Field Performance of False Horn Plantain (*Musa AAB*) Corms Treated Mechanically and with Hormone Solutions

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Abstract. The growth and yield performance of macropropagated plantlets of the False Horn plantain cultivar ‘Apantu’ was evaluated due to the lack of reliable data on the effectiveness of that planting material under typical farming conditions in West Africa, Ghana. Corms were either mechanically treated by the Plants Issus de Fragments de tige (PIF) technique to destroy the apical meristem or remained intact as untreated controls. Subsequently, PIF-treated corms were vacuum infiltrated with either natural or synthetic plant hormone solutions. Emerging plantlets were harvested, acclimatized for three months and planted in a freshly prepared field. Vegetative growth characteristics of each mother (main) plant were taken at 6 and 9 months after planting and for the main and first sucker crop along with yield parameters at harvest, respectively. The results indicated that treatment induced growth differences at 6 and 9 months after planting and were no longer significant at harvest. Consequently, final growth performance was quite homogenous across all treatments for the main and sucker crop, respectively. In contrast, fruit yield parameters of the main and sucker crops were to some extent affected by treatment; however, hormone infiltration tended to have little additional effect over the PIF-treatment. Nevertheless, treating corms with hormonal solutions enhanced the production of rooted plantlets at the nursery stage and ensured improved field performance.

Introduction

Plantain (*Musa AAB*) is an important food crop that is widely grown in the humid tropics of Africa, providing food for more than 70 million people in that region [1]. The majority of plantain production comes from rural families’ backyard gardens as well as cultivated fields of smallholders and is an essential income source for resource poor farmers in developing countries [1], [2]. In West Africa, Ghana produces the largest plantain crop, which is of great socio-economic importance in terms of food security and job opportunity [3]. The demand for the ‘cooking banana’ is relatively high in both urban and rural communities and has resulted in an increased market price [4]–[6]. Consequently, many households have gradually expanded the field cultivation of plantain [4].

However, access to sufficient and inexpensive planting material by smallholder plantain farmers is a major constraint in Sub-Saharan Africa [5], [7], [8]. This is as a result of several factors, including low sucker production due to the apical dominance behaviour of the main pseudostem [1], [9], [10] and poor field management by smallholder farmers [11], [12]. Farmers often rely on young suckers or old corms directly from the field for the establishment of new plantings; however, this plant material is frequently infested with pathogens or various pests [8].

Therefore, several clonal propagation techniques have been developed to overcome the inadequate sucker production in plantain [13]–[16]. An innovative micropropagation technique for raising plantlets is tissue culture [17]–[20]; however, this procedure requires high initial investment costs for specialised laboratories. In contrast, a macropropagation technique that is now commonly employed by many smallholder plantain and banana farmers in Sub-Saharan Africa is the *Plants Issus de Fragments de tige* (PIF) treatment [13], [16], [21] that destroys the apical meristem with a

crosswise incision and leads to robust and healthy plantlets at the nursery stage [5]. This is especially the case, when pest (e.g. banana weevil and nematodes) infested suckers and corms are treated with hot water at 52°C for 20 min prior to planting [11], [22]. Moreover, the PIF technique in combination with synthetic or natural plant growth regulators has increased the number of shoots per corm [21].

Despite several studies having demonstrated that large numbers of clean and healthy plantlets can be produced by macropropagation, there are only few data available on the performance of that planting material under typical farming conditions [23]. Therefore, the objective of this study was to assess the growth and yield performance of macropropagated plantlets. It is hypothesized, that suckers from corms manipulated with PIF and infiltrated with either natural or synthetic plant hormones had a better growth and yield performance than those from only PIF-treated corms.

Materials and Methods

Macropropagation of plantain plantlets was carried out at the Crops Research Institute (CRI) in Kumasi, Ghana, in 2016. Sword and ratoon sucker corms of the False Horn plantain cultivar ‘Apantu’ were harvested from an experimental plantation at the CRI. The corms were pared by removing roots before all leaf sheaths around the collar were carefully cut-off with a sharp knife that was frequently sterilized in 70% ethanol to reduce microbial contamination of the corms. The corms were then washed under running tap water to remove any foreign material. Air-dried corms were either mechanically manipulated by employing the PIF-technique or remained unchanged as an untreated control. PIF-treated corms were vacuum infiltrated with various aqueous solutions (Table 1) and planted in sterilized sawdust within a germination bed. The use of coconut water, seaweed extract and 6-benzylaminopurine as source of plant hormones followed an earlier study by [24] to assess the response of plantain to these hormones in terms of shoot proliferation. Moreover, these are the available sources of plant hormones smallholder farmers could access and employ to multiply plantains in the field.

