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Timing of bunch pruning enhances bunch and fruit qualities of 'PITA 24' plantain (*Musa* AAB) hybrid

[1*]Baiyeri, K. P.; [1]Aba, S. C. and [2]Tenkouano, A.
[1]Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
[2]International Institute of Tropical Agriculture, P.M.B 5320, Ibadan, Oyo state, Nigeria.

*Corresponding author: paul.baiyeri@unn.edu.ng or paulkayodebaiyeri@yahoo.com
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ABSTRACT
Objective: Reports on the effects of sink-source modifications on banana fruit growth differ between studies; and may be related to differences in fruit age at the time of bunch pruning. This study investigated the post-anthesis period at which bunch pruning would be most effective in enhancing post harvest qualities of 'PITA 24' plantain hybrid.
Methodology and results: Bunch pruning (i.e., removal of two distal hands and the male bud) was applied at full anthesis (at opening of last female hand) and at weekly intervals of 1, 2, 3 or 4 weeks thereafter. These were compared to a non-prune control in a randomized complete block design. Data were collected at harvest on bunch weight, hand and fruit count, bulking duration, bunch-fill index (BFI) and number of properly-filled fruits (PFF) per bunch. Others were harvest index (HI), fruit weight, length and girth, pulp dry matter content and fruit edible proportion. Bunch and fruit quality traits generally improved with bunch pruning until 3 weeks after the full anthesis, but best fruit traits were obtained when pruning was applied immediately after the opening of the last female hand. There was a drop in BFI, PFF, HI, fruit yield and individual fruit size when bunch pruning was delayed for 4 weeks after full bunch anthesis.
Conclusion and application of findings: Our results confirmed that bunch and fruit qualities of plantains could be improved through a judicious and timely application of bunch pruning. Bunch pruning management should not be delayed beyond 3 weeks after the opening of the last female hand for optimum result.
Key words: Bunch pruning, timing, bunch and fruit traits, plantain.

INTRODUCTION

'PITA 24', a secondary triploid plantain-derived hybrid, is among the *Musa* genotypes recently selected for their biotic stress tolerance and good horticultural traits. Besides sigatoka disease tolerance, earliness and fast cycling, increased concentrations of pro-vitamin A (β-carotene), iron and zinc (as compared to the landrace 'Agbagba') constitute other attractive features of the 'PITA 24' hybrid (Tenkouano *et al.*, 2002).
This genotype produces a very large bunch of about 9-12 hands (nodal clusters), but only the first four to five proximal hands are properly filled to marketable fingers. Fruit size is an important commercial characteristic for markets specializing in plantains (Ferris *et al.*, 1996). Consumers often prefer larger fruits and associate high quality with bunches that have a few (20-25 fingers, ≥ 250g), but large fruits per bunch as typified in horn plantains. This poor fruit-filling feature of 'PITA 24' hybrid could, therefore, have a negative impact on its adoption potential.

Recent studies on 'PITA 24' and 'Mbi-Egome' plantains (Aba *et al*., 2009 & Baiyeri *et al*., 2009) proved that bunch pruning (i.e., decreasing sink size by removal of male bud and few distal hands from bunches soon after flowering) has the potential to increase the size and grade, and consequently the price of harvested fruits. These studies revealed a progressive qualitative improvement of the 40 percent prune-derived bunches (i.e. when 40% of the entire hands of fruits was severed) over the 20 percent pruned and the non-prune (control) bunches.

In many fruit trees, pruning or 'fruit thinning' improves fruit colour and organoleptic or sensory qualities, reduces limb breakage and promotes general tree vigour, thus producing fruits of more alluring appearance at harvest (Relf, 1997). Westwood (1978) had earlier reiterated the importance of the degree and timing of thinning on fruit filling and ultimate fruit size, noting that the earlier thinning is done and the more intense the thinning, the larger the harvest realized .

