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Full Length Research Paper

Seasonal effects on bunch components and fatty acid composition in Dura oil palm (*Elaeis guineensis*)

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Rainfall and temperature in the different seasons can affect yield and oil quality of oil palm. A study was carried out on bunch components and fatty acid content of oil samples from Dura oil palm (*Elaeis guineensis*) in the wet (July to October 2007) and dry (January to April 2008) seasons. Experimental area was a farmer's plantation in Pathio district, Chumphon province, the southern part of Thailand. Significant differences among seasons were observed in fruits/bunch, kernels/bunch and oil/bunch ratios. Myristic and palmitic acid in mesocarp oil from the fruits harvested in dry season showed reduction of percentage compared to those from wet season. However, stearic and linoleic acid percentages increased 0.90 and 1.79%, respectively, in the samples from dry season more than those from wet season. In kernel oil, oleic acid content from dry season was higher than that from wet season. The data suggest that different harvesting times affect oil content and fatty acid composition in the oil. This study found a statistically significant correlation (P < 0.01) between mesocarp oil yield (kg) and amount of rainfall as well as accumulated temperature in the three months before harvesting while the kernel oil yield (kg) showed higher correlation with accumulated temperature than the amount of rainfall.

Key words: Bunch component, fatty acid composition, palm mesocarp, palm kernel.

INTRODUCTION

Oil palm (*Elaeis guineensis*) is a major economic plant in Southeast Asia. Indonesia and Malaysia are the two largest producers with the planted area of 7 and 4.49 million hectares, respectively, while Thailand is the third largest producer with the planted area of 512,000 ha. The major growing area of oil palm in Thailand is in the southern region which exhibits two clear seasons, wet and dry. Palm oil is used largely for cooking fat, deep-frying oil, bakery products, potato crisps, other snacks and ice-creams (Wood and Beattie, 1981). The commercial type of oil palm used in plantations is the Tenera type with thin-shelled kernel and thick mesocarp.

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Tenera is produced from Dura oil palm (thick-shelled type with thin mesocarp) pollinated by Pisifera type, which usually has no kernel and low yield. To develop high yield Tenera varieties the oil palm, breeders must select good Dura plants to begin with.

Recently, palm oil has been used as a major raw material in biodiesel, while bunches are used as fuel burnt in power stations to produce electricity. The fuel properties of biodiesel are greatly dependent on fatty acid chains of the oil used in esterification. The cetane index (used as a substitute for the cetane number of diesel fuel) can be affected by changing in the fatty acid composition. A very strong positive relationship was found between the calculated cetane index of crude oil and oleic acid concentration, and an equally strong negative correlation was estimated with linoleic acid (Duffield et al., 1998).

Table 1. Accumulated rainfall and temperature within 6 months before harvesting in wet and dry season.

Season	Harvested month	Accumulated rainfall (mm)	Accumulated temperature (°C)
Wet	July 2007	1,036.8	4,804.1
	August 2007	1,119.9	4,939.7
	September 2007	1,207.9	4,888.9
	October 2007	1,358.2	4,860.1
	Means	1,180.7	4,873.2
	SD	137.4	56.6
Dry	January 2008	839.8	4,596.5
	February 2008	983.2	4,520.1
	March 2008	945.8	4,536.3
	April 2008	673.1	4,569.4
	Means	860.5	4,555.6
	SD	138.9	34.1

The oil palms which are predominant in oleic, palmitic and lauric acids are considered high quality raw material for biodiesel and cooking oil (Bamgboye and Hansen, 2008). Such Dura are usually chosen as parents in oil palm breeding. Seasonal variation in palm oil content was regularly observed while there are very few studies on variation in fatty acid content (Ekpa et al., 1994). Apart from fruit set, oil content in mesocarp and kernel, ratio of mesocarp and kernel per fruit and fruit per bunch may be affected by the weather (Corley and Tinker, 2003). Caliman and Southworth (1998) found a positive correlation between oil extraction ratios with total solar radiation during the last four weeks before harvesting. Ochs and Daniel (1976) showed that oil to mesocarp tended to be depressed in bunches harvested two months after the period of greatest moisture deficit in Benin. In North Sumatra where millions of hectares of oil palm were grown, there was an appreciable difference in oil to bunch percentage between different regions, with a higher value in the wettest climate, compared to the value in two other regions (Prabowo et al., 2002).

