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Genome variability and plant age influence susceptibility to moisture stress in the cultivated bananas (*Musa* species)

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ABSTRACT

Objective: Water stress is one of the major environmental constraints to crop productivity worldwide. As a consequence of climatic change, moisture availability (in terms of quantity, quality and duration) has become highly unpredictable in most places. In this study, the effects of moisture stress on six *Musa* genotypes were investigated at varying plant ages to ascertain the influence of age and genome composition on their susceptibility to transient drought condition.

Methodology and results: A six-week moisture stress was imposed on six *Musa* genotypes comprising the dessert bananas (AAA), plantains (AAB) and the ABB cooking bananas at varying growth ages (8, 12 or 16 weeks after planting) in a glasshouse. Growth changes in plant height, girth, number of live leaves, leaf area, and dry matter yield were evaluated after six-week drought and 6-week rehydration cycles. All the growth parameters were affected by moisture stress. Genome variability and plant age significantly influenced the response and sensitivities of these plants to moisture stress. The cooking bananas (ABB) and plantains (AAB) were more drought-tolerant than the AAA - dessert bananas. Similarly, the landrace triploid genotypes were relatively more susceptible to water stress than the tetraploid hybrids. The effects of moisture stress were more severe in the 16-week plants, while the 8- and 12-week-old plants were fairly tolerance.

Conclusion and application of findings: This study suggests that *Musa* crops at their early vegetative growth stage are more likely to withstand moisture stress than at their reproductive transition phase. Thus, field planting and other cultural practices (like irrigation and mulching) should be conscientiously planned to avoid prolonged exposure of plants to drought during their reproductive growth phase. The differential sensitivities of the genomic groups to the induced moisture stress makes breeding a viable option in combating soil moisture deficits in *Musa* species.

Key words: Musa genomes; ploidy level; plant age; reaction to water stress.

INTRODUCTION

The cultivated bananas (*Musa* species) comprise of three main genomic groups, which include the dessert (AAA), the cooking (ABB) and the plantains (AAB). They are staples in sub-Saharan Africa (SSA), from which more than 70 million people derive up to 25% of their daily carbohydrate intake (Wilson, 1987). Bananas are sources of income among the subsistence farmers that grow them. Per capital consumption in West and Central Africa (WCA) is about 150 kg, and could be as high as 450 - 500 kg in the Great lake region of eastern Africa (Akyeampong, 1999).

In sub-Saharan Africa, the three *Musa* genomic groups differ in their eco-regional distribution. The plantains (AAB) are predominantly distributed in the humid forest lowlands of WCA while the cooking bananas and beer bananas (ABB and EA-AAA) are prevalent in the highlands of East Africa (Daniells *et al*., 2001). The dessert bananas (AAA) are cultivated in home gardens in most countries of SSA, although large scale commercial cultivation exists in South Africa, Cameroon and Cote d'Ivoire.

Breeding efforts around the world have led to selection of hybrid genotypes possessing stable and durable genes for resistance to most *Musa* biotic stresses. These hybrids alongside cultivated landraces have been evaluated extensively in the *Musa* growing belt of Nigeria (Baiyeri *et al*., 2004 & 2005) and recently in the sub-humid zone which, hitherto, was not very popular for *Musa* production (Baiyeri and Tenkouano, 2008). Significant genotype-by-environment interaction in these studies was due to temporal and spatial factors, suggesting that recommendation of putative hybrid cultivars must be targeted to specific agricultural niches where they are best suited.

However, availability of abundant cultivable land in the traditional *Musa* growing region of the humid rainforest belt (Keay, 1963) no longer subsist due to population growth and as such, pressure on available land for both urban development and other competing agricultural and industrial activities. Thus, in sub-humid agro-ecology land area allotted to *Musa* production has increased (Ajayi and Baiyeri, 1997). The quantity of annual rainfall in this location is adequate for *Musa* production but the distribution pattern often leaves about five months of dry period annually leading to negative soil moisture recharge. Besides, plantation establishment is recommended when the rains have stabilized, usually June, giving about 3 – 4 months of growth before the dry season sets in. Bananas and plantains however, require 100 mm of moisture monthly if growth is not to be limited (Stover and Simmonds, 1987). There is therefore, a need to evaluate genomic responses to moisture stress with a view to identifying putative tolerant or less susceptible genotype(s). Also, there is likelihood that genotypes within the same genomic group but varying in ploidy level may differ in tolerance to water stress. Existing information suggests that hardiness in *Musa* species is influenced by genomic grouping (Price, 1995; Robinson, 1996; Baiyeri and Aba, 2005)

Tolerance of cultivated *Musa* species to low soil moisture is associated with genetic constitution. Higher 'B' dosage in the genome suggests higher tolerance to moisture stress, thus, the ABB is reported to be more tolerant to low moisture recharge than the AAA and the AAB groups (Stover and Simmonds, 1987). Similarly, significant genotypic differences in leaf conductance have been observed (Ekanayake *et al*., 1994) and genotypes of the ABB genomic group are potentially more tolerant to transient dry conditions than the AAB genome. However, basic data on agronomic evaluation of *Musa* germplasm response to water stress are still lacking. Thus, in this study; we evaluated the susceptibility to, and recovery pattern from water stress of six *Musa* genotypes under a glasshouse environment.

