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Region of bunch pruning influences the bunch and fruit physical traits of 'PITA 24' plantain (*Musa* AAB) hybrid

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ABSTRACT
Objective: Achieving maximum uniformity of fruit size within a bunch is of great importance commercially. In bananas, distal fruits which often do not reach commercial size constitute a loss in respiration and redistribution of dry matter with no commercial value. This study aimed at promoting uniformity in fruit size and quality within a bunch through pruning at opposite ends of a developing infrutescence.
Methology and results: Treatments comprised of proximal pruning (PP), distal pruning (DP), pruning at both ends of the bunch (BE) and a no-prune control. These were evaluated in randomized complete blocks of four replicates. Two nodal clusters (hands) were severed from the developing bunch as soon as the last female hand opened. Male bud was removed in all the pruned bunches. Data were collected at harvest on bunch weight, hand and fruit count, bunch-fill index and number of properly-filled fruits per bunch. Other parameters were harvest index, fruit weight, length and girth, pulp dry matter content and fruit edible proportion. Results showed a non-significant difference in bunch weight between the treatments, although fruit and bunch yield drastically reduced in the proximally pruned bunches. Bunch and fruit metric traits were similar and superior in bunches pruned at the distal (DP) and both ends (BE) of the bunch. Bunches pruned at both ends also produced fairly uniform fruits.
Conclusion and application of findings: Our results revealed that an improvement in fruit yield and quality could be achieved through selective removal of some distal fruits with the terminal male bud, but a complementary excision of some proximal fruits is necessary when uniformity of fruits is desired.
Key words: Bunch yield, fruit quality, bunch pruning, plantain

INTRODUCTION
Fruit position on a developing infrutescence (bunch) is an important source of variability in fruit size at harvest. Banana fruits are arranged in nodal clusters (hands) that are inserted helicoidally through the pedicels (fruit stalks) to a central axis called the peduncle. Hands at the base of the bunch are the first to be initiated on the meristem, and bear fruits (proximal fruits) that are approximately 40 percent bigger than those at the terminal (distal end) of the bunch (Robinson, 1996). Hand one, being the closest to the photosynthetic source (leaves) and the oldest as well, exerts the greatest 'sink pull' within a bunch and hence fills better than other hands, but often has relatively fewer fingers. Internal limitations to fruit growth due to competition for photo-

assimilates within the plant are well known (Dennis, 1982). Sink competition depends on the photosynthetic capacity of a genotype to supply the photo-assimilates required for maintenance of plant metabolism on one hand and fruit-filling on the other hand. In bananas, competition may initially occur between fruits and lateral shoot growth. Simultaneously, competition occurs between fruit development and male bud growth and between every newly formed hand and its predecessor resulting in a progressive decrease in hand and fruit size from the proximal to the distal extremities of the infrutescence (Stover and Simmonds, 1987).

This negative gradient in fruit weight and size is related to differences in developmental stages between proximal fruits (initiated first) and the distal fruits resulting from differences in pulp cell number between fruits (Jullien *et al.*, 2001). This gradient in growth stages between the proximal and distal fruits within a bunch influences the final size and grade in the distal fruits, as the entire bunch is harvested at the same time.

'PITA 24' hybrid is a secondary triploid plantain recently selected for its biotic stress tolerance and good horticultural traits (Tenkouano *et al.*, 2002). This genotype produces a very large bunch of about 9-12 hands (nodal clusters), but only the first four or five proximal hands often fill to marketable fingers. Fruit weight and size (length and girth) are important commercial criteria for export bananas, as they influence the selling price in European market (Jullien *et al.*, 2001). These traits are also valued in Nigerian local markets particularly in cities where plantain and banana harvest is seldom sold as whole bunch. For a fruit to qualify for export from French West Indies to the continental France, it must be at least 30 mm in diameter and 170mm long. In our earlier studies (Aba *et al.*, 2009; Baiyeri *et al.*, 2009), 'bunch pruning', i.e., the selective removal of male bud and some distal fruits from the developing bunch soon after full anthesis (at the opening of the last female hand), was found to improve the final harvest size and fruit quality in 'Mbi-Egome' and 'PITA 24' plantains.

