VARIABILITY IN FATTY ACID COMPOSITION, IODINE VALUE AND CAROTENE CONTENT IN THE MPOB OIL PALM GERMPLASM COLLECTION FROM ANGOLA

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ABSTRACT

*Forty-two progenies of oil palm (*Elaeis guineensis *Jacq.) from the Malaysian Palm Oil Board (MPOB) germplasm collection from Angola were analysed for their fatty acid composition and carotene content using gas chromatography and UV spectrophotometry, respectively. Their variations in the fatty acid traits and carotene content were considerably larger than in the current breeding materials in Malaysia. Their means for all the traits, except palmitic acid, were also higher. The phenotypic correlations were negative between palmitic/stearic acids and palmitic/oleic acids, so increasing palmitic acid is likely to decrease stearic and oleic acids, and* vice versa*. A negative relationship was also found between oleic/linoleic acids. A number of progenies had carotene contents >1000 ppm and one progeny had iodine value >60. The heritability estimates for the individual fatty acids and carotene content were moderate to high, indicating good genetic control over the traits. The Angolan germplasm is therefore potentially useful breeding materials for improving Malaysian oil palm for commercial planting. However, further studies are needed before the breeding materials proper can be selected and used in actual breeding.*

Keywords: oil palm, fatty acids, iodine value, carotene content, heritability.

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is Malaysia's main crop, occupying about 60% of its cultivated area (Asean Agriculture, 2001). The present commercial planting materials used are derived from an extremely narrow genetic base, and this has been the major constraint to genetic improvement (Hardon and Thomas, 1968; Jagoe, 1952). Recognizing this, in 1991, *E. guineensis* germplasm was collected from Africa, including Angola, to widen the gene pool in Malaysia. The materials collected, however, have had to be evaluated for their potential before their use in breeding. Previous evaluations have shown great variability in the morphological and agronomic characteristics (Rajanaidu *et al.*, 1991). However, no study has yet been done on the chemical composition of the oil. The objective of this study was, therefore, to evaluate the fatty acid composition (FAC) and carotene content of the oil from the Angolan germplasm. It is hoped that the data obtained will be useful in the selection of breeding materials for the future improvement of planting materials in this country.

MATERIALS AND METHOD

Materials

The materials evaluated were the Angolan germplasm from MPOB Oil Palm Genebank in Kluang. Forty-two open pollinated progenies with

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16 palms/progeny/replicate with two replicates had been planted in predominantly Rengam Series soil (*Typic paleudult*) in 1994 as Trial 0.312 in a completely randomized design with equitriangular spacing of 8.84 m between palms (148 palms ha^{-1}). The trial covers nearly 9 ha. Fertilizing was done every six months at the standard rates recommended by the MPOB Agronomy and Fertilizer Technology Unit. All the 42 progenies were evaluated. Ten bunches from each progeny were taken at random from different palms giving a total of 420 bunches for analysis. No palm had more than one bunch sampled.

Method

The oil was conventionally solvent-extracted using hexane - from three spikelets taken at random from each bunch. The crude mixture of oil and hexane was then separated using a rotary evaporator, and the oil converted to methyl esters before the FAC was determined. The analyses for FAC were carried out in glass columns (1.8 m long and 3 mm internal diameter) using the Perkin-Elmer, Gas Chromatography System. The column temperature was maintained at 180°C while the injection and detector temperatures were both 220°C. Helium gas was used as the carrier at a flow rate of 40 ml min^{-1}. The system was calibrated with a standardized mixture of palm methyl esters. Data output from the system was in the form of a chart showing peaks for the individual fatty acids. For the percentage of each fatty acid, a data integrator converted the area under each peak to a percentage of the total area under all the peaks.

The carotene content was determined using a spectrophotometer. The measurement was taken at 446 nm of the absorbency of a homogenized and diluted sample, using 1 cm quartz cuvettes. The 2,2,4-trimethylpentane was used as the reagent to dilute the oil samples. Normally, the colour of the diluted oil is brighter so that the absorbance at 446 nm is within Beer's Law. In general, all tests must be carried out within the confines of the law, as outside of it makes the results inaccurate.

Data Analyses

All the data were analysed using analysis of variance (ANOVA) (Cochran and Cox, 1957). Comparison between the progeny means was by Duncan's New Multiple Range Test (DNMRT) at the minimum 5% level of probability. The relationships between the traits were determined by simple correlation, and their heritabilities estimated using the ANOVA components method.