MATERIALS AND METHODS

Description of study area: The study was conducted in a glasshouse of the Department of Crop Science, University of Nigeria, Nsukka, between May and December, 2005. During the study period, the average noon temperature of the glasshouse was about 40°C. Nsukka is located at 6° 52'N, 7° 24'E and 447.2 m above the sea level, in the derived savannah agro-ecology of Nigeria. Average ambient temperature was about 31±2°C, relative humidity ranged between 60 – 80% and the annual rainfall was about 1500 mm. Monthly rainfall equal to or above 100 mm was recorded in the months of May to October leaving six months of the year with inadequate soil moisture for *Musa* growth.

Experimental set up:

Banana varieties: Six *Musa* genotypes comprising 'Nsukka Local' [3x] and 'FHIA 17' [4x] (dessert bananas, AAA); 'Agbagba [3x] and 'PITA 22' [4x] (the plantains, AAB); and 'Fougamou' [3x] and 'BITA 7' [4x] (the cooking bananas, ABB) were evaluated in the study. Fairly uniform early sword suckers obtained from UNN-IITA collaborative research farm at the University of Nigeria were utilized; the suckers were cut-back to about 10 cm height to allow uniform re-growth. Seventeen kilograms (or an equivalent of 25 l) of topsoil of a sandy loam ultisol (Nkpologu series) was weighed into each of 120 nursery bags. Detailed physicochemical characteristics revealed that the soil was acidic (pH = 5.1, H_20; 4.2, KCl), organic matter 1.72%, nitrogen 0.84%, exchangeable bases (in meq/100 g soil) was 0.12, 0.196, 1.2, and 6.8 for Na, K, Ca, and Mg respectively. The CEC was 9.2 ppm while the soil phosphorus was 21.1 ppm. A systemic insecticide, Furadan 5G, was applied and thoroughly mixed with soil at the rate of one gram per bag to control *Cosmopolite sordidus*. Furadan is a broad spectrum pesticide that protected the planting materials against infestation by nematodes and other related pests.

The experiment was a 6 x 4 factorial arranged in a completely randomized design (CRD). Factor A was six *Musa* genotypes (listed above) and factor B was the age of plant at introduction of water stress, comprising 8, 12, and 16 weeks old plants (i.e., ages after nursery establishment in the glasshouse). The three ages were selected to simulate plant ages under field condition when moisture recharge usually becomes negative in most locations in the sub-humid agro-ecology of Nigeria. There was a control treatment in which the plants were watered throughout the duration of the experiment. Each treatment combination was replicated five times, and spaced 0.5 x 0.5 m in the glasshouse. Prior to the introduction of water stress, plants were watered following an earlier watering schedule recommended for similar experimental environment by Baiyeri (1996). At the specific age of introducing water stress, watering was withdrawn for six weeks and thereafter re-introduced for six weeks; this watered-stressed-watered cycle was to elucidate genotypic responses to, and recovery from water stress.

Data recording: Growth parameters including height, girth, number of live leaves, area of the last two youngest fully unfurled leaves was determined at the onset and end of stress and recovery periods. Plant height (cm) was measured as the distance between the soil level and the last two unfurled level while plant girth (cm) was measured as the circumference of the pseudostem at 30 cm above the soil level. The leave area (cm^2) was determined as the product of the leaf length and the width at the widest point multiply by a correction factor, 0.8 (Obiefuna and Ndubizu, 1979). All measurements were made with tape rule. From the data, growth differential during the stress and recovery periods were estimated for specific age groups in comparison with the control treatment. At the end of the watered-stressed-watered cycle, destructive sampling to determine dry matter distribution was carried out. All data collected were subjected to analysis of variance for factorial in CRD using GENSTAT 5.0 Release 4.23DE, Discovery Edition 1 (GENSTAT, 2003).

RESULTS

Morphological growth changes that occurred between the control and moisture-stressed plants of the six genotypes, after a 6-weeks moisture stress period imposed on 8 week-old plants (WOP) are shown in table 1. The negative values observed in the stressed plants are indications of shrinkage or outright loss of plant parts due to tissue desiccation. Although the genotypic main effect and the interactions were non-significant in most of the growth components studied on 8 WOP, the cooking bananas ('Fougamou' and 'BITA 7') seemed to have adapted better considering the higher mean values observed in plant height and girth, and the fewer number of leaves lost following the induced stress. 'BITA 7' however lost the greatest leaf area, while the plantains ('Agbagba' and 'PITA 22') gained the largest leaf area during the moisture stress period. The 12 week-old plants (Table 2) seemed to adapt better than the 8 week old plants (Table 1) to the imposed moisture stress. Despite the significant ($P < 0.05$) growth differences observed between the control and the stressed plants in all the growth components (which are clear indications of the deleterious effect of moisture stress), there were observable increments in leaf area and plant height in the 12 week-old plants (Table 2). More so, no significant change in girth size was observed in all the clones after the 6-weeks dry period. The significant ($P < 0.05$) genotypic effect observed in the number of leaves maintained per plant after the stress period, showed that the dessert bananas ('Nsukka Local' and 'FHIA 17') lost more leaves than the plantains ('Agbagba' and 'PITA 22') and the cooking bananas ('Fougamou' and 'BITA 7'), in that order. Similarly, the landrace genotypes ('Agbagba', 'Nsukka Local', and 'Fougamou') lost more leaves than the tetraploid hybrids ('FHIA 17', 'PITA 22', 'BITA 7').

Table 1: Differential changes in growth components of 8-week old plants of six *Musa* genotypes after six weeks of water stress.

