

Interrelationship and association of characters in robusta coffee (*Coffea canephora* var. *robusta*)

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Abstract: Commercial coffee is obtained from the processed beans of two species of the genus *Coffea* namely *C. arabica* and *C. canephora*, the former yielding arabica coffee and the latter yielding robusta coffee. Most of the agronomic characters of crop plants are controlled by polygenes and hence they show different levels of interrelationships. Analysis of correlation between such characters and further study of relative contribution of each character towards the genetic potential of the species provide valuable tools to identify the lead characters among them so that further improvement programmes could be based on such characters. The present study of the agronomically important polygenic characters of robusta coffee, utilizing the robusta coffee germplasm maintained in the Regional Coffee Research Station, Chundale, Wayanad, Kerala, India by the Central Coffee Research Institute of India has shown that girth of primary branches, weight of 100 dry fruits and percentage of A grade beans have got significant positive correlation with the maximum number of other characters. Factor analysis revealed that bush spread showed the maximum factor loading followed by length of primary branches and girth of primary branches. This shows the strength of the association of these characters with others and their importance in robusta breeding programmes.

Keywords: *Coffea Canephora*, Correlation, Factor Analysis, Variance, Germplasm, Character Association

1. Introduction

The beverage coffee is obtained from the processed beans of two species of the genus *Coffea* namely *Coffea arabica* L. (arabica coffee) and *Coffea canephora* Pierre ex Froehner var. *robusta* (robusta coffee). It is a small tree in the wild and a shrub under cultivation. Both the species grow in humid tropics of the world with high rainfall. Even though arabica coffee is superior in certain quality aspects, it is susceptible to pests like white stem borer and diseases like leaf rust and it is a high elevation crop. Hence, robusta coffee which is tolerant to stem borer and leaf rust and suitable for cultivation in low altitude is being recommended for such areas. It gives a fairly good decoction and is also useful in making specialty coffees [1]. As in the case of other crops, in coffee most of the agronomic characters are polygenic [2] and they show different levels of interrelationship. This relationship is partly due to the involvement of same sets of alleles in the control of different cha-

acters and partly due to the mutually complementing nature of the characters. Correlation analysis is an important tool to identify the relationship between characters. Subsequent analysis of factor loading can be used to study the association of characters and the relative contribution of each character towards the genetic potential of the crop. Study of interrelationship and association of characters provides an efficient tool to select the most important characters to be considered in breeding programmes. The present study is an effort to analyse the interrelationship of agronomic characters in robusta coffee and to select characters that are representative in nature due to common sharing of genes.

2. Materials and Methods

The experimental field, the germplasm collection of robusta coffee at Regional Coffee Research Station, Chundale, Wayanad, Kerala, India (13°22' N and 75°28'E)

which is a part of India's national coffee germplasm is located in the western ghat region of India, 840m above MSL with an annual rainfall of 2000-3000mm spread over a period of nine months ranging from March to November. Average humidity of this area is 88.9% with average minimum and maximum temperature between 17.6°C and 27.3°C. Soil is generally lateritic, the soil structure varying from sandy to clayey loams with soil pH varying from 5.2-6.3. The 74 accessions/ genotypes of robusta coffee used for the present study were collected from India and outside by Coffee Board of India and planted in 1979-83 (Table 1). The experiment was laid down in subplots with three replications and eight plants per plot in Randomized Block Design. Seedlings were planted in 3m x 3m spacing and maintained uniformly under rainfed condition as per the package of practices prescribed by Coffee Board of India. Observations were made on twenty eight growth/ yield/ quality characters (Tables 2&3) for three consecutive years starting from 2002.

Table 1. Details of the robusta coffee accessions studied.

