Morphological Descriptors for Ethiopian Wild *Coffea arabica* L. Genetic Resources Conserved in India

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Eighteen accessions of wild *Coffea arabica* from different geographic locations of Ethiopia available in the gene bank of Central Coffee Research Institute; Balehonnur, Karnataka, India, were evaluated for vegetative, inflorescence and flowering traits. Three cultivated varieties of Ethiopian Arabica coffee *viz.*, Agaro, Cioccie and Tafarikela were considered as standards in the present study. Morphological descriptor of International Plant Genetic Resource Institute was used as the basic format for the characterization. Vegetative characters showing large variation were identified to be young leaf colour and angle of insertion of primary branches. Among the reproductive traits studied, flower number per axil was found to manifest large variation. These traits offer scope for selection and thus, this information is expected to be useful for conservation of genotypes in the Gene Bank and selection and utilization in the breeding programmes.

Key Words: *Coffea*, Descriptors, Characterization, Germplasm

Introduction

Coffee is one of the world's most valuable commodities, contributing largely to the economy of more than 50 countries of Asia, Latin America and Oceania. Of approximately 100 taxa of the genus *Coffea* (Family Rubiaceae), only two species are economically important *i.e., Coffea arabica* L. and *Coffea canephora* Pierre ex Froehner, accounting respectively for about 70 per cent and 30 per cent of the world coffee production. In India, the area under coffee cultivation is around 3,48,995 ha, of which arabica and robusta account for 48 per cent and 52 per cent, respectively. The annual average production is around 2,80,000 metric tons, a share of 4.54 per cent of the world production. Arabica coffee is believed to have originated in the Southwestern highlands of Ethiopia (erstwhile Abyssinia) (Sylvain, 1955; Meyer, 1965). Literature on coffee provides a vivid description of the spread of *C. arabica* from Arabia Felix (present Yemen) to other countries (Chevalier, 1929; Cramer, 1957; Meyer, 1965; Smith, 1985; Wrigley, 1988). Morphological traits were the earliest markers used in germplasm collection, management and utilization in breeding (Smith and Smith, 1992). Study of morphological and agronomic traits is the best approach to understand the genetic constitution of the coffee plant and helped in various breeding programmes for the improvement of yield, quality, disease resistance and other desirable characters. Morphological characters such as vegetative development, angle of insertion of primary branches, young leaf colour, leaf length, leaf width, number of days from rainfall to flowering, inflorescence position, inflorescence on old wood, number of flowers per axil, number of flowers per fascicle, number of fascicles per node, inflorescence stalk length, corolla tube length, anther insertion and number of stamens per flower have considerable importance in the coffee breeding programme (Vishveshwara and Ahmed, 1975; Srinivasan and Vishveshwara, 1973; Srinivasan, 1969, 1980, 1985; Selvakumar and Sreenivasan, 1986; Montagnon and Bouharmont, 1996).

Wild relatives and progenitors of cultivated plants represent a strategic component of germplasm collections. Characterization of the accessions maintained in the gene bank and related documentation is imperative for the optimal conservation of genetic resources and effective use in breeding programmes (Ferreira, 2005). As the genetic base and variability of agricultural crops are relatively narrow, introgression of genes from wild sources can substantially influence the breeding progress. Morphological descriptors are reliable, easy to study and relatively less expensive to evaluate with very few limitations. These descriptors enable correct taxonomic ranging and precise characterization of genetic resources and define infraspecific variation. As wild species constitute the base of genetic resources for coffee breeding, interspecific crosses have been realised to test breeding possibilities by introgression (Louarn, 1992). Despite the importance of morphological data in breeding, very little work has been done on the characterization and evaluation

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of coffee germplasm available at the Central Coffee Research Institute (CCRI), India. The specific objective of this study is to generate descriptors of the various accessions from different geographical locations of Ethiopia, maintained in CCRI Gene Bank to understand the organization of existing morphological diversity in the wild coffee germplasm in a universally acceptable format (IPGRI) for current and future use in genetic improvement of the crop.

