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Yield performance of East African highland banana hybrids on farmers' fields under high disease pressure

Erima, R.[1,2*], Ssebuliba, J. M.[2], Nankinga, C. M. K.[1], Ragama, P.[1,3], Barekye, A.[1] and Tushemereirwe, W.[1]

[1]National Banana Research Programme, National Agricultural Research Organisation, P. O. Box 7065, Kampala, Uganda.
[2]Department of Crop Science, Makerere University, P. O. Box 7062, Kampala, Uganda.
[3]Kabarak University, Private Bag, 20157, Kabarak, Nakuru, Kenya.

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The production of the East African highland cooking banana is constrained by pests, diseases and narrow genetic base amongst others. Research to develop resistant / tolerant genotypes has been on going at Kawanda. 18 promising banana hybrids have been identified. The hybrids were planted on farmers' fields in Kasangombe Sub-county in central Uganda for evaluation against black Sigatoka and yield. Data were collected on some of the agronomic traits, banana weevil damage and response to black Sigatoka disease on the plant and first ratoon crops. The data were analysed using mixed model procedures on SAS software. Means within each crop cycle were separated by comparing hem to Mbwazirume using adjustment to Dunnett's Test at 5% level of significance. The hybrids had more functional leaves (at least 9) compared to Mbwazirume (approximately 8 leaves). Youngest leaf spotted was significantly higher in the hybrids. All the hybrids except 2734K-1 retained significantly higher number of leaves at harvest (approximately 3 leaves). Most of the hybrids produced bigger bunches (at least 16 kg and 19 in the plant crop and first ratoon respectively) and the yield (t/ha/yr) of the banana hybrids was also higher compared to Mbwazirume. A Bi-plot of principal component analysis 1 against principal component analysis 2 showed that banana hybrids 12419S-13, 2625K-1 and 7798S-2 displayed very good agronomic traits in terms of plant height, girth and bunch weights. They also appeared to be tolerant to black Sigatoka disease as compared to Mbwazirume. These could be recommended for further evaluation with farmers to establish their culinary qualities and acceptability.

Key words: East African highland banana hybrids, black Sigatoka disease.

INTRODUCTION

The East African highland cooking banana (*Musa* spp., AAA-EA) is an important food crop as well as a source of income for over 20 million small scale farmers in the Great Lakes region of Eastern Africa. In Uganda, over 7

*Corresponding author. E-mail: erima_r@kari.go.ug. Tel: +905073818713.

Million people including 65% of the urban population depend on banana as their staple food (Tushemereirwe et al., 2003).

Annual production is estimated at 8.45 million tons, accounting for 15% of the total banana /plantain output. The popularity of this perennial crop has spread throughout the country because of its multiple uses and ability to provide food and cash all year round. Most people in Uganda and the great lakes region use the term ‘food’ and ‘matooke’, (cooked banana) interchangeably (Karugaba and Kimaru, 1999). However, the production of East African highland bananas is declining due to declining soil fertility, pests and diseases, poor planting materials, post-harvest handling, poor husbandry practices, socio-economic issues, marketing constraints and poor rural road networks (Karugaba and Kimaru, 1999).

Banana weevil (*Cosmopolitis sordidus, Gemar*) and black Sigatoka are some of the major banana pests and diseases. Banana weevils cause premature death of the plant, delayed maturation of fruits and production of small bunches of low economic value. This accounts for 45% of yield loss in bananas (Rukazambuga, 1996). On the other hand, black Sigatoka has been reported to cause yield decline of 30 to 50% on plantains (Mobambo et al., 1993), while Tushemereirwe (1996) reported a yield loss of 37% on East African Highland bananas.

A number of control options have been used to manage banana weevils and black Sigatoka disease. For instance habitat management, trapping, use of clean planting materials, natural enemies and pesticides were employed in the control of banana weevils. While management of black Sigatoka disease was mainly through the use of fungicides and de-leafing.

In general, these control options have been less efficient or they are not user friendly due to socio-economic reasons (Craenen, 1998, Gold et al., 1999). Therefore, National Agricultural Research Organisation (NARO) has opted for use of host plant resistance.

Through convectional breeding, National Banana Research Programme and International Institute of Tropical Agriculture (IITA) developed some promising hybrids derived from East African highland banana crosses at National Agricultural Research Laboratories (NARL), Kawanda. Therefore, this study aims to evaluate banana hybrids response to black Sigatoka and yield on farmers’ fields.

