

Effect of Acidic Soil on Free Fatty Acid of Palm Oil in Thailand

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Abstract

Oil palm is the most important plants that serve as raw materials for producing biodiesel and is considered as an important part of energy sources in Thailand. Some oil palm plantations were grown in soil pH with acid conditions, which lacked of supporting data for agriculturalist. Attempts were made to study the effect of the level of soil pH on the quality of palm oil. Three palm varieties were used for studying the production of the fruit and the kernel. Free fatty acids (FFA) existed in three levels of soil pH with acid conditions were analyzed using AOCS Ca 50-40 method. It was found that *UV*, *Tenera*, and *Deli Compact* were varieties that could grow in acidic-pH soil. The highest yields of the production of the fruit and the kernel from the oil palm plantations that were grown in soil-pH conditions less than 6 were 3,855.2, 3,172, and 2,623 kg/ha in the variety *UV*, *Tenera*, and *Deli Compact*, respectively. Results of FFA found in three varieties of acidic soil in the three varying levels were not different. The mean values of FFA of *UV*, *Deli Compact*, and *Tenera* species were 3.59, 3.65, and 3.72 %, respectively, while the FFA of three varieties of oil palm that were grown in soil pH conditions greater than 6 were 3.48, 3.66, and 3.50 %, respectively. This finding suggested that acidity conditions of soil did not affect the quality of production yield of oil palm and can use as a guideline in the planning for more effective expansion of oil palm plantations in the future.

Keywords: Acidic soil, free fatty acid, palm oil, Thailand

1. Introduction

Oil palm (*Elaeis guineensis*) is a monocotyledon and a perennial plant which has the highest production per hectare among oil crops, i.e., seven to eight times of peanut's yield, and 9 to 10 times of soybean's yield. It was shown that an average of 3.7 tons of oil per hectare per year was obtained from the extraction in Malaysia (Sundram et al., 2003).

In Thailand, there has been rapid expansions in oil palm plantations throughout the country since 2006. There are variations in yields of oil palm among the productions of oil palm in the South, Northeastern, Eastern, and the Central part of Thailand where the average value was ranged from 1.07 tons/rai/year to 6.49 tons/rai/year. Factors that cause the variations of the production of oil palm were nutrient supply, water stress, weed, pests, diseases, pollination, and shading (Therapong, 2011).

The crop produces two types of oil. The fleshy mesocarp (palm meat) produces palm oil which is used mainly for its edible properties, and the kernel produces palm kernel oil which has wide application in the oleochemical industry. The palm oil (PO) is very unique in that it contains 50% saturated fatty acids, 40% unsaturated fatty acids, and 10% polyunsaturated fatty acids (Naiyana and Wahlqvist, 2003). The quality of PO is determined by different factors, where free fatty acid (FFA) is one of the most frequently used as quality indices during the production processes, storage, and marketing, whereas the price of PO in the market is dictated by FFA content (Saad et al., 2007). Other parameters that dictate the price of a palm oil product include moisture, impurities and iodine value (IV). Many researchers have reported FFA content (Saad et al., 2007) and IV (Haryati et al., 1997) of PO, but most of the material of PO were refined PO, not extracted from fresh palm meat (PM). The fatty acid components of PO (Sundram et al., 2003) and palm kernel oil (PKO) (Kritchevsky et al., 2000), the tocopherol and carotene content of PO (Ping et al., 2002) were also studied.

In Thailand, the expansion of oil palm plantation is very rapid. Thai government has set its policy on producing palm oil-based biodiesel as a renewable energy. Attempts on the mixing 2% of the B2 biodiesel with 98% of diesel oil on trucks was done during 2006 – 2010, and B5 biodiesel was used with other types of car in 2011 where the percentage of biodiesel combination was changed to B10 in 2013. The plan to envision the bright future of a sustainable development of the palm oil industry and an increase in the production of value-added products is pursued. It targets a yearly development of new plantings of oil palm in 80,000 ha and a yearly replanting of oil palm in 16,000 ha until 2011. The average overall oil extraction rate (OER) is aimed to increase to 18.5% and the average fresh fruit bunch (FFB) yield to 21 t/ha by 2011. The expansion of oil palm plantations is explicitly targeted at “waste” land such as abandoned paddy fields, degraded land, abandoned fruit orchards, land with acid soils and land with previously used for rubber cultivation. Research has shown that actual expansion of oil palm plantations in the Southern provinces are mainly taken place in paddy fields and land that is previously grown rubber plantation, i.e., in Chon Buri and Chachoengsao Provinces, and also on the land that is formerly used for cassava, pineapple, and rice cultivation.