The growth cycle of *Musa* sp. consists of two major phases (Swennen and Ortiz, 1997), that is, the vegetative and reproductive phases. The vegetative phase begins with the production of leaves by the planted suckers, and ends when the floral shoot (inflorescence) appears at the top of the plant, which marks the beginning of the visible reproductive phase. The fruit filling (bulking) period, i.e., the time lapse between anthesis and harvest (at full maturity), completes the reproductive phase and the growth cycle. The main features of post emergence development of fruit bunch are the onset of cell division in the pulp initiating region at two weeks after emergence (or shooting of the inflorescence), the cessation of cell division at four weeks and the progressive fruit growth by cell enlargement thereafter (Ram *et al*., 1962). Rapid starch accumulation begins in the pulp after the end of cell division (Jullien *et al*., 2001b). Morphologically, bulking begins after the bract exposes the hand, and continues until harvest when fruits have reached full size (Swennen and Ortiz, 1997).

Internal limitations to fruit growth due to competition for photo-assimilates within the plant are well known (Dennis, 1982). Once a threshold number is reached, further increases in fruit number per plant reduce fruit size (Krauss et al., 1999), a fact which dictates removal of some fruits. Rodriguez et *al.* (1988) noted that the distal hands, which do not reach commercial size, constitute a loss in respiration and represent a redistribution of dry matter which is of no commercial use. When such hands are severed, dry matter would be redistributed between the remaining hands in the bunch, thereby increasing their size.

Timing is a crucial factor in routine horticultural practices (Fixen and Reetz, 2006), as applications misapplied or too late in the season may not be as effective as desired. The present study investigated the post-anthesis period at which bunch pruning would be most effective in enhancing the bunch and fruit qualities of 'PITA 24' plantain.

MATERIALS AND METHODS

Study site: The study was conducted at the high rainfall station of the International Institute of Tropical Agriculture (IITA), Onne (4^0 43'N, 7^0 01'E, 10 m above sea level), in southern Nigeria between November 2006 and May 2008. The station is located in a degraded rainforest swamp area, characterized by an ultisol derived from coastal sediments, and an annual unimodal rainfall of 2400 mm (Ortiz *et al.*, 1997). Analytical results revealed that the soil is a sandy loam with granulometric distribution of 68% sand, 7% silt and 25% clay, acidic $pH_{(water)}$ of 5.0 and organic matter content of 2.59%, total nitrogen 0.15%, phosphorus 0.01%, 8.44 mg of Zn/kg soil, 282 mg/kg Fe, 1.25 mg/kg Cu and Mn 38.5 mg /kg soil. Exchangeable cations ($cmol^+$/kg) were 0.32, 4.43, 0.30 and 0.43 for K, Ca, Mg and Na, respectively, while exchangeable acidity and CEC were 0.30 and 5.78 $cmol^+$/kg, respectively. Average daily temperature is 27 ± 3 ^{0}C and solar radiation averages 14 MJm^{-2}.

Experimental design: The treatments comprised of a non-prune control, and five bunch pruning periods (time of pruning) applied consecutively at weekly intervals (0-4 weeks) after the opening of the last female hand (as marked by the lifting of the bract) on the developing infrutescence. The six treatments were laid-out on single-row plots of seven plants replicated four times in

a randomized complete block design (RCBD), giving a total of 168 plants.

Treatment application: Three-month-old seedlings of *in-vitro* plants were planted in holes measuring 40x40x40cm in dimensions and spaced 3m between rows and 2m within row, giving a hectare population of 1667 plants. Twenty tons per hectare of composted poultry manure from a deep litter commercial farm was split-applied at half the calculated dose during planting and the complement at the onset of flowering (six months after planting). Twenty percent of the entire hands (nodal clusters) borne on the developing inflorescence were severed from the distal end of the bunch as soon as the last hand emerged at full anthesis (i.e. at the opening of the last female hand) as recommended in earlier studies (Aba *et al*., 2009 & Baiyeri *et al*., 2009), or at intervals of one to four weeks after full anthesis (WAFA). Male bud was severed in all the pruned bunches whereas in the control (non-prune) plants it was left intact. Other cultural practices were carried out as described by Swennen (1990).

