FRUIT SETTING, INHERITANCE OF NUT COLOUR, GERMINATION AND EARLY SEEDLING GROWTH OF KOLA (COLA NITIDA (VENT.) SCHOTT AND ENDL).

by

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DECLARATION

It is hereby declared that this thesis "Fruit Setting, Inheritance of nut colour, Germination and the Early Seedling growth of *Cola nitida* (Vent.) Schott and Endl" has not been submitted for a degree in any other University.

It is entirely my own work and all help has been duly acknowledged.

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ABSTRACT

In a diallel cross involving six kola trees, two from each of the cultivars Laboshie white ex Nigeria, Kumasi white and Kade pink, a self compatible tree of the Kade pink cultivar was found to be the most efficient female but the least efficient male parent for fruit set.

The frequency of red, white and pink nuts that segregated in the progeny of the various crosses suggests that a single locus with multiple alleles controls the inheritance of kolanut colour.

At physiological fruit maturity, freshly harvested nuts of the different cultivars showed varying degrees of dormancy when sowed. Storage of the nuts for two months improved their germination rates suggesting that dormancy was breaking down.

The most vigrous seedlings were from nuts of the progeny from crosses between the local cultivars, Kade pink and Kumasi white.

INTRODUCTION

The kola tree, *Cola nitida* (Vent.) Schott and Endl. is a tropical rainforest tree belonging to the family Sterculiaceae. It is indigenous to the lowland forests of West Africa, from Sierra Leone to Ghana. It owes its economic importance to its seeds which have stimulating and sustaining properties due to the presence of some alkaloids including caffein and theobromine.

The seeds have a bean shape and structure; and, when the seed coat is removed, kolanuts with red, white or pink colour are revealed. The colours are due to the presence of various polyphenols which, according to Ogutuga (1975), are a potential source of food colour. In Ghana, nuts produced in the Ashanti and Brong Ahafo Regions are mostly red. Those produced in the Eastern Region are mostly white.

Outside West Africa, kolanuts are of little economic importance except in the Carribbean Islands (Van Eijnatten, 1973). In contrast to the areas of spread where kolanuts are of little economic importance, there has been a considerable trade in these nuts in West Africa in the past and this trade still persists.

Outstanding among the cultivars that have been developed by the Nigerian farmers is Laboshie white. Unlike other introduced cultivars of *Cola nitida* which were cultivated in the humid forests of Western Nigeria, Laboshie white is found in a small area beyond the forest zone in the drier climate to the north. Its seeds are large and white (Russell, 1955).

In Ghana, trade in kolanuts is still dependent on spontaneous trees whose yields are low. Owing to increase in demand for kolanuts both internally and externally, attention has been drawn to the need to improve yield and quality. For this purpose, various local strains of Cola nitida including Kade pink and Kumasi white as well as Laboshie white ex Nigeria have been established at the Kade Research Station of the University of Ghana.

Generally, kola in West Africa show certain undesirable characters among which are low rate of seed germination, slow growth rate of seedlings and late maturity and low productivity (Russell, 1955; Van Eijnatten, 1964; 1973). Genetic variability exists in these characters (Van Eijnatten, 1964).

As an out crossing tree crop, the breeding method that would be appropriate for the rapid improvement of Cola nitida is the development of hybrid varieties through the hybridization of elite clones. It is important that the F_1 hybrid seeds germinate uniformly and rapidly to produce vigrous and early maturing seedlings. The adult trees must also be mutually compatible in order to produce high yields. Furthermore, the colour of the nuts should be acceptable both in the local markets and in export trade. Red nuts are preferred in Northern Ghana whilst white and pink nuts are preferred in Nigeria.

The objective of this work was therefore, to study the compatibility reactions of six kola trees, two trees from each of the cultivars Laboshie white, Kumasi white and Kade pink, and their combining ability with regard to rate of germination and seedling growth, and to study the inheritance of nut colour in Cola nitida.

LITERATURE REVIEW

YIELDS OF THE KOLA TREE

Hunter (1927) and Russell (1955) observed that mature kola trees have highly variable yields ranging from 0 - 300 nuts per annum with a few trees yielding over 1,000 nuts per annum. This indicates that the yield of individual kola trees is skewed. Van Eijnatten (1962) after analysing eleven year yield records of mature kola trees confirmed the skewed distribution of individual kola tree yields found by Russell (1955).

FLORAL DEVELOPMENT AND MORPHOLOGY

The intensity of flushing and flowering in mature kola trees are affected by climatic factors. Russell (1955) observed in Nigeria that a complete flush involving nearly all trees occurred soon after the rainy season started in April. Partial flushes occurred again on some trees after intervals of ten or twelve weeks. Flowering followed the same pattern as the flushes with a profusion of flowers on most trees four or five months after the main flush and a sporadic burst of flowers thereafter. There is thus a definite flowering season in kola although flowers may be obtained all year round.

The flowers of *Cola nitida* may be male with a rudimentary gynoecium or female with a well developed gynoecium and an apparently developed but non functional androecium. Large differences exist in individual trees in the proportion of male to female flowers produced.

Russell (1955) found that female flowers are structurally hermaphrodite but functionally female, with no difference in the viability of pollen grains of both types of flowers. Bodard (1962) self- and cross-pollinated hermaphrodite flowers with pollen grains from these flowers but there was no fruit set. Van Eijnatten (1969) suggests that barring cross incompatibility, Bodard's (1962) observations indicate that pollen grains from hermaphrodite flowers are not functional.

FRUITING

Bodard (1962) calculated that for every hundred opened inflorescences, one fruit was formed naturally. Dublin (1961) estimated the percentage of female flowers that set naturally at 11 percent and obtained a positive correlation between productivity and high number of female flowers. Russell (1955) however, could not attribute productivity in kola to the availability of female flowers. This is because most of the female flowers he observed dropped without setting fruit within four to seven days after opening. Many of the rather few female flowers that set failed to develop and dropped within six weeks after fruit setting. On selfing eight trees, there was fruit set on six trees, but two others failed to set fruit. Russell (1955) therefore suggested that productivity in kola may be influenced by the activity of pollinating agents and incompatibility factors.

Fruit setting in kola is increased 10 to 20 fold by controlled pollination compared with that obtained naturally since up to 50 percent fruit setting may be achieved by controlled pollination (Van Eijnatten, 1969 b). Artificial pollination has been used to produce various progenies for yield trials in Nigeria. The flowers open early in the morning from 4 or 5 a.m. up to around 8 a.m. and may be pollinated any time of the day. Observations indicate that receptivity decreases with time (Van Eijnatten, 1964).

SELF-INCOMPATIBILITY

Russell (1955) concluded that self-compatibility was the rule in kola trees in Nigeria after obtaining fruit set on six out of eight trees which were self-pollinated. This led Bodard (1962) to speculate that there may be biologically different races of Cola nitida since a larger percentage of kola trees in Ivory Coast was found to be self-incompatible. Extensive artificial pollinations carried out by Van Eijnatten (1967 a) revealed that the majority of kola trees are self-incompatible and cross-incompatibility is common within the species. Parents show considerable differences in their influence on the success of artificial pollination, the influence of the female parent usually being more pronounced than the pollen parent with the result that varying levels of intercompatibility exist in kola trees. Jacob and Okoloko (1974) found that significantly different levels of compatibility exist within and between three distinct cultivars and attributed the low yields in the cultivar Gambari white to the presence of similar incompatibility alleles. Most of the high yielding trees selected by Van Eijnatten (1962) are, however, self incompatible. This indicates that provided suitable pollinator trees are available, self-incompatibility may not necessarily limit yield in kola. Jacob (1971) indicated that self-incompatibility in kola is similar to that in Theobroma cacao L. in being under sporophytic, homomorphic and multi allelic control. The difference lies in the dominance relationship between the pistil and pollen. He succeeded in breaking self-incompatibility in kola by differential pollination of four of the five stigmatic lobes of the female flower of a white kola with a cross compatible pollen carrying a dominant red nut factor and selfing the remaining stigmatic lobe.

