PGR Newsletter
FAO - BIOVERSITY

Published in **Issue No.144,** page 51 to 55

Morphological characterization of two species of Abelmoschus: Abelmoschus esculentus and Abelmoschus caillei

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Introduction

Okra is grown throughout Africa, often as a vegetable, and is cultivated widely for its immature fruit as well as leaves, petioles, stems, shoots, rhizomes, inflorescences, seeds and fruit (Duckworth 1966; Okigbo 1975). In addition, okra is an important source of protein, minerals, vitamins and roughage for those populations that include it as part of their diet. The species constitutes a major economic crop in West and central Africa (Grubben 1977; Hamon and Charrier 1997).

However, like most tropical crops, very little attention has been devoted to this versatile crop. Its genetic diversity is clearly shown by the wide range of morphological characteristics displayed by the taxon in different ecogeographical, edaphic and environmental conditions. This may well point to the considerable genetic resources inherent in the genus, in particular the taxon *Abelmoschus caillei*, which is endemic to the region and which is widely used in subsistence farming.

Taxonomy of *Abelmoschus*

The current interest in okra has arisen because of a perceived ambiguity in the status of the cultivated and wild species of the *Abelmoschus* section, particularly the group known as West African okra, which is quite diverse and shows a wide range of morpho-agronomic characters. These groups of related plants are not well known and share a wide range of traits with cultivated *Abelmoschus esculentus*. Consequently, there is confusion about their classification, which often leads to misidentification and uncertainty among taxonomists and hinders breeders' selection efforts.

The taxonomy of *Abelmoschus* is complex. Originally cultivated and wild species were grouped within the genus *Hibiscus*, section *Abelmoschus* by Linnaeus (1773), later raised to a distinct genus *Abelmoschus* by Medikus (1787), further re-established as a genus based on the caducous nature of the calyx by Schumann (1908), and later rehabilitated by Hochreutiner (1924) based on the relationship of the calyx to the petal and staminal column aestivation.

Describing the genus, Bates (1968) considered the group to belong to the family Malvaceae, with a number of circumscriptive characters. Van Borssum-Waalkes (1966) and Bates (1968) further reviewed the genus. Van Borssum-Waalkes distinguished only six species: three cultivated (*A. moschantus*, *A. manihot* and *A. esculentus*) and three wild (*A. ficuleus*, *A. crinitus* and *A. angulosus*). However, van Borssum-Waalkes's classification did not mention *Abelmoschus manihot* var. *caillei*.

Abelmoschus caillei was described by Chavalier (1940) as a West African taxon resembling *Abelmoschus esculentus* and later elevated to a distinct species by Stevels (1988). Kandu and Biswas (1973) and Terrel and Winters (1974) distinguished the genus *Abelmoschus* from *Hibiscus*.

The present practice is to isolate a large and diverse group as the West African okra. Wild and cultivated members of the genus *Abelmoschus* share a range of morpho-agronomic (vegetative and reproductive) characters, emphasizing the complexity of the genus. The present study seeks to clarify this complexity (inter- and intraspecific relationships) among the accessions in southern Nigeria through the use of cluster analysis.

Materials and methods

Fifteen accessions of the genus *Abelmoschus* were sourced for the present study (**Table 1**). Seven accessions were procured from the National Horticultural Research Institute (NIHORT); the other accessions were procured from various local markets in southern Nigeria, identified on the basis of preliminary information obtained from the vendor.

The accessions were grown in a randomly designed plot (2 × 3 m 2) of three replicates during the 1999/2000 planting season; the accessions were sown and harvested between May and September 2000. Twelve qualitative characters (seven vegetative and five reproductive) and 12 quantitative characters (3 vegetative and 9 reproductive) were recorded and data were pooled for analysis. Description was as outlined by Hamon and Hamon (1991).

Leaf characteristics of the third and fifth leaves from the apex were recorded in order to obtain full expression of characters. Floral characters were recorded on five flowers from each accession. Pod/fruit characters were recorded from five mature pods.

A hierarchical cluster analysis, coefficient of variation on the unweighted pair group method (Sneath and Sokal 1973) was carried out using the SPSS 10.0 software package. Squared Euclidean distance was used as a measure of distance for cluster formation after standardization of quantitative data.