Acid soils in Thailand are found scatter throughout the country with a total area of 22.8 million ha. Acid soils are mainly found in the Northeast Thailand, with an area of 10.4 million ha. Some areas in the South, the Central Plain, Northern, Western, and Eastern Thailand are 4.3, 4.0, 3.04, and 1.12 million ha, respectively (Chareonchamratcheap et al., 1997). The vast majority of the acid soils composition is Ultisols (around 22.6 million ha) while the remaining is Oxisols. These soils are characterized by low pH and their major

constraints are low cation exchange capacity (CEC), base saturation, high acidity, aluminum toxicity, manganese toxicity, iron toxicity and infertility. Even though acid soils are considered as a problem soil that has long been experienced in the country, their magnitude and intensity are continuously increasing as a result of inappropriate use for agriculture, deforestation, and soil mismanagement have been occurred in recent decades, thus an increasing in the magnitude of the problems should be solved in order to face the demands of future food needs. Increasing interest in studying the problem of acid soils is a result of their widespread distribution in the country, representing 44% of the total land, which is generally used for agricultural production. To fulfill the demand, a daily production of 8.5 million liters of biodiesel must be met. That means another five million rai (or about 800,000 hectares) of oil palm plantation areas must be expanded into a total of eight million rai (1.2 million hectares) of the palm cultivation and reach 10 million rai (1.6 million hectares) by 2029. So, a variety of discourse on oil palm has emerged to promote as a renewable source of energy and a transformation of deserted rice fields into palm field especially in the Eastern Thailand, such as Chachoengsao and Nakhonnayok Province where the soils are mostly consisted of acid soil condition. Thus, the appropriate palm variety, and quality of palm oil should be addressed to serve as a guideline in decision-making in the planning and more effective expansion of oil palm plantations in acid soil area to reduce a great concern of environmental impact from an expansion of oil palm plantation.

2. Methodology

2.1 Data sampling

The study was carried out in 6 districts, i.e., Sanam Chai Khet, Tha Takiab, Plang Yao, Phanom Sarakham, Ratchasan, and Muang districts of Chachoengsao province, Thailand. The survey area was composed of a variety of acidic soil, i.e., pH<4, pH 4-6, and pH>6, respectively. The data of management of palm plantation were collected from Land Development Station, Department of Agriculture Extension, palm fruit milling industry, and palm owners by indepth interview approach. FFB yields were recorded at each harvesting round of every 15 days. These values were then extrapolated to a yield in tons of FFB per hectare per years.

2.2 Determination of Free Fatty Acid value: The FFA value of the oil samples was determined in duplicated manner using standard analytical methods for fats and oils by the American Oil Chemists Society(AOCS, 1990) at 95% confidence limit. The percentage FFA value was calculated from the equation below:

$$\text{Free fatty acids (FFA)\%} = \frac{VmM}{10w}$$

where, w = weight (in grams of samples), v = volume (in milliliters) of sodium hydroxide solution, m = molarity of sodium hydroxide solution, and M = molecular weight of the FFA.

3. Results and Discussion

Plantation and management

The data clarification by the farmers for palm oil plantations and management in Chachoengsao province were as follows:

1. Palm oil started producing at around 4/5 year, while first few years were around 15 kilograms per palm then 30 kilograms per palm after 6 years. Palm was cut at every 20 days with 22 palm trees per rai. Forty percent of the plantation management went back into the trees as fertilizer cutting and pruning. The farmers visited every tree at least once a month and paid a visit more during the period of heavy rain. The actual harvesting times were determined by looking at the fruit bunches, and harvesting the ripe ones.

