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Position dependent effect of oil palm (*Elaeis guineensis* Jacq.) seeds on germination aptitude

Tabi-Mbi Kingsley[1,2*], Ntsomboh-Ntsefong Godswill[1,2], Ngando-Ebongue George Frank[2], Anjambang Walters Nchu[2], Youmbi Emmanuel[1, 3]

[1] *Department of Plant Biology, University of Yaounde I, Cameroon*

[2] *Specialised Centre for Oil Palm Research (CEREPAH) IRAD La Dibamba, Douala, Cameroon*

[3] *Tissue Culture Laboratory, African Centre for Research on Banana and Plantain, Njombe (CARBAP), Cameroon*

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Abstract

Oil palm seed germination is erratic, fluctuating between varieties and within seeds of the same fresh fruit bunch (FFB). The cause of the low rate of germination and within-FFB germination variation is not quite clear. This study was carried out to verify if seed position on the spikelet influences germination capacity (GP) in theoil palm. The study was carried out on open and controlled pollinated FFBs with the criteria for FFB harvesting being 2-5 detached fresh fruits (FF). FF were striping from spikelets collected randomly from base, middle and apex of all FFBs sampled. 60 deep red coloured fruits usually attached at the spikelet apex and 60 orange coloured fruits habitually found at the base of the spikelet were randomly chosen to evaluate some biometric parameters after which the seeds were subjected to the traditional dry heat treatment to assess the GP. The results revealed significance in number, heteromorphism and heteroblasty between apex and basal seeds. The numerical strength/FFB of basal seeds was appreciably greater than that of apex seeds, with a mean of 57.9 % for basal and 42.1 % for apex. However, apex seeds presented a higher germination capacity (46%) than basal seeds (28 %) in open pollinated FFB while in controlled pollinated FFB mean GP of 64% and 48.4% were scored for apical and basal seeds respectively. The fact that basal seeds, greater in numeric strength presented low GP compared to apical seeds could explain the general low germination rate/FFB reported in oil palm.

* **Corresponding Author:** Tabi-Mbi Kingsley ✉ kingotabimbi@yahoo.com

Introduction

Germination in the oil palm is slow, low and unsynchronized, making demand and supply of improved oil palm seeds challenging. Many authors have ascribed the low and erratic germination capacity in oil palm seeds to intense dormancy that must be alleviated for seeds to germinate (Hussey, 1958; Rees, 1962; Hartley, 1988; Corley and Tinker, 2003). It has been reported that in most plant species, seeds vary in their germination capacity between and within populations and among individuals due to varying degrees of dormancy (Gutterman, 2000). Variations in dormancy and germination may occur in seeds/fruits from subterranean versus aerial flowers of amphicarpic plants (Baskin and Baskin, 2001) or from flowers produced in at different parts of the same inflorescence (Datta*et al.*, 1970), inflorescences at different positions on a plant (Venable *et al*., 1987), and their positions in a bud (Baskin and Baskin, 2001) or fruit (Maun and Payne, 1989). The possession of different germ inability properties by seeds of the same fruit, inflorescence, plant or plants of the same species even under optimal conditions is described as heteroblasty (Gutterman, 1980). Frequently, such seeds also differ morphologically e.g. in size, colour or coat thickness to which the term polymorphism is applied. The cause of such polymorphism is unknown but could include unequal partitioning of assimilates, hormones, and other substances participating in growth, development, unset of dormancy and maturation of the developing seeds (Baskin and Baskin, 1998). Nonetheless, early studies on this subject have suggested that the erratic germination of seeds from the same inflorescence may be of genetic origin, but much of this variation is known to be phenotypic. In other words, heteroblasty could be caused by the local conditions under which the seeds matured. These conditions consist of a combination of the microenvironment experienced by the seed due to its position on the parent plant and the abiotic environment of the plant such as; the ambient temperature, day length, water availability, etc. (Gutterman, 1969, 1974; Thomas *et al.*,1979; Grey and Thomas, 1982). Seed position on the plant is one of the components of within-plant variation that may account for part of the variation in physical (size, weight, length and diameter) or physiological (such as viability, vigour) seed attributes. The position of a seed or fruit on a plant can affect its morphology, mass and dormancy/germination characteristics (Escalante, 1993) and these responses are described as 'position dependent effects' (Moravcova *et al.*, 2005).