Results and discussion

Qualitative characters

Amongst the accessions studied, the growth pattern was generally determinate for *A. caillei* and indeterminate for *A. esculentus*. Stem type was stiff, strong and erect in all the *A. caillei* accessions as well as for *A. esculentus* accessions, except for the accessions LD88/1-8, LD88/1-8-5-2, LD88/1-8-13-2 and Ola 99/29, with flexible, weak and procumbent stems.

Table 1. Accessions studied

S/N	Species	Accession number	Origin (Province)	Latitude	Longitude
1	*A. esculentus*	47-4	Ibadan	07°22'S	03°01'W
2	*A. esculentus*	LD88/1-8	Ibadan	07° 22'S	03°01'W
3	*A. caillei*	Os2000/01	Ugbogui	06°34'S	05°16'W
4	*A. esculentus*	LD88/1-8-26-2	Ibadan	07° 22'S	03°01'W
5	*A. caillei*	Os2000/02	Iguobazuwa	06°32'S	05°17'W
6	*A. caillei*	Os2000/03	Benin (Ediaken)	06°18'S	05°42'W
7	*A. caillei*	Os2000/04	Ehor	06°33'S	06°01'W
8	*A. caillei*	Os2000/05	Abudu	06°15'S	06°06'W
9	*A. caillei*	Os2000/06	Benin (Oregbeni)	06°18'S	05°42'W
10	*A. caillei*	Os2000/07	Benin (New Benin)	06°18'S	05°42'W
11	*A. caillei*	Os2000/08	Benin (New Benin)	06°18'S	05°42'W
12	*A. esculentus*	LD88/1-8-5-2	Ibadan	07° 22'S	03°01'W
13	*A. esculentus*	LD88/1-8-13-2	Ibadan	07° 22'S	03°01'W
14	*A. esculentus*	Ola 99/29	Ibadan	07° 22'S	03°01'W
15	*A. esculentus*	Ola 99/7	Ibadan	07° 22'S	03°01'W

All accessions of *A. esculentus* and accessions Os2000/01 and Os2000/05 of *A.caillei* showed green coloration of the stem; accessions Os2000/03 and Os2000/04 showed red pigment on green stems; while stem pigmentation was wholly red in accessions Os2000/02, Os2000/06, Os2000/07 and Os2000/08.

Hairiness (pubescence) was conspicuous on stems of accessions Ola 99/29 and Ola 99/7 of *A.esculentus* and accessions Os2000/03 and Os2000/07 of *A.caillei*; slightly less pronounced in accessions Os2000/01, Os2000/02, Os2000/04 and Os2000/06 of *A.caillei*; and completely absent on stems of accessions 47-4, LD88/1-8, LD88/1-8-26-2, LD88/1-8-5-2 and LD88/1-8-13-2 of *A.esculentus* and accessions Os2000/05 and Os2000/08 of *A.caillei*.

All accessions of *A.esculentus* showed moderate orthotropic branching while all *A.caillei* accessions were strongly branched. Stem internodes were long in Os2000/01, Os2000/02, Os2000/03, Os2000/05, Os2000/06 and Os2000/08 of *A.caillei*; of intermediate length in accessions LD88/1-8-26-2, LD88/1-8-5-2 and Ola 99/29 of *A.esculentus* and Os2000/04 and Os2000/07 of *A.caillei*; and short in accessions 47-4, LD88/1-8, LD88/1-8-13-2 and Ola 99/7 of *A.esculentus*.

Flower epicalyxes were persistent throughout the early flowering period in all the accessions of *A.caillei* and through to the onset of fruit in *A.esculentus* accessions. Epicalyx shape was similar in the accessions of the two species: lanceolate in *A.esculentus* and triangular in *A.caillei* accessions.

Fruit shape was fusiform in *A.esculentus* accessions and ovoid to oblong/globose in *A.caillei* accessions. The position of the fruit in relation to the stem was pendulous in all the accessions of *A.caillei* and erect to horizontal in *A.esculentus*. Fruits were slightly rough in all accessions of both species, except accessions 47-4, LD88/1-8, LD88/1-8-26-2, Ola 99/29 and Ola 99/7 of *A.esculentus*, in which they had prickly surfaces.

