Tropical and Subtropical Agroecosystems, 2004(4): 137 – 144.

Tropical and Subtropical Agroecosystems

PHENOLOGICAL AND YIELD EVALUATION OF *MUSA* GENOTYPES UNDER ALLEY AND SOLE CROPPING SYSTEMS IN SOUTHEASTERN NIGERIA

[EVALUACIÓN FENOLÓGICA Y PRODUCTIVA DE GENOTIPOS DE MUSA EN SISTEMAS DE CULTIVO PURO Y ASOCIADO EN NIGERIA]

K.P. Baiyeri[1*], A. Tenkouano[2], B.N. Mbah[1] and J.S.C. Mbagwu[1]
[1]Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria.
e-mail: paulkayodebaiyeri@yahoo.com
[2]International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria.
[*]Corresponding author:

SUMMARY

Adaptation pattern of landraces and hybrids of Musa AAA, AAB and ABB was studied for two crop cycles under alley and sole cropping systems. Most of the phenological and yield trait varied significantly (P<0.01) across cropping system and crop cycles. Fruit circumference was the most stable trait across cropping systems. Cropping system by crop cycle interaction did not affect the incidence of black sigatoka disease, fruit length and fruit circumference. Ratoon crop had higher productivity than the plant crop in both cropping systems. Yield under alley crop was higher than under sole crop for both plant and ratoon crops. Ratoon crop yield under alley crop was as high as the yields for plant and ratoon crops under sole cropping. Whereas the high yielding hybrid genotypes showed specific adaptation to alley cropping, the low yielding plantain landraces were adapted to sole cropping system. Cardaba, a cooking banana landrace exhibited high and stable yield in both cropping systems. Significant (P < 0.01) genotype by cropping system interaction and genotype by crop cycle interaction suggests that genotype recommendation could not be generalized over cropping systems: Besides, more than one crop cycle is needed for effective genotype selection. AMMI analysis enhanced genotype selection for broad and specific adaptation.

Key words: Cropping system; genotype adaptation; plantain and banana.

RESUMEN

Se estudiaron los patrones de adaptación de líneas e híbridos de Musa AAA, AAB y ABB durante dos ciclos de cosecha en sistemas de cultivo puro y asociado. La mayoría de las características fenológicas y de producción variaron (P<0.01) entre sistemas de cultivos y ciclos de cosecha. La circunferencia del fruto fue la característica más estable entre los sistemas de cultivo. No existió interacción de sistema de cultivo y ciclo de cosecha para la incidencia de la enfermedad de sigatoka negra, longitud y circunferencia del fruto. La cosecha de rebrote fue más mayor en ambos sistemas de cultivo. La producción en cultivos asociados fue mayor que la de cultivos puros. Los genotipos hibrídos de alta productividad mostraron una mejor adaptación al sistema de cultivo asociado, los genotipos de baja productividad estuvieron major adaptados al sistema de cultivo puro. La variedad Cardaba (de cocina) mantuvo una productividad alta y estable en ambos sistemas. La interacción (P < 0.01) genotipo x sistema de cultivo y la interacción genotipo x ciclo sugiere que las recomendaciones del un sistema no deben ser generalizados a otros sistemas. Más aún, es necesario más de un ciclo de cultivo para una selección efectiva. El esquema de selección AMMI permitió una mejora en la selección de genotipos para con adaptación amplia y especifíca.

Palabras clave: Sistemas de cultivo, adaptación genotípica, platanos.

INTRODUCTION

The genetic composition of a crop and growth resources available to the crop in an environment determine the performance of the crop in that environment. Thus, to fully understand the information contained in multi-environment trials, it is necessary to study the factors influencing crop growth and yield in individual environments and the reason for differential performance of genotype (Bidinger *et al.* 1996).

