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RESEARCH ARTICLE

Association and variability studies for yield and yield components of robusta coffee hybrids (*Coffea canephora*)

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Abstract

Twenty-four introduced and locally generated half sibs of coffee established in 2016 located at Cocoa Research Institute of Ghana (CRIG) experimental station Akim Tafo in the Eastern Region of Ghana was used for the study. Three randomly selected stands of each genotype was used to study 12 quantitative traits. Data was analyzed using Genstat 12 edition and the differences separated at 5 percent. The analysis of variance revealed significant difference among the accessions for all the traits studied except for plant spread, number of laterals per plant and number of nodes per laterals. The estimated phenotypic variance was greater than the genotypic variance for all the traits. Genotypic variance was also greater than the environmental variance for the traits studied except for plant height, plant spread, number of laterals per plant and number of nodes per lateral indicating a high influence of environment on these traits. PCV which was higher than the modify as for all the traits under study. None of the traits recorded high heritability, but fruit length, 100-berry dry weight, plant girth and 10-berry wet weight recorded moderately high heritability whereas fruit width, hundred dry bean weight, outturn and plant height recorded medium heritability. Plant girth and 100-berry wet weight recorded high heritability coupled with high GA and 100-dry bean weight, outturn and fruit width recorded high heritability coupled with medium GA. This indicates less influence of environment in their expression and prevalence of additive gene action. This makes plant girth, 100-berry wet weight, 100-dry bean weight, outturn and fruit width important traits to consider for the improvement of coffee in Ghana.

Keywords: Correlation, heritability, genetic advance, coffee

Introduction

Coffee (*Coffea Arabica* L.) is one of the world's most important agricultural commodities and is the main livelihood for more than 125 million people worldwide deriving their income directly or indirectly from its products (Lashermes *et al.*, 2011). Up to 126 species of coffee have been classified under the genera, *Coffea* but commercial coffee production relies mainly on two related species, *Coffea Arabica* which is a tetraploid specie (2n = 4x = 44) and *Coffea canephora Pierre* which is a diploid and already proved by many (Davis *et al.*, 2006; Davis and Rakotonasolo, 2008; Davis *et al*., 2011). Coffee has its center of genetic diversity in southwest Ethiopia and the Boma Plateau of Sudan (Anthony *et al.,* 1987). Also wild populations of *C. arabica* have been found in Mount Imatong (Sudan) and Mount Marsabit (Kenya) (Thomas 1942). Genetic diversity is an important aspect of biodiversity necessary for improvement and breeding of crops (Mooney *et al.,* 1995). Quantifying genetic variability among species will ensure effective conservation of genetic resources. Availability of genetic variation provides the probability for improvement of the crop for any desirable trait of interest.

Currently in Ghana, only few coffee varieties have been released and being planted by farmers. This limited number of varieties being grown in the country puts the coffee sector at high risk in the event of biotic or abiotic attacks, particularly disease outbreak. It is very possible that the coffee sector would be wiped out if efforts are not made in the area of developing new varieties that could augment the current varieties thereby increasing the gene pool of deployed varieties, hence the possibility of withstanding any biological attacks in the future. Additionally, the current on farm and experimental yields of coffee are approximately > 0.5 t ha^{-1} and > 2 t ha^{-1}, respectively while the yield potential of the crop has been estimated to be above 5 t ha^{-1}. Genetic variability studies are essential for the improvement of crops. Findings of GCV, PCV, heritability and GA are vital for planning efficient breeding program to improve the potential of the crops. Correlation studies among traits is of great important to the plant breeder in selecting methods of breeding for those traits and also selecting desirable genotypes (Desawi et al.,2014; Falconer and Mackay, 1996).

Breeding programs to assess experimental lines for improvement in growth and yield through selection is imperative to close the yield gap which would lead to higher national productivity. It is therefore important to assess the level of genetic diversity and estimate the genetic variance of the yield and yield related traits of twenty–four (24) hybrids and introduced accessions of coffee for improvement of coffee production in Ghana

Materials and methods

The research was carried out from September, 2018 to March 2019 at the experimental fields of Cocoa Research Institute of Ghana (CRIG), Tafo (latitude 6° 13′N, longitude 0° 22′W) in the Eastern Region of Ghana. Twenty-four (24) hybrids which were made up of twenty-one (21) locally derived half-sib families, two (2) recently introduced half-sib families (TR4 and TR9) and 1 hybrid standard variety (E138 × C134) planted in June 2016 was used for the study (Table 1). The locally derived half-sib families were generated from an open-pollinated field planted in an isolated area consisting of 177 clones. Seeds were harvested from the top 21 trees based on 3-year average yield and out-turn. Seedlings were generated from the seeds and transplanted to the field after six (6) months. The recent introductions were received as half-sib seeds. The coffee plants were planted at a spacing of 4 m × 6 m in a randomized complete block design with 5 replications. *Gliricidia sepium* was planted between rows to serve as shade for the coffee seedlings when they were transplanted. Three (3) plants were selected in each replicate block for the study. All the agronomic procedures where done to keep the field in shape throughout the year.

