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Relationships between Phenological and Yield traits of the Plant Crop and first Ratoon Crop of *Musa* Genotypes as Affected by Ploidy level and Genomic group

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ABSTRACT

Multiple correlation of phenological and yield traits of the plant crop (PC) with those of the first ratoon crop (RC) of 36 Musa genotypes was carried out. The genotypes were landraces (triploid) belonging to AAA, AAB and ABB Musa genomic groups and hybrids (mostly tetraploid) thereof. The plants were grown under four environments for two crop cycles (PC and RC). Genomic group and ploidy level significantly affected the number of traits correlated and their coefficient of correlation. Plantains (AAB) had fewer and weaker correlated traits than cooking bananas (ABB) and dessert bananas (AAA). In all the genomic groups plant height of RC at harvest of the PC was significantly correlated with days to flowering and yield of the RC. In the hybrid genotypes, the black sigatoka disease score of the PC correlated with days to flowering, bunch weight and harvest interval in RC. Yield of RC was predictable from the yield of PC (except for the plantains). It was conclusive from the study that early selection of sucker for the ratoon crop and other crop management options that will enhance healthy growth of the PC will sustain high yield in Musa genotypes.

Key words: Bananas and Plantains, Crop cycles, Multiple correlation, Path coefficient analysis, Yield.

Introduction

The growth and development processes in bananas and plantains (*Musa* spp L.) including the formation of lateral shoots (ratoon) make possible their cultivation as perennial crops. Under tropical environments, cultivation systems of bananas and plantains include permanent system and small farms replanted after 3 - 8 years (Stover and Simmonds, 1987). Perennial cultivation of *Musa* spp in subsistence and small scale commercial farms is characterised by yield decline after few years of cultivation under West African conditions (Swennen, 1990). The yield decline is often associated with edaphic and biotic stresses (Robinson, 1996). Although crop adaptability is important to the plant breeder and seed merchant, of more significance to the individual farmers especially the subsistence farmer, is the reliability of yield from one year to the next (Evans, 1993). Yield is the ultimate outcome of all the processes involved at all stages in the growth and development of a crop, any one of which may limit the yield of a particular crop (Evans, 1993). Thus an understanding of the quantitative relationships between phenological and yield components is essential in interpreting seasonal variations of crop yield under different environments (Turner, 1971). Also, knowledge of phenotypic and genotypic correlation among yield traits, or for a single trait among different generations, provides the opportunity to predict response in one trait when selection is practiced on another (Lippert and Hall, 1982).

It is of interest to compare the degree of association of yield and yield components of crops (Fraser and Eaton, 1983). Such comparison has been shown in barley (Park *et al.* 1977), mustard (Ahmed, 1980), strawberry (Mason and Rath, 1980), plantain (Swennen & de Langhe,

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1985, Baiyeri & Mbah, 1994) and bananas (Baiyeri & Ortiz, 1995).

Growth and yield correlation of a single crop cycle has been reported for *Musa* genotypes (Simmonds, 1966; Swennen & de Langhe, 1985; Baiyeri & Mbah, 1994). The relationships among growth and yield components of two crop cycles (eg. plant and ratoon crops) are uncommon in the literature. Yet significant phenotypic correlation between plant crop components of growth and yield with those of the ratoon crop should permit the enhancement and prediction of ratoon crop yield. This study is therefore, aimed at identifying the components of growth and yield of the plant crop that correlate with the yield of the ratoon crop

Materials and Methods

Thirty-six genotypes representative of the major *Musa* taxonomic groups (Table 1) were evaluated across three agroecologies: Onne (high rainfall humid forest), Ibadan (forest-savanna transition) and Abuja (Southern guinea savanna). Plants were grown as sole cropping at all locations and an additional experiment under a multispecies hedgerow alley cropping at Onne. The characterisation of the locations is shown on Table 2.