Materials and Methods

Fifteen different coffee germplasm accessions enlisted as S. 2440, S. 2441, S. 2600, S. 2601, S. 2602, S. 2615, S. 2604, S. 2608, S. 2642, S. 2644, S. 2649, S. 2650, S. 2707, S. 2709, S. 2708 in the Gene Bank planting register of Botany Division (CCRI), and growing in the Germplasm blocks of CCRI, constitute the experimental material for studying variations in the morphological characters such as, vegetative, inflorescence and floral morphology. The materials S. 2440 and S. 2441 were collected from Abyssinia during 1955 and the rest were from different geographical locations of Ethiopia collected in the wild during an FAO sponsored expedition to Ethiopia in 1964 for exploration of coffee germplasm and the establishment of World Coffee Collections (Narasimhaswamy, 1965). Accessions S. 2600 and S. 2601 represent Harrar province; S. 2602 and S. 2615 represent Shoa province; S. 2604 and S. 2608 represent Sidamo province; S. 2642 and S. 2644 represent Kaffa province; S. 2649 and S. 2650 represent Illubabor province; S. 2707 and S. 2709 represent Gojjam province and S. 2708 represents Eritrea province. The study was conducted during the peak periods of vegetative and reproductive growth. For all vegetative characters, average of 10 plant observations was taken; for inflorescence and floral characters average of 10 inflorescence and 10 flower observations were taken, as recommended by the International Plant Genetic Resource Institute (IPGRI, 1996). Descriptors and numerical weightages used for genetic diversity are presented in Tables 1 and 2. The three cultivated types of Ethiopian arabica coffee *viz.*, Agaro, Cioccie and Tafarikela were included as standards.

Table 1. Plant morphological descriptors of *Coffea* spp. used for diversity analysis of vegetative characters

Characters	Weightage
Plant habit	1 Bush (<5 m – without distinct trunk) 2 Shrub or small tree (<5 m - one or more trunks) 3 Tree (>5 m - single trunk)
Plant height	1 Very short; 3 Short; 7 Tall; 9 Very tall
Overall appearance	1 Elongated conical; 2 Pyramidal; 3 Bushy
Vegetative development	1 Monopodial; 2 Sympodial
Branching habit	1 Very few branches (primary) 2 Many branches (primary) with few secondary branches 3 Many branches (primary) with many secondary branches 4 Many branches (primary) with many secondary and tertiary branches
Angle of insertion of primary branches	1 Drooping; 2 Horizontal or spreading; 3 Semi-erect
Stipule shape	1 Round; 2 Ovate; 3 Triangular; 4 Deltate (equilaterally triangular); 5 Trapeziform; 6 Other
Stipule arista length	Measured in mm
Young leaf colour	1 Greenish; 2 Green; 3 Brownish 4 Reddish brown; 5 Bronze; 6 Other
Leaf shape	1 Obovate; 2 Ovate; 3 Elliptic; 4 Lanceolate; 5 Other
Leaf apex shape	1 Round; 2 Obtuse; 3 Acute; 4 Acuminate; 5 Apiculate; 6 Spatulate; 7 Other
Leaf length	Measured in mm (Average of ten mature leaves, measured from petiole end to apex)
Leaf width	Measured in mm (Average of ten mature leaves, measured at the widest part)
Leaf petiole length	Measured in mm (Average of ten one-year leaves, measured from the base to the insertion with the blade)
Leaf petiole colour	1 Green; 2 Dark brown; 3 Other
Young shoot colour	1 Green; 2 Dark brown; 3 Other
Mature leaf colour	1 Green; 2 Dark brown; 3 Other
Bud wax colour	1 Yellowish; 2 Other

Table 2. Plant morphological descriptors of *Coffea* spp. used for diversity analysis of inflorescence and flower characters

Characters	Weightage
Number of days from rainfall to flowering	Number of days (d)
Inflorescence position	1 Axillary
	2 Terminal
Inflorescence on old wood	0 Absent 1 Present
Number of flowers per axil	Measured in numbers (Average of 10 axils, randomly selected from different nodes)
Number of flowers per fascicle	Measured in numbers (Average of 10 fascicles, randomly selected from different nodes)
Number of fascicles per node	Measured in numbers (Average of 10 nodes, randomly selected from different branches)
Inflorescence stalk length	Measured in mm (Average of ten inflorescences, randomly selected from different nodes)
Corolla tube length	Measured in mm (Average of ten flowers, randomly selected from different nodes)
Number of petals per flower	Average of 10 flowers, randomly selected from different nodes
Anther insertion	1 Excluded 2 Included
Number of stamens per flower	Average of 10 flowers, randomly selected from different nodes

