# Vegetative propagation of kola (*Cola nitida* Vent. Schott and Endl.) by stem cuttings

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ABSTRACT

The effects of some technical, environmental and physiological factors on the rooting of kola stem cuttings were investigated at the Cocoa Research Institute of Ghana from 1997 to 2002. These factors included hormonal, fungicidal and wounding treatments, rooting media, leaf area, and effects of type of wood. Within the range of concentration tested, indole-butyric acid (IBA) rooting hormone did not have any significant effect on rooting success. All the candidate fungicides tested were effective in reducing rotting of cuttings. However, the copper-based fungicides caused a slight reduction in rooting. No significant differences were recorded for effect of rooting media. Wounding treatment improved rooting in hardwood cuttings. Rooting was significantly better ($P \leq 0.05$) in semi-hard- wood cuttings than in hardwood cuttings. Clipping of leaves to half the normal size had virtually the same results as leaving all leaves intact. Further areas to improve success in propagating kola by stem cuttings are discussed.

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RÉSUMÉ

AMOAH, F. M., OSEI-BONSU, K., AKROFI, A. Y. & ABDUL-KARIMU, A.: *Propagation végétative de kola* (Cola nitida *Vent. Schott et Endl.) par les boutures de tige.* Propagation végétative des arbres de kola s'est prouvée d'être une proposition pratique surtout pour la multiplication des clones sélectionnés. Alors que le bourgeonnement et le greffage avaient donné dans l'ensemble les proportions de succès très élevées, la propagation par les boutures de tige avait été très difficile toujours, donnant un succès moyen d'environ 35 pour cent. Des études se sont déroulées à l'Institut de Recherche du Cacao du Ghana de 1997 à 2002 pour enquêter sur les effets de quelques facteurs techniques, environnement aux et physiologiques sur l'enracinement des boutures de tige de kola. Ces facteurs comprennent le traitement hormonal, fungicidal et blessant ainsi que les effets de milieu d'enracinement, superficie foliaire et type de bois. Dans la portée de concentration testée, l'hormone IBA d'enracinement n'a pas eu aucun effet considérable sur le succès d'enracinement. Tous les candidats de fongicides passès au test étaient efficace à la réduction de pourriture des boutures. Toutefois les fongicides basés sur le cuivre provoquaient une réduction de l'enracinement. Il n'y avait pas des différences considérables liées à l'effet de milieu d'enracinement. Le traitement blessant améliorait l'enracinement de bouture de bois dur. L'enracinement était considérablement meilleure *($P \leq 0.05$)* avec les boutures de bois semi-dures qu'avec les boutures de bois dur. La taille des feuilles jusqu'au demi de la dimension normale donnait pratiquement les mêmes résultats que toutes les feuilles laissées intactes. D'autres facteurs qui peuvent améliorer le succès de propagation de la bouture de tige de kola sont discutés.

## Introduction

Vegetative propagation is essential for multiplying and improving some tree species, because it facilitates the perpetuation of the genetic constitution of the plant barring any somatic mutation. The response of various tree species to methods of vegetative propagation varies considerably (Nanda & Tandon, 1967; Nanda *et al.*, 1968). While some trees respond easily to propagation by budding, grafting, or rooting by stem cuttings, others do not readily respond to any of these conventional vegetative methods of propagation.

Kola nuts play an important role in the internal trade in West Africa. The main production areas lie along the coast, with South Western Nigeria as the most important producer, Ghana and Ivory Coast being production centres of secondary importance. The produce is traded mainly in a northerly direction (Van Eijnatten, 1969).

The decline in kola yields as a result of pests and diseases, physiological decline, deforestation, and natural disasters--for example, drought and bush fires and deforestation in some kola-producing areas – has led to the necessity to intensify the production of high-yielding clonal kola planting materials for new establishments and rehabilitation of old and unproductive farms. While propagation of the kola tree by budding or grafting may be quite easy, propagation by stem cuttings is very difficult. Rooting success in kola has often been very low (Van Eijnatten, 1969), with an average of 35 per cent rooting (Clay, 1963). This poor response to rooting could be due to genetic, environmental, or technical factors.