Component of Growth	**Moisture Status**	**Plantains**		**Dessert Bananas**		**Cooking Bananas**		
		Agbagba	PITA 22	Nsukka Local	FHIA 17	Fougamou	BITA 7	**Mean**
Leaf Area (cm^2)	Stressed	8.8	-11.5	-86.2	7.8	-20.7	-366.7	**-78.1**
	Control	21.7	73.2	54.2	21.9	27.0	275.3	**55.5**
	Mean	**15.2**	**30.8**	**-16.0**	**14.9**	**3.2**	**-45.7**	**-**
Number of Leaves	Stressed	-5.4	-2.7	-3.4	-2.8	-2.2	-3.7	**-3.4**
	Control	-0.5	0.6	0.0	0.8	1.0	1.3	**0.5**
	Mean	**-3.0**	**-1.1**	**-1.7**	**-1.0**	**-0.6**	**-1.3**	**-**
Girth (cm)	Stressed	-0.6	-0.4	-0.4	0.2	-0.7	-0.4	**-0.4**
	Control	2.5	1.2	0.8	0.8	1.5	2.5	**1.5**
	Mean	**0.9**	**0.4**	**0.2**	**0.5**	**0.4**	**1.1**	**-**
Height (cm)	Stressed	0.0	-0.3	0.2	0.2	-0.4	0.0	**0.0**
	Control	5.0	6.6	9.4	2.4	8.0	13.5	**7.5**
	Mean	**2.5**	**3.2**	**4.8**	**1.3**	**3.8**	**6.7**	**-**
LSD (0.05)								
		Leaf Area		Number of Leaves		Girth	Height	
Genotype (G)		ns		ns		ns	ns	
Moisture status (M)		ns		0.9		0.9	2.8	
G x M		32.9		ns		ns	ns	
		ns = non-significant at 5% probability level						

Table 2: Differential changes in growth components of 12-week old plants of six *Musa* genotypes after six weeks of water stress.

Component of Growth	**Moisture Status**	**Plantains**		**Dessert Bananas**		**Cooking Bananas**		
		Agbagba	PITA 22	Nsukka Local	FHIA 17	Fougamou	BITA 7	**Mean**
Leaf Area (cm^2)	Stressed	8.6	2.7	7.0	8.0	1.7	7.3	**5.9**
	Control	14.2	14.8	67.6	55.2	10.2	9.7	**28.6**
	Mean	**11.4**	**8.7**	**37.3**	**31.6**	**6.0**	**8.5**	**-**
Number of Leaves	Stressed	-5.0	-3.3	-6.4	-4.0	-3.0	-2.7	**-4.1**
	Control	2.0	2.2	1.2	1.4	2.5	3.0	**2.0**
	Mean	**-1.5**	**-0.6**	**-2.6**	**-1.3**	**-0.2**	**0.2**	**-**
Girth (cm)	Stressed	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	Control	1.5	2.2	1.9	1.2	1.3	1.0	**1.5**
	Mean	**0.7**	**1.1**	**0.9**	**0.6**	**0.6**	**0.5**	**-**
Height (cm)	Stressed	0.6	0.5	0.4	0.7	0.3	0.8	**0.5**
	Control	1.0	1.4	1.4	1.9	1.2	1.7	**1.4**
	Mean	0.8	1.0	0.9	1.3	0.8	1.2	**-**
LSD (0.05)								
		Leaf Area		Number of Leaves		Girth	Height	
Genotype (G)		ns		1.0		ns	ns	
Moisture status (M)		1.5		0.6		0.27	0.4	
G x M		**ns**		**ns**		**ns**	**ns**	

Table 3 shows the differential growth changes observed on the 16-week-old *Musa* plants after a six-week moisture stress period. Significant (P < 0.05) moisture treatment effects were observed in all the growth components studied, with the well-watered plants (control) expectedly showing better growth than the stressed plants. The significant genotypic differences observed showed that the dessert bananas gained the largest leaf area, whereas the landrace plantain 'Agbagba' lost the most. The cooking bananas ('Fougamou' and 'BITA 7') lost the least number of leaves, but had the greatest reduction in girth and the poorest height increment after the 6-weeks dry period. The dessert bananas gained greatest in height. Among the three genomic groups, the landrace genotypes lost more leaves and girth in the plantains and dessert bananas, but not in cooking bananas.

Table 4 compares the relative sensitivities of the genotypes to the 6-weeks drought imposed at varying plant growth ages. Both genotype and plant age (at the introduction of the stress), as well as their interactions were found to have significant (P < 0.05) effects on the performance of the plants. Leaf area of the plants was significantly depressed when watering was withdrawn at 8 weeks, but a more severe effect was observed on the landrace plantain 'Agbagba' at 16-weeks of age. The effects of moisture stress on plant girth and the number of leaves per plant were more severe on the 16-week-old plants, though these plants had the greatest height increment. The mean values (for number of leaves, leaf area and plant girth) also showed the landrace genotypes in plantains and dessert bananas to be more sensitive to moisture stress than their tetraploid counterpart.

Table 3: Changes in growth parameters of 16-week old plants of six *Musa* genotypes after six weeks of water stress.