The present study was designed to compare bunch components and palm oil fatty acid composition of the Dura type oil palm in wet and dry seasons from growing areas in the southern part of Thailand where oil palm are grown in a large scale plantation.

MATERIALS AND METHODS

Oil palm materials

Seventeen healthy Dura plants were chosen as the plant materials from a 7-year-old commercial plantation in Pathio District, Chumphon province, Southern Thailand during July 2007 to October 2007 (wet season) and January 2008 to April 2008 (dry season). Mature bunches were harvested monthly from each tree. Upon harvesting, all oil palm bunches were marked with the plant number and weighed on-site. The bunches were taken to the laboratory in the Department of Agronomy, Kasetsart University, Kamphaeng Saen Campus, Thailand. The spikelets and stalk were separated and weighed. The fruits from all spikelets were removed and weighed and a fruit weight to spikelet (F/Sp) ratio and the fruit to bunch weight (F/B) ratio were computed. The mesocarp was scraped off from a sample of 1 kg normal fertile fruit, and then nuts and mesocarp were weighed separately to give the ratio of wet mesocarp to fruit (WM/F). The mesocarp was then oven-dried and weighed again to give the dry matter content of the mesocarp (DM/WM). Finally, the oil was extracted from the dry mesocarp by petroleum ether to give the ratio of oil to dry mesocarp (O/DM). The last two ratios were multiplied together to give oil to wet mesocarp ratio (O/WM). Similarly, oil to bunch ratio (O/B) was calculated from the formula suggested by Corley and Tinker (2003) as follows:

$$O/B = O/DM \times DM/WM \times WM/F \times F/B$$

After removal of the mesocarp, the nut was oven-dried and cracked. The shell was removed and the kernel was weighed, so the kernel to fruit ratio (K/F) was obtained. Finally, the kernel to bunch ratio (K/B) was calculated from:

$$K/B = K/F \times F/B$$

The monthly average data of percentage fruit/bunch, total fruit weight and oil yield per month were obtained from two separated seasons, wet and dry. The accumulated rainfall and temperature within 6 months before harvesting were calculated (Table 1) for studying the relationship with percent fruit/bunch, total fruit weight and oil yield.

Oil extraction

Oil from dry mesocarp and kernel was extracted using petroleum ether in soxhlet extractor (Buchi Universal Extraction System B-811) to obtain crude palm oil and palm kernel oil. Then percent oil in dry mesocarp (O/DM or DK (%)) was obtained.

Table 2. Seasonal effects on bunch composition of Dura oil palm from the plantation in Pathio district, Chumphon Province.

Bunch components	Harvesting season		Paired t-test
	Wet (Jul-Oct 2007)	Dry (Jan-Apr 2008)	
Total bunch weight (kg/plant)	66.9 ± 3.88[a]	21.6 ± 8.13	**
Total fruit weight (kg/plant)	38.2 ± 2.37	14.6 ± 5.45	**
Mesocarp oil yield (kg/plant)	9.7 ± 0.48	3.5 ± 1.36	**
Kernel oil yield (kg/plant)	2.5 ± 0.19	1.0 ± 0.37	**
Mean bunch weight (kg)	25.4 ± 1.42	25.6 ± 1.74	ns
Fruit/Bunch (%)	56.6 ± 0.76	67.5 ± 0.93	**
Mesocarp/Bunch (%)	24.2 ± 0.34	26.1 ± 0.87	ns
Kernel/Bunch (%)	7.1 ± 0.30	8.3 ± 0.62	*
Mesocarp oil/Bunch (%)	15.4 ± 0.28	17.4 ± 0.53	*
Kernel oil/Bunch (%)	2.9 ± 0.14	3.6 ± 0.28	*

*,** = Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively; ns = non significant; [a] = mean ± SE.

Fatty acid profile

The Fatty acid methyl esters (FAME) and gas chromatography methods were carried out in accordance with the AOAC's official method for oil and fats (AOAC, 2000). Lipid extracts were methylated to produce fatty acid methyl esters (FAME). The FAME was analyzed by a CP9001 gas chromatograph (Chrompack, Middelburg, The Netherlands) on a WCOT fused silica column (100 m x 0.25 mm, i.d.) coated with CP-SIL 88 (Varian). Initial temperature was 140°C for 5 min then increased to 200°C at the rate of 4°C /min and finally increased to 225°C at the rate of 5°C /min and stayed on for 15 min. The injector temperature was set at 270°C and detector temperature was set at 280°C. Helium was used as the carrier gas. Chromatographic peaks were identified by comparison with the retention times of methyl esters of the constituent fatty acids purchased from Sigma-Aldrich Chemie (Steinheim, Germany).