DEVELOPMENT OF KOLANUTS

Within two weeks after successful pollination, the ovary turns from creamy white to green and its carpels open up to form five folliculous pods which mature after approximately 130 days (Van Eijnatten, 1969). At maturity, the pods drop either on their own accord or as the result of the mechanical action of wind or rain, and the seeds become exposed. Kolanuts lose their viability very rapidly on exposure. When they are stored in baskets lined with fresh banana leaves, their viability can be maintained for over one year (Van Eijnatten, 1973).

THE GERMINATION OF KOLANUTS

As the nuts mature, their germination rate progressively improves. Van Eijnatten and Quarcoo (1968) found that in the cultivar Gambari white, 100 percent germination was achieved in 22 days when the nuts were harvested at 133 days after pollination. Those at 105 days of maturity took 87 days to score 94 percent germination whilst nuts at 60 days of maturity failed to germinate. Karikari (1973) made similar findings in two cultivars namely Laboshie white and Kumasi white. In Laboshie white nuts harvested 130 days after pollination scored 95.7 percent germination in 16±1 days. Nuts of Kumasi white at 130 and 116 days after pollination scored 90.2 percent germination in 22±1 and 26±1 days respectively but nuts of the two cultivars at 60 days after pollination failed to germinate.

Kolanuts generally germinate slowly and irregularly and may take up to six months or more to reach 50 percent germination. Large differences in speed of germination occur both within and between cultivars (Van Eijnatten, 1973). Karikari (1973) observed that Laboshie white had a greater capacity to germinate than Kumasi white. Van Eijnatten (1969) noted that 50 percent germination in freshly harvested Agege red nuts planted in nursery beds occurred in 180 days whilst Gambari white nuts planted under similar conditions scored 50 percent germination in 118 days. Stored kolanuts germinate much more evenly and faster than freshly harvested nuts. Clay (1964) found that storage of pods for a few days under cool moist conditions gave faster germination but it had little effect on total germination. Van Eijnatten and Quarcoo (1968) found that Agege red nut stored for one year germinated in moist sawdust in 27±2 days whilst nuts of the same cultivar stored for one month germinated in 94±10 days under similar conditions. According to Van Eijnatten (1969) these figures indicate that kolanuts pass through a dormancy period which vary in length according to their origin. Odegbaro and Ogutuga (1967) suggested that kolanuts may have a dormant period of three months, but according to

Van Eijnatten (1969) storage for five months was not sufficient to reduce the germination period of Agege red.

Karikari (1973) suggested that the length of storage period required by various cultivars to enhance germination depends on how long the cultivar has been under cultivation. He found that the necessity for storing the nuts for a period to enhance germination is lost in Laboshie white cultivar but retained in the Kumasi white cultivar. Laboshie white cultivar has been in cultivation longer than Kumasi white cultivar which is an unselected material. Van Eijnatten (1969) noted significant changes in the size and tissue differentiation in the embryos of stored nuts compared with those of freshly harvested nuts and related these changes to the apparently obligatory dormancy period which kolanuts need prior to their germination.

According to Ibikunle and Mackenzie (1974) delayed germination in kolanuts is also due to the mechanical constraint imposed on the embryo by the two cotyledons. The two cotyledons are very firmly held together, and the adhesive force between them tends to be greater in freshly harvested nuts than in stored nuts. By mechanically separating the cotyledons from their normal contact without breaking their union with the embryo, thus removing the mechanical constraint, they obtained significant improvement in germination rate. The same treatement also improved germination rate in stored kolanuts. They indicated that the improvement in germination by removing the mechanical constraint imposed by the embryo could also be due to enhanced moisture uptake and gaseous exchange resulting from the exposure of adaxial cotyledonary surfaces.

Van Eijnatten and Quarcoo (1968) found accidentally that spliting kolanuts along the edges of the cotylodons into two resulted in improved germination rate. Van Eijnatten (1969) suggested that this could be due to the wound inflicted on the cauliculus of the embryo, but Ibikunle and Mackenzie (1974) disagreed with this suggestion and stated that the most likely reason was the removal of mechanical constraint imposed by the two cotyledons on the embryo. Van Eijnatten (1964) found that cutting off tips of cotyledons produced significant improvement in germination rate. Brown and Afirifa (1971) found a marked improvement in both the speed and total shoot emergence after cutting off the upper half of the cotyledons. With nuts thought to be mature, 90 percent shoot emergence occurred in 58 days for cut nuts and in 99 days for whole nuts. With immature nuts, however, there was no significant effect due to cutting off top bits of the nuts. Ibikunle and Mackenzie (1974) suggested that the force of adhesion between the cotyledons is greatest at the tip so that cutting off the tip of the cotyledons leads to a weakening of the mechanical constraint imposed on the embryo by the two cotyledons, and this leads to the observed improvement in germination.

Faster germination may be induced in kolanuts by removal of the testa (Clay, 1964) and treating the nuts with the chemicals Kinetin, Thiourea and Thiourea dioxide (Ashiru, 1969). Light and temperature also influence the germination rate of kolanuts. Van Eijnatten (1967) found that illumination of kolanuts placed on top of a moist planting medium (sawdust or sand and sawdust) and covered with clear polythene sheeting resulted in the greening of the nuts and promoted rapid germination, compared to similarly planted nuts covered with black polythene sheeting. The illuminated nuts continued to grow better than the non-illuminated nuts after planting out.

Clay (1964) attributed lowered germination rates in kolanuts to increase in temperature to 57°C caused by direct sunlight on nuts planted ½in. deep. Van Eijnatten (1964b) showed that a continuous temperature of 45°C and above caused the death of nuts within a short time. At 37°C the nuts died over an average period of 54±6 days. At 30°C the nuts germinated slightly more rapidly than those planted at ambient temperature fluctuating between 24°C and 30°C. 20°C slowed down root emergence. The ambient temperature of 24°C to 30°C produced the tallest seedlings in spite of the earlier root emergence at 30°C. Ashiru (1969) concluded that abnormally high temperatures and light intensities are not essential for germination of kolanuts though they might influence the rate of germination and the subsequent seedling growth.

Planting the nuts in nursery beds results in a lower germination rate compared to pregermination of the nuts in seed boxes (Van Eijnatten, 1964b). It is thought that slightly higher temperatures and the continuous moist environment in seed boxes are the main promoting factors. In the shaded nursery beds, the nuts are in a cooler environment and are usually subject to intermittent wetting and drying (Van Eijnatten, 1969). Thus, the type of sowing medium used to germinate kolanuts influences the germination rate. Sand mixed with equal parts of top soil or sawdust gives a more rapid germination than sand or sawdust alone (Van Eijnatten, 1964).

Seed size has no effect on germination rate but heavier nuts produce more vigrous seedlings than lighter nuts (Van Eijnatten and Quarcoo, 1968). This indicates that the seedling is dependent on the food reserves in the cotyledons for its growth.

SEEDLING GROWTH

Kola seedling grows monopodially for the first two to three years after which it develops multiple fork or jorquette. Observations were made by Van Eijnatten (1967) on the quantity of dry matter in the cotyledons of planted nuts and on its distribution over various parts of the seedling plant at two months after planting. Loses in the dry matter from the germinating kolanut due to respiration and to the exchange of energy required for the germination process amounted to 15 percent of the initial dry matter. Of the remaining dry matter, 90 to 94 percent was contained in the cotyledons and only 6 to 10 percent was contained in the root, stems and leaves together. Thus, the percentage of dry matter transferred from the cotyledons to the developing seedling is very small at two months from sowing. This also indicates that kola seedlings exhaust their food reserve very slowly. Turgid cotyledons remain attached to the young plant until they are nine months of age, after which period they shrivel and are shed (Van Eijnatten, 1969).

Hunter (1927) observed that the early growth of young kola plants is slow and the seedlings require overhead shade for better establishment. Van Eijnatten (1969) found that under 33 percent shade, growth of transplanted seedlings in terms of dry matter accumulation was better than full exposure. Most rapid development of roots occurred under 33 percent shade than under 66 percent shade. The rate of growth of kola seedlings is also influenced by its origin (Van Eijnatten, 1967) but not by fertilizer applications. Egbe (1967, 1968) showed that in sand culture, three months old kola seedlings are sensitive to deficiencies of N, P, K, Ca and Mg, but he obtained no effect of fertilizers on the growth of kola seedlings in the field.