Sl. No.	Accession Number	Source
1	DR.1	India
2	DR.2	India
3	DR.3	India
4	DR.4	India
5	DR.5	India
6	DR.6	India
7	DR.7	India
8	DR.8	India
9	DR.9	India
10	DR.10	India
11	DR.11	India
12	DR.12	India
13	DR.13	India
14	DR.14	India
15	DR.15	India
16	DR.16	India
17	DR.17	India
18	DR.18	India
19	DR.19	India
20	DR.20	India
21	Wt.1	India
22	Wt.2	India
23	Wt.3	India
24	Wt.4	India
25	Wt.5	India
26	Wt.6	India
27	WC.1	India
28	WC.2	India

29	WC.3	India
30	WC.4	India
31	WC.5	India
32	WC.6	India
33	WC.7	India
34	WC.8	India
35	WC.9	India
36	WC.10	India
37	WC.11	India
38	WC.12	India
39	WC.13	India
40	WC.14	India
41	WC.15	India
42	WC.16	India
43	WC.17	India
44	WC.18	India
45	WC.19	India
46	WC.20	India
47	WC.21	India
48	WC.22	India
49	WC.23	India
50	WC.24	India
51	WC.25	India
52	WC.26	India
53	WC.27	India
54	WC.28	India
55	WC.29	India
56	WC.30	India
57	WC.31	India
58	WC.32	India
59	WC.33	India
60	WC.34	India
61	S.879	Java
62	S.1932	Madagascar
63	S.1902	Saigon
64	S.880	Uganda
65	S.1979	Uganda
66	S.3399	Costa Rica
67	S.1509	Ivory Coast
68	S.1977	Uganda
69	S.1481	Guatemala
70	S.3400	Costa Rica
71	S.3655	Ivory Coast
72	S.3656	Ivory Coast
73	S.3657	Ivory Coast
74	S.274	Selection from CCRI, India

Table 2. Correlation of characters in the case of the robusta coffee accessions studied.

	Stem girth	No. of primary branches	No. of secondaries/primary primary	Girth of primary branches	Length of primary branches	Inter nodal length	Bush spread	Leaf length	Leaf breadth	Leaf area	Fruits/node	Fruit length	Fruit breadth	Fruit thickness
Stem girth	1.00													
No. of primary branches	-0.08	1.00												
No. of secondaries per primary	0.59**	-0.04	1.00											
Girth Of primary branches	0.68**	-0.13	0.70**	1.00										
Length of primary branches	0.52**	0.05	0.63**	0.75**	1.00									
Intermodal length	-0.25	-0.10	-0.25	-0.09	0.18	1.00								
Bush spread	0.54**	0.12	0.60**	0.71**	0.91**	0.13	1.00							
Leaf length	0.15	-0.38	0.34**	0.44**	0.28*	0.12	0.27*	1.00						
Leaf breadth	0.11	-0.24	0.13	0.34**	0.26*	0.41**	0.24*	0.49**	1.00					
Leaf area	0.20	-0.32	0.30**	0.47**	0.32**	0.30**	0.31**	0.83**	0.86**	1.00				
Fruits Per node	0.21	0.04	0.22	0.25*	0.19	-0.13	0.20	0.16	0.14	0.18	1.00			
Fruit length	-0.04	0.02	-0.06	0.07	-0.17	-0.02	-0.22	0.20	0.09	0.16	-0.23	1.00		
Fruit breadth	0.09	0.20	0.08	0.20	-0.09	-0.25	-0.15	0.07	-0.04	0.03	-0.04	0.66**	1.00	
Fruit thickness	0.08	0.22	0.07	0.14	-0.14	-0.22	-0.20	0.07	-0.10	0.00	-0.08	0.75**	0.90**	1.00
Fruit volume	0.03	0.17	0.03	0.14	-0.14	-0.16	-0.20	0.13	-0.01	0.08	-0.15	0.89**	0.90**	0.95**
Wt. of 100 fresh fruits	-0.04	0.26*	0.02	0.21	0.07	-0.12	0.04	0.12	0.07	0.10	0.12	0.47**	0.72**	0.57**
Wt. of 100 dry fruit	0.08	0.25*	0.24*	0.30**	0.21	-0.14	0.19	0.12	0.06	0.10	0.04	0.46**	0.65**	0.56**
Bean length	0.02	0.22	0.25*	0.27*	0.16	-0.07	0.21	0.18	0.07	0.14	0.07	0.51**	0.47**	0.47**
Bean breadth	-0.08	0.11	0.14	0.20	0.22	0.03	0.22	0.18	0.05	0.13	0.16	0.20	0.39**	0.35**
Bean thickness	-0.07	0.21	0.09	0.23*	0.15	-0.03	0.14	0.14	0.06	0.11	0.16	0.28*	0.59**	0.41**
Bean volume	-0.03	0.19	0.19	0.27*	0.19	-0.04	0.20	0.18	0.08	0.15	0.15	0.41**	0.55**	0.48**
Bean density	-0.06	0.00	0.00	-0.02	-0.14	-0.19	-0.18	0.20	0.00	0.10	0.13	0.09	0.13	0.10

