# Rapid field multiplication of plantains using benzyl adenine or coconut water-treated split corms

J. K. OSEI
*Agricultural Research Station, Kade - Faculty of Agriculture, University of Ghana, Legon, Ghana*

**ABSTRACT**

An appropriate inexpensive technique for rapid field multiplication of local false and true horn plantain cultivars, Apantu and Asamienu, has been developed by injecting 6 or 8 ml boiled and filtered coconut water from fully ripe dried fruit or 4 ml $10^{-2}$ M benzyl adenine on 3 consecutive alternate days at the base of over 35 cm tall split corm-derived suckers, and sprouting the split corms of the treated suckers in moist sawdust, 3 weeks after the injection treatments. Up to 1,000 suckers can be generated from one Apantu sucker in a year, and 3,375 suckers from one Asamienu sucker in 18 months with the coconut water treatment. The cost of 25 ml coconut water required to treat one sucker is insignificant compared with the multiplication ratios derived from the treated suckers.

Original scientific paper. Received 05 Mar 03; revised 19 Oct 05.

**RÉSUMÉ**

OSEI, J. K.: *Multiplication rapid sur Ie terrain de surgeon de plantain utilisant benzyle adenine ou les bulbes divises traits du jus de noix de coco*. Une technique appropriee et moins chere pour la multiplication rapide sur Ie terrain de deux varietes locales de plantain Apantu (une corne fausse) et Asamienu (une come veritable) a ete obtenue par injection de 6 ou 8 ml du jus de noix de coco mur sec apres L' ebullition et la filtration ou de 4 ml $10^{-2}$ M benzyle adenine pour trois jours. Consecutifs alternes a la base de surgeons-derives de bulbes divises d'une taille au-dessus de 35 cm, et germant les bulbes divises de surgeons traites en sciure de bois moullee, trois semaines apres les traitements d'injection. Jusqu'a 1000 surgeons pourraient etre produits d'un surgeon d' Apantu dans un an et 3,375 d'un surgeon d' Asamienu en 18 mois avec Ie traitement du jus de noix de coco. Le cout de 25 ml du jus de coco exige pour traiter un surgeon est insignificant compare avec les proportions de multiplication obtenues de surgeons traites.

## Introduction

Plantain (Musa AAB, ABB) is a major starchy staple in Ghana. Three major cultivar groups, Apantu (false horn), Apem (French plantain), and Asamienu (true horn), have been identified and classified (Karikari, 1971). One major constraint in producing the crop is the lack of many uniform-sized planting materials (suckers) to plant at the optimum times recommended for the different cultivars (Hotsonyame, Doku & Karikari, 1988; Hotsonyame, 1991). Farmers obtain suckers from old farms. Such suckers may be infected with pests and diseases including nematodes (*Helicotylenchus* spp., *Practelenchus* spp. and *Rhadopholus* spp.), the plantain weevil, *Cosmopolites sordidus* (Afreh-Nuamah, 1994) and the banana streak and cucumber mosaic viruses (Osei, 1995), all of which are transmitted through infected suckers and adversely affect the growth and yield of plantains. Because the movement of plantain suckers in the country is unrestricted, there is a real danger of epidemics if steps are not taken to produce many disease and pest-free suckers for farmers (Osei, 1995).

*In vitro* and rapid field multiplication techniques have been developed to overcome the problem of obtaining many vigorous and uniform suckers which are free from non-obscure pathogens (Vuylsteke & Swennen, 1992). Although the *in vitro* techniques can produce millions of suckers from a single apical meristem, the resulting suckers are prone to infection by the banana streak virus, which is now known to be integrated in the plantain genome (Hughes,

Dahai & Thotta-pilly, 1997). Besides, *in vitro* techniques require expensive equipment and expertise unavailable to most plantain farmers in Ghana.

An appropriate inexpensive rapid field multiplication for plantain is the split corm technique. This technique involves paring and splitting plantain corms into smaller pieces and planting them in a moist soil or sawdust to permit the dormant axillary buds to sprout. With the local plantain cultivars, regular-sized plantable suckers may be produced from the sprouted split corm 3 to 4 months after field nursery. A major disadvantage of the split corm technique is that the multiplication ratio is about 1:4 when regular-sized plantable sword suckers are used as starting materials. In three cycles at intervals of 3 to 4 months, up to 64 suckers may be produced from one sword sucker in a year. This is too low for large-scale commercial planting schemes being contemplated for the country.

Cytokinins are a group of plant growth regulators which, among other things, stimulate the growth of lateral meristems. Benzyl adenine (BA) is a synthetic cytokinin (Salisbury & Ross, 1985) which is used in plantain tissue culture techniques to induce calli to produce shoots (Vuylsteke, 1989). Coconut water is known to contain zeatin and zeatin riboside and, thus, it is a natural source of cytokinin (Salisbury & Ross, 1985).

This study aimed at determining the physiological growth stage of the major local plantain cultivars at which plantain will respond maximally to external application of BA and coconut water to release maximum number of axillary buds on the corm from dormancy and enhance their development into suckers.

## Materials and methods

The study was at the University of Ghana Agricultural Research Station, Kade from July 1998 to November 2000. Split corms of the three major local cultivars, Apantu, Apem and Asamienu, were sprouted in sterilized moist sawdust and planted in a field nursery at 1 m × 0.5 m. After suckers had grown to over 25 cm tall, they were treated with BA or coconut water as described in Experiments 1 to 5. Data collected in each experiment were analysed by SAS computer programme.