Multi-environments evaluation trial helps to identify adaptation pattern of crop genotypes based on the stability of the phenotypic expression of important agronomic traits (Byth *et al.*, 1976; Dashiell *et al.* 1994; Crossa, 1990; Pritts and Lubby, 1990; Kang, 1998). This information is used to make reliable recommendations for specific uses or targeted environment of the genotypes (Gauch, 1992; Dashiell *et al.* 1994).

The performance of bananas and plantains (*Musa* spp. L.) is significantly affected by cropping practices (Rao and Edmunds, 1984). Perennial plantain production can be achieved with regular organic matter input (Swennen, 1990). Thus, in West Africa, plantains are cultivated mainly in home gardens where the use of household refuse ensure continuous organic matter supply resulting in high yield (Nweke *et al.*, 1988; Robinson, 1996).

Banana and plantains are also cultivated on large-scale commercial farms often under sole cropping system (Obiefuna, 1986). In this system, yield decline observed after the first cropping season is essentially due to loss of soil organic matter and nutrient depletion. Poor nutrient status also causes increased susceptibility of plantains to a range of pests and diseases (Robinson, 1996). Perennial production can be achieved by cultivating plantain between hedgerows of multiple species complex. This has been reported to enhance nutrient use and cycling (Ruhigwa *et al.,* 1992) and sustainable yield (Shannon *et al*., 1994). This is because alley cropping favors a humid microenvironment (Baiyeri, 1992) and allows for organic matter building from the pruning of the hedgerows, thereby enhancing soil nutrient recycling (Owoeye *et al*., 1996).

Musa genotypes recently selected for their biotic stress tolerance and good horticultural traits (Jones, 1994), should be evaluated under different production systems for adaptation and consistency of performance. Therefore, in this study 36 banana and plantain genotypes were evaluated for their phenological and yield patterns under alley and sole cropping systems. The aim was to identify genotype(s) adaptation pattern under the two cropping systems.

MATERIAL AND METHODS

Musa genotypes and location of study:

Thirty-six genotypes, representative of the major *Musa* taxonomic groups (Table 1), were evaluated under sole and alley cropping with multiple hedgerows at the high rainfall station of the International Institute of Tropical Agriculture (IITA) at Onne (4^{o}43’N’ 7^o 01’E, 10m.a.s. L.), in southeastern Nigeria. Details of the plant materials and study location have been reported in Baiyeri *et al.* (1999).

Planting was done on 19 and 20th June 1995, utilizing a 6 x 6 simple lattice design. Each genotype was grown in a single-row plot of five plants per replicate and cultural practices were those described by Swennen (1990). Data, collected for two-crop cycles (1995 to 1998), included number of days to flowering, number of days to harvest, number of days for fruit filling (bulking). Plant height at flowering (cm), determined as distance from ground level to the junction of the last two fully expanded leaves, and height of the tallest sucker (cm) at the time of harvest of the mother plant. Cycling index was determined as the ratio of sucker height to plant crop height multiplied by 100 (PBIP, 1995). This ratio is an indication of the interval between two consecutive harvests. Response to black sigatoka disease was assessed using the youngest leaf spotted criterion (Vakili, 1968). Other characters measured included bunch weight per plant (kg), number of hands (nodal clusters) per bunch, number of fruits per bunch, fruit weight (g), fruit length (cm) and fruit circumference (cm).

Table 1. List of 36 *Musa* genotypes evaluated in the study.

Classification	Genome	Ploidy level	Genotypes
Dessert bananas	AAA	3x	KM5, Pisang Ceylan, Valery
	AAA x AA	4x	FHIA-1, FHIA-2, FHIA-23, SH3436-9, SH3640, EMB-402, EMB-403, EMC-602
Plantains	AAB	3x	Agbagba, Obino L’Ewai, UNN.DB
	AAB x AA	4x	PITA-1, PITA-2, PITA-3, PITA-5, PITA-7, PITA-8, PITA-9, PITA-11, PITA-12, PITA-14, PITA-16, FHIA-21, FHIA-22
Cooking bananas	ABB	3x	Bluggoe, Cardaba, Pelipita, Fougamou, Saba
	ABB x AA	4x	BITA-1, BITA-2, BITA-3, FHIA-3