Results and Discussion

Morphological description of cultivated coffee is available; however the characterization of wild *Coffea arabica* accessions in gene banks is far from complete. The germplasm showed a wide range of variations in vegetative, inflorescence and floral characters. Mean performance of morphological characters studied and weightage used for indexing genetic diversity are presented in Tables 3 and 4. Angle of insertion of primaries in S. 2440 and S. 2441 varied from drooping to semi-erect type, while rest of the accessions is with semi-erect type. Stipule arista length was found to be maximum in the germplasm accession S. 2600 (5.3 mm) and the lowest was observed in S. 2708 (3.3 mm). More variation was recorded in young leaf colour. Among the accessions S. 2440, S. 2441, S. 2604, S. 2608, S. 2649, S. 2650 and S. 2708 this varied from greenish to brownish colour; while S. 2600, S. 2601 and S. 2615 manifested brownish colour; whereas S. 2602, S. 2642, S. 2644, S. 2707 and S. 2709 showed only greenish colour. Leaf shape was found to be ovate in all except S. 2644 which was varying from ovate to lanceolate. Highest leaf length was recorded in S. 2644 (153.3 mm) and lowest in S. 2708 (110.5 mm). Leaf width was maximum in S. 2649 (64.3 mm) and minimum in S. 2441 (48.2 mm). Maximum leaf petiole length was recorded in S. 2600 (9.7 mm) and minimum in S. 2604 (5.7 mm). No differences were recorded in plant habit, plant height, overall appearance, vegetative development, branch habit, stipule shape, leaf apex shape, petiole colour; young shoot colour, leaf colour and bud wax colour characters.

Among the vegetative characters, young leaf colour showed the highest range of variation indicating its value in selection exercises. This is closely followed by the angle of insertion of primary branches that has the potential to determine the plant habit that is also a very valuable agronomic trait.

Highest number of flowers per axil was recorded in S. 2649 (9.1) and lowest number in S. 2604 (3.8). Number of flowers per fascicle was found to be maximum in S. 2649 (3.9) and minimum in S. 2604 (2.5). Number of fascicles per node was highest in S. 2615 (4.5) and lowest in S. 2707 (3.0). Inflorescence stalk length was maximum in S. 2615 (6.5 mm) and minimum in S. 2440 (3.8 mm). Maximum length for corolla tube was recorded in S. 2709 (13.6 mm) and lowest in S. 2601 (10.0 mm). Number of petals and stamens per flower was varying from 5 to 6 in all except S. 2644 in which it was only 5. No differences were found in the number of days from rainfall to flowering, inflorescence position, inflorescence on old wood and anther insertion, characters.

Among the reproductive characters, flower number per axil offered the largest variation implying scope for selection. This is a very important agronomic trait that translates into yield.

From the experimental findings it was observed that for the vegetative characters studied all the germplasm were closer to Cioccie, except S. 2642 and S. 2649 that share some characters with Agaro also (Table 5). For five variable inflorescence and floral characters, only germplasm S. 2649 and S. 2708 were closer to Tafarikela

Table 3. Mean performance of 10 plant characters and weightage on vegetative parts of plants of different accessions of germplasm of coffee on the basis of IPGRI descriptors

Germplasm	Plant habit	Plant height	Overall appea-rance	Vegetative develop-ment	Branch habit	Angle of Insertion	Stipule shape	Stipule arista length	Young leaf colour	Leaf shape	Leaf apex shape	Leaf length	Leaf width	Leaf petiole length	Petiole colour	Young shoot colour	Leaf colour (mature)	Bud wax colour
S. 2440	2	7	1	2	4	3 to 1	2	5.1	1 to 3	2	4	140.2	51.9	6.4	1	1	1	1
S. 2441	2	7	1	2	4	3 to 1	2	4.4	1 to 3	2	4	137.0	48.2	6.7	1	1	1	1
S. 2600	2	7	1	2	4	3	2	5.3	3	2	4	136.4	61.4	9.7	1	1	1	1
S. 2601	2	7	1	2	4	3	2	4.5	3	2	4	128.9	55.6	7.9	1	1	1	1
S. 2602	2	7	1	2	4	3	2	4.0	1	2	4	136.2	59.7	6.7	1	1	1	1
S. 2615	2	7	1	2	4	3	2	3.4	3	2	4	142.3	62.2	6.5	1	1	1	1
S. 2604	2	7	1	2	4	3	2	4.2	1 to 3	2	4	139.5	58.4	5.7	1	1	1	1
S. 2608	2	7	1	2	4	3	2	4.6	1 to 3	2	4	140.2	56.8	6.1	1	1	1	1
S. 2642	2	7	1	2	4	3	2	4.2	1	2	4	147.5	56.5	6.3	1	1	1	1
S. 2644	2	7	1	2	4	3	2	4.4	1	2 to 4	4	153.3	56.1	5.9	1	1	1	1
S. 2649	2	7	1	2	4	3	2	3.8	1 to 3	2	4	150.6	64.3	7.1	1	1	1	1
S. 2650	2	7	1	2	4	3	2	4.4	1 to 3	2	4	144.0	61.1	9.0	1	1	1	1
S. 2707	2	7	1	2	4	3	2	4.3	1	2	4	124.0	48.4	8.1	1	1	1	1
S. 2709	2	7	1	2	4	3	2	4.7	1	2	4	138.7	56.2	9.0	1	1	1	1
S. 2708	2	7	1	2	4	3	2	3.3	1 to 3	2	4	110.5	51.7	6.2	1	1	1	1
Agaro	2	7	1	2	4	3	3	4.0	2	4	4	160.0	72.5	8.5	1	1	1	1
Cioccie	2	7	1	2	4	2 to 1	3	4.5	2	4	4	142.5	59.5	7.5	1	1	1	1
Tafarikela	2	7	1	2	4	3 to 1	3	4.5	2	4	4	145.0	64.0	8.5	1	1	1	1
Standard deviation								0.53				11.08	6.00	1.23				