MATERIALS AND METHODS

Study site selection

The study sites were selected in Kasangombe Sub-county; Nakaseke District in Central Uganda. The sub-county is at an altitude of 1311metres above the sea level, about 0°56'N of latitude and longitude 32°42'E; with mean annual rainfall range between 1200 to 1375 mm, and average temperatures of 17.5 and 28°C minimum and maximum respectively.

This is one of the ‘hot-spots’ of black Sigatoka disease and banana pests.

Farmer selection and banana hybrids

A multistage stratified sampling method was used to select 15 farmer fields for the study. A list of Parishes within the sub county was produced, out of which three parishes were randomly selected. A total of 15 farmers that is, 6 farmers from Nakaseeta Parish, 5 farmers from Bulyake Parish and 4 farmers from Bukuku Parish were randomly selected. The number of farmers per parish was based on the number of banana farmers per parish.

Eighteen (18) East African highland banana hybrids namely; 2729K-1, 2729K-2, 2625K-1, 2734K-1, 11777S-6, 9540S-2, 9494S-36, 12478S-13, 12419S-13, 9509S-5, 365K-1, 2409K-3, 7798S-2, 8386S-19, 9187S-8, 9494S-10, 9750S-13 and 2695K-4 were evaluated against two local checks (Mbwazirume and Kisansa). These derived hybrids were triploids which were a product of first crossing land races (East African highland bananas triploids, AAA) with either Calcutta 4 or *Musa acumiunata burmanica* (diploids) to get the tetraploid hybrid bananas. The tetraploid hybrids were further crossed with the male diploid bananas to obtain the triploid hybrids.

The bananas hybrids were planted in the farmers’ fields in September, 2005. An augmented incomplete block experimental design was used. Each of the farmer’s field per parish was randomly assigned four different hybrids and two local checks (Mbwazirume and Kisansa) used as controls. Each hybrid and the local checks comprised of 12 plants. These were planted in holes of 60 cm wide by 60 cm deep dug manually at a spacing of 3 x 3m between and within the plants. A total of 72 plants per farmer’s field were established.

Data collection

Agronomic traits

A data collection sheet was designed and used in collecting growth and yield (agronomic) data for two consecutive plant cycles (plant crop and first ratoon crop). The dates on which the plantlets were planted and when the sucker for the next cycle emerged from the soil were recorded. These dates were taken to be the planting dates for the plant crop and first ratoon crop respectively, and they were used to calculate the yields in the plant crop and first ratoon crop.

Agronomic traits of the banana hybrids were recorded at flowering and harvest. On the day of flowering, the pseudostem height and circumference (girth) was gotten. The pseudostem height was determined using a calibrated pole of 3 m at a precision of 5 cm interval from ground level up to the level of inflorescence (point where the unfurled leaf forms a V-shape with the last open leaf). While the girth was measured and recorded on fully round part of the pseudostem, 100 cm above the ground using a standard tape measure.

On the day of harvesting, the following parameters were recorded: harvest date, the weight for each harvested bunch was taken using a Spring-Dial Host scale. The physiological maturity of bunches was established when the colour of one of the fingers on the first hand begun to turn from green to yellow. The yield (tons/ha/year) for each banana hybrid was then calculated according to Noupadja and Tomekpé (2000) for each crop cycle (Plant crop and first ratoon crop):

$$\text{Yield} = (\text{Plant density} \times 365 \text{ days} \times \text{bunch weight (kg)}) / 1000 / \times \text{period from planting to harvest} \quad (1)$$

Where period from planting to harvest (days) = Date of harvest –

Date of planting

Black sigatoka disease assessment

Assessing the response of banana hybrids to black Sigatoka disease, data were collected on the following parameters: number of functional leaves (NSL) and youngest leaf spotted (YLS) at flowering, and the number of functional leaves at harvest of the plant crop and the first ratoon crop. The number of functional leaves were physically counted and recorded for each plant on the date of its flowering. Leaves with more than 50% of non-functional surface area were considered dead. YLS was determined by physically counting down from the first unfurled leaf. For instance in the resistant plants, it will be on the older leaves and the opposite is true for susceptible plants. The YLS had at least ten discrete, necrotic lesions or one large necrotic area with ten light coloured dry centres. YLS and NSL were used to calculate the index of non-spotted leaves (INSL) (Carlier et al., 2003).

$$\text{INSL} = 100 - 100x\left[\left(NSL - YLS + 1\right)/NLS\right] \quad (2)$$

This index, provide an estimation of available photosynthetic leaf area prior to fruit filling and it is a measure of resistance (Carlier et al., 2003).