2. Farmers got approximately 80 kg/tree or more when the trees were about 8 years of age. Yields dropped considerably when the precipitation was low. Most of farmers planted 22-24 palm trees per rai resulted in low density of palm trees. In generally in Thailand, the farmers recommended to use 8.5 meter grid (or less) when the precipitation was low. To maximize the revenue usually meant that the oil palms were planted at higher densities, where the trees were planted upwards of 160 trees per hectare or more. But some of farmers planted the palm upto 185 trees per hectare. The farmers needed to put more afford on the investment and had access to water, where a drip irrigation system was used more than paying for itself.

3. Total costs for oil palm palntation depended on paying and how efficient they were. The current Thai prices of fruits were 5 baht/kg, and 29 baht/kg for crude palm oil (CPO), 40% was a hefty chunk unless including interest on capital for purchase of the land. The high yields of input (such as irrigation) decreased overall costs as a percentage of income. Fertilizers were the most effective factor during the early years of investment, whereas there was a significantly less demand when trees were mature. So, this factor is highly variable, where it is estimated for labor in the maintainance of the plantation.

4. Rats are a big problem that reduce the yield of the oil palm. It was estimated that about 5% attribution rate during the early years of plantation occurred if there was less effective rodent control plan.

Results of survey on varieties of Palm Tree in the study areas of Chachoengsao Province

Results in Table 1 showed that Univanich (UV) variety was the most popular one that planted in Chachoengsao because it was a hybrid produced by the Suksomboon Palm Oil Company Ltd, where all kinds of knowledge were provided and supported to agriculturists from cultivating to harvesting crops. The second popular variety was Tenera (DxP) which the plantation was supported by Eastern Palm Oil Company Ltd. that was located in the boundary area between Chachoengsao and Chon Buri; and some agriculturists bought it from Lamae district, Chumphon Province. Moreover, it was found that there were three varieties of palm trees planted in the acid soil area, i.e., Univanich (UV), Tenera (DxP), and Deli Compact. Tha Takiep District was the most populous planting area (39.48%), whereas Sanam Chai Khet District was a less popular one (21.43%). The least populous planting area was in the Dong Noi Sub-district, Rachasarn District where it was a newly planting area with a very acidic soil which attempts were made to grow oil palm (Table 2).

Table 1. Showing results of survey on varieties of palm tree in each district in Chachoengsao Province.

Palm varieties	District	Area(rai)	Hectare(ha)	Percent(%)
Univanich	Sanam Chai Khet	2,690	430.4	30.04
	Tha Takiap	3,475	556	38.80
	Plaeng Yao	1,620	259.2	18.09
	Phanom Sarakham	200	32	2.23
	Ratchasan	50	8	0.56
Tenera(DxP)	Tha Takiap	554	88.64	6.19
	Plaeng Yao	50	8	0.56
	Phanom Sarakham	30	4.8	0.33
	Mueang	50	8	0.56
	Ratchasan	10	1.6	0.11
Deli x Lamae	Sanam Chai Khet	60	9.6	0.67
Surat Thani	Plaeng Yao	62	9.92	0.69
Deli x Compact	Phanom Sarakham	75	12	0.84
Nhongped(DxP)	Phanom Sarakham	30	4.8	0.84
		8,956	1,432.96	100.00

Remark: 1 Hectare(ha) = 6.25 Rai

Table 2. Showing varieties of palm tree in Chachoengsao province.

Palm varieties	Area(rai)	Hectare(ha)	Percent(%)
Univanich	8,035	1,285.6	89.72
Tenera(DxP)	694	111.04	7.75
Deli x Lamae	60	9.6	0.67
Surat Thani	62	9.92	0.69
Deli x Compact	75	12	0.84
Nhongped(DxP)	30	4.8	0.33
	8,956	1,432.96	100.00

According to the survey of palm tree grown in Chachoengsao, it was found that the average age of palm trees was 11.5 years. Those trees that less than four years of age were planted in an area of 2,843 Rai; those of 4 – 8 years were 1,866 Rai; of 8 – 15 years were 3,913; and

more than 15 years were 200 Rai, which were equivalent to 31.84%, 20.92%, 43.83%, and 2.24%, respectively. To sum up, the tendency of growing palm oil in the area of Chachoengsao had been increasing (Figure 1).