Weight Of 100 beans	0.02	0.22	0.21	0.32**	0.20	-0.12	0.19	0.18	0.08	0.14	0.16	0.45**	0.66**	0.55**
Yield Per plant	0.28*	-0.09	0.15	0.43**	0.13	-0.24	0.08	0.37**	0.12	0.29*	0.31**	0.44**	0.37**	0.37**
Out Turn (fresh to dry)	0.23*	-0.04	0.42**	0.13	0.24*	-0.06	0.26*	-0.05	-0.07	-0.08	-0.21	-0.12	-0.26	-0.14
Out Turn (dry to clean)	-0.31	-0.01	-0.27	-0.22	-0.13	0.07	-0.16	-0.14	-0.03	-0.09	0.10	-0.15	-0.07	-0.11
Out Turn (fresh to clean)	-0.22	-0.04	-0.19	-0.29	-0.13	-0.02	-0.11	-0.30	-0.26	-0.32	-0.19	-0.35	-0.25	-0.29
A grade beans %	-0.12	0.00	-0.08	0.10	0.13	0.40**	0.07	0.36**	0.23*	0.33**	-0.08	0.42**	0.29*	0.33**
	Fruit volume	Wt. of 100 fresh fruits	Wt. of 100 dry fruits	Bean length	Bean breadth	Bean thickness	Bean volume	Bean density	Weight of 100 beans	Yield/ plant (fresh to dry)	Out Turn (dry to clean)	Out Turn (fresh to clean)	A grade Beans %	
Fruit volume	1.00													
Wt. of 100 fresh fruits	0.62**	1.00												
Wt. of 100 dry fruits	0.60**	0.88**	1.00											
Bean length	0.52**	0.73**	0.80**	1.00										
Bean breadth	0.33**	0.67**	0.72**	0.61**	1.00									
Bean thickness	0.46**	0.81**	0.77**	0.63**	0.81**	1.00								
Bean volume	0.52**	0.83**	0.87**	0.86**	0.87**	0.90**	1.00							
Bean volume	0.52**	0.83**	0.87**	0.86**	0.87**	0.90**	1.00							
Bean density	0.08	0.07	-0.06	-0.01	-0.11	-0.06	-0.09	1.00						
Weight Of 100 beans	0.59**	0.89**	0.93**	0.81**	0.81**	0.88**	0.94**	-0.01	1.00					
Yield/ plant	0.42**	0.31**	0.17	0.25*	0.05	0.25*	0.23*	0.14	0.28*	1.00				
Out Turn (fresh to dry)	-0.16	-0.42	0.03	-0.02	-0.02	-0.22	-0.10	-0.25	-0.13	-0.35	1.00			
Out Turn (dry to clean)	-0.14	0.10	-0.04	-0.02	0.08	0.05	0.05	-0.04	0.03	-0.15	-0.27	1.00		
Out Turn (fresh to clean)	-0.35	-0.05	-0.10	0.00	0.05	-0.01	0.00	0.02	-0.06	-0.34	-0.06	0.69	1.00	
A grade beans %	0.38**	0.31**	0.28*	0.15	0.37**	0.35**	0.32**	-0.05	0.29*	0.21	-0.13	0.06	-0.16	1.00

*: significant at 5% level; **: significant at 1% level.

Table 3. Factor loading, percentage of variance contributed by each character and characters that show significant positive correlation in the case of the robusta coffee accessions studied.

