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GENETIC CONTROL OF FERTILITY IN THE OIL PALM (*ELAEIS GUINEENSIS* JACQ.)

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INDEX WORDS

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SUMMARY

A study was conducted on the segregating populations from *tenera* × *tenera*, *tenera* × fertile *Pisifera* crosses and *tenera* selfings. *Pisifera* palms were categorised as (1) fertile *Pisifera* palms if producing mature ripe bunches regularly under natural conditions, and (2) partially female sterile *pisifera* palms if producing a few or no bunches in several years.

Based on observations on the segregation patterns of the fruit forms (*dura*, *tenera* and *pisifera*) and bunch production patterns, a genetic model was formulated to explain the genetic basis of fertility in the oil palm. Fertility in the oil palm is shown to be controlled by a single gene which is linked to the gene controlling fruit form. Chi-square tests confirmed that the model agreed with the segregating ratios of fruit form and fertility observed.

The implications of this finding with regard to oil palm breeding and improvement, and the potential of the fertile *pisifera* palm for increasing palm oil yields in plantations are discussed.

INTRODUCTION

The oil palm has 3 fruit forms: the *dura* with thick-shelled fruit, the *tenera* with thin-shelled fruit and the *pisifera* with shell-less fruit. The monofactorial inheritance of these 3 fruit forms was established by BEIRNAERT & VANDERWEYEN (1941). The absence of shell in *pisifera* is a homozygous recessive condition usually designated *dd*. The presence of shell is a dominant condition and the thick-shelled *dura* is usually designated *DD*. The thin-shelled *tenera* is designated *Dd*. *Pisifera* is thought to be a mutant which has lost the ability to lignity the protective endocarp (SPARNAAIJ, 1969). BEIRNAERT & VANDERWEYEN (1941) showed that they differ in more than just shell thickness. *Dura* palms produce fewer but heavier bunches than *tenera*, the overall bunch yield being the same. The total number of inflorescences is also in general, the same for *dura* and *tenera* but is higher for *pisifera* (SPARNAAIJ, 1969). The proportion of female inflorescences (sex ratio) is highest in *pisifera*, lowest in *dura* and intermediate in *tenera*. The number of spikelets and flowers per spikelet is highest in *pisifera* but the proportion of normal fruits is lowest, often being nil.

Dura and *tenera* are generally fertile. That is, they produce mature ripe bunches regularly under natural conditions with very rare exceptions. *Pisifera* is often unproductive, and is said to be partially female sterile, the female inflorescences tending to abort soon after anthesis. There are however some *pisifera* palms which produce mature ripe bunches regularly under natural conditions. These are called fertile *pisifera* palms to distinguish them from the more common partially female sterile *pisifera* palms which produce a few or no bunches at all in several years. Parthenocarpic fruit formation can be induced in partially female sterile *pisifera* palms by treating the female inflorescences with the growth hormone 2, 4, 5 T.P. (–2,4,5 trichlorophenoxy propionic acid). Some *pisifera* palms which are thought to be completely female sterile are known to produce bunches if they are observed for a long period (OBASOLA, 1974). Different categories of fertile *pisifera* palms have been recorded (GASCON, 1956; SPARNAAIJ, 1960; OBASOLA, 1974; WONKYI-APPIAH, 1975; CHIN, 1981).

For commercial oil palm plantations *tenera* is preferred to *dura* because of its superior fruit characteristics – thin shell and higher percentage of mesocarp, hence a higher oil yield per hectare. *Pisifera,* which is generally partially female sterile, is used only as the pollen parent for the production of the *tenera* commercial seed. However, of special interest is the fertile *pisifera* palm. Some pisifera palm trees have good or even better bunch production than the *tenera* palms and give higher oil yield because of their higher oil-to-bunch ratio (WONKYI-APPIAH, 1980). If the genetic control of fertility or partial female sterility in *pisifera* can be established it will be possible to make any desired combinations that could lead to the establishment of high yielding pure or partial stands of fertile *pisifera* palms in commercial plantations. This study was therefore initiated to investigate the mode of inheritance of fertility in the oil palm.

MATERIALS, METHODS AND RESULTS

The study was conducted on some *tenera* × *tenera* and *tenera* × fertile *pisifera* crosses and *tenera* selfings at the Oil Palm Research Centre, Kade, Ghana. All populations known to contain some fertile *pisifera* palms were included in the study covering a production period of 8–10 years. The fruit form of each palm was ascertained as either *dura, tenera* or *pisifera.* The *pisifera* palms were classified either as fertile, producing mature ripe bunches regularly or partially female sterile, producing a few or no bunches at all over a long period. The different phenotypes in each population were noted. The populations were then categorised into 3 main groups (table 1).