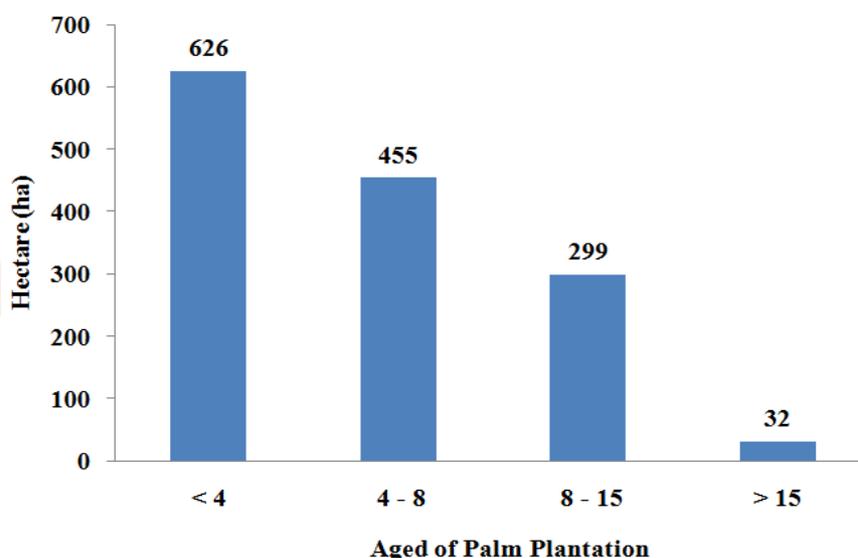


Figure1. Showing the age of Palm tree grown in 6 districts of Chachoengsao Province.

The Spreading of Oil Palm Tree varieties in Acid Soil in the Chachoengsao Province

It was found that Univanich (UV) variety was the most popular variety in Chachoengsao because it was supported by Suksomboon Palm Oil Company Ltd, where all knowledge concerning systematic techniques of how to cultivate through the harvestation of crops were provided to agriculturists. The second rank of the popular variety of oil palm tree was Tenera (DxP) which was supported by Eastern Palm Oil Company Ltd., where it was grown in the boundary area between Chachoengsao and Chon Buri. Some agriculturists bought it from Lamae district, Chumphon Province. It was incidentally found that 3% of soil in the planting area was very severe acidic level with the value of **pH below 4**, 51 % had moderate acidic level with the values of pH ranged from 4 to 6, and 46 % were non acidic level with the values of pH were 6. Moreover, more than 50% of palm planting was done in an acidic area (Table 3).

Table 3. The spreading of varieties of oil palm that found in various pH level soils in Chachoengsao Province.

Palm varieties	pH			Area	
	<4	4-6	>6	Rai	Hectare
Univanich	250	3,695	585	4,530	724.8
Tenera(DxP)	10	554	1,886	2,450	392
Deli x Lamae	-	80	1,189	1,269	203.04
Surat Thani	-	-	431	431	68.96
Deli x Compact	-	-	60	60	9.6
Nhongped(DxP)	-	-	62	62	9.92
Total	260	4,329	4,231	8,802	1,408.32

Products of Oil Palm in Chachoengsao province

Results in Table 4 suggest that the pH level of soil at 6 was the suitable soil conditions for oil palm cultivation (Theerapong, 2011). The hybrid variety, Tenera (DxP) could produce the highest yield, which was commonly grown in Tha Takiap, Pleang Yao, Phanom Sarakham, Mueang, and Ratchasan District, respectively. All of them were highly suitable for the cultivation. The soil with pH level less than 6 was suitable for the cultivation of the Univanich variety which yielded 632 kgs per rai, whereas the Tenera variety (DxP) and Deli Compact yielded 30 and 520 kgs per rai, respectively. In addition, it was found that the plantation of the Univanich variety in acid soil where the pH level was less than 4 yielded a good level of the product in several areas, i.e., Bang Khla sub-district of Ratchasarn District, and Khao Hinson sub-district of Phanom Sarakham.

Table 4. Showing FFB yields of various varieties of oil palm in Chachoengsao Province.