On the date of harvesting, the number of functional leaves were also physically counted and recorded on every harvested plant, since there is no leaf replacement after flowering of bananas. The numbers of functional leaves at harvest indicate how fast the disease progresses in the plant. According to Barekye et al. (2002), the disease progresses fast in susceptible plants causing rapid loss of leaves so that by harvest time only few leaves or none remain on the banana plant.

Weevil damage assessment

Weevil damage assessment was done according to Rukazambuga (1996), two cross sections were made at pseudostem base or the collar region (upper cross- section) and 5 cm below the pseudostem (lower cross-section). The percentage of tissue consumed by the weevils was estimated by consolidating the consumed area in each cross section. To obtain the inner section damage (central cylinder, XI); the upper and lower inner damage were averaged. Also, the average of the upper and lower outer portions gave percentage corm damage in the outer (cortex) section (XO). Calculating the total cross-sectional damage (XT), the inner (XI) and outer (XO) percentage corm damage were added together and then divided by 2 for every harvested plant.

Data analysis

Response variables for growth parameters, yield components, and disease scores were checked for normality and found to be relatively normally distributed necessitating no transformation. Exploring the effect of farms on genotype performance was done by exposing the data to analysis of variance (ANOVA) using a general linear model (GLM) using SAS software (SAS Institute Inc., 2008) with genotype, crop cycles and their interactions being fixed while farms nested in sites were taken as random. This analysis was based on assumption that farms are a random sample of many possible farms. Means within each crop cycle were separated by comparing to a standard check (Mbwazirume) using adjustment Dunnett's Test at 5% level of significance.

Multivariate analysis

Prior to the stepwise regression analysis, corm damage scores were first transformed using arcsine-transformation to reduce non-normality and heterogeneity of variance. All the data collected on the agronomic variables (height, girth, bunch weight and yield), weevil damage (XI, XO and XT) and black sigatoka disease scores (NSL at flowering, YLS, NSL at harvest and INSL) were then subjected to stepwise regression analysis. This was to remove variables that were highly correlated and carried similar information. To enhance the dispersion of banana hybrids to the agronomic traits, principal component analysis (PCA) was done on the variables that were retained by stepwise regression. The principal component axis was then plotted on a bi-plot to this effect.

RESULTS

Agronomic traits

Plant height, girth at 100 cm above the ground at flowering and the bunch weight of the banana hybrids are presented in Table 1. The height of banana hybrids at flowering was significantly different from that of Mbwazirume (286.33 cm) with hybrids12419S-13 and 7798S-2 being significantly taller in both the plant crop and first ratoon. Plant crop of Kisansa was also significantly taller than Mbwazirume, while banana hybrids 2729K-1, 9509S-5, 2409K-3, 9187S-8, 9494S-10, 2695K-4, 9540S-2, 9494S-36 and 12478S-13 and first ratoon crop of banana hybrids 9509S-5, 2409K-3, 9494S-36 and 12478S-13 were significantly shorter .

In general, most of the banana hybrids had small girths in both the plant and first ratoon crops. The pseudostem circumference (girth) for the banana hybrids ranged from 34.27 to 69.70 cm over the two seasons. The plant and first ratoon crops of banana hybrids 2729K-1, 9509S-5, 365K-1, 2409K-3, 8386S-19, 9187S-8, 9494S-10, 9750S-13, 2695K-4, 2729K-2, 2734K-1, 11777S-6, 9540S-2, 9494S-36 and 12478S-13 had significantly smaller girths compared to that of Mbwazirume (54.8 cm). Banana hybrids 7798S-2 and 12419S-13 had the largest pseudostem circumference amongst the hybrids in both the plant and first ratoon crops but they were not significantly different from Mbwazirume (Table 1).

The bunch weights of all the banana hybrids except the plant crop of banana hybrids 9509S-5, 2409K-3, 9540S-2 and 12478S-13 and the ratoon crop of 9540S-2 were heavier than that of Mbwazirume. The plant crop of banana hybrids 2625K-1, 9494S-36 and 12419S-13 were significantly heavier than that of Mbwazirume (13.9 kg). Banana hybrid 12419S-13 had the biggest bunch (24.3 kg). The plant crop of Kisansa was also heavier than Mbwazirume but it was not significantly different from it. In the first ratoon crop banana hybrids produced bunches that ranged from 17.3 to 26.3 kg. Banana hybrid 2729K-2 had the biggest bunch (26.3 kg). But they were not significantly different from that of Mbwazirume (17.8 kg) (Table 1).

The yield (t/ha/yr) of most banana hybrids was higher

Table 1. Means (n=1080) of the agronomic and yield parameters for East African highland banana derived hybrids by crop cycles compared to Mbwazirume in Kasangombe Sub County, Nakaseke District.