Statistical analysis

A paired t-test was used to compare means of bunch components and fatty acid composition of each plant between the two seasons, using R program (R-Development Core Team, 2008). Correlation between percentage of fruit/bunch with accumulated rainfall and temperature were calculated from the monthly average data of plants that harvested in wet (July to October 2007) and dry (January to April 2008) seasons, and accumulated rainfall and temperature within the five months before harvesting. Oil yield (kg) and total fruit weight (kg) were correlated with accumulated rainfall and temperature in the three months before harvesting.

RESULTS AND DISCUSSION

Seasonal variation in bunch component and oil content

The average bunch weight of Dura oil palm harvested in wet (July to October 2007) and dry (January to April 2008) seasons were similar, regardless of seasons. All the sampled trees yielded ripe fruit bunches in wet season, whereas some of them gave the fresh fruit bunches in both wet and dry seasons. Bunch components showed significant difference between seasons. Percent wt/wt of fruits/bunch and kernels/bunch harvested in dry season were higher than those in wet season. Similarly, the mesocarp and kernel oil to bunch ratio of the dry season samples were higher than those in wet season (Table 2). The difference is likely affected by the average rainfall during fruit development to ripeness that normally takes 6 months. The fruits develop steadily in size and weight from anthesis until 100 days or more after anthesis. Oil formation in the kernel commences at about 70 days and is probably complete by about 120 days (Corley and Tinker, 2003). At 8 weeks from pollination, the amount of lipid in mesocarp is very small until the 12th week, when lipid formation becomes more rapid. There is a major accumulation of oil in mesocarp at the 20th week after pollination and continues until the fruit is overripe (Oo et al., 1986). Alvarado and Sterling (1998) reported that fruit per bunch showed a positive correlation with hours of sunshine, and a negative correlation with precipitation received five or six months prior to harvest, the period during which pollination would have occurred. During the months of high rainfall, raindrops may knock the pollen off the inflorescences, or too-wet pollen may not adhere to insects. Bunches that developed during the wet season are exposed to more precipitation, thus, have poorer fruit setting and development. This is an indication that %F/B was low during the wet season. On the other hand, bunches that developed during the dry season are

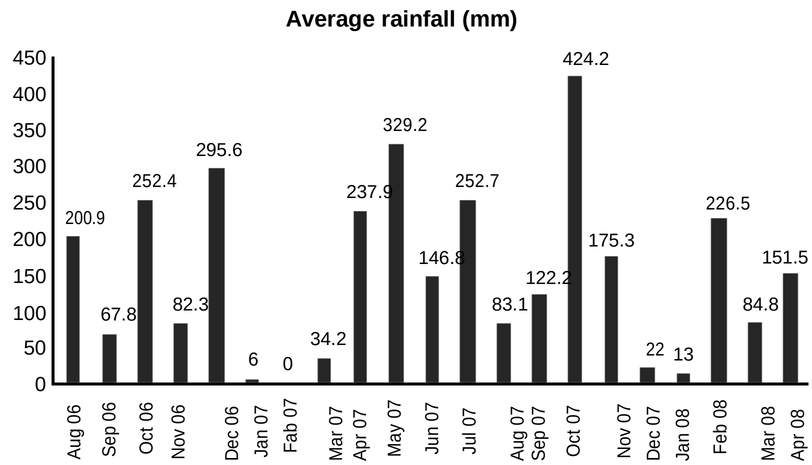


Figure 1. Monthly rainfall (mm) during fruit development at oil palm plantation in Pathio district, Chumphon province.