		Plantains		**Dessert Bananas**		**Cooking Bananas**		
Component of Growth	Moisture Status	Agbagba	PITA 22	Nsukka Local	FHIA 17	Fougamou	BITA 7	Mean
Leaf Area (cm²)	Stressed	-1449.8	-4.0	11.5	8.0	4.0	13.0	236.2
	Control	22.5	26.2	32.4	38.0	28.2	20.3	27.9
	Mean	**-713.7**	**11.1**	**21.9**	**23.0**	**16.1**	**16.7**	**-**
Number of Leaves	Stressed	-6.0	-5.2	-7.5	-5.5	-4.0	-5.0	-5.5
	Control	2.0	2.0	1.8	1.8	1.5	1.7	1.8
	Mean	**-2.0**	**-1.6**	**-2.8**	**-1.8**	**-1.2**	**-1.7**	**-**
Girth (cm)	Stressed	-2.0	-0.8	-1.2	-0.5	-2.5	-3.0	-1.7
	Control	1.0	1.0	0.6	1.2	1.5	1.3	1.1
	Mean	**-0.5**	**0.1**	**-0.3**	**0.4**	**-0.5**	**-0.8**	**-**
Height (cm)	Stressed	3.0	2.3	4.0	3.5	1.0	1.0	2.5
	Control	6.5	6.0	7.2	6.2	7.4	6.0	6.5
	Mean	**4.8**	**4.1**	**5.6**	**4.9**	**4.2**	**3.5**	**-**

LSD (0.05)	Leaf Area	Number of Leaves	Girth	Height
Genotype (G)	10.6	0.9	0.6	1.1
Moisture status (M)	6.1	0.5	0.3	0.6
G x M	15.0	1.2	0.8	1.6

The recovering pattern of the six *Musa* genotypes (of varying ages) after a 6-week re-watering cycle (Table 5) indicates that the 16-week-old plants experienced the greatest shock following the 6-weeks dry period. The reduction observed on leaf area, plant height and girth in the 16-week-old plants after the re-watering cycle is due to shrinkage or outright loss of plant tissues due to drying and/or death and re-growth of plants. Considering the mean values across the varying plant ages for each genotype, the cooking bananas ('Fougamou' and 'BITA 7') and the plantains ('Agbagba' and 'PITA 22') had a better growth recovery as evident from the higher values recorded in plant height, girth and number of leaves per plant after the rehydration period. Survival counts revealed that no plant was lost from the 8-and 12- week old and the control plants throughout the study period. However, the percentage survival values showed clearly that the 16-week-old plants were more susceptible to the transient drought; the dessert bananas had only 40% survival while the landrace genotypes ‘Agbagba’ and ‘Fougamou’ had 37% and 50% survival, respectively.

Table 4: Changes in growth parameters of six *Musa* genotypes exposed to moisture stress at 8, 12 and 16 weeks after planting.

Component of Growth	**Moisture Status**	**Plantains**		**Dessert Bananas**		**Cooking Bananas**		
		Agbagba	PITA 22	Nsukka Local	FHIA 17	Fougamou	BITA 7	Mean
Leaf Area (cm^2)	8	8.8	-11.5	-86.2	7.8	-20.7	-366.8	-78.1
	12	8.6	2.7	7.0	8.0	1.7	7.3	5.9
	16	-1446.4	-4.0	11.5	8.0	3.9	13.0	235.7
	Mean	**-476.3**	**-4.3**	**-22.6**	**7.9**	**-5.6**	**-115.5**	**-**
Number of Leaves	8	-5.4	-2.7	-3.4	-2.8	-2.2	-3.7	-3.4
	12	-5.0	-3.3	-6.4	-4.0	-3.0	-2.7	-4.1
	16	-6.0	-5.2	-7.5	-5.5	-4.0	-5.0	-5.5
	Mean	**-5.5**	**-3.8**	**-5.8**	**-4.1**	**-3.1**	**-3.8**	**-**
Girth (cm)	8	-0.6	-0.4	-0.4	0.2	-0.7	-0.4	-0.4
	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16	-2.0	-0.8	-1.2	-0.5	-2.5	-3.0	-1.7
	Mean	**-0.9**	**-0.4**	**-0.5**	**-0.1**	**-1.1**	**-1.1**	**-**
Height (cm)	8	0.0	-0.3	0.2	0.2	-0.4	0.0	-0.1
	12	0.6	0.5	0.4	0.7	0.3	0.8	0.5
	16	3.0	2.3	4.0	3.5	1.0	1.0	2.5
	Mean	**1.2**	**0.8**	**1.5**	**1.5**	**0.3**	**0.6**	**-**

LSD (0.05)	Leaf Area	Number of Leaves	Girth	Height
Genotype (G)	134.8	1.0	0.5	0.6
Age (A)	95.3	0.7	0.3	0.4
G x A	233.5	ns	0.8	1.0
	ns = non-significant at 5% probability level			

Figure 1 shows the total dry matter yield of the six *Musa* genotypes as influenced by the imposed moisture stress at varying plant ages. The control plants (watered continuously) accumulated the largest dry matter. Dry matter yield was higher in the cooking bananas (‘Fougamou’ and ‘BITA 7’) and the plantains (‘Agbagba’ and ‘PITA 22’) than in the dessert bananas. The landrace plantain ‘Agbagba’ was the most stable genotype; its dry matter yield was not largely influenced by moisture availability. The ‘PITA 22’, Nsukka local banana and the ‘Fougamou’, plants subjected to moisture stress at 16 weeks accumulated more dry matter than other age groups, while other clones produced higher dry matter yield when moisture stress was imposed at a younger age