Emerging plantlets were harvested and potted in 3-liter polyethylene bags, using soil that was sterilized with hot water steam for 3 hours. Potted plantlets were then acclimatized for three months under a shade structure constructed from palm fronds.

Table 1. Aqueous solutions used for vacuum infiltration of corms that were mechanically manipulated with the PIF-technique.

Treatment	Complete description of treatment
1. CW _f	fresh coconut water
2. CW _a	autoclaved coconut water at 121°C for 15 min
3. CWP _a	coconut water with 0.1% (w/v) pulverized papain, incubated at 40°C for 40 min and stirred every 10 min for 1 min and then autoclaved at 121°C for 15 min
4. CW _a SW	autoclaved coconut water with 0.5% (v/v) of sea weed extract (Tecamin Raiz, AgriTecno, Spain)
5. SW	0.5% (v/v) sea weed extract dissolved in distilled water
6. BAP	2.25 mg of 6-Benzylaminopurine (Carl Roth, GmbH, Germany), dissolved in 1N NaOH and diluted in 1 L of distilled water
7. W _d	distilled water

Experimental site

A fallow that was not cultivated for about 10 years was selected for the field experiment at the CRI. Land preparation included clearing the sandy-loam (Arenosol) site from woody vegetation and mulching with the cuttings to improve soil fertility and water holding capacity [4], [25]. This type of land preparation is often recommended instead of the slash and burn approach [26], [27].

Acclimatized plants, each about 40 cm tall with 3-5 leaves, were selected from the nursery and planted in holes of 30 cm depth and 30 cm diameter at a spacing of 3 x 2m in the middle of the rainy season in July 2016[4], [28]. Each hole received 250 g well-decomposed poultry manure one week prior to planting.

The experimental site was fertilized in three split applications at 3, 6 and 9 months after planting with 170 kg urea (46% N), 192 kg potassium chloride (approx. 50% K) and 42 kg triple super phosphate (46% P₂O₅) per hectare, respectively. Moreover, each plant received approximately 2 kg of cow dung prior to flowering. Weed control was carried out regularly either manually or by herbicide applications to ensure good plant growth and development. De-suckering of the main crop was performed at harvest to maintain two sword suckers and one ratoon sucker per plant mat.

Experimental design and data collection

The experimental set-up consisted of nine treatments each with 5-plant-plots assigned randomly to three replicated blocks, respectively. Vegetative growth parameters were taken for each mother (main) plant at 6 and 9 months after planting, respectively, and at harvest and of the first sucker crop (ratoon) at harvest: pseudostem girth at 50 cm above the soil line, pseudostem height from girth measuring point to the most recent unfolded upper leaf, and number of unfolded green leaves. Dead yellow-brownish leaves and leaves with more than 50% black sigatoka disease symptoms at the leaf surface were excluded. In addition, number of suckers were recorded for each plant mat at harvest of the main and sucker crop, respectively.

Crop phenology of both main and first sucker plants was evaluated by recording the number of months to flowering after planting and also days to fruit maturity from flowering. Moreover, yield performance was assessed by taking records of bunch weight, number of hands and fingers per bunch for each plant. Fruit maturity for the main plant started in September 2017 and that of the sucker plants in October 2018.

Statistical analysis

Analysis of variance (ANOVA) was used to evaluate the effect of mechanically manipulated and with varying aqueous solutions vacuum-infiltrated False Horn corms on pseudostem characteristics and yield performance. Data were analysed using Genstat (18th Edition Rothamsted, United Kingdom) and displayed graphically with Microsoft Excel.

Results

Crop phenology

The timing of flowering after planting was not affected by the treatments and occurred between 13 and 15 months for the main crop and about 24 months for the sucker crop. Fruit maturity was reached for both crops between 90 and 105 days after flowering, irrespective of treatment.

Growth characteristics of the main crop

There was a significant treatment effect on pseudostem height at 6 and 9 months of plant growth in the field. Pseudostem height at 6 months after planting was on average 111 cm for CW_f treated corms, followed by corms treated with BAP, which were 21% and 12.5% taller than those of PIF-treated corms (Table 2). At 9 months after planting, the highest pseudostems with about 158 cm were found by corms treated with SW and CW_f, which were about 11% longer than those of corms treated with BAP and the PIF-technique (Table 2). In contrast, there were no effects found at fruit harvest and average pseudostem height was at 2.9 m across all treatments.

There were no significant treatment effects on pseudostem girth at both growth stages. However, pseudostem girth tended to be with 29 cm in the CW_f and with 43 cm in the SW treatment greater than in other treatments at 6 and 9 months after planting, respectively. At harvest, all treatments had a pseudostem girth of about 50.6 cm.