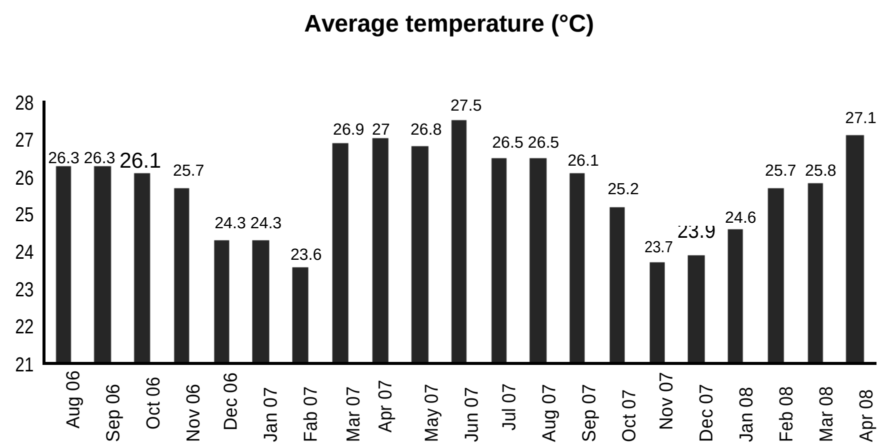


Figure 2. Monthly temperature (°C) during fruit development at the oil palm plantation in Pathio district, Chumphon province.

exposed to low precipitation (Table 1) thus have better fruit setting and development, the percentages of fruit and kernel to bunch and oil to bunch of oil palm harvested in dry season increased significantly (Table 2). Considering the rainfall deficit during fruit development to ripening (Figure 1), the number of harvested bunches per plant decreased in dry season. Low bunch number can affect fruit development of oil palm harvested in the dry season. While the total bunch weight and total fruit weight per plant of oil palm harvested in wet season which had the greater number of bunches were higher than that in dry season (Table 2). Negative correlations of oil to bunch with rainfall in the previous month before harvesting have been reported earlier in Malaysia (Hoong and Donough, 1998). This may be due to effect of solar radiation on oil synthesis, since during the high rainfall condition most of solar radiation is both reflected and absorbed by cloud causes lower photosynthesis and consequently low oil synthesis. An equally important factor is that bunches may have a higher water content in wet weather, so the samples harvested in wet season are affected by high rainfall in the previous months or during the harvesting months. The relationship between fruit weight (kg), and accumulated rainfall (mm) and temperature (°C) (Figure 2) during three months before harvesting is positive with the regression coefficient of

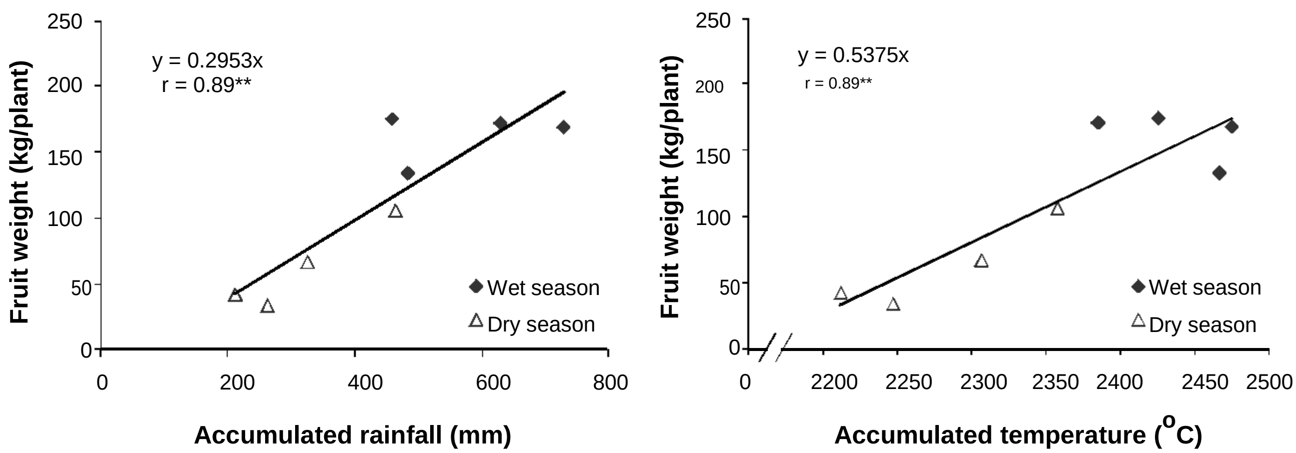


Figure 3. Relationship between fruit weight (kg/plant) with accumulated rainfall (mm) and temperature (°C) during fruit development (3 months before harvesting).

