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Variation in growth, dry matter production, nitrogen and potassium uptake by six *Musa* genotypes in a soilless culture

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Abstract

Six genotypes comprising a landrace and a hybrid from each of the three *Musa* major genomic groups were evaluated in a soilless potting mix. Effect of genotype on most of the growth parameters was non-significant. But the uptake (total quantity accumulated, distribution pattern and tissue concentration) of N and K was significantly ($P < 0.05$) influenced by genotype (G), age of plant at sampling (AP) and G x AP interaction. Dessert bananas had higher N uptake while 'PITA 22' (a plantain hybrid) demonstrated an exceptional propensity for K uptake. Nitrogen and potassium concentration varied with tissue, genotype and age of plant at sampling. Nitrogen concentration in roots and leaves decreased with plant age while it increased in the corm. Potassium concentration in roots, corm and leaves increased progressively with plant age in all the genotypes. Significant differences in the quantity of N and K accumulated per plant, even though all the genotypes were planted in the same potting mix, suggested differential nutrient mining capacity of the genotypes. Implying that nutrient uptake and consequently nutrient demand varies with genotype, supplemental application would vary accordingly. The study suggested that genotype that had higher nutrient uptake will impoverish the soil faster, and thus require more external nutrient inputs to maintain/restore soil productivity.

Key words: Bananas and plantains, genotypic differences, nutrient uptake.

Introduction

Bananas and plantains (*Musa* species L.) are important staples in West and Central Africa sub-region where they contribute to the socio-economic wellbeing of the people. Per capita consumption of plantain in some traditional production areas could be as high as 150 kg (Vuylsteke *et al.*, 1997).

The introduction of improved cultivar is one of the most effective and cost-efficient means of enhancing crop productivity and farmers' incomes (Kueneman, 2002). However, ensuring sustainability of production of improved cultivar in farmers' field requires agronomic packages based on sound scientific principles. Soil fertility management on small farms in the tropics has become a major crop production issues, as a result of continued land degradation and rapid population growth (FAO, 1981) and external nutrient inputs are essential to improve and sustain crop production on these soils (Hossner and Juo, 1999).

Earlier fertilizer recommendations in Nigeria were based on landrace genotypes (Ndubizu, 1978; Obiefuna *et al.*, 1981; Obiefuna, 1984; Baiyeri, 2002). But recent *Musa* germplasm evaluation studies in Nigeria had identified high yielding and disease resistant hybrids that are adapted to some specific agro-ecological niches (Baiyeri *et al*, 2004; 2005). But before final release of a variety for large scale production, standardization of the basic agronomic package will ensure sustainable production in farmers' field. Most important is the nutritional demand for optimum production. In assessing nutrient requirements, quantitative information should be obtained between yield and nutrient uptake and between nutrient supply and crop demand (Keerthisinghe *et al.*, 2003).

Thus, an increased knowledge of the growth pattern and nutrient uptake of the new hybrids can lead to a better understanding of their responses under commercial conditions or in farmers' field. Nitrogen and potassium are the key nutrient elements for optimum growth and yield in *Musa* species (Twyford and Walmsley, 1974; Lahav and Turner 1989; Lahav, 1995). Therefore, the general objective of this study was to evaluate genotypic differences in growth, biomass yield and uptake of key nutrient elements in *Musa* germplasm. More specifically, genotypic differences in nitrogen and potassium mining capacity were determined to establish differential nutrient demand by landrace and hybrid genotypes.

Materials and methods

The experiment was conducted in the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, between May 2004 and June 2005. Suckers were generated following the method described by Baiyeri and Aba (2005). The method ensured that uniform sucker plantlets at a similar physiological age were used. Besides, since the study was to compare growth and nitrogen and potassium uptake by different *Musa* genotypes, the plantlets were cut-back to allow a re-growth under the experimental conditions provided. Six *Musa* genotypes belonging to the three major *Musa* genomic groups were evaluated (Table 1). Each genome group consisted of a landrace and a hybrid genotype.

The potting medium was ricehusk mixed with poultry manure at 3:2 (v/v) and composted for about five months before use. The medium was analyzed for elemental composition (Table 2). Potting bag measured 60 x 60 cm in dimension and spaced 1 x 1 m after planting. The experimental layout was completely randomized design; each genotype was replicated nine times. Watering frequency followed the recommendation of Baiyeri (1996).