THE INHERITANCE OF KOLANUT COLOUR

The value of kolanuts depends among other things on the colour. The colour may be white, red or pink. Nuts classified as white are actually cream with sometimes a greenish tinge, and are quite distinguishable from red and pink nuts. Pink nuts vary in intensity from light red to maroon. A continuous range of deepening colour from pale pink to deep red is therefore found in kolanuts (Russell, 1955). Voelcker (1935) classified kolanuts into red, white or pink with this understanding. Russell (1955) stated that white and paler pink nuts fetch a higher price in Nigeria. In Ghana, however, red nuts are commonly sold and chewed. Private communications with kola traders indicate that white nuts are more difficult to store than red nuts. White nuts turn green on exposure, losing their quality and are liable to germinate in storage.

Red nuts are predominantly found in Ghana's area of highest production of kolanuts. White nuts occur in certain restricted areas (Mills, 1928; Wills, 1962). In Nigeria, red nuts predominate but relatively higher percentages of pink nuts occur in Owode and Laboshie areas, whilst in Ivory Coast, red nuts predominate in the Abidjan Bingerville-Divo area and pink nuts are abundant more to the north (Van Eijnatten, 1964). Thus, there appears to be a regional occurrence of red, white and pink kolanuts.

Chamney (1927) reported on the segregation of kolanut colour in plantations of kola at Aburi and Kibi grown from white nuts collected from various sources. Under open pollination at Kibi, 10 trees gave white nuts only whilst one tree gave pink nuts only. The rest produced pink and white nuts in different proportions varying with the age of the tree. Similarly at Aburi, four trees gave white nuts only whilst three trees gave pink nuts only. The rest produced pink and white nuts also varying in proportion to the age of the trees. Chamney (1927) could not explain the segregation ratios of the various nut colours in terms of simple Mendelian ratios and therefore attributed the variation in the proportion of kolanut colours to the age of the tree. Voelcker (1935) stated that the nut colour may vary from tree to tree, year to year and follicle to follicle. Using artificial pollination, he found that the nut colour is determined by the genotype of the embryo, as the nuts being the cotyledons form part of the next generation. However, sometimes kolanuts are found with one white and one pink or red cotyledon. Bodard (1962) pointed out that such bicoloured nuts invariably develop more than one embryo.

Voelcker (1935) found that trees established from white nuts always produce white nuts when self-pollinated, but red, pink or white when crossed with pollen from a tree grown from a red nut. The reciprocal crosses gave similar results. He concluded that the absence of colour is recessive. Russell (1955) summarised later work in Nigeria carried out on progenies established by Voelcker (1935). The work showed that trees established from white nuts obtained by self pollination of a white tree or by crossing two such trees produced white nuts when selfed or back crossed. The pink nut colour proved to be dominant to white and a red nut colour dominant to both white and pink indicating that kolanut colour is controlled by at least two pairs of epistatic genes.

Observations by Van Eijnatten (1967b) on the types of kolanut colour arising from controlled pollinations could not be explained by the assumption of two or three genes controlling the red or pink nut factor as suggested by Russell (1955). In trees which normally produced white nuts only when intercrossed, in seven out of 2679 pollinations, other colours were found probably due to contamination. Some white trees differed among themselves by their colour segregation ratios when intercrossed with trees normally producing red nuts. A cross between a red tree and a white tree gave red nuts only but when the same red tree was crossed with another white tree, pink and red nuts were obtained. Furthermore, in crosses which produced red nuts only, pink nuts occasionally were found at low frequencies. Beck (1960) suggested after chromatographic analysis that a single pigment is present in both red and pink nuts and its aglycone is present in white nuts.

Progenies derived from white female plants and respectively white, pink or red male plants increased in productivity in that order. Beck (1958), therefore, assumed that the red nut factor is linked with a high yielding gene complex which achieves maximum expression in progenies obtained from crosses between red and white nuts. Self incompatibility in *Cola nitida* is however commonly associated with the red nut factor, although some white trees set no fruit after repeated self pollinations (Van Eijnatten, 1969).

MATERIALS AND METHODS

Trees numbers 1/9 and 1/12 of the Kumasi white cultivar numbers 2/1 and 3/4 of the Kade pink cultivar and numbers 4/6 and 11/6 of the Laboshie white cultivar (where $^x/y$ refers to tree y in row x) selected from the University of Ghana kola plot at Kade, were selfed and inter-crossed in all possible combinations from 10 May 76 to 19 July 76 during the main flowering season. The original seeds of Kumasi white were white and were purchased from Kumasi market (Ghana). Under open pollination it produces 88 percent white nuts, 5 percent pink nuts and 7 percent red nuts. The original seeds of Kade pink were obtained from Kade (Ghana). Under open pollination, it produces 57 percent pink nuts, 28 percent red nuts and 15 percent white nuts. The original seeds of Laboshie white were obtained from Moor plantation, Nigeria. Under open pollination it produces 96 percent white nuts, 3 percent red nuts and 1 percent pink nuts (Opoku, 1969). The trees used in the experiment were selected on the basis of synchronous flowering, accessibility of flowers and, in the case of the local cultivars, high yield. The selected trees from the Kumasi white cultivar were designated K_1 and K_2 respectively. Similarly, those selected from Kade pink and Laboshie white were designated as P_1, P_2 and L_1 and L_2 respectively.

CROSSABILITY STUDIES

Prior to pollination, female flowers about to open were bagged with transparent polythene bags after the male flowers had been removed. Nearness to flower opening was judged by the tension in the sepal furrows of the female flowers as described by Van Eijnatten (1969). Pollinations were done early in the morning between 6.30 a.m. and 9 a.m. Freshly opened female flowers were pollinated with pollen grains from newly opened male flowers. Pollen grains from newly opened male flowers were collected with 15cm thin sticks with sharp ends and applied to each of the stigmatic lobes of freshly opened female flowers. Pollinated female flowers were rebagged immediately for further forty-eight hours.

For each combination, the proportion of successful set to number of crosses was recorded two weeks after pollination. At this time, successful pollinated flowers turned from creamy white to green and their carpels opened up to form up to five folliculous pods (FIG. 1). All unsuccessful crosses had dropped. Developing fruits were sprayed against insect pests with 3 percent $^{v}/v$ Unden 20 insecticide three times at fortnight intervals beginning from six weeks after pollination.

INHERITANCE OF KOLANUT COLOUR

After 104 to 108 days from pollination, well developed fruits began to drop (FIG.2). The fruits were thus judged mature and were harvested, and the seeds removed. The seed coats were then peeled off and for each cross, the nuts were classified into red, white and pink. The frequency of each colour class for each cross was noted.

STUDIES ON GERMINATION AND EARLY SEEDLING GROWTH

For each cross, sixty fresh nuts free from disease or insect damage were selected on the basis of the observed frequency of the various colour types and weighed individually. The sixty nuts

FIG. 1

IMMATURE FRUITS OF C. nitida SHOWING FIVE FOLLICULOUS PODS

FIG 2
MATURE KOLA FRUITS

were planted in three replicates of twenty nuts each. The rest of the nuts were then stored in baskets lined with fresh banana leaves for two months in the laboratory. The germination experiment was repeated using the stored nuts from crosses with P_1 and K_1 as female parents as enough sound nuts were not available from the other crosses. The nuts were planted in 20cm x 25cm black polythene bags filled with 1 : 1 top soil: sand and mulched with oil palm fibre from which palm oil had been extracted and dried. During planting the nuts were placed horizontally at 4 - 6cm deep as suggested by Van Eijnatten (1969). The polythene bags with the planted nuts were kept under palm frond shed. Watering was done every other day by an overhead sprinkler irrigation. The nuts were judged as germinated when the radicle had emerged. Beginning from two weeks after planting records were taken on weekly germination rate for each cross for both fresh and stored nuts. The dates of plumule emergence were also recorded and the seedlings were allowed to grow under the palm frond shed.