Data collection

The following data were collected on the genotypes based on the standard coffee descriptor of International Plant Genetic Resources Institute (IPGRI) (1996). Data was collected on three (3) randomly selected trees for each genotype and the figures averaged.

Plant girth: taken at 10cm above the ground in millimeters(cm)

Table 1: List of coffee families evaluated

No	Accession Name	Source
1	E139 x C134	Standard Variety
2	TR4	Recent Introduction
3	TR9	Recent Introduction
4	U112	Locally Derived Half-Sib
5	U148	Locally Derived Half-Sib
6	U17	Locally Derived Half-Sib
7	U177	Locally Derived Half-Sib
8	U24	Locally Derived Half-Sib
9	U29	Locally Derived Half-Sib
10	U41	Locally Derived Half-Sib
11	U48	Locally Derived Half-Sib
12	U52	Locally Derived Half-Sib
13	U54	Locally Derived Half-Sib
14	U55	Locally Derived Half-Sib
15	U56	Locally Derived Half-Sib
16	U57	Locally Derived Half-Sib
17	U60	Locally Derived Half-Sib
18	U62	Locally Derived Half-Sib
19	U63	Locally Derived Half-Sib
20	U67	Locally Derived Half-Sib
21	U69	Locally Derived Half-Sib
22	U79	Locally Derived Half-Sib
23	U80	Locally Derived Half-Sib
24	U93	Locally Derived Half-Sib

Plant height: taken from the ground level to the tip of the plant in meters(m)

Plant span: taken as the width of the canopy measured at the widest portion of the tree in centimeters(cm)

The following data were collected on the genotypes based on the standard coffee descriptor of International Plant Genetic Resources Institute (IPGRI) (1996). Data was collected on three (3) randomly selected trees for each genotype and the figures averaged.

Plant girth: taken at 10cm above the ground in millimeters(cm)

Plant height: taken from the ground level to the tip of the plant in meters(m)

Plant span: taken as the width of the canopy measured at the widest portion of the tree in centimeters(cm)

Number of laterals: taken by counting the number of laterals on the plant from the base to the top

Number of nodes per lateral: taken by randomly selecting three (3) healthy long lateral and each nodes counted and averaged

Hundred wet berry weight: hundred berry was harvested from each accession and weighed in grams (g).

Hundred dry berry weight: hundred berry was harvested from each accession and air dried for 14days and weighed in grams(g).

Fruit height: The longest side of three randomly selected fruit from each genotype was measured in millimeters(mm) and averaged.

Fruit breadth: The shortest side of three randomly selected fruit from each genotype measured in millimeters(mm) and averaged.

Hundred dry bean weight: hundred harvested berry from each accession was dried and dehusked, the beans were the in grams weighed.

Outturn: This was estimated as the average of weight of dry beans divided by weight of wet berries.

Yield (tons): Cherry weight of berries collected from October 2018 to January2019 was recorded and expressed in tons.

Statistical analysis

The mean measurements for each trait were subjected to analysis of variance (ANOVA) using GenStat statistical software, version 12 (VSN International Ltd, Hemel Hempstead, UK) and the means separated at 5% probability. Correlation analysis (Pearson's) was performed to assess the association among traits studied.
The phenotypic, genotypic and environmental variances was calculated according to formula suggested by Johnson *et al*., (1955) as follows:

Genotypic variance (σ^2g) = $\frac{MSG-MSE}{r}$

Phenotypic variance (σ^2ph) = $\frac{MSG}{r}$

Error variance (σ^2e) = $\frac{MSE}{r}$

Where,
MSG is Genotypic Mean Squares,
MSE is Error Mean Square and r is number of replication

The variance component was used to compute the genotypic Coefficient of Variability (GCV), Phenotypic Coefficient of Variability (PCV), Heritability in the broad sense (h^2) and Genetic Advance (GA) according to the formulae suggested by Burton (1952) and Allard (1960) as follows:

Genotypic coefficient of variability (GCA %) = $100 \times \frac{\sqrt{\sigma^2 g}}{X}$

Phenotypic coefficient of variability (PCV %) = $100 \times \frac{\sqrt{\sigma^2 ph}}{X}$

Where σ^2g and σ^2ph are the genotypic and phenotypic variations respectively and X is the grand mean for the character under consideration.
Estimation of heritability in broad sense was done as follows:

Heritability (broad - sense) = $h^2 = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e}$

Where,
σ^2g is the estimate of genotypic variance, σ^2e is the estimate of environmental variance.

