# GENETIC CONTROL OF POLYMORPHISM FOR KERNEL-TO-FRUIT RATIO IN THE OIL PALM (*Elaeis guineensis* Jacq.)

**Keywords**: *Elaeis guineensis Jacq.*; oil palm; polymorphism; kernel-to-fruit ratio; genetics.

OKWUAGWU, C O AND OKOLO, E C*

*The Nigerian Institute for Oil Palm Research
Benin City, Nigeria

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*A study to clarify the genetic control of polymorphism in kernel-to-fruit ratio in the oil palm* Elaeis guineensis *Jacq. was carried out on the basis of the following crosses from the NIFOR oil palm breeding programme – 45* tenera *(T) × *tenera*; 24* tenera *(T) selfings; 33* dura *(D) ×* tenera*; and 29* tenera *(T) ×* dura *(D).*

*The mean kernel-to-fruit ratio (%K/F) for the* dura *and* tenera *fruit forms and the* tenera:dura *(T:D) ratio of %K/F were determined for each of the segregating progenies. Estimates of correlation coefficient (r) and narrow-sense heritability ($h^2$) derived from parent-offspring regression analysis for the T:D ratio of %K/F were obtained for each type of cross.* Dura *and* tenera *fruit forms showed distinct differences in their mean %K/F, thus confirming that the oil palm exhibits polymorphisms in its kernel size, with the* dura *progeny having a higher mean %K/F than the* tenera *in all the segregating crosses.*

*The coefficient of correlation between the %K/F of the* tenera *parent and the* tenera:dura *ratio of %K/F of selfed offspring was highly significant (r = 0.52**). The comparison between the female* tenera *parent T:D ratio of %K/F and that of the T×T offspring was highly significant (r = 0.44**) with a high narrow-sense heritability estimate ($h^2$ = 67%). A similar comparison with* *the male* tenera *parent was not significant (r = 0.18NS) and had a low heritability estimate ($h^2$ = 25%). In D×T and T×D crosses the estimates of the correlation coefficient of the* tenera *parent to T:D ratio of %K/F and the offspring values were not significant (r = 0.17NS and 0.20NS respectively).*

*This indicated that* tenera *parents carry a certain kernel inhibiting factor (or factors) that reduces the kernel size of the* tenera *offspring relative to their* dura *sibs. This factor(s) was transmitted to the* tenera *offspring especially when* tenera *was the female parent. The kernel inhibiting factor(s) is proposed to be closely linked with the recessive allele of the gene controlling shell thickness. The implication of this for the kernel size and fertility of* pisifera *palms is discussed.*

## INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) exhibits polymorphism in its fruit composition which is the basis for the classification of the forms of this species. The monofactorial inheritance of the three fruit forms was established by Beirnaert and Vanderweyen (1941). The thick-shelled *dura* (D), homozygous for the major gene (*Sh Sh*) that determines the presence or absence of shell is characterized by the production of large fruits with large kernels (endosperm) and a small proportion of oil-bearing mesocarp. The thin-shelled *tenera* (T) form, heterozygous for the shell gene (*Sh sh*), produces smaller fruits with smaller kernels and a larger proportion of oil-bearing mesocarp, as compared with the *dura*. The shell in the *tenera* is always surrounded by a distinct fibre ring. The shell-less *pisifera* (P) form, homozygous recessive for the shell gene (*sh sh*) has smaller fruits with a distinct fibre ring surrounding a very much reduced kernel. In some cases the kernel may be absent, with the oil-bearing mesocarp constituting the entire *pisifera* fruit. The *pisifera* is an essentially female sterile palm which occasionally produces mature bunches with varying frequencies of pathenocarpy and immature fruits. The *dura* and the *pisifera* breed true for their respective forms in intra-fruit form crosses, while *tenera* × *dura* or *dura* × *tenera* crosses segregate *dura* and *tenera* offspring in equal proportions. *Tenera* × *tenera* and *tenera* selfings segregate *dura*, *tenera* and *pisifera* palms in a monofactorial ratio of 1:2:1 respectively.