For each replicate, the monthly growth in height, girth and number of leaves were taken on ten seedlings grown from fresh nuts. The girth was measured at 10cm above soil surface. After five months from plumule emergence, the above ground parts of the ten seedlings for each cross for each replicate were oven dried at 80°C for one week and the dry weights recorded. The leaf areas of the ten seedlings were determined before being dried. For each replicate, 10gm of fresh leaves were traced on square paper and the areas determined by counting squares. The total leaf area for each cross in each replicate was then computed from the respective total leaf fresh weights.

STATISTICAL ANALYSIS

FRUIT SETTING

The proportion of successful set to number of crosses for each of the various combinations was expressed as percentage fruit set and the correlation co-efficient between the number of crosses per combination and percentage fruit set was calculated. A two way classification with non additive interaction was then used to analyse the effect of male and female parents on fruit set. The percentages were not transformed into angles owing to the large differences in the number of crosses per combination. Non additive interaction was calculated according to Turkey (1949).

GERMINATION RATES

For each progeny, correlation co-efficients was calculated between seed weight and the number of weeks to radicle emergence. The cummulative weekly percentage germination of the various progeny was transformed to angles and analysed according to a two way classification with non additive interaction. The classes were males and females. The interaction was calculated according to Mandel (1961) since the female variance was much higher than the male variance.

SEEDLING GROWTH

A covariance analysis using mean progeny seed weight as a covariate was used to adjust values of each of the measured growth parameters of the various progeny for differences in seed size. The adjusted values were then analysed using a two way classification as before. The interaction was calculated according to Turkey (1949).

INHERITANCE OF KOLANUT COLOUR

Chi square test was used to fit the observed frequency of red, white and pink nuts of the various progeny to expected simple Mendelian ratios.

RESULTS

1. FRUIT SETTING

The number of crosses made for the various combinations of the selected cultivars of *Cola nitida* studied are presented in Table 1. Selfings have been excluded since only P_1 was self compatible. Crosses of the combinations with L_1 as a female parent have also been excluded since L_1 produced mainly male flowers.

TABLE 1

Number of attempted crosses between the selected cultivars of *Cola nitida*

	K_1	K_2	L_1	L_2	P_1	P_2	Female Total
K_1	-	47	93	66	64	68	338
K_2	37	-	45	35	40	34	191
L_2	24	28	21	-	42	22	137
P_1	55	49	56	77	-	57	294
P_2	59	53	60	49	84	-	305
Male Total	175	177	275	227	230	181	

Variations in the number of crosses attempted for the various combinations reflect on the accessibility of female flowers in the selected cultivars. There was, however, no significant positive correlation ($r = 0.19$) between the number of crosses per combination (Table 1) and the percentage fruit set (Table 2). Out of a total of 1,261 female flowers cross pollinated, 816 set fruit giving an over-all percentage fruit set of 64.7.

Percentage fruit set recorded for the different combinations of *Cola nitida*

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	63.8	62.4	59.1	82.8	77.9	69.2 cd
K_2	51.4	-	66.7	74.3	45.0	61.8	59.8 de
L_2	58.3	35.7	66.7	-	28.6	50.0	47.9 e
P_1	78.2	71.4	83.9	86.3	-	73.7	78.7 c
P_2	83.1	64.2	80.0	61.2	20.2	-	61.7 de
Male means	67.8a	58.8ab	71.9a	70.2a	44.2b	65.9a	

Means with similar letters are not significantly different according to Duncan's Multiple Range Test (within male or female tns).

Table 2 shows that the range of fruit set was 20.2 - 86.3 percent with most of the crosses producing over 50 percent fruit set indicating that the cultivars were intercompatible though to varying degrees. Analysis of variance (Appendix 1) showed that both males and females were significantly different at 5 percent level in their influence on fruit setting. Their interaction was, however, not significant. The most efficient female parent for fruit set with the other cultivars was P_1 which was found to be self compatible. P_1 was, however, the least efficient male parent for fruit set. L_1 and L_2 were the most efficient male parents for fruit set though they were not significantly different from K_1, K_2, and P_2 which were similar in their effects both as male and female parents. L_2 was the least efficient female parent for fruit set, but it was not significantly different from K_2 and P_2.

Although the analysis of variance showed no significant interactions between the males and females, reciprocal differences in some of the combinations of P_1 with other cultivars were apparent. $P_1 \times P_2$ for instance gave 73.7 percent fruit set from 57 crosses whilst the reciprocal cross gave 20.2 percent fruit set from 84 crosses (Table 1 and 2). There was, however, no apparent reciprocal difference in the combinations of P_1 and K_1.

2. THE SEGREGATION OF KOLANUT COLOUR

The number of red (R), white (W) or pink (P) nuts that segregated in the F_1 progeny of the various crosses are shown in table 3 below.

TABLE 3

The Segregation of Kolanut Colour

	K_1			K_2			L_1			L_2			P_1			P_2		
	R	W	P	R	W	P	R	W	P	R	W	P	R	W	P	R	W	P
K_1	-	-	-	0	471	0	0	606	0	0	443	0	0	0	278	0	204	228
K_2	0	300	0	-	-	-	0	225	0	0	400	0	71	0	75	96	202	92
L_1	0	55	0	0	45	0	-	-	-	-	-	-	27	0	28	15	31	15
L_2	0	173	0	0	153	0	0	148	0	-	-	-	40	0	41	33	86	28
P_1	0	0	390	242	0	204	201	0	219	257	0	180	60	0	0	172	0	171
P_2	0	273	366	95	173	124	154	205	129	47	73	47	58	0	64	-	-	-

There was no reciprocal difference in the types of colour which segregated in the progeny of the various crosses. For each combination, the proportions of the various colour types that segregated in the F_1 progeny were also similar for both reciprocal crosses (Table 3). Crosses between the two white cultivars (K_1 and K_2; L_1 and L_2) gave only white nuts in their progeny indicating that white nuts breed true to type. When K_2, L_1 and L_2 were crossed with either P_1 or P_2 similar segregation results were obtained, but different results were obtained for crosses with K_1. Only distinctly pink nuts segregated in the progeny of $P_1 \times K_1$ whilst distinctly pink and red nuts segregated in the progeny of the crosses between P_1 and either K_2, L_1 or L_2. Also only white and pink nuts segregated in the progeny of $P_2 \times K_1$ but distinctly red, white and pink nuts segregated in the progeny of the crosses between P_2 and either K_2, L_1 or L_2.

P_1 and P_2 were supposedly planted from pink nuts but on selfing P_1, distinctly light red nuts were produced. Crosses between P_1 and P_2 produced light red and pink nuts. These two colours were difficult to distinguish. Attempts to self P_2 and the other white cultivars proved unsuccessful, probably due to self incompatibility or sterility.

3 THE GERMINATION OF KOLANUTS

1. THE GERMINATION OF FRESH NUTS

There was no correlation between seed size and germination rate (Table 4).

TABLE 4

Correlation Coefficients between Seed size and the Speed of Germination of fresh nuts of the Various Crosses df=18

	K_1	K_2	L_1	L_2	P_1	P_2
K_1	-	-0.146	-0.372	-0.283	-0.182	0.068
K_2	0.247	-	0.0117	0.288	0.129	0.209
L_2	-0.405	.015	-0.072	-	0.285	-0.173
P_1	0.0163	.050	-0.437	-0.329	-	0.052
P_2	-0.227	0.081	-0.056	0.00	-0.474	-

Analysis of variance showed that there was a highly significant difference due to male and female parents for the onset and the speed of germination. The variance due to female parents was about twice that due to male parents. The interaction (slopes) between male and female parents was also significant (Appendix 2).

Kumasi white cultivar as a male parent (K_1 and K_2) induced little or no dormancy in its progeny with the other cultivars whilst Laboshie white cultivar (L_1 and L_2) induced a long rest period requirement in its progeny, with L_1 inducing the longest dormancy period in its progeny with the other cultivars. The effect of Kade pink cultivar was intermediate between Kumasi white and Laboshie white cultivars. (FIG. 3).