*Experiment 1*

The Apantu cultivar was used for Experiment 1. Twelve weeks after planting sprouted split corms, the resulting suckers were classified into plants with height range between 25 and 35 cm (Group A plants), and those with height range between 36 and 45 cm (Group B plants). Girth measurements were taken at ground level. Four plants in each height group were injected at the base with 0 or 2 ml distilled water, 2 or 4 ml $10^{-2}$ M BA, or 6 or 8 ml coconut water on 3 consecutive alternate days. The coconut water was collected from fully ripe dried fruits. It was boiled and filtered through Watman No. 4 filter paper before using it for the injections. The injection treatments were replicated four times in a randomized block design.

Three weeks after the injections, height and girth measurements were taken on the treated plants. The suckers were carefully dug out from the soil. The roots were carefully removed and the corms washed to expose the developing axillary buds on the corms for counting. Well-developed plantlets were removed from the corms and potted under shade in 20 cm × 25 cm black polythene bags containing 2:1 top soil: sand potting mixture. The corms were then split again and planted in sterilized moist sawdust to sprout. Four weeks later, the number of additional plantlets produced by the BA or coconut water-treated split corms were counted. Afterwards, they were planted at 3 m × 3 m in the field to observe the growth and yield of the BA or coconut water-treated split corm-derived suckers. For each injection treatment, plant height and girth at flowering, number of days to 50 per cent flowering, and bunch weight were taken on 10 plants.

*Experiment 2*

In Experiment 2, 45-60 cm tall split corm-derived

Apantu suckers were used. Four plants in this height range were selected and injected as before with 0 or 2 ml distilled water, 2 or 4 ml $10^{-2}$ M BA, or 6 or 8 ml coconut water on 3 consecutive alternate days. The injection treatments were replicated three times in a randomized block design. Growth measurements were taken as described in Experiment 1. Three weeks after the injections, the procedures outlined in Experiment 1 were used to determine the number of fully formed plantlets before corm splitting, and the total number of plantlets produced per plant after sprouting split corms in moist sawdust for each injection treatment.

*Experiment 3*

The split corm-derived Apantu suckers used in Experiment 3 were 55-100 cm tall. Split corms of maiden Apantu suckers were planted in 1 m × 1 m in April 1999 in a field that had fallowed for 4 years. Fourteen weeks later, developing suckers were classified by height into two groups as follows:

| *Group* | *Height range (cm)* |
|---|---|
| 1 | 55-75 |
| 2 | 76-100 |

Four plants in each height group were selected and injected with 0 or 2 ml distilled water, 4 ml $10^{-2}$ M BA, or 6, 8 or 10 ml boiled and filtered coconut water on 3 consecutive alternate days. The injection treatments were replicated three times in a randomized block design. Growth measurements were taken as described in Experiment 1. Three weeks after the injections, the procedures outlined in Experiment 1 were used to determine the number of fully formed plantlets before corm splitting, and the total number of plantlets produced per plant after sprouting split corms in moist sawdust for each injection treatment.

*Experiment 4*

The 45 to 60-cm tall split corm-derived Apem suckers were used. Four plants within the height range were injected with 0 or 2 ml distilled water, 2 ml $10^{-2}$ M BA, or 6 or 8 ml coconut water, on 3 consecutive alternate days. Growth measurements were taken as described in Experiment 1. Three weeks after the injections, the procedures outlined in Experiment 1 were used to determine the number of fully formed plantlets before corm splitting, and the total number of plantlets produced per plant after sprouting split corms in moist sawdust for each injection treatment.

*Experiment 5*

The 60 to 100-cm tall split corm-derived Asamienu suckers were used in this experiment. Four representative plants in the height range were injected with 0 or 2 ml distilled water, 6 ml coconut water on 2 consecutive alternate days, 6 ml coconut water on 3 consecutive alternate days, 8 ml coconut water on 2 consecutive alternate days, and 8 ml coconut water on 3 consecutive alternate days. The injection treatments were replicated three times in a randomized block design. Growth measurements were taken as described in Experiment 1. Three weeks after the injections, the procedures outlined in Experiment 1 were used to determine the number of fully formed plantlets before corm splitting, and the total number of plantlets produced per plant after sprouting split corms in moist sawdust for each injection treatment.

## Results

*Experiment 1*

Tables 1 and 2 show the mean growth in height and girth of the 25 to 45-cm tall split corm-derived Apantu suckers 3 weeks after the injection treatments. The significant differences in growth in height and girth of the suckers in the two different height groups were due to the injection treatments. Suckers between 36 and 45 cm increased in height by about 8 per cent, and those between 25 and 35 increased in height by about 20 per cent 3 weeks after the injections. Treatment with BA or coconut water significantly reduced