Table 1. List of genotypes evaluated

Genome group	Name/Code	Breeding status	Source
Plantains	Agbagba [AGB]	Landrace	Southern Nigeria
	PITA 22 [P22]	Hybrid	International Institute of Tropical Agriculture (IITA), Nigeria.
Dessert bananas	Nsukka Local [NSK]	Landrace	Southeastern Nigeria
	FHIA 17 [F17]	Hybrid	Fundacion Hondurena de InvestigacionAgricola, Honduras.
Cooking bananas	Fougamou [FOU]	Landrace	Southeast Asia
	BITA 7 [BT7]	Hybrid	IITA

Table 2. Nutrient composition of the soilless culture (ricehusk plus poultry manure in 3:2 v/v)

Nutrients	Quantity
Nitrogen (%)	1.86
Phosphorus (mg $100g^{-1}$)	18.34
Potassium (mg $100g^{-1}$)	8.15
Calcium (mg $100g^{-1}$)	1900.00
Magnesium (mg $100g^{-1}$)	346.67
Sulphur (mg $100g^{-1}$)	11.22

Data were collected monthly from the fourth month after planting (MAP) to the sixth MAP. This growth period is physiologically significant in *Musa* because, it signals the transformation of the plant from vegetative to reproductive growth stage (Ndubizu *et al.*, 1981; Stover and Simmond, 1987). Plant height, girth, number of leaves and leaf area were measured. Leaf area was determined following Obiefuna and Ndubizu (1979) method. Fresh weight of plant components was determined and samples were dried at 70°C until constant weight was obtained, thereafter dry weight was measured. Nitrogen and potassium content were determined using dried samples milled to pass through 0.2 mm sieve using Thomas Wiley Hammer Mill. Leaf number three from the top was used for N and K determination following standard procedures as recommended by AOAC (1981). Data collected were analyzed as factorial completely randomized design to compare the main effect of genotype, age of plants at sampling and the interaction of these two factors. Significance test of variance components was by least significant difference.

Results

The elemental composition of the potting medium after five months of composting is shown in Table 2. The relative abundance of potassium was low while others were high. Growth parameters of the six genotypes were in most cases similar irrespective of age at sampling. However, significant variations were obtained in leaf area at four and five months after planting (MAP), and in plant girth and height at four and six MAP, respectively (Table 3). Total dry matter production at the four and five MAP was similar in each genotype; however, there was a tremendous increase in dry matter yield at six MAP (Fig 1a). Total dry matter yield was generally higher in the landrace genotypes. Partitioning of dry matter to above and below ground components varied with age and genotypes (Fig. 1b). Partitioning pattern in 'Nsukka Local' was nearly equal between the above and the below ground components. Exceptionally high proportion of the total dry matter was reported in above ground part in 'BITA 7' and 'PITA 22' at six MAP. The proportions of the total photo assimilate in different plant parts are shown in Fig. 2. Generally, higher proportion of the total dry matter was contributed by the leaf and corm irrespective of genotype and age at sampling. The contribution of root to the total dry matter decreased with plant age in most genotypes while the contribution of leaf remained fairly stable over time in most genotypes. There was inconsistent proportion of contribution of the corm to the total dry matter yield.

The concentration of N and K in specific plant tissues was significantly ($P < 0.05$) influenced by genotypes (Table 4). The N concentration in root was highest in landrace dessert banana 'Nsukka Local' and lowest in cooking banana landrace 'Fougamou'. The quantity of N in the corm was highest in landrace plantain 'Agbagba' and was closely followed by 'Nsukka Local'. 'BITA 7', a cooking banana hybrid had the highest percent N in the pseudostem and leaf, followed by 'Nsukka Local'. Generally,

Table 3.The effects of age after planting on growth parameters of six *Musa* genotypes in a soilless culture