The oil palm fresh fruit bunch (FFB) is developed from a fertilized female inflorescence. Each female inflorescence is made up of several spikelets with flowers spirally arranged around the rachis of the spikelet. In all oil palm female inflorescences, the number of flowers on the central spikelets is larger compared to lower or upper spikelets. Flowers on spikelets at the base of the inflorescence open before those on the spikelet at the top and within each spikelet those at the base open first. At the end of each spikelet is a spine of very variable length (Hartley, 1988; Corley and Tinker, 2003).Each spikelet has inner and outer fruits. A few of the inner fruits are somewhat flattened and less pigmented and are parthenocarpic i.e. developed even though fertilisation did not take place or possibly following partial abortion. FFB weight varies with age of palm. Well set FFB carry 500-4000 fruits with a fruit to bunch ratio of 60-70 %. Prior to this study, the authors hadnoticed, a number of variations between FF at the apex and those found at the base of each spikelet at the time of harvest, For example; apex FF are usually deep red while those at the base are somewhat orange given that ripening is usually from the apex downward to the base, secondly, apex FF are generally larger and heavier appearing to be more mature than those at the base; finally, FF senescence begins from the apex towards the base. The latter motivated this study whose objective was to investigate the possibility of a link between oil palm seed position on the spikelet and germination rate.

Materials and methods

All seeds used in this study were collected from the seed garden of the centre for oil palm research station (IRAD CEREPAH) La Dibamba, Cameroon. The

experiment was carried out on 8 FFB derived from open pollination and 5 FFB derived from controlled pollination. The criterion for FFBs to be harvested was that a minimum of 2-5 fresh fruits must have detached from the FFB.

Bunch analysis

The whole bunch was weighed on the Beckel's scale, after which all spikelets were pruned off the FFB using a small axe. For each FFB pruned, the seeds were manually separated from the spikelets using a well sharpened knife. The FF were separated into two lots; lot 1 constituted FF that were deep red in colour while lot 2 was comprised of orange coloured FF (Fig. 1e. and 1f.).

Fig. 1. Preparation of seeds from FFB for analysis
A. Tenera type FFB; **B**. types of spikelets: **1**. Basal, **2**. Central, **3**. Apex; **C**. spikelet showing fruits position and colour **1**. Orange coloured fruits located at the base, **2**. Red coloured fruits sited at the apex; **D**. manual separation of fruits from spikelet; **E**. Red coloured fruits (apex seeds), **F**. orange coloured fruits (basal seeds).

The total number of FF for lots 1 and 2 for each sampled FFB and their weight were then assessed. 60 FF were randomly taken from each lot to constitute the sample for biometric analysis and germination test. The 60 FF were depulped manually and weighed using an electronic balance, while the length and diameter of 20 randomly selected seeds for each lot were taken using a digital Vienna calliper (150mm digital calliper, Nankai Japan technology; measuring range 150mm/6″, maximum measurement speed 1.5m/sec and accuracy ±0.02mm/±0.001″). Physical analysis was carried out only on open pollinated FFB while germination capacity was measured for both open and controlled pollinated FFB. As a precaution, physical analysis was carried out immediately FFBs got to the laboratory because if allowed to ferment, colour based separation into the two lots was going to be impossible given that orange coloured FF gradually get a deep red colour over time.

Preparation of seeds for germination analysis

Depulped FF (seeds) were treated by soaking in a 20% fungicide (penncozeb) solution for 3-5 min. Treated seeds were then air dried under shade until no free water was seen on their surface. The seeds were then dried in an air conditioned room at 20°C for 30 days.

