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Association and interrelationship of yield and agronomic characters in coffee (*Coffea* sp L)

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Coffee is an important commodity in the international market. However, little attention is given to it and its breeding research in Nigeria. This has resulted to low production and foreign earning. The information on relationship between yield and yield- related characters is an excellent and significant tool for breeding. The experiment was conducted on Cocoa Research Institute of Nigeria coffee germplasms. The objectives of this study were to determine the genetic relationship and identify traits that have a direct and indirect effect on yield of coffee. A total of 45 coffee genotypes were studied during 2016/2017 cropping season. The data were subjected to correlation coefficients and regression analyses. The result revealed significant (P<0.05) correlation among traits. Weight of seed per tree (actual yield) has strong and positive correlation with trunk height, leaf length, leaf width, stiple arista length, number of flower per axil, number of flower per fascicle, berry width, berry thickness, 100 berry weight, 100 seed weight, and weight of berry per tree. Weight of berry per tree, plant height, number of flower per axil and number of fascicle per node were the predictors and accounted for 94% of the variation observed and therefore be given serious consideration in coffee breeding programmes.

Key words: Coffee, germplasm, yield, characters, correlation, stepwise regression.

INTRODUCTION

Coffee is one of the most economically important beverage crops, and it stands second only to crude oil in terms of international trade on the world market. It is originated from tropical Africa where wild populations occur abundantly in the tropical regions (Berthaud and Charrier, 1988; Maurin et al., 2007). Its production is fundamental in over 50 developing countries for which it is the main foreign currency earner. In many producing countries, besides contributing a tremendous amount to the foreign exchange as main crop, it serves as a main crop for livelihood for millions of people and plays a vital role in their socio-economic life (Orozco Castillo et al., 1994; Agwanda et al., 1997; Carneiro, 1999; Anthony et al., 2001; Steiger et al., 2002). Coffee trees are evergreen which range from shrubs to trees and can grow to a height of 10 m. The stems are orthotropic and developed from aerial part of the stem. The primary branches arise in pairs opposite each other and are subsidiary to the main stem. The sub lateral branches that is, secondary, tertiary and quaternary branches

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developed from primary branches (Coste, 1992; Clifford and Wilson, 1985). The upper side of leaves is shiny, waxy, spear-shaped, and elliptical with conspicuous vein. They grow on the side of main stem and branches in pairs with buds at the leaf stalk base. Leaf color varies. It can be greenish, yellowish, dark green, bronzed or purple tinged young flush. Leaf can be as long as 40 cm. Some trees are deciduous while others retain leaves for three or more years with a leaf area index of 7-8 for a high yielding variety (Wintgens, 2004; Ngugi and Aluka, 2017).

In developing adapted cultivars of any crop, available genetic resources of the crop are important for its improvement. The significant positive correlation coefficient, genetic advance, variability and heritability are an excellent tool to explore for genotype selection in crop improvement programme (Akbar et al., 2003, Mwenye et al., 2010). Yield is a quantitative trait that is complex because of the influence of a number of characters contributing to yield (Xie, 2015). There is need therefore to understand the interrelationships and the magnitude of characters among themselves and with the yield in order to improve the selection efficiency through a combination of suitable characters (Ahmad et al., 2013). The correlation coefficient is an imperative statistical method to evaluate breeding programs for high yield and to study direct and indirect input of the yield variables (Mohamed, 1999). Correlation may be due to phenotypic, genotypic and environmental factors.

However, traits that are not important could be eliminated through stepwise regression analysis. Stepwise regression proved to be the more resourceful predictive equation for yield (Naser and Leilah, 1993). Therefore, traits that are most important with considerable effects on yield, which is a dependable trait or variable, will be verified. The traits selected through stepwise regression analysis can be used as selection criteria in a breeding programme (Williams et al., 1990; Ogrodowczyk and Warzyniak, 2004; Sabaghnia et al., 2010). Moreover, the stepwise regression model is a technique that is used to estimate the value of a quantitative variable regarding its relationship with one or some other quantitative variables. This relation is such that it is possible to predict other changes using one variable.

Getachew (2019) in his research reported a significant and positive correlation of coffee yield with average internode length on stem, angle of primary branches, number of primary branches, stem diameter, the width of fruit, length of fruit, thickness of fruit and average length of primary branches. Percentage of bearing primary branches, hundred bean weight, leaf length, and canopy diameter also had a positive and significant correlation with coffee yield. Lemi et al. (2017), similarly reported canopy diameter, length of first primary branch, plant height have direct effect that had positive and significant on coffee. Seyoum (2003) reported his findings that the highest direct effect on coffee yield was exerted by length of the longest primary branches and angle of primary branches. All these suggested that selection, using these characters, would be of help in coffee improvement. In order to meet the demand for coffee, there is need for increase in yield per hectare. Therefore, the objectives of the study are to determine the genetic relationship and identify traits that have a direct and indirect effect on coffee.