Rooting of recalcitrant tree species difficult to propagate vegetatively often require high technical expertise as well as specialized facilities for an acceptable success rate (Ofori-Gyamfi, 1998). Hitherto, most commercial kola plantations have been derived from seeds.

Unfortunately, seedlings show a high degree of variability, with relatively small proportions contributing a major percentage of the yield of the population.

The task of obtaining greater homogeneity and improving crop yield significantly, coupled with perpetuating other desirable genetic characters by means of vegetative propagation, demand intensive research to develop techniques for improving rooting in kola. Though propagation of kola by budding or grafting is attractive as propagation materials are intensively used, propagation by rooted cuttings is still preferred. The problem associated with propagation by budding and grafting is the difficulty in causing bud break and forming new shoots from the scion. After budding, buds may develop into flowers instead of shoots.

Considering the importance of kola in the Ghanaian economy, efforts should be made in developing the crop and producing large quantities of clonal planting materials for research work and establishment of plantations. Several factors, either in isolation or in combination with others, affect the degree of success in propagating tree crops by rooted cuttings (Amoah, 1986). These factors may be broadly categorised as physiological, environmental, biochemical, pre-treatment effect, or seasonal influence.

The objective of this work was to study the effects of some physiological, environmental, and pre-treatment factors on rooting in kola to develop a package to facilitate the intensification of kola propagation by rooted cuttings for farmers and research programmes.

## Materials and methods

A series of experiments were set up at the Cocoa Research Institute of Ghana at Tafo (00$^0$ 22W 06$^1$ 13N 198m a.s.l) between 1997 and 2002 to study the effects of some physiological, environmental, and pre-treatment factors on rooting in kola. Two propagation systems used for the study were the Nutrient Film Technique (NFT) and the conventional propagation pits.

The NFT, as described by Amoah & Fordham (1997), had plastic channels lined with polythene sheets installed on a 1-m high bench. The channels, each measuring 4 m × 12.5 cm × 10 cm (L × B × H), were set 15.0 cm apart at a gradient of 1 in 50. Temperature-controlled plain water, warmed by 200-W immersion heaters, was pumped by Eheim portable pumps from floor tanks to the top of the channels *via* a hose pipe; it was then discharged into the channels *via* small inlet pipes about 0.5 m in diameter connected to the main delivery pipe. The flow rate was regulated at 0.5-1.0 l/min per channel, using metal clips. Transparent medium-gauge polythene was placed over metal loops 60 cm apart, forming a tunnel about 20 cm high over each channel and creating a high humidity micro-environment around the leaves, preventing them from drying out during rooting. The plain water in the tank was changed weekly, and the tank washed thoroughly and refilled to limit algae growth. Vermiculite carried in 5-cm mesh pots was used as rooting medium in the NFT. Each channel carried 40 pots, with one cutting per pot.

The conventional propagation pits were constructed with concrete, and each measured 4 m × 1 m × 1 m (L × B × H). The pits were constructed under a shed of shade net with 35 per cent light transmission. Various media were used for rooting in the propagation pits, depending on the objectives of the specific experiment. The lower 40 cm of the pits were filled with large stones on top of which were placed gravel to another depth of 40 cm before the various media were placed on top of the gravel to a depth of 20 cm.

*Cola nitida* cuttings for the various experiments were collected from Tafo, Asikam, Okumaning, and Akwasiho in the Eastern Region and Juaben in Ashanti Region. The kola trees in each location were about 20 years old, robust and in luxuriant growth. Unless otherwise stated under the respective experiments, each cuttings had a wood portion of about 15 cm length, diameter of about 4 mm, and with four to six leaves which were clipped to about half the normal size. Semi-hardwood cuttings were used. The cuttings were normally rooted for 16 weeks after which they were lifted and assessed for rooting. Except for rooting media studies, the river sand medium was used for the experiments in the propagation pits. The number of cuttings used in each trial depended on the availability of propagation materials. A 2 × 2 contingency table, used for testing significant levels in propagation trials (Al Baraz, 1983), was used for statistical analysis in this study.

*Experiment 1: Response of kola cuttings to rooting hormone*

Three concentrations of indole-butyric acid (IBA) – 0, 2 500 and 5 000 ppm – were tested on rooting in kola. The rooting hormone was applied to the cuttings as a quick dip. The river sand medium was used for rooting in propagation pits. The 200 cuttings per treatment were selected from a mixed population of trees which had white, red and pink nuts. The cuttings were rooted between June and September. Table 1 presents the results of the experiment.