The 8- and 12-week-old plants in most of the clones, as well as, the control plants partitioned more than 65 percent of the accumulated dry mass to the root region (Figure 2). Plants subjected to stress at 16-weeks of age allotted the greatest proportion of dry matter yield to the shoot components. Similarly, the cooking bananas (‘Fougamou’ and ‘BITA 7’) and the plantains (‘Agbagba’ and ‘PITA 22’) allotted a greater proportion of the photosynthate to the root region, compared to ‘Nsukka Local’ banana. Notwithstanding the skewed pattern of root distribution (Figure 3), the well-watered plants produced more roots while longer roots were observed on the stressed plants. Longer roots were found in dessert and the cooking bananas, whereas number of roots was fairly similar for all the genomes. In general, all the genotypes showed reduction in height and number of live leaves after the water stress treatment (Fig. 4). Plants subjected to moisture stress at 16 weeks of age tended to produce the shortest plants with fewer leaves.

Table 5: The recovery pattern and changes in growth components of six *Musa* genotypes of varying ages estimated after a 6-weeks rehydration cycle following water stress treatment.

Component of Growth	**Plant Age at onset of stress (weeks)**	**Plantains**		**Dessert Bananas**		**Cooking Bananas**		
		Agbagba	PITA 22	Nsukka Local	FHIA 17	Fougamou	BITA 7	Mean
Leaf Area (cm^2)	8	38.8	87.8	42.0	143.6	45.8	29.3	64.5
	12	12.2	16.3	22.8	18.2	14.5	32.3	19.4
	16	-1166.4	83.2	-329.0	-2028.0	-1449.0	-145.0	-839.0
	Mean	**-371.8**	**62.4**	**-88.1**	**-622.1**	**-462.9**	**-27.8**	**-**
Number of Leaves	8	2.2	3.2	1.6	3.0	2.0	3.3	2.6
	12	1.8	2.7	1.6	2.6	2.0	2.3	2.2
	16	3.0	3.3	2.0	2.0	3.0	3.5	2.8
	Mean	**2.3**	**3.1**	**1.7**	**2.5**	**2.3**	**3.0**	**-**
Girth (cm)	8	1.4	1.5	2.2	1.2	3.2	1.3	1.8
	12	1.0	1.7	0.8	1.8	1.0	1.0	1.2
	16	3.0	1.8	2.5	-5.0	-2.0	10.5	1.8
	Mean	**1.8**	**1.6**	**1.8**	**-0.7**	**0.7**	**4.2**	**-**
Height (cm)	8	6.8	7.2	6.4	7.0	7.3	6.8	6.9
	12	2.4	2.7	2.8	3.4	4.0	3.0	3.1
	16	-16.8	5.7	-11.0	-45.0	-11.0	36.7	-6.9
	Mean	**-2.5**	**5.2**	**-0.6**	**-11.5**	**0.1**	**15.5**	**-**
Percentage survival (%)	8	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100
	16	33	80	40	40	50	100	57.2
	Control	100	100	100	100	100	100	100

LSD (0.05)	Leaf Area	Number of Leaves	Girth	Height
	107.2	0.4	1.9	6.3
Genotype (G)	75.8	0.3	ns	4.4
Age (A)	185.7	0.6	3.2	10.8
G x A				
	ns = non-significant at 5% probability level			

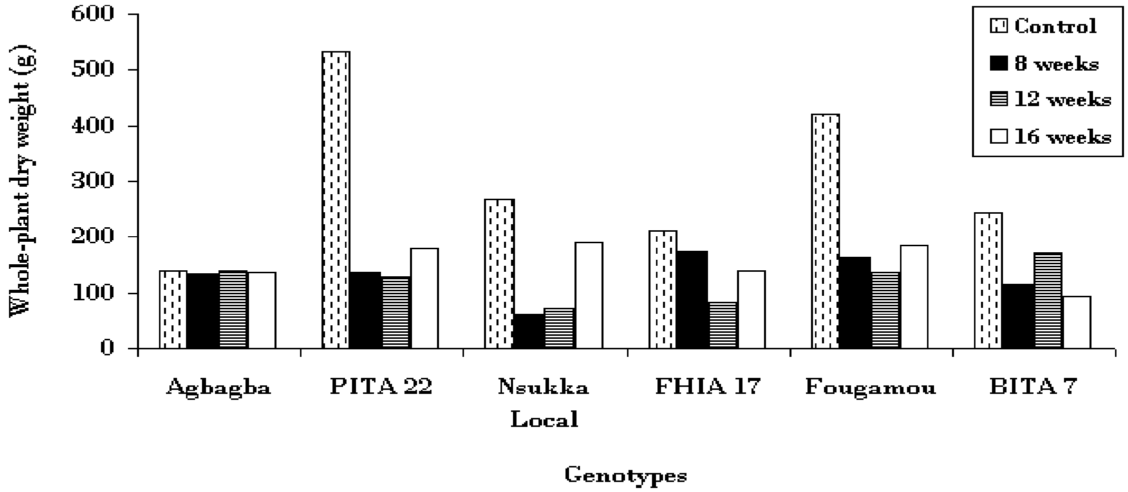

Figure 1: Whole-plant dry matter of six *Musa* genotypes as influenced by induced moisture stress at varying growth ages.