Laboshie white cultivar (L_1) as a female parent was outstanding in inducing a long rest period in all its progeny with the other cultivars. Germination began in L_1 after eight weeks from planting. K_1

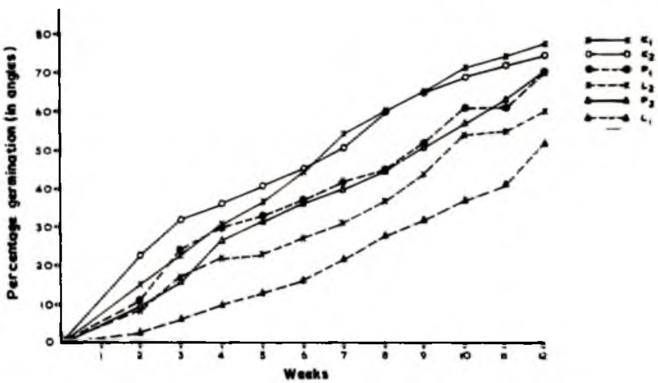

Fig. 3. The effect of Six male parents on the cummulative weekly % germination of fresh kolanuts

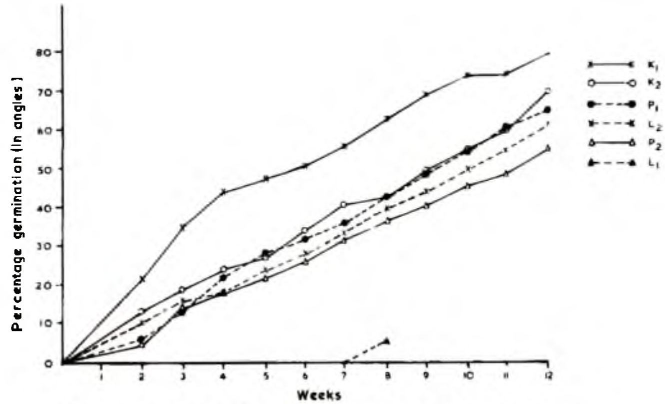

Fig. 4 The effect of Six female parents on the cummulative weekly % germination of fresh kolanuts

was the female parent for the most rapid germination. The effect of K_2, P_1 and L_2 were similar (FIG. 4).

Table (5) shows the percentage germination of the various progeny after two weeks from planting.

TABLE 5

PERCENT GERMINATION OF FRESH KOLANUTS 2 WEEKS AFTER PLANTING

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	41.7	1.7	7.0	15.0	7.0	14.5 a
K_2	21.7	-	0	0	0	3.3	5.0 b
L_1	0	0	-	0	0	0	0 b
L_2	1.7	13.3	0	-	0	0	3.0 b
P_1	1.7	3.3	0	0	-	0	1.0 b
P_2	1.7	1.7	0	0	0	-	.68b
Male means	6.7b	15.0a	.34b	1.8b	3.8b	2.6b	

Means with similar letters are not statistically different according to Duncan's multiple range test(Within male or female treatments).

Kumasi white progeny (K_1 x K_2) germinated readily soon after planting whilst nuts of the progeny from crosses between Laboshie white cultivar (L_1 or L_2) or Kade pink cultivar (P_1 or P_2) and Kumasi white cultivar (K_1 or K_2) were just emerging from dormancy. Nuts of the crosses between Laboshie white cultivar and Kade pink cultivar were dormant two weeks after planting. These nuts were still dormant four weeks after planting (Table 6). Nuts of the Kumasi white progeny (K_1 x K_2) had a faster germination rate than those of Kade pink (P_1 x P_2) and the crosses between Kumasi white cultivar and Kade pink cultivar germinated at an intermediate rate between $K_1 \times K_2$ and $P_1 \times P_2$ (Table 6).

TABLE 6

PERCENT GERMINATION OF FRESH KOLANUTS FOUR WEEKS AFTER PLANTING

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	85.0	10.0	48.3	55.0	41.7	48.0a
K_2	41.7	-	1.7	1.7	18.3	16.7	16.7b
L_1	0	0	-	0	0	0	0.0c
L_2	13.3	23.3	1.7	-	8.3	3.3	10.0b
P_1	36.7	16.7	0	1.7	-	20.0	15.0b
P_2	11.7	15.0	1.7	1.7	18.3	-	9.7b
Male means	25.9b	35.0a	3.0d	13.4c	24.9b	20.4bc	

Means with similar letters are not different according to Duncan's multiple range test (Within male or female treatments).

Table 7 below shows the same trend of germination as in Table 6 above.

TABLE 7

PERCENT GERMINATION OF FRESH KOLANUTS EIGHT WEEKS AFTER PLANTING

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	98.3	56.7	81.7	81.7	78.3	79.3a
K_2	86.7	-	35.0	13.3	43.3	56.7	47.0b
L_1	0	5.0	-	0	0	0	1.0c
L_2	75.0	63.3	8.3	-	45.3	15.0	41.0b
P_1	85.0	68.3	1.7	31.7	-	48.3	47.0b
P_2	46.7	68.3	10.0	18.3	33.3	-	35.3b
Male means	73.4a	74.6a	22.3d	36.3c	50.4b	50.0b	

Means with similar letters are not different according to Duncan's multiple range test (Within male or female treatments).

Whilst Kumasi white progeny (K_1 x K_2) had almost completed germination, eight weeks after planting, Kade pink progeny (P_1 x P_2) had not reached 50 percent germination and Laboshie white progeny (L_1 x L_2) and the crosses between Kade pink cultivar (P_1 and P_2) and Laboshie white cultivar (L_1 and L_2) were just emerging from dormancy (Table 7).

II THE GERMINATION OF NUTS STORED FOR TWO MONTHS

There was no significant difference in the speed of germination due to male or female parents after two months storage. Their interaction was also not significant (Appendix 2).

TABLE 8

PERCENT GERMINATION OF STORED KOLANUTS TWO WEEKS AFTER PLANTING

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	85.0	8.3	43.3	21.7	26.7	37.0
P_1	46.7	23.3	6.7	5.0	-	18.3	20.0
Male means	46.7	54.15	7.5	24.15	21.7	22.5	

Table 8 shows that stored nuts germinated much more readily than fresh nuts (Table 5). Although parental interactions were not significant, nuts of the Kumasi white progeny (K_1 x K_2) germinated very rapidly after storage for two months. Nuts of the Progeny of P_1 x L_1 or P_1 x P_2 germinated at a slower rate than those of

K_1 x L_2, K_1 x P_1 or K_1 x P_2. This trend of the germination rates of stored nuts of the various progeny was maintained till the termination of the experiment at 5 weeks from planting when the Kumasi white progeny (K_1 x K_2) reached 100 percent germination (Table 9).

TABLE 9

PERCENT GERMINATION OF STORED NUTS 5 WEEKS AFTER PLANTING

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	100.0	61.7	100.0	88.3	85.0	87.0
P_1	98.3	86.7	21.7	50.0	-	71.7	65.7
Male Means	98.3	93.4	41.7	75.0	85.3	78.4	

4. THE EARLY SEEDLING GROWTH OF COLA NITIDA

Analysis of covariance with seed size as the covariate showed that seed size had effect on total dry matter of above ground parts (leaves, petioles and stems), the mean seedling height and girth, the mean number of leaves per seedling and the total leaf area. The effect of the various seed sizes on the above growth parameters was, however, small as indicated by the adjusted and unadjusted F ratios (Table 10).