Dry heat treatment

After storage for 30days, the seeds were re-soaked in water for 5 days to raise moisture content to 20%. The seeds were then put in double layer polythene bags and treated with dry heat at 40°C. After 80 days at 40°C, the seeds from dry heat treatment were re-submerged in water for 5 days. This was followed by treatment with fungicide as describe above and finally, they were put in polythene bags and kept at room temperature for germination. A seed was considered to have germinated successfully once a plumule and radical axis appeared. Germination capacity (GP) was the lone parameter of germination evaluated and this was done after 60 days using the following formula;

$$GP = \frac{\text{number of germinated seeds}}{Number of tested seeds} x\ 100$$ (Labouriau,1983a)

Data analysis

The experimental design was random with one main factor (fruit positioned) and two levels (seeds at the apex and seeds at the base of spikelet). The data was analysed using SPSS ver. 20, and the means for treatment combinations for biometric parameters and GP were compared using the student t test at a probability of 0.05.

Results and discussion

The effect of seed position on number of fruit/FFB

In all the open pollinated FFBs analysed, the number of basal seeds was generally greater than that of apical seeds (Fig. 2.). Averagely, basal seeds represented 57.9 % of seeds while seeds at the apex constituted 42.1 %. Significant variations were observed in the number of seeds at the base and apex of spikelet in 87.5 % of FFBs analysed. This could be explained by the fact that only very few seeds are in direct contact with the surrounding.

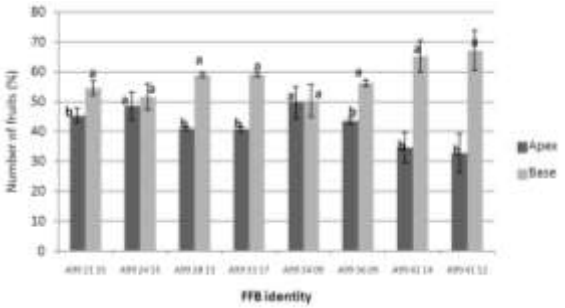

Fig. 2. Percentage of red and orange fruits in an oil palm FFB Different letters on histograms for a given FFB indicates significant difference.

Effect of seed position on biometric parameters

As far as fresh biomass is concerned, it was observed that the fresh weight of the seeds from the spikelet apex was generally greater than that of seeds found at the base in 75 % of the FFB analysed with glaring statistical differences. Although basal seeds outweighed apex seeds in terms of fresh weight in samplesA99 41 14 and A99 41 12 (Fig. 3.), the differences were not significant. Averagely, the fresh biomass of basal seeds was 43 % while that of apex seeds stood at 56.7 %. In 75 % of FFBs sampled, the average length of apex seeds was greater than that of basal seeds. Statistically significant differences in mean length of seeds were observed in six out of the eight FFB analysed (Fig. 4.). The average length of apex seeds was ranged 2.5 cm while for basal, a mean length of 2.2 cm was observed.

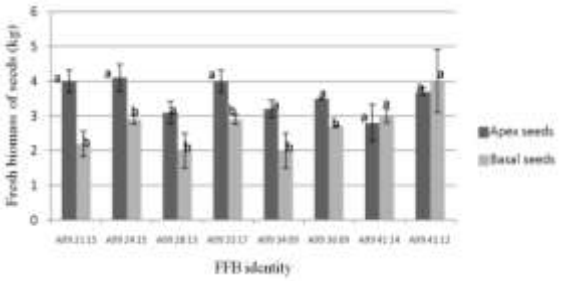

Fig. 3. Variation in weight of oil palm seeds found on different positions on the spikelet Different letters on histograms indicates significant difference.