TABLE 1

*Mean Percentage Increase in Plant Height (cm) of 12-week-old Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With Different Volumes of BA or Coconut Water*

| *Treatment* | *Percentage increase in height of 25 to 35 cm plants* | *Percentage increase in height of 36 to 45 cm plants* | *Treatment mean* |
|---|---|---|---|
| Control | 34.4 | 22.0 | 28.2 |
| Injection with 2 ml distilled water | 29.9 | 23.7 | 26.8 |
| Injection with 2 ml $10^{-2}$ M BA | 17.1 | 8.0 | 12.5 |
| Injection with 4 ml $10^{-2}$ M BA | 7.0 | 5.0 | 6.0 |
| Injection with 6 ml coconut water | 18.1 | 8.2 | 13.2 |
| Injection with 8 ml coconut water | 11.2 | 8.7 | 9.9 |
| Mean | 19.6 | 12.6 | |

LSD for treatment means = 9.9
LSD for plant group means = 5.3

TABLE 2

*Mean Circumference at Ground Level (cm) of 12-week-old Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With Different Volumes of BA or Coconut Water*

| *Treatment* | *Mean circumference of 25 to 35 cm plants* | *Mean circumference of 36 to 45 cm plants* | *Treatment mean* |
|---|---|---|---|
| Control | 16.8 | 17.3 | 17.0 |
| Injection with 2 ml distilled water | 15.8 | 17.3 | 16.5 |
| Injection with 2 ml $10^{-2}$ M BA | 18.5 | 21.5 | 20.0 |
| Injection with 4 ml $10^{-2}$ M BA | 22.5 | 28.5 | 25.5 |
| Injection with 6 ml coconut water | 16.0 | 22.7 | 19.4 |
| Injection with 8 ml coconut water | 17.0 | 22.5 | 19.8 |
| Mean | 17.8 | 21.6 | |

LSD for treatment means = 3.7
LSD for plant group means = 2.1

growth in height compared to the untreated controls, especially for the plants between 36 and 45 cm tall. The biggest girth was recorded in treatment with 4 ml BA. Girth of suckers treated with 2 ml BA and 6 or 8 ml coconut water were bigger than the controls, though the LSD test showed no significant differences.

Table 3 shows the number of fully differentiated axillary buds produced by injecting 12-week-old split corm-derived Apantu suckers with different volumes of $10^{-2}$ M BA or coconut water. The number of well-differentiated axillary buds which developed into new suckers increased as the volume of BA and coconut water increased. Suckers between 36 and 45 cm produced significantly more well-differentiated axillary buds, which developed into new suckers, than those between 25 and 35 cm. The highest number of well-differentiated axillary buds was produced with 3 consecutive alternate daily injections of 36 to 45-cm tall plants with 8 ml coconut water, followed by 4 ml $10^{-2}$ M BA and 6 ml coconut water.

Some fully differentiated axillary buds had already developed into plantlets, 3 weeks after the injection treatments. Table 4 shows the number of such plantlets produced with the

TABLE 3

*Mean Number of Fully Differentiated Axillary Buds Produced by Corms of 3-month-old Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With Different Volumes of BA and Coconut Water*

| *Treatment* | *25-35 cm tall plants* | *36-45 cm tall plants* | *Treatment mean* |
|---|---|---|---|
| No injection | 0.53 | 1.37 | 0.95 |
| Injection with 2 ml distilled water | 0.37 | 1.67 | 1.02 |
| Injection with 2 ml $10^{-2}$ M BA | 1.67 | 2.83 | 2.25 |
| Injection with 4 ml $10^{-2}$ M BA | 0.87 | 6.0 | 3.43 |
| Injection with 6 ml coconut water | 1.33 | 5.0 | 3.17 |
| Injection with 8 ml coconut water | 0.83 | 7.0 | 3.92 |
| Mean | 0.93 | 21.6 | |

LSD for treatment means = 1.22
LSD for plant group means = 0.70

various injection treatments. Treatment of 36 to 45-cm tall plants with 6 or 8 ml coconut water or 4 ml BA produced significantly more fully developed plantlets than the untreated controls.

Table 5 shows the mean number of additional plantlets per plant produced from split corms of BA or coconut water-treated Apantu suckers, 4 weeks after planting their split corms in moist sawdust. Significantly more plantlets were produced from split corms of 36 to 45-cm tall plants than from those of 25 to 35-cm tall plants. Similarly, significantly more plantlets were derived from plants treated with 4 ml BA, followed by 8 ml coconut water. Treatment of 36 to 45-cm tall plants with 8 ml coconut water or 4 ml BA had the highest number of additional plantlets.

Table 6a shows the total number of plantlets produced after 3 consecutive alternate daily injections of 12-week-old Apantu suckers with 2 or 4 ml $10^{-2}$ M BA, or 6 or 8 ml coconut water. The difference in the total number of plantlets produced was highly significant due to the various injection treatments and the plant groups. The number of plantlets produced by injecting 36 to 45-cm tall plants was more than double the number for 25 to 35-cm plants. Similarly, the number of

TABLE 4

*Mean Number of Fully Developed Plantlets Per Plant Obtained 3 Weeks After 3 Consecutive Alternate Daily Injections With Different Volumes of BA or Coconut Water*

| *Treatment* | *25-35 cm tall plants* | *36-45 cm tall plants* | *Treatment mean* |
|---|---|---|---|
| No injection | 0.1 | 0.57 | 0.33 |
| Injection with 2 ml distilled water | 0.37 | 0.63 | 0.60 |
| Injection with 2 ml $10^{-2}$ M BA | 0.37 | 0.83 | 0.60 |
| Injection with 4 ml $10^{-2}$ M BA | 0.23 | 2.67 | 1.45 |
| Injection with 6 ml coconut water | 0.7 | 3.17 | 1.93 |
| Injection with 8 ml coconut water | 0.1 | 3.67 | 1.89 |
| Mean | 0.31 | 1.56 | |