Statistical analysis

Statistical analysis was based on plot means due to the unequal number of observations per plot (Piepho, 1997). Due to missing values, data were analyzed according to randomized complete block design model instead of lattice design model. Data were subjected to analysis of variance and separation of means using the GLM procedure in SAS (SAS Institutte, 1992). Genotype adaptation pattern based on yield data was evaluated using additive main effect and multiplicative interaction (AMMI) model (Zobel *et al.,* 1988: Gauch, 1992). Four environments were defined for performing AMMI analysis i.e. two cropping systems (alley and sole crops) by two crop cycles (plant and ratoon crops). The AMMI analysis generates information on genotype performance within and across the environments. The information generated makes it possible to identify genotypes' stability and adaptation patterns.

RESULTS

Tests of significance of components of variance:

Significant differences were observed among genotypes, both between and within genomic groups, for phenological and disease response traits (Table 2). Cropping system, crop cycle, and cropping system by crop cycle interaction were also highly significant ($P < 0.01$) for these traits except days for fruit filling. Significant genetic by cropping system and genetic by crop cycle interactions were observed in phenological and disease response traits.

Yield and its components, except fruit circumference, were significantly ($P < 0.05$) affected by cropping system and crop cycle (Table 3). Cropping system by crop cycle interaction influenced only bunch yield. Genetic effects and their interactions with cropping system and crop cycle caused highly significant ($P < 0.01$) variation in most of the yield traits. The number of hand per bunch varied significantly only among genotypes (Table 3).

Response of phenological and yield traits of Musa genotypes to cropping system and crop cycle:

Plants flowered and were harvested earlier under alley cropping (Table 4). Also, plants were taller, produced taller suckers and had faster cycling index when grown under alley crop compared to sole crop. Alley cropping system had about 72.5% yield advantage over the sole cropping system and supported plants with more healthy leaves (Table 4). Components of yield, such as number of fruits per bunch and fruit size, were significantly higher under alley crop than the sole crop. There was no significant difference in days for fruit filling under the two cropping systems.

The number of youngest leaf spotted at flowering was higher during the plant crop than ratoon crop (Table 4). Ratoon plants were significantly taller than the plant crops although sucker size was not influenced by crop cycle. Yield was 44% higher for ratoon than plant crops and was associated with several fruits that were long and had bigger circumference. However, fruit weight was higher for plant crop than the ratoon crop (Table 4).

Table 2. ANOVA showing sources of variation and significance test of mean squares of phenological traits and black sigatoka disease resistance index of 36 *Musa* genotypes grown under two cropping system for two crop cycles: 1995 – 1998.

Source	df	DTF[a]	DFF	DTH	PHF Cm	HTSH cm	CYCLING %	YLSF #
Cropping system (CS)	1	***	NS	***	***	***	***	***
Crop cycle (CC)	1	***	NS	***	***	NS	***	***
CS x CC	1	***	NS	***	NS	***	***	NS
Reps within CS x CC	3	***	NS	***	NS	NS	NS	NS
Blocks within Reps	10	***	NS	*	**	NS	NS	*
Genomic group	5	***	***	***	***	***	NS	***
Genotype (G)	35	***	***	***	***	***	***	***
G x CS	35	***	***	***	***	***	NS	NS
G x CC	35	***	*	***	***	NS	***	***
Residual	151	-	-	-	-	-	-	-
R-square (%)		95.6	85.6	95.9	96.3	91.3	86.9	79.2

a: DTF: days to flowering: DFF: days for fruit filling; DTH: days to harvest; PHF: plant height at flowering:
HTSH: height of the tallest sucker at harvest of plant crop: CYCLING: ratio of HTSH to PHF;
YLSF: youngest leaf spotted at flowering; #: number
*, **, ***: Significant at 5%, 1%, 0.1% probability level, respectively; NS: Non-significant

Table 3. ANOVA showing sources of variation and significance test of mean squares of yield and yield components of 36 *Musa* genotypes grown under two cropping system for two crop cycles: 1995 – 1998.