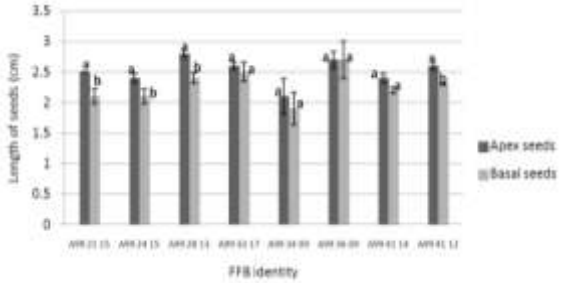

Fig. 4. Variation in length with seed position on the spikelet Different letters on histograms indicates significant difference.

In spite of the higher % in terms of numerical strength (57.9 % against 42.1 %), seeds from the base of the spikelet had a lower average fresh biomass (43.3 %) compared to those at the apex (56.7 %) (Fig.3.). In all, the seeds at the apex of the spikelet appear to be more mature than those at the base. The cause of variations in length and fresh weight could include unequal partitioning of assimilates, hormones, and other substances participating in growth, development, with apex seeds receiving more than basal seeds. This result ties with other findings in which heteromorphism in seed, number, mass, dormancy and germination had been reported for seeds found at different positions within an inflorescence in some plant families like *Asteraceae* (Baskin and Baskin, 2001) and *Poaceae* (Datta *et al.*, 1970). Similar variations had been reported by Breure

(2006) who attributed variations observed in tenera oil palm type to different origin, genetic and selection criteria of the Pisifera and dura type. Lim (2003) and Teo *et al.* (2004) confirmed that there are many types of dura and Pisifera in the world which are also known as parent material. The fact that all seeds used in the present study were from open pollination; meaning that the pollen sources were not identical, could explain variations observed between apex and basal in biometric parameters and germination capacity. The variations in parameters assessed in the present study endorse the assertion that a natural hybrid between different parent materials produces large variety of planting material (Esnan *et al.*, 2004).

Effect of seed position on seed germination

In oil palm commercial seed production process, the heterosis effect is exploited by crossing Dura (D) × Pisifera (P) parents to produce improved oil palm hybrids characterised with high quality and quantity palm oil (Hartley, 1988). The disparity that exists between demand and supply of improved oil palm seeds can only be bridged by improving on germination capacity of hybrids seeds is generally very low, ≤ 20% under natural conditions (Rees, 1962).

In the present study, significant differences in GP were obtained between apex seeds and basal seeds for 80 % FFBs assessed for open (Fig. 5.) and 100 % for controlled (Fig.6.) pollinated FFBs samples. In open pollinated samples, apex seeds recorded higher rates of germination than basal seeds at p≤0.05 for five out of the eight FFBs sampled (Fig. 5). Globally, a significant difference was found when the mean germination of all apex seeds (5.625) was compared to the mean germination of basal seeds (2.625) at p≤0.05. In different plant species, maternal factors, such as the position of the inflorescence on the mother plants or the position of the seeds in the inflorescence or in the fruit, can markedly influence the germinability of seeds (Gutterman, 1992a; 1994a).

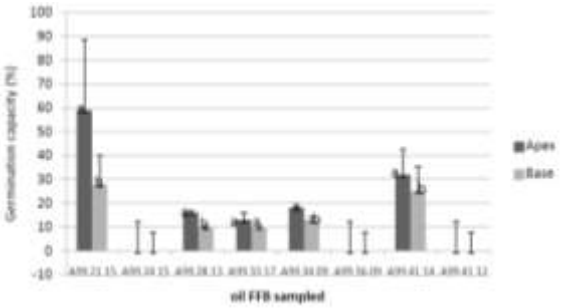

Fig. 5. Variation in germination capacity between basal and apical seeds in open pollinated FFB Different letters on histograms on FFB indicates significant difference at P≤ 0.05.