Data collection and analysis: At harvest, data were collected on bunch weight (kg), number of hands per bunch, total fruit count per bunch, days to complete fruit-filling (bulking period, i.e., days from flowering to harvest at full bunch maturity as signalled by the yellowing of one or two finger tips), and number of properly-filled fruits per bunch. Bunch-fill index (%) was calculated as the ratio of properly-filled fruits to total fruit count per bunch multiplied by 100 (Aba *et al*., 2009). Harvest index, the ratio of harvestable product (bunch) to the total above-ground biological yield (fresh weights of leaves, pseudostem and bunch) was calculated following Baiyeri (2002), and Baiyeri & Tenkouano (2007).

Other parameters were fresh weights (kg) of hands 1-6 (proximal hands), fruit weight (g), length and girth (cm) of the four middle fingers on each reference hand. Fruit yield (tonnes) per hectare was also calculated for each treatment. Pulp fresh weight (g) of the fruits was determined after manual peeling. The pulp weight: fruit weight ratio was calculated to estimate the edible proportion of the fruits. The pulp fraction was oven-dried at 65 ^{0}C for 48 hr to determine the dry matter content (%), which was calculated as the dry weight/fresh weight ratio multiplied by 100. All data were subjected to Analysis of Variance (ANOVA) following RCBD model using GENSTAT Release 7.2 DE (GENSTAT, 2007). Separation of treatment means with significant differences was by least significant difference (LSD) at 5 percent probability level as described in Steel and Torrie (1980).

RESULTS

Time of bunch pruning significantly ($P<0.05$) influenced most of the yield components studied at harvest (Table 1). Except for the plants pruned at four weeks after full anthesis (WAFA), pruned bunches yielded heavier than the control, but the non-prune bunches had significantly ($P<0.05$) higher number of hands and fingers per bunch. Number of days to fruit filling (DFF), i.e., bulking period was not significantly different between the treatments, although bunches pruned at one week of full anthesis filled earliest. Bunch-fill index (BFI), the proportion of properly-filled fruits per bunch, as well as the actual number of properly-filled fingers (PFF) increased significantly ($P<0.05$) with bunch pruning, when applied not later than 3 WAFA. There was a drop in BFI, PFF, harvest index (HI) and fruit yield (FYld) per hectare when bunch pruning was delayed for 4 weeks after the opening of the last female hand. Individual hand weights were heavier in the pruned bunches but reduced substantially when pruning was applied at 4 WAFA.Data on fruit metric traits (Table 2) shows a substantial improvement in individual fruit weight, length and girth with bunch pruning, but there was no significant difference between the control and the treatments where pruning was delayed until 4 WAFA. Bunch pruning applied at full anthesis till 3 WAFA produced similar effects in most cases, but produced larger fruits than the non-prune bunches. A similar trend existed for fruit edible proportion and pulp dry matter content (Table 3), particularly on the distal fruits (hands 4-6).

Irrespective of the time of pruning, whole-bunch mean values for hand and fruit weight, fruit length, girth and fruit edible proportion showed clearly that fruit quality traits improved significantly ($P<0.05$) with bunch pruning, although when delayed till 4 WAFA the effects diminished. Values for pulp dry matter content seem to be similar between the treatments, but somewhat skewed in favour of bunches pruned at 4WAFA which had the highest value (Fig. 1). Best fruit metric traits were observed when pruning was applied immediately after the opening of the last female hand at full anthesis. Generally, hand and fruit weight, fruit girth, length and fruit edible proportion parameters improved with bunch pruning until 3 WAFA, suggesting that bunch pruning should not be delayed beyond 3 weeks after the opening of the last female hand

Table 1: Bunch yield components of 'PITA 24' plantain hybrid as influenced by time of bunch pruning.