Source	df	BWT[a] Kg/plant	YIELD tons/ha	FWT g	FRUITS #/bunch	HANDS #/bunch	FLT cm	FCR cm
Cropping system (CS)	1	***	***	***	***	***	***	NS
Crop cycle (CC)	1	***	***	*	***	*	***	***
CS x CC	1	***	***	NS	NS	NS	NS	NS
Reps within CS x CC	3	NS	NS	NS	NS	NS	NS	NS
Blocks within Reps	10	***	***	NS	NS	NS	NS	**
Genomic group	5	***	***	NS	***	NS	***	***
Genotype (G)	35	***	***	***	***	**	NS	***
G x CS	35	***	***	*	***	NS	**	**
G x CC	35	***	NS	***	***	NS	***	***
Residual	151	-	-	-	-	-	-	-
R-square (%)		88.9	88.8	83.8	95.3	56.33	88.5	84.2

[a]: BWT: bunch weight; YIELD: bunch yield in tons per hectare; FWT: fruit weight;
FRUITS: number of fruits per bunch; HANDS: number of hands (nodal cluster) per bunch;
FLT: fruit length; FCR: fruit circumstance; #: number
*, **, ***: Significant at 5%, 1% probability level, respectively; NS: Non-significant

The number of days to flowering and harvest for plant and ratoon crops were significantly ($P < 0.01$) longer under sole than alley crop (Table 5). The number of days for fruit filling, youngest leaf spotted at flowering, hand per bunch, fruit length, fruit circumference and fruit weight were not influenced by cropping system by crop cycle interaction. Bunch yield of ratoon crop under alley cropping was as high as the yield for both plant and ratoon crops under sole cropping (Table 5). Several fruits per bunch under alley crop had no depressive effect on fruit weight relative to sole crop that supported fewer fruits per bunch.

Variation in phenological and yield traits due to genomic group:

There were significant variations between ploidy (3x and 4x) within genome group for most growth and yield traits (Table 6). Tetraploid genotypes flowered and were harvested earlier except in dessert bananas. Plantain landraces produced the smallest sucker size but had the shortest number of days for fruit filling. Triploid genotypes were taller than the tetraploid hybrids in each genome. Hybrid genotypes (4x) had highly significant ($P < 0.01$) higher number of leaves without black sigatoka disease spot than the landraces (3x) except among the cooking bananas (Table 6). Significant yield differences due to ploidy within genomes were observed in plantains and dessert bananas (Table 6). Lower yield among plantains was associated with fewer fruits per bunch compared with the other genomes. Variation in fruit traits was not consistent with ploidy within genomes. For example, landrace plantain (AAB) had fewer but bigger fruits than the hybrids (AAAB), while dessert banana landraces (AAA) had several but small fruits than their hybrid (AAAA) genotypes (Table 6).

AMMI 1 winning genotypes:

AMMI analysis ranked genotype performances within and across cropping systems and crop cycle. Winning genotypes (the highest yielding) in each genomic group under alley crop and sole crop for the two crop cycles are shown in Table 7. Valery was most productive desert banana landrace under alley crop, but Pisang Ceylan was adaptive to alley and sole crops. Obino I'Ewai and UNN.DB (plantain landraces) exhibited similar performance in both cropping systems. Cardaba was the most productive cooking banana landrace under the two cropping systems, but Fougamou and Pelipita were similarly adapted to alley crop and sole crop, respectively. FHIA 1 was a high-yielding dessert banana hybrid under the two cropping systems. Also, FHIA 23 was comparatively adapted to alley crop. PITA 16 was the most adapted plantain hybrid to sole crop while PITA 5 and PITA 2 were highly productive under alley crop. FHIA 3 was the most consistent high yielding cooking banana hybrid.

Table 4. Phenology, yield and yield components of 36 *Musa* genotypes grown under alley crop and sole crop for two crop cycles.