MATERIALS AND METHODS

Forty-five coffee genotypes from Cocoa Research Institute of Nigeria (CRIN) coffee germplasms located in headquarter in Ibadan, Oyo state and two of her substations (Ibeku, Abia state and Kusuku Mambilla, Taraba state) were used for the study as represented in Table 1. The sites are situated between latitude 5.3130° and 7.3775^{0}N; and longitude 3.9470° and 11.7200°E (Figure 1). The experiment was conducted during 2016/ 2017 cropping season on existing coffee trees. The experimental design was Randomised Complete Block Design. Data were collected from 4 individual plants using a random sampling procedure. Descriptor of Coffee (IPGRI, 1996) was used for data collection. Twenty quantitative characters namely: trunk height (cm), trunk diameter (cm), number of primary branches, leaf length (mm), leaf width (mm), leaf petiole length (mm), stipule arista length (mm), number of flower per axil, number of flower per fascicle, number of fascicle per node, berry length (mm), berry width (mm), berry thickness (mm), seed length (mm), seed width (mm), seed thickness (mm), weight of berry per tree (g), 100berry weight (g), weight of seed per tree (g) (actual yield), and 100seed per tree (g) were scored on the morphology of the 45 genotypes. The quantitative characters were determined by measurement and weighing (Table 2).

Genetic parameters and association among characters

The phenotypic, genotypic and environmental correlation coefficients were estimated using the formula of Miller et al. (1958) thus:

$$r\,(x, y) = \frac{\mathrm{Cov}\,(xy)}{\sqrt{(\sigma x)^2 .\ (\sigma y)^2}}$$

Where r(x,y) is either genotypic or phenotypic or environmental correlation between variables x and y; $Cov_{(xy)}$ is the covariance of variables x and y; $(\sigma_x)^2$ is either the genotypic or phenotypic or environmental variance of variable x; $(\sigma_y)^2$ is either the genotypic or phenotypic or environmental variance of variable y.

The significance of the correlation coefficients was tested using the non-directional probability in the software of Lowry (2009). Stepwise regression analysis was performed using SAS software version 9 (SAS Institute Inc. 2004.

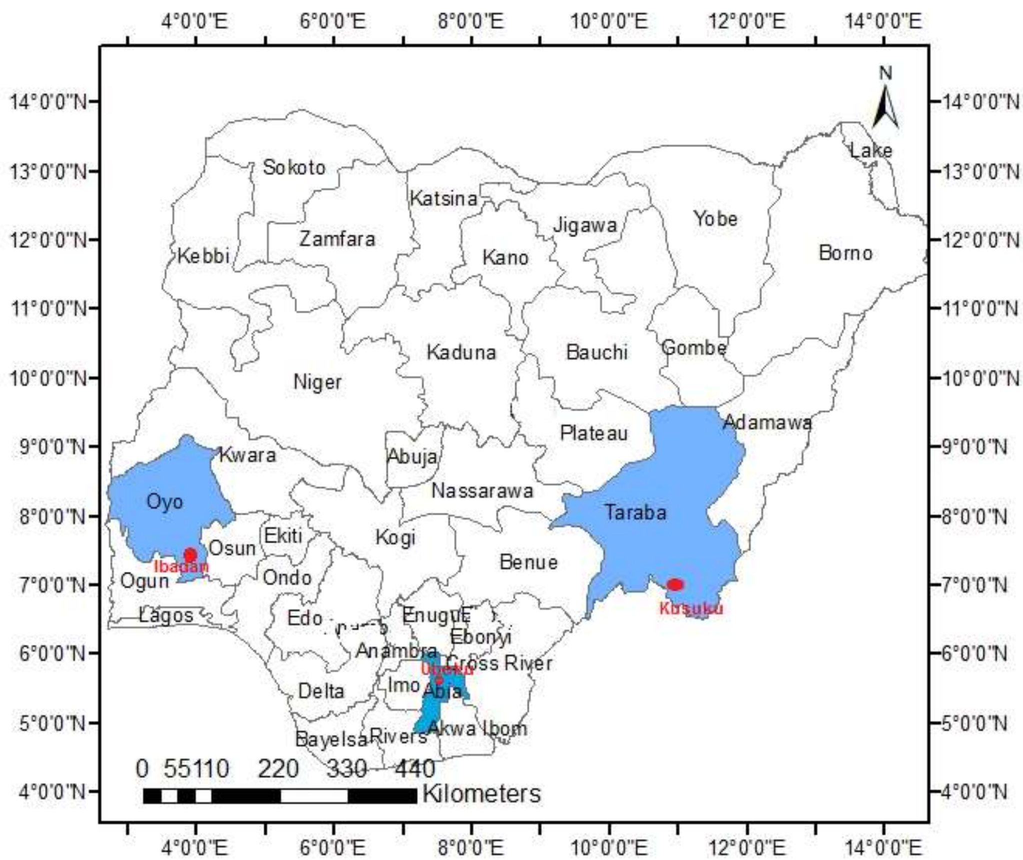
RESULTS

The result of phenotypic correlation coefficient is presented in Table 3. Trunk height had a positive correlation with trunk diameter, number of primary branches, leaf length, leaf width, leaf petiole length, stipule arista length, weight of berry per tree, 100 berry

