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Research Application Summary

Assessment of morphological traits of coffee used in determining the performance of Arabusta hybrids generated from crosses between the tetraploid Robusta and Arabica coffee

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Abstract

Coffee is one of the most important commodities in the world being traded second after oil. One of the objectives of coffee breeding programs is to select for good quality coffee with high yields. The aim of this study was to determine variations within the Arabusta hybrids, its backcrosses to Arabica coffee and to estimate the relationships between the different growth traits. The study was carried out in two different locations (Siaya and Busia counties) and data were collected in 2017. The experimental design used was a Randomized Complete Block Design (RCBD) with three replications. Experimental plots were comprised of five trees. Data were collected on various growth and yield traits during the second year. These included height (cm), nodes on main stem, internode length on main stem (cm), primaries, bearing primaries, % bearing primaries, longest primary (cm), nodes on longest primary, internode length on longest primary (cm), bearing nodes on longest primary, % bearing nodes, laterals, berries, berries per node and node with highest berry number. There was a highly significant difference ($P<0.001$) within all traits except number of nodes on main stem and % berries on primaries. The correlation results showed statistically significant associations between different traits. The correlation of number of berries with number of berries on primaries and the nodes with number of berries was significant. Further data need to be collected for the third year to be able to take advantage of production for all trees since by the second year not all trees within the plots had berries.

Key words: Arabusta hybrids, Kenya, quantitative traits, yield

Résumé

Le café est l'un des produits de base les plus importants au monde, après le pétrole. L'un des objectifs des programmes de sélection du café est de sélectionner un café de bonne qualité avec des rendements élevés. Le but de cette étude était de déterminer les variations au sein des hybrides Arabusta, ses rétrocroisements avec le café Arabica et d'estimer les relations entre les différents caractères de croissance. L'étude a été menée dans deux endroits différents (comtés de Siaya et Busia) et les données ont été collectées en 2017. La conception expérimentale utilisée était une conception de bloc complet aléatoire (RCBD) avec trois réplications. Les parcelles expérimentales étaient composées de cinq arbres. Des données ont été recueillies sur divers caractères de croissance et de rendement au cours de la deuxième année. Celles-ci comprenaient la hauteur (cm), les nœuds sur la tige principale, la longueur des entre-nœuds sur la tige principale (cm), les primaires, les primaires porteuses, le pourcentage de primaires porteuses, le plus long primaire (cm), les nœuds sur le primaire le plus long, la longueur d'entre-nœud sur le primaire le plus long (cm), nœuds porteurs sur les nœuds primaires les plus longs,% nœuds porteurs, latéraux, baies, baies par nœud et nœud avec le plus grand nombre de baies. Il y avait une différence très significative (P <0,001) pour tous les caractères sauf le nombre de nœuds sur la tige principale et le pourcentage de baies sur les primaires. Les résultats de corrélation ont montré des associations statistiquement significatives entre différents traits. La corrélation du nombre de baies avec le nombre de baies sur les primaires et les nœuds avec le nombre de baies était significative. Des données supplémentaires doivent être collectées pour la troisième année afin de pouvoir profiter de la production de tous les arbres puisque la deuxième année, tous les arbres des parcelles n'avaient pas de baies.

Mots clés : hybrides Arabusta, Kenya, caractères quantitatifs, rendement

Introduction

Globally, coffee is the second most traded commodity after oil (Davis *et al*., 2012; Esquivel and Jiménez, 2012). Among some 90 species of the genus Coffea, *C. arabica* L. (Arabica coffee) and *C. canephora* Pierre (Robusta coffee) economically dominate the world coffee trade, being responsible for about 99% of world bean production (Da Matta and Ramalho, 2006). Coffee remains a major cash crop and top foreign exchange earner for the Kenyan economy and is ranked 5th contributor to GDP after horticulture, tourism, tea, and diaspora remittance. The industry contributes about 1% of the national GDP, about 8% of the total agricultural export earnings and up to 25% of the total labor force employed in agriculture (AFFA, 2013). Coffee is majorly cultivated by the small scale farmers.