Genotype	Plant crop				First ratoon			
	Height (cm)	Girth (cm)	Bunch Weight (kg)	Yield (Tones/ha/yr.)	Height (cm)	Girth (cm)	Bunch weight (kg)	Yield (Tones/ha/yr.)
Mbwazirume	286.3	54.8	13.9	10.2	332.4	66.6	17.8	14.2
Kisansa	311.2*	51.9	15.8	11.5	343.4	58.3*	17.6	13.5
2729K-1	244.3*	42.7*	18.9	13.5	293.2	51.2*	21.8	16.3
9509S-5	217.1*	34.3*	11.1	8.8	272.8*	44.1*	20.4	16.9
365K-1	254.8	44.6*	14.4	11.2	307.5	54.0*	20.0	16.9
2409K-3	222.6*	35.2*	11.9	9.7	278.4*	45.6*	19.6	16.3
7798S-2	336.7*	57.4	17.6	13.1	402.6*	69.7	-	-
8386S-19	280.4	46.7*	16.3	12.4	347.7	58.5*	24.9	19.9
9187S-8	252.6*	42.4*	16.5	12.2	307.4	54.9*	23.3	18.5
9494S-10	246.3*	39.6*	17.9	13.6	279.2*	47.0*	24.1	18.6
9750S-13	275.3	42.6*	19.5	15.2*	326.4	51.5*	22.7	18.4
2695K-4	249.1*	46.0*	18.1	13.4	306.9	56.7*	23.7	19.2
2729K-2	269.5	44.3*	18.9	14.8	318.4	53.3*	26.3	20.7
2625K-1	300.4	49.1	21.3*	16.5*	343.3	58.7*	23.2	18.3
2734K-1	257.9	43.7*	16.4	12.6	318.4	52.3*	19.9	16.3
11777S-6	292.1	44.6*	17.9	13.4	345.4	53.8*	19.8	15.4
9540S-2	254.0*	36.7*	13.0	10.2	302.0	43. 5*	17.3	14.5
9494S-36	249.0*	45.8*	20.7*	16.4*	280.6*	50.8*	22.0	18.3
12478S-13	230.9*	40.3*	13.4	10.4	286.3*	51.5*	19.0	15.3
12419S-13	342.6*	56.0	24.3*	17.0*	381.9*	63.1	25.9	18.6

*Means within the same column are significantly different from Mbwazirume, - missing data.

than that of Mbwazirume in the two cycles. But only the plant crop of banana hybrids 9750S-13, 2625K-1, 9494S-36 and 12419S-13 had significantly higher yield (Table 1).

Response to black Sigatoka disease

Table 2 shows the number of functional leaves at flowering, harvest and the scores for the youngest leaf spotted. The plant crop of banana hybrids 9509S-5, 365K-1, 2695K-4 and 9540S-2 displayed significantly higher number of functional leaves than the local check (Mbwazirume). Banana hybrid 8386S-19 had the highest number of functional leaves (approximately 12 leaves). While the first ratoon crop of banana hybrids 9509S-5, 2409K-3, 8386S-19, 9187S-8, 9494S-10, 9750S-13, 2729K-2, 2625K-1, 11777S-6, 9540S-2, 12478S-13 and 12419S-13 produced significantly higher number of functional leaves at flowering than Mbwazirume. Banana hybrid 12478S-13 had the highest number of leaves (approximately 13) on the day of flowering. But the local checks (Kisansa and Mbwazirume) had almost the same number of functional leaves at flowering (Table 2).

In addition to what was earlier mentioned all the banana hybrids displayed significantly higher scores of youngest leaf spotted when compared to Mbwazirume and Kisansa in both the plant and first ratoon crops. However, the ratoon crop of banana hybrid 2734K-1 was not significantly different from Mbwazirume. Banana hybrid 8386S-19 and 12478S-13 had the highest score of youngest leaf spotted in the plant crop and first ratoon crop respectively (Table 2).

Index of non-spotted leaf was also significantly higher for the banana hybrids in both the plant crop and the first ratoon crop than Mbwazirume (Table 2). Banana hybrid 9494S-10 and 8386S-19 had the highest index of non-spotted leaf in the plant crop and first ratoon crop respectively. Also the plant crop of Kisansa had significantly higher index of non-spotted leaf compared to Mbwazirume.

At harvest, all banana hybrids except 2734K-1 had significantly more functional leaves in both the plant and first ratoon crops. The plant crop of banana hybrids 12478S-13 and 2729K-2 retained the highest number of leaves (approximately 6 leaves). Banana hybrid 7798S-2 and 9540S-2 retained the least number of leaves (approximately 3 leaves). In the first ratoon crop banana hybrids 2729K-2, 12478S-13 and 9494S-10 retained the highest number of leaves (approximately 5 leaves). Banana hybrid 2625K-1 retained the least number of leaves (approximately 3 leaves) (Table 2).