Table 1. Information on the coffee genotypes**.**

S/N	Code	Germplasm location
1	A81	Ibadan
2	A110	Ibadan
3	C36	Ibadan
4	C96	Ibadan
5	C105	Ibadan
6	C107	Ibadan
7	C108	Ibadan
8	C111	Ibadan
9	D57	Ibadan
10	E1	Ibadan
11	E106	Ibadan
12	M10	Ibadan
13	M53	Ibadan
14	H139	Ibadan
15	T24	Ibadan
16	T204	Ibadan
17	T921	Ibadan
18	T1049	Ibadan
19	W109	Ibadan
20	TG181	Ibeku
21	TG405	Ibeku
22	TG107	Ibeku
23	TG149	Ibeku
24	TG468	Ibeku
25	TG375	Ibeku
26	TG211	Ibeku
27	TG216	Ibeku
28	TG202	Ibeku
29	TG126	Ibeku
30	C Arabica Porto Rico	Kusuku, Mambilla
31	TH-F1 12-2	Kusuku, Mambilla
32	T.992 Padang	Kusuk, Mambilla
33	Porto Rico	Kusuku, Mambilla
34	T.1997 A187	Kusuku, Mambilla
35	TH-F1 5-1	Kusuku, Mambilla
36	T,971 Guadeloupe	Kusuku, Mambilla
37	TH-F1 18-1	Kusuku, Mambilla
38	T.977	Kusuku, Mambilla
39	TH-F1 4-1	Kusuku, Mambilla
40	T.990	Kusuku, Mambilla
41	TH-F1 9-3	Kusuku, Mambilla
42	T.2000 Semper Florens	Kusuku, Mambilla
43	Nicaragua	Kusuku, Mambilla
44	T.1996 Selection Fica Flora	Kusuku, Mambilla
45	TH-F1 32-2	Kusuku, Mambilla

weight, weight of seeds per tree and 100 seed weight (r = 0.33, 0.26, 0.71, 0.80, 0.41, 0. 51, 0.34, 0.49, 0.39, and 0.52 respectively) but negatively correlated with number of flower per fascicle, seed length and seed thickness (-0.23, -0.35 and -0.42 respectively). The trunk diameter had positive significant correlation with number of primary



Ibadan……453 ft
Mambilla, Kusuku….5114 ft
Ubeku…..490 ft

Figure 1. Map of Nigeria showing the three locations where the study were carried out.

branches, leaf length, leaf width, leaf petiole length, stipule arista length and 100 berry weight (0.80, 0.22, 0.25, 0.35, 0.62 and 0.21 respectively) but negative significant correlation with berry width and berry thickness (-0.25 and -0.34 respectively). Number of primary branches had positive correlation with leaf length, leaf width, leaf petiole length, stipule arista length and seed width (0.26, 0.28, 0.46, 0.55, 0.32) but negatively correlated with berry width and berry thickness (-0.26, -0.40). Leaf length had positive significant correlation with leaf width, leaf petiole length, stipule arista length, berry width, weight of berry per tree, 100 berry weight and 100 seed weight (0.90, 0.59, 0.49, 0.24, 0.23, 0.33 and 0.41 respectively) but negative significant correlation with number of flower per fascicle, seed length and seed thickness (-0.26, -0.26 and -0.43 respectively).

Similarly, leaf width had a positive significant correlation with leaf petiole length, stipule arista length, berry width, 100 berry weight and 100 seed weight (0.55, 0.49, 0.24, 0.37 and 0.43 respectively) and negative significant correlation with number of flowers per fascicle, seed length and seed thickness (-0.27, -0.30 and 0.45 respectively). Leaf petiole length had positive significant correlation with stipule arista length and seed width (0.65 and 0.33 respectively) and negative significant correlation with number of flowers per fascicle and number of fascicles per node (-022 and 0.41 respectively). Stipule arista length had a positive significant correlation with weight of berries per tree and weight of seed per tree (0.20 and 0.21 respectively) and negative significant correlation with seed length and seed thickness (-0.20 and -0.33 respectively). Number of flowers per axil positive significant correlation with number of flowers per fascicle, number of fascicles per node, berry length, weight of berries per tree, 100 berry weights, weight of seeds per tree and 100 seed weight (0.20, 0.59, 0.20, 0.31, 0.46, 0.32, and 0.45respectively). Number of flowers per fascicle is positive significant correlation with number of fascicle per node (0.29). Number of fascicles per node had positive significant correlation with berry length, berry thickness, seed thickness, 100 berry weights and 100 seed weight (0.23, 0.25, 0.24, 0.32, and 0.34 respectively).

Berry length had positive significant correlation with

Table 2. Description of the 20 morphological characters used for the study.