TABLE 10

COVARIANCE ANALYSIS OF THE EFFECT OF SEED SIZE ON KOLA SEEDLING FROWTH

Mean seed size (g) of the various crosses

	K_1	K_2	L_1	L_2	P_1	P_2
K_1	-	12.67	13.0	11.67	14.0	12.33
K_2	14.0	-	11.0	10.33	14.33	12.33
L_2	8.67	11.67	12.0	-	10.0	10.0
P_1	13.67	11.33	14.0	12.33	-	13.33
P_2	12.67	11.0	13.67	14.0	12.33	-

GROWTH PARAMETER:	UNADJUSTED F RATIO	ADJUSTED F RATIO
Total dry matter after five months	6.95 **	8.06 **
Mean seedling height after five months	9.56 **	8.93 **
Mean seedling girth after five months	7.56 **	8.04 **
Total leaf area after five months	7.79 **	8.64 **
Mean number of leaves/seedling after five months	4.15 *	3.99 *

TABLE 11

Total dry matter (g) of above parts of 5 months old kola seedlings

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	57.5	52.7	83.4	81.8	75.7	70.2 d
K_2	82.8	-	81.4	86.1	99.0	94.4	88.8 c
L_2	67.7	82.7	56.9	-	72.3	80.0	71.9 d
P_1	91.7	87.9	44.8	61.7	-	78.2	72.9 d
P_2	55.2	68.1	41.0	43.8	84.1	-	58.4 d
Male means	74.4a	74.1a	53.4b	68.8ab	84.3a	82.1a	

Means with similar letters are not different according to Duncan's multiple range test (Within male or female treatments).

Both male and female parents significantly influenced dry matter accumulation in their progeny at 5 percent level (Appendix 3a). Their interaction was, however, not significant. Kade pink cultivar (P_1 and P_2) was the most efficient male parent for dry matter accumulation. This was, however, not statistically different from Kumasi white cultivar (K_1 and K_2). Laboshie white cultivar (L_1) was the least efficient male parent.

K_2 was the most efficient female parent for dry matter accumulation. The other female parents were similar in their effect on dry matter accumulation in their respective progeny. Table 11 also shows that progeny from crosses between Kumasi white cultivar and Kade pink cultivar had higher dry matter than progeny from crosses between Kade pink and Laboshie white, although analysis of variance showed no significant interaction between parents.

There was a positive correlation ($r = .629$, $p < .001$) between the adjusted total dry matter of the seedlings (Table 11) and the adjusted mean seedling height (Table 12).

TABLE 12

MEAN HEIGHT (CM) OF 5 MONTHS OLD KOLA SEEDLINGS

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	30.2	29.1	35.6	39.1	33.7	33.6 a
K_2	35.2	-	30.2	32.1	32.9	36.5	33.4 a
L_2	25.6	26.9	22.8	-	25.4	29.7	26.1 b
P_1	39.1	40.1	27.1	32.2	-	33.2	34.2 a
P_2	32.1	37.4	25.2	23.5	29.8	-	29.6ab
Male means	33.0	33.6	26.9	30.9	31.8	33.4	

Means with similar letters are not different according to Duncan's multiple range test (Within male or female treatments).

Analysis of variance (Appendix 3b) showed that female parents were significantly different at 5 percent level in height. The interaction between male and female parents was also significant at 5 percent level. Laboshie white cultivar (L_2) was the least efficient female parent for growth in height. The rest were similar. Progeny from crosses between Kumasi white and Kade pink cultivars grew taller than those from crosses between Kade pink and Laboshie white. $L_1 \times L_2$ produced the shortest progeny. There was a positive correlation ($r = .52$, $p < .01$) between height (Table 12) and girth (Table 13).

Table (13) shows the adjusted mean girth of the various progeny. None of the parents was significantly different (Appendix 3e).

TABLE 13

MEAN GRITH (CM) OF 5 MONTHS OLD KOLA SEEDLINGS

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	.51	.50	.64	.64	.60	.58
K_2	.54	-	.53	.57	.57	.53	.55
L_2	.53	.52	.51	-	.58	.59	.55
P_1	.65	.63	.50	.57	-	.59	.59
P_2	.56	.55	.47	.52	.56	-	.53
Male means	.57	.55	.50	.58	.59	.58	

The adjusted total leaf area of the seedlings after five months is shown in Table 14.

TABLE 14

TOTAL LEAF AREA (SQ. CM) OF 5 MONTHS OLD KOLA SEEDLINGS

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	710.3	623.7	961.4	938.9	777.6	802.4bc
K_2	1155.3	-	1121.9	1135.1	1266.0	1224.6	1180.6a
L_2	863.1	1082.4	786.1	-	921.0	957.4	922.0b
P_1	983.9	979.0	524.9	719.2	-	843.1	810.0bc
P_2	552.3	809.9	542.2	439.3	980.6	-	664.8c
Male means	888.6	894.4	718.8	813.8	1026.6	950.6	

Means with similar letter are not different according to Duncan's multiple range test (Within male or female treatments).

Analysis of variance (Appendix 3c) showed that only female parents were significantly different at 1 percent level in leaf area. K_2 produced the highest leaf area. The other female parents were not statistically different from each other. There was a positive correlation ($r = .92$, $p < .001$) between total leaf area (Table 14) and total dry matter (Table 11), but there was no correlation between total leaf area (Table 14) and the adjusted mean number of leaves per seedling (Table 15).

TABLE 15

MEAN NUMBER OF LEAVES PER SEEDLING OF 5 MONTHS OLD KOLA SEEDLINGS

	K_1	K_2	L_1	L_2	P_1	P_2	Female means
K_1	-	11.1	14.0	17.7	17.3	14.9	15.0 ab
K_2	13.2	-	13.0	14.0	15.1	13.8	13.9 bc
L_2	12.6	12.8	13.2	-	11.4	13.9	12.9 c
P_1	18.5	16.4	13.7	15.7	-	14.8	15.8 a
P_2	12.9	16.1	12.5	10.3	12.1	-	12.8 c
Male means	14.3	14.1	13.3	14.3	14.0	14.4	

Means with similar letters are not different according to Duncan's multiple range test (Within male or female treatments).

Female parents were significantly different in mean number of leaves per seedling produced (Appendix 3d), with Laboshie white cultivar (L_2) and Kade pink cultivar (P_2) being the least efficient female parents for leaf production. K_1 and P_1 were the most efficient parents for leaf production.

DISCUSSIONS

FRUIT SETTING

The percentage fruit set of 64.7 obtained in this work is consistent with the observations of Van Eijnatten (1967a, 1969) that fruit set in kola can be increased by controlled pollinations compared to natural pollination. This also emphasises the observations by Russell (1955) that ineffective natural pollination in kola is not due to lack of fertile pollen, but rather due to the activity of pollinating agents and incompatibility factors.

In this work, it was found that P_1 was the most efficient female parent for fruit set but the least efficient pollinator. L_2 behaved in the reverse manner. It may, therefore, be inferred that the ability of kola cultivars to influence fruit set varies depending upon whether they are used as male or female parents. This is an indication of reciprocal difference in the compatibility relationship of the alleles involved as pointed out by Jacobs (1971). Since the alleles of K_1 showed no reciprocal difference with the alleles of P_1 (Table 2), they may be considered different from those of K_2, P_2 and L_2 which showed reciprocal differences with the alleles of P_1. This agrees with the findings of Jacob (1971) that multiallelic series may control incompatibility in *Cola nitida*.

Given that natural pollination is effective, a plantation consisting of a mixture of clones derived from P_1 and K_1 will set fruit readily since there was no reciprocal difference in their combinations for fruit set. The two cultivars are therefore a potential source of clonal materials for rehabilitating unproductive kola farms. Furthermore since P_1 is self compatible, it may be expected that the progeny from the cross between P_1 and K_1 will set fruit readily and thus constitute a potential high yielding seedling population if the mature trees will produce adequate number of male and female flowers. A similar situation exists in *Theobroma cacao* L., also of the family sterculiaceae, where hybrids derived from the crosses between self incompatible Upper Amazonian selections and selections from self compatible West African Amelonado are very vigorous and high yielding (Toxopeus, 1969). On the other hand, seedling trees derived from the F_1 progeny between P_1 and the other cultivars might not necessarily set fruit readily owing to the reciprocal difference in the action of the incompatibility alleles involved.