LSD for treatment means = 0.63
LSD for plant group means = 0.36

TABLE 5

*Mean Number of Additional Plantlets Per Plant Produced From Split Corms of BA or Coconut Water-treated Apantu Suckers 4 Weeks After Planting Their Split Corms in Moist Sawdust*

| *Treatment* | *25-35 cm tall plants* | *36-45 cm tall plants* | *Treatment mean* |
|---|---|---|---|
| No injection | 2.0 | 4.0 | 3.0 |
| Injection with 2 ml distilled water | 2.5 | 4.2 | 3.3 |
| Injection with 2 ml $10^{-2}$ M BA | 2.7 | 4.5 | 3.6 |
| Injection with 4 ml $10^{-2}$ M BA | 4.3 | 6.3 | 5.3 |
| Injection with 6 ml coconut water | 3.3 | 5.3 | 4.3 |
| Injection with 8 ml coconut water | 3.2 | 6.7 | 4.9 |
| Mean | 3.0 | 5.2 | |

LSD for treatment means = 1.26
LSD for plant group means = 0.72

TABLE 6a

*Total Number of Plantlets Produced After 3 Consecutive Alternate Daily Injections of 12-week-old Apantu Suckers With Different Volumes of $10^{-2}$ M BA or Coconut Water and Sprouting Their Split Corms in Moist Sawdust*

| *Treatment* | *25-35 cm tall plants* | *36-45 cm tall plants* | *Treatment mean* |
|---|---|---|---|
| No injection | 2.0 | 4.5 | 3.25 |
| Injection with 2 ml distilled water | 2.8 | 5.0 | 3.90 |
| Injection with 2 ml $10^{-2}$ M BA | 3.0 | 5.3 | 4.17 |
| Injection with 4 ml $10^{-2}$ M BA | 4.5 | 9.0 | 6.75 |
| Injection with 6 ml coconut water | 4.0 | 8.5 | 6.25 |
| Injection with 8 ml coconut water | 3.2 | 10.3 | 6.75 |
| Mean | 3.25 | 7.1 | |

LSD for treatment means = 1.14
LSD for plant group means = 0.66

plantlets produced by injecting 4 ml $10^{-2}$ M BA and 6 or 8 ml coconut water was double the number for the untreated controls. Eight millilitres of coconut water was equally effective as 4 ml $10^{-2}$ BA in inducing higher number of plantlets in 12-week-old split corm-derived Apantu suckers. The highest multiplication ratio of 1:10 was recorded by treating 36 to 45-cm tall suckers with 8 ml coconut water.

Table 6b shows the mean height at flowering, girth at 50 cm above ground level at flowering, days to 50 per cent flowering, and bunch weight of benzyl adenine or coconut water-treated split-corm derived Apantu suckers.

The injection treatments did not adversely affect the subsequent growth, maturity, and yield of the suckers derived from pretreatment of corms of young suckers with different volumes of $10^{-2}$ M BA or coconut water.

*Experiment 2*

Table 7 shows the increase in height and girth of 45 to 60-cm tall split corm-derived Apantu suckers, 3 weeks after injection with BA or coconut water.

Injection with BA or coconut water significantly reduced growth in height but increased growth in girth of the Apantu suckers

TABLE 6b

*Mean Height, Girth at 50 cm Above Ground Level, Days to 50 Per Cent Flowering, and Bunch Weight of BA or Coconut Water-treated Split Corm-derived Apantu Suckers*

| *Injection treatment* | *Mean height (cm)* | *Mean girth (cm)* | *Days to 50% flowering* | *Mean bunch wt (kg)* |
|---|---|---|---|---|
| No injection | 315.0 | 64.0 | 305 | 9.0 |
| Injection with 2 ml water | 310.0 | 64.3 | 307 | 9.1 |
| Injection with 2 ml $10^{-2}$ M BA | 307.0 | 60.3 | 290 | 9.0 |
| Injection with 4 ml $10^{-2}$ M BA | 311.4 | 63.0 | 265 | 9.1 |
| Injection with 6 ml coconut water | 312.0 | 63.0 | 309 | 9.3 |
| Injection with 8 ml coconut water | 321.8 | 66.6 | 295 | 9.3 |
| Mean | 312.9 | 63.3 | 295 | 9.1 |
| SE | 5.1 | 2.1 | 16.5 | 0.36 |

TABLE 7

*Percentage Increase in Height and Girth of 45 to 60-cm Tall Split Corm-derived Apantu Suckers 3 Weeks After Injection With BA or Coconut Water*

| *Treatment* | *Mean percentage increase in height (cm)* | *Mean percentage increase in girth (cm)* |
|---|---|---|
| No injection | 27.4 | 20.5 |
| Injection with distilled water | 28.7 | 29.1 |
| Injection with 2 ml $10^{-2}$ M BA | 6.6 | 68.1 |
| Injection with 4 ml $10^{-2}$ M BA | 4.4 | 70.2 |
| Injection with 6 ml coconut water | 9.0 | 53.5 |
| Injection with 8 ml coconut water | 5.8 | 53.0 |
| LSD | 4.77 | 6.01 |

compared with the untreated controls. Injection with BA significantly reduced growth in height but increased growth in girth of the Apantu suckers more than injections with coconut water. The effect of 4 ml $10^{-2}$ M BA on growth was significantly higher than that of 2 ml $10^{-2}$ M BA. The effect of 6 or 8 ml coconut water on growth was the same.