Concerning controlled pollinated FFBs analysed, significant differences were noticed in GP between basal and apex seeds (Fig. 6). Averagely, apex seeds gave a germination score of 64 % while basal seeds scored 48.4 %. The significant difference obtained with respect to GP between apex and basal seeds in both open and controlled pollinated FFBs sampled in this study are indications that the position of seeds on the spikelet influences germination rate of oil palm. Position dependent differences may be due to resources not being allocated equally to all seeds (Datta *et al.*, 1970) and/or seeds produced at one position (e.g. at the base of an inflorescence) developing under different environmental conditions than those produced at another position (e.g. at the top of an inflorescence), including differences in physiological age of the mother plant at the time seeds are produced (Baskin and Baskin, 2001). Besides climatic and edaphic conditions experienced by the mother plant during seed development, the degree of maturity at harvesting time is an important factor among others that account for variation in the seed germination and emergence of seedling in the field (Mahdi *et al.*, 2012).

Some earlier studies on this subject hold that the dynamics of dormancy/germination depends on stage of maturation and ripeness at the time of harvest (Gutterman and Evenari, 1972; Do Cao *et al.*, 1978). The FFB of oil palm generally requires 20-22 weeks to get ripe (Azis *et al.*, 1990) but this can be influenced by environmental conditions. However, FFBs on the

same plant and fruitlets on the same FFB do not ripen simultaneously due to the slight variation in the time of pollination (Sambanthamurthi *et al.*, 2000).

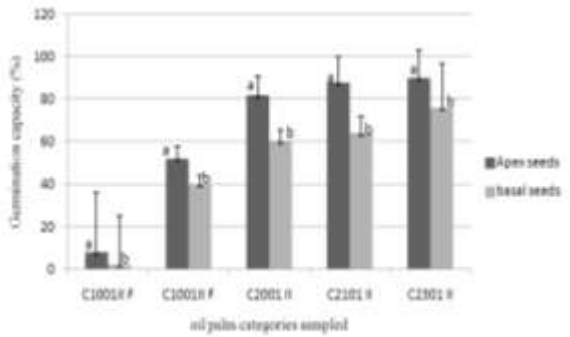

Fig. 6. Comparison of germination capacity between base and apex seeds for FFBs derived from controlled pollination Different letters on each sample indicate significant differences at $P \leq 0.05$.

In the oil palm the question of gauging ripeness is still not quite clear, reason why several criteria are used to determine whether FFB is ready for harvest or not. Most plantations are more interested in quality and quantity of palm oil hence FFBs ripeness gauge is not based seed production, but some seed production centres are mistakenly using same criteria for ripeness. For example, mesocarp colour is one of the important indicators among the several grading methods used to gauge ripeness of oil palm FFB (Sunilkumar and Sparjan-Babu, 2013; Singh *et al.*, 2014). If mesocarp colour is orange FFB can be classified as ripe. Otherwise if the colour is still yellow or yellowish orange, it can be unripe or under ripe (Abdul *et al.*, 2009). Generally, mesocarp colour changes from green to orange for *virescens* at maturity while in *nigrescens* type the colour change goes from black or brown cheek colour for immature fruits to red (Esnan *et al.*, 2004).

Other grading methods for ripeness include the flotation technique proposed by Azis (1990) and empty fruitlet sockets considered by many to assist in a more accurate gauge because it indicates the number of fruit detached from a bunch. Even here, researchers differ with the number of detached fruits. If more than 10% of total FF in one bunch detaches, the bunch is categorised as ripe (Choong *et al.*, 2006).On the other hand, Ng and Southworth (1973) considered 20-25% detached fruit/FFB for ripeness. In another classification, Mohd and Abdul (2011) considers, 1-9% of detached FF for under ripe, 10-50% for a ripe, and 50-90% for an over ripe FFB. However, oil palm fruit abscission depends on several factors amongst which are, normal ripening, sudden changes in physiological conditions associated with environmental changes and chemical changes, artificial termination of bunch development and genetic make-up of plants which produce FFB that detach FF before maturity (Flingoh and Zukarinah, 1985).

