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Inflorescence developmental polymorphism and its horticultural significance in plantain (*Musa* spp. AAB)

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Inflorescence developmental polymorphism and its horticultural significance in plantain (*Musa* spp. AAB) was investigated in this study. The study was designed to evaluate the consistency of inflorescence dichotomy as well as the horticultural significance of the double and triple bunching plantain phenotypes during several production cycles. Four plantain accessions with different types of multiple bunches or inflorescence dichotomy designated here as 3(SP), 3(TP), 3(DP) and 2(DP), and 'Agbagba', a single bunch bearing cultivar that served as control, were replicated five times and laid out in a randomized complete block design in a field plot, in three cropping seasons with two production cycles. The data demonstrated significant ($p \leq 0.05$) differences in agronomic traits including pseudostem height, girth, number of functional leaves, number of suckers and fruit length amongst the accessions. Differences in yield and yield components (as represented by number of bunches per plant, hands, fingers, fruit circumference, bunch weight and yield per hectare), however, were not significant ($p \leq 0.05$). Overall, 'Agbagba' expressed the lowest flowering index and produced only a single bunch throughout the three cropping seasons evaluated in this study. Inflorescence dichotomy was inconsistent as reversals in inflorescence branching were commonly observed among all the multiple bunching accessions. The double-bunching accession usually reverted to a single bunch while the triple-bunching accessions reverted to either a single or double-bunching inflorescence; tacitly implying that inflorescence dichotomy in these plantain accessions is a random and unstable genetic trait.

Key words: Inflorescence dichotomy, *Musa* spp., phenotypic variation, plantain accessions.

INTRODUCTION

Musa is one of the three main genera of plants in the family *Musaceae*, which includes the bananas and

plantains. There are over 50 species in this family, having a broad variety of uses ranging from the edible bananas

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and plantains of the tropics to cold hardy fiber and ornamental plants, which can grow within a wide range of environments. Bananas and plantains are of extraordinary significance. For example, plantain (*Musa* spp. AAB) is one of the few most important suppliers of dietary energy in the humid and sub-humid tropical regions of the world, where it is cultivated and utilized as a major starchy staple and consumed by an estimated half a billion people. Africa grows more plantain than the rest of the world with Uganda, Rwanda, DR Congo, Nigeria and Ghana as the leading producing countries (FAO, 2010). In fact, in many areas of sub-Saharan Africa, plantain and a few other crops such as cassava and yam constitutes either a year-round or seasonal basic staple foods. Plantain is equally utilized as a raw material in many rural-based cottage industries including the production of wine (Ssebuliba et al., 2000), vinegar and local beer, which is important nutritionally as it is described to be very rich in vitamin B due to the high yeast content. Aside from these, plantain is also converted into high quality flour by drying and grinding the green fruit. Such flour is said to be more digestible than cereal flour and is known to be very good for diabetics.

There are currently about 116 different cultivars of plantain, which belong to the three main categories of French, Horn and False Horn plantains that are cultivated by farmers in different parts of Africa even though, the frequency of occurrence of these cultivars vary between countries as well as from one geographical locality to the other within the same country (Ogazi, 1996). Naturally, a unique feature to all of these plantain cultivars is the fact, that they are known to flower only once, bearing a single bunch at fruiting from a pseudostem that would consist of several hands and fingers, which may vary in size depending on several agronomic factors. However, it has been observed that some False Horn cultivars produce several forms of inflorescence dichotomy which is caused by branching of the peduncle that often results in the production of two, or sometimes even three bunches at fruiting from the single pseudostem (Odeigah, 1997; Tenkouano, 2000). The first detailed account of dichotomous inflorescence in plantain was reported by Pospisil (1966) in Ghana who recognized five different forms of dichotomous bunching. Gill (1968) also reported on two plantain mutants with dichotomous branching and later on Karikari et al. (1971), which described seven different plantain cultivars with dichotomous inflorescence. The occurrence of these unusual plants with multiple bunches in *Musa* species has also been documented with double inflorescences by Stover and Simmonds (1987) in 'Grande Naine' as well as Tang (1995) for Cavendish bananas (*Musa* sp., AAA) in Taiwan.