There were on average 8 and 10 green leaves per pseudostem at 6 and 9 months after planting with only small differences among the treatments (Table 2). CW_aSW produced with about 12 leaves per pseudostem significantly more leaves than any other treatment at 9 months of growth. At harvest, treatments had averagely 2 leaves per plant. The number of young suckers growing at harvest was not significantly affected by the treatment (Figure 1) and ranged between 3 and 4 shoots within the mat of the main crop.

Table 2. Effects of treatment (UTC - untreated control; PIF - Plant Issus de Fragments de tige; CW_a - autoclaved coconut water; CW_f - fresh coconut water; CW_aSW - autoclaved coconut water with seaweed extract; BAP – 6-benzylaminopurine; CWP_a - coconut water with pulverized papain; SW - seaweed extract; W_d - distilled water) on vegetative growth characteristics of main plant pseudostem of False Horn plantain.

Treatment	6 month		9 month	
	Length (cm)	Leaf number	Length (cm)	Leaf number
UTC	84.5 ^a	8.1 ^{abc}	127.1 ^{ab}	9.9 ^{ab}
PIF	87.5 ^a	8.2 ^{abc}	137.7 ^{abc}	10.5 ^{abc}
CW _a	87.3 ^a	7.3 ^a	119.6 ^a	9.5 ^a
CW _f	110.6 ^b	8.8 ^c	156.8 ^c	10.9 ^{bcd}
CW _a SW	99.2 ^{ab}	8.3 ^{bc}	152.3 ^{bc}	11.9 ^d
BAP	100.0 ^{ab}	7.5 ^{ab}	142.1 ^{abc}	9.9 ^{ab}
CWP _a	89.5 ^a	7.2 ^a	130.1 ^{ab}	9.6 ^{ab}
SW	96.0 ^{ab}	8.3 ^{bc}	159.0 ^c	11.7 ^{cd}
W _d	88.3 ^a	7.9 ^{abc}	141.7 ^{abc}	9.4 ^a
<i>Statistics</i>				
P-value	*	*	*	***
LSD _{0.05}	16.1	1.1	25.6	1.4

Data are means (n=15) with different letters in the same column indicating significant difference at $p \leq 0.05$. * and *** are significant at $p \leq 0.05$ and $p < 0.001$, respectively.

Growth characteristics of the sucker crop

The pseudostem height and girth of the first sucker crop at harvest were not significantly affected by treatment. Plant height ranged between 3.2 m and 3.4 m across all treatments with an average girth of 63 cm. There were 1-2 green leaves per plant at harvest. The number of young suckers grown within the mat of the first sucker crop at harvest was significantly affected by the treatment. BAP and SW had with averagely 3.3 suckers the highest number of all treatments (Fig. 1).

Figure. 1. Effects of treatment (UTC - untreated control; PIF - Plant Issus de Fragments de tige; CW_a - autoclaved coconut water; CW_f - fresh coconut water; CW_aSW - autoclaved coconut water with seaweed extract; BAP - 6-benzylaminopurine; CWP_a - coconut water with pulverized papain; SW - seaweed extract; W_d - distilled water) on sucker production of the main and sucker crop, respectively, at harvest of False Horn plantain. Vertical bars indicate standard error of the means (main crop, n= 9 and sucker crop, n= 12) and different letters represent significant difference using LSD test at $P \leq 0.05$.

Yield performance of main and sucker crop

Bunch weight of the main crop was significantly affected by treatment with the heaviest bunches of about 11 kg harvested of corms treated with BAP and SW (Table 3). Control plants (W_d) produced the smallest bunches with 9.5 kg. In contrast, bunch weight of the first sucker crop was similar across the treatments, yielding about 11 kg (Table 3).

There were no treatment effects on yield parameters of the main crop with averagely 6.4 hands per bunch and 29.6 fingers per bunch (Table 3). However, these yield parameters were significantly affected by treatment for the first sucker crop. Plants from corms treated with SW produced with 6.9 hands per bunch and 30.9 fingers per bunch the highest numbers, but in both cases was not significantly different from the PIF, BAP and CW_f treatments, respectively (Table 3).

Table 3. Effects of treatments (UTC - untreated control; PIF - Plant Issus de Fragments de tige; CW_a - autoclaved coconut water; CW_f - fresh coconut water; CW_aSW - autoclaved coconut water with seaweed extract; BAP – 6-benzylaminopurine; CWP_a - coconut water with pulverized papain; SW - seaweed extract; W_d - distilled water) on yield characteristics of main and sucker crops, respectively, of False Horn plantain.