Table 2. Mean (n=1080) number of functional leaves at flowering and harvest of East African highland banana hybrids and the scores for the youngest leaf spotted on the plant crop and first ratoon crop.

Genotype	Plant crop				First ratoon crop			
	Number of functional leaves at flowering	Youngest leaf spotted	Index of non-spotted leaf	Number of functional leaves at harvest	Number of functional leaves at flowering	Youngest leaf spotted	Index of non-spotted leaf	Number of functional leaves at harvest
Mbwazirume	7. 9	4.6	46.0	1.7	7.7	4.6	45.5	1.6
Kisansa	8.0	5.2	53.1*	1.3	7.6	4.7	48.6	1.5
2729K-1	10.2*	9.3*	82.6*	3.6*	9.5	9.1*	85.3*	3.9*
9509S-5	9.6	8.8*	79.1*	4.4*	11.4*	11.0*	85.9*	4.0*
365K-1	9.4	8.4*	77.8*	4.4*	8.9	8.0*	79.2*	4.3*
2409K-3	9.7*	8.7*	79.3*	4.0*	11.9*	9.8*	74.8*	3.5*
7798S-2	11.0*	9.1*	75.5*	3.3*	10.2	8.4*	69.3*	-
8386S-19	12.1*	10.8*	80.5*	4.4*	12.5*	12.1*	89.7*	3.5*
9187S-8	10.8*	10.3*	85.8*	3.7*	10.4*	10.1*	86.9*	4.4*
9494S-10	10.9*	10.5*	87.3*	5.2*	11.2*	11.0*	88.8*	5.4*
9750S-13	11.0*	10.2*	85.7*	4.7*	10.7*	10.5*	89.0*	4.1*
2695K-4	9.2	8.5*	82.4*	4.0*	9.5	8.7 *	80.9*	3.7*
2729K-2	11.4*	10.3*	83.3*	5.6*	11.7*	11.1*	86.1*	5.3*
2625K-1	10.0*	9.6*	85.3*	3.5*	10.2*	9.2*	80.7*	3.4*
2734K-1	10.1*	7.6*	65.0*	1.3	8.9	6.3	58.9*	1.3
11777S-6	11.8*	9.5*	72.9*	4.2*	10.6*	9.0*	76.7*	4.6*
9540S-2	9.2	8.6*	81.9*	3.3*	10.85*	9.3*	76.1*	3.5*
9494S-36	10.3*	9.5*	82.2*	3.5*	9.5	8.7*	81.4*	3.6*
12478S-13	11.2*	10.4*	84.1*	5.5*	12.7*	12.6*	89.0*	5.4*
12419S-13	11.9*	9.4*	71.6*	4.1*	11.1*	9.9*	79.7*	5.1*

*Means within the same column are significantly different from Mbwazirume, - missing data.

Multivariate analysis

From the stepwise regression analysis only plant height, girth and number of functional leaves at flowering, index of non-spotted leaf and total cross section damage greatly influenced the yield of the hybrids (Table 3). The principal component analysis (PCA) based on a correlation matrix between the agronomic variables and total cross section damage, showed that all variables except total cross section damage positively influenced bunch weight (Table 4).

PCA grouped the agronomic variables, disease and weevil total cross sectional damage variables into six components that together accounted for 100% of the original variation (Table 5). However, three principal components were retained as these accounted for 88.79% of the total variability in the data, where PCA 1 accounted for 48.42% of the total variation, while PCA 2 accounted for 31.93% and PCA 3 accounted for 8.44% of the total variation.

PCA components presented in Table 5 can therefore be interpreted as correlations between

Table 3. Parameter estimates of variables that affect banana yield (bunch weight) of East African highland banana derived hybrids using stepwise regression analysis

Variable	Parameter estimate	Standard error	Type II SS	F -Value	Pr > F
Intercept	-14.86121	1.49795	3070.89513	98.43	<.0001
Girth	0.32850	0.02873	4078.93230	130.74	<.0001
Height	0.01805	0.00517	379.66705	12.17	0.0005
Number of functional leaves at flowering	0.72701	0.07648	2818.96030	90.35	<.0001
Index of non-spotted leaf	0.07781	0.01051	1711.16966	54.85	<.0001
Total cross section damage	-0.08527	0.03311	206.94301	6.63	0.0101

Table 4. Correlation coefficient between agronomic and weevil damage variables of the data collected from East African highland banana derived hybrids in Kasangombe Sub-county, Nakaseke District.