S/N	Character	Descriptive value
1	Trunk height	The length from the ground level to the tip of the tree
2	Trunk diameter (cm)	Measured as a diameter of the main stem at five cm above the ground
3	Number of primary branches	Total number of primary branches counted per tree
4	Leaf length	Average of five normal (> node 3 from the terminal bud) leaves, measured from petiole end to apex
5	Leaf width	Average of five normal (> node 3 from the terminal bud) leaves, measured at the widest part
6	Leaf petiole length	Average of five normal (> node 3 from the terminal bud) petioles, measured from the base to the insertion with the blade
7	Stipule arista length	Average of five well-developed stipule arista
8	Number of flower per axil	Average number of flowers counted per axil
9	Number of flower per fascicle	Average number of flowers counted per fascicle
10	Number of fascicle per node	Average number of fascicles counted per node
11	Berry length	Average of ten normal and mature green fruits of each tree measured at the longest part
12	Berry width	Average of ten normal and mature green fruits of each tree measured at the widest part
13	Berry thickness	Average of ten normal and mature green fruits of each tree measured at the thickest part
14	Seed length	Average of ten normal beans of each tree measured at the longest part
15	Seed width	Average of ten normal beans of each tree measured at the widest part
16	Seed thickness	Average of ten normal beans of each tree measured at the thickest part
17	Weight of berry per tree	Weight of mature and riped berries per tree
18	100berry weight	Average of four samples of 100 berry weight of each tree
19	Weight of seed per tree	Weight of green beans harvested per tree
20	100seed weight	Average of four samples of 100 beans weight of each tree

Coffee descriptor (IPGR).

berry width, berry thickness, seed length, seed width, seed thickness and 100 seed weight (0.77, 0.80, 0.65, 0.44, 0.53 and 0.28 respectly). Berry width had positive significant correlation with berry thickness, seed length, seed width, and seed thickness, weight of berry per tree, weight of seeds per tree and 100 seed weight (0.88, 0.53, 0.20, 0.21, 0.32, 0.30, and 0.31 respectively). Berry thickness had a positive correlation with seed length, seed width, seed thickness weight of seed per tree and 100 seed weight (0.49, 0.26, 0.34, 0.23 and 0.27 respectively). Seed length was significantly correlated with seed width and seed thickness (0.35 and 0.69 respectively). Seed width had positive significant correlation with seed thickness, 100 berry weight and100 seed weight (0.63, 0.28, and 0.21 respectively). Weight of berries per tree had positive significant correlation with 100 berry weights, weight of seeds per tree and 100 seed weight (0.48, 0.98, and 0.45 respectively). Also, 100 berry weights had positively correlated with weight of seed per tree and 100 seed weight (0.48 and 0.91 respectively). Weight of seeds per tree had positive correlation with 100 seed weight (0.46).

Table 4 presents the genotypic correlation coefficient. Trunk height had strong, positive correlation with trunk diameter, number of primary branches, leaf length, leaf width, stipule arista length, weight of berries per tree, 100berry weight, weight of seeds per tree and 100 seed weight (0.35, 0.28, 0.75, 0.84, 0.43, 0.53, 0.37, 0.53, 0.38 and 0.55 respectively) but negative significant correlation with number of flowers per fascicle, seed length and seed thickness (-0.64, -0.37 and -0.46 respectively). Similarly, trunk diameter correlated positively with number of primary branches, leaf length, leaf width, leaf petiole length, stipule arista length and 100berry weight (0.97, 0.24, 0.27, 0.39, 0.67 and 0.24 respectively) but exhibited negative and significant correlation with number of flowers per fascicle, berry width and berry thickness (-0.43, -0.30 and -0.39 respectively) . Number of primary branches had a positive correlation with leaf length, leaf width, leaf petiole length, stipule arista length and seed width (0.29, 0.31, 0.52, 0.61 and 0.42 respectively) but negatively and significant correlation with number of flowers per fascicle, beery width and berry thickness (-0.45, -0.28 and -0.45 respectively). Leaf length had a positive correlation with leaf width, leaf petiole length, stipule arista length, berry width, seed width, weight of berries per tree, 100berry weight, weight of seeds per tree and 100seed weight (0.91, 0.60, 0.51, 0.25, 0.20, 0.24, 0.35, 0.20 and 0.45 respectively) and negative correlation with number of flowers per fascicle, seed length and seed thickness (-0.75, -0.28 and -0.46 respectively). Leaf width had positively correlated with leaf petiole length, stipule arista length, berry width, weight of berries per tree, 100berry weight, weight of

Table 3. Phenotypic correlation coefficient among twenty characters of coffee.