Sl. No.	Character	Factor loading	Percentage of variance contributed	Number of characters that show significant positive correlation	Characters that show significant positive correlation
1	Stem girth	.639807	5.538649	6	Number of secondaries per primary, girth of primary branches, length of primary branches, bush spread, yield, out turn (fresh to dry)
2	Number of primary branches	.584578	5.060545	2	Weight of 100 fresh fruits, weight of 100 dry fruits
3	Number of secondaries per primary	.693735	6.00549	9	Stem girth, girth of primary branches, length of primary branches, bush spread, leaf length, leaf area, weight of 100 dry fruits, bean length, out turn (fresh to dry)
4	Girth of primary branches	.768921	6.656356	14	Stem girth, number of secondaries per primary, length of primary branches, bush spread, leaf length, leaf breadth, leaf area, fruits per node, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans, yield per plant
5	Length of primary branches	.787217	6.81474	8	Stem girth, number of secondaries per primary, girth of primary branches, bush spread, leaf length, leaf breadth, leaf area, out turn (fresh to dry)
6	Internodal length	.666879	5.773004	3	Leaf breadth, leaf area, percentage of A grade beans
7	Bush spread	.789702	6.836252	8	Stem girth, number of secondaries per primary, girth of primary branches, length of primary branches, leaf length, leaf breadth, leaf area, out turn (fresh to dry)
8	Leaf length	.535227	4.633326	8	Number of secondaries per primary, girth of primary branches, length of primary branches, bush spread, leaf breadth, leaf area, yield, percentage of A grade beans
9	Leaf breadth	.525249	4.546949	7	Girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf area, percentage of A grade beans
10	Leaf area	.617314	5.343933	9	Number of secondaries per primary, girth of primary branches, length of primary branches, internodal length, bush spread, leaf length, leaf breadth, yield, percentage of A grade beans
11	Fruits per node	.336301	2.911274	2	Girth of primary branches, yield per plant
12	Fruit length	.247852	2.145593	11	Fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
13	Fruit breadth	.000968	0.00838	12	Fruit length, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
14	Fruit thickness	.095800	0.829317	12	Fruit length, fruit breadth, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
15	Fruit volume	.165224	1.430303	12	Fruit length, fruit breadth, fruit thickness, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
16	Weight of 100 fresh fruits	.136114	1.178305	13	Number of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, yield, percentage of A grade beans
17	Weight of 100 dry fruits	.272386	2.357977	14	Number of primary branches, number of secondaries per primary, girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans, percentage of A grade beans
18	Bean length	.230790	1.997891	13	Number of secondaries per primary, girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean breadth, bean thickness, bean volume, weight of 100 beans, yield
19	Bean breadth	.398686	3.451325	10	Fruit breadth, fruit thickness, fruit volume, weight of 100

20	Bean thickness	.293330	2.539284	12	fresh fruits, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans, percentage of A grade beans Girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean volume, weight of 100 beans, percentage of A grade beans
21	Bean volume	.325072	2.814067	13	Girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, weight of 100 beans, yield, percentage of A grade beans
22	Bean density	-.027831	-0.24093	Nil	Nil
23	Weight of 100 beans	.265992	2.302626	13	Girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean length, bean breadth, bean thickness, bean volume, yield, percentage of A grade beans
24	Yield per plant	.181576	1.571858	13	Stem girth, girth of primary branches, leaf length, leaf area, fruits per node, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean thickness, bean volume
25	Out turn (fresh to dry)	.574606	4.97422	4	Stem girth, number of secondaries per primary, length of primary branches, bush spread
26	Out turn (dry to clean)	.477259	4.131512	1	Out turn (fresh to clean)
27	Out turn (fresh to clean)	.539188	4.667615	1	Out turn (dry to clean)
28	Percentage of A grade beans	.429739	3.720143	14	Internodal length, leaf length, leaf breadth, leaf area, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean breadth, bean thickness, bean volume, weight of 100 beans

The data were analysed for correlation of characters as suggested by Rangaswamy (1995) [3] with reference to 28 characters of the 74 genotypes. Factor loading has been studied using the statistical programme STATISTICA.