THE INHERITANCE OF KOLANUT COLOUR

It is significant to note that the colour of kolanuts that segregated in the progeny of the cross $K_1 \times P_1$ was different from that obtained for the progeny from crosses between P_1 and the other white cultivars (K_2, L_1 and L_2, Table 3). This indicates that alleles controlling white nut colour in different cultivars are dissimilar. Results of the segregation of kolanut colour obtained in this work (Table 3) agree with the observations of Van Eijnatten (1967) that it is not always valid that there is a dominant red factor which is epistatic over a pink factor, with white being the double recessive genotype as suggested by Voelcker (1935) and Beck (1958).

A tentative explanation of the various ratios in table 3 is obtained if it is assumed that a single locus with multiple allelic series controls the colour of kolanuts, with some of the alleles acting as iso-alleles, whilst others interact quantitatively. Designating this locus as C, the genotypes below are suggested for the trees and the nut colour types observed.

Tree (Cultivar)	Genotype	Phenotype of nut colour
K_1	$C^{w1}\ C^{w1}$	white
K_2	$C^{w1}\ C^{w2}$	white
L_1	$C^{w1}\ C^{w2}$	white
L_2	$C^{w1}\ C^{w2}$	white
P_1	$C^{r}\ C^{r}$	light red
P_2	$C^{w1}\ C^{r}$	pink
	$(C^{w2}\ C^{r})$	red

On the basis of the above genotypes, the expected phenotypic ratios of red, white or pink nuts that would segregate in the progeny of the various crosses is shown below.

Cross	Genotype of Parents		Genotypes of F_1 Progeny	Expected Phenotypic Ratios Red	:	White	:	Pink nuts
$K_1 x\ K_2$	$C^{w1}C^{w1} x\ C^{w1}C^{w2}$	=	$C^{w1}C^{w1} + C^{w1}C^{w2}$	0	:	1	:	0
$K_1 x\ P_1$	$C^{w1}C^{w1} x\ C^{r}\ C^{r}$	=	$C^{w1}C^{r}$	0	:	0	:	1
$K_2 x\ P_1$	$C^{w1}C^{w2} x\ C^{r}\ C^{r}$	=	$C^{w1}C^{r} + C^{w2}C^{r}$	1	:	0	:	1

Cross	Genotype of Parents		Genotypes of F_1 Progeny	Expected Phenotypic Ratios				
				Red	:	White	:	Pink nuts
$K_1 \times P_2$	$c^{w1}c^{w1} \times c^{w1}c^{r}$	=	$c^{w1}c^{w1} \times c^{w1}c^{r}$	0	:	1	:	1
$K_2 \times P_2$	$c^{w1}c^{w2} \times c^{w1}c^{r}$	=	$c^{w1}c^{w1} + c^{w1}c^{w2} + c^{w1}c^{r} + c^{w2}c^{r}$	1	:	2	:	1
$P_1 \times P_2$	$c^{r}c^{r} \times c^{w1}c^{r}$	=	$c^{r}c^{r} + c^{w1}c^{r}$	1	:	0	:	1

Chi square test (Appendix 4) showed that most of the observed segregation ratios in table 3 showed no discrepancy with the expected segregation ratio based on the above genotypes. In a few cases such as $P_2 \times K_1$ or $P_2 \times K_2$ where the observed ratios showed discrepancies, their reciprocal crosses did not.

THE GERMINATION OF KOLANUTS

The lack of correlation between seed size and germination rate observed in this work is in agreement with the findings of Van Eijnatten and Quarcoo (1968) and indicates that the rate of germination of freshly harvested kolanuts is independent of the amount of storage products in the nuts. The capacity of kolanuts to germinate soon after harvest is known to be influenced by the stage of maturity at which the fruit is harvested. According to Karikari (1973) at Kade and Van Eijnatten (1969) in Nigeria, fresh kolanuts germinate best after 120 - 130 days from pollination when the fruits are well mature and are shed. In this work, shedding of well developed fruits occurred between 104 and 108 days from pollination. This indicates that the rate of development of kola fruit may be dependent on season and cultivars.

The varying degree of dormancy observed in the cultivars indicates that the time at which freshly harvested kolanuts are capable of rapid germination in the different cultivars may not coincide with the time at which the fruit is physiologically mature. Thus kolanuts may develop at different rates in different cultivars. Since the female variance was higher than the male variance, the female parent largely controls the speed of germination of freshly harvested kolanuts. This suggests that maternal effects may affect the development of kolanuts and that reciprocal difference in the rate of germination of fresh kolanuts is expected. This is well illustrated in L_1 which as a female parent induced a rest period of eight weeks in all its progeny with other cultivars, but less so as male parent (Table 7). Karikari (1973) found that Laboshie white had greater capacity to germinate than Kumasi white. The opposite result was obtained in this work. This indicates that variability in the rate of germination of fresh kolanuts may occur within the same cultivar probably due to maternal effects on the development of kolanuts.

Van Eijnatten (1969) noted significant growth in size and tissue differentiation of embryos of stored nuts of a Nigerian cultivar (Agege red) compared with embryos of fresh nuts of the same cultivar. Since nuts from K_1 germinated readily soon after harvest and those of P_1 needed some rest period before germination (FIG. 3 and 4), but stored nuts from these cultivars showed no significant difference in their germination rates (Table 8 and 9), it is probable that the physiological maturity of the fruits of K_1 coincided with the time its embryos were fully grown and capable of rapid germination whilst those of P_1 did not. Two months storage was probably adequate for the embryos of P_1 to be fully grown and capable of rapid germination at the same rate as K_1.

The rate of germination of kolanuts is also known to be affected by the mechanical constraint imposed on the embryo by the adhering cotyledons so that parting the cotyledons without breaking their union with the rest of the embryo or cutting the tip of the nuts promotes rapid germination (Ibikunle and Mackenzie, 1974; Brown and Afrifa, 1971). The degree of adhesive force between the cotyledons may be related to the kind of storage products in the nuts which depends on the stage of maturity of the nuts (Oyebade, 1973) and on the male and female parents so that different progeny have different rates of germination. That varying kinds of storage products are stored in kolanuts is inferred from the various colours of the nuts and the degree of bitterness which regular chewers of kolanuts recognise in different cultivars.

Stored kolanuts imbibe water at a faster rate than fresh nuts (Van Eijnatten, 1969) and the adhesive force between the two cotyledons decrease with storage (Ibikunle and Mackenzie, 1974). These observations indicate that moisture is lost during storage which affects the turgidity in the cotyledons and consequently the adhesive force between them. These changes in the nuts together with embryo growth during storage might have led to improved germination rate of the stored nuts.

SEEDLING GROWTH

Although Kumasi white progeny (K_1 x K_2) germinated more rapidly than the progeny from the cross between Kade pink and Kumasi white (K_1 x P_1) (Tables 5,6 and 7), the seedlings of the latter exceeded those of K_1 x K_2 progeny in dry weight, height, girth and number of leaves produced (Tables 11, 12, 13 and 15). This shows that rapidly germinating kolanuts will not necessarily grow into the most vigorous seedlings. It is remarkable that fresh nuts of the progeny of K_1 x P_1 germinated fairly readily (Tables 5, 6 and 7) and produced vigorous seedlings. This emphasises the high potential of K_1 and P_1 as good parents for kolanuts which will germinate uniformly and rapidly to produce early maturing and high yielding trees. The slow growth of Laboshie white progeny (L_2 x L_1) suggests that inbreeding depression may occur in Cola nitida. This is because Laboshie white comes from a population of a narrow genetic base which has become established in Laboshie (Jacob and Okoloko, 1974).

The significant positive correlations between total dry weight and height and leaf area, and between girth and height indicate that linear growth in above ground parts of kola seedlings is associated with increase in dry matter accumulation in these parts. The dry matter accumulated in the seedling after five months of growth represents both translocated food material from the seed and photosynthates from the leaves. Significant difference in the seedling growth of the various progeny might, therefore, be attributed to either or both of these factors. Kola seedlings exhaust their food reserves in the nuts very slowly (Van Eijnatten, 1969). It is therefore likely that differences in photosynthetic efficiency in the various progeny would be more important in determining seedling growth rate after enough leaves have been produced by the seedlings.

