harvest data, after converting the latter to dry weights. The equation used was similar in form to that which Corley and Breure (1992) used to calculate 'fruiting activity'; *i.e.*

$$BDMP^* = (a \times Bn)+(b \times Bn+1) + (c \times Bn+2) +\ldots.. (n \times Bn+n) \qquad (2)$$

Here, a..n are the calculated coefficients and Bn the bunch dry weight harvested in month n. The variable number of the bracketed items reflects the application of the formula to growth periods of varying durations.

Approximately 7-8 per cent of BDMP* is already present at anthesis as the frame and inflorescences. For convenience, this was added to BDMP* formed in the earliest post anthesis period. A further approximation in formulating the model was to assume each harvest 'month' to contain 30 days.

RESULTS AND DISCUSSION

Bunch composition

Bunch composition, based on the bunch analyses for each site, is shown in *Tables 2* and *3*. Bunches at the coastal site had a higher PO content but a lower percentage dry weight than those sampled from the inland site, resulting in the former having the higher energy content on a dry weight basis. At both sites, PO plus KO constituted over 61 per cent of the bunch on an energy basis while the dry bunch had from 1.52 to 1.56 times the energy content of VDM.

TABLE 2. BUNCH COMPOSITION: COASTAL SITE

Component	% of		
	Fresh wt	Dry weight	Energy
Frame	38.7	17.4	11.2
Fruit	60.3	82.6	88.8
Mesocarp	49.1	65.8	73.9
Fibre	25.2	19.3	12.3
Oil	23.9	46.5	61.6
Shell	6.2	9.8	8.1
Kernel	5.0	7.0	6.8
Fibre	3.1	3.3	2.1
Oil	1.9	3.7	4.7

Notes:

i) Bunch dry weight = 51.3 % (Equation 1)
ii) Bunch energy content = 30.14 Mj/kg
iii) Bunch 'non-oil' dry matter equivalent (BDM*) = 1.562 x 'vegetative' dry matter (= FFB x 0.8009)
iv) Data based on 550 bunches harvested over 22 months

TABLE 3. BUNCH COMPOSITION: INLAND SITE

Component	% of		
	Fresh wt	Dry weight	Energy
Frame	31.8	17.7	11.6
Fruit	68.2	82.3	88.4
Mesocarp	52.3	59.7	68.0
Fibre	29.8	18.1	11.8
Oil	22.5	41.6	56.2
Shell	9.5	14.2	12.1
Kernel	6.3	8.4	8.3
Fibre	3.9	3.9	2.6
Oil	2.4	4.5	5.7

Notes:

i) Bunch dry weight = 54.2 % (Equation 1)
ii) Bunch energy content = 29.51 Mj/kg
iii) Bunch 'non-oil' dry matter equivalent (BDM*) = 1.529 x 'vegetative' dry matter (= FFB x 0.829)
iv) Data based on 75 bunches harvested over three months

Bunch growth curves

Differences between sites in bunch composition had a negligible effect on BDM* growth curves for the two sites *(Figure 1)*. Over half of the energy content of the mature bunch was accumulated during the last 40 days prior to harvest. It is during this period that the bulk of the mesocarp oil is produced.

Model output: seasonal changes in BDMP*

Using the model, monthly changes in BDMP* at the two sites were calculated from FFB yields recorded from the first months of harvest onwards. These data are referred to in *Figures 2* and *3* as BDMP* 'modelled'. For comparison, an estimate of BDMP* was also obtained simply by multiplying the monthly FFB yields by the site conversion factors given in note iii of *Tables 2* and *3* . These data are referred to as BDMP* 'harvested'. It can be seen that the trends in modelled BDMP* follow closely the harvested BDMP* but that the two are displaced in time. This is seen more clearly by use of running means which remove short-term fluctuations, as, for example, for the data sets