Group A. Tenera × *tenera* crosses and *tenera* selfings with the Mendelian monofactorial F2 ratio for fruit form i.e. *dura: tenera: pisifera* = 1:2:1. All the *pisifera* palms, except a few are partially female sterile.

Group B. Tenera × fertile *pisifera* crosses with the Mendelian backcross ratio for fruit form, i.e. *tenera:pisifera* = 1:1. Half the *pisifera* palms are fertile and half are partially female sterile. Thus the ratio is *tenera*: fertile *pisifera*: partially female sterile *pisifera* = 2:1:1.

Group C. Tenera × fertile *pisifera* crosses with the Mendelian backcross ratio for fruit from i.e. *tenera:pisifera* = 1:1. All the *pisifera* palms are fertile.

In an attempt to explain these fruit forms and bunch production patterns, a genetic model was formulated by postulating that:

1) There is an allele, F, for fertility as defined above which is dominant to its allele, f, which confers partial female sterility in the homozygous state.

2) The allele F (or f) is linked to the allele D (or d) which controls shell thickness.

Table 1. *Tenera* × *tenera* and *tenera* × fertile *pisifera* crosses, and *tenera* selfings and their segregation into phenotypes.

Code	Progeny	Segregation into phenotypes					Ratios	Chi-square	P
		dura (D)	*tenera* (T)	fertile *pisifera* (FP)	partially sterile *pisifera* (PSP)	un-known			
	Group A						*D:T:PSP*		
(1)	851.53T × 851.53T	13	27	–	8	2	1:2:1	1.7316	0.5 to 0.3
(2)	4.838T × 4.838T	7	15	–	7	–	1:2:1	0.0344	0.99 to 0.98
(3)	4.838T × 32.2612T	9	26	–	9	1	1:2:1	1.4545	0.5 to 0.3
(4)	32.3005T × 32.2612T	24	52	2[1]	21	–	1:2:1	0.6908	0.8 to 0.7
(5)	32.3005T × 32.3005T	9	13	–	10	–	1:2:1	1.1875	0.7 to 0.5
(6)	3.415T × 3.415T	27	37	–	21	3	1:2:1	2.2706	0.5 to 0.3
(7)	3.415T × 15.4382T	21	51	5[1]	17	2	1:2:1	2.2576	0.5 to 0.3
(8)	4.1935T × 15.4382T	26	69	2[1]	19	2	1:2:1	5.9123	0.1 to 0.05
(9)	14.892T × 14.892T	24	58	–	25	3	1:2:1	0.7757	0.7 to 0.5
(10)	14.892T × 4.1935T	14	35	1[1]	12	–	1:2:1	1.4590	0.5 to 0.3
	Group B						*T:FP:PSP*		
(11)	851.53T × 4/3029FP		31	18	16	–	2:1:1	0.2615	0.9 to 0.8
(12)	851.74T × 4/3029FP		20	10	6	2	2:1:1	1.3333	0.7 to 0.5
(13)	851.53T × 16/6758FP		35	13	11	1	2:1:1	2.1864	0.5 to 0.3
(14)	851.74T × 16/6758FP		32	27[2]	9	–	?		
(15)	851.550T × 16/6758FP		24	8	9	1	2:1:1	1.2439	0.7 to 0.5
(16)	851.254T × 4/3029FP		33	14	11	1	2:1:1	0.4583	0.8 to 0.7
(17)	851.53T × 1.2215FP		8	5	5	2	2:1:1	0.2222	0.9 to 0.8
	Group C						*T:FP*		
(18)	851.194T × 4/3029FP		22	31	–	5	1:1	1.5283	0.3 to 0.2
(19)	1.2895T × 4/3029FP		18	23	–	–	1:1	0.6098	0.5 to 0.3

[1] Individuals resulting from crossing over and recombination.
[2] Includes some individuals from crossing over and recombination.

The linkage is not absolute.

3) The *dura* and the *tenera* palms which are generally fertile have the dominant allele, F, and the *pisifera* palms which are partially female sterile are homozygous for the recessive allele, f.

4) Occasionally there is crossing over and recombination giving rinse to fertile *pisifera* palms and partially female sterile *tenera* and *dura* palms.