Genotype	Plant girth (cm)			Plant height (cm)			Number of leaves			Leaf area (cm^2)		
	M4	M5	M6	M4	M5	M6	M4	M5	M6	M4	M5	M6
Agbagba	13.7	15.3	20.5	34.6	44.0	65.7	7.1	7.4	9.8	624.2	689.4	1114.7
PITA 22	13.2	14.5	20.5	38.0	39.5	61.5	7.7	8.3	10.5	554.9	578.0	965.0
Nsukka Local	11.6	15.6	24.3	30.8	39.3	58.5	7.8	8.2	9.8	381.3	624.1	958.3
FHIA 17	14.6	17.0	21.3	36.0	41.6	60.8	9.1	8.3	9.9	658.6	836.3	1005.5
Fougamou	15.7	15.5	21.3	32.4	40.8	60.8	7.9	8.2	9.9	568.9	681.6	1005.5
BITA 7	12.9	15.2	19.7	31.9	39.5	57.4	8.2	8.7	9.3	513.3	680.7	983.4
LSD (P=0.05)	2.5	NS	NS	NS	NS	6.2	NS	NS	NS	174.3	153.1	NS

M4, M5, M6: Plants at four, five and six months after transplanting, respectively. NS: Non-significant.

Table 4. Variation in nitrogen and potassium concentration in different plant components as influenced by genotypes

Genotype	Nitrogen (%)				Potassium (mg $100g^{-1}$)			
	Root	Corm	Pseudostem	Leaves	Root	Corm	Pseudostem	Leaves
Agbagba	1.34	1.60	1.10	1.81	70.0	74.0	19.0	49.0
PITA 22	1.43	1.11	1.35	1.69	197.0	250.0	219.0	189.0
Nsukka Local	3.08	1.50	2.02	2.20	89.0	75.0	21.0	39.0
FHIA 17	2.50	1.45	1.72	1.76	85.0	61.0	84.0	54.0
Fougamou	0.77	0.80	0.68	1.47	103.0	89.0	21.0	33.0
BITA 7	1.82	1.14	2.43	2.22	136.0	80.0	93.0	58.0
LSD (P=0.05)	0.10	0.01	0.04	0.04	2.7	4.5	3.1	2.7

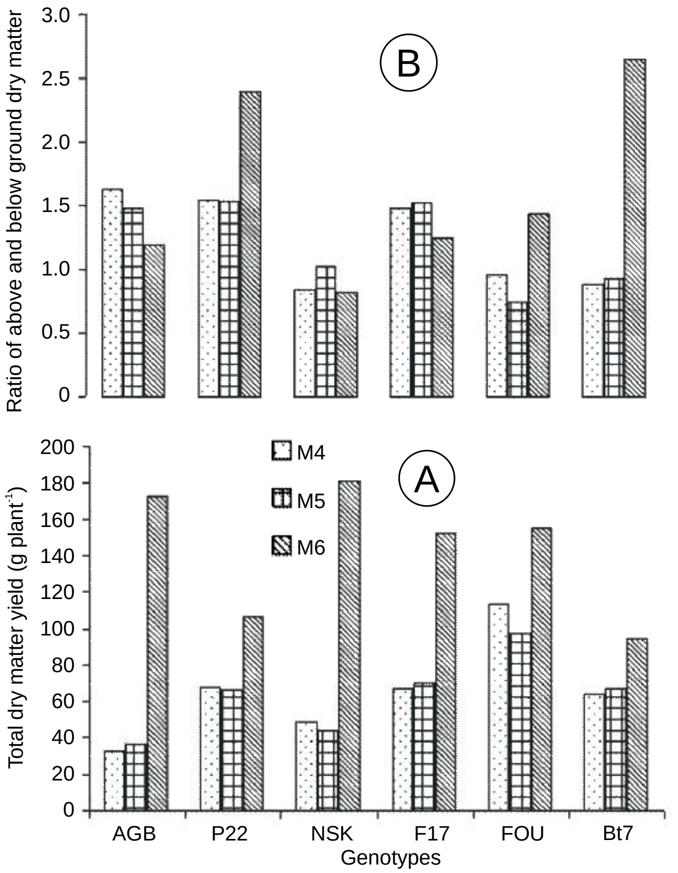

Fig. 1. The effects of genotype and age at sampling on [A] total dry matter yield and [B] ratio of dry matter above ground to the dry matter below ground.