Character	TD (cm)	NPB	LL	LW	LPL	SAL	NFA	NFF	NFN	BL	BW	BT	SL	SW	ST	WBT	100BW	WST	100SW
TH (cm)	0.33**	0.26**	0.71**	0.80**	0.41**	0.51**	0.07	-0.23*	0.14	-0.02	0.14	0.01	-0.35**	0.05	-0.42**	0.34	0.49**	0.35**	0.52**
TD (cm)		0.80**	0.22*	0.25*	0.35*	0.62**	0.05	-0.11	-0.04	-0.15	-0.25*	-0.34**	-0.17	0.18	-0.13	0.16	0.21*	0.19	0.07
NPB			0.26**	0.28**	0.46**	0.55**	-0.04	-0.13	-0.06	-0.14	-0.26**	-0.40**	-0.04	0.32	0.04	0.08	0.16	0.13	0.01
LL				0.90**	0.59**	0.49**	0.01	-0.26**	-0.10	0.04	0.24*	0.03	-0.26**	0.17	-0.43**	0.23*	0.33**	0.19	0.41**
LW					0.55**	0.49**	-0.03	-0.27**	0.01	0.05	0.24*	0.04	-0.30**	0.08	-0.45**	0.23	0.37**	0.19	0.43**
LPL						0.65**	-0.16	-0.22*	-0.41**	-0.04	0.05	-0.19	-0.04	0.33**	-0.14	0.09	0.09	0.11	0.12
SAL							0.01	-0.11	-0.13	-0.15	-0.04	-0.16	-0.20*	0.16	-0.33**	0.20*	-0.06	0.21*	-0.09
NFA								0.27**	0.59**	0.20*	0.04	0.10	0.11	0.07	0.16	0.31**	0.46**	0.32**	0.45**
NFF									0.29**	0.07	-0.06	0.00	0.18	-0.14	0.08	0.13	0.05	0.11	0.04
NFN										0.23*	0.07	0.25*	0.15	0.04	0.24*	0.03	0.32**	0.01	0.34**
BL											0.77**	0.80**	0.65**	0.44**	0.53**	0.11	0.18	0.09	0.28**
BW												0.88**	0.53**	0.20*	0.21*	0.32**	0.13	0.30**	0.31**
BT													0.49**	0.26**	0.34**	0.23*	0.09	0.18	0.27**
SL														0.35**	0.69**	0.07	-0.04	0.11	0.03
SW															0.63**	0.00	0.28**	-0.02	0.21*
ST																0.02	0.11	0.02	0.06
WBT																	0.48**	0.98**	0.45**
100BW																		0.48**	0.91**
WST																			0.46**

TH-Trunk height, TD-trunk diameter, NPB-number of primary branches, LL-leaf length, LW-leaf width, LPL-leaf petiole length, SAL-stipule arista NFA-number of flower per axil, NFF- number of flower per fascicle NFN- number of fascicle per node, length BL-berry length, BW-berry width, BT-berry thickness, SL-seed length, SW-seed width, ST- seed thickness, WBT-weight of berry per tree, 100BW-100berry weight, WST-weight of seed per tree, 100SW-100seed weight.
NB: *, **- significance at 0.05 and 0.01 respectively. The values without any asterisk are not significant.

seeds per tree and 100seed weight (0.56, 0.51, 0.25, 0.24,0.40, 0.20 and 0.48 respectively) and negatively correlated with number of flowers per fascicle, seed length and seed thickness (-0.79, -.0.32 and 0.48 respectively).

Leaf petiole length had positive correlation with stipule arista length, number of flowers per axil and seed width (0.67, 0.21, and 0.38 respectively), but negatively correlated with number of flowers per fascicle, number of fascicles per node and berry thickness (-0.67, 0.52 and -0.20 respectively). Stipule arista length was negatively correlated with number of flowers per fascicle, seed length and seed thickness (-0.33, -0.22 and -0.36 respectively) but exhibited positive and significant correlation with weight of berries per tree and weight of seeds per tree (0.22 and 0.23 respectively). Number of flowers per axil had positive and significant correlation with number of flowers per fascicle, number of fascicles per node, weight of berries per tree, 100bery weight, weight of seeds per tree and 100seed weight (0.73, 0.68, 0.36, 0.54, 0.37 and 0.53 respectively). Number of flower per fascicle had positively correlated with number of number fascicles per node, seed length, weight of berries per tree and weight of seeds per tree (0.91, 0.36, 0.35 and 0.30 respectively) and negative correlation with berry width and seed width (-0.23 and -0.68 respectively). Number of fascicles per node had positive correlation with berry thickness, seed thickness, 100berry weight and 100seed weight (0.22, 0.20, 0.37 and 0.40 respectively).

Berry length had positively correlated with berry width, berry thickness, seed length, seed width, seed thickness and 100seed weight (0.76, 0.80,

Table 4. Genotypic correlation coefficient among twenty characters of coffee.