Variable	Bunch weight	Girth	Height	Number of functional leaves at flowering	Index of non-spotted leaf	Total cross section damage
Bunch weight	1.00	-	-	-	-	-
Girth	0.31	1.00	-	-	-	-
Height	0.41	0.85	1.00	-	-	-
Number of functional leaves at flowering	0.36	-0.26	-0.02	1.00	-	-
Index of non-spotted leaf	0.39	-0.51	-0.36	0.71	1.00	-
Total cross section damage	-0.17	0.48	0.32	-0.57	-0.60	1.00

Table 5. Eigenvectors of principal component analysis using agronomic, disease and weevil damage variables.

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Bunch weight	-0.07	0.62	0.59	-0.31	-0.39	0.10
Girth	0.46	0.39	-0.15	-0.04	0.50	0.60
Height	0.37	0.50	-0.34	0.05	0.01	-0.70
Number of functional leaves at flowering	-0.41	0.38	-0.41	0.57	-0.33	0.29
Index of non spotted leaf	-0.51	0.23	0.33	0.24	0.69	-0.23
Total cross section damage	0.47	-0.12	0.49	0.72	-0.11	-0.02
Percentage of total variation:	48.42%	31.93%	8.44%	6.83%	2.56%	1.82%
Eigen Value:	2.9	1.9	0.5	0.4	0.2	0.1

bunch weight, growth, disease and pest parameters with the components. The first PCA (PC 1) is about the performance for growth parameters; Girth (with 0.46 loading) and height (with 0.37 loading) and banana weevil damage scores (with 0.47 loading) contrasted by disease score parameters (functional leaves (with -0.41 loading) and index of non-spotted leaf (with -0.51 loading). The second PCA is about the performance of bunch weight and growth parameter both have large positive loadings (Table 5). This was then put on a bi-plot of PC1 and PC2 against the hybrids (Figure 1). Hybrids (12419S-13, 2625K-1 and 7798S-2) are grouped in the first quadrant. While hybrids (9509S-5, 9540S-2, 12478S-13 ,2409K-3, 2729K-1 and 9187S-8) in third quadrant. On the other hand, hybrids 2695K-4, 2734K-1 and 365K-1 were grouped together so are the local checks (Mbwazirume and Kisansa) but these two groups are in the second quadrant. Hybrids 9494S-36, 11777S-6, 9494S-10, 9750S13, 8386S-19 and 2729K-2 are grouped in the fourth quadrant.

Girth, index of non-spotted leaves and total cross sectional damage contributed higher in the first PCA (PC 1). Height and bunch weight had higher loading in the second PCA (PC 2). Bunch weight and total cross