Breeding for increased yield is one of the main objectives in the breeding programme within the Coffee Research Institute (CRI) in Kenya. One of the major constraints to coffee productivity is the high costs of production caused by increased costs of inputs for example use of chemicals to spray against the coffee diseases (Coffee Berry Disease and Coffee Leaf Rust). The success of any breeding programme largely depends on the selection foryield. Shortening the time required to obtain an accurate evaluation of yield potential would allow for faster release of new varieties at reduced cost, thus making the breeding programme more efficient (Anim-Kwapong and Adomako, 2010). Coffee, like any other perennial crop experiences yield fluctuation from year to year as a result of successive vegetative reproductive cycles and the genotype-environment interactions. It may also be possible that growth and yield characters have an influence on yield stability in coffee as is in a number of other crops (Zuber *et al*., 1960).

The genetic correlation, which is the proportion of variance that two traits share due to genetic causes is useful in studying the genetic relationships among traits under selection (Anim-Kwapong and Adomako, 2010). Due to biennial bearing and the long productive nature of coffee, the production cycle is long and this might take up to eight years making it difficult to release a variety in a short period. It is therefore important to identify genotypes with good growth characters that relate positively to increased yield within the early years of production. More correlation studies among yield of coffee and juvenile and mature plant characteristics have been reported (Walyaro, 1983; Dessalegn, 2014). This study utilized the coffee growth characters to determine the performance of the Arabusta hybrids being evaluated at Siaya and Busia counties.

Material and methods

Seven Arabusta hybrids, six backcross derivatives of Arabica to Arabusta hybrids were evaluated together with other six coffee varieties. The study site is located in Siaya and Busia counties. These are low altitude areas and suitable for robusta coffee. Siaya is located at the extreme western part of Kenya between longitude East and latitudes 0º 30 N' and 0º 45' E. The altitude varies from 1,135m to 1,500m above sea level. The mean annual rainfall is 1,500mm with most parts of the county receiving between 890 mm and 1,900mm. The annual mean temperatures range from 20.9º C and 22.7º C. The soils are well drained, moderately deep to very deep (chromic/ orthic acrisols and ferrasols) (Jaetzold *et al*., 2009). Busia county is also located in western Kenya between 0º 30 N' and 34º 30' SE. The altitude varies from 1241 m to 1343 m above sea level. The mean annual rainfall is 1400mm with most parts receiving between 925 mm to 1900 mm. The annual maximum temperatures range from 26º C and 29º C while the annual mean minimum temperatures vary between 14º C and 17º C. The soils are developed on basic and intermediate rocks (Dolerites and Andesites).

Each of the backcrosses was planted at a spacing of 2.74 m x 2.74 m with five coffee trees per plot and replicated three times. The experiment was laid out in a Randomized Complete Block Design (RCBD). The plots were surrounded by a guard row of Robusta coffee. All management practices such as weeding and fertilizer application were carried as recommended.

Phenotypic trait scoring. The red ripe cherry was harvested during peak harvesting period of May to July and from September to November. The growth parameters were recorded as described by Walyaro (1983.) and these included height (cm), nodes on main stem, internode length on main stem (cm), primaries, bearing primaries, % bearing primaries, longest primary (cm), nodes on longest primary, internode length on longest primary (cm), bearing nodes on longest primary, % bearing nodes, laterals, berries, berries per node and node with highest berries. The quantitative traits data were subjected to Analysis of Variance (ANOVA) using the Gen-stat Software package version 16. Pearson correlations were carried out for the different traits. Results are presented in Table 2.

Results

The analysis of variance showed highly significant (P d"0.001) differences within the 15 different traits, indicating a great variation amongst the genotypes tested (Table 1). The range of percentage berries per node was 20.6-44.8% with the commercial variety having a significantly higher percentage (44.8%) followed closely by BC05 while BC06 had a significantly lower percentage. Batian had a significantly higher berry number per node on the longest primary of 13.7 followed closely by BC05. ARH4 had a significantly higher number of berries per node (7.7) followed by ARH4 (7.5). .

Genotype ARV3 had a significantly large girth (18.1 cm) with ARV2 having a significantly small girth (12.5 cm). ARV3 was also significantly taller (163.1 cm) while Ruiru 11 which is a dwarf commercial variety was the shortest (98.1 cm). The internode length on the longest primary varied from 3.2 to 4.5 cm with BC04 having the longest internodes on longest primary. The number of laterals varied with genotype, with BC06 having significantly larger numbers. The internode length on the mains stem varied significantly within the genotypes. ARV3 had significantly longer internodes (3.8 cm) compared to other genotypes (Table 1).