*Experiment 2: Effect of some fungicides on rooting in kola*

The objective of this trial was to attempt to reduce rotting in kola cuttings, a major problem to kola propagation by rooted cuttings (Clay, 1963). Fungal attack had been identified as the main cause of rotting in kola cuttings during propagation. Five candidate fungicides plus a control (spraying with water) were applied to cuttings in the NFT system and in propagation

TABLE 1

*Response of Kola Cuttings to Rooting Hormone (Indole-butyric Acid)*

| *Concentration of rooting hormone (ppm IBA)* | *Number of cuttings set* | *Number rooted after 16 weeks* | *Number dead* | *Number alive and calloused* |
|---|---|---|---|---|
| 0 (control) | 200 | 50 a | 38 a | 102 a |
| 2500 | 200 | 55 a | 35 a | 110 a |
| 5000 | 200 | 58 a | 45 a | 97 a |

pits. The candidate fungicides studied were Ridomil Plus, Kocide 101, Champion, Nordox, and Diathane M45. The cuttings were sprayed with the various fungicides at the recommended rates (3 ml/l) at the time of setting the cuttings, and subsequently at 2 weekly intervals throughout the rooting period. The cuttings were rooted in the NFT and in propagation pits. The 100 cuttings per treatment were collected from Tafo. Table 2 presents the results of the trial.

*Experiment 3: Effect of reduced rates and frequency of application of some fungicides on rooting*

The objective of this study was to investigate the efficacy of reduced rates of fungicides on rooting in kola cuttings. The candidate fungicides tested were Ridomil Plus, Kocide 101, Champion, Nordox, and Diathane M45. The cuttings were rooted in the NFT and propagation pits. The NFT trial investigated the effect of reduced rates (half the recommended rate) on rooting success, whilst the studies in the propagation pits investigated the effect of two frequencies of application of the fungicides at the full recommended rate. The reduced rates of the fungicides were applied to the cuttings in the NFT at 2 weekly intervals. The full recommended rates were applied to the cuttings in the propagation pits at 3 and 6-week intervals. The fungicides were applied to the cuttings throughout the rooting period. Tables 3 and 4 present the results of the study.

*Experiment 4: Effect of propagation media on rooting*

Three propagation media and their various combinations in 1:1 ratio were tested on their effectiveness in improving rooting in kola. The media studied were top soil, river sand, decomposed palm fibre, top soil + river sand (1 :1), top soil + palm fibre (1:1), and river sand + palm fibre (1:1). Table 5 presents the results of the rooting experiment in the propagation pits.

*Experiment 5: Effect of different rates and frequencies of application of some copper-free fungicides on rooting*

The objective of this study was to investigate the effect of different rates and frequencies of

TABLE 2

*Effect of Some Fungicides on Rooting in Kola*

| *Candidate fungicide* | *Number of cuttings set* | *Number rooted* | *Number dead* | *Number alive and calloused* |
|---|---|---|---|---|
| a) *NFT propagation* | | | | |
| Ridomil Plus | 100 | 9 a | 34 a | 57 c |
| Kocide 101 | 100 | 8 a | 29 a | 63 c |
| Champion | 100 | 6 a | 35 a | 59 c |
| Nordox | 100 | 11a | 27 a | 62 c |
| Diathane M45 | 100 | 38 b | 32 a | 30 b |
| Control | 100 | 35 b | 52 b | 13 a |
| b) *Pit propagation* | | | | |
| Ridomil Plus | 100 | 11 a | 25 ab | 64 bc |
| Kocide 101 | 100 | 10 a | 18 a | 72 c |
| Champion | 100 | 10 a | 26 ab | 64 bc |
| Nordox | 100 | 8 a | 26 ab | 66 bc |
| Diathane M45 | 100 | 21 b | 30 b | 49 ab |
| Control | 100 | 25 b | 44 c | 31 a |