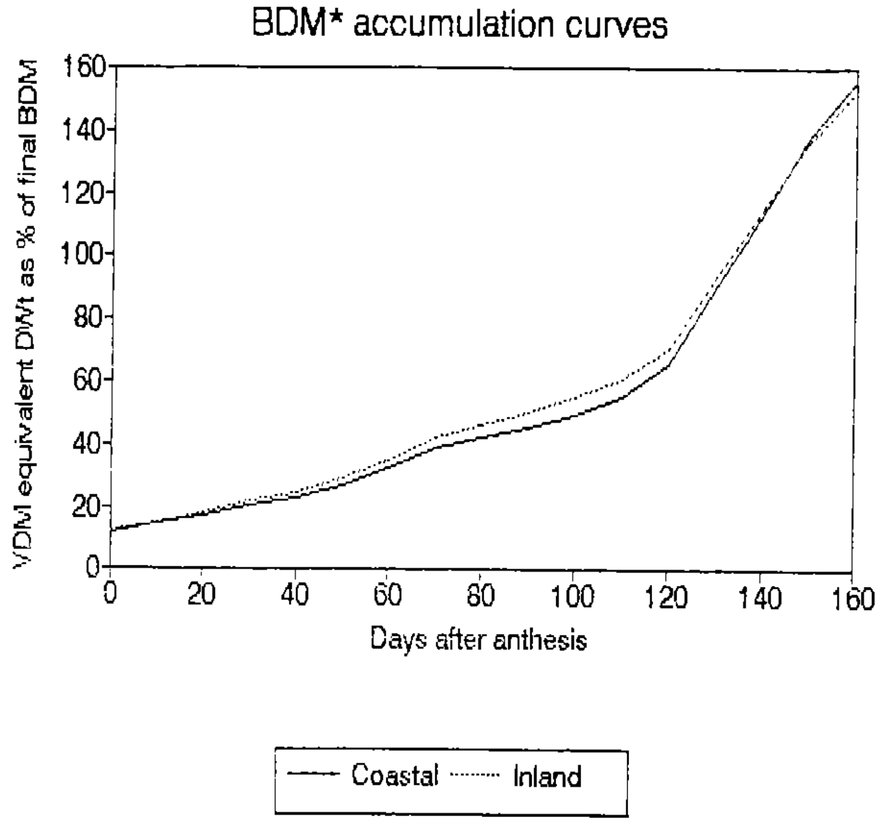

Figure 1. Standard accumulation curves for coastal and inland sites of bunch 'non-oil equivalent dry matter' (BDM) based on bunch component growth curves, energy contents and bunch analysis at maturity.*

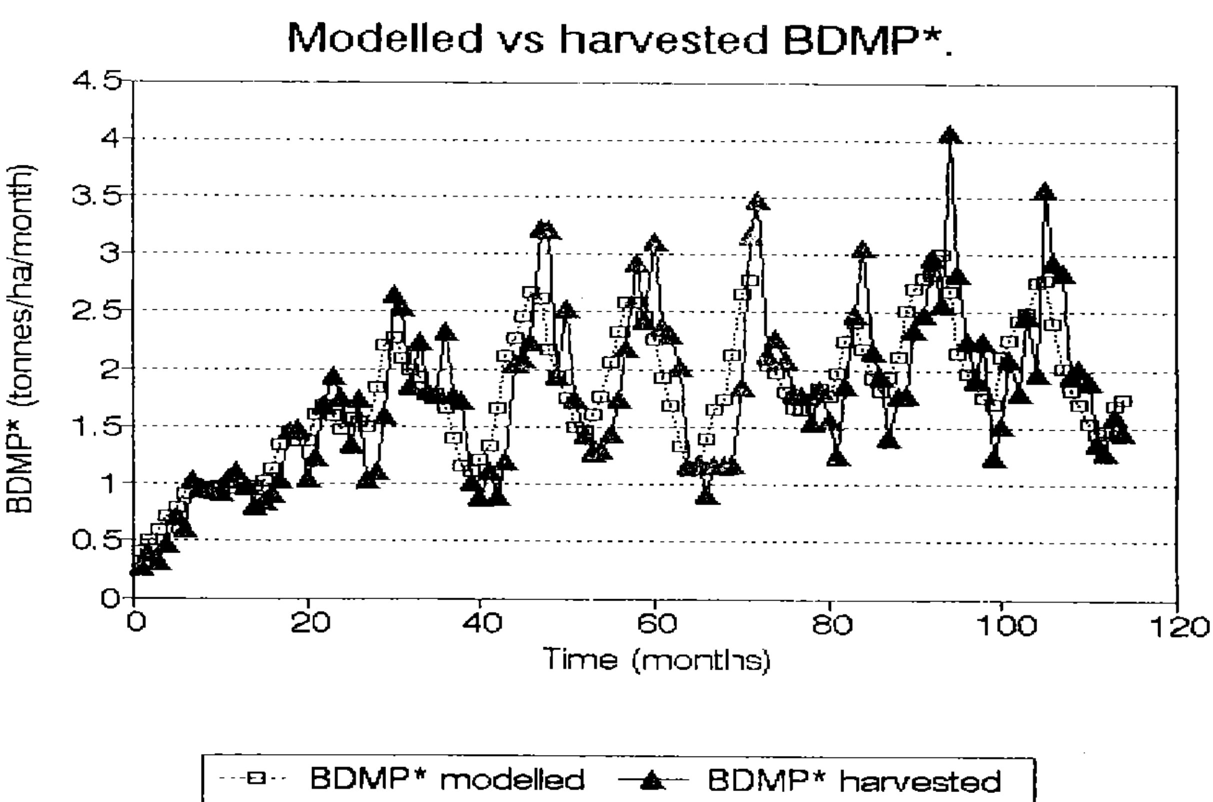

Figure 2. Monthly changes in 'modelled' and 'harvested' BDMP at the coastal site.*