Lately, these dichotomous or multiple bunching varieties of plantain have become quite commonly noticeable in many parts of southern Nigeria, where the

plants have become quite a source of curiosity to many locals. Not surprising, there has been a myriad of local beliefs, some outrightly bizarre, surrounding the emergence of such plantain morphotypes. Dichotomous branching plantain varieties are suspected to be of great horticultural value because of the inspiring possibility that they can provide a higher yield in terms of edible fruit weight, arising from the two or three bunches produced from the single pseudostem and granted that, the anatomical modifications associated with floral induction in plantain, have been quite well documented (Israeli and Blumenfeld, 1985; Stover and Simmonds, 1987; Tenkouano, 2000). However, the molecular events responsible for initiation and control of polymorphism for the increased number of inflorescences have remained shrouded in secrecy up until now for lack of scientific information. Thus far, only one investigation which demonstrated that the phenomenon may be genetic in origin and is a stable event, probably arising out of a spontaneous mutation from an already existing plantain cultivar has been reported (Odeigah, 1997). Inflorescence dichotomy has also been considered to be a process associated with an advanced stage in the evolution of plantain (Karikari et al., 1971). Expectedly, defining the exact nature of the event and having an insight into the molecular mechanisms controlling its expression may be, crucial for understanding the phenomenon itself.

MATERIALS AND METHODS

The study was conducted in the research farm at University of Calabar, Calabar, Nigeria for a period of three cropping seasons with two production cycles between 2010 and 2013. The area is within the rainforest zone of south-eastern Nigeria, with a mean relative humidity of 86%, annual rainfall of 2000 to 2500 mm that is distributed from February to early November and minimum and maximum daily temperatures of 23 and 34°C, respectively.

Four plantain (*Musa* spp. AAB) cultivars designated as 3(SP) with three bunches derived from a single peduncle, 3(TP) with three bunches derived from three different peduncles, 3(DP) with three bunches derived from double peduncles, 2(DP) with double bunches derived from two peduncles and 'Agbagba' with a single bunch derived from one peduncle (for control), were arranged in a randomized complete block design (RCBD) with five replications. Each replication consisted of 25 experimental plants per treatment, which were mulched with *Eupatorium odoratum* earlier removed from the field. The planting materials collected from mother stools in local farmlands, consisted of conventional uniform and vigorously growing sword suckers with a minimum height and girth of 50 and 15 cm, respectively, as suggested by Nelson et al. (2006) and Oluwafemi, (2013). They were soaked in a liquid insecticide (pyrethrin) solution for 72h and planted out in deep holes, each with dimensions of 0.3 m x 0.3 m x 0.3 m using a spacing of 2 m x 3 m between and within plants under a monocropping system in the field according to Shiyam (2010) and Akinro et al. (2012). At flowering, each bunch was supported by African bamboo poles.

The first and second ratoon crops following the first harvest were also mulched at 3, 6 and 9 months after planting for maximum uptake of nutrients by the plants. Sword suckers were managed and removed in such a way that only one healthy ratoon or follower

Table 1. Mean effect of cultivars on plant pseudostem height and girth, number of function leaves and number of suckers in five plantain accessions with different types of inflorescence.

Plantain accession	Morphological and phonological traits							
	1st Ratoon crop				2nd Ratoon crop			
	Plant height (cm)	Pseudostem girth(cm)	Number of functional leaves	Number of suckers	Plant height (cm)	Pseudostem girth (cm)	Number of functional leaves	Number of suckers
3 (SP)	287.2 ^b ± 20.8	55 ^c ± 0.4	4.2 ^b ± 0.2	4.8 ^b ± 0.4	266.2 ^b ± 4.9	54.33 ^c ± 1.1	4.2 ^b ± 0.2	4.8 ^c ± 0.4
3 (TP)	286.8 ^b ± 19.7	53.64 ^{cd} ± 0.3	4.4 ^b ± 0.2	8.8 ^a ± 0.4	260 ^b ± 2.4	52.85 ^c ± 0.7	4.6 ^b ± 0.2	8.4 ^a ± 0.2
3 (DP)	272 ^b ± 16.4	52.73 ^d ± 0.9	4.6 ^b ± 0.2	4.6 ^b ± 0.2	262 ^b ± 3.2	52.36 ^c ± 1.4	4.4 ^b ± 0.2	4.8 ^c ± 0.4
2 (DP)	299.4 ^b ± 21.1	57.82 ^b ± 1.2	4.6 ^b ± 0.2	5.4 ± 0.2	265.8 ^b ± 4.8	58.2 ^b ± 0.8	4.8 ^b ± 0.2	5.6 ^b ± 0.2
Agbagba	343.6 ^a ± 2.3	67.15 ^a ± 0.6	5.4 ^b ± 0.2	3.6 ^c ± 0.2	355.8 ^a ± 1.2	65.2 ^a ± 0.6	5.6 ^a ± 0.2	3.8 ^d ± 0.4
LSD (P=0.05)	38.64	2.01	0.75	0.94	11.69	3.02	0.72	0.78