The genetic advance was calculated as:

Genetic Advance (GA) = heritability x K x $\sqrt{\sigma ph}$

Where,
K (selection differential expressed in phenotypic standard deviations) = 2.06
Genetic advance over mean (GAM) was calculated using the following formula and was expressed in percentage.

GAM = $\frac{GA}{X}\ X\ 100$

Where,
x = Grand Mean

Results and discussion

The Analysis of variance revealed significant difference ($p< 0.05$) for all the traits studied except for plant spread, number of laterals per plant and number of nodes per laterals (Table not shown). The significance difference gives a clear indication of the presence of high degree of genetic variation which will aid in selection of the genotypes for use in coffee breeding programs in Ghana. Beksisa and Anyano (2016), Gatachew *et al.,* 2013 and Olika *et al.*, (2011a) reported significant differences among Limmu coffee accessions.

Estimation of genotypic and phenotypic coefficients of variation

Estimated phenotypic variance was greater than the genotypic variance for all the traits. Genotypic variance was however greater than the environmental variance for all the traits studied except plant height, plant spread, number of laterals per plant and number of nodes per lateral (Table 2). According to Deshumkh *et al.* (1986), PCV and GCV values less than 10% are considered low, between 10-20% are moderate and greater than 20% is high. The PCV ranges from 6.36% to 38.80% for fruit width and yield (tons) respectively. GCV also ranges from 3.142% to 21.19% for number of nodes per lateral and 100-berry wet weight respectively. Yield, 100-bean dry weight, and 100-berry wet weight recorded high PCV and GCV values while plant girth, outturn and 100-dry berry weight recorded medium PCV and GCV values (Table 3). Which indicates the traits are less controlled by the environment and may respond to selection. Beksisa and Ayano (2016) and Alemayehu (2019) reported similar results for coffee accessions in Ethiopia. The remaining traits recorded low PCV and GCV values which indicates the influence of the environment in expression of the traits and that they cannot be used for the phenotypic selection of coffee for improvement.

Heritability and genetic advance

GCV and PCV alone cannot be used in determining the extent of variation which is heritable. However, it is important to know the heritability of a character which helps breeders in predicting the genetic advance for quantitative character thus in selection processes. The heritability ranged from 16.26% to 71.89% for yield (tons) and 100-bean dry weight respectively. According to Singh and Chaudhary (2001), heritability values greater than 80% are considered high, 60%-79% are moderately high, 40-59% are medium and less than 40% are low. Based on the classification, none of the traits recorded high heritability, but fruit length, 100-berry dry weight, plant girth and 100-berry wet weight recorded moderately high heritability whereas fruit width, 100-dry bean weight, outturn and plant height recorded medium heritability. The other traits recorded low heritability (Table 3). The results are in accordance with the works of Yonas and Tarekegn (2015); Olika *et al*., (2011a); Atinafu *et al.,* (2017) and Gatachew *et al*., (2013). The GA for the traits ranged from 5.6 for yield(tons) to 89.4 for fruit width. The GAM also ranged from 2.61 for number of nodes per lateral to 37.00 for hundred berry dry weight. According to Johnson *et al*., (1955), GA value of less than 10% is regarded to be low, and a range of 10-20% is considered moderate, whereas more than 20% is considered to be high. Based on the classification all the traits recorded high to medium GA except for yield which recorded low GA . High heritability estimates have been found to be helpful in making selection of superior accessions on the basis of phenotypic performance (Beksisa and Ayano, 2016). High heritability estimates with high genetic advance is indicative of additive gene action and selection based on these parameters would be more effective and reliable (Johnson *et. al.*, 1955).

The studied revealed that plant girth and 100-berry wet weight recorded high GA coupled with high heritability in the braodsense while 100-dry bean weight, outturn and fruit width recorded high heritability coupled with medium genetic advance. This indicates that these traits have less influence of environment in their expression and the presence of additive gene action in their inheritance. This makes plant girth, 100-berry wet weight, 100-dry bean weight, outturn and fruit width the most important traits to consider for the improvement of coffee and selection based on them will result in improvement of the performance of the coffee genotypes. Also low estimate of GA coupled with low heritability was recorded for yield(tons) and plant spread indicating the absence of additive gene action and therefore these traits cannot be selected for improvement of coffee. The results collaborate with the work of Gatachew Nikhila *et al.,* (2017); Alemayehu (2019); Atinafu Nikhila *et al.,* (2017) and Gatachew (2012).