The present study compared the effects of bunch pruning at the opposite ends of a developing infrutescence on fruit metric traits, bunch yield attributes, quality and uniformity of fruits within a bunch. Uniformity in size and quality of fruits (Marchal, 1998), makes sorting and grading easier in grocery stores, facilitates handling and minimizes uneven and unpredictable ripening.

MATERIALS AND METHODS

Experimental site: The experiment 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 a.s.l.) in the Niger Delta area of southern Nigeria between November 2006 and May 2008. The soil was characterized as an acidic (pH 4.6) sand loam (68% sand, 7% silt and 25% clay) with organic matter content of 1.84%. Total nitrogen was 0.09%, while phosphorus and potassium contents were 172.57 µg/g and 0.03 $cmol^+$/kg, respectively; cation exchange capacity is 5.78 $cmol^+$/kg. An annual unimodal rainfall of 2400mm, average daily temperature of 27 ± 3 ^{0}C and solar radiation averaging 14 MJm^{-2} prevailed.

Cultural practices: Micropropagated plantain seedlings were planted at a spacing of 3m x 2m (inter-row x intra-row, giving a plant population of 1667 per hectare) in holes measuring 0.4 x 0.4 x 0.4m in dimensions. An annual application rate of 20 t/ha of decomposed poultry manure was applied as two-split doses during planting and at flowering (six months after planting) as recommended by Baiyeri and Tenkouano (2007).A follower-sucker was maintained as ratoon after flowering. De-suckering (pruning of side shoots) and cutting of dry leaves were routine operations. Weeds were controlled when necessary through manual slashing or with a systemic herbicide 'Round-up', while bearing plants were propped to prevent wind damage.

Treatment application: The experimental treatments comprised of three alternative pruning arrangements [proximal pruning (PP), distal pruning (DP), and pruning at both ends (BE) of the bunch] on a developing fruit bunch [see Figure 1]. These were evaluated alongside a no-prune control in a randomized complete block design (RCBD) of four replications. Two hands of fruits (nodal clusters) were severed from the respective region of the bunch as soon as the last female hand was exposed after the lifting of the bract. Male bud was

removed in all the pruned bunches, while in the control plants the buds were left intact. One hand each was severed from both ends of the bunch in those bunches pruned at both ends (BE).

Data collection and analysis: Data were collected at harvest on bunch weight (kg), number of hands per bunch, total fruit count per bunch and number of properly–filled fruits. Bunch fill index (%) was calculated as the ratio of properly-filled fruits to the 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).

Other parameters were fresh weights (kg) of hands 1-6 (proximal hands), mean fruit weight (g), length and girth (cm) of the four middle fingers on each reference hand. Total fruit yield (tonnes) per hectare was also calculated for each treatment. Pulp fresh weight (g) was determined after manual peeling, and fruit edible proportion (%) calculated for each fruit as the pulp weight: fruit weight ratio multiplied by 100. The pulp fraction was later oven-dried (65 ^{0}C, 72 hr) to determine the pulp dry matter content (%), which was calculated as the dry weight: fresh weight ratio multiplied by 100. Analysis of Variance (ANOVA) was performed for all the variables following the standard procedure for RCBD models using GENSTAT 7.2 DE release (GENSTAT, 2007). Separation of treatment means with significant differences was by least significant difference (LSD) at 5 percent probability level (Steel and Torrie, 1980).