RESULTS AND DISCUSSION

Progeny Performance

The ANOVA (*Table 1*) showed great variability among the progenies. This was not unexpected as the palms were derived from wild groves where the palms were highly variable.

Palmitic acid (C16:0), a saturated fatty acid, had progeny means of 37.2% to 42.6%, with individual values ranging from 29.8% to 48.6% (*Table 2*). The frequency distribution for the trait showed that the majority of progenies had means between 39.5% and 40.5% (*Figure 1*). A previous evaluation of commercial *dura* x *pisifera* (DxP) materials by Tan and Oh (1981) found individual values of 41.8% to 46.8%. This indicates that the Angolan germplasm was more variable than the DxP materials. The ideal palmitic acid level for palm oil as recommended by Tan *et al.* (1986) is <25%. A lower content is preferred because palmitic acid is the main component of stearin, the lower price fraction of palm oil. With lower stearin and higher olein, a higher oil price can be commanded.

Stearic acid (C18:0), another saturated fatty acid, showed progeny means of 4.2% to 6.6%, with individual values of 0% to 9.7% (*Table 2*). The majority of the progenies had between 4.5% and 6.5% (*Figure 1*). Tan and Oh (1981) found the individual stearic acid contents in commercial DxP materials to range from 4.2% to 5.1%. The Angolan germplasm was again more diverse. The wider range is seen as an advantage, as it would be more possible to select for low stearic acid. However, high stearic acid may also be desirable as a high value fat substitute for confectionery applications.

Oleic acid (C18:1) is monounsaturated, the largest single fatty acid component of palm oil. The progeny means of oleic acid content were between 37.8% and 43.8%, with the individual values between 30.7% and 50.2% (*Table 2*). The majority of the progenies were between 40.5% and 43.5% (*Figure 1*). Comparing with the results of Tan and Oh (1981) on DxP materials (37.3%-40.8%), the Angolan materials were more variable. Although they had only a slightly higher overall mean than the DxP materials, several of the individual values were considerably higher (up to 50.2%). Oleic acid is mainly responsible for the liquid nature of palm oil, and the high values of some of the progenies would be very useful in breeding. Six progenies contained >43% oleic acid, compared with the normal palm oil content of 39%. However, there is a negative correlation between oleic/linoleic acids which detracts from the breeding as both contribute to the iodine value (I.V.) of the oil. Therefore, raising one may merely lower the other for little change in the I.V.

TABLE 1. RESULTS OF ANALYSIS OF VARIANCE FOR THE EFFECTS OF ANGOLAN GERMPLASM PROGENIES ON THE CHARACTERISTICS OF PALM OIL

Source of variation	d.f.	Mean squares					
		Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Iodine value	Carotene content
Progenies	41	15.54**	3.738**	26.79**	9.361**	6.759**	539 814**
Error	378	7.33	1.748	9.88	3.258	5.743	117 264

Note: ** Significant at p-0.01.

TABLE 2. RANGE OF PROGENY MEANS, OVERALL MEANS AND RANGE OF INDIVIDUAL VALUES FOR OIL CHARACTERISTICS IN THE ANGOLAN OIL PALM GERMPLASM

Trait	Range of progeny mean	Overall mean	Range of individual values
Palmitic acid (%)	37.3 - 42.6	39.6	29.8 - 48.6
Stearic acid (%)	4.2 - 6.6	5.4	0.0 - 9.7
Oleic acid (%)	37.8 - 43.8	41.1	30.7 - 50.2
Linoleic acid (%)	9.9 - 14.7	12.4	0.4 - 19.4
Iodine value*	54.7 - 60.4	57.4	49.6 - 67.4
Carotene content (ppm)	409 - 1 280	785	211 - 2 604

Note: * In absolute units.

Linoleic acid (C18:2) is a polyunsaturated fatty acid. The progeny means were 9.9% to 14.7%, and the individual values 0.40% to 19.4% (*Table 2*). Most of the progenies had between 11.5% and 12.5% (*Figure 1*). Compared with the results of Tan and Oh (1981), both the means and variation were much higher in the Angolan germplasm than in the former (9.1%-11%). Linoleic acid is a significant contributor to the oil I.V. and, within limits, a higher content is nutritionally desirable.

The I.V. reflects the liquidity and unsaturated FAC of the oil. In palm oil, the I.V. is contributed by its contents of palmitoleic, oleic, linoleic and linolenic acids. The progeny means among the Angolan germplasm were from 54.7 to 60.4, with the majority between 55.5 and 59.5 (*Figure 1*). The individual values ranged from 49.6 to 67.4 (*Table 2*). A comparison with the results of Tan and Oh (1981) showed that the range in individual values from the Angolan germplasm (49.6-67.4) was greater than that from DxP materials. The global trend in edible oil consumption is towards liquid oils, and the wider I.V. range should facilitate the breeding for higher I.V. palm oil.