Time of Pruning	Bchwt [kg]	After Prune		DFF[#]	BFI[%]	PFF[#]	HI[%]	FYld [tha^{-1}]	Hand Weight [kg]					
		nHds [#]	nFgs[#]						Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6
FA	16.1	7.5	131.6	99.1	64.3	84.4	26.5	24.1	3.3	3.2	2.6	2.0	1.5	1.3
1WAFA	15.9	7.6	133.2	94.8	61.1	80.7	24.2	23.7	3.4	3.0	2.6	1.8	1.4	1.2
2WAFA	15.5	7.5	133.3	102.2	62.4	85.2	25.3	23.1	4.9	3.0	2.5	1.8	1.4	1.1
3WAFA	16.7	7.5	133.6	99.4	60.5	88.3	25.5	25.1	3.6	2.9	2.5	2.1	1.6	1.3
4WAFA	14.1	7.5	131.2	100.1	52.7	68.4	23.7	21.0	3.3	2.7	2.3	1.7	1.3	1.0
CONTROL	15.0	9.6	162.2	97.0	42.5	68.9	25.8	22.1	3.1	2.8	2.0	1.5	1.2	0.9
$LSD_{(0.05)}$	ns	0.7	17.6	ns	6.8	10.4	ns	2.8	ns	ns	0.3	0.3	ns	0.3

FA = at full anthesis; WAFA = Week(s) after anthesis; Bchwt = Bunch weight; nHds = Number of hands per bunch; nFgs = Number of fingers per bunch; DFF = Days to fruit-filling; BFI = Bunch fill index; PFF = Number of properly-filled fruits; HI = Harvest index; FYld = Fruit yield per hectare; Hd_1-Hd_6 = Hands 1-6; $LSD_{(0.05)}$ = Least significant difference at 5% probability level; ns = Non-significant.

Table 2: Effect of time of bunch pruning on fruit metric traits of 'PITA 24' plantain hybrid.

Time of Pruning	Fruit weight [g]						Fruit length [cm]						Fruit girth [cm]					
	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6
FA	158.1	150.1	136.8	105.4	89.4	71.6	24.6	24.8	23.7	21.7	20.5	19.3	11.6	11.3	11.1	10.5	10.1	9.5
1WAFA	155.0	151.9	131.0	91.8	78.9	62.2	24.6	25.4	23.8	21.0	20.1	18.5	11.3	11.2	11.0	10.1	9.9	9.2
2WAFA	162.2	152.7	135.9	97.5	75.9	65.7	24.6	24.7	23.6	20.9	19.0	17.1	11.6	11.4	11.1	10.1	9.5	9.0
3WAFA	154.7	146.7	134.8	108.6	78.6	68.4	24.0	24.3	23.5	21.0	19.3	18.6	11.6	11.3	11.1	10.6	9.7	9.3
4WAFA	146.7	147.2	129.3	85.9	75.7	56.0	24.0	24.9	23.1	19.7	19.3	17.5	11.2	11.2	10.9	9.8	9.5	8.8
CONTROL	140.5	138.6	110.1	81.2	68.0	50.3	23.9	24.0	22.3	19.7	19.0	17.1	11.2	11.0	10.3	9.7	9.2	8.7
$LSD_{(0.05)}$	ns	ns	ns	17.5	ns	15.1	ns	ns	ns	0.9	1.0	ns	ns	ns	0.5	0.6	ns	ns

FA = at full anthesis; WAFA = Week(s) after anthesis; Hd_1-Hd_6 = Hands 1-6; $LSD_{(0.05)}$ = Least significant difference at 5% probability level; ns = Non-significant.

Table 3: Post-harvest quality traits of plantain 'PITA 24' hybrid as influenced by time of bunch pruning.