Character	TD (cm)	NPB	LL	LW	LPL	SAL	NFA	NFF	NFN	BL	BW	BT	SL	SW	ST	WBT	100BW	WST	100SW
TH	0.35**	0.28**	0.75**	0.84**	0.43**	0.53**	0.11	-0.64**	0.18	-0.04	0.14	0.00	-0.37**	0.06	-0.46**	0.37**	0.53**	0.38**	0.55**
TD		0.97**	0.24*	0.27**	0.39**	0.67**	0.07	-0.43**	-0.05	-0.19	-0.30**	-0.39**	-0.19	0.19	-0.16	0.18	0.24*	0.21	0.10
NPB			0.29**	0.31**	0.52**	0.61**	-0.04	-0.45**	-0.06	-0.15	-0.28**	-0.45**	-0.03	0.42**	0.05	0.09	0.18	0.15	0.00
LL				0.91**	0.60**	0.51**	-0.01	-0.75**	-0.11	0.05	0.25*	0.02	-0.28**	0.20*	-0.46**	0.24*	0.35**	0.20*	0.45**
LW					0.56**	0.51**	-0.04	-0.79**	0.03	0.05	0.25*	0.04	-0.32**	0.11	-0.48**	0.24*	0.40**	0.20*	0.48**
LPL						0.67**	0.21*	-0.67**	-0.52**	-0.04	0.05	-0.20*	-0.04	0.38**	-0.15	0.10	0.08	0.12	0.11
SAL							0.04	-0.33**	-0.13	-0.16	-0.05	-0.17	-0.22*	0.18	-0.36**	0.22*	-0.07	0.23*	-0.10
NFA								0.73**	0.68**	0.17	-0.02	0.05	0.06	-0.04	0.13	0.36**	0.54**	0.37**	0.53**
NFF									0.91**	0.16	-0.23*	-0.05	0.36**	-0.68**	0.05	0.35**	0.10	0.30**	0.11
NFN										0.14	-0.02	0.22*	0.07	-0.16	0.20*	0.04	0.37**	0.03	0.40**
BL											0.76**	0.80**	0.63**	0.38**	0.52**	0.13	0.17	0.10	0.28**
BW												0.88**	0.51**	0.12	0.18	0.35**	0.10	0.32**	0.32**
BT													0.47**	0.20*	0.31**	0.25*	0.06	0.20*	0.26**
SL														0.25**	0.71**	0.07	-0.08	0.11	-0.02
SW															0.63**	-0.01	0.24*	-0.04	0.17
ST																0.03	0.08	0.02	0.02
WBT																	0.51**	0.99**	0.49**
100BW																		0.52**	0.94**
WST																			0.50**

TH-Trunk height, TD-trunk diameter, NPB-number of primary branches, LL-leaf length, LW-leaf width, LPL-leaf petiole length, SAL-stipule arista NFA-number of flower per axil, NFF-number of flower per fascicle NFN- number of fascicle per node, length BL-berry length, BW-berry width, BT-berry thickness, SL-seed length, SW-seed width, ST- seed thickness, WBT-weight of berry per tree, 100BW-100berry weight, WST-weight of seed per tree, 100SW-100seed weight.
NB: *, **- significance at 0.05 and 0.01 respectively. The values without an asterisk are not significant.

0.63, 0.38, 0.52, and 0.28 respectively). Berry width had positively correlated with berry thickness, seed length, weight of berries per tree, weight of seeds per tree and 100seed weight (0.88, 0.51, 0.35, 0.32, and 0.32 respectively). Similarly, berry thickness was correlated with seed length, seed width, seed thickness, weight of berries per tree, weight of seeds per tree and 1000seed weight (0.47, 0.20, 0.31, 0.25, 0.20 and 0.26 respectively). Seed length was correlated with seed width and seed thickness (0.25 and 0.71 respectively). Seed width was correlated seed thickness and 100berry weight (0.63 and 0.24). Weight of berries tree was correlated with 100berry weight, weight of seeds per tree and 100seed weight (0.51, 0.99 and 0.49 respectively). 100berry weight was correlated with weight of seeds per tree and 100seed weight (0.52 and 0.94 respectively). Weight of seeds per tree was correlated with 100seed weight (0.50). Trunk height had positively correlated with trunk diameter, number of primary branches, stipule arista length and 100seed weight (0.22, 0.22, 0.29 and 0.26 respectively) (Table 5). Trunk diameter had a positive correlation with leaf length and stipule arista length (0.21 and 0.33 respectively). Number of primary branches had positively correlated with stipule arista length (0.23). Leaf length was strongly correlated with leaf width (0.72). Leaf width had negative correlation with seed width (-0.20). Leaf petiole length had positively correlated with 100 berry weight and 100 seed weight (0.23 and 0.21 respectively). Stipule arista length had a negative correlation with number of fascicles per node (-0.21). Number of flowers per axil had positively correlated with

Table 5. Environmental correlation coefficient among twenty characters of coffee.