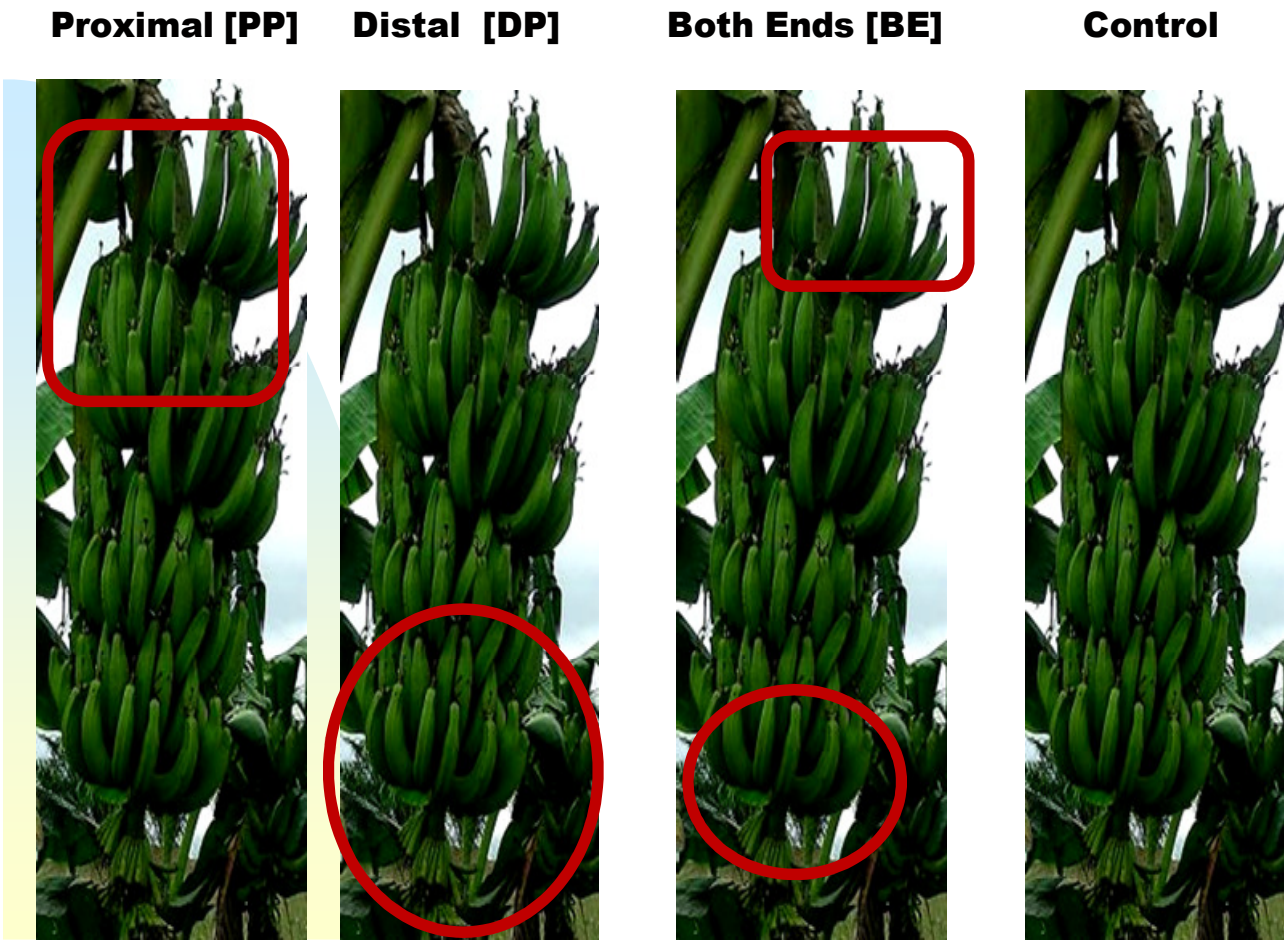

Figure 1: An illustration of the bunch pruning treatments. [The respective regions of pruning were marked in red]

RESULTS

Data (Table 1) shows the bunch yield components of 'PITA 24' plantain as influenced by region of bunch pruning. Although the non-pruned bunches bore more hands (nodal clusters) and fruits, there were no significant differences between the bunch weights among the treatments. Bunches pruned from the proximal end (PP), however, had the least bunch weight, while those pruned from both ends (BE) produced the heaviest bunches. Harvest index (HI), the ratio of harvestable product to the total above-ground biological yield was also superior in those bunches pruned at both ends as with the distally pruned bunches.