Environment	DTF	DFF	DTH	PHF cm	HTSH cm	CYCLE %	YLSF #	HANDS #	FRUITS #	FLT cm	FCR cm	FWT g	BWT kg/plant	YLDHA tons/ha
Cropping system														
Alley crop	466.6	111.8	576.6	369.1	288.0	78.43	7.6	8.9	121.5	15.4	11.3	111.3	12.9	21.4
Sole crop	519.2	110.4	618.8	273.1	191.5	72.1	6.9	6.4	78.0	14.3	11.1	99.2	7.5	12.4
LSD (0.05)	10.8	ns	10.0	4.7	8.69	2.8	0.3	0.8	3.2	0.4	ns	6.1	0.6	0.9
Crop cycle														
Plant crop	361.6	110.6	471.3	285.4	237.5	83.3	7.9	7.2	84.4	14.3	10.8	109.2	8.3	13.7
Ratoon crop	622.8	111.5	721.1	353.9	240.6	67.2	6.6	8.0	113.4	15.4	11.7	101.4	11.9	19.8
LSD (0.05)	10.8	ns	10.0	4.7	ns	2.8	0.3	0.8	3.2	0.4	0.2	6.1	0.6	0.9

DTF: days to flowering; DFF: days for fruit filling; DTH: days to harvest; PHF: plant height at flowering; YLSF: number of youngest leaf spotted at flowering; HTSH: height of the tallest sucker at harvest of the plant crop; HANDS: number of hands per bunch; FRUITS: number of fruits per bunch; CYCLE: ratio of HTSH to PHF; BWT: bunch weight; FWT; fruit weight; FLT: fruit length; FCR: fruit circumference; YLDHA: yield/ha.

Table 5. Cropping system by crop cycle interaction effect on phenology, yield and yield components of 36 *Musa* genotype.

Cropping System	Crop cycle	DTF	DFF	DTH	PHF cm	HTSH cm	CYCLE %	YLSF #	HANDS #	FRUITS #	FLT cm	FCR cm	FWT g	BWT kg/plant	YLDHA tons/ha
Alley crop	Plant crop	343.6	111.3	455.2	327.9	297.9	90.5	8.2	8.4	102.6	14.8	10.9	117.4	10.4	17.3
	Ratoon crop	581.0	112.2	682.8	406.9	279.0	67.5	7.1	9.2	138.2	15.9	11.6	106.0	15.0	24.9
Sole crop	Plant crop	378.4	110.0	485.4	246.4	183.7	76.9	7.6	6.0	68.2	13.8	10.7	101.9	6.4	10.6
	Ratoon crop	666.3	110.7	762.2	300.1	199.8	66.9	6.2	6.8	88.0	14.8	11.5	96.4	8.6	14.2
LSD (0.05)		15.1	ns	14.0	6.6	12.2	3.9	Ns	Ns	4.4	ns	ns	ns	0.8	1.3

DTF: days to flowering; DFF: days for fruit filling; DTH: days to harvest; PHF: plant height at flowering; YLSF: number of youngest leaf spotted at flowering; HTSH: height of the tallest sucker at harvest of the plant crop; HANDS: number of hands per bunch; FRUITS: number of fruits per bunch; CYCLE: ratio of HTSH to PHF; BWT: bunch weight; FWT; fruit weight; FLT: fruit length; FCR: fruit circumference; YLDHA: yield/ha

Table 6. Phenology, yield and yield components of 36 *Musa* genotypes grown under alley crop and sole crop for two crop cycles: The main effects of genomic group.