There is continuous variation in kernel size within fruit form in all populations. However, the mean kernel-to-fruit ratio (%K/F) of the *dura* form is generally higher than that of the *tenera* form, irrespective of the source of the segregating population, with the *tenera* %K/F being about 1/5 lower than that of the *dura*. Thus there is some overlap in the distribution of kernel size of the *dura* and *tenera* forms. Kernel-to-fruit ratio in the *dura* can range from 6% to 25% while in the *tenera* it can vary from 2% to 20% . In the shelless *pisifera* the kernel-to-fruit ratio ranges from 0% in 'blind' parthenocarpic fruits to 8% in fertile palms (Hartley, 1977).

The objective of this study was to clarify the genetics of polymorphism for kernel-to-fruit ratio in the oil palm.

## MATERIALS AND METHODS

The palms used in this study have been described in an earlier report (Okwuagwu and Okolo, 1992). The crosses were derived from the first cycle population of the modified Reciprocal Recurrent Selection oil palm breeding programme of the Nigerian Institute for Oil Palm Research (NIFOR). Four segregating populations were evaluated, *viz*: 24 *tenera* selfings; 45 *tenera* × *tenera* (T×T); 29 *tenera* × *dura* (T×D), and 33 *dura* × *tenera* crosses. Palms resulting from these crosses were planted at the NIFOR Main Station between 1960 and 1964.

Standard fruit and bunch analyses by weight percentages as described by Blaak *et al.* (1963) were carried out on ripe bunches on an individual palm basis from the second year of bunch production over a period of 3–4 years. 15–20 *dura* and 20–30 *tenera* palms were analysed per progeny, with an average of 3–4 bunches analysed per palm. Mean percent kernel-to-fruit ratio (%K/F) was then calculated separately for each of the two fruit forms in each progeny. Because of the very limited analysis of *pisifera* palms, this investigation was limited to the *dura* and the *tenera* fruit forms, from which inferences were made for the *pisifera*.

Using the segregating *tenera* and *dura* offspring of the *tenera* selfings, the *tenera:dura* ratio for %K/F was derived for each *tenera* parent. This *tenera:dura* ratio for %K/F was then related to the %K/F of the *tenera* parents. Similarly, the *tenera:dura* ratio of %K/F was determined for the T×T, D×T and T×D crosses. The *tenera:dura* ratio for %K/F of each full sib family was then used for correlation and regression analyses with the respective *tenera:dura* ratio of %K/F estimated for the corresponding *tenera* parent. There was no direct method of estimating the inherent *tenera:dura* ratio of %K/F for the *dura* parents, as *dura* selfings breed true for the *dura* fruit form. Narrow-sense heritability ($h^2$) for the *tenera:dura* ratio of %K/F was estimated by the regression coefficient (b) for mid-parent values, and by twice the regression coefficient in single parent comparisons.

## RESULTS

The variation in percentage kernel-to-fruit ratio (%K/F) of *dura* and *tenera* progenies from the four types of segregating crosses is presented in *Table 1* and illustrated in *Figure 1*. In all four types of crosses, the mean %K/F of the *dura* progenies are consistently higher than those of their *tenera* sibs. However, there is overlap in the %K/F values of the *dura* and *tenera* sibs, the over-lapping of values being highest in D×T crosses and lowest in T×T crosses (*Figure 1*). Thus the mean %K/F of *tenera* palms produced by D×T crosses is closer to that of the their *dura* sibs. The mean *tenera:dura* ratio of %K/F for D×T crosses is 0.858, while the mean *tenera:dura* ratio of %K/F of T×T crosses is 0.774. The *tenera:dura* ratio of %K/F for the segregating selfs is highly correlated with the %K/F of their *tenera* parents (r = 0.52**). The *tenera:dura* ratio of %K/F ranged from 0.58 in the *tenera* parent with 5.7 %K/F to 1.032 in the *tenera* parent with 11.4 %K/F.