3. Results and Discussion

Out of the 28 characters, girth of primary branches, weight of 100 dry fruits and percentage of A grade beans showed significant positive correlation with the maximum number of characters. Girth of primary branch was found to be significantly correlated with stem girth, number of secondaries per primary, length of primary branches, bush spread, leaf length, leaf breadth, leaf area, fruits per node, weight of 100 dry fruits, bean length, bean thickness, bean volume, weight of 100 beans and yield per plant. Weight of 100 dry fruits showed significant positive correlation with 14 characters namely number of primary branches, number of secondaries per primary, girth of primary branches, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean breadth, bean thickness, bean volume, weight of 100 beans and percentage of A grade beans. Percentage of A grade beans showed significant positive correlation with 14 characters, namely internodal length, leaf length, leaf breadth, leaf area, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, weight of 100 dry fruits, bean breadth, bean thickness, bean volume and weight of 100 beans. Weight of 100 fresh fruits, bean volume, weight of 100 beans and yield per plant showed significant positive correlation with 13 characters each. Yield per plant was significantly and

positively correlated with stem girth, girth of primary branches, leaf length, leaf area, fruits per node, fruit length, fruit breadth, fruit thickness, fruit volume, weight of 100 fresh fruits, bean length, bean thickness and bean volume (Tables 2&3). Characters that show significant positive correlation are interrelated and they can be jointly considered for selection programmes. The present study shows that girth of primary branches, fruit weight, bean weight, bean volume and percentage of A grade beans are the most important characters that are to be considered in robusta coffee selection programmes because they are interrelated with majority of the agronomic characters of coffee.

Study of factor loading in the case of the twenty eight growth/quality characters of robusta coffee revealed the relative factor loading of each character and the percentage of variance contributed by each. The highest factor loading was shown by bush spread followed by length of primary branches and girth of primary branches indicating their contribution of higher share towards the population variance (Table 3). Fruit thickness, fruit breadth and bean density showed the lowest factor loading and lowest share of variance contributed.

Characters that show the highest factor loading and that contribute the highest percentage of variance can be considered the lead characters of the population. Such characters can be focused for when selection programmes to improve desirable characters are carried out. It shows that in the case of robusta coffee, bush spread, length of primary branches and girth of primary branches are the most important characters to be considered while practicing selection.

A study conducted by Srinivasan (1969) [4] has shown

that stem girth has significant positive correlation with cherry yield, both in arabica and robusta coffee selections thus indicating that stem girth might be a useful character for the purpose of selecting high yielding lines. A study by Berthoud *et al.* (1978) [5] showed that stem and primary branch diameter and number of nodes were positively interrelated. A study by Srinivasan (1980) [6] revealed high positive correlation of stem girth and length of primary branches with fruit yield. Sundar (1983) [7] found that in robusta coffee fruit volume was positively and significantly correlated with all other fruit and bean characters. The significant positive relationship in CxR coffee between stem girth and tree radius and girth of primary branches and stem girth has been reported by Ahmed and Sreenivasan (1988) [8]. Raghu *et al.* (2003) [9] have reported significant relationship of crop yield in CxR coffee with total number of fruiting nodes per plant and mean number of berries per plant.

Positive correlation of raw bean colour with cup quality has been reported by Awatramani *et al.* (1974) [10]. According to Srinivasan and Vishveshwara (1980) [11] bean thickness, body of liquor and acidity showed significant positive correlation with cup quality. Raju *et al.* (1978) [12] found that bean thickness, body of the liquor and acidity showed significant positive correlation with cup quality in CxR coffee. Correlation between organoleptic inferiority and poor physical quality of beans has been reported by Roman and Vega (1998) in Costa Rica [13].

4. Conclusion

The present study has revealed the interrelationship between agronomic characters in robusta coffee. Girth of primary branches, weight of 100 dry fruits and percentage of A grade beans showed significant positive correlation with maximum number of characters. Factor analysis to study factor loading and relative contribution of each character towards the variability of the study population has revealed that bush spread showed the maximum factor loading followed by length of primary branches and girth of primary branches. This shows the strength of their association with other characters and their importance in robusta coffee breeding programmes. The observation further revealed that the highest quantum of variance of the population was also contributed by these characters.

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