TABLE 3

*Effect of Reduced Rate of Some Fungicides on Rooting in Kola*

| *Candidate fungicide* | *Number of cuttings set* | *Number rooted* | *Number dead* | *Number alive and calloused* |
|---|---|---|---|---|
| Ridomil Plus | 40 | 13 a | 11 a | 16 b |
| Kocide 101 | 40 | 12 a | 9 a | 19 b |
| Champion | 40 | 11 a | 9 a | 20 b |
| Nordox | 40 | 12 a | 11 a | 17 b |
| Diathane M45 | 40 | 14 a | 14 ab | 12 a |
| Control | 40 | 13 a | 15 b | 12 a |

TABLE 4

*Effect of Frequency of Fungicide Application on Rooting*

| *Candidate fungicide* | *Number of cuttings set* | | *Number rooted* | | *Number dead* | | *Number alive and calloused* | |
|---|---|---|---|---|---|---|---|---|
| | *3 weekly* | *6 weekly* | *3 weekly* | *6 weekly* | *3 weekly* | *6 weekly* | *3 weekly* | *6 weekly* |
| Ridomil Plus | 40 | 40 | 14 a | 15 a | 10 a | 12 a | 16 ab | 15 b |
| Kocide | 40 | 40 | 12 a | 12 a | 12 a | 11 a | 16 ab | 16 b |
| Champion | 40 | 40 | 12 a | 14 a | 10 a | 11 a | 18 b | 15 b |
| Nordox | 40 | 40 | 10 a | 12 a | 11 a | 19 b | 19 b | 16 b |
| Diathane M45 | 40 | 40 | 16 b | 15 a | 11 a | 10 a | 13 a | 14 ab |
| Control | 40 | 40 | 14 a | 14 a | 16 b | 15 ab | 10 a | 11 a |

TABLE 5

*Effect of Propagation Media on Rooting*

| *Propagation medium* | *Number of cuttings set* | *Number rooted* | *Number dead* | *Number alive and calloused* |
|---|---|---|---|---|
| Top soil | 50 | 20 a | 14 a | 16 a |
| River sand | 50 | 22 a | 16 a | 12 a |
| Palm fibre | 50 | 18 a | 15 a | 17 a |
| Top soil + river sand | 50 | 19 a | 16 a | 15 a |
| Top soil + palm fibre | 50 | 21 a | 14 a | 15 a |
| River sand + palm fibre | 50 | 23 a | 14 a | 13 a |

application of some copper-free fungicides on rooting. Two fungicides, Diathane M45 and Bavista FL, known not to inhibit rooting, were tested at two rates (half the recommended and full rate) combined with two frequencies of application (3 and 6 weeks). The cuttings were rooted by the NFT. Table 6 presents the results of the study.

*Experiment 6: Effect of leaf area per cutting and propagation media on rooting*

The objective of this trial was to ascertain the effect of leaf area, in combination with propagation media, on rooting. Two leaf areas, about 600 and 300 cm$^2$ and equivalent to leaving all four to six leaves intact or clipped to half the normal size per

TABLE 6

*Effect of Different Rates and Frequency of Application of Some Fungicides on Rooting*

| | | Candidate fungicide | | | | | |
|---|---|---|---|---|---|---|---|
| | | Bavista FL | | | Diathane M45 | | |
| *Application rate and frequency* | *Number set* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* |
| *Half rate at:* | | | | | | | |
| 3 weekly intervals | 40 | 20 a | 8 a | 12 b | 18 ab | 10 a | 12 a |
| 6 weekly intervals | 40 | 18 b | 10 ab | 12 a | 20 b | 8 a | 12 a |
| *Full rate at:* | | | | | | | |
| 3 weekly intervals | 40 | 22 a | 6 a | 12 a | 21 a | 8 a | 11 a |
| 6 weekly intervals | 40 | 20 a | 9 a | 10 a | 22 a | 9 a | 9 a |
| Control | 40 | 18 a | 14 b | 8 a | 17 a | 13 b | 10 a |

cutting, were tested in combination with six propagation media. The media tested were top soil, river sand, palm fibre, top soil + river sand (1:1), top soil + palm fibre (1:1), and river sand + palm fibre (1:1). The cuttings were rooted in propagation pits. Table 7 presents the results of the trial.