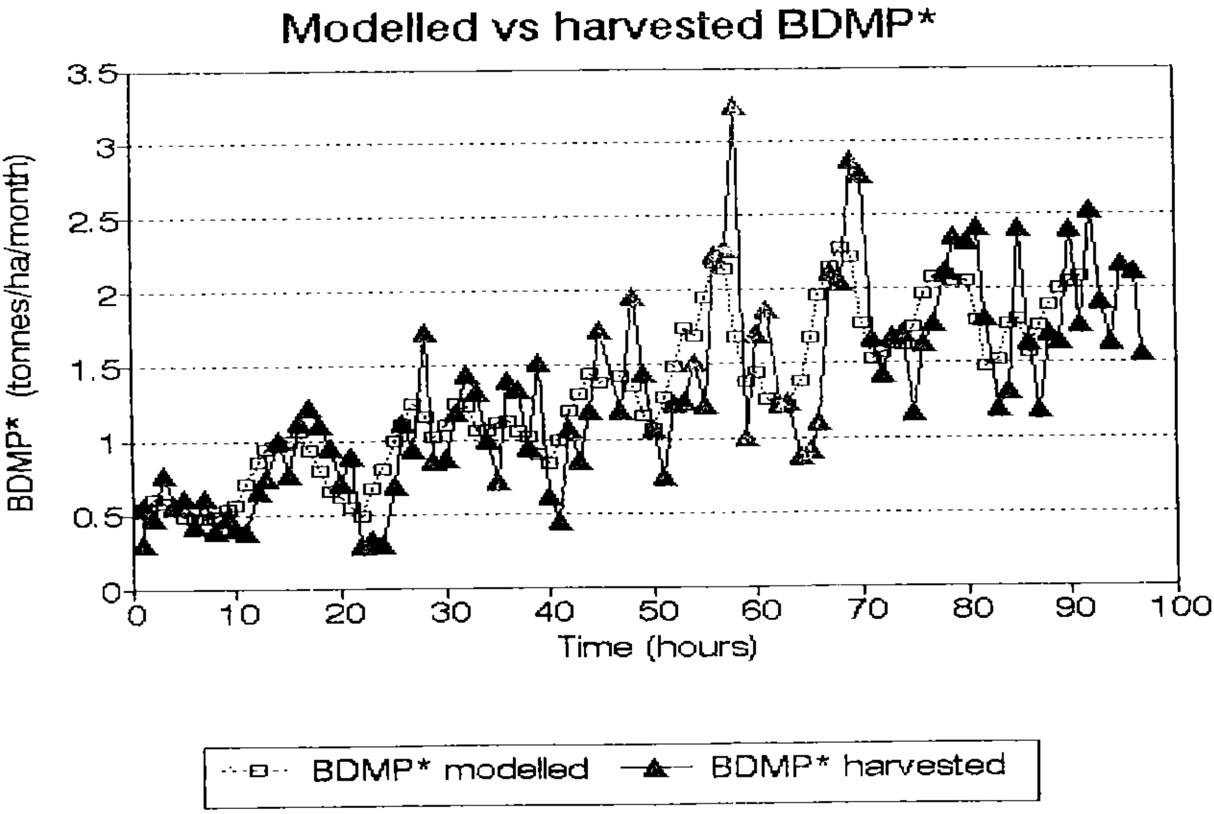

Figure 3. Monthly changes in 'modelled' and 'harvested' BDMP at the inland site.*