The criteria for ripeness above are based on the stage at which optimal quantity and quality crude palm oil can be extracted from FF (Mohd *et al.*, 2012). Unfortunately, ripeness of the mesocarp does not necessarily mean maturity of the embryo, which actually affects the rate of progeny production for the next generation through seed germination. The degree of dormancy or germinability of a seed lot depends on the physiological maturity of the embryo at harvesting (Gutterman, 1969; 1980; 1992). Generally, ripe fruits or seeds that detach from the plant or a FFB on their own appear to have a high germination capacity than those harvested before their natural abscission. The fact that within a given oil palm FFB, some seeds undergo abscission before others could be an indication that ripening period of fruits on the same bunch does also vary. This may account for the significant difference in germination capacity between apex and basal seedin the present study. The result obtained in this study seem to be consistent with the work of Kaida and Zulkefly (1992) who reported that in the oil palm, ripening begins from the apical to the basal part of the FFB and from the outer to the inner halve of the spikelet. Based on the report by Kaida and Zulkefly (1992), seeds that abscised early analogically lost their dormancy before those that detach later, explaining the disparity in germination. In the present study, the higher germination rate by apex seeds could presumably be attributed to the fact that their embryos were more

mature than those of basal seeds at the time of harvest.

The result also revealed a higher germination capacityin controlled pollinated samples (Fig. 6.) than open pollinated samples (Fig. 5.).Concerning seeds at the apex, the optimum germination among all open pollinated FFB was 59 % while for the sampled controlled pollinated FFBs; the best GP obtained was 90 %. For basal seeds, a maximum of 27.9 % and 76 % were observed for open and controlled pollinated FFB respectively (Fig 5 and 6).This result corroborate with the findings of Santos *et al.* (2015) who reported higher germination in passion fruits seeds derived from controlled pollination than in seeds derived from open pollination. Better germination performance of controlled than open pollinated seeds as observed in this study could be explained by the fact that the parents (Pisifera × Dura) crossed have been carefully studied and identified to show hybrids vigour in seed emergence, biometric parameters and resistance to environmental conditions. The 5 FFB obtained from controlled pollination, could be grouped into two based on their GP. The first group consist of C2001II, C2101 II and C2301 II where GP for apex was > 80 % and no significant difference was found when these three samples were compared. The GP of basal seeds in this first group was also high ranging between 60 -76 %. The second group is made up of C1001 IIF where apex seeds score a GP ≥ 52 % while basal scored a very low GP of 2% in one of the two FFBs (Fig. 6). The appreciably distinction in germination scores from three out of the five controlled pollinated samples (Fig. 6), could be attributed to the origin of the pollen source, given that the three sampleswith higher GP both in apical and basal seeds had the same pollen source. This variation observed ties with the work of Breure (2006) who reported that even though tenera is the main planting materials, there exist several cultivars of tenera whose variation in form is due to the diversity in origin of D × P parents.

Conclusion

In the present study, the criteria for FFB readiness for harvesting was 2-5 detached FF. Based on this criterion therefore the following assumptions could be drawn: basal seeds represent approximately 57.9 % while apex seeds represent 42.1 % in terms of numerical strength /FFB; Seeds at the apex appear to be more mature with an average fresh biomass of 56.7 % compared to 43.3 % for seeds located at the base of oil palm FFB spikelet; Above all, apex seeds have a higher GP (46 %) and (64 %) than base seeds (28 %) and (48.4 %) for open and controlled pollinated FFBs respectively. This study also reveals that GP is higher in seeds obtained from controlled pollination than seeds derived from open pollination. The results of the study indicate that there exists a linkage between FF position on the spikelet and seed germination in the oil palm, with seeds at the upper half of the spikelet having a higher germination aptitude. The fact that base seeds have a higher representation /FFB, but with a lower germination capacity could be one of the causes of the general low germination rate reported in the oil palm. Based on these results the authors recommend that, the harvesting period of FFB destined for seed production be prolonged for one month after 2-5 detached FF in order to maximize the ripening of embryos and natural FF abscission of base seeds.

However, variation in the level of dormancy within a seed lot remains a natural strategy for survival of the species. It will therefore be very difficult if not impossible to have all seeds from a given FFB germinate at the same time.

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