There was a significant difference in the longest primary length with ARV3 having significantly long (112.6 cm). Genotype BC04 had short primaries compared to other genotypes. ARH4 had a significantly higher number of nodes with larger number of berries. There was a variation in the number of nodes on the longest primaries with BCO6 having significantly higher numbers (27.9 nodes) followed closely by BC02 (26.2 nodes). Robusta genotype had a significant higher number of primaries of 53.4 followed by BC01 (50.2). Ruiru had a significantly lower number of primaries of 40.4 (Table 1).

Table 2 shows the correlation coefficients amongst the 15 different traits. The berries were positively correlated with the number of bearing nodes on the longest primaries, bearing primaries, bearing nodes and the nodes with highest number of berries. The percentage of bearing primaries were positively related with all other traits except for internode length on the longest primary, nodes on the main stem and primaries. It also showed a significant difference in association to berries per node on the longest primary, bearing primaries and the nodes on the longest primary. The number of bearing primaries had a positive relationship with all traits.

Discussion

The analysis of variance showed highly significant ($p<0.001$) differences among the different genotypes with respect to the studies traits. Various studies (Gichimu, 2010; Dessalegn, 2014) have shown simmilar results. The variations amongst the genotypes shows that the genotypes differ from each other genetically and therefore can be utilized in improvement breeding programs whereby different traits can be selected for based on their importance. For example, the shortness in height for some genotypes can be selected for to increase the density of plants per unit area thus increasing production. The shortness expressed by Ruiru 11 (Table1) is as a result of Catimor which is the female parent in Ruiru 11 hybrid. It has the “Cat” gene responsible for dwarfness in coffee.

Several studies carried out have shown positive correlations between the different traits (Table 2). The positive relationship between berry number and number of bearing nodes on the longest primary, bearing primaries, bearing nodes and nodes with highest berries can be used as a yield indicator. Coffee takes up to 5-6 years in the field for one to determine its yield performance. This time delays the breeding program. Walyaro (1983) indicated that the selection efficiency for yield can be indirectly done in the early years of coffee production using some recommended traits. The selection efficiency of yield would be higher if the components of yield the growth parameters are measured early enough.

Conclusion

The use of growth traits and yield components is key in determining the performance of coffee genotypes in the early stages of production. This would shorten the breeding programs for coffee which takes several years to select, evaluate and release a variety. Results of this study have been taken from 2 year old coffee that had just started to bear. It is therefore recommended that 3rd year growth data be collected and incorporated in the analysis to obtain more reliable data since then all the trees will be bearing.

Table 1. Combined means of two sites for growth traits of arabusta hybrids

Variety	%BN	BE	BNLPR	%BPR	B/N	G	H	ILLPR	ILMS	LAT	LPR	NHB	NOLPR	NOMS	PR
ARH1	32.5	64.8	8.4	46.1	5.1	14.6	146.8	3.6	3.3	11.3	90.8	10.1	25.2	29.8	48.1
ARH2	29.1	30.5	6.4	41.1	4.2	14.2	124.5	3.5	2.8	10.7	76.2	6.6	22.0	30.4	44.2
ARH3	29.3	41.1	6.6	38.8	4.7	13.5	125.7	3.2	2.7	13.3	68.3	9.0	21.8	31.1	45.6
ARH4	33.7	79.9	8.5	46.0	7.7	12.3	122.2	3.4	2.7	10.2	82.0	14.0	24.4	30.0	48.2
ARH5	34.0	55.9	8.7	45.6	5.5	13.6	122.2	3.4	2.7	9.5	86.8	10.0	25.3	31.1	47.5
ARH6	28.1	31.2	6.3	46.4	3.9	13.6	137.1	3.6	3.3	10.2	82.9	6.6	22.8	27.8	43.3
ARH7	28.9	60.2	7.6	47.3	5.3	13.7	129.5	3.6	3.1	9.2	93.5	9.5	26.4	27.8	47.8
BC01	27.2	49.8	6.8	44.1	5.4	15.2	148.8	3.8	3.3	9.3	95.7	9.2	25.0	30.7	50.2
BC02	26.4	26.3	7.0	48.2	3.1	15.5	139.0	3.6	2.9	14.1	93.9	6.0	26.2	33.4	47.2
BC03	21.5	15.5	5.2	46.5	2.7	14.9	143.5	3.8	3.2	10.3	89.6	4.4	23.7	30.1	44.5
BC04	35.0	64.3	8.1	51.1	6.6	16.7	159.6	4.5	3.9	5.3	106.5	10.5	23.6	27.8	46.3
BC05	44.8	72.2	12.3	48.8	4.7	14.2	149.5	3.7	3.2	10.4	95.4	9.1	25.4	31.2	47.9
BC06	20.7	30.3	5.7	50.8	4.0	15.6	119.1	3.3	2.8	15.0	91.6	6.3	27.9	28.7	43.5
Robusta	21.1	40.4	5.3	29.6	4.2	15.5	141.5	4.1	3.0	6.6	104.9	6.6	25.6	31.9	53.4
Ruiru 11	39.6	62.6	9.5	56.6	5.4	13.2	98.1	3.2	2.4	12.2	75.6	10.3	23.7	28.1	40.4
Batian	53.7	89.0	13.7	51.9	6.1	14.7	129.9	3.4	3.0	10.8	86.3	11.6	25.5	35.2	43.8
ARV1	30.0	65.3	7.0	42.5	7.5	12.6	138.8	3.7	3.0	7.7	87.8	13.3	23.6	30.7	48.3
ARV2	25.8	61.0	6.2	37.2	6.9	12.5	141.8	3.9	3.3	6.4	90.4	12.0	23.0	28.8	47.2
ARV3	42.2	59.4	10.7	51.4	5.1	18.1	163.1	4.5	3.8	9.2	112.6	10.2	25.0	28.5	47.1
LSD	10.7	21.0	2.8	12.3	2.0	1.6	15.9	0.3	0.3	3.7	10.1	3.0	2.6	5.3	5.0
Cv%	20.4	31.3	21.6	16.3	23.7	6.6	7.1	5.2	6.4	22.2	6.8	19.7	6.3	10.7	6.9
Ftest	S	S	S	NS	S	S	S	S	S	S	S	S	S	NS	S