Table 8 shows the number of well-developed plantlets removed before splitting the BA or coconut water-treated corms, and the additional and total number of plantlets produced after sprouting the treated corms of 45 to 60-cm tall Apantu suckers in moist sawdust.

The difference was highly significant due to the injection treatments in the mean number of well-developed buds removed before splitting the injected corms, and after sprouting the split corms in moist sawdust, as well as the total number of plantlets produced with the treatments. The total number of plantlets produced with the BA or coconut water-treated corms was more than double that for the untreated controls. The 6-ml coconut water had the highest multiplication ratio of 1:10.8, though this was not significantly different from the multiplication ratios for 2 or 4 ml $10^{-2}$ M BA or 8 ml coconut water.

*Experiment 3*

Tables 9 and 10 show the percentage increase in height and girth of the 14-week-old Apantu suckers grown on fallowed land at 1 m × 1 m from split corms, 3 weeks after 3 consecutive alternate daily injections with 4 ml $10^{-2}$ M BA, or 6 or 8 or 10 ml coconut water. Injection with coconut water and BA significantly decreased percentage growth in height, but increased percentage growth

TABLE 8

*Number of Well-developed Buds Removed Before Splitting BA or Coconut Water-treated 45 to 60-cm Tall Apantu Corms, Additional Plantlets Produced After Splitting and Sprouting the Corms, and the Total Number of Plantlets Produced Per Plant*

| *Treatment* | *Mean number of well-developed buds removed before splitting corms* | *Mean number of additional plantlets produced after sprouting corms in moist sawdust* | *Total number of plantlets produced per plant* |
|---|---|---|---|
| No injection | 0.0 | 4.2 | 4.2 |
| Injection with distilled water | 0.0 | 4.1 | 4.1 |
| Injection with 2 ml $10^{-2}$ M BA | 2.0 | 7.4 | 9.4 |
| Injection with 4 ml $10^{-2}$ M BA | 3.4 | 6.9 | 10.3 |
| Injection with 6 ml coconut water | 3.1 | 7.7 | 10.8 |
| Injection with 8 ml coconut water | 3.2 | 6.5 | 9.0 |
| LSD | 1.76 | 2.86 | 3.41 |

TABLE 9

*Percentage Increase in Height of 50 to 100-cm Tall Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With BA or Coconut Water*

| *Treatment* | *Mean percentage increase in height of 50 to 75-cm tall plants* | *Mean percentage increase in height of 76 to 100-cm tall plants* | *Treatment mean* |
|---|---|---|---|
| No injection | 28.1 | 21.9 | 25.0 |
| Injection with distilled water | 33.8 | 16.7 | 25.3 |
| Injection with 4 ml $10^{-2}$ M BA | 6.9 | 8.4 | 7.7 |
| Injection with 6 ml coconut water | 12.7 | 7.9 | 10.3 |
| Injection with 8 ml coconut water | 6.6 | 8.1 | 7.4 |
| Injection with 10 ml coconut water | 6.9 | 7.4 | 7.2 |
| Group means | 15.8 | 11.7 | |

LSD treatment means = 5.4
Group means = 3.12

in girth compared with the untreated controls. The increase in percentage growth in height and girth due to treatment with BA and coconut water was higher for 50-75 cm tall plants than for 76-100 cm tall plants. The effect of 4 ml $10^{-2}$ M BA on plant growth in girth was higher than for the different amounts of coconut water used. The effect of coconut water on plant growth in girth increased as the volume of coconut water increased, though the LSD test showed no significant differences.

Tables 11, 12 and 13 show the number of fully developed plantlets per plant before sprouting split corms, and the additional and total number of plantlets produced after sprouting split corms of 50 to 100-cm tall field-grown Apantu suckers, 3 weeks after 3 consecutive alternate daily injections with different volumes of coconut water or BA. The number of fully developed plantlets produced per plant was significantly higher for the coconut water and BA-treated suckers than for the untreated controls.

The total number of suckers produced by 3

TABLE 10

*Percentage Increase in Girth of 50 to100-cm Tall Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With BA or Coconut Water*

| *Treatment* | *Mean percentage increase in height of 50 to 75-cm tall plants* | *Mean percentage increase in height of 76 to100-cm tall plants* | *Mean* |
|---|---|---|---|
| No injection | 37.8 | 31.5 | 34.7 |
| Injection with distilled water | 40.7 | 28.0 | 34.4 |
| Injection with 4 ml $10^{-2}$ M BA | 89.2 | 62.2 | 75.7 |
| Injection with 6 ml coconut water | 51.1 | 40.6 | 45.9 |
| Injection with 8 ml coconut water | 58.6 | 42.8 | 50.7 |
| Injection with 10 ml coconut water | 63.8 | 46.9 | 55.4 |
| Group means | 56.9 | 42.0 | |