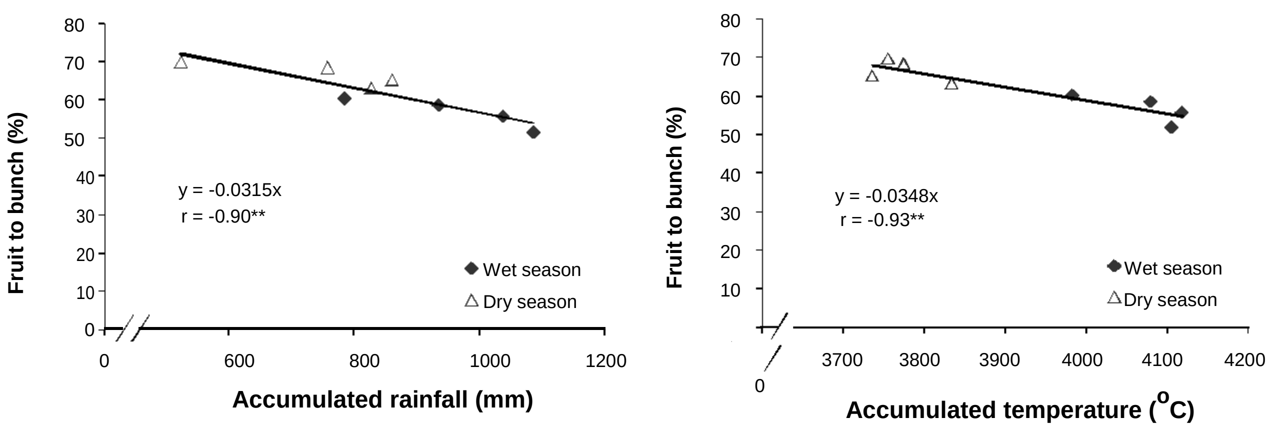


Figure 4. Relationship between fruit to bunch (%) with accumulated rainfall (mm) and temperature (°C) in the five months before harvesting.

0.2953 kg fruits per mm rainfall and 0.5375 kg fruits/°C, respectively (Figure 3). This showed that rainfall and temperature are a major environmental factors affecting fruit weight. The accumulated rainfall and temperature (X-axis) began from above the zero point. This equation is realistic only between the range of rainfall and temperature under study. This relationship should not be extrapolated. Thus we do not show the Y-intercepts in the regression equations. In this study, we found a negative correlation between fruit weight to bunch (%) with accumulated rainfall and temperature during five months before harvesting (Figure 4). During this period of time, the fruits are developing in size and weight. This could be the effect of low radiation from high rainfall at that period.

Furthermore, we observed a positive correlation between mesocarp oil yield (kg) with the amount of rainfall and accumulated temperature during three months before harvesting. High rainfall promoted more bunches that resulted high yield of palm oil. It was also found that, kernel oil yield (kg) showed higher relationship with the accumulated temperature than the amount of rainfall (Figure 5).

Seasonal variation in fatty acid contents of Dura oil palm

Table 3 shows fatty acid composition of the oil extracted from Dura oil palm. In both seasons, the amount of saturated fatty acids in palm kernel oil depended mainly