Table 4. Mean performance of 10 flower characters and weightage on flower parts of different accessions of germplasm of coffee on the basis of IPGRI descriptors

Germplasm	Number of days from rainfall to flowering	Inflorescence position	Inflorescence on old wood	Number of flowers per axil	Number of flowers per fascicle	Number of fascicles per node	Inflorescence stalk length	Corolla tube length	Number of petals per flower	Anther insertion	Number of stamens per flower
S. 2440	8	1	1	6.8	3.5	3.9	3.8	12.0	5 to 6	1	5 to 6
S. 2441	8	1	1	5.2	3.0	3.9	4.8	11.6	5 to 6	1	5 to 6
S. 2600	8	1	1	6.9	3.2	4.2	5.6	11.4	5 to 6	1	5 to 6
S. 2601	8	1	1	4.6	2.8	3.7	5.0	10.0	5 to 6	1	5 to 6
S. 2602	8	1	1	7.4	3.3	3.8	5.7	11.8	5 to 6	1	5 to 6
S. 2615	8	1	1	8.1	3.1	4.5	6.5	11.2	4 to 6	1	4 to 6
S. 2604	8	1	1	3.8	2.5	3.2	5.3	11.1	5 to 6	1	5 to 6
S. 2608	8	1	1	5.9	3.5	3.9	5.4	12.8	5 to 6	1	5 to 6
S. 2642	8	1	1	6.8	3.6	3.6	5.5	12.7	5 to 6	1	5 to 6
S. 2644	8	1	1	9.1	3.8	4.0	6.1	12.3	5	1	5
S. 2649	8	1	1	6.9	3.9	3.2	6.0	11.3	5 to 6	1	5 to 6
S. 2650	8	1	1	6.6	3.0	3.6	5.9	13.5	5 to 6	1	5 to 6
S. 2707	8	1	1	7.1	3.3	3.6	6.0	13.0	5 to 6	1	5 to 6
S. 2709	8	1	1	7.6	3.4	3.6	5.8	13.6	5 to 6	1	5 to 6
S. 2708	8	1	1	5.9	3.1	3.0	6.2	10.6	5 to 6	1	5 to 6
Agaro	8	1	1	5.5	2.8	3.8	3.5	8.2	5	1	5
Cioccie	8	1	1	4.3	2.0	4.1	3.6	6.5	5	1	5
Tafarikela	8	1	1	4.5	3.7	3.2	3.4	10.7	5	1	5
Standard deviation				1.42	0.48	0.39	1.00	1.79			

and rest of the studied germplasm shared characters with all three standards, e.g. S. 2440, S. 2604, S. 2608 and S. 2644 have more of the characters of Cioccie and Tafarikela; S. 2441, S. 2600, S. 2615 and S. 2642 have more of the characters of Agaro and Cioccie; S. 2601, S. 2602, S. 2650, S. 2707 and S. 2709 shared more of the characters with Agaro and Tafarikela (Table 6).