*Experiment 7: Effect of wood type and hormone concentration on rooting*

The objective of this study was to test the rooting response of different types of wood to different concentrations of hormones. Two wood types, semi-hardwood and hardwood, were combined with four concentrations of IBA: 0, 2 000, 4 000 and 6 000 ppm. The cuttings were rooted in propagation pits. Table 8 presents the results of the study.

*Experiment 8: Effect of rooting media and season of propagation on rooting*

The objective of this study was to ascertain if there were any interaction effect between rooting media and season of propagation on rooting. Six propagation media, top soil, river sand, palm fibre, top soil + river sand (1:1), top soil + palm fibre (1:1), and river sand + palm fibre (1:1), were tested on rooting of cuttings in two seasons (wet and dry); that is, June to September and December to March, respectively. The cuttings were rooted in propagation pits. Table 9 presents the results of the study.

TABLE 7

*Effect of Leaf Area and Propagation Media on Rooting*

| | | 300 $cm^2$ leaf area | | | 100 $cm^2$ leaf area | | |
|---|---|---|---|---|---|---|---|
| *Propagation medium* | *Number set* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* |
| Top soil | 40 | 16 a | 10 a | 14 b | 18 ab | 10 a | 12 a |
| River sand | 40 | 21 b | 11 a | 8 a | 22 b | 8 a | 10 a |
| Palm fibre | 40 | 18 ab | 11 a | 11 ab | 16 a | 11 a | 13 a |
| Top soil + river sand | 40 | 20 ab | 9 a | 11 ab | 20 ab | 10 a | 12 a |
| Top soil + palm fibre | 40 | 22 b | 8 a | 10 ab | 18 ab | 10 a | 12 a |
| River sand + palm fibre | 40 | 20 b | 10 a | 10 ab | 19 ab | 9 a | 12 a |

TABLE 8

*Effect of Wood Type and Hormone Concentration on Rooting*

| | | Semi-hardwood | | | Hardwood | | |
|---|---|---|---|---|---|---|---|
| *Hormone concentration (ppm IBA)* | *Number set* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* |
| 0 (control) | 50 | 20 ab | 14 a | 16 a | 4 a | 27 b | 19 b |
| 0 | 50 | 22 ab | 10 a | 18 a | 4 a | 22 a | 24 c |
| 4 000 | 50 | 24 b | 12 a | 14 a | 5 a | 25 ab | 17 ab |
| 6 000 | 50 | 18 a | 16 a | 16 a | 7 a | 30 b | 13 a |

TABLE 9

*Effect of Propagation Media and Season of Propagation on Rooting*

| | | Wet season | | | Dry season | | |
|---|---|---|---|---|---|---|---|
| *Propagation medium* | *Number set* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* |
| Top soil | 50 | 24 ab | 13 ab | 13 a | 18 ab | 17 ab | 15 a |
| River sand | 50 | 22 ab | 11 ab | 17 ab | 19 b | 21 b | 15 a |
| Palm fibre | 50 | 22 ab | 9 a | 20 b | 15 ab | 15 a | 20 b |
| Top soil + river sand | 50 | 20 a | 15 b | 15 a | 14 a | 15 a | 21 b |
| River sand + palm fibre | 50 | 25 b | 12 ab | 13 a | 16 ab | 28 c | 20 b |

*Experiment 9: Effect of wounding and hormone concentration on rooting*

The objective of this trial was to test the possibility of increasing hormone uptake through wounding to improve on rooting in cuttings. Three wounding treatments, no wounding (control), single vertical split at the lower 1.0-cm base of the cuttings, and double vertical splits in opposite directions at the lower 1.0-cm base, were investigated. These were combined with three concentrations of IBA: 0 (control), 4 000, and 6 000 ppm. The cuttings were rooted in propagation pits. The hormone was applied by the quick-dip method to the lower 1.0-cm base of the cuttings for 30 sec. Table 10 presents the results of the study.