The estimates of the coefficient of correlation (r) and the narrow-sense heritability ($h^2$) for the *tenera:dura* ratio of %K/F derived from offspring-parent regression in the three types of crosses are presented in *Table 2*. In T×T crosses, the correlation between the *tenera:dura* ratio of %K/F for the female parent and its offspring is highly significant (r = 0.44**) with a high narrow-sense heritability estimate ($h^2$ = 67%). A similar comparison using the *tenera* male parent gave a non-significant correlation coefficient (r = 0.18NS) and a low heritability estimate ($h^2$ = 25%). The mid-parent offspring comparison for T×T crosses is highly significant (r = 0.47**) and the heritability estimate is average ($h^2$ = 56%). For the 29 T×D crosses, the estimates of the correlation coefficient for the female *tenera* parents is not significant (r = 0.20NS); the heritability estimate is also low ($h^2$ = 35%). Similarly, using 33 D×T crosses, the relationship between the *tenera:dura* ratio of %K/F of the male *tenera* parent and the segregating *tenera* and *dura* offspring gave a non-significant correlation coefficient (r = 017NS) and a lower $h^2$ estimate ($h^2$ = 26%).

## DISCUSSION

Kernel-to-fruit ratio (%K/F) in the oil palm shows continuous variation, but *dura* and *tenera* fruit forms have distinct differences in their mean %K/F as illustrated in *Figure 1*, thus confirming that the oil palm exhibits polymorphism in its kernel-to-fruit ratio, with *dura* having a higher mean %K/F than *tenera* in all types of crosses.

On selfing, a *tenera* palm produces *dura* and *tenera* offspring whose relative difference in %K/F (*tenera:dura* ratio of %K/F) is found to be highly correlated with the %K/F of the parent. The *tenera* palms with higher %K/F produce on selfing

TABLE 1. MEAN KERNEL-RATIO-TO-FRUIT RATIO (%K/F) AND *Tenera*:Dura RATIO OF %K/F OF *Dura* AND *Tenera* SEGREGANTS FROM *Tenera* SELFINGS, *Tenera* × *Tenera*, *Tenera* × *Dura*, AND *Dura* × *Tenera* CROSSES

| Type of cross | Number of Crosses | *Dura* Progeny Mean %K/F | CV(%) | *Tenera* Progeny Mean %K/F | CV(%) | *Tenera*:*Dura* Ratio of %K/F |
|---|---|---|---|---|---|---|
| *Tenera* selfed | 24 | 10.1 | 18 | 8.0 | 12 | 0.792 |
| *Tenera* × *Tenera* | 45 | 10.6 | 12 | 8.2 | 16 | 0.774 |
| *Tenera* × *Dura* | 29 | 10.6 | 10 | 8.7 | 14 | 0.821 |
| *Dura* × *Tenera* | 33 | 11.3 | 11 | 9.7 | 12 | 0.858 |

TABLE 2. ESTIMATES OF THE CORRELATION COEFFICIENT (r) AND THE NARROW-SENSE HERITABILITY ($h^2$) DERIVED FROM PARENT-OFFSPRING REGRESSION ANALYSIS FOR *Tenera*:*Dura* RATIO OF %K/F IN THREE TYPES OF CROSSES IN THE OIL PALM

| Type of cross | Number of Crosses | Parent | r | b | $h^2$(in %) |
|---|---|---|---|---|---|
|  | 45 | Female | 0.44** | 0.33 | 67 |
| 1. *Tenera* × *Tenera* | 45 | Male | 0.18NS | 0.13 | 25 |
|  | 45 | Mid Parent | 0.47** | 0.56 | 56 |
| 2. *Tenera* × *Dura* | 29 | Female *Tenera* | 0.20NS | 0.18 | 35 |
|  | 29 | Male *Dura* | – | – | – |
| 3. *Dura* × *Tenera* | 33 | Female *Dura* | – | – | – |
|  | 33 | Male *Tenera* | 0.17NS | 0.13 | 26 |