Genomic group	DTF	DFF	DTH	PHF cm	HTSH cm	CYCLE %	YLSF #	HANDS #	FRUIT #	FLT cm	FCR cm	FWT g	BWT kg/plant	YLDHA tons/ha
Plantain hybrids (AAAB)	467.8	111.0	573.2	317.6	235.8	75.3	7.3	7.1	89.6	15.6	11.0	108.9	9.8	16.2
Plantain landraces (AAB)	612.1	82.7	689.2	343.8	132.9	37.3	5.5	7.4	46.2	19.0	12.2	168.0	6.7	11.2
Cooking banana hybrids (AABB)	528.4	116.9	631.8	327.8	232.8	69.8	7.9	7.1	101.4	14.7	12.3	113.1	11.6	19.3
Cooking banana hybrids (ABB)	529.8	123.5	644.7	376.0	336.6	90.3	7.4	7.6	104.0	13.4	12.5	1104	11.1	18.4
Dessert banana hybrids (AAAA)	476.6	111.0	583.1	286.4	208.3	73.7	7.5	8.1	111.9	141.1	10.5	88.1	10.9	18.1
Dessert banana landraces (AAA)	434.6	109.3	541.9	296.1	266.3	91.8	6.8	9.0	141.7	12.3	9.6	61.8	9.0	15.0
LSD (0.05)	36.1	7.2	33.1	18.5	28.4	8.6	0.8	1.7	14.8	1.3	0.7	18.4	1.7	2.9

DTF: days to flowering; DFF: days for fruit filling; DTH: days to harvest; PHF: plant height at flowering; YLSF: number of youngest leaf spotted at flowering; HTSH: height of the tallest sucker at harvest of the plant crop; HANDS: number of hands per bunch; FRUITS: number of fruits per bunch; CYCLE: ratio of HTSH to PHF; BWT: bunch weight; FWT; fruit weight; FLT: fruit length; FCR: fruit circumference; YLDHA: yield /ha.

Table 7: AMMI winning genotypes (based on yield, ton per hectare) from each genome group grown under alley crop and sole crop for two crop cycles.

Genomic group	AC-PC	AC-RC	SC-PC	SC-RC	Environment*
AAA	Valery (17.3)[a]	Valery (25.1)	Pisang ceylan (15.2)	KM5 (16.6)	Pisang ceylan (17.04)
AAB	UNN.DB (19.2)	Obino I'Ewai (13.9)	Obino I'Ewai (10.1)	UNN.DB (10.0)	UNN.DB (11.8)
ABB	Fougamou (23.4)	Cardaba (35.1)	Bluggoe (13.1)	Pelipita (18.0)	Cardaba (21.4)
AAAA	FHIA 23 (38.6)	FHIA 1 (38.0)	FHIA 1 (16.0)	SH 3640 (18.0)	FHIA 1 (23.9)
AAAB	PITA 5 (22.2)	PITA 2 (37.0)	FHIA 21 (14.7)	PITA 16 (19.7)	PITA 2 (22.1)
AABB	FHIA 3 (29.8)	FHIA 3 (42.0)	FHIA 3 (19.9)	FHIA 3 (28.1)	PHIA 3 (30.0)

[a]: Values in bracket are bunch yield (tons/ha);
AC-PC: plant crop under alley crop; AC-RC: ratoon crop under alley crop; SC-PC: plant crop under sole crop; SC-RC: Ratoon crop under sole crop; Environment*: Winning genotypes when the four cropping environments (AC-PC, AC-RC, SC-PC and SC-RC) were pooled

DISCUSSION

Significant cropping system effect and variable adaptation pattern of the genotypes under the two cropping systems justifies the study. Significant interaction of genotype by cropping system and or crop cycle indicated that genotype recommendation could not be made based on trial conducted under one cropping system and or crop cycle (Oritz and Vuylsteke, 1995).

Crop performance is a direct product of the resources available in the environment. Resource potential of alley crop and sole was different and would explain differential genotype performance under the two cropping systems. The alley crop was characterized by high organic matter buildup (throughout the cropping season) from pruning of the hedgerows, and the microclimate was humid. High organic matter buildup under alley crop increased the soil ECEC and soil microbes coupled with improved soil structure and stable chemical properties (Delvaux, 1995). Poor performance under sole crop was due to edaphic factors (Ortiz *et al.,* 1997). Perhaps as a result of low organic matter turnover under the sole crop, the soil was prone to nutrient leaching and surface runoff.