Character	TD (cm)	NPB	LL	LW	LPL	SAL	NFA	NFF	NFN	BL	BW	BT	SL	SW	ST	WBT	100BW	WST	100SW
TH (cm)	0.22*	0.22*	0.07	0.10	0.12	0.29**	-0.12	-0.09	0.00	0.11	0.15	0.16	-0.06	0.04	0.11	0.02	0.09	0.00	0.26**
TD (cm)		0.12	0.21*	0.16	0.01	0.33**	-0.01	0.07	-0.02	0.04	0.10	0.02	0.01	0.13	0.10	0.01	-0.03	-0.01	-0.13
NPB			0.10	0.06	0.07	0.23*	-0.05	0.01	-0.06	-0.09	-0.15	-0.12	-0.11	-0.06	-0.02	0.03	0.03	0.02	0.05
LL				0.72**	0.03	0.08	0.16	-0.03	-0.10	0.05	0.14	0.05	-0.08	-0.06	0.06	0.06	-0.06	0.03	-0.12
LW					0.03	0.10	-0.06	-0.07	-0.18	-0.01	0.02	-0.01	-0.18	-0.20*	0.01	-0.03	-0.12	-0.06	-0.17
LPL						0.06	0.09	0.01	-0.01	-0.08	-0.04	0.03	-0.06	0.06	0.09	0.05	0.23*	0.06	0.21*
SAL							-0.16	-0.01	-0.21*	0.04	0.05	0.03	-0.03	0.05	-0.06	-0.07	0.04	-0.07	0.00
NFA								0.12	0.41**	0.35**	0.40**	0.40	0.36**	0.39**	0.35**	0.09	0.16	0.15	0.20
NFF									0.08	0.07	0.07	0.07	0.22*	0.14	0.22*	0.05	0.07	0.07	0.00
NFN										0.58**	0.54**	0.54**	0.52**	0.53**	0.47**	-0.03	0.21*	-0.06	0.21*
BL											0.93**	0.87**	0.79**	0.78**	0.62**	-0.02	0.31**	-0.01	0.29**
BW												0.93**	0.75**	0.76**	0.61**	-0.04	0.37**	-0.02	0.31**
BT													0.72**	0.72**	0.64**	-0.09	0.44**	-0.06	0.39**
SL														0.90**	0.58**	0.09	0.39**	0.12	0.36**
SW															0.66**	0.11	0.52**	0.10	0.43**
ST																-0.06	0.48**	-0.07	0.35**
WBT																	0.03	0.90**	0.05
100BW																		0.03	0.75**
WST																			0.13

TH-Trunk height, TD-trunk diameter, NPB-number of primary branches, LL-leaf length, LW-leaf width, LPL-leaf petiole length, SAL-stipule arista NFA-number of flower per axil, NFF- number of flower per fascicle NFN- number of fascicle per node, length BL-berry length, BW-berry width, BT-berry thickness, SL-seed length, SW-seed width, ST- seed thickness, WBT-weight of berry per tree, 100BW-100berry weight, WST-weight of seed per tree, 100SW-100seed weight. NB: *, **- significance at 0.05 and 0.01 respectively. The values without an asterisk are not significant.

number of fascicles per node, berry length, berry width, berry thickness, seed length, seed width, seed thickness and 100 seed weight (0.41, 0.35, 0.40, 0.40, 0.36, 0.39, 0.35 and 0.20 respectively). Similarly, number of flowers per fascicle had a positive correlation with seed length and seed thickness (0.22 and 0.22 respectively). Number of fascicles per node had positively correlated with berry length, berry width, berry thickness, seed length, seed width, seed thickness, 100 berry weight, and 100 seed weight (0.58, 0.54, 0.54, 0.52, 0.53, 0.47, 0.21 and 0.21 respectively).

Berry length had strong a positive correlation with berry width, berry thickness, seed length, seed width, seed thickness, 100 berry weight, and 100 seed weight (0.93, 0.87, 0.79, 0.78, 0.62, 0.31 and 0.29 respectively). Berry width had a strong positive correlation with berry thickness, seed length, seed width, seed thickness, 100 berry weight, and 100 seed weight (0.92, 0. 75, 0.76, 0.61, 0.37 and 0.31 respectively). Berry thickness was strongly positively correlated with seed length, seed width, seed thickness, 100 berry weight, and 100 seed weight (0.72, 0.72, 0.64, 0.44 and 0.39 respectively). Seed length had strong positive correlation with seed width, seed thickness, 100 berry weights and 100 seed weight (0.90, 0.58, 0.39 and 0.36 respectively). Seed width had strong positive correlation with seed thickness, 100 berry weight and 100 seed weight (0.66, 0.52 and 0.43 respectively). Seed thickness had positively correlated with 100 berry weight and 100 seed weight (0.48 and 0.35 respectively). Weight of berries per tree was strongly correlated with weight of seeds per tree (0.90). Also,100 berry weight strongly correlated with 100 seed weight (0.75).

Stepwise regression analysis identifies the best subset of predictors or independent variables and

Table 6. Stepwise regression analysis of independent characters on 100seed weight and weight of seed per tree of coffee.