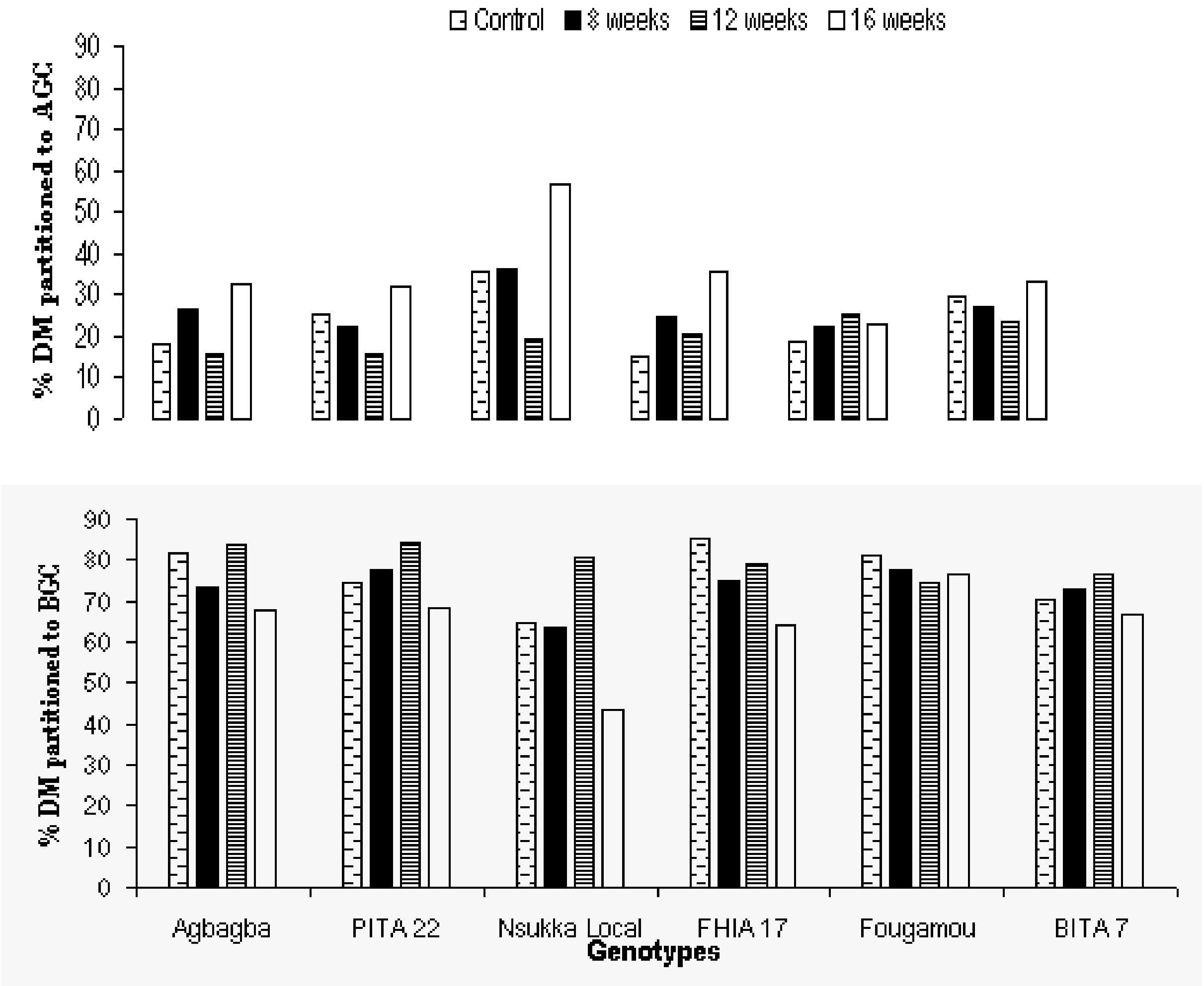

Figure 2: Variation in dry matter (DM) distribution pattern of six *Musa* genotypes as influenced by age of plants at introduction of moisture stress. AGC = Above-ground components; BGC = Below-ground components.