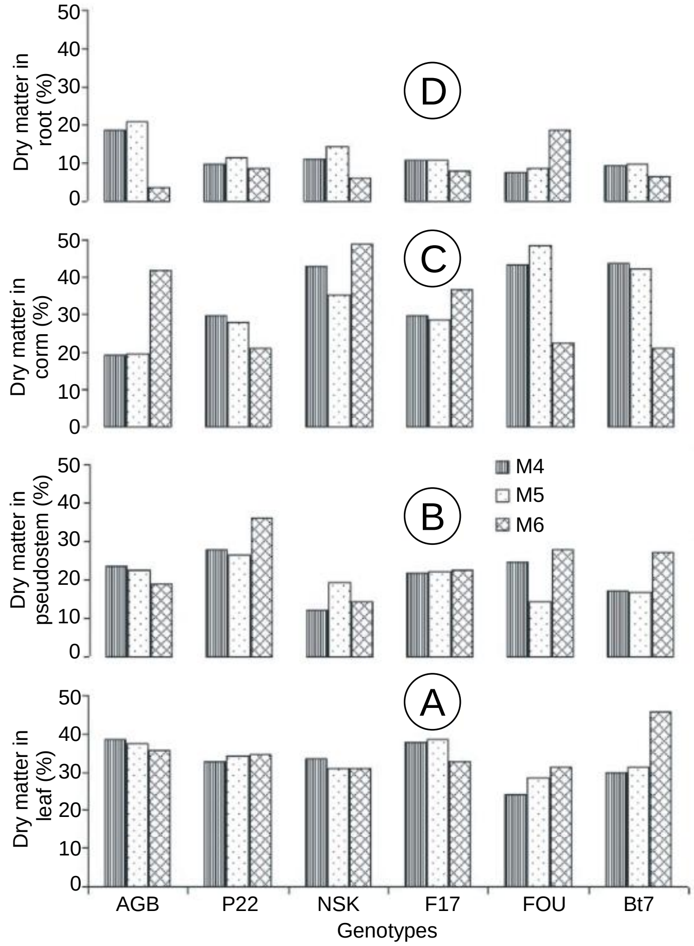

Fig. 2. Dry matter distribution pattern in six *Musa* genotypes as influenced by age at sampling and plant components (A: leaf; B: pseudostem; C: corm and D: root).

the dessert bananas had higher tissue N while 'Fougamou', a landrace cooking banana, had the lowest value of N in all the plant components considered. 'PITA 22', a plantain hybrid, contained the highest concentration of K in all the plant parts sampled. Also, 'BITA 7' had relatively high concentration of K in the tissues than the remaining four genotypes. Earlier field observation by the first author revealed that these two genotypes had impressive growth under limited water conditions when nine other genotypes went in to growth dormancy.

Table 5. Variation in nitrogen and potassium concentration in different plant components as influenced by age at sampling and genotypes

Genotype		Nitrogen (%)				Potassium (mg 100g^{-1})			
	Age	Root	Corm	Pseudostem	Leaves	Root	Corm	Pseudostem	Leaves
Agbagba	M4	1.64	1.79	1.23	2.05	35.0	73.0	1.2	46.0
	M5	1.65	1.85	1.42	2.01	51.0	76.0	2.0	48.0
	M6	1.37	2.26	1.44	1.95	137.0	87.0	3.0	53.0
PITA 22	M4	1.91	1.23	1.64	2.05	111.0	13.0	100.8	70.0
	M5	1.81	1.25	1.70	2.00	117.0	20.0	126.7	80.0
	M6	1.64	1.67	1.78	1.63	490.0	907.0	576.7	547.0
Nsukka Local	M4	4.37	1.64	2.19	2.46	84.0	75.0	1.1	25.0
	M5	3.85	1.68	2.41	2.44	83.0	76.0	2.0	30.0
	M6	3.03	2.01	2.40	2.28	132.0	90.0	2.0	40.0
FHIA 17	M4	3.28	1.78	2.19	2.32	81.0	46.0	84.1	50.0
	M5	3.31	1.75	2.15	2.27	90.0	48.0	92.0	59.0
	M6	2.73	1.89	2.05	1.71	101.0	92.0	80.0	50.0
Fougamou	M4	0.82	0.70	0.55	1.37	73.0	81.0	1.1	23.0
	M5	0.84	0.70	0.62	1.39	76.0	88.0	3.0	28.0
	M6	0.72	1.37	0.66	1.37	185.0	137.0	3.0	31.0
BITA 7	M4	2.19	1.10	3.01	2.87	148.0	64.0	86.2	56.0
	M5	2.15	1.16	3.13	2.81	156.0	69.0	92.7	57.0
	M6	1.58	1.50	3.03	1.96	177.0	138.0	117.0	69.0
LSD (*P*=0.05)		0.23	0.06	0.08	0.09	6.2	10.4	6.8	6.3

M4, M5 and M6 are plants at four, five and six months after transplanting, respectively.