The experiment was laid out as a simple lattice in each location, comprising single-row plots of five plants per genotype. Planting distance and cultural practices were as recommended by Swennen (1990). Phenological and yield data were collected for the plant crop and the first ratoon crop between June 1995 and June 1998. Traits monitored included days to flowering (DTF), days for fruit filling (DFF), plant height at flowering (PHF) (cm), height of the tallest sucker at harvest of the plant crop (HTSH) (cm), black sigatoka disease resistance status measured as the number of youngest leaf spotted at flowering (YLSF), bunch weight per plant (kg), fruit weight (g), number of hands (nodal cluster) per bunch and the number of fruits per bunch.

Multiple correlation analysis using PROC CORR (SAS, 1992) was performed on the data. The multiple correlation analysis was based on ploidy within genome irrespective of locations. Also, combined multiple correlation, ignoring both the locations and genomic groups differentiation was done. Furthermore, path coefficient analysis was carried out to identify plant crop traits that have high direct effects on the bunch weight of the ratoon crop. Path coefficient was calculated following the methods of Dewey and Lu (1959) and Ortiz and Langhe (1997).

Results

Correlation between corresponding plant and ratoon crop traits

Plantain landraces had fewer traits correlation than other landrace genotypes (Table 3). All the plant crop (PC) traits were significantly ($P<0.05$) correlated with their corresponding ratoon crop (RC) traits in cooking banana landraces. In dessert banana landraces however, only the fruit weight was not significantly correlated (Table 3). Coefficient of correlation was highest for number of fruits per bunch for plantain landraces, and days to flowering in cooking banana and dessert banana landraces. Among the tetraploid hybrid genotypes, youngest leaf spotted at flowering (YLSF) of the PC was not significantly correlated with the YLSF of the RC. Correlation co-efficient between bunch weight of the PC and RC was >0.80 in cooking banana and dessert banana hybrids but was <0.40 in plantain hybrids (Table 3).

Correlation between height of the ratoon crop plant at harvest of the plant crop with its phenology and yield traits

The height of RC plant at harvest of the PC had negative significant correlation with its days to flowering and duration from harvest of the PC to the harvest of RC in all genomic groups (Table 4). The height of RC at flowering (PHF) gave the highest correlation coefficient with its previous height at harvest of the PC. The number of fruits per bunch and bunch weight of RC were significantly correlated with the previous height of RC only among plantain hybrids, cooking banana landraces and dessert banana landraces (Table 4). YLSF and fruit weight showed no signifi-

Table 1: List of genotypes used in this study

Classification[1]	Landraces (3x)		Hybrids (4x)[3]	
	Genome[2]	Genotype	Genome	Genotype
Desert bananas	AAA	KM 5, Pisang Ceylan, Valery	AAA x AA	FHIA-1, FHIA-2, FHIA23, SH3436-9, SH3640, EMB402, EMB 403, EMC 602
Plantains	AAB	Agbagba, Obino L'Ewai, UNN.DB	AAB x AA	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	Bluggoe, Cardaba, Pelipita, Fougamou, Saba	ABB x AA	BITA-1, BITA-2, BITA-3, FHIA-3

1. Distinction between dessert bananas, cooking bananas, and plantains follows the principles of Robinson (1996)
2. Based on the numbers of complements of the A and B genomes from ancestors species *Musa accuminata* colla (donor of A genome) and *M. balbisiana* colla (donor of B genome)
3. FHIA and SH series are hybrids from Fundacion Hondurena de Investigacion Agricola, Honduras; PITA and BITA series are hybrids from the International Institute of Tropical Agriculture, Nigeria; EMB and EMC hybrids are from Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) and Empresa Capixaba de Pesquisa Agropecuaria (EMCAPA), respectively, Brazil; others are landraces.