TABLE 10

*Effect of Wounding and Hormone Concentration on Rooting*

| | | No wounding | | | Single split | | | Double split | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hormone concentration (ppm IBA)* | *Number set* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* | *Number rooted* | *Number dead* | *Number alive and calloused* |
| 0 (control) | 40 | 10 a | 12 a | 18 b | 15 a | 12 a | 13 a | 16 a | 12 ab | 12 a |
| 4 000 | 40 | 13 ab | 13 a | 14 ab | 17 a | 12 a | 11 a | 17 a | 14 b | 9 a |
| 6 000 | 40 | 16 b | 11 a | 13 a | 16 a | 9 a | 15 a | 19 a | 9 a | 12 a |

*Experiment 10: Effect of wounding and wood type on rooting*

The objective of this trial was to test the possibility of improving rooting in semi-hardwood and hardwood cuttings through wounding. The wounding treatments tested were as described in Experiment 9. The quick-dip method was used in applying 6 000 ppm IBA to all cuttings. The cuttings were rooted in propagation pits. Table 11 presents the results of the study.

## Results and discussion

Several workers have attempted to simplify the technique of rooting tropical tree crops by studying a wide range of factors, for example, coffee (Thomas, 1940) and cocoa (Murray & Bridge 1956; Mckelvie, 1957; Nichols, 1958). These techniques, it is hoped, will be widely applied by researchers and commercial farmers.

Tables 1 to 11 show the results for the series of experiments carried out in this study. Indole-butyric acid did not have any marked effect on kola rooting at the range of concentrations tested (Tables 1, 8 and 10), except at 6 000 ppm which recorded significantly higher percentage rooting ($P$<0.05) than the untreated control (Table 10). The lack of marked improvement in rooting after applying the hormone could be due to the concentrations used, which might have been low for kola. Similar results were reported by Frimpong & Adomako (1989) on rooting in shea and kola, who observed that rooting was enhanced by applying 15 000 ppm of IBA. Al Barazi (1983) also recommended higher rates of IBA (10 000 ppm) for cuttings difficult to propagate. Future work in kola propagation may, therefore, aim at using higher concentrations of rooting hormones, or extend the dipping time other than using the quick-dip method.

Wounding of cuttings, particularly in hardwood cuttings, improved rooting significantly ($P$<0.5) (Tables 10 and 11). Double-split wounding was also observed to be superior to single-split wounding.

Hartman & Kester (1983) observed that wounding resulted in cuttings being more responsive to hormone treatment, as the surface exposed for absorption increased. Wounding was also reported to break any continuous ring of sclerenchymatous cells, which might otherwise have impeded root emergence (Amoah, 1986; Hartman & Kester, 1983). The improved rooting in kola observed in this study as the result of wounding might probably be due to enhanced uptake of hormones (Table 10), or to a break in lignified tissues in the hardwood cuttings which resulted in improved rooting (Table 11).

Histological studies on the anatomy of kola stem cuttings, particularly in hardwood, will further explain the improved rooting in kola after wound treatment. Rooting was significantly better in semi-hardwood than in hardwood cuttings (Tables 8 and 11). The effect of physiological age on rooting of cuttings is well documented. Hartman & Kester (1983) have stated that the ability of cuttings to form adventitious root decreases with increasing

TABLE 11

*Effect of Wounding and Wood Type on Rooting*

| Wounding treatment | Number set | Semi-hardwood: Number rooted | Semi-hardwood: Number dead | Semi-hardwood: Number alive and calloused | Hardwood: Number rooted | Hardwood: Number dead | Hardwood: Number alive and calloused |
|---|---|---|---|---|---|---|---|
| No wounding (control) | 40 | 16 ab | 12 a | 12 ab | 2 a | 18 a | 20 b |
| Single split | 40 | 14 a | 10 a | 16 b | 3 a | 23 b | 14 a |
| Double split | 40 | 19 b | 10 a | 11 a | 10 b | 18 a | 12 a |

Means in columns carrying the same letter are not significantly different at $P$<0.05

age. Cuttings collected from plants in the juvenile phase form roots more readily than those collected from plants in the matured phase. Opoku-Ameyaw, Amoah & Yeboah (2002) have also similarly observed in shea cuttings that improved rooting in juvenile shoots may be related to vigorous growth. Whereas meristematic activity leading to root initiation and development may be fast in juvenile materials, most cells in mature tissues may be completely differentiated with little meristematic activity and, hence, poor rooting ability (Hartman & Kester, 1983). Thus, in most horticultural plants, mature shoots are often pruned to rejuvenate to produce juvenile shoots that are easy to root.