The carotene content of an oil is actually a measure of its β-carotene level. Among the progenies, the mean carotene contents were 409 ppm to 1280 ppm, with the majority between 550 ppm and 1150 ppm (*Figure 1*). The individual values ranged from 211 ppm to 2604 ppm (*Table 2*). The results of Choo *et al.* (1989) for *E. guineensis* were 997 ppm for *dura*, 673 ppm for *tenera* and 428 ppm for *pisifera*. This indicates that the carotene levels in some of the Angolan progenies may be higher than the maximum for *E. guineensis* materials in this country.

Ten progenies with carotene contents >1000 ppm were identified, and can potentially be used for breeding towards the MPOB criterion of >1000 ppm carotene. One of the progenies also had an I.V. of >60% and may be a useful parent for breeding for both high I.V. and carotene.

Correlations

Simple correlation coefficients between the traits are shown in *Table 3*. In general, averaged over all the progenies, there were strong negative individual relationships between palmitic acid, on the one hand, and stearic acid, oleic acid and I.V., on the other. There was also a similar relationship between oleic and linoleic acids. Thus, increasing the palmitic acid would decrease the levels of stearic acid, oleic acid and I.V. in the oil. It is well known that increasing palmitic acid would decrease the liquidity of the oil, which would be undesirable, especially in cooking oil. The breeding objective should therefore be the converse – to increase the oleic acid, which should decrease the palmitic acid and thereby increase the unsaturation and liquidity of the oil. The positive correlation between palmitic acid/carotene content and negative correlation