Dependable character	Model	Independable characters	Partial R^2	Cumulative	Model R^2
		X1= 100berry weight (g)	0.867		
		X2= Berry length (mm)	0.009	0.879	
100 seed weight	Y= -2.6+0.154+0.269+0.151+0.005-0.014	X3= Number of flower per fascicle	0.003	0.882	
		X4= Trunk height (cm)			
		X5=Trunk diameter (cm)	0.002	0.884	
			0.004	0.888	0.888**
		X1= weight of berry per tree (g)	0.934	0.934	
		X2= Plant height			
Weight of seed per tree	Y=84.833+0.266-31.885+10.315-18.590	X3= Number of flower per axil	0.004	0.968	
		X4= Number of fascicle per node	0.003	0.971	
			0.002	0.973	0.973**

** 0.01.

the order in which variables are included in the regression equation. The order tells the relative importance of the predictors, which is the best predictor, second best and so on. The result for 100 seeds weight as dependent variables showed that 100 berries weight, berry length, number of flower per fascicle, trunk height and trunk diameter are the predictors for 100seed weight and accounted for 93% of variation observed. Each trait made a significant contribution to 100seed weight with 100berry weight as best predictor, which accounted for 86% of the total variation (Table 6). Similarly, the result obtained for weight of seed per tree showed that weight of berry per tree, plant habit, number of flower per axil and number of fascicle per node in that order are the predictors and accounted for 94% of the variation observed with weight of berry per tree as best predictor, accounting for 93.4%.

DISCUSSION

Knowledge of correlations among characters is useful in designing an effective breeding programme for any crop. The mutual association among characters is often expressed by the phenotypic, genotypic and environmental correlation (Searle 1961; Ariyo, 1989; Akinyele and Osekita, 2006). Weight of seed per tree which is actual yield is has strong and positive correlation with trunk height, leaf length, leaf width stiple arista length, number of flower per axil, number of flower per fascicle, berry width, berry thickness, 100 berry weight, 100seed weight and weight of berry per tree. According to Getachew (2019), coffee yield was found to have strong and positive association with fruit width and fruit thickness at genotypic level. Gizachew and Hussei (2017) in their findings reported that average yield has positive and significant correlation with 100 bean weight and leaf length. Ermias (2005) also reported strong and positive correlation with plant height. Phenotypic correlation is a composite of genotypic and environmental correlations. There are several reasons for using indirect selection. Sometimes the main character is expressed late, or measurement of the indirect character is much easier than for the direct character. Although yield is not directly correlated with seed length and berry length but has correlation with berry width and berry thickness which in turn have direct correlation seed length (0.51 and 0.47) and berry length (0.76, 0.80). Selection could be made for seed length and berry length during breeding programme resulting to yield improvement.

Moreover, complex plant characters such as yield are quantitatively inherited and influenced by genetic effects, as well as by genotype x environment interaction. Due to these reasons, selections to improve yield directly may be difficult and time-consuming, especially for perennial crops with a long juvenile period such as coffee. Therefore, identification and use of positively correlated characters are appropriate.

From the results obtained, the lower values of phenotypic correlation coefficients (weight of seed per tree with trunk height, weight of berry per tree, 100seed weight and correlation among traits) to the genotypic correlation coefficient values, indicates that the influence of environmental factors is minimal and lower than the inherent genetic effects. This is in line with the work of Walyaro and Van der Vossen, 1979 where genotypic correlation values were greater than phenotypic values. According to Falconer (1989), linkage effects or pleotropic effect of genes may be the source of significant correlation coefficients among various characters. Negative correlation between two traits implies selection of one trait for improvement will cause decrease in the other trait especially if it is of high magnitude. In this study, number of flower per fascicle had strong negative correlation with leaf length, leaf width and leaf petiole length (-0.75, -0.79 and -0.67 respectively). When the correlation is strong and positive, simultaneous improvements of both traits could be achieved (Rangaswamy, 1995). All flower characters (number of flower per axil, number of flower per fascicle, and number of fascicle per node) and some yield and yield related characters were positively correlated with one another. The implication of this is that selection/breeding for any of the characters is invariably selecting /breeding for others. Moreover, those with high values of correlation show that no matter how many times the trial is repeated, the result will be highly dependent.

Stepwise regression procedure was used to determine the variables that accounted for the majority of total yield variability. At each step, one variable was added to the regression equation. The added variable was the one that included the greatest reduction in the error sum of square. It was also the variable that had the highest partial correlation with the dependent variable for fixed values of those variables already added. Moreover, it was the variable which had the highest F-value. Stepwise regression is, therefore designed to find the most parsimonious set of predictors that are most effective in predicting the dependent variables (Ndukauba et al., 2015).

In order to remove the effect of non-effective characteristics in the regression model of coffee yield, stepwise regression was used in the analysis. 100seed weight and weight of seeds per tree as dependent variable and other traits as an independent variable were considered.

The result suggested that 100 berry weight, berry length, number of flowers per fascicle, trunk height and trunk diameter were the major contributors towards 100seed weight. In contrast, the weight of berries per tree, plant height, number of flowers per axil and number of fascicles per node were the major contributors towards weight of seeds per tree of coffee and should therefore be given serious consideration in coffee breeding programs.

Conclusion

In conclusion, genotypic correlations among characters affecting yield elucidate true relationship as they eliminate the environmental influences. It can be recommended that coffee yield improvement could be accomplished through selections based on these correlations. Consequently, knowledge of associations between yield and its component traits as well as among the component traits themselves can promote the efficiency of selection in coffee breeding programs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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