Mean in the same column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher Least Significant Difference; Number of bunches are represented as coefficients. Mean ± SEM are obtained from Fisher's LSD result.

sucker was maintained to succeed the parent plant after each harvest. Weeding was conducted regularly with a hoe every 6 to 8 weeks. Morphological traits and yield components were measured according to the methods described by Dadzie and Orchard (1997). The method described by Mahdi et al. (2014) was adopted to determine the number of days to flowering as well as harvesting.

The plants were grouped according to the number of bunches in each production cycle. Concordance analysis was carried out to determine the proportion of plants that showed the same inflorescence phenotype in both production cycles, excluding dead plants. The concordance coefficient, denoted CC, was calculated according to Tenkouano, (2000) as:

$$CC = 100 \times \frac{\sum_i N_{ii}}{\sum_i N_{ii} + \sum_{i \neq j} N_{ij}}$$

Where, N_{ii} is the number of plants that expressed the same number of bunches in the plant crop and in the ratoon crop, N_{ij} is the number of plants that produced different numbers of bunches in the plant crop and in the ratoon crop, and the subscripts i and j refer to the number of classes in the plant crop and the ratoon crop, respectively.

A concordance coefficient approaching zero would indicate completely random occurrence of the different inflorescence classes across crop cycles. In contrast, a coefficient near unity would suggest a high probability that a plant expressing a given phenotype in a given crop cycle would express the same phenotype in subsequent crop cycles.

Statistical analysis

Data on vegetative growth parameters and yield components collected, were subjected to analysis of variance (ANOVA) using Statistical Analysis Systems (SAS) according to the procedure outlined for randomized complete block design (RCBD) (SAS 9.2 version 2009). Fisher's Least Significant Difference (LSD) was used to separate means at 5% significant level ($p \leq 0.05$).

RESULTS AND DISCUSSION

The phenological characteristics of the multiple bunching plantain accessions compared to those of the single bunch phenotype ('Agbagba') are

provided in Table 1. The pseudostem height and girth as well as number of functional leaves at harvest of the single-bunching 'Agbagba' accession were significantly different ($p \leq 0.05$) from those of the multiple bunching accessions during the two production cycles (parent and follower) examined. The single-bunching 'Agbagba' cultivar developed rapidly taller and thicker pseudostems, with an average of 343.6 and 67.2 cm for the first ratoon and 355.8 and 65.2 cm for the second ratoon crops, respectively, which were statistically significant ($p \leq 0.05$). The taller pseudostem observed amongst the single bunching plantain accessions is in consonance with what was reported by Njukwe et al. (2010), Ndukwe et al. (2011), Shiyam and Bello (2011) and Oluwafemi (2013) which may be an indication of a more aggressive vegetative growth characteristic amongst these accessions.

The single bunching 'Agbagba' accession also had a higher number of functional leaves at harvest for both the first and second ratoon crops

Table 2. Mean effect of cultivars on number of bunches number of hands, number of fingers, fruit length and circumference in five plantain accessions with different types of inflorescence.