5) Thus possible genotypes and phenotypes are:*Dura*: D-F // D-F fertile (common genotype); D-F // D-f fertile; D-f // D-f partially female sterile;
Tenera: D-F // d-f fertile (common genotype); D-F //d-F fertile; D-f // d-F fertile; D-f // d-f partially female sterile;
Pisifera: d-f // d-f partially female sterile (common genotype); d-F // d-f fertile; d-F // d-F fertile.

Explanation for the observations by means of the genetic model:

1) Genotypes of parents and offspring in Group A (Table 1) are of the types:

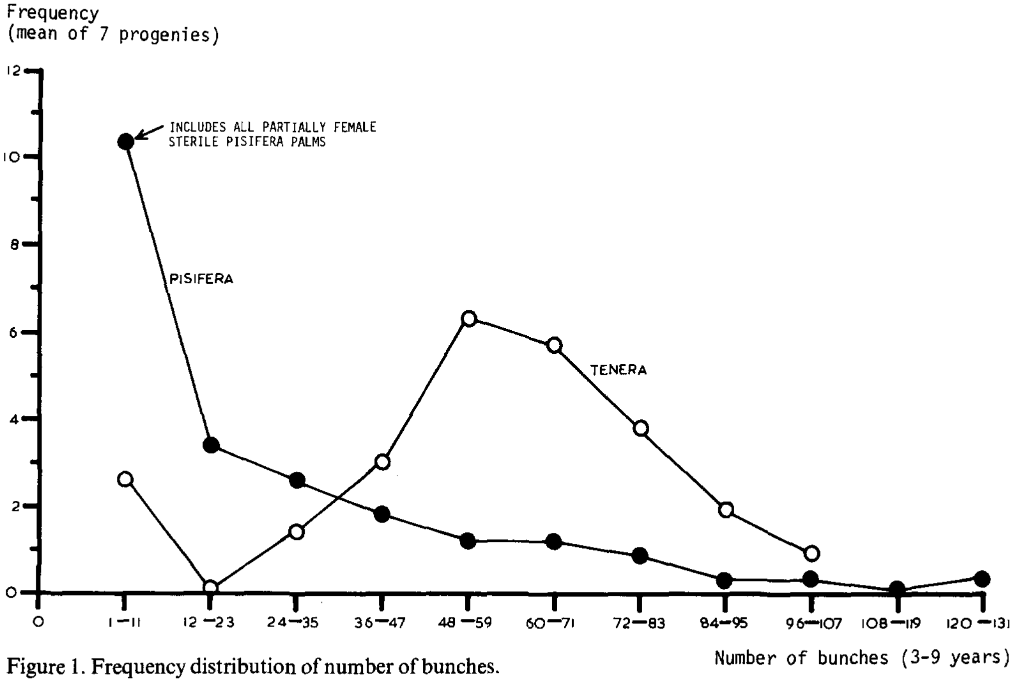

Figure 1. Frequency distribution of number of bunches.

Parents				*Progeny*		
Tenera × *tenera*	→	*dura*		*tenera*		*Pisifera*
D-F//d-f × D-F//d-f		D-F//D-F		D-F//d-f,	D-F//d-f	d-f//d-f
		fertile		fertile	fertile	partially female sterile

This gives a segregation ratio *dura*:*tenera*:partially female sterile *pisifera* = 1:2:1. Where there is crossing over on one or both parents at meiosis, chromosomes of genotype d-F result giving rise to fertile *pisifera* palms of genotype d-F//d-f or d-F//d-F in the population as in progenies (4), (7), (8) and (10) (Table 1).

2) Genotypes of parents and offspring in Group B are of the types:

Parents		*Progeny*			
Tenera × fertile *pisifera*	→	*Tenera*		*Pisifera*	
D-f//d-f × d-F//d-f		D-F//d-F,	D-F//d-f,	d-F//d-f,	d-f//d-f
		fertile	fertile	fertile	partially female sterile

This gives a segregation ratio of *tenera*: fertile *pisifera*: partially female sterile *pisifera* = 2:1:1. The only exception is progeny (14) where this ratio is not obtained and the number of fertile *pisifera* palms is higher than the number of partially female sterile *pisifera* palms in the offspring. The genotype of the parents however fit the segregation in the other crosses in which they are involved (12), (13) and (15). This may be due to a high incidence of crossing over in the *tenera* giving rise to more fertile *pisifera* palms and reducing the number of partially female sterile *pisifera* palms.