Bunch-fill index, ratio of properly-filled fruits to the total fruit count per bunch was significantly ($P<0.05$) higher in the pruned bunches, and fairly similar for the three pruning treatments. A similar result was observed in the number of properly filled fruits per bunch, but fruit yield (tonnes) per hectare was greatest in bunches pruned from both ends, followed closely by distally pruned bunches, while the proximally pruned bunches produced the poorest fruit yield (21.8 tonne ha^{-1}) at par with the non-pruned bunches.

Individual hand weights were superior in the distally pruned bunches, as in those bunches pruned from both ends. Similar results (Table 2) were observed in the fruit metric traits (weight, length and girth), with the bunches pruned from both ends producing the largest sized fruits. The poorest fruits were derived from the non-pruned (control) bunches, particularly on the distal (hands 3-6) portion.

The values of fruit edible proportion and pulp dry matter content were superior in the pruned bunches (Table 3). The whole-bunch mean values showed clearly that the largest sized (best quality) fruits came from the bunches pruned at the distal end and those pruned on both-ends. Values for fruit edible proportion and pulp dry matter content were highest in the proximally pruned bunches, but were not significantly greater than other pruning treatments.

The results of the individual fruit and hand weights, fruit length and girth (Figure 2) showed clearly that the largest sized fruits were derived from the bunches pruned on the distal end or on both-ends. The overall improvement in fruit size particularly on the distal fruits was greatest on the bunches pruned from both ends. This pruning regime produced curves of more uniform gradients (Figure 2), representing bunches with more uniform fruits at harvest. The poorest fruits were derived from the non-pruned bunches, although exclusive proximal pruning (as evident in Table 1) may drastically reduce bunch yield

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Table 1: Yield components of 'PITA 24' plantain hybrid as influenced by region of bunch pruning.

		After Prune						Hand Weight [kg]					
Region of Pruning	Bchwt [kg]	nHds [#]	nFgs [#]	HI [%]	BFI [%]	PFF [#]	FYld [tha^{-1}]	Hd_1	Hd_2	Hd_3	Hd_4	Hd_5	Hd_6
Distal	15.5	8.0	132.0	25.3	61.6	80.9	23.6	3.2	2.7	2.4	1.6	1.5	1.0
Proximal	14.3	8.0	131.0	23.1	60.9	78.5	21.8	2.6	2.4	2.0	1.6	1.2	1.1
Both Ends	15.8	8.0	132.0	26.7	59.8	78.1	24.0	3.1	2.7	2.5	1.8	1.3	1.2
Control	15.0	10.0	164.0	25.6	41.6	68.2	21.8	3.0	2.8	1.9	1.5	1.2	0.9
$LSD_{(0.05)}$	ns	0.8	18.7	2.0	10.9	9.1	ns	0.5	ns	0.4	ns	ns	ns

Bchwt = Bunch weight; nHds = Number of hands per bunch; nFgs = Number of fingers per bunch; 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 region of bunch pruning on fruit metric traits of 'PITA 24' plantain hybrid

	Fruit weight [g]						Fruit length [cm]						Fruit girth [cm]					
Region 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**	**Hd_1**	**Hd_2**	**Hd_3**	**Hd_4**	**Hd_5**	**Hd_6**
Distal	152.5	142.3	130.0	94.5	77.6	62.8	24.8	25.5	24.3	21.3	20.5	18.9	11.3	10.9	10.9	10.1	9.5	9.2
Proximal	145.7	134.3	124.2	97.8	71.3	65.2	23.8	22.7	22.5	20.5	19.2	18.7	11.2	11.2	11.0	10.5	9.6	9.4
Both Ends	170.6	155.2	135.0	109.2	83.4	69.3	26.0	25.3	23.4	21.9	20.7	19.5	11.6	11.4	11.3	10.6	10.0	10.0
Control	138.9	136.0	108.0	80.1	70.6	50.3	23.9	23.8	22.4	19.4	19.2	17.8	11.1	10.9	10.2	9.6	9.3	8.7
$LSD_{(0.05)}$	23.0	16.0	ns	17.1	ns	15.0	ns	1.5	ns	1.7	ns	ns	ns	0.3	0.7	0.6	ns	0.5

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 'PITA 24' plantain hybrid as influenced by region of bunch pruning