Plantain accessions	Morphological and Yield components									
	1st Ratoon crop					2nd Ratoon crop				
	Number of bunches	Number of hands	Number of fingers	Fruit length	Fruit circumference	Number of bunches	Number of hands	Number of fingers	Fruit length	Fruit circumference
3 (SP)	1 ^a ± 0.0	7.2 ^a ± 0.2	3.1 ^a ± 0.3	16.86 ^c ± 0.3	15.63 ^b ± 0.5	1.4 ^{ab} ± 0.2	9 ^a ± 1.2	30.6 ^{ab} ± 0.4	15.17 ^d ± 0.3	15.74 ^{bc} ± 0.3
3 (TP)	1.4 ^a ± 0.4	8.8 ^a ± 1.6	33.8 ^a ± 2.8	17.13 ^c ± 0.2	16.17 ^b ± 0.2	1.4 ^{ab} ± 0.2	8.8 ^a ± 1.3	30.4 ^{ab} ± 0.2	16.29 ^c ± 0.4	15.68 ^c ± 0.3
3 (DP)	1.2 ^a ± 0.2	8 ^a ± 1.0	30.8 ^a ± 0.4	18.15 ^b ± 0.2	16.33 ^b ± 0.4	1.8 ^a ± 0.4	9.2 ^a ± 1.4	33 ^{ab} ± 3.0	18.08 ^b ± 0.2	16.21 ^{abc} ± 0.5
2 (DP)	1.4 ^a ± 0.2	9 ^a ± 1.2	31 ^a ± 0.4	18.17 ^b ± 0.3	16.3 ^b ± 0.2	1.4 ^{ab} ± 0.2	8.8 ^a ± 1.3	27.6 ^b ± 3.2	18.07 ^b ± 0.2	16.5 ^{ab} ± 0.2
Agbagba	1 ^a ± 0.0	7.8 ^a ± 0.2	34.4 ^a ± 0.4	24.19 ^a ± 0.3	17.27 ^a ± 0.2	1 ^b ± 0.0	8.2 ^a ± 0.2	35.2 ^a ± 0.2	22.82 ^a ± 0.2	16.77 ^a ± 0.2
LSD (P=0.05)	NS	NS	NS	0.82	0.91	NS	NS	NS	NS	0.78

Mean in the same column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher Least Significant Difference; Number of bunches are represented as coefficients. Mean \pm SEM are obtained from Fisher's LSD result.

with a range of 5.4 and 5.6, respectively, compared to all the four multiple bunching plantain accessions that showed non-significant differences for this parameter.

In terms of number of follower suckers produced, there was a higher value observed amongst the plants in 3(TP) than all other accessions. For example, there was an average of 8.8 and 8.4 suckers, respectively, for the first and second ratoon crops compared to the mean of 3.6 and 3.8, respectively, which was observed amongst the 'Agbagba' accessions. Up to now, the consistency of the dichotomous habit from the follower suckers after harvesting the parent plant crop has not been fully established. Consequently, this has drawn a significant degree of interest and was considered as a point of great importance in the design of the current study. The regenerative potentials in the number of suckers exhibited among multiple bunching plantain accessions demonstrated its horticultural value for exploitation by plantain breeders. Table 2 shows the number of bunches, number of hands, number of fingers, fruit length and circumference of the

different plantain accessions evaluated. No significant differences ($p \leq 0.05$) were observed in the number of bunches amongst plants with the different inflorescence types (Figures 1 to 3), perhaps due in part to the inflorescence reversals that were noted amongst the multiple bunching phenotypes in the first and second ratoon crops, respectively. Unlike the results reported by Tenkouano (2000), most of the plants with multiple bunches in the current study did not maintain their inflorescence morphotype in the ratoon crop. For example, the double bunching morphotype (Figure 1) depicted here as 2(DP) easily reverted to single bunches in the first and second production cycles, respectively, while four out of the triple-bunching plants in 3(TP) (Figure 2) showed a similar trend of reversal, to a single bunch phenotype. In addition, all the other accessions reverted to producing either a single-bunch or double-bunches in the follower crop (Figure 4). Interestingly, all the single-bunching 'Agbagba' plants maintained their single inflorescence in both the first and follower crops. An earlier study by Baiyeri, (1994), also

demonstrated that double bunching could easily be seen amongst False Horn plantain cultivars even though about half of the suckers from these plants when cropped reverted back to single bunching.