	Fruit Edible Proportion [%]						Pulp Dry Matter Content [%]						Whole-bunch mean values					
Time of Pruning	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6	Hdwt [kg]	FW [g]	FL [cm]	FG [cm]	EP [%]	PDMC [%]
FA	55.0	55.7	53.2	50.0	46.8	42.2	27.8	27.8	28.1	24.5	22.2	21.4	2.3	118.3	22.5	10.7	51.9	26.2
1WAFA	56.8	56.5	53.7	49.9	44.3	41.3	27.8	28.1	27.0	24.7	20.5	19.1	2.2	111.8	22.2	10.4	52.5	25.5
2WAFA	59.0	56.8	55.0	50.1	44.9	37.0	28.9	29.4	29.3	22.8	17.6	19.2	2.4	113.3	21.6	10.4	53.5	26.4
3WAFA	57.6	57.9	56.3	57.6	47.2	45.8	27.1	27.8	27.4	24.4	21.3	20.2	2.3	114.9	21.8	10.6	55.4	25.7
4WAFA	55.6	56.7	54.5	45.7	44.4	37.4	29.9	29.4	29.1	24.7	18.9	15.8	2.1	105.5	21.4	10.2	51.6	27.0
CONTROL	56.1	55.1	51.8	45.3	40.7	34.0	27.6	30.3	26.2	21.9	18.1	13.2	1.9	98.1	21.1	10.0	50.3	26.1
$LSD_{(0.05)}$	ns	ns	2.6	7.6	4.6	ns	ns	ns	ns	ns	2.5	5.1	0.4	12.1	0.9	0.4	2.4	ns

FA = at full anthesis; WAFA = Week(s) after anthesis; Hdwt = Hand weight; FW = Fruit weight; FL = Fruit length; FG = Fruit girth; EP = Fruit edible proportion; PDMC = Pulp dry matter content; Hd_1-Hd_6 = Hands 1-6; $LSD_{(0.05)}$ = Least significant difference at 5% probability level; ns = Non-significant.