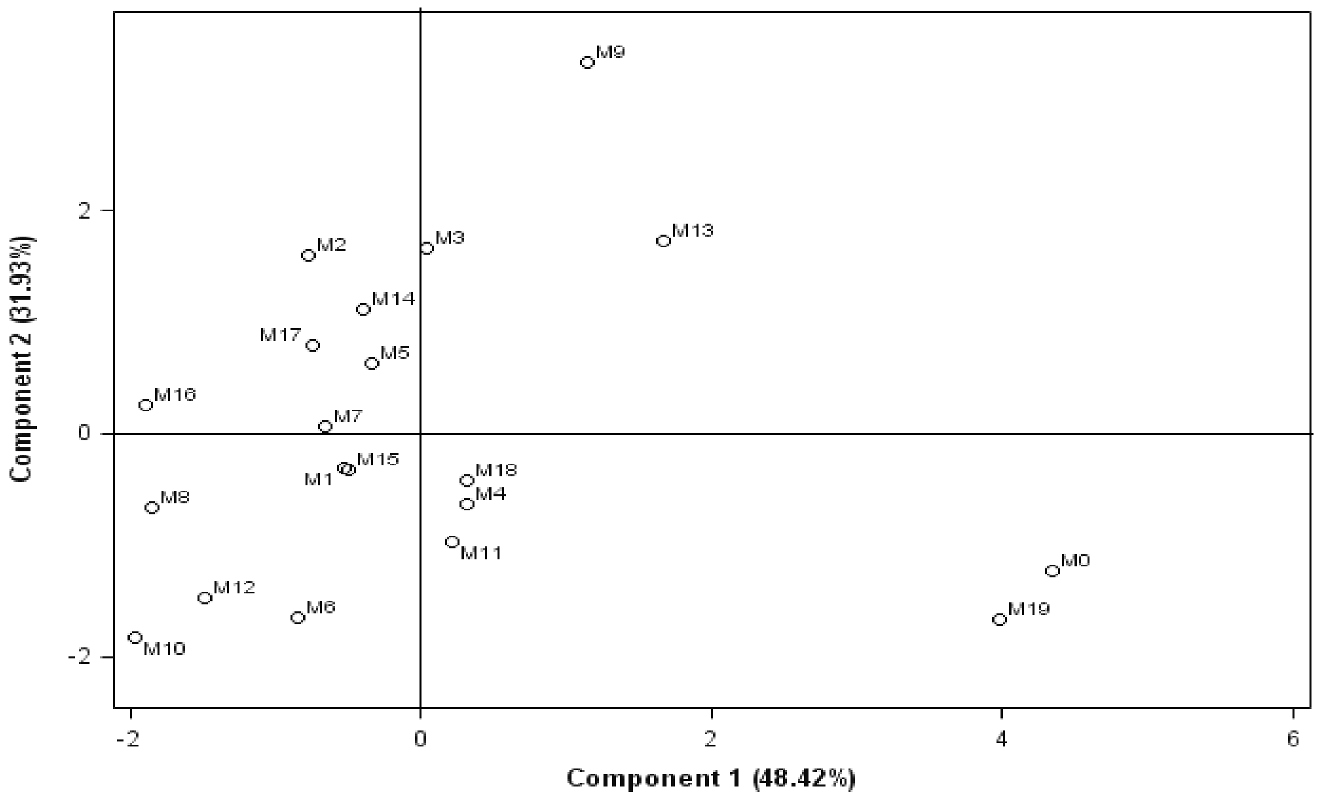

Figure 1. Plot of first (PC1) and second (PC2) principle components from a principal component analysis of agronomic, black Sigatoka disease and one weevil damage variables of East African highland banana derived hybrids in Kasangombe sub county, Nakaseke District. (Codes for the hybrids / genotypes: M0 = Kisansa M10 = 9509S-5; M1 = 2729K-1 M11 = 365K-1; M2 = 2729K-2 M12 = 2409K-3; M3 = 2625K-1, M13 = 7798S-2; M4 = 2734K-1, M14 = 8386S-19; M5 = 11777S-6, M15 = 9187S-8; M6 = 9540S-2, M16 = 9494S-10; M7 = 9494S-36, M17 = 9750S-13; M8 = 12478S-13, M18 = 2695K-4; M9 = 12419S-13, M19 = Mbwazirume.

sectional damage had higher loading in the third PCA (PC3) (Table 5). A bi-plot of PC1 and PC2 against the hybrids, grouped banana hybrids 12419S-13, 2625K-1 and 7798S-2 in the first quadrant . While hybrids 9509S-5, 9540S-2, 12478S-13, 2409K-3, 2729K-1 and 9187S-8 in third quadrant (Figure 1). On the other hand, banana hybrids 2695K-4, 2734K-1 and 365K-1 were grouped / clustered together so are the local checks (Mbwazirume and Kisansa) but these two groups are in the second quadrant . Banana hybrids 9494S-36, 11777S-6, 9494S-10, 9750S13, 8386S-19 and 2729K-2 are grouped in the fourth quadrant. These two groups are placed on the second axis (Figure 1).

DISCUSSIONS

All the banana hybrids except 7798S-2 and 12419S-13 were short but they were within the expected heights (≤ 3m) (Jones 1994). They also had smaller pseudostems, suggesting that only banana hybrids7798S-2 and 12419S-13 had an advantage of big support in the soil, and this could also make them more tolerant to snapping due to wind or storm, one of the causes of yield loss in banana plantations (Stover and Simmonds, 1987). Thus some of these losses are reduced and translated into economic benefits for commercial growers but also enhanced food security for subsistence farmers (Daniels, 2002). These hybrids can further support heavier bunches without any form of bunch support like wooden props (Alvarez, 1997; Daniels, 2002). Similarly, Mukasa et al. (2005) reported that for successful perennial establishment of *Musa* plants accompanied by high yields depends on good root and shoot development in combination with good suckering.

Bunches of most banana hybrids were generally heavier than Mbwazirume. The development of a big / heavy bunch in bananas depends on the photosynthetic potential of the leaves. An increase in banana leaf area results in an increase in fruit production but this parameter will have some location specificity as photosynthetic activity is a function of leaf area and incident solar radiation (Smithson et al., 2001). The size of a bunch would influence consumer preference and according to Thompson and Wainwright (2007) most banana producers and consumers prefer cultivars with big bunches. This probably puts the hybrids 12419S-13, 9494S-36, 2625K-1, 9750S-13, 2729K-1, 2695K-4 and 2729K-2 at an advantage of being preferred by consumers.