Unexpectedly, the fruit length of bunches in the single-bunching 'Agbagba' accession was significantly longer than that of all the multiple bunching accessions. The individual fruits in the 'Agbagba' plants were also bigger and heavier than those obtained from the dichotomous plantain accessions. Consequently, this may have accounted for the insignificant differences in terms of the number of hands and fingers expressed that were observed among the multiple bunching plantain accessions. The number of days from flowering to harvest, bunch weight and yield are indicated in Table 3. The number of days to flowering and harvest in 'Agbagba' and 2(DP) demonstrated significant differences ($p \leq 0.05$) in the parent plant crop when compared with all other accessions. There was no significant difference ($p \leq 0.05$) in the number of days from flowering to harvest among plantain accessions in



Figure 1. Double bunching plantain morphotype (2(DP)).



Figure 2. Triple bunching plantain morphotype (3(TP)).

the follower crop, which could be attributed to nutrient depletion, nematode infestation in the rhizome and other environmental factors among the accessions (Gold et al.,

1994).

The results demonstrated that the 'Agbagba' cultivar expressed the shortest production cycle as compared to



Figure 3. Triple bunching plantain morphotype (3(SP)).

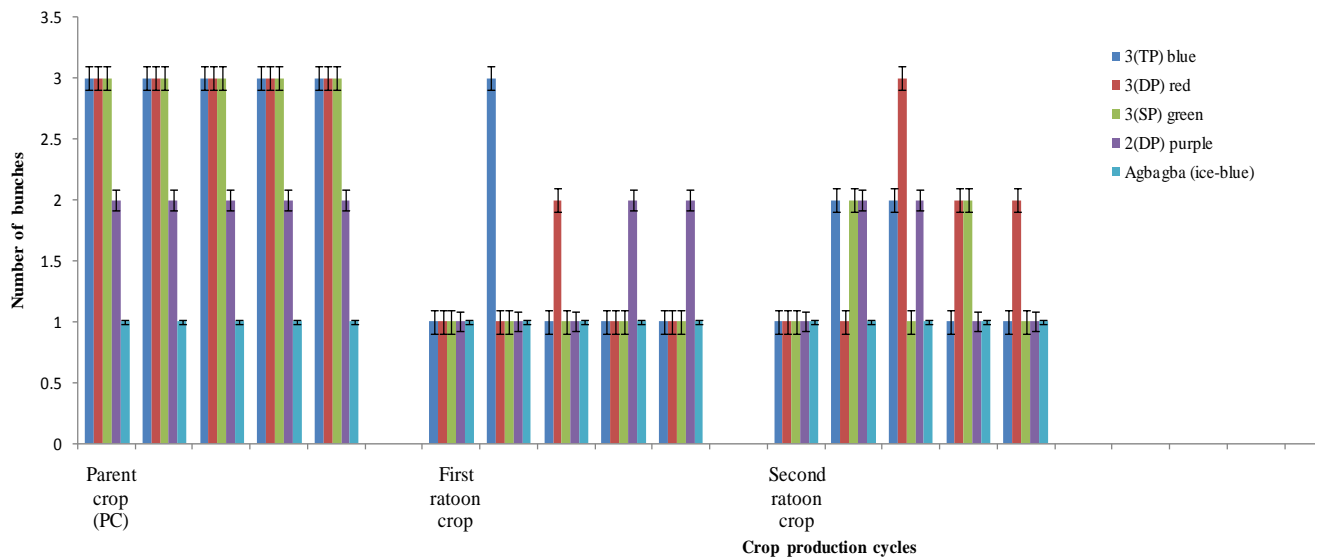


Figure 4. Reversions in the number of bunches produced by the different plantain accessions. The horizontal axis corresponds to crop generation cycles: parent, first and second ratoon crops of 25 experimental plants depicted in colours (blue, red, green, purple, ice-blue) for various plantain accessions. The number of bunches represented in the vertical axis ranged from one to three. LSD ($p \leq 0.05$) bar (I) is used for comparing means across accessions and crop generation cycles.

all the multiple bunching accessions. It is completed from the planting to harvesting cycle within an average of 387.4 days and the fruits matured earlier than those of all the other accessions. Consequently, the reversals in inflorescence dichotomy observed amongst the different accessions, evaluated in the current study provides an

explanation of the inherent nature of this phenomenon and implies that inflorescence dichotomy in plantain may not be genetically stable but rather a random and an unstable genetic trait within the accessions (Table 4). The results of the current study are also in consonance with what has been reported by Tenkouano (2000), who

Table 3. Mean effect of cultivars on number of days to flowering and harvest, bunch weight and yield tonnes/ ha in five plantain accessions with different types of inflorescence.