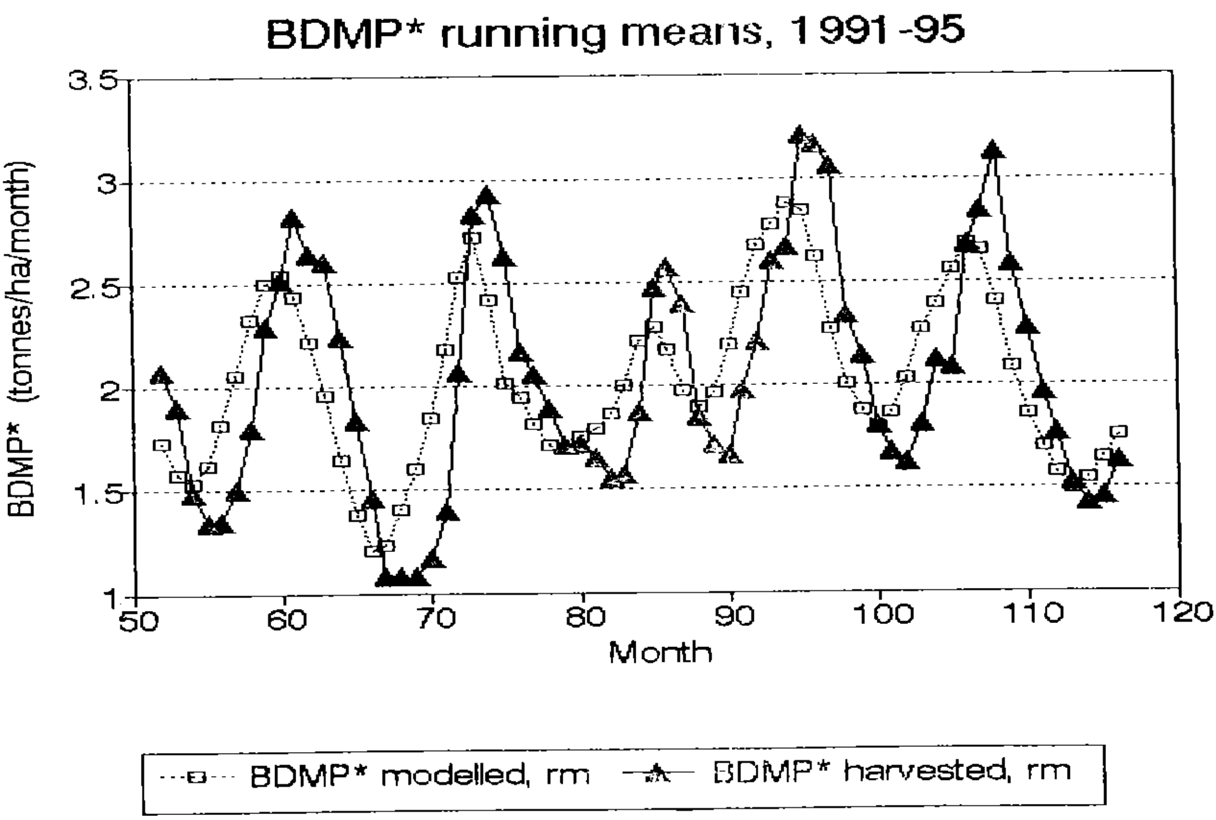

Figure 4. Monthly changes in 'modelled' and 'harvested' BDMP during later years of stable yields at the coastal site, plotted using running means (n=3).*

for the coastal site during the 'mature' period *(Figure 4)*.

It is known that duration of bunch growth can vary appreciably, even in the absence of prolonged dry periods. In Malaysia the bunch development period may vary by as much as 60 days and bunches maturing 130 days after anthesis are not uncommon (K C Chang, pers. comm.). In drier climates development may be slowed and Hartley (1977) gives 170-195 days as being the usual duration of bunch growth in Zaire.

The choice of a 'standard' 160 day bunch growth period (anthesis to harvest) was not critical for the outcome of the model. Almost identical curves were produced using 130, 160 and 190 day growth models (*e.g. Figure 5*).

Use of the bunch growth model not unexpectedly reduced the seasonal variation in BDMP* when compared with calculations based on current yields. This was true, even if running means were used for the latter but not the former *(Table 4a)*. Variation was less with long, rather than short, growth durations *(Table 4b)*.