Table 2: Characterization of the study locations

Characteristics	Abuja	Ibadan	Onne
Latitude/Longitude	9° 16'N 7° 20'E	7° 30'N 3° 54'E	4° 51'N 7° 3'E
Altitude (m, a.s.l)	300	210	5
Agroecology	Southern guinea savanna	Derived savanna	Humid rain forest
Soil	Ferris luvisol	Alfisol	Ultisol
Maximum temperature range (°C)	26-34	20-35	28-32
Average relative humidity (%)	-	64-83	78-89
Annual solar radiation (MJ/m^3/year)	5846	5285	5060

Table 3: Correlation between corresponding plant and ratoon crops' traits

	Genomic group						
Traits	PH	PL	CBH	CBL	DBH	DBL	Combined#
DTF	0.69***	0.12	0.73***	0.82***	0.82***	0.91***	0.71***
DFF	0.55***	0.73***	0.82***	0.49**	0.65***	0.53*	0.69***
PHF	0.66***	0.74***	0.88***	0.76***	0.79***	0.82***	0.76***
HTSH	0.63***	0.08	0.87**	0.62***	0.76***	0.83***	0.75***
YLSF	0.20	0.33	0.26	0.51**	0.19	0.56**	0.28***
Bwt	0.35***	0.02	0.86***	0.77***	0.83***	0.51*	0.69***
Fwt	0.25*	0.73***	0.45*	0.81***	0.70***	0.29	0.62***
Hands	0.10	0.74***	0.74***	0.71***	0.84***	0.86***	0.33***
Fruits	0.61***	0.80***	0.76***	0.79***	0.85***	0.82***	0.82***

DTF: days to flowering; DFF; days for fruit filling; PHF: plant height at flowering (cm); HTSH; height of the tallest sucker at harvest of the plant crop (cm); YLSF: youngest leaf spotted at flowering; Bwt: bunch weight (kg/plant); Fwt: fruit weight (grams); hands: number of hands per bunch ; Fruits: numbers of fruits per bunch; PH: plantain hybrids; PL: plantain landraces; CBH: cooking banana hybrids, CBL: cooking banana landraces; DBH: dessert banana hybrids; DBL: dessert banana landraces;

#Combined: correlation analysis was performed on traits based on data from all genomic groups.
*, **, ***: Significant at 5%, 1% and 0.1% probability level respectively.

Table 4: Correlation between height of ratoon crop at harvest of plant crop with its phenological and yield traits.

	Genomic group						
Traits	PH	PL	CBH	CBL	DBH	DBL	Combined#
DTF	-0.58***	-0.50*	-0.42*	-0.53***	-0.34**	-0.36	-0.47***
DFF	0.35**	-0.40	0.67***	0.06	0.34**	-0.09	0.37***
PHF	0.66**	0.64**	0.86***	0.89***	0.71***	0.88***	0.77***
HTSH	0.63**	0.08	0.87***	0.62***	0.76***	0.83**	0.75***
YLSF	0.01	0.07	0.34	0.27	0.09	0.19	0.16**
Har-Har	-0.43***	-0.24	-0.63***	-0.73***	-0.31*	-0.60**	-0.47***
Bwt	0.35***	0.14	0.25	0.63***	0.04	0.58**	0.33***
Fwt	0.08	0.19	-0.10	0.04	0.00	-0.23	0.03
Fruits	0.46***	-0.05	0.44*	0.71***	0.17	0.77***	0.49***

DTF: days to flowering; DFF: days for fruit filing; PHF: plant height at flowering (cm); HTSH: height of the tallest sucker at harvest of the plant crop (cm); YLSF: youngest leaf spotted at flowering; Har-Har: days from harvest of the plant crop to the harvest of the ratoon crop; Bwt: bunch weight (kg/plant); Fwt: fruit weight (grams); fruits: number of fruits per bunch; PH: plantain hybrids; PL: plantain landraces; CBH: cooking banana landraces; DBH: dessert banana hybrids; DBL: dessert banana landraces;

#Combined: correlation analysis was performed on traits based on data from all genomic groups
*, **, ***: Significant at 5%, 1% and 0.1% probability level respectively.

cant relationship with previous height of the RC. of the RC. The number of fruits per bunch and bunch weight of the hybrid genotypes at PC were

Table 5: Correlation between black sigatoka disease resistance (measured as YLSF) of the plant crop and phenological and yield traits of the ratoon crop.