Table 6. Variability in total nitrogen, total potassium and percent N and K distribution in plant components as influenced by genotype

Genotype	Total N ($g\ plant^{-1}$)	Nitrogen distribution (%)				Total K ($mg\ plant^{-1}$)	Potassium distribution (%)			
		Root	Corm	Pseudostem	Leaf		Root	Corm	Pseudostem	Leaf
Agbagba	1.49	13.8	30.8	17.3	38.0	44.3	17.2	44.6	1.0	37.2
PITA 22	1.30	10.9	21.9	31.4	35.7	248.3	13.3	15.1	40.3	31.2
Nsukka Local	1.98	19.7	35.8	17.2	27.3	53.5	20.0	64.8	0.6	14.6
FHIA 17	1.94	14.8	28.3	22.8	34.1	66.9	13.7	29.6	29.1	27.6
Fougamou	1.12	9.8	35.9	15.0	39.4	76.1	23.9	62.3	0.9	12.9
BITA 7	1.50	8.4	21.7	30.7	39.2	64.3	16.6	35.7	24.2	23.5
LSD (P=0.05)	NS	5.3	11.4	5.3	8.2	69.3	6.6	11.2	3.2	7.4

NS: non-significant

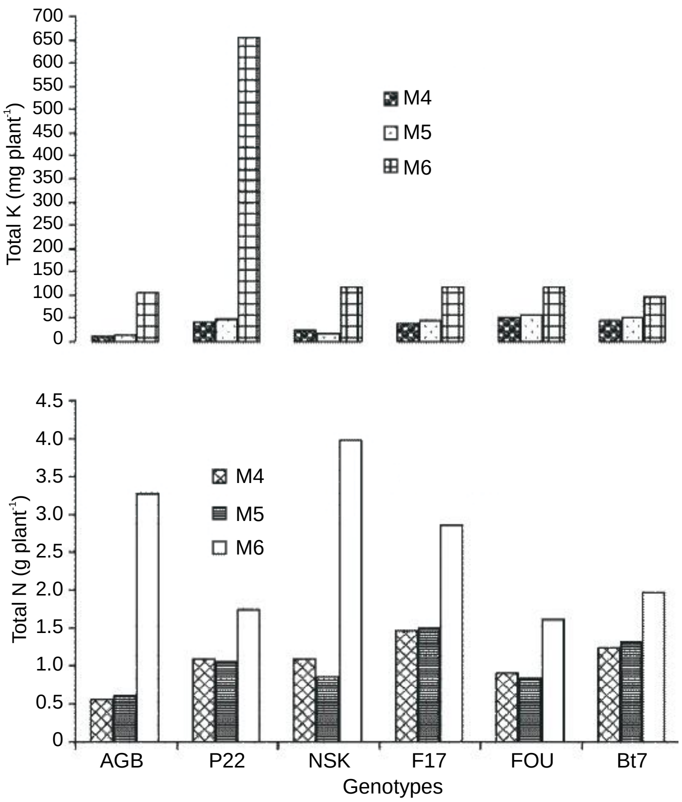

Fig. 3. The effect of genotype and age at sampling on total nitrogen (g plant^{-1}) and total potassium (mg plant^{-1}) per plant.

There was significant (P < 0.05) genotype by sampling age interaction on N and K concentration in the entire plant tissues sampled (Table 5). Generally, root N decreased with age while N concentration in the corm increased with age in all genotypes. N in pseudostem was relatively stable over time for each genotype, however, leaf N slightly declined with age of sampling in all genotypes. There was progressive increase in K concentration in the roots and corm with age of plant in all genotypes. Similarly, leaf K increased with plant age in all genotypes. K concentration was exceptionally low in the pseudostem of all the landrace genotypes. The quantity of K in 'PITA 22', a plantain hybrid, was very high in all the tissues sampled at the sixth MAP.