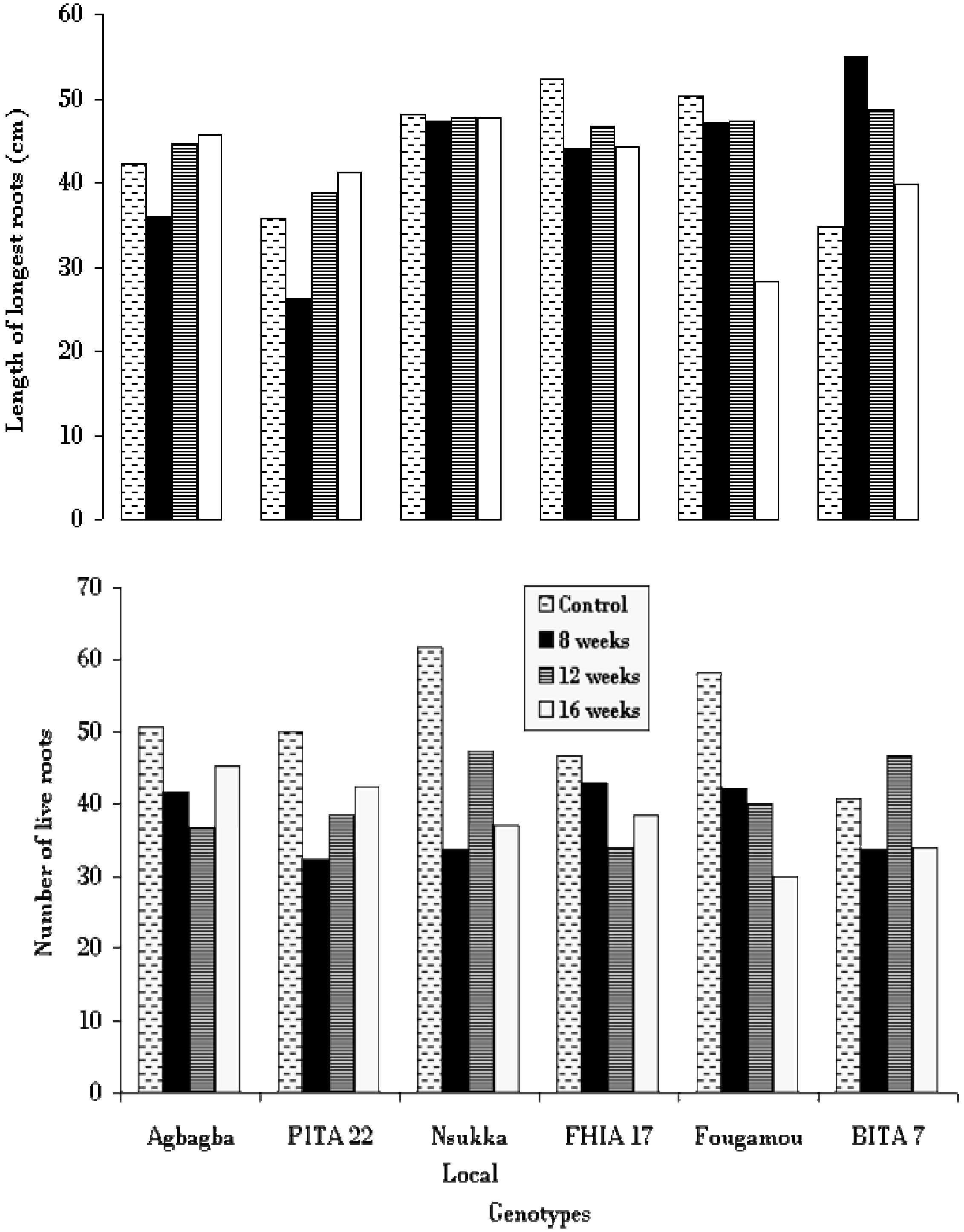

Figure 3: Root system development in six *Musa* genotypes as influenced by moisture stress introduced at varying plant ages.