NS = not significant
* = significant at 5% level
** = significant at 1% level

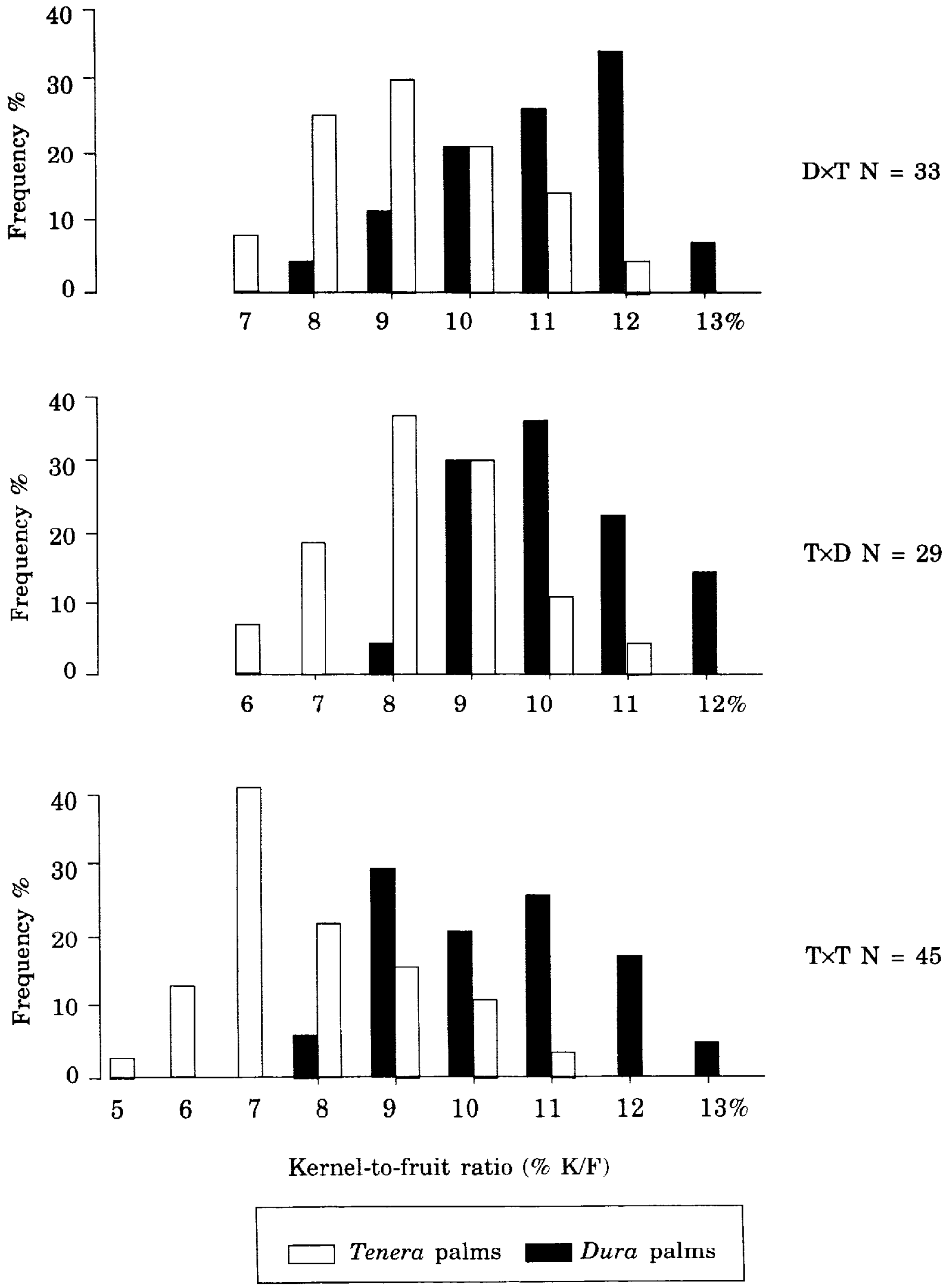

*Figure 1. Histogram for mean kernel-to-fruit ratio of* Dura *and* Tenera *palms from three types of crosses in the oil palm.*