Palm varieties	FFB yield (kg/rai/time of harvesting)		
	pH <4	pH 4-6	pH >6
Univanich	332	632	650
Tenera(DxP)	200	430	700
Deli x Lamae	-	520	550
Surat Thani	-	-	500
Deli x Compact	-	-	570
Nhongped(DxP)	-	-	510
Total	532	1,582	3,480

The Quality of Oil Palm in Acidic Soil in Chachoengsao Province

Due to the fact that this research was to investigate the quality of oil palm from the fresh palm fruits after the extracting process during each period of extraction. After three months of recording of the oil quality (June – August, 2012) using Free Fatty Acid (Analysis method = AOCS Ca 50-40) and the process of separating the plantation areas in the soils with the pH levels of soil were less than and greater than 6, it was found that 2-3 % was in high oil quality, and 3-4% was in moderate oil quality. There were more than 4% which was grown in highly acidic soil could affect the oil quality for bio-diesel (B100). The Free Fatty Acid level in palm oil (or the acidity of palm oil) in normal plantations, where the pH level of soil was greater than 6 are recorded, and it was found that Univanich (UV), Tenera (DxP), and Deli Compact variety had an average acidity of 3.48, 3.66, and 3.50, respectively. In acidic soil where the pH level was greater than 6, it was found that the Univanich variety (UV) had a lowest level when compared with Tenera (DxP) and Deli Compact, which had an average acidity at 3.72 and 3.63, respectively. It was also found that the Univanich (UV) variety was the most productive one in both acidic and normal soil. It was clearly shown that the Univanich variety was the one that was able to grow in low acidic soil and gave a productive result as well as a desirable variety for oil distillery factories. (Figure 2 and Figure 3)

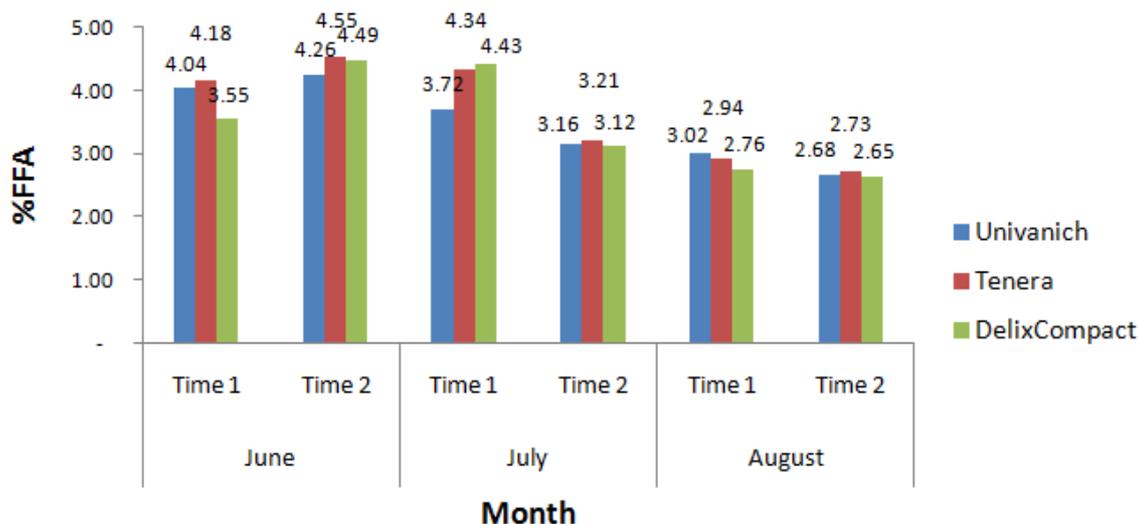


Figure 2. Showing a comparison of FFA detected in varieties Univanich, Tenera, and Deli x Compact grown in soil pH > 6 in Chachoengsao province.