Significant crop cycle effect on traits could be associated with duration for biomass accumulation and crop growth factors. Plant crop had short vegetative growth (Stovers and Simmonds, 1987), while the long duration of the ratoon crop could be advantageous in terms of biomass production potential (Evans, 1993). The ratoon crop benefited from resource (in terms of fertilizer) available to the plant crop while constituting a competitive sink to the plant crop during early growth stage (Baiyeri and Ortiz, 1995).

Early *Musa* cultivar trials elsewhere (Turner and Hunts, 1984; Daniells and O'Farrell, 1988) reported significant differences in growth and yield due to genetic effects as obtained in this study. Better performance of the hybrid genomes could be due to heterosis and higher disease resistance (Ortiz, 1995: Rowe and Rosales, 1996).

CONCLUSION

It was evident that alley cropping was a more productive *Musa* management system. The crop under this cropping system combined earliness with high yield. Yield of some genotypes was more than 50% higher under alley crop than the sole crop. In most cases, genotypes adapted to sole crop were similarly adapted to alley crop. On the contrary, high yielding genotype under alley crop may perform poorly under sole crop. This suggests that under budget constraints for multi-cropping systems trial, breeders should carry out their genotypes evaluation trials under sole cropping. This is because genotype selected for high yielding under sole cropping will also produce high yield under alley cropping. However, AMMI 1 analysis showed that Cardaba, FHIA 1, FHIA 3, PITA 2 and Pisang Ceylan were well adapted to the two cropping systems.

REFERENCES

Baiyeri, K.P. 1992. Trees may enhance plantain production: observation from Nigeria's derived savanna zone Agroforestry Today 4(4):17.

Baiyeri, K.P. and Ortiz, R, 1995. Path analysis of yield in dessert bananas. MusAfrica 8:3-5.

Baiyeri, K.P., Tenkouano, A, B.N. Mbah and J.S.C. Mbagwu. 1999. Genetic and cropping system effects on yield and postharvest characteristics of Musa spp. L. in southeastern Nigeria. African Crop Science Journal 7: 1-7.

Bindinger, F.R., Hammer, G.L. and R.C. Muchow. 1996. The physiological basis of genotype by environment interaction in crop adaptation. In: Plant adaptation and crop improvement. M, Cooper and G.L. Hammer (eds), CAB International. UK, pp. 329-347

Byth, D. E.; R. L. Eisemenn and I. H. De Lacy. 1976. Two-way pattern analysis of a large data set to evaluate genotypic adaptation. Heredity 37: 215 - 230

Crossa, J. 1990. Statistical analysis of multi-location trials. Advances in Agronomy 44: 55-85.

Danniells, J.W and O'Farrell, P.J. 1988. Yield and plant characteristics of 21 banana cultivars in north Queensland. Queensland Jounal of Agriculture and Animal Science 45: 139-143.

Dashiell, K, E,: Ariyo O. J.: Bello L, and Ojo. 1994. Genotype x environment interaction and simultaneous selection for high yield and stability in soybeans (*Glycine max (L)* Merr.) Annals of applied biology 124: 133 - 139.

Delvaux, B. 1995. Soils. In: Bananas and Plantains, S. Gowen (ed.), Chapman and Hall, London. pp. 230 – 275.

Evans, L.T. Crop evolution, adaptation and yield. 1993. Cambridge University Press.

Gauch, H.G. 1992. Statistical analysis of regional yields trias: AMMI analysis of factorial designs, Elsevier, Amsterdam, The Netherlands.

Jones, D.R. 1994. International *Musa* Testing Program Phase 1. In: The Improvement and testing of *Musa*: a Global Partnership, D.R., Jones (ed). Proceeding of the First Global Conference of the International *Musa* Testing Program held at FHIA, 27 - 30 April, 1994, Honduras, pp. 12 - 20

Kang, M.S. 1998. Using genotype-by-environment interaction for crop cultivar development. Advances in Agronomy 62:199 - 252.