LSD treatment means = 7.3
Group means = 4.23

TABLE 11

*Number of Fully Developed Plantlets Per Plant Removed Before Splitting 50 to 100-cm Tall Split Corm-derived Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With Benzyl Adenine or Coconut Water*

| *Treatment* | *Mean number of plantlets removed from 50 to 75-cm tall plants* | *Mean number of plantlets removed from 76 to 100-cm tall plants* | *Mean* |
|---|---|---|---|
| No injection | 0.00 | 0.6 | 0.4 |
| Injection with distill water | 0.00 | 0.5 | 0.3 |
| Injection with 4 ml benzyl adenine | 1.2 | 2.5 | 1.9 |
| Injection with 6 ml coconut water | 1.0 | 2.8 | 1.9 |
| Injection with 8 ml coconut water | 1.1 | 2.8 | 2.0 |
| Injection with 10 ml coconut water | 1.2 | 2.3 | 1.8 |
| Group means | 0.79 | 1.92 | |

LSD treatment means = 0.74
Group means = 0.43

consecutive alternate daily injections of 12-week-old field-grown 50 to100-cm tall Apantu plants was about two times that for untreated controls. The 3 consecutive alternate daily injections with 8 ml coconut water had the highest multiplication ratio of 1:8.

*Experiment 4*

Table 14 shows the percentage increase in height and girth of 45 to 60-cm tall split corm-derived Apem suckers, 3 weeks after 3 consecutive alternate daily injections with BA or coconut water.

Injection with BA or coconut water on 3 consecutive alternate days significantly slowed growth in height, but increased growth in girth of the Apem suckers compared with the untreated controls. The effect of BA on the increase in growth in height was the same as that of coconut water. The increased growth in girth of the Apem

TABLE 12

*Number of Additional Plantlets Produced After Sprouting Split Corms of 50 to 100-cm Tall Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With Benzyl Adenine or Coconut Water*

| *Treatment* | *Mean number of plantlets removed from 50 to 75-cm tall plants* | *Mean number of plantlets removed from 76 to 100-cm tall plants* | *Mean* |
|---|---|---|---|
| No injection | 3.1 | 3.4 | 3.3 |
| Injection with distillled water | 3.9 | 4.2 | 4.1 |
| Injection with 4 ml benzyl adenine | 4.3 | 4.4 | 4.4 |
| Injection with 6 ml coconut water | 4.8 | 5.0 | 4.9 |
| Injection with 8 ml coconut water | 5.3 | 5.5 | 5.4 |
| Injection with 10 ml coconut water | 4.4 | 5.5 | 5.0 |
| Group means | 4.31 | 4.67 | |

LSD treatment means = 0.91
Group mean = 0.52

TABLE 13

*Total Number of Plantlets Produced After Sprouting Split Corms of 50 to 100-cm Tall Apantu Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With BA or Coconut Water*

| *Treatment* | *Mean number of plantlets generated from 50 to 75-cm tall plants* | *Mean number of plantlets generated from 76 to 100-cm tall plants* | *Mean* |
|---|---|---|---|
| No injection | 3.2 | 4.0 | 3.6 |
| Injection with distilled water | 3.9 | 4.7 | 4.3 |
| Injection with 4 ml benzyl adenine | 5.5 | 7.0 | 6.3 |
| Injection with 6 ml coconut water | 5.8 | 7.8 | 6.8 |
| Injection with 8 ml coconut water | 6.5 | 8.2 | 7.4 |
| Injection with 10 ml coconut water | 5.7 | 7.8 | 6.8 |
| Group means | 5.1 | 6.5 | |

LSD treatment means = 1.26
Group means = 0.73

suckers was higher with BA than with coconut water treatments, though the LSD test did not show any differences.

Table 15 shows the number of well-developed plantlets removed before splitting the corms injected on 3 consecutive alternate days with BA or coconut water, and the additional plantlets produced per plant after sprouting the treated Apem corms in moist sawdust.

Owing to the injection treatments, there was a highly significant difference in the mean number of well-developed buds removed per plant before splitting the injected corms, and after sprouting the split corms in moist sawdust, as well as the total number of plantlets produced per plant with the treatments. The total number of plantlets produced with the BA or coconut water-treated corms was more than double that for the untreated controls. The 8 ml coconut water had the highest multiplication ratio of 1: 5.9, though this was not

TABLE 14

*Percentage Increase in Height and Girth of 45 to 60-cm Tall Split Corm-derived Apem Suckers 3 Weeks After 3 Consecutive Alternate Daily Injections With BA or Coconut Water*

| *Treatment* | *Mean percentage increase in height* | *Mean percentage increase in girth* |
|---|---|---|
| No injection | 38.3 | 35.4 |
| Injection with distilled water | 39.6 | 39.3 |
| Injection with 2 ml $10^{-2}$ M BA | 8.1 | 72.3 |
| Injection with 4 ml $10^{-2}$ M BA | 7.0 | 73.7 |
| Injection with 6 ml coconut water | 8.0 | 65.8 |
| Injection with 8 ml coconut water | 8.1 | 65.9 |
| LSD | 7.87 | 9.49 |