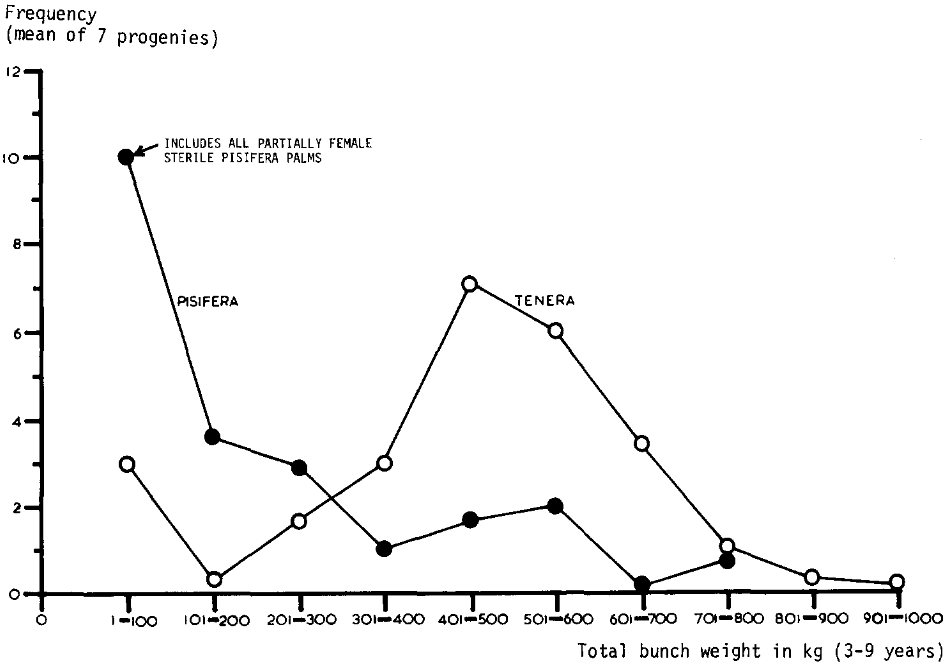

Figure 2. Frequency distribution of bunch weight.

3) Genotypes of parents and offspring in Group C are of the types:

Parents		*Progeny*			
Tenera × fertile *pisifera*	→	*Tenera*		*Pisifera*	
D-F // d-F × d-F // d-f		D-F // d-F,	D-F // d-f	d-F // d-F,	d-F // d-f
		fertile	fertile	fertile	fertile

This gives a segregation ratio of *tenera*: fertile *pisiform* = 1:1.

Chi-square tests showed that the theoretical ratios derived from the model agreed with the defined classes in all but one of the 19 progenies studied (Table 1). An explanation for the discrepancy in progeny (14) is that there was an unusually high frequency of crossing over druing the formation of gametes in the *tenera* parent thus increasing the proportion of fertile *pisifera* palms in the offspring.

A detailed study of the populations in Group B showed that while the distribution of number of bunches and bunch weight in the *tenera* population showed that for normal distribution for quantitative characters, this was not so in the *pisifera* population (Figs 1 and 2) which consisted of equal proportions of partially female sterile *pisifera* palms and fertile *pisifera* palms as defined. In the *pisifera* population, the frequency decreassed with increase in the number of bunches and total bunch weight from year 3 to year 9. The partially female sterile *pisifera* palms fell into one group as indicated on the graphs.

DISCUSSION

In illustrating the genetic control of fertility in the oil palm, the emphasis was put on the *pisifera* palms. But the other fruit forms, the *dura* and *tenera,* could also be used for illustration depending on which fruit form is classified into production patterns – fertile and partially female sterile. The model should apply. It should however be noted that partially female sterile *dura* and *tenera* palms are extremely rare in modern breeding materials. Where there is little or no production the presence or otherwise of the gene for partial female sterility can be confirmed by crossing with an identified genotype. This condition of fertility or partial female sterility is controlled by a single gene which is linked to the gene controlling the inheritance of shell thickness. This linkage is, however, not absolute. It must be emphasised that this gene controls fertility, that is, bunch production pattern as categorised above, and not bunch number or total yield, although it has an indirect effect on cumulative yield.

Total bunch yield is the product of two components, bunch number and bunch weight. Both are inherited independently as additive quantitative factors (SPARNAAIJ, 1969). The ultimate yield of the palm will however depend on whether it will produce bunches or no bunches at all. This is the basic condition number consideration here.