Rooting was better in cuttings which were set in the wet season in all the media tested than in the dry season (Table 9). This may also be related to plant physiological activity which is enhanced during the wet season, resulting in better rooting compared to the dry season. During the wet season, plants are in active growth and nutrient uptake and photosynthesis is enhanced (Hartman & Loreti, 1965). Environmental factors such as relative humidity and temperature are unfavourable for rooting in the wet season compared to the dry season.

Frimpong & Adomako (1989) also observed a clear seasonal influence on rooting in the shea tree, and stated that the time of the year at which cuttings were collected and their physiological status had a marked influence on rooting success. Wounding of cuttings selected for rooting in the wet season, particularly in hard-wood cuttings, improved rooting significantly ($P<0.05$) (Tables 10 and 11). Double-split wounding was also observed to be superior to single-split wounding. Rooting was significantly better in semi-hardwood than in hardwood cuttings (Tables 8 and 11).

No major differences in rooting were recorded for the two leaf areas investigated (Table 7). This suggests that kola cuttings could have their leaves clipped to half the normal size to reduce mutual shading and facilitate the setting of more cuttings per unit area. Evans (1953) observed that the function of the leaf during rooting was to provide the cuttings with carbohydrates and, to a lesser extent, with nitrogen compounds which promoted rooting. Bowman (1950) stated that above an optimum number of leaves, excess foliage on cuttings offered no added advantage to rooting. The results from this study suggest that trimming off the leaves on kola cuttings to between four and six and clipping them to half the normal size has no adverse effect on rooting. Trimming rather facilitates the setting of more cuttings per unit area and reduces self and mutual shading.

No clear effects of propagation media on rooting were observed (Tables 5, 7 and 9). However, the overall best results were recorded in river sand + palm fibre mixture (1:1) which had an average of 50 per cent rooting. This was the highest rooting percentage recorded throughout the study. Root initiation depends on the physiological, anatomical, and biochemical condition of the cuttings. However, subsequent development of the roots depends on the rooting medium (Ofori-Gyamfi, 1998).

Criteria for selecting good rooting medium include texture, consistency, water-holding capacity, and temperature stabilization. However, the most important of these are temperature and water relations (Amoah, 1986). Different rooting media may have different water relations, and are able to facilitate favourable rooting in cuttings over a narrow optimal watering regimen. All the media tested in this study were watered adequately and regularly, and this probably accounted for the lack of major differences in their response to rooting. This suggests that kola cuttings will root in a wide range of rooting media, if watering is adequate.

All the fungicides tested in this study controlled rotting. However, rooting was often inhibited by the fungicides, except with the use of Diathane M45 and Bavista FL (Tables 2, 3, 4 and 6). These fungicides which inhibited rooting may contain copper, because copper-based fungicides are widely reported to inhibit rooting (Hartman & Kester, 1983). With the application of the copper-based fungicides, a large percentage of the cuttings remained dormant after 16 weeks. The control of rotting was more effective in the propagation pit than in the NFT system (Table 2). This is probably due to the high humidity (almost 100 %) recorded in the NFT. This observation suggests that effective fungal control is necessary for rooting in water-based systems such as the NFT.

The effects of all the factors studied on number of cuttings that died or were dormant after 16 weeks in propagation were either insignificant or did not follow any regular trend. This suggests that these parameters were unimportant in assessing the rooting response of kola cuttings to the various factors studied. Results from this study were generally better than what had been reported elsewhere (Clay, 1963; Van Eijnatten 1969), as a mean of about 50 per cent rooting was recorded in this study. This is probably due to the use of improved techniques and specialized facilities like the NFT. Future work will aim at developing the techniques further, as well as at investigating a wider range of factors and their interaction effects. Information on the effect of anatomical and biochemical factors on kola propagation is also limited. This will also be addressed in future research work.

## Conclusion

Rooting of kola cuttings is generally very low, as cuttings do not normally respond to most physiological, environmental, and pre-treatment considerations. Among all the factors studied, wood type seemed very important, as rooting was always better in semi-hardwood than in hardwood cuttings. When lack of suitable materials dictate the use of hardwood cuttings, basal wounding will be beneficial to rooting.

Rotting of cuttings during propagation could be reduced by applying fungicides. However, non-copper-based fungicides should be preferred, as copper-based fungicides reduce rooting.

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