TABLE 15

*Number of Well-developed Buds Removed Before Splitting 3 Consecutive Alternate Daily BA and Coconut Water-treated 45 to 60-cm Tall Apem Corms, Additional Plantlets Produced After Splitting and Sprouting the Corms, and the Total Number of Plantlets Produced Per Plant*

| *Treatment* | *Mean number of well-developed buds removed before splitting corms* | *Mean number of additional plantlets generated after sprouting corms in moist sawdust* | *Total number of plantlets generated per plant* |
|---|---|---|---|
| No injection | 0.7 | 1.4 | 2.1 |
| Injection with distilled water | 0.4 | 1.9 | 2.3 |
| Injection with 2 ml $10^{-2}$ M BA | 1.6 | 2.5 | 4.2 |
| Injection with 4 ml $10^{-2}$ M BA | 1.6 | 3.8 | 5.5 |
| Injection with 6 ml coconut water | 2.5 | 3.1 | 5.9 |
| LSD | 1.80 | 1.36 | 1.80 |

significantly different from the multiplication ratios for 2 or 4 ml $10^{-2}$ M BA or 6 ml coconut water.

*Experiment 5*

Table 16 shows mean percentage increase in height and girth of 60 to 100-cm tall split corm-derived Asamienu suckers, 3 weeks after injection with different volumes of coconut water on 2 or 3 consecutive alternate days. There was a highly significant difference in the growth in height and girth of the suckers due to the injection treatments. Treatment with the different volumes of coconut water reduced the growth in height, but increased the growth in girth compared to the untreated controls. Injection with 8 ml coconut water on 2 consecutive alternate days significantly retarded growth in height, but largely increased growth in girth compared to injection with 6 ml on 2 consecutive days.

Table 17 shows the mean number of fully developed plantlets per plant removed before splitting the corms, additional number of plantlets produced per plant 4 weeks after sprouting the split corms in moist sawdust, and the total number of plantlets produced per plant after injecting 60 to100-cm tall Asamienu suckers with the different volumes of coconut water on 2 or 3 consecutive alternate days. There was no correlation between plant height and the total number of plantlets produced within the range of 60 to100-cm for each treatment.

There were highly significant differences, due to the treatments, in the number of fully developed

TABLE 16

*Percentage Increase in Growth in Height and Girth of Split Corm-derived Local True Horn Plantain Cultivar, Asamienu, 3 weeks After Injection With Different Volume of Coconut Water*

| *Treatment* | *Percentage increase in height 3 weeks after injection* | *Percentage increase in girth 3 weeks after injection* |
|---|---|---|
| No injection | 42.2 | 26.5 |
| Injection with distilled water | 35.5 | 29.2 |
| Injection with 6 ml coconut water on 3 consecutive days | 11.2 | 46.3 |
| Injection with 8 ml coconut water on 3 consecutive days | 8.0 | 51.8 |
| Injection with 6 ml coconut water on 2 consecutive days | 26.2 | 38.5 |
| Injection with 8 ml coconut water on 2 consecutive days | 7.9 | 50.8 |
| LSD | 10.0 | 15.2 |

TABLE 17

*Mean Number of Fully Developed Plantlets Per Plant Removed Before Splitting the Corms, Additional Number of Plantlets Produced Per Plant 4 Weeks After Sprouting the Split Corms in Moist Sawdust, and the Total Number of Plantlets Produced Per Plant After Injecting 60 to 100-cm Tall Asamienu Suckers With the Different Doses of Coconut Water*

| *Treatment* | *Mean no. of plantlets removed before splitting treated corms* | *Additional no. of plantlets produced after sprouting* | *Total number of plantlets produced* |
|---|---|---|---|
| No injection | 0.0 | 3.0 | 3.0 |
| Injection with 2 ml distilled water | 0.0 | 3.1 | 3.1 |
| Injection with 6 ml coconut water on 3 consecutive days | 4.4 | 8.1 | 12.5 |
| Injection with 8 ml coconut water on 3 consecutive days | 5.5 | 9.8 | 15.3 |
| Injection with 6 ml coconut water on 3 consecutive days | 1.9 | 7.2 | 9.1 |
| Injection with 8 ml coconut water on 2 consecutive days | 7.4 | 8.8 | 16.2 |
| LSD | 2.6 | 3.0 | 4.5 |

plantlets per plant removed before splitting the corms, additional number of plantlets produced per plant after sprouting the split corms in moist sawdust for 4 weeks, and the total number of plantlets generated per plant. The multiplication ratio for injections with 6 ml coconut water on 3 consecutive alternate days was better than that for injections with 6 ml on 2 consecutive alternate days. Injections with 8 ml coconut water on 2 alternate consecutive days had the highest multiplication ratio of 1:16, but this was not significantly different from the ratio of 1:15 for injections with 8 ml on 3 consecutive alternate days. The multiplication ratio for untreated controls was 1:3.

## Discussion

The observation that there was a significant decrease in growth in height and a significant increase in growth in girth within the 3-week period after the injection with BA or coconut water in all the experiments indicates that the activity of the apical meristem of the growing suckers was suppressed by the injected BA or coconut water,

but there was increased lateral cellular activity (Salisbury & Ross, 1985). The dormant axillary buds on the corm were, therefore, released from dormancy, developing into plantlets. The results clearly show that suckers can be produced rapidly in plantain by injecting well-developed and actively growing suckers with BA or coconut water, sprouting the split corms in moist sawdust 3 weeks after the injection treatments. The rate of sucker production depends on the number of preformed viable axillary buds on the corm before the injection (Salisbury & Ross, 1985). Thus, small suckers below 25 cm tall do not respond to the injection treatments, whilst overgrown suckers above 50 cm do not respond better than those between 35 and 45 cm tall, for the Apantu cultivar.