Plantain accessions	Morphological and Yield components							
	1st Ratoon crop				2nd Ratoon crop			
	Number of days to flowering	Number of days harvest	Bunch weight	Yield t/ha	Numbers of days to flowering	Number of days to harvest	Bunch weight	Yield t/ha
3 (SP)	371.8 ^b ± 21.4	486.6 ^b ± 22.1	10.85 ^b ± 0.4	18.08 ^b ± 0.7	476.6 ^{ab} ± 24.3	591.6 ^a ± 24.7	9.64 ^a ± 0.4	16.06 ^a ± 0.7
3 (TP)	363 ^b ± 10.2	478.6 ^b ± 10.4	11.53 ^{ab} ± 0.6	19.24 ^{ab} ± 0.9	465.6 ^{ab} ± 24.5	575.6 ^{ab} ± 24.2	11.79 ^a ± 2.4	19.65 ^a ± 0.2
3 (DP)	429.2 ^a ± 21.3	537.4 ^a ± 22.1	11.57 ^{ab} ± 0.9	19.29 ^{ab} ± 1.5	486.6 ^a ± 23.9	593.4 ^a ± 25.1	11.11 ^a ± 1.6	18.52 ^a ± 2.7
2 (DP)	316.6 ^c ± 15.0	416 ^c ± 16.6	12.24 ^a ± 0.4	20.39 ^{ab} ± 0.6	455.6 ^{bc} ± 26.8	555.8 ^{bc} ± 27.7	13.25 ^a ± 1.4	22.08 ^a ± 2.3
Agbagba	292.8 ^d ± 10.8	387.4 ^d ± 10.3	12.58 ^a ± 0.0	20.97 ^a ± 0.0	434.4 ^c ± 22.5	538.8 ^c ± 18.9	12.7 ^a ± 0.2	21.17 ^a ± 0.3
LSD (P=0.05)	20.81	21.67	NS	NS	NS	NS	NS	NS

Mean in the same column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher Least Significant Difference; Number of bunches are represented as coefficients. Mean \pm SEM are obtained from Fisher's LSD result.

Table 4. Concordance analysis of the number of plants showing single, double or triple bunches in the plant crop (PC), first and second ratoon crops (RC) for four dichotomous bunching plantain accessions.

Number of bunches	Plantain accessions					
	PC	RC	Different types of Inflorescence			
			3(SP)	3(TP)	3(DP)	2(DP)
1		1	5	4	4	3
		2	0	0	1	2
		3	0	1	0	0
		Dead	0	5	3	4
2		1	3	3	2	3
		2	2	2	2	2
		3	0	0	1	0
		Dead	0	0	2	0
3		1	4	3	5	4
		2	1	1	0	1
		3	0	1	0	0
		Dead	3	4	0	0
Total in PC			18	24	20	19
Total in RC			15	15	15	15
CC(%) ^z			100	96	100	100

^zConcordance coefficient.

attributed the reversals in inflorescence dichotomy to random and reversible insertional activation events that were caused by transposable genetic elements. Conversely, the current study differed from the study reported by Odeigah (1997), who ascribed the consistent expression of double-bunching in a False Horn plantain accession across three growth cycles to a stable genetic mutational event.

It is expected that since a higher number of bunches that have more hands and fingers could be obtained from multiple bunching plantain accessions, their cultivation (perhaps on a larger scale) may lead to increased plant productivity per unit area. However, comparative assessment of the single non-dichotomous bunching plantain cultivar to confirm superior yields with the dichotomous inflorescence plants conducted in the current study demonstrated that, such an increase in yield arising from the increased number of bunches, number of hands, and number of fingers was quite insignificant. The overall effect of performance of the agronomic traits observed in the dichotomous accessions was lower than the single-bunching 'Agbagba' cultivar.

Conclusion

Expectedly, the horticultural value observed in the number of suckers among dichotomous plantain accessions could be exploited for clonal propagation by Musa breeders. A tacit implication in using the number of bunches as one of the criteria for selection, to increase yields and productivity of plantain accessions with inflorescence dichotomy may not be advisable.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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