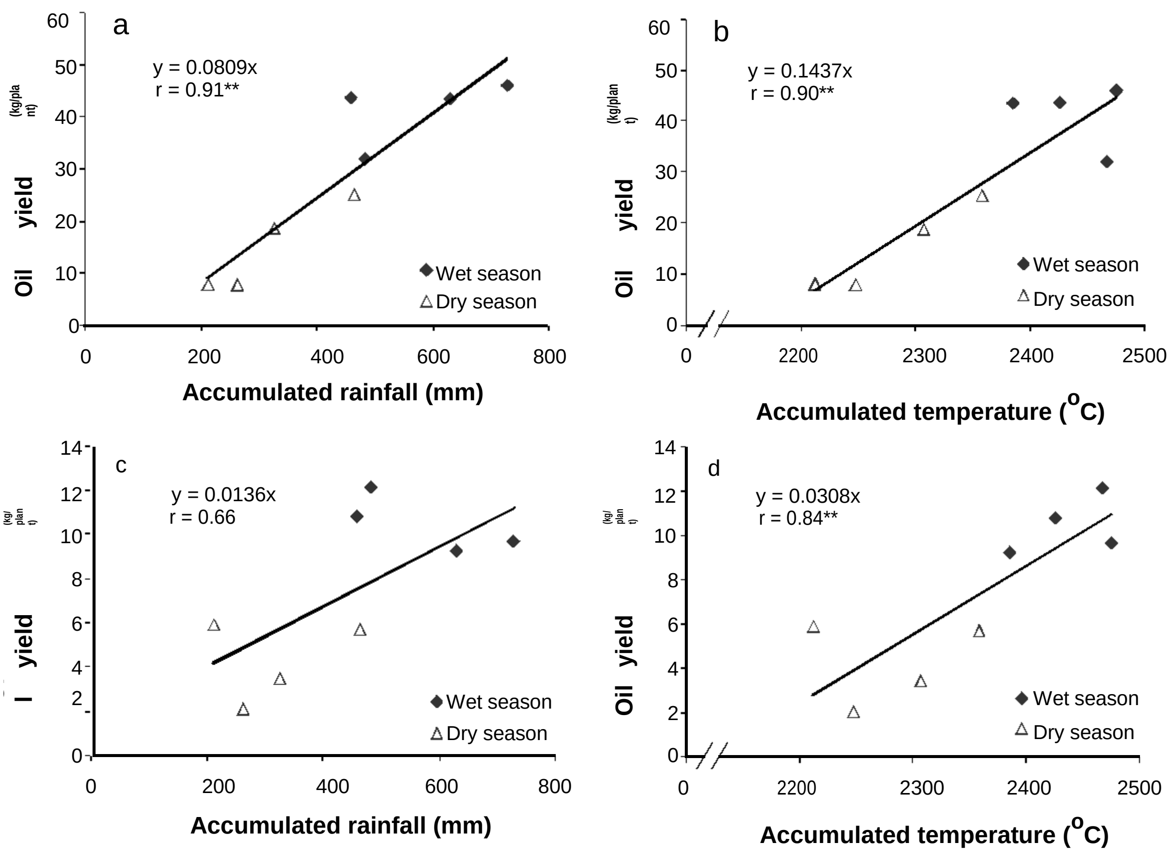


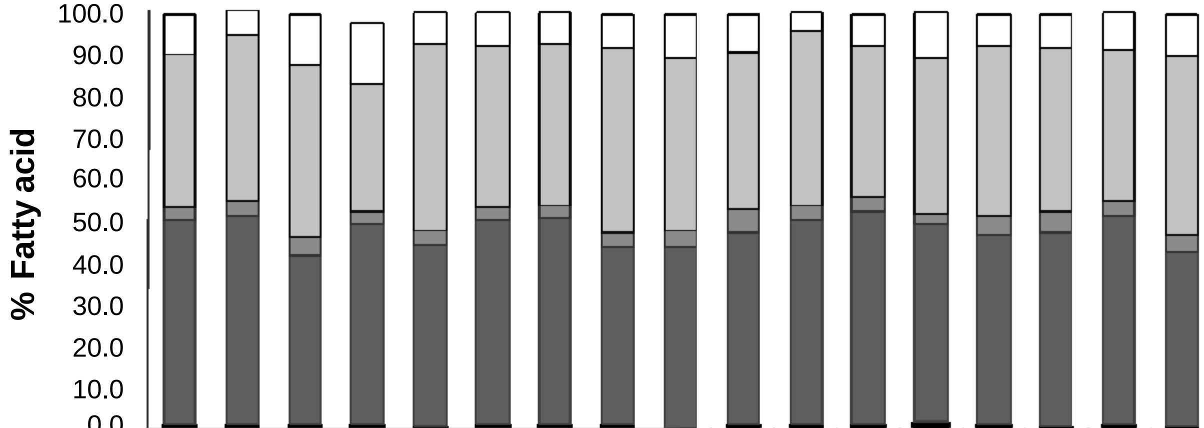
Figure 5. Relationship between mesocarp (a, b) and kernel (c, d) oil yield (kg/plant) with amount of rainfall (mm) and accumulated temperature (°C) in the three months before harvesting.

Table 3. Seasonal effects on fatty acid composition of oil from mesocarp and kernel of Dura oil palm from the plantation in Pathio district, Chumphon province.