	Fruit Edible Proportion [%]						Pulp Dry Matter Content [%]						Whole-bunch mean values					
Region 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 [%]
Distal	55.0	55.3	53.6	49.0	44.9	41.4	28.2	28.7	28.3	24.0	23.2	18.0	2.1	110.0	22.5	10.3	49.8	25.0
Proximal	58.4	57.6	57.2	53.1	45.2	46.1	29.7	30.8	29.4	26.6	22.3	22.1	1.8	106.4	21.2	10.5	53.0	26.8
Both Ends	57.2	58.6	56.2	50.9	46.7	43.2	28.3	27.4	28.1	22.4	21.7	18.6	2.1	120.4	22.8	10.8	52.1	24.4
Control	55.3	54.1	51.2	44.9	41.4	33.9	27.3	28.8	26.3	21.6	18.6	12.6	1.9	97.3	21.1	10.0	46.8	22.5
$LSD_{(0.05)}$	ns	ns	5.0	ns	ns	5.9	ns	1.8	ns	3.4	3.6	4.1	ns	16.4	1.3	0.4	4.5	1.9

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.

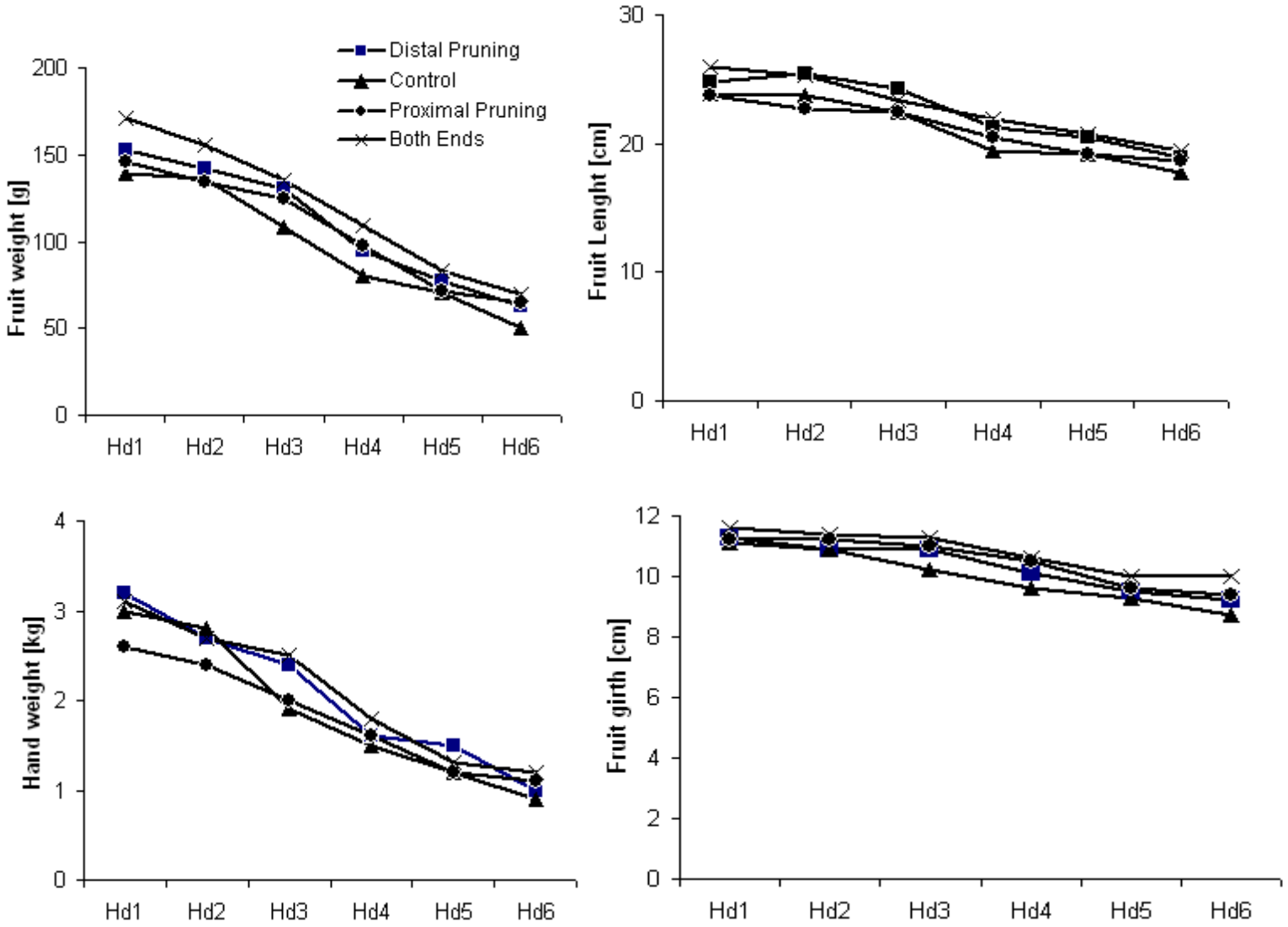

Figure 2: Charts showing the fruit metric traits of 'PITA 24' plantain as influenced by region of bunch pruning. Hd_1-Hd_6 represents the first six proximal hands.

DISCUSSION

A lack of significant difference in bunch weights between the treatments suggests that the increase in weight and size of fruits resulting from the selective removal of some fruits compensated for the reduction in the number of fruits in the pruned bunches. The significant improvement in fruit yield and other quality traits (size, edible proportion, dry matter yield, bunch-fill and harvest indices) observed in the distally pruned bunches and those pruned from both ends confirmed our earlier observation (Aba *et al.*, 2009 & Baiyeri *et al*., 2009) that bunch pruning can improve harvest size and quality of fruits in 'PITA 24' plantain. Similar opinions had earlier been reported by several authors (Prasannakumariamma *et al.*, 1986; Irizarry *et al.*, 1991; Daniells *et al.*, 1994; Quintero and Aristizabal, 2003; Weerasinghe and Ruwanpathirana, 2004; Wanichkul and Boonma, 2009) for different *Musa* cultivars in the tropics and semi-tropics.

Thinning immature fruits at the appropriate time (when they are fairly small) allows each remaining fruit to develop to its maximum size (Ingels *et al*., 2001), following a reduction in the inherent competition that exists between fruits. The poor yield and quality of fruits observed in the proximally pruned bunches suggests that it is a wasteful practice to remove the first two proximal hands. The proximal fruits are the first to be initiated on the bunch meristem, and the most matured and the largest at any point of harvest (Ram *et al.