Yield of most banana hybrids in both the two cycles were above the national average yield (14.9 tonnes per ha.) for bananas (Uganda National Household Survey Report 1995-96; Bagamba, 2007). The high yields could be due to the big bunches produced coupled with short production cycle. This was in agreement with Bananuka et al. (2000) who reported that large bunch weight and yield in bananas is attributed to higher growth rate before flowering and high number of functional leaves at flowering and harvest.

Most of the banana hybrids had many functional leaves (at least 9) at flowering compared to local checks. To guarantee good development of the bunch and high quality fruits, a plant must have at least 8 functional leaves during its whole growth period and similar number of healthy at flowering (Ortiz and Vuylsteke 1994; Orjeda 1998; Tushemereirwe et al., 2003). The presence of many leaves in these hybrids may be explained by the fact that they were less susceptible to black Sigatoka disease at flowering. This was further supported by high scores of youngest leaf spotted (YLS) at flowering. Basing on Craenen (1998) levels of host response to black Sigatoka disease, banana hybrids can therefore be categorized as follows: 2734K-1 was susceptible hybrid (< 8 leaves without symptoms); 2729K-1, 9509S-5, 365K-1, 2409K-3, 7798S-2, 2695K-4, 2625K-1, 11777S-6, 9540S-2, 9494S-36 and 12419S-13 were less susceptible hybrids (between 8 – 10 leaves without spots) while 12478S-13, 2729K-2, 9750S-13, 9494S-10, 9187S-8 and 8386S-19 were partially resistant (>10 leaves without spots). The higher the number of youngest leaf spotted and functional leaves at harvest the better the tolerance to black Sigatoka (Barekye et al., 2002). It also correlates significantly with disease development time (Craenen, 1998). This implied that most of the banana hybrids (>8 leaves without spots) were less affected by the necrotic effect of the fungus (*Mycosphaerella fijiensis*), so the foliage of these plants remains green for long time hence less frequency of deleafing. Consequently, the banana hybrids had high index of non-spotted leaf because of high surface area to capture more radiant energy from the sun. They therefore had better potential of photosynthesizing and producing more assimilates which eventually turns into a big bunch. The opposite was true with the local checks (Mbwazirume and Kisansa).

In addition to what was earlier mentioned, the principal component analysis based on a correlation matrix between the agronomic and total cross section damage was in agreement with the study of Mukasa et al. (2005) who also reported that for successful perennial crop establishment of *Musa* plants, high yields depends on good root and shoot development in combination with good suckering. Pests and diseases also cause direct plant damage, hence affecting plant growth and yield (Gold et al., 2001).

Principal component (PC) 1 and PC2 were retained because they explained the largest proportion of the total variation (>70%) (Bartholomew et al. 2002). A plot of PC1 and PC2 showed that banana hybrids 12419S-13, 2625K-1 and 7798S-2 displayed very good agronomic traits (plant height and girth), and consequently bigger bunches but they appeared to be susceptible to black Sigatoka disease as compared to the banana hybrids in the third quadrant. This therefore implies that banana hybrids in the third quadrant were more tolerant to black Sigatoka disease but they produced smaller bunches. Heavier bunches are as a result of greater active leaf area as they lead to high total dry matter production or accumulation (Buah et al., 2000). But genotype could be a more critical factor in determining the yield potential of a given cultivar (Njuguna et al., 2008). This probably explains why some hybrids produced relatively smaller bunches even though they had many functional leaves both at flowering and harvest. On the other hand, on the second principal axis, Mbwazirume and Kisansa had good agronomic traits (girth and height) but they were more susceptible to black Sigatoka and thus produced smallest bunches compared to the hybrids that were also groupedin the fourth quadrant but they were more tolerant to black sigatoka disease. This also indicated that bigger bunches and higher yields in banana could be attributed to higher growth rate before flowering and high number of functional leaves at flowering and harvest (Bananuka et al., 2000).

Conclusion

Banana hybrids produced better bunches compared to the local check (Mbwazirume), and they also exhibited better response to black Sigatoka disease. Banana hybrids 12419S-13, 7798S-2 and 2625K-1 had outstanding big bunches and they also had better tolerance to black Sigatoka disease. They should therefore be recommended for sensory evaluation to establish the ones that would be preferred by farmers. Those with consumer desired traits can then be multiplied and distributed to other areas where black Sigatoka disease is still a production constraint.

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Conflict of Interests

The authors have not declared any conflict of interests.

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