	Genomic group						
Traits	PH	PL	CBH	CBL	DBH	DBL	Combined
DTF	-0.31**	-0.19	-0.43*	-0.25	-0.26*	-0.01	-0.30***
DFF	0.14	-0.06	0.18	0.39*	0.27*	0.23	0.32***
PHF	0.28**	0.01	0.23	0.15	0.07	O.23	0.18**
HTSH	0.28*	-0.44	0.01	-0.06	0.05	0.12	0.11
YLSF	0.20	0.33	0.26	0.51**	0.19	0.56**	0.28**
Har-Har	0.12	0.10	0.01	-0.04	0.25	0.00	0.12
Bwt	0.23*	0.23	0.50*	0.54***	0.53***	0.17	0.44***
Fwt	0.33***	-0.05	0.22	0.31	0.61***	0.14	0.33***
Hands	-0.6	0.49	0.23	0.27	0.11	0.09	0.11
Fruits	0.07	0.16	0.33	0.25	0.10	0.10	0.18

DTF: days to flowering; DFF: days for fruit filing; PHF: plant height at flowering (cm); HTSH: height of the tallest sucker at harvest of the plant crop (cm); YLSF: youngest leaf spotted at flowering; Har-Har: days from harvest of the plant crop to the harvest of the ratoon crop; Bwt: bunch weight (kg/plant); Fwt: fruit weight (grams); Hands: number of hands per bunch; Fruits: number of fruits per bunch; PH: plantain hybrids; PL: plantain landraces; CBH: cooking banana landraces; DBH: dessert banana hybrids; DBL: dessert banana landraces;

*Combined: correlation analysis was performed on traits based on data from all genomic groups
*, **, ***: Significant at 5%, 1% and 0.1% probability level, respectively.

Correlation between YLSF of the PC and the phenology and yield traits of the RC

The youngest leaf spotted at flowering (YLSF) of the PC had no significant correlation with phenology and yield traits in plantain landraces but correlated significantly with bunch weight in cooking banana landraces and YLSF of dessert banana landraces (Table 5). Among the hybrid genotypes, days to flowering of RC had significant negative correlation with the YLSF of the PC. Similarly, bunch weight was significantly but positively correlated with YLSF of the PC (Table 5).

Correlation between phenology and yield traits of the PC with bunch weight of the RC

There were no PC traits that significantly correlated with the bunch weight of the RC in plantain landraces. (Table 6). In contrast, yield traits of PC of cooking banana landraces showed significant relationships with the bunch weight significantly correlated with the bunch weight of the RC (Table 6).

Path coefficient analysis to estimate direct and indirect effects of some plant crop traits on the bunch weight of the ratoon crop

Four PC traits were defined as pathways to bunch weight of the RC (Fig 1). Path coefficients estimated showed the relative importance of the traits (Table 7). Bunch weight of the PC was the highest indicator of the expected bunch weight of the RC. Also, height of the RC at the harvest of the PC had relatively high direct effect on its subsequent bunch weight. The direct effect of number of fruits per bunch of the PC on the bunch weight of the RC was negative. However, its positive indirect effect through the bunch weight of the PC indicated that, genotypes that had several fruits per bunch during PC also had heavy bunches. Heavy bunch weight of the PC demonstrated high positive direct effect on bunch weight of the RC (Table 7, Fig. 1).

Table 6: Correlation between plant crop phenological and yield traits and bunch weight of the ratoon crop.