*, 1962; Robinson, 1996). They are closer to the photosynthetic source; hence they fill earlier than most of the other fruits located around the terminal male bud.

Results from the present study showed that selective removal of one hand of fruits from each end of the developing bunch is a better option for improving the quality and uniformity of the remaining fruits. The best fruits (at harvest) are often found in the second proximal hand of the bunch, and have been recommended for use in the postharvest assessment of bananas (Baiyeri and Ortiz, 1995; Dadzie and Orchard, 1996). As a determinate species, removal of the first two proximal hands is an abysmal waste of accumulated food reserve, as the leaves may not be maintained until the undersized fruits of the distal region are completely filled.

In contrast, distal pruning or pruning at both ends by removing hand-1 (first proximal fruits) and the last distal hand together with the male bud modulates the sink volume. The male bud is a competing 'sink' for assimilates and provides shelter for thrips and mites to proliferate (Robinson, 1996). Removal of the terminal bud with few distal hands is recommended to improve bunch weight (Morton, 1987) and decrease the chance of bacteria wilt caused by *Xanthomonas vasicola* pv *musacearum* (Ee, 1992; Mwangi, 2009).

A reduction in sink size improves the growth rate of the remaining fruits and ensures greater efficiency in dry matter partitioning to the harvestable portion (Aba *et al*., 2009), as assimilates are not wasted on the non-essential portions of the bunch, but channelled for the optimum growth of the remaining fruits.It was apparent from the study that an improvement in fruit yield and quality could be achieved through selective removal of some distal fruits and the male bud from a developing bunch. When uniformity of fruits is desired, complementary excision of some proximal fruits is necessary.

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