The model explains the genetic origin of the fertile *pisifera* palm and the rare partially female sterile *dura* and *tenera* palms which arise as a result of crossing over and recombination. The model shows both homozygous and heterozygous conditions for fertility in *dura, tenera* and *pisifera* palms. This may partly explain the genetic basis of yield differences between palms and the average performance of progenies.In a breeding programme the identification of genotypes of plants will help in making desired combinations or avoiding genotypes which will have a depressive effect on overall yield of populations. It is also possible to make combinations ensuring high yielding pure or partially pure stands of fertile *pisifera* palms.

Of special interest is the creation of populations of high yielding fertile *pisifera* palms or 1:1 mixture of *tenera* and fertile *pisifera* palms in commercial plantations with the aim of increasing palm oil yield. The *pisifera* has the highest sex ratio. The fertile *pisifera* has the best fruit composition of all the 3 fruit forms because of the absence of shell and high percentage of mesocarp. It should therefore be theoretically ideal for commercial exploitation.

Some factors will have to be considered in commercial exploitation of the fertile *pisifera* palm:

1) Yield. It is generally thought that the fertile *pisifera* palm has low yield. This is attributed mainly to low fruit-to-bunch ratio. But this may not be true for all populations. Some fertile *pisifera* palms are very high yielding and perform even better than the *tenera* palms in the same progeny (WONKYI-APPIAH, 1980; CHI, 1981). With selection, improvement can be achieved. Progeny testing of combinations may even enhance special combining ability. The high sex ratio and much greater oil-to-bunch ratio will greatly improve the oil yield per unit area.

2 Establishment of fertile pisifera populations: Once the genetic basis of fertility has been established, any desired combinations can be made.

3 Germination of the fertile pisifera seed: The problem of the germination of the *pisifera* seed under laboratory conditions has been investigated by many workers (THOMAS

& HARDON, 1968; ARASU, 1970; WONKYI-APPIAH, 1975). *Pisifera* seeds can be germinated under plantation conditions (WONKYI-APPIAN, 1973). This method is very simple and cheap and may be considered for the large scale germination of fertile *pisifera* seeds. The problem of germinating *pisifera* seeds may be avoided by making *tenera* × *fertile pisifera* crosses with *tenera* as the female parent to get *tenera* seeds for germination. This will lead to the establishment of a populatin of 1:1 mixture of *tenera* and fertile *pisifera* palms.

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REFERENCES

ARASU, N. T., 1970. A note on the germination of *pisifera* (Shell-less) oil palm seeds. Malay. agric. J. 47: 524–527.

BEIRNAERT, A. & R. VANDERWEYEN, 1941. Contribution à l'étude génétique et biométrique des variétés *d'Elaies guineensis* JACQ. Publs. Inst. natn. Étude agron. Conge belge. Série Scinetifique 27, 101 p.

CHIN, C. W., 1981. Segregation of fertility, fruit forms and early yield performance of selected sibbed and outcrossed fertile *pisifera* progenies. Proceedings of the International Oil Palm Conference, Kuala Lumpur, Malaysia.

GASCON, J. P., 1956. Études sur les *pisifera* et les croisements dura et *pisifera*. Bull. Agron. Inst. natn. Étude agron. Congo belge 14: 48–57.

OBASOLA, C. O., 1974. *Pisifera* investigation. Annual Report (1974–1975) NIFOR, Benin City, Nigerai. 37 pp.

SPARNAAIJ, L. D., 1960. The analysis of bunch production in the oil palm. J. W. Afr. Inst. Oil Palm Res. 3 (10): 109–180.

SPARNAAIJ, L. D., 1969. Oil palm (*Elaeis guineensis* JACQ.) In: F. P. FERWERDA & F. WIT (Eds), Outlines of perennial crop breeding in the tropics. Miscellaneous Papers Landbouwhogeschool, Wageningen, No. 4, pp. 339–387. Veenman, Wageningen.

THOMAS, R. L. & J. J. HARDON, 1968. An outline of breeding and selection in the oil palm. Malays. agric. J. 46: 324–331.

WONKYI-APPIAH, J. B., 1973. Germination of *pisifera* oil palm seeds under plantation conditions. Ghana J. Agric. Sci. 6: 223–226.

WONKYI-APPIAH, J. B., 1975. Fertility and germination in *pisifera* oil palm. Ghana J. agric. Sci. 8: 85–88.

WONKYI-APPIAH, J. B. 1980. Exploitation of the fertile *pisifera* palm to increase palm oil yield in oil palm plantations. Paper presented at the 12th Biennial Conference of the West African Science Association, Univ. of Ife, Ile Ife, Nigeria (Mimeo).