*dura* and *tenera* palms which differ less in their %K/F than segregants of a *tenera* parent with lower %K/F. The difference between *tenera* and *dura* kernel-to-fruit ratio is inherited by the *tenera* offspring from its *tenera* parent, especially when *tenera* is the female parent. The *tenera* offspring inherits from its *tenera* parent a certain factor(s) which tends to inhibit its kernel development relative to its *dura* sibs, as is apparent in all crosses. Since the *dura* does not inherit this kernel inhibiting factor(s) from its *tenera* parent, the factor may be seen to be closely linked to the *sh* allele of the *Sh-sh* locus. It follows that in the *pisifera* (P) fruit form, which is homozygous recessive for the shell gene (*sh sh*), the kernel inhibiting factor(s) is inherited from both parents either in T×T or T×P crosses, accounting for the very much reduced kernel size of the *pisifera*. Therefore, *tenera* parents with large kernels will be expected to produce a higher frequency of fertile *pisifera* palms. Such *pisifera* palms have inherited lower levels of the kernel inhibiting factor(s) thus allowing for a reasonable level of kernel development, which is essential for fertility. The general observation, therefore, that thick-shelled *tenera* palms are always found in progenies segregating for high frequency of fertile *pisifera* may indeed be a consequence of the highly positive correlation between kernel size and shell thickness in the *tenera* (van der Vossen, 1974).

The difference in the %K/F of *dura* and *tenera* palms segregating from the three types of crosses (*Figure 1*), provides further support for the concept of the heritable genetic factor(s) that limits kernel growth in the *tenera* palms relative to their *dura* sibs. In *tenera* × *tenera* crosses, a *tenera* offspring inherits the kernel inhibiting factor(s) from a parent, particularly from the female parent, thus accounting for its lower *tenera:dura* ratio of %K/F (0.77) relative to the progeny of D×T or T×D crosses. In T×D crosses, the presence of the *dura* parent appears to reduce the effect of the kernel inhibitor(s) of the female *tenera* parent, from 76% as in T×T crosses to 35% in T×D crosses. Thus the *tenera* palms that result from T×D crosses have %K/F values slightly higher than the *tenera* palms derived from T×T crosses, 8.7 % and 8.2% respectively, while the %K/F of the resultant *dura* palms from both types of crosses remains the same, at 10.6 per cent. For D×T crosses, the effect of the kernel inhibitor(s) becomes much more reduced, and the *tenera:dura* ratio of %K/F consequently becomes higher, 0.86 percent. This confirms that indeed the *dura* female parent is unable to confer the factor(s) which reduces kernel development in *tenera* palms relative to their *dura* sibs, and since the kernel inhibiting factor(s) is mainly inherited maternally, the effect of the male *tenera* parent on its D×T *tenera* offspring is limited. This absence of the full expression of the kernel inhibiting factor(s) of the male *tenera* parent in D×T crosses allows for fuller development of the kernel in both the *dura* and *tenera* segregants recorded for the D×T crosses as compared with either T×T or T×D crosses (*Table 1*).

In an earlier study (Okwuagwu and Okolo, 1992), the kernel-to-fruit ratio in the oil palm was shown to be determined by factor(s) in the female parent which interact with the *dura* parent when it is used as the male. In the present study, the relative difference between the *tenera* and *dura* ratio of %K/F (polymorphism in kernel size) is shown to be the result of a kernel inhibiting factor(s) closely linked to the *sh* allele carried by the *tenera* and inherited mainly through the female parent. The *dura* parent transmits a factor(s) that allows for normal and certainly fuller development of the kernel in both fruit forms. Thus, while the maternal inheritance of kernel size is functional irrespective of the fruit form of the female parent, the determination of polymorphism in %K/F in the oil palm is inherent in the *tenera* parent. This factor(s), which has been described in this report as having an inhibiting effect on kernel development, has also been proposed to be closely linked with the recessive allele of the shell gene (*sh*), and consequently, accounts for the much reduced kernel in the *pisifera* fruit form.

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