	Genomic group						
Traits	PH	PL	CBH	CBL	DBH	DBL	Combined*
DTF	-0.35**	-0.03	-0.49*	-0.14	0.07	-0.28	-0.18
DFF	-0.0	0.16	-0.31	0.51***	0.09	0.22	0.23***
PHF	0.49***	0.09	0.24	0.30	0.31*	0.47*	0.26***
HTSH	0.35***	0.14	0.25	0.63***	0.04	0.58**	0.33***
YLSF	0.23*	0.23	0.50*	0.54***	0.53***	0.17	0.44***
Bwt	0.35	0.20	0.86***	0.77***	0.83***	0.51*	0.69***
Fwt	0.10	0.01	0.17	0.47**	0.80**	0.23	0.58***
Hands	0.10	0.26	0.72***	0.33*	0.59***	0.47*	0.22***
Fruits	0.53***	0.31	0.78***	0.32*	0.65***	0.58*	0.22***

DTF: days to flowering; DFF: days for fruit filing; PHF: plant height at flowering (cm); HTSH: height of the tallest sucker at harvest of the plant crop (cm); YLSF: youngest leaf spotted at flowering; Har-Har: days from harvest of the plant crop to the harvest of the ratoon crop; Bwt: bunch weight (kg/plant); Fwt: fruit weight (grams); Hands: number of hands per bunch; Fruits: number of fruits per bunch; PH: plantain hybrids; PL: plantain landraces; CBH: cooking banana landraces; DBH: dessert banana hybrids; DBL: dessert banana landraces;

*Combined: correlation analysis was performed on traits based on data from all genomic groups

*, **, ***: Significant at 5%, 1% and 0.1% probability level, respectively.

Table 7: Path coefficients of bunch weight of first ratoon crop showing components of direct and indirect effects based on plant crop traits. Analysis was based on data from 36 *Musa* genotypes grown in four environments in Nigeria

	Path coefficients by traits				
Traits[1]	Bwt	YLSF	HTSH	Fruits	Correlation[3]
Bwt	**0.89**[2]	0.05	0.05	-0.30	0.69
YLSF	0.28	**0.17**	0.08	-0.09	0.44
HTSH	0.13	0.04	**0.34**	-0.18	0.33
Fruits	0.55	0.03	0.13	**-0.49**	0.22
Residual					0.30

[1]Bwt: bunch weight; YLSF: number of the youngest leaf spotted at flowering; HTSH: height of the tallest sucker at the harvest of the plant crop; Fruit: number of fruits per bunch.

[2]Values on the diagonal (highlighted) are direct effects of the components on bunch weight of the ratoon crop; off-diagonal values are indirect effects through the specific path.

[3]Correlation between specific plant crop traits and bunch weight of the ratoon crop.

Discussion

The ratooning system in *Musa* spp. ensure a continuous physiological link between the mother plant and its sucker. As a consequence the mother plant influences the ratoon plant. Therefore, significant plant and ratoon crops traits correlation as observed in this study is justified. Earlier reports (Swennen & De Langhe, 1985; Baiyeri and Ortiz, 1995) indicate that suckers are sinks and so depended on the mother plant during early growth. To a large extent therefore, the phenology and yield performance of the ratoon crop should have some relationships with plant crop traits due to their physiological interdependence.

Genomic differences in correlated traits and in coefficient of correlation might be related to their physiological genetic differences. In most cases, plantains had fewer and weaker correlation suggesting that their phenotypic expression was highly variable across crop cycles. Bradshaw (1965) reported that population and species show different levels of plasticity for the same character in response to the same environmental variable.

The significant negative correlation between height of RC plant at harvest of the PC with days to flowering and harvest interval of the RC showed that vigorous earlier growth of the RC will lead to its earlier flowering thereby reducing harvest interval between crop cycles.