Treatment	Yield (kg/bunch)		Hands per bunch		Fingers per bunch	
	Main Crop	Sucker Crop	Main Crop	Sucker Crop	Main Crop	Sucker Crop
UTC	10.7 ^{bc}	10.9 ^a	6.3 ^a	6.3 ^a	29.3 ^a	28.9 ^{ab}
PIF	10.4 ^{bc}	11.0 ^a	6.4 ^a	6.4 ^{abc}	28.1 ^a	29.7 ^{abc}
CW _a	10.7 ^{bc}	11.0 ^a	6.6 ^a	6.4 ^{abc}	29.4 ^a	28.9 ^{ab}
CW _f	10.7 ^{bc}	11.1 ^a	6.6 ^a	6.7 ^{abc}	32.1 ^a	30.5 ^c
CW _a SW	10.0 ^{ab}	10.8 ^a	6.3 ^a	6.3 ^{ab}	29.6 ^a	28.8 ^{ab}
BAP	11.3 ^c	11.0 ^a	6.6 ^a	6.8 ^{bc}	28.1 ^a	30.0 ^{bc}
CWP _a	9.8 ^{ab}	10.9 ^a	6.4 ^a	6.2 ^a	30.2 ^a	28.2 ^a
SW	11.0 ^c	11.4 ^a	6.1 ^a	6.9 ^c	29.6 ^a	30.9 ^c
W _d	9.4 ^a	10.8 ^a	6.4 ^a	6.2 ^a	29.1 ^a	28.3 ^a
<i>Statistics</i>						
P-value	*	ns	ns	*	ns	*
LSD _{0.05}	0.9	0.4	0.6	0.5	3.1	1.5

Data are means (main crop n=9; sucker crop n=12) with different letters in the same column indicating significant difference at $p \leq 0.05$. * is significant at $p \leq 0.05$; ns: not significant.

Discussion

Growth and yield performance of plantain plants derived from *Plants Issus de Fragments de tige*, which is currently and widely employed by smallholder plantain farmers in West and Central Africa, has not been intensively studied. In contrast, this technique in combination with hormone applications, has been thoroughly evaluated for its potential on the rate of shoot proliferation. However, smallholder farmers are aiming to achieve high yields for securing their livelihood through product sales and thus income generation. Consequently, this study investigated the effect of plantain corms treated with PIF and hormone solutions on the growth and yield performance of both the main crop and the first sucker crop.

The lack of treatment effect on the number of suckers of the main crop might be due to all plantlets having developed sufficient roots during the nursery and acclimatization phase [29]. It has been suggested by [30] that vigorous growth and high suckering ability is the results of a strong root system rather than carry-over effect from corms treated with growth hormones. Moreover, the main crop from corms treated with the PIF-technique and hormone solutions, particularly CW_f, had longer psuedostems than those that were only mechanically manipulated. This has also been described for in-vitro plantain plants, which were significantly taller when treated with growth hormones [18]. The generally stronger growth of the first sucker crop compared to the main crop was also reported by [31] and might be attributable to the application of manure [32] in combination with the regular fertilizer.

The plantain cultivar used in the current trial is a landrace, which is susceptible to black Sigatoka, a fungal disease caused by *Mycosphaerella fijiensis* [33]. [34] reported that all landrace plantain cultivars are susceptible to the black Sigatoka disease with detrimental effects on leaf production [18]. In the current study little to none leaf pruning was employed to control the disease.

The time of flowering and fruit maturity of the cultivar ‘Apantu’ could not be altered with hormone and fertilizer applications. Nevertheless, the slightly longer time to flowering after planting of the main crop from PIF-treated corms was reported earlier by [35]. The average bunch weights are comparable to those reported in other studies with the same cultivar [36], [37]. However, the sucker crop generally recorded heavier bunch weights than the main crop. Similar findings were reported by

[38], demonstrating bigger bunches in the ratoon crops than their respective mother crops. In summary, it should be emphasized that good management practices of plantain fields are imperative for attaining high yield [36].

Conclusions

The study demonstrated that both main and sucker plantain crops from hormonally treated corms did not significantly perform better than those from only PIF-treated corms in most of the growth and yield parameters. However, yield performance also depends on good agronomic practices in the field. In contrast, treating corms with growth hormones is highly relevant at the propagation stage to raise robust plantlets with high numbers of roots for improving their field performance. Moreover, the PIF-technique is a reliable low cost option for smallholder farmers to enhance the proliferation rate of the source material in the nursery.

Conflict of Interest

The authors declare no conflict of interest.

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