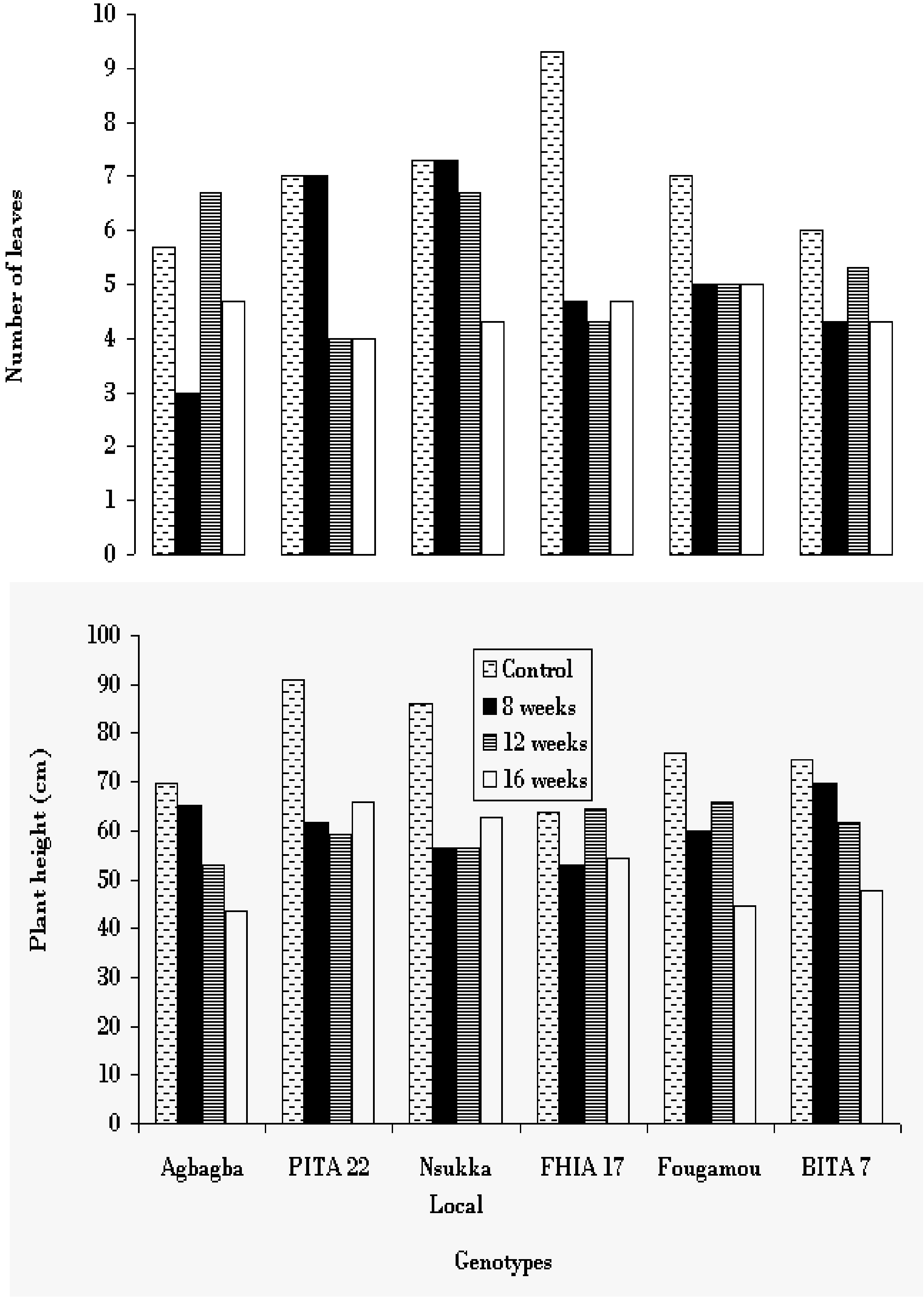

Figure 4: Effect of induced moisture stress on plant height and number of live leaves in six *Musa* genotypes of varying ages.

DISCUSSION

Moisture availability has been identified as one of the most critical productivity determining factors in *Musa* species (Ndubizu and Okafor, 1976; Robinson and Bower, 1986; Baiyeri, 1996; Turner *et al*., 2007). Water deficit imposes huge reductions in crop yield via diminished leaf carbon fixation and general growth inhibition (Chaves and Oliveira, 2004). Results from the present study noted significant differences between *Musa* genomes in their relative sensitivities and tolerance to soil moisture deficits. At all ages of evaluation, the control plants (watered continuously) were superior in growth and dry matter yield showing the deleterious effect of moisture stress on growth and productivity of *Musa* crops.

The genomic differences observed in moisture stress tolerance and other components of growth are a function of their physiological genetic differences confirming that tolerance to moisture stress is genetically controlled. The cooking bananas ('Fougamou' and 'BITA 7') were the most drought tolerant among the studied genotypes followed by the plantains (AAB). This supports previous anecdotal and experimental evidence (Simmonds, 1966; Stover and Simmonds, 1987; Ekanayake *et al*., 1994; Price, 1995; Horry *et al*., 1997) that higher 'B' in *Musa* genomes suggests higher tolerance to moisture stress.

The landrace genotypes were found to be more susceptible to moisture stress than the tetraploid hybrids, although the triploid landrace plantain 'Agbagba', even at moisture-limiting conditions, accumulated a somewhat stable dry matter yield. Total dry matter yield was higher in the cooking bananas and plantains compared to the dessert bananas. This confirms an earlier observation that dessert bananas (AAA) often produce lower values for most root and shoot growth components while plantains (AAB), cooking bananas (ABB) and their tetraploid hybrids have higher values for root and shoot growth parameters (Blomme *et al*., 2000).

The 8 and 12-week-old plants showed more tolerance to the transient drought condition. These younger plants were found to allot a greater proportion (ca. 65-85 %) of the total dry matter yield to the root and corm components as compared to less than 65% observed in the 16-week-old plants. A similar high proportion of the dry matter yield was allotted to the root regions in cooking bananas and the plantains where high tolerance to moisture stress was observed. A good under-ground growth of the root system and corm is essential for healthy shoot growth and high yield (Blomme *et al*., 2003). Banana roots and corm components determine water and nutrient uptake potential (Robinson, 1996). Bananas undergo pre-floral (vegetative), floral initiation and reproductive growth phases (Swennen and Ortiz, 1997). Both the floral initiation and reproductive phases are sensitive to stress (Shepherd, 1976) of which weather remains the most complex factor (Obiefuna, 1986). Robinson (1996) reported a 15 % reduction in corm dry matter during the reproductive stage due to a redistribution of assimilates towards the developing infrutescence and the lateral shoots.

The 16-week-old plants may possibly have initiated reproductive growth. The deleterious effects of moisture stress in most species (Evans, 1993), and particularly cereals are more disastrous during the reproductive growth stage (Hall *et al*., 1981; Grant *et al*., 1989; Sürek and Beser, 1997). The longer root growth observed in the stressed plants is an effective adaptive mechanism in moisture-limiting environments to explore the soil for nutrients and water, whereas the reduced leaf growth is to minimize transpiration losses. Obiefuna (1986) established the months of August through December as the best (in terms of yield cycle) for field planting of plantain suckers in Southern Nigeria. Sucker-corms planted in dry months of November through February may overcome drought by apparently remaining dormant throughout the dry periods, and sprouting with the early rains (Obiefuna, 1980). For *in-vitro* and macro-propagated plants with well-developed root and shoot systems, August or September planting would be more ideal. This gives about 12-weeks of growth before the dry season sets in. Such plants at their vegetative growth stage are more likely to withstand soil moisture deficits.

The significant variability existing in moisture stress tolerance among the genomes makes breeding a viable option for upgrading drought resistance/tolerance in bananas in readiness for the changing global climate.

CONCLUSION

From the study, it was evident that: [1] The 12-week old plants were more tolerant to the six-week moisture withdrawal.[2] Shrinkages and complete loss of plant parts were highest in 16-week old plants.[3]

Susceptibility to moisture stress varied with plant age, genome group and ploidy levels.[4] Genotypes belonging to ABB genome were more tolerant. In contrast, those of the AAA genome group were more susceptible to the transient moisture tress.

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