All consistently observed characters are possible manifestations of adaptation that has a genetic basis. Many recent studies of interspecific/intraspecific interactions have emphasized variations in traits and interaction outcomes within populations, among populations, and across geographic ranges because such variation contributes to the evolution and co-evolution of these interactions that lead to the manifested adaptation (Thompson, 1988). The characters like plant habit, height, phyllotaxy, angle of insertion and leaf shape is an adaptation for good realization of sunlight, which influences higher rate of photosynthesis and other biosynthetic processes. Petiole colour, young shoot colour and leaf colour are probably an adaptation to protect against insect damage and pathogens. Characters like stipule shape bud wax colour are of taxonomic value and the characters like number of days from rainfall to flowering, inflorescence position, inflorescence on old wood, number of flower per axil, per fascicle, inflorescence stalk length, and corolla tube length are of agronomic value. Sylvain (1958) states that the variability of Ethiopian germplasm of coffee is an indicator of its richness and the existing genetic diversity is greater than that indicated only by morphological differences. Recent studies on molecular markers confirmed this (Lashermes *et al.*, 1995, 1996a,b, 1999; Anthony *et al.*, 2001). Genetic basis of the above discussed characters can be

Table 5. Comparison of wild *Coffea arabica* germplasm with the standard types for five vegetative characters

Germplasm	Angle of Insertion	Stipule arista length	Leaf length	Leaf width	Leaf petiole length	No. of characters resembling			Germplasm closer to standard (T)
						Agaro	Cioccie (A)	Tafarikela (C)	
S. 2440	T	T	C	C	C	nil	3	2	Cioccie
S. 2441	T	C	C	C	C	nil	4	1	Cioccie
S. 2600	A	T	C	C	A/T	1	2	1	Cioccie
S. 2601	A	C	C	C	C	1	4	nil	Cioccie
S. 2602	A	A	C	C	C	2	3	nil	Cioccie
S. 2615	A	A	C	C	C	2	3	nil	Cioccie
S. 2604	A	A	C	C	C	2	3	nil	Cioccie
S. 2608	A	C	C	C	C	1	4	nil	Cioccie
S. 2642	A	A	T	C	C	2	2	1	Agaro / Cioccie
S. 2644	A	C	A	C	C	2	3	nil	Cioccie
S. 2649	A	A	T	T	C	2	1	2	Agaro/Tafarikela
S. 2650	A	C	T	C	A/T	1	2	1	Cioccie
S. 2707	A	C	C	C	A/T	1	3	nil	Cioccie
S. 2709	A	C	C	C	A/T	1	3	nil	Cioccie
S. 2708	A	A	C	C	C	2	3	nil	Cioccie

Table 6. Comparison of wild *Coffea arabica* germplasm with the standard types for five inflorescence and floral characters

Germplasm	Number of flowers per axil	Number of flowers per fascicle	Number of fascicles per node	Inflorescence stalk length	Corolla tube length	No. of characters resembling			Germplasm closer to standard
						Agaro	Cioccie	Tafarikela	
S. 2440	A	T	C	C	T	1	2	2	Cioccie / Tafarikela
S. 2441	A	A	C	C	T	2	2	1	Agaro / Cioccie
S. 2600	A	A	C	C	T	2	2	1	Agaro / Cioccie
S. 2601	T	A	A	C	T	2	1	2	Agaro / Tafarikela
S. 2602	A	T	A	C	T	2	1	2	Agaro / Tafarikela
S. 2615	A	A	C	C	T	2	2	1	Agaro / Cioccie
S. 2604	C	A	T	C	T	1	2	2	Cioccie / Tafarikela
S. 2608	A	T	C	C	T	1	2	2	Cioccie / Tafarikela
S. 2642	A	T	A	C	T	2	1	2	Agaro / Tafarikela
S. 2644	A	T	C	C	T	1	2	2	Cioccie / Tafarikela
S. 2649	A	T	T	C	T	1	1	3	Tafarikela
S. 2650	A	T	A	C	T	2	1	2	Agaro / Tafarikela
S. 2707	A	T	A	C	T	2	1	2	Agaro / Tafarikela
S. 2709	A	T	A	C	T	2	1	2	Agaro / Tafarikela
S. 2708	A	T	T	C	T	1	1	3	Tafarikela

substantiated and validated by research on biochemical and molecular aspects that is presently undertaken.

Conclusion

Vegetative characters of the studied genetic resources are nearer to Cioccie type and for inflorescence and floral characters most of the genetic resources are in an intermediate condition between Cioccie and Tafarikela; Agaro and Cioccie; Agaro and Tafarikela. Natural out crossing and autogamous nature of wild arabica germplasm might have led the transfer and fixation of genes conditioning these character complexes in the wild populations in the course of their evolution. Subsequent selection of types for cultivation from the wild types fixed the characters in Cioccie, Agaro and Tafarikela that are included as standards in the present study. Such germplasm, thus, can be considered for utilization in further breeding programme and should be conserved in the gene bank.

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