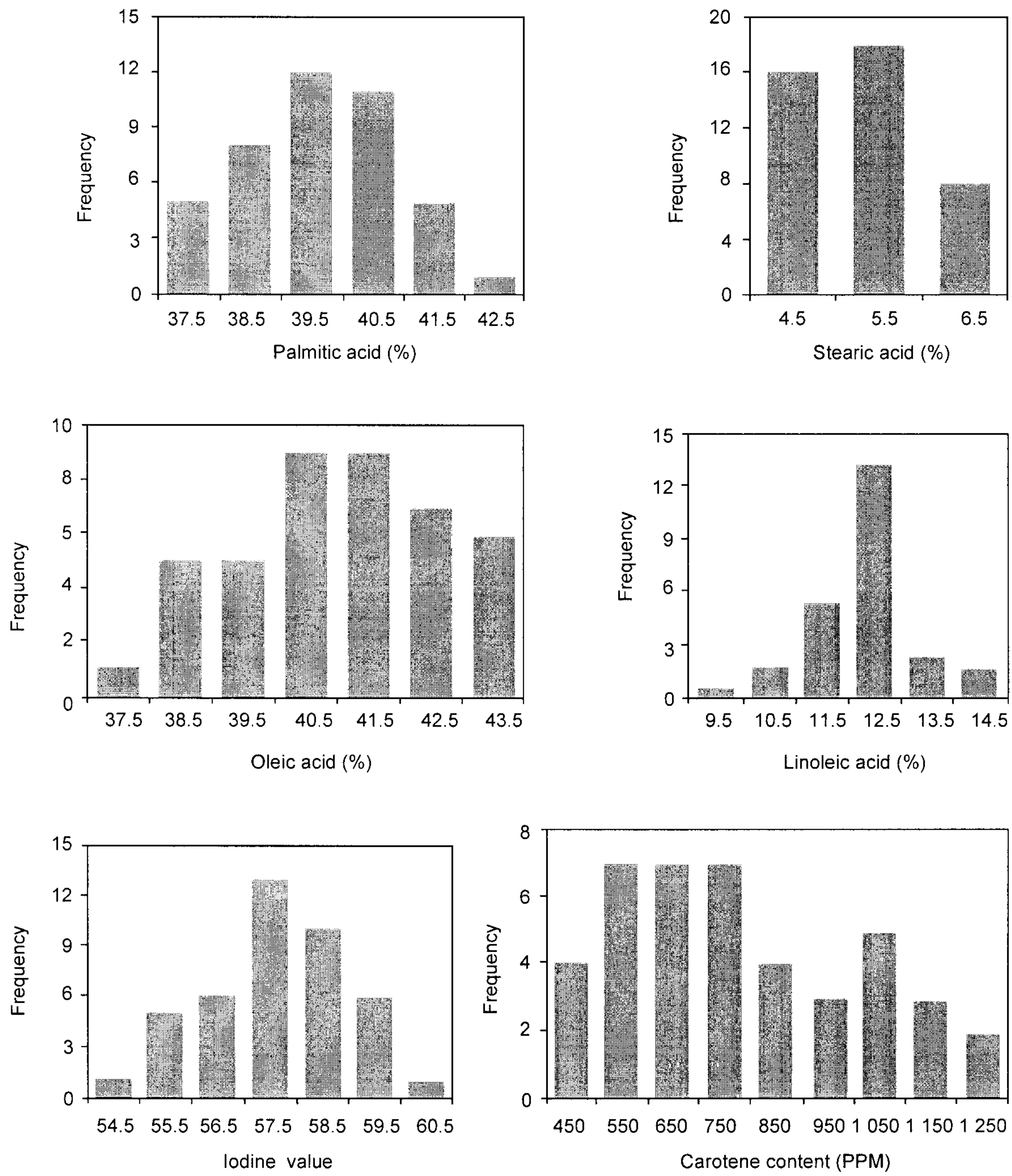

Figure 1. Frequency distribution of fatty acids and carotene content in palm oil from the Angolan germplasm.

between the latter and linoleic acid are unfortunate. However, this problem may perhaps be overcome through methods such as backcrossing and intercrossing. Besides these, the negative correlation between oleic/linoleic acids is also of concern since these acids contribute significantly to the quality and liquidity of palm oil. The positive correlations between I.V. and oleic and linoleic acids are a boon as both these contribute to the I.V. Similar correlations were obtained by Arasu (1985) between the fatty acids but the carotene content was not studied.

Heritability

The heritabilities were moderate to high (*Table 4*), with those for carotene (0.78) and palmitic acid (0.52) contents the highest and lowest, respectively. The reasonable heritabilities indicate that the traits are under fairly good genetic control, and should be

TABLE 3. SIMPLE CORRELATION COEFFICIENTS BETWEEN THE TRAITS MEASURED ON THE 42 PROGENIES OF THE ANGOLAN OIL PALM GERMPLASM

	Palmitic acid content	Stearic acid content	Oleic acid content	Linoleic acid content	Iodine value
Stearic acid content	-0.5492**	-	-	-	-
Oleic acid content	-0.7282**	0.0986*	-	-	-
Linoleic acid content	-0.0944*	0.0058	-0.6356**	-	-
Iodine value	-0.6924**	0.1085*	0.2900**	0.5124**	-
Carotene content	0.0711*	0.0305	-0.0325	-0.1703**	-0.1848**

Notes: ** Significant at p-0.01.
* Significant at p-0.05.

TABLE 4. PROGENY MEAN SQUARES AND ERROR MEAN SQUARES FROM ANALYSIS OF VARIANCE AND ESTIMATES OF BROAD-SENSE HERITABILITY FOR THE TRAITS MEASURED IN THE 42 PROGENIES FROM THE ANGOLAN OIL PALM GERMPLASM

Trait	Progeny mean square ($\sigma^2 + s\sigma^2_p$)	Error mean square (σ^2)	Broad-sense heritability (h_B^2) (%)
Palmitic acid	15.53	7.33	0.52
Stearic acid	3.73	1.74	0.53
Oleic acid	26.78	9.87	0.63
Linoleic acid	9.36	3.25	0.65
Iodine value	16.75	5.74	0.65
Carotene content	539 814	117 264	0.78

easily transmissible in breeding. The study by Arasu (1985) on Nigerian germplasm materials, however, found generally low heritabilities for the fatty acid traits. To verify the results, therefore, more progeny tests should be done.

CONCLUSION

The Angolan germplasm collected by MPOB exhibited wide variability in FAC, I.V. and carotene content in their oils. The variabilities found were greater than those in the current DxP materials. In addition, the germplasm also had a lower mean palmitic acid content.

The negative correlations between palmitic acid and stearic acid and oleic acid in the Angolan germplasm should be advantageous in breeding. Selecting for high oleic acid would likely reduce the level of palmitic acid.

With their reasonable variation and heritabilities for several important oil traits, the Angolan germplasm has much to offer towards the genetic improvement of Malaysian oil palm planting materials. The favourable traits can be introgressed into the current DxP to improve their performance besides broadening their present narrow genetic base. However, further studies such as progeny testing and evaluation of GxE interaction would need to be carried out before the germplasm can be used in breeding programmes proper.

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