Correlation

Correlation among traits can be used to identify important traits that are desired for coffee breeding (Tran, 2005). From the study, plant girth had highly significant ($p<0.001$) and positive correlation with plant height (r=0.7368), plant span (r=0.6842), number of laterals per plant (r=0.6448), number of nodes per lateral (r=0.3285) and yield(tons) (r=0.3075). Plant height also possessed highly significant ($p< 0.001$) and positive correlation with plant span (p=0.6633), number of laterals per plant (p=0.7043). Fruit length also exhibited highly significant ($p<0.001$) and positive correlation with fruit breadth (r=0.7370), 100-berry wet weight (r=0.7105), 100-dry bean weight (r=0.6527) indicating greater importance and reliability of these characters for selection for improvement of yield in coffee (Table 4). Yield also recorded a positive significant correlation with plant girth (r=0.3075), plant height (r=0.3330), span (r=0.2764) and number of laterals per plant (r=0.2849). There was no significant ($p<0.05$) negative association between the traits however there was negative non-significant correlation between outturn and plant girth, plant height, plant spread, number of laterals per plant and number of nodes per lateral.

Table 3: Genotypic variance, phenotypic variance, heritability and genetic advance of yield and yield component of coffee

Traits	GV	PV	EV	GCV (%)	PCV (%)	H (%)	GA (%)	GAM
Plant girth (mm)	21.753	31.53	9.77	11.161	13.44	69.00	79.81	19.10
Plant height (m)	0.011	0.02	0.01	5.980	8.22	52.98	15.8	8.97
Plant Span (m)	0.010	0.03	0.02	5.423	8.73	38.55	12.7	6.94
Number of nodes/lateral	5.110	20.79	15.68	4.381	8.84	24.58	23.08	4.47
Number of laterals /plant	0.292	1.79	1.50	3.142	7.78	16.31	44.9	2.61
100-berry wet weight	321.27	492.13	170.87	19.315	23.91	65.28	29.833	32.15
100- berry dry weight	92.100	128.10	36.00	21.19	24.98	71.89	16.763	37.00
100-Dry bean weight	13.370	24.15	10.78	13.783	18.52	55.36	56.04	21.12
Out turn	9.733	18.61	8.88	11.751	16.25	52.30	46.48	17.51
Yield/ ha (tons)	0.005	0.03	0.02	15.647	38.80	16.26	5.6	13.00
Fruit length (mm)	0.702	0.99	0.29	6.824	8.12	70.66	14.51	11.82
Fruit width (mm)	0.330	0.58	0.25	4.806	6.36	57.04	89.4	7.48

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Table 4: Correlation matrix for yield and yield components of coffee

	Plant girth (mm)	Plant height (m)	Span (m)	Number of laterals	Number of nodes/ plant	100-berry wet weight (g)	100-berry dry weight (g)	100 Dry bean weight (g)	Out turn	Yield/ ha (tons)	Fruit length (mm)
Plant height (m)	0.7368***	1									
Span(m)	0.6842***	0.6633***	1								
Number of laterals	0.6448***	0.7043***	0.6742***	1							
Number of nodes/plant	0.3285**	0.2081	0.6391***	0.4831***	1						
100-berry wet weight (g)	0.2891*	0.2667*	0.3664**	0.3659**	0.3959***	1					
100- berry dry weight (g)	0.3251*	0.2714*	0.3812***	0.3712**	0.4124***	0.9621***	1				
100 Dry bean weight (g)	-0.0288	-0.2714	-0.0226	-0.016	0.0361	0.5012***	0.4523***	1			
Out Turn	-0.1672	-0.0968	-0.1865	-0.1401	-0.2563*	0.0398	0.0574	0.4233***	1		
Yield/ ha(tons)	0.3075**	0.3330**	0.2764*	0.2849*	0.1937	0.2065	0.2151	-0.0565	-0.208	1	
Fruit length (mm)	0.2869*	0.1272	0.1428	0.2047	0.2483*	0.7105***	0.6527***	0.4089***	-0.133	0.2048	1
Fruit width(mm)	0.1246	0.0048	0.0629	0.1025	0.2735*	0.6811***	0.6159***	0.6159**	-0.017	0.1214	0.7370***

***=P<0.001, ** = P< 0.01, * = P< 0.

Yield also recorded negative non-significant correlation with 100-dry bean weight and outturn. The significant correlation between yield and plant girth, plant height, span and number of laterals indicates that improving one of these traits will lead to simultaneous improvement of yield. Muvunyi *et al.*,(2017); Olika *et al.*, (2011) and Nikhila *et al.*, (2008) reported similar results for quantitative traits in coffee.

Conclusion

The study revealed the existence of wide range of variations among the coffee genotypes for most of the traits studied. The phenotypic variance which was greater than the environmental variance indicates the less influence of environment in the expression of the traits thereby providing good opportunity for genetic gain through selection and hybridization. High boradsense heritability with high genetic advance for plant girth, hundred berry wet weight, hundred dry bean weight, outturn and fruit width makes these traits beneficial for the improvement of coffee in Ghana. The strong inter correlation between yield and plant girth, plant height, span and number of laterals indicates improvements in any of these traits will cause and increase in the yield of coffee which needs further investigation.

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