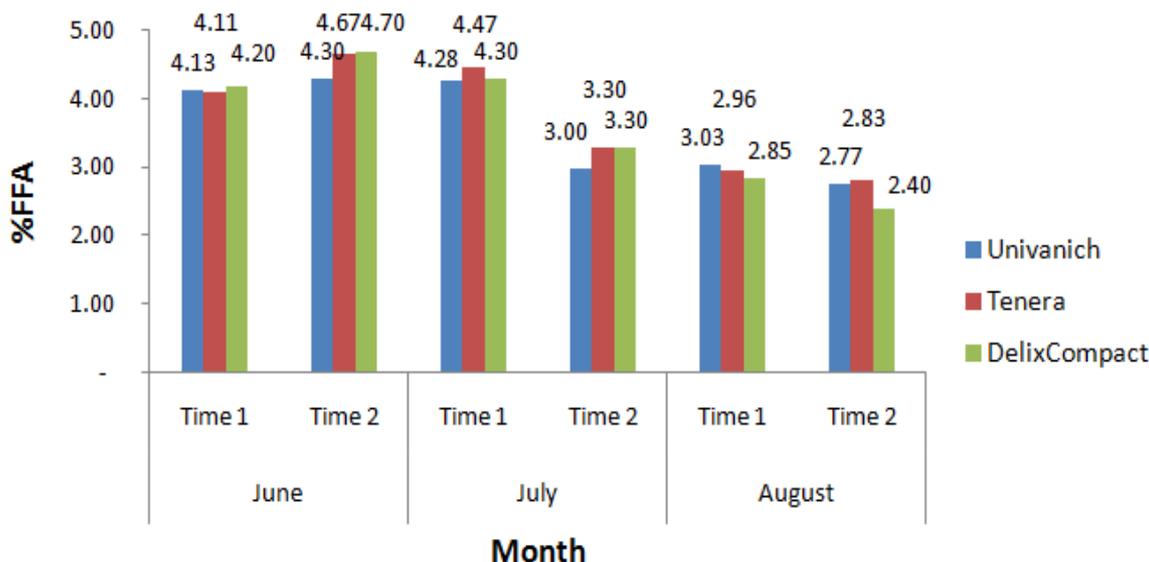


Figure 3. Showing a comparison of FFA detected in varieties Univanich, Tenera, and Deli x Compact grown in soil pH < 6 in Chachoengsao province.

4. Conclusion

The study revealed that the spreading of oil palm plantation in the eastern Thailand originated from the government policy of plantation area enlargement in promoting the substitute-energy policy. In regards to this policy, the promotion of exploitation in the waste areas was done. By this, infertile areas or non-irrigated areas were changed to be a palm oil plantation

for substitute energy. Incidentally, the private sectors like Suksomboon Palm Oil Company Ltd. and Eastern Palm Oil Company Ltd. played an important role for spreading the plantation area as well as being the market for the eastern Thailand. In Chachoengsao, the palm plantation area was totally 8,927 Rai. The six varieties of palm trees were Univanich for 8,036 Rai (92%), Tenera for 694 Rai (7.77%), Deli Lama for 60 Rai (0.67%), Surat Thani for 62 Rai (0.69%), Deli Compact for 75 Rai (0.84%), and Nong Ped for 30 Rai (0.33%). The variety Univanich (UV) was the most fruitful variety in the acidic area, which produced 632 kgs/Rai, Tenera produced 430 kgs/Rai, and Deli Compact 520 kgs/per Rai. The difference of fruitfulness quantity was resulted from their heredity. Therefore, the spreading of palm plantation should be considered for the suitable condition of plantation areas in order to secure both qualitative and quantitative productivity.

For the percentage of acidity or Free Fatty Acid (%FFA) of three varieties, i.e., Univanich, Tenera and Deli Compact, it was found that it was between 3-4 levels of crude palm oil (CPO). Also, it was explicit that the palm oil was in accordance with the standard of the biodiesel oil distillery factory of the Ministry of Energy and the Department of Internal Trade of Thailand after the oil extracting process (Energy Policy and Planning Office, 2011). Interestingly, the soil acidity did not affect the oil quality. The quality of Free Fatty Acid (FFA) of the variety Univanich, Deli Compact, and Tenera was 3.59, 3.65, and 3.72, respectively. The factors effecting the increase of FFA were the 15-20 day-pre-harvesting period (Nithedpattarapong *et al.*, 1996), lack of water in arid season, and bad effects from harvesting and transporting, etc. The Free Fatty Acid of three palm hybrids was not different in the acidic plantation area. Definitely, the suitable arrangement of palm plantation resulted in good harvesting and quality control, e.g. FFA quality. It was a way to add value and decrease the investment (capital) for bio-diesel.

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