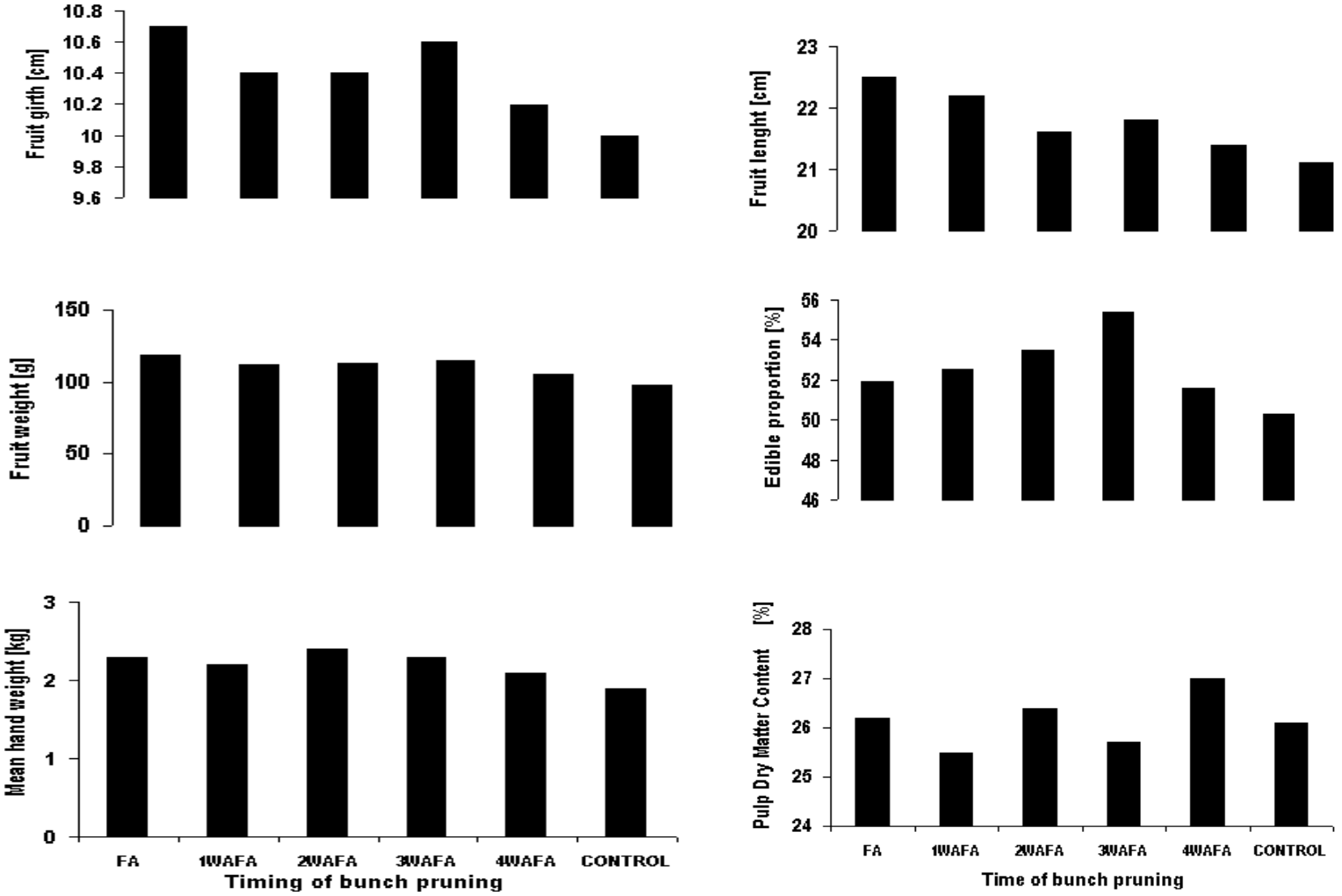

Figure 1: Bar charts showing the fruit quality traits of plantain PITA 24 hybrid as influenced by time of bunch pruning.

DISCUSSION

The significant improvement in fruit and bunch quality traits (size, edible proportion, dry matter yield and bunch-fill index) observed with bunch pruning in this study confirms our earlier observation (Aba *et al*., 2009 & Baiyeri *et al.,* 2009) that bunch pruning can improve the harvest size and quality of fruits in 'PITA 24' hybrid. Similar observations had earlier been reported by several authors (Prasannakumariamma *et al*., 1986; Irizarry *et al*., 1991; Daniells *et al*., 1994; Quintero & Aristizabal, 2003; Weerasinghe & Ruwanpathirana, 2004; Wanichkul & Boonma, 2009) for different *Musa* cultivars in the tropics and semi-tropics.

Baiyeri *et al.* (2009) opined that this improvement in fruit quality traits observed with pruning could be attributed to the reduction in available sink size; thereby concentrating assimilates in a smaller sink volume. The growth rate of banana fruit varies with the source/sink ratio during fruit growth (Jullien *et al.*, 2001a). Pruning, therefore, assures that assimilates are not wasted on the non-essential portions of the bunch, but channelled for the optimum growth of the remaining fruits.

Effects of source/sink modifications on banana fruit growth rate differ between studies and may be related to differences in fruit age at the time a treatment is applied (Jullien *et al*., 2001a). In the present study, the best fruit quality traits were observed when pruning was applied immediately after the opening of the last female hand. Fruit traits generally improved with bunch pruning until 3 weeks after full anthesis, suggesting that bunch pruning treatment should not be delayed beyond 3 weeks after the opening of the last female hand.

At 4 WAFA, cell division must have been completed and fruit growth progresses mainly by cell enlargement. Pruning during cell division phase seems to have a positive effect on the ultimate fruit size, as delayed pruning (i.e., application during cell enlargement) would amount to loss of accumulated food reserve. Fruit growth by cell division and enlargement on the proximal hands (which are the first to be initiated on the bunch meristems) is in advanced stage compared with fruits on the distal extremities (Jullien *et al.*, 2001b). The earlier few of these distal fruits are severed, the better the growth potential of the remaining fruits on the developing infrutescence.

Our results confirmed that fruit qualities of plantains could be improved through bunch pruning, but pruning should not be delayed beyond 3 weeks after the opening of the last female hand for optimum result.

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