The coconut water used was from different batches, yet the results were consistent with all the major local cultivars. Thus, the response to coconut water and BA treatments was not cultivar-specific, but was general for all the major local plantain cultivars. Although facilities were unavailable to determine the concentration of zeatin and zeatin riboside in the coconut water, the activity of 8 ml of the coconut water used was equal to 4 ml $10^{-2}$ M BA.

The injection treatments in Experiment 5 were designed to deliver a total coconut water volume of 0, 12, 16, 18, or 24 ml per treatment. The total number of plantlets produced per plant increased as the total volume of coconut water administered increased from 0 to 16 ml per plant, and then leveled off. This dosage response relationship was expected under the conditions of the experiment. The optimum volume of coconut water required to induce maximum plantlet production was between 16 and 24 ml. It was more effective to administer the coconut water in units of 8 ml than in units of 6 ml.

The highest multiplication ratio for Apantu cultivar with the optimum volumes of coconut water was 1: 10. For Asamienu, it was 1:15. These results are consistent with the fact that of the major local plantain cultivars, Asamienu produces the highest number of suckers at flowering (Karikari, 1971). The multiplication ratio of 1:5.9 for the Apem cultivar was the lowest probably because, of the three major local cultivars, it was the slowest-growing and the latest-maturing cultivar. Therefore, not many preformed lateral buds had been formed at the time of injection.

At a multiplication ratio ranging between 1:8 and 1:10, and in three cycles at intervals of about 18 weeks, between $8^3$ and $10^3$ or 512 and 1000 plants can be produced from one Apantu sucker in a year by injecting over 35-cm tall split corm-derived suckers on 3 consecutive alternate days with 8 ml coconut water, compared with $4^3$ or 64 that may be produced from one untreated sucker. For Asamienu, $15^3$ or 3,375 plants may be produced in 18 months in three cycles at intervals of 24 weeks with suckers over 60 cm tall. Because the injection treatments did not affect the subsequent growth, maturity and bunch yields of the suckers derived from the coconut water or BA-treated split corms, planting materials produced by the technique are suitable for commercial planting.

A total of 25 ml coconut water is required to treat one sucker to produce 8 to10 Apantu and 15 Asamienu plants. One fully mature dried coconut fruit contains an average of 150 ml coconut water costing less than $0.25 cents. The additional cost of producing the additional suckers is very small compared with the multiplication ratios involved. Therefore, an inexpensive rapid field multiplication of local plantain cultivars using coconut water-treated split corms has been realised.

*Acknowledgement*

The technical assistance of Messrs Ohemeng Minta and Ohene Agyei of University of Ghana-Agricultural Research Station, Kade, is gratefully acknowledged. The study was sponsored by the International Network for Banana and Plantain (INIBAP).

REFERENCES

**Afreh-Nuamah, K.** (1994) Factors responsible for the lodging of plantains at the University of Ghana

Agricultural Research Station, Okumaning-Kade. *Musa Africa* **5**. IITA, Ibadan, Nigeria.

**Hotsonyame, G. K., Doku, E. V.** & **Karikari, S. K.** (1988) Effects of dry weather on the yield of plantains (*Musa* AAB Group) grown under rainfed conditions in the forest zone of Ghana. *Niger. agric. J.* **23**, 57-71.

**Hotsonyame, G. K.** (1991) The influence of pattern, density and season of planting on the growth and yield of the horn type of plantain cultivar, Borodewuio (*Musa acuminata* and *Musa balbisiana* AAB) *Trop. Sci.* **31**, 421-424.

**Hughes, J., Dahai, G.** & **Thottapilly, G.** (1997) Virus indexing, diagnostics and elimination for germplasm distribution. In *Improving plantain and banana-based systems*, pp. 34-35. Annual Report, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

**Karikari, S. K.** (1971) A note on plantain (*Musa* AAB Group) and banana (*Musa* AAB Group) cultivars in Ghana. *Ghana Jnl agric. Sci.* **4**, 78-85.

**Osei, J. K.** (1995) Cucumber mosaic virus (CMV) infects plantain in Ghana. *Musa Africa* **6.** IITA, Ibadan, Nigeria.

S**alisbury, F. B.** & **Ross, C. W.** (1985) *Hormones and growth regulators cytokinnins, ethylene, abscisic acid, and other compounds in plant physiology*, Ch. 17. Wadsworth Publishing Company, Belmont, California.

**Vuylsteke, D.** (1989) *Shoot tip culture for propagation, conservation and exchange of* Musa *germplasm: Practical manuals for handling crop germplasm* in vitro. 2 IBPGR, Rome, Italy.

**Vuylsteke, D.** & **Swennen, R.** (1992) Biotechnological approaches to plantain and banana improvement at IITA. In *Biotechnology: Enhancing research on tropical crops in Africa* (ed. G. Thottapilly, L. M. Monti, D. R. Mohan Raj and A.W. Moore). Published by The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.