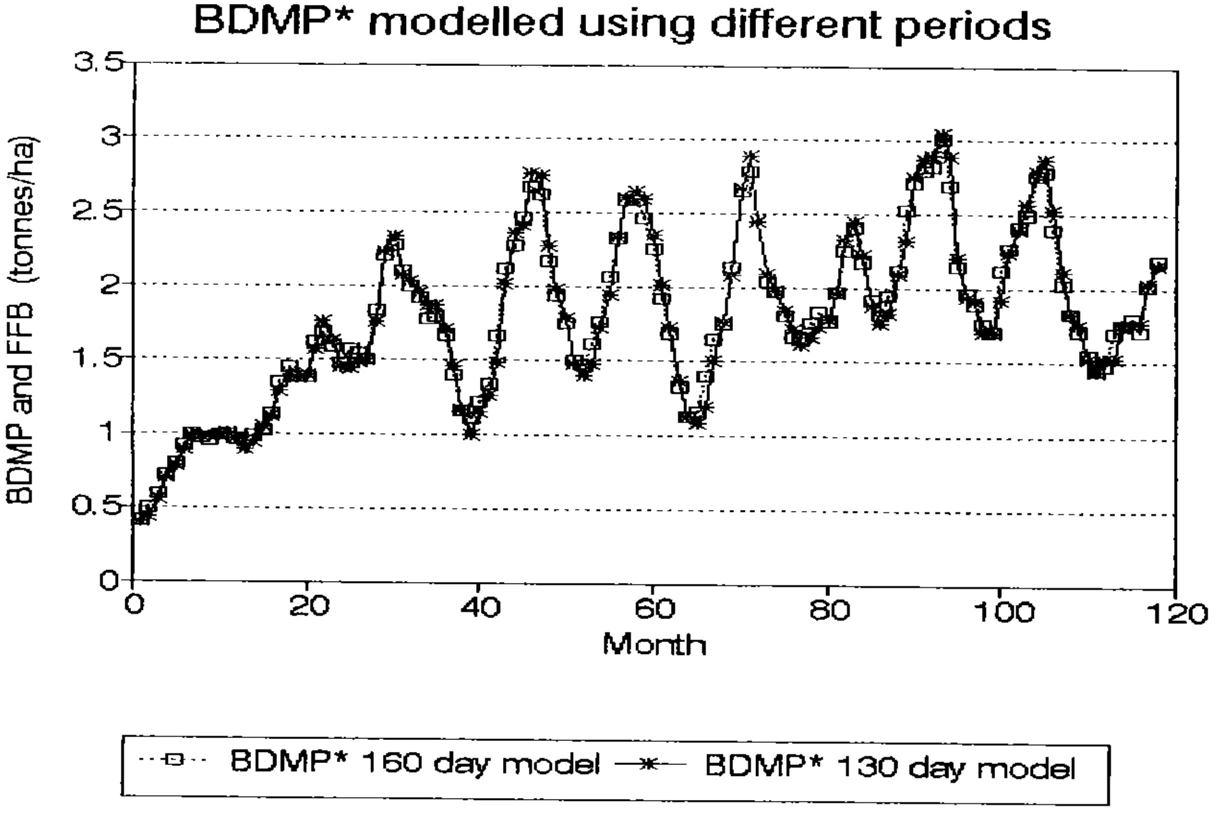

Figure 5. Monthly changes in 'modelled' BDMP at the coastal site based on 130 and 190 days duration of bunch growth.*

TABLE 4. EFFECTS OF MODELLING BUNCH DRY MATTER PRODUCTION

a) Comparison of seasonal variation in FFB and modelled BDMP* over n months from month of first FFB harvest (160 day model).

Site	mean	std dev	%CV
Coastal, n=117-118			
FFB, monthly harvest	1.78	0.744	41.9
FFB, running means	1.79	0.646	36.2
BDMP*	1.79	0.562	31.3
Inland, n=83-84			
FFB, monthly harvest	1.22	0.640	52.4
FFB, running means	1.24	0.562	45.4
BDMP*	1.24	0.506	40.7

b) Comparison of seasonal variation in modelled BDMP* using models with different growth durations, and FFB over n months from month of first FFB harvest (Coastal site; n=118).

Model	mean	std dev	%CV
BDMP*			
130 day	1.79	0.593	33.0
160 day	1.79	0.562	31.3
190 day	1.78	0.530	29.8
FFB, monthly harvest	1.78	0.744	41.9

CONCLUSIONS

The method of assessing BDMP* described here represents an improvement over the direct use of bunch harvest data as a measure of production, particularly for short intervals of measurement. The ability to follow more precisely the variation in BDMP* throughout the year should facilitate studies of the causes and origins of seasonal yield variation and especially the role of environmental factors.

It is recognized that there are still deficiencies in the method in so far as it is based on limited data with respect to bunch component growth curves and final bunch composition. The growth curves were based on data for bunch weights of ca. 19.5 kg fresh weight, similar to the mean bunch weight at about the eighth to ninth year of harvest at the present sites, while the bunch analyses were done only from the 10th year after planting. However, it is known that O/B ratio is relatively stable once bunch weight exceeds about 4 kg (Corley and Gray, 1976), a weight which was achieved at the sampled sites by the second year of harvest.

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