Nweke, F.I., Njoku, J.F. and Wilson, G.F. 1988. Productivity and Limitations of plantain (*Musa* spp. cv AAB) production in compound gardens in southeastern Nigeria. Fruits 43: 161 - 166.

Obiefuna, J.C. 1986. The effect of monthly planting on yield, yield patterns and yield decline of plantains (*Musa AAB*). Sciential Horiculturae. 29:47 - 54.

Ortiz, R. and Vuylsteke, D. 1995. Genotype-by-environment interaction in *Musa* germplasm revealed by multi-site evaluation in sub-Saharan Africa. HortScience Abstract 30: 795.

Oritz, R. 1995. Musa genetics, pp. 84 - 109, In: Bananas and Plantains. S. Gowen (ed), Chapman and Hall, London.

Oritz, R., Austin, P.D. and Vuylsteke, D. 1997. IITA High Rainfall Station: twenty years of research for sustainable agriculture in the West Africa Humid forest. HortScience 32: 969 - 972.

Owoeye, L.G., Ortiz, R., Gichuru, M.P and Vuylsteke, D. 1996. Variations in soil nutrient level under multi-species hedgerow cropping with plantain, First International conference on banana and plantain for Africa, Kampala, Uganda. 14 - 18 Oct., 1996. Abstract p. 18 - 19.

PBIP, 1995. Plantain and Banana Improvement Program, 1994 Annual Report. Crop

Improvement Division, International Institute of Tropical Agriculture, Nigeria.

Piepho. H. P. 1977. Analysis of a randomized block design with unequal subclass numbers. Agronomy Journal 89:718 - 723.

Pritts, M. and Luby J. 1990. Stability indices for horticultural crops. HortScience 25: 740 - 745.

Rao, M.M. and Edmunds, J.E. 1984. A review of banana/plantain cropping systems. Fruit 39: 79 - 88.

Robinson, J.C. 1996. Bananas and Plantains. CAB International, UK.

Rowe, P.R. and F.E. Rosales, 1996. Current approaches and future opportunities for improving major *Musa* (ABB) types present in the Asian/Pacific region: Saba, Pisang Awka, Bluggoe, pp. 129 - 141. In New frontiers in resistance breeding for nematode, fusarium and sigatoka, E.A. Frison, J-P. Horry and D. DeWaele (eds.), INIBAP/IPGRI.

Ruhigwa, B.A.; Gichuru M.P.; Mambani, B. and Tariah, N.M. 1992. Root distribution of *Acio barteri, Alchornea cordifolia, Casia siamea* and *Gmelina arboreal* in an acid Ultisol. Agroforestry systems 19: 67 - 78.

SAS Institute, 1992. SAS system for personal computers, 1002, SAS Institute Inc. Carry, NC 27512 - 8000, USA.

Shannon, D.A.: Vogel, W.O. and Kabaluapa, K.N. 1994. The effects of alley cropping and fertilizer application on continuously cropped maized. Tropical Agriculture. (Trinidad) 71: 163 - 169.

Stover, R.H. and Simmonds, N.W. 1987. Bananas, 3rd ed. Longman, London, UK.

Swennen, R. 1990. Plantain cultivation under West Africa conditions - a reference manual. IITA, Ibadan, Nigeria.

Turner, D.W. and Hunt, N. 1984. Growth, yield and leaf nutrient composition of 30 banana varieties in subtropical New South Wales. Technical Bulletin 31, Dept. of Agriculture New South Wares. 36pp.

Vakili, N.G. 1968. Responses of *Musa acuminata* species and edible cultivars to infection by *Mycosphaerella musicola.* Tropical Agriculture 45:13 - 22.

Zobel, R.W., Wright, M.J. and Gauch, H.G. 1988. Statistical analysis of a yield trial. Agronomy Journal. 80: 388 - 393.

Submitted March 25, 2004 - Accepted October 28, 2004