The lack of correlation between leaf area and the number of leaves produced indicates that variation in leaf area observed (Table 14) is associated with the linear dimension of the individual leaves rather than their number. It is a common observation that kola trees vary significantly in the linear dimension of their leaves (Van Eijnatten, 1969 b). This character is present in five months old kola seedlings.

SUMMARY AND CONCLUSIONS

Two trees from each of the cultivars Laboshie white ex Nigeria, Kumasi white and Kade pink were intercrossed in all possible combinations to study their compatibility reactions and the segregation of kolanut colour, germination and early seedling growth of Cola nitida in their F_1 progeny.

All the cultivars were found to be intercompatible but to varying degrees. Kade pink cultivar (P_1) which was found to be self compatible was the most efficient female but the least efficient male parent for high fruit set. It showed no reciprocal difference for high fruit set in combination with Kumasi white cultivar (K_1). The fruits that developed from the successfully pollinated female flowers matured between 104 - 108 days after pollination, about two weeks earlier than previously reported.

Crosses between Kumasi white and Laboshie white cultivars produced white nuts only, but red, white and pink nuts were produced in their F_1 progeny with the Kade pink cultivar. Kumasi white cultivar (K_1) differed from the other white trees in the segregation ratio of red, white and pink nuts in its F_1 progeny with the Kade pink cultivar. The ratio of red, white and pink nuts that segregated in the F_1 progeny of the crosses could be explained by assuming that a single locus with multiple alleles controls the inheritance of kolanut colour.

Female parents influenced germination rate of fresh kolanuts more than male parents. Fresh nuts of the Kumasi white progeny germinated readily whilst those of Laboshie white were dormant and those of Kade pink germinated at an intermediate rate between Kumasi white and Laboshie white. Storage improved the germination rates of the nuts.

Seedlings of the crosses between Kumasi white and Kade pink were the most vigorous and those of Laboshie white progeny were the least vigorous.

It is concluded from the forgoing that:-

(1) The yield of *Cola nitida* may be improved by selecting for self compatible and self incompatible parents which show no reciprocal difference for high fruit set when inter-crossed. Further work is, however, required to test the compatibility reactions of the progeny derived from such parents to establish their potential as high yielding seedling populations.

(2) The low and variable rates of germination of kolanuts may be due to variable rates of development of kolanuts and the kind of storage products in the nuts in different cultivars. Large variation in the speed of germination of kolanuts may occur within the same cultivar as a result of maternal effects on the development of kolanut. Further work is required to study the speed of germination of kolanuts in relation to the kind of the storage products in the nuts and the degree of embryo development at physiological fruit maturity of different cultivars.

(3) Since the forests of Ghana are within the centre of origin of *Cola nitida*, desirable genetic variability may be found from the existing spontaneous trees or from local cultivars to improve the rate of seedling growth of the crop rather than from introductions such as Laboshie white which comes from a population of low genetic base.

(4) Further studies on the segregation ratios of red, white and pink nuts from F_1, F_2 and backcrosses of different kola cultivars are necessary to establish that a single locus with multiallelic series controls the inheritance of kolanut colour.

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APPENDIX

APPENDIX 1 : FRUIT SETTING

Analysis of Variance Table

Source	df	Tss	Mss	F
Total	24	7284.91		
Males	5	2218.37	443.67	3.11*
Females	4	2623.13	655.78	4.59*
Non additive interaction	1	444.38	444.38	3.11
Error	14	1999.03	142.79	

APPENDIX 2 : THE GERMINATION OF KOLANUTS

Analysis of Variance Tables for Fresh Nuts

Two Weeks after Planting

Source	df	Tss	Mss	F
Total	29	2911		
Males	5	703.40	140.68	4.84**
Females	5	1220.88	244.18	8.40**
Slopes	5	579.81	115.96	3.99*
Error	14	406.91	29.07	

Three Weeks after Planting

Source	df	Tss	Mss	F
Total	29	6115.65		
Males	5	1341.77	268.35	20.06**
Females	5	3169.90	633.98	47.38**
Slopes	5	1416.65	283.3	21.17**
Error	14	187.33	13.38	

Four Weeks after Planting

Source	df	Tss	Mss	F
Total	29	8357.55		
Males	5	1043.87	208.77	7.64**
Females	5	4878.14	975.62	35.70**
Slopes	5	1693.75	338.75	12.40**
Error	14	382.65	27.33	

Five Weeks after Planting

Source	df	Tss	Mss	F
Total	29	9785.30		
Males	5	1796.15	359.23	6.19**
Females	5	5569.45	1113.89	19.18**
Slopes	5	1606.83	321.37	5.53**
Error	14	813.11	58.08	

Six Weeks after Planting

Source	df	Tss	Mss	F
Total	29	11933.66		
Males	5	1981.36	396.27	3.26*
Females	5	6874.46	1374.83	11.30**
Slopes	5	1374.71	274.94	2.26
Error	14	1703.13	121.65	

Seven Weeks after Planting

Source	df	Tss	Mss	F
Total	29	14875.54		
Males	5	2442.40	488.48	2.39
Females	5	8515.30	1703.06	8.33**
Slopes	5	1057.03	211.41	1.04
Error	14	2860.81	204.34	

Eight Weeks after Planting

Source	df	Tss	Mss	F
Total	29	16289.00		
Males	5	2654.18	530.84	11.32**
Females	5	10044.00	2008.8	42.85**
Slopes	5	2934.45	733.61	156.65**
Error	14	656.37	46.88	

Analysis of Variance Tables: Stored Nuts

Two Weeks from Planting

Source	df	Tss	Mss	F
Total	9	2394.24		
Females	1	345.15	345.15	0.88
Males	5	1242.20	248.44	0.63
Turkey's Non additivity	1	8.70	8.70	0.02
Error	2	780.48	390.24	

Three Weeks from Planting

Source	df	Tss	Mss	F
Total	9	2825.84		
Females	1	477.07	477.07	1.71
Males	5	1763.20	352.64	1.26
Turkey's Non additivity	1	28.23	28.23	0.10
Error	2	557.34	278.67	

APPENDIX 3

SEEDLING GROWTH : ANALYSIS OF VARIANCE TABLES

a. Total Dry Matter after Five Months

Source	df	Tss	Mss	F
Total	24	6597.01		
Males	5	2467.88	493.58	3.89*
Females	4	2336.55	584.14	4.06*
Non additivity	1	15.53	15.53	
Error	14	1777.14	126.94	0.12

b. Mean Plant Height after Five Months

Source	df	Tss	Mss	F
Total	24	594.77		
Males	5	147.13	29.43	2.79
Females	4	242.63	60.66	5.7 **
Int. Non additivity	1	57.38	57.38	5.44*
Error	14	147.62	10.54	

c. Total Leaf Area after Five Months

Source	df	Tss	Mss	F
Total	24	1244128.63		
Females	5	746180.36	186545.09	10.83**
Males	4	252713.46	50542.69	2.95
Non additivity	1	5241.02	5241.02	.31
Error	14	239993.79	17142.41	

d. Number of Leaves per Plant after Five Months

Source	df	Tss	Mss	F
Total	24	102.33		
Males	5	4.04	0.81	0.51
Females	4	36.42	9.11	5.73**
Non additivity	1	39.63	39.63	24.92**
Error	14	22.24	1.59	

e. Girth after Five Months

Source	df	Tss	Mss	F
Total	24	.05		
Males	5	.02	.004	2.86
Females	4	.01	.0025	1.79
Non additivity	1	.00047	.00047	0.335
Error	14	.0195	.0014	

APPENDIX 4

Chi square values calculated from the data obtained for the segregation of kolanut colour in the crosses studied

	K_1	K_2	L_1	L_2	P_1	P_2
K_1	-	0	0	0	0	1.33
K_2	0	-	0	0	0.11	0.58
L_1	0	0	-	-	0.018	0.016
L_2	0	0	0	-	0.012	4.60
P_1	0	3.24	0.77	13.57**	-	0.003
P_2	13.54**	9.68**	15.02**	2.64	0.296	-

**Significant at 1 percent level.