Fatty acid	Mesocarp oil		Paired t-test	Kernel oil		Paired t-test
	Wet season	Dry season		Wet season	Dry season	
Caprylic (C8:0)	ND	ND	-	4.25 ± 0.16	3.52 ± 0.15	ns
Capric (C10:0)	ND	ND	-	4.03 ± 0.12	3.54 ± 0.12	ns
Lauric (C12:0)	ND	ND	-	54.27 ± 0.39	50.11 ± 1.06	ns
Myristic (C14:0)	1.02 ± 0.03[a]	0.75 ± 0.03	*	15.9 ± 0.17	16.26 ± 0.17	ns
Palmitic (C16:0)	46.73 ± 0.53	42.31 ± 0.57	*	6.89 ± 0.12	7.88 ± 0.26	ns
Stearic (C18:0)	3.8 ± 0.11	4.7 ± 0.29	**	2.04 ± 0.14	2.09 ± 0.08	ns
Oleic (C18:1)	40.15 ± 0.52	41.77 ± 0.66	ns	9.99 ± 0.30	14.18 ± 0.77	*
Linoleic (C18:2)	7.9 + 0.23	9.69 + 0.16	*	1.82 + 0.14	2.29 + 0.15	ns

*,** = Significant at P ≤ 0.05 and P ≤ 0.01, respectively; ns = non significant; ND = non-detectable; [a] = mean ± SE.

on the amount of lauric acid. Oleic acid (C 18:1) was the dominant unsaturated fatty acid present in the mesocarp at 40.15 to 41.77% of the oil. The oleic acid content in the mesocarp oil was not different between seasons. The

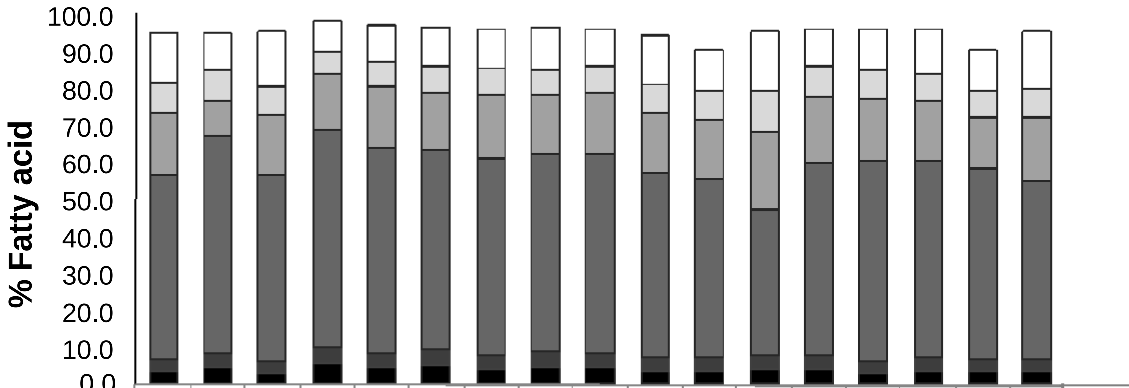


	Dura 1	Dura 2	Dura 3	Dura 4	Dura 5	Dura 6	Dura 7	Dura 8	Dura 9	Dura 10	Dura 11	Dura 12	Dura 13	Dura 14	Dura 15	Dura 16	Dura 17	paired t-test
Linoleic	9.8	5.8	12.0	14.4	7.1	8.0	7.7	8.1	10.2	9.0	4.8	7.7	11.1	7.5	8.3	9.2	10.0	***
Oleic	36.4	39.5	41.5	30.7	44.8	38.6	38.5	44.2	41.4	38.0	41.7	36.5	37.0	40.8	39.2	36.1	42.8	**
Stearic	3.1	3.9	4.4	3.2	3.5	3.0	3.2	3.6	4.0	5.6	3.3	3.2	2.9	4.4	4.9	3.2	4.2	***
Palmitic	48.9	49.6	40.0	47.8	43.2	49.1	49.1	42.5	43.2	45.7	48.8	50.7	47.1	45.6	46.0	50.2	41.7	*
Myristic	1.1	1.3	1.5	1.2	0.9	1.2	1.4	1.1	0.4	1.1	1.2	1.4	1.7	1.0	1.0	1.1	0.6	***

Figure 6. Fatty acid composition in mesocarp oil of Dura oil palm from the plantation in Pathio district, Chumphon province. *,**,*** = Significantly different at P $\leq$ 0.05, P $\leq$ 0.01 and P $\leq$ 0.001, respectively.