Key: %BN = % bearing nodes BE = berries, BNLPR = bearing nodes on longest primary, %BPR =% bearing primaries, B/N = berries per node, G = girth, H = height (cm), ILLPR = internode length on longest primary (cm), ILMS = internode length on main stem (cm) LAT = laterals, LPR = longest primary (cm), NHB = node with highest berries, NOLPR = nodes on longest primary NOMS = nodes on main stem,) and PR = primaries

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Table 2. Correlation coefficients among 15 growth traits for arabusta coffee genotypes

	BE	BNLPR	BPR	B_N	G	H	ILLPR	ILMS	LAT	LPR	NHB	NOLPR	NOMS	PR
%BPR	0.25	0.550***	0.891***	0.089	0.229	0.05	-0.0881	0.12	0.287*	0.143	0.223	0.3897**	-0.0966	-0.0842
BE	-	0.707***	0.294**	0.785***	-0.13	-0.012	0.0188	0.071	-0.249	0.101	0.831***	0.1461	-0.0113	0.092
BNLPR		-	0.530**	0.246	0.125	0.064	-0.0426	0.078	0.068	0.143	0.488***	0.2966**	0.114	-0.0161*
BPR			-	0.135	0.275*	0.25	0.0189	0.161	0.211	0.283*	0.296*	0.4632***	0.085	0.321*
B_N				-	-0.257	-0.007	0.1218	0.101	-0.4459***	0.043	0.885***	-0.0848	-0.0951	0.129
G					-	0.5344***	0.529***	0.449***	0.061	0.715***	-0.2449	0.4255**	0.127	0.199
H						-	0.76***	0.837***	-0.3783**	0.744***	0.021	0.1547	0.0204	0.485***
ILLPR							-	0.806***	-0.6129***	0.799***	0.041	-0.0731	-0.1424	0.293**
ILMS								-	-0.464**	0.668**	0.058	-0.0163	-0.37246*	0.143
LAT									-	-0.3076*	-0.3082*	0.3425**	0.129	-0.227
LPR										-	0.051	0.5373***	0.022	0.469***
NHB											-	0.0367	0.012	0.208
NOLPR												-	0.226	0.3589**
NOMS													-	0.385**

*** indicates significance at pd” 0.001; ** indicates significance at pd” 0.01 and * indicates significance at p< 0.05

Key: %BN=% bearing nodes BE=berries, BNLPR= bearing nodes on longest primary, %BPR=% bearing primaries, B/N= berries per node, G=girth, H= height (cm), ILLPR= internode length on longest primary (cm), ILMS=internode length on main stem (cm) LAT=laterals, LPR=longest primary (cm), NHB= node with highest berries, NOLPR= nodes on longest primary NOMS=nodes on main stem,) and PR=primarie

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