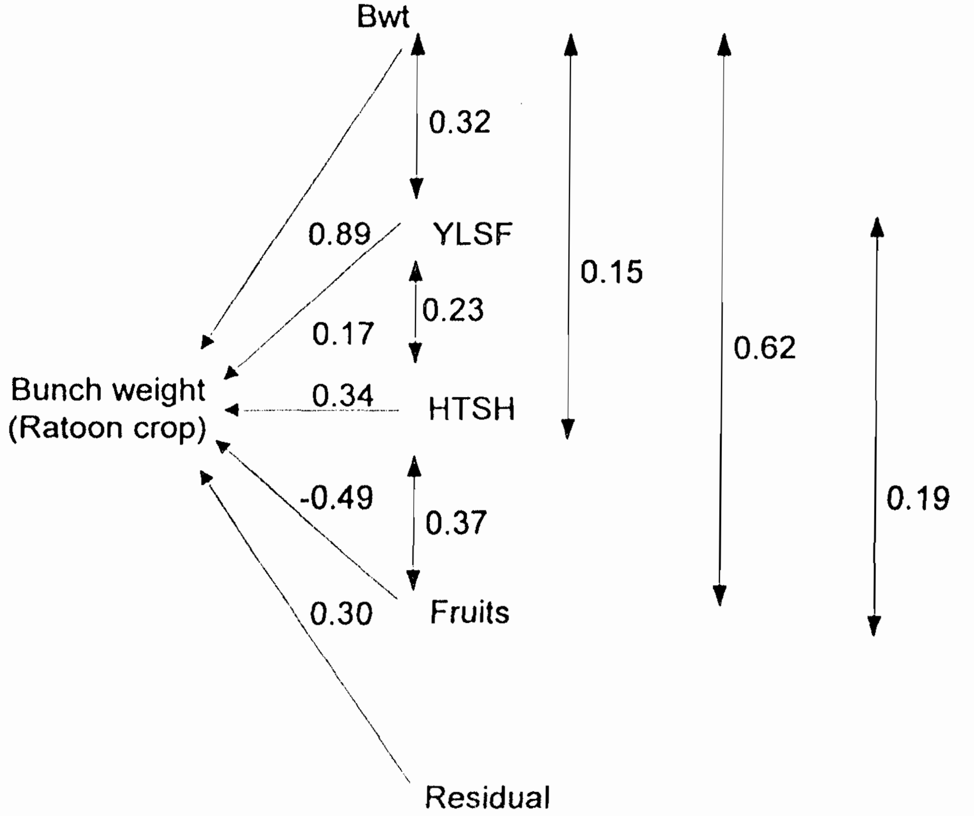

Fig. 1: Path diagram showing causal relationship between four predictor variables and the response variable. The residual is the undetermined portion. The double-arrowed lines indicate mutual association as measured by correlation coefficient, and the single-arrowed lines represent direct influence as measured by path correlation coefficient. The predictor variables are from the plant crop while the response is the ratoon crop bunch weight.

Bwt: bunch weight; YLSF: youngest leaf spotted at flowering; HTSH: height of the tallest sucker at harvest of the plant crop; Fruits: number of fruits per bunch.

Besides, it suggests that selecting suckers for RC early in season while other competing suckers are pruned will ensure vigorous growth of the ratoon plant and enhance its yield. This was seen in the significant positive correlation between the earlier height of the ratoon plant (HTSH) and its subsequent yield.

Black sigatoka disease resistance status (measured as YLSF) of the PC was an important predictor of the performance of the ratoon crop except in plantain landraces. High YLSF of the PC led to earlier flowering and heavy bunch weight of the RC of the hybrid genotypes. This implies that sustainable performance across crop cycles is associated with health status of the previous crop (in our case, the PC). Thus, diseased PC will produce weak RC plant that would yield poorly. In contrast, healthy PC (either via agronomic manipulation or genotype selection) will partition adequate photosynthate to the RC plant, vigorous ratoon plant will flower early and produce heavy bunches.

Pathways defined could suggest agronomic manipulations during the PC that will boost the performance of the RC. For example, high direct effect of bunch weight of PC on the bunch weight of the RC could imply that management options that supported the yield of the PC if maintained would ensure high yield of the RC. Also, it could mean that once a plant crop produces an acceptable yield, the ratoon will produce equally heavy or even heavier bunches (Swennen & De Langhe, 1985).

This study showed that to a obtain good performance of the ratoon crop, the PC must have had healthy and vigorous growth. Besides, yield of the PC was indicative of the RC yield. Therefore, selecting vigorous ratoon plant early in season and embarking on crop management options that will increase the YLSF of the mother plant will sustain high yield in *Musa* genotypes.

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