results of this study complemented that of Ekpa et al. (1994) who did not observe the difference in oleic acid of palm oil harvested in January (dry season) or May (wet season) in Nigeria. The present results showed appreciable difference in oleic acid content in kernel oil. The percentage of oleic acid in dry season palm kernel oil was 14.18% compared with 9.99% in wet season. Significant variation of myristic (C 14:0), palmitic (C 16:0), stearic (C 18:0) and linoleic (C 18:2) acids in mesocarp oil was also noticeable in oil palm harvested in the two seasons. The level of saturated fatty acid, particularly myristic and palmitic, appeared to decline from wet to dry seasons, while stearic and linoleic acid contents were increased. This is an obvious relationship because these fatty acids are the components of oil and thus their contents are highly dependent among each other (Harwood, 1996; Wu, 2009). We expect that the increase in content of some fatty acids always occurs as an expense of the other fatty acids.

When the fatty acid compositions of individual palm were averaged across seasons, we found significant differences in the profiles (Figures 6 and 7), which are basically due to different genetic make-up of the plants. This genetic variation was taken care by paired comparing of the bunch components and fatty acid compositions obtained from two seasons within the same plant. Oil varying in fatty acid contents can be utilized in various ways and products. For example, palm oil is particularly suitable for deep frying oil because it is relatively stable at high temperature (Berger, 1996). Cocoa butter substitutes and coffee whiteners are manufactured mainly from lauric oils or luaric stearins, particularly palm kernel stearin (Maarsen, 1985). Oil obtained from dry season which is lower in palmitic acid but higher in linoleic acid, would be more suitable for processing into vegetable oil because palmitic acid is a saturated fatty acid which tends to increase blood cholesterol if the level of linoleic acid in the diet is too low (Hayes and Khosla, 1992). On the other hand, linoleic acid is polyunsaturated fatty acid which results in lower total cholesterol (Sambanthamurthi et al., 2000). The palm kernel oil containing high level of lauric acid is desirable as the raw material for production of soap and cosmetic (Kalustian, 1985), and the oil with high lauric acid content helps improve the quality of biodiesel (Bamgboye and Hansen, 2008). Some Dura plants that we have studied exhibited high oleic, linoleic and luaric acid contents in oil which would be of great benefit to use as female parents in oil palm breeding program for producing Tenera oil palm containing high quality oil.



	Dura 1	Dura 2	Dura 3	Dura 4	Dura 5	Dura 6	Dura 7	Dura 8	Dura 9	Dura 10	Dura 11	Dura 12	Dura 13	Dura 14	Dura 15	Dura 16	Dura 17	paired t-test
Oleic	13.6	10.1	14.9	8.3	9.7	10.8	10.4	11.2	10.1	13.6	11.3	16.3	10.5	11.4	12.4	11.1	15.3	*
Palmitic	8.3	7.8	8.0	5.9	7.0	7.0	7.5	7.0	7.0	7.9	7.5	10.6	8.2	7.4	7.2	6.9	7.6	**
Myristic	16.4	9.6	15.8	15.0	16.3	15.6	17.0	15.7	16.5	15.9	16.1	21.3	17.8	16.9	15.7	14.2	17.1	***
Lauric	49.7	58.3	50.0	58.3	55.0	53.7	53.3	53.4	53.5	49.8	48.2	39.1	51.9	53.9	53.3	51.1	48.6	***
Capric	3.5	4.3	3.5	4.9	4.3	4.2	3.9	4.4	4.2	3.5	3.5	4.0	3.8	3.1	3.9	3.6	3.3	*
Caprylic	3.4	4.6	3.1	5.5	4.5	5.3	3.9	4.6	4.5	3.7	3.8	4.1	4.0	3.3	3.6	3.5	3.4	**

Figure 7. Fatty acid composition in kernel oil of Dura oil palm from the plantation in Pathio district, Chumphon province. *,**,*** = Significantly different at P $\leq$ 0.05, P $\leq$ 0.01 and P $\leq$ 0.001, respectively.

Conclusion

It can be concluded from our study that Dura oil palm grown in the Southern part of Thailand showed high response to rainfall and temperature in total fruit weight, percentages of fruit to bunch, and oil yield from mesocarp and kernel in wet and dry seasons. The fatty acid compositions in palm oil from the wet and dry season fruits were also different. The results from this study indicated that oil content and fatty acid compositions in palm oil are influenced not only by genetical but also by environmental factors. This research results are beneficial to oil palm farmers, palm oil factories, biodiesel producers and breeders in improving yield and palm oil quality.

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