The total N accumulation (g plant^{-1}), K (mg plant^{-1}) and the percent contribution to these totals by the different plant parts is shown in Table 6. The total N was statistically similar for all the genotypes evaluated; however, higher quantity was accumulated by the dessert bananas ('Nsukka Local' and 'FHIA 17'). More than 60% of total N accumulated by the landraces was contributed by the corm and the leaves. But for the hybrid (except 'FHIA 17') total N was largely due to the contribution by the pseudostem and the leaves. The highest proportion of the total plant N was contributed by the leaves except in 'Nsukka Local'. The quantity of K accumulated varied significantly (***P*** < 0.05) with genotypes. Total K accumulated was highest in 'PITA 22'(a plantain hybrid) whereas 'Agbagba' (a plantain landrace) contained the lowest amount of K. Data in Table 6 revealed that the quantity of K in the corm contributed most to the total K in landraces, whereas in the hybrid it was due to the leaves and pseudostem.

The quantity of N and K as influenced by age at sampling and genotype is shown in Fig. 3. Accumulation of N and K was highest at six MAP for all genotypes. The quantity of N was generally highest in the dessert bananas while the highest amount of K was found in 'PITA 22' at six MAP.

Discussion

Variability in N and K with age of plant as recorded in this study has been reported by other authors also (Twyford and Walmsley, 1974; Samuels *et al.* 1978; Lahav, 1995). This suggested the need for periodic external nutrient inputs. Periodic input through judicious fertilizer management will ensure adequate tissue concentration of these important elements. Adequate concentration will support optimum plant growth and development.

The significant differences in quantity of N and K accumulated by the genotypes depicted differential nutrient mining capacity, and so, fertilizer recommendation for optimum plant growth and development will vary. There was an evident difference in N and K uptake between landrace and hybrid within a genomic group, an indication that nutritional requirement varied, and fertilizer recommendation will therefore, also vary.

Non-significant differences in dry matter yield was probably due to differences in nutrient use efficiency (NUE). The implication is that detailed fertilizer study to elucidate NUE in *Musa* germplasm is urgently needed to assure profitable fertilizer input to bunch yield output ratio. However, Samuels *et al.* (1978) reported that dry matter yield of plantain is similar within the first five months of growth. They reported a surge in growth from the sixth month of planting similar to the results obtained in this experiment.

Pattern of N and K partitioning was influenced by the combined effects of plant age and genotype. Meaning that nutrient uptake from the rhizosphere and distribution pattern within the plant tissues was dependent upon plant type and age. Nutritional status of *Musa* is usually monitored via leaf analysis; the lamina of the third youngest leaf is recommended for sampling (Turner and Lahav, 1983; Lahav, 1995). Leaf N and K in this study was significantly influenced by genotype and age of plant. This result further supports the view that nutritional management for optimum productivity should be genotype specific. While K increased with plant age, significant N decline at the 6 MAP was probably because available nitrogen in the potting mix had decreased through leaching and plant uptake. However, this result might suggest a more regular N supplementation via fertilizer application.

Evidences from the study suggested that higher N supplementation was needed for dessert bananas, whereas K uptake by 'PITA 22" was exceptionally high, suggesting the need for high K supplementation to sustain productivity in a ratooning cropping system. High K uptake by 'PITA 22' explained its high water economy under water stressed savanna environment (unpublished data of the first author). Potassium improves water use efficiency via osmotic regulation of plant stomata by modulating transpiration of water and the penetration of atmospheric carbon dioxide into the leaf (Fischer and Hsiao, 1968; Sawhney and Zelitch, 1969; IPI, 2006). Therefore, breeding *Musa* genotypes for water limited environment will be efficient by selecting genotypes that possessed high K mining capacity. Furthermore, results from this study revealed that in each genome group, hybrids accumulated higher quantity of K. Given the fact that both hybrids and landraces were planted in the same potting mix, it suggested that hybrids had higher K mining capacity, thus selection for high K uptake is possible within *Musa* germplasm. Higher K uptake by the hybrids probably explained higher productivity of hybrids than the landraces as commonly reported in relevant literatures.

Further studies to elucidate the physiological roles of K in *Musa*, especially with regards to sustainable production under water limited environments should urgently be carried out. This should enhance breeding *Musa* germplasm for water stress prone areas.

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