Although a great degree of similarity exists, there were marked morphological differences between members of the two groups. This reflects the difference in cultivation zones: *Abelmoschuscaillei* is commonly grown in the high-rainfall zone of West Africa and mainly in subsistence systems. In contrast, *A.esculentus* is commonly grown under irrigation in areas with less rainfall (Schipper 1998). However, a worrying finding is the small amount of *A.caillei* germplasm present in institutional reserves compared with the more common *A.esculentus*. Nevertheless, the prevalence of *A.caillei* in homesteads and cultivated fields within the region is indicative of its richness as a genetic resource and the preference of local farmers.

Quantitative characters

The standard deviation (an index of the disparity between the 12 characters), the range and coefficient of variation showed a high degree of variability among the 15 accessions analysed for all except two of the 12 quantitative morphological characters assessed (**Table 2**).

The accessions showed similar flowering regimes. However, *A.caillei* accessions (Os2000/01–08) recorded a longer flowering period (>43 days) than those of *A.esculentus*, which had a maximum 43-day flowering period. The percentage of pods produced per plant ranged from 40% in accession LD88/1-8 (*A. esculentus*) to 77% in accession Os2000/04 (*A.caillei*), with a generally lower percentage of pods recorded for *A.esculentus* accessions than for *A.caillei* accessions. The higher percentage of pods produced by the *A.caillei* accessions may be connected with the longer flowering (and thus fruiting) period, although it may be the effect of other factors such as genetic composition and environmental differences.

There was marked difference between the species in reproductive traits analyzed. The range of flowering days was higher for most *A.caillei* accessions than for *A.esculentus* accessions. Flower epicalyx, fruit and pedicel length were greater in *A.caillei* accessions than in

A.esculentus accessions. The number of segments on the fruiting stem and the number of ridges on the fruit was lower for *A.caillei* accessions than for *A.esculentus*. The number of nodes with pods, the number of pods produced per plant, and thus the total number of pods produced per accession, was higher for *A.caillei* accessions than for *A.esculentus*. Similarly, taller plants were recorded for *A. caillei* accessions; 52.20 cm and 52.00 cm for accession Os2000/07 and Os2000/03 respectively, while shorter plant heights were recorded for the *A.esculentus* accessions; 30.10 cm (LD88/1-8-5-2) to 21.30 cm (LD88/1-8-26-2).

Table 2. Mean, standard deviation (SD), range and co-efficient of variation (CV) for 12 quantitative characters

S/N	Character	Mean	SD	Range	CV
1	Range of flowering day	8.86	5.44	59–63 (LD88/1-8-13-2) – 49–68 (Os2000/02)	61.30
2	Flowering period	44	1.25	43 (47-4) – >47 (Os2000/03)	2.85
3	Plant height (cm)	34.62	11.15	21.30 (LD88/1-8-26-2) – 52.20 (Os2000/07)	32.23
4	No. of stem segments	9.07	2.84	7 (Os2000/03) – 12 (Ola 99/7)	31.32
5	Epicalyx length (mm)	1.76	0.52	0.8 (47-4) – 2.7 (Ola 99/7)	29.35
6	Fruit length (cm)	7.14	2.32	3.8 (LD88/1-8-26-2) – 10.4 (Os2000/02)	32.53
7	Pedicel length (cm)	2.25	1.46	0.7 (47-4) – 6.2 (Os2000/03)	64.82
8	No. of ridges	7.35	1.81	5 (Os2000/01) – 11 (LD88/1-8-5-2)	24.00
9	No. of pods	13.47	6.48	6(LD88/1-8) – 25(Os2000/08)	48.11
10	Nodes with pods	13.07	7.60	6 (LD88/1-8) – 25 (Os2000/08)	58.17
11	Total no. of nodes	24.13	10.12	14 (LD88/1-8-26-2) – 36 (Os2000/08)	41.93
12	% pods produced	56.08	10.66	40.0 (LD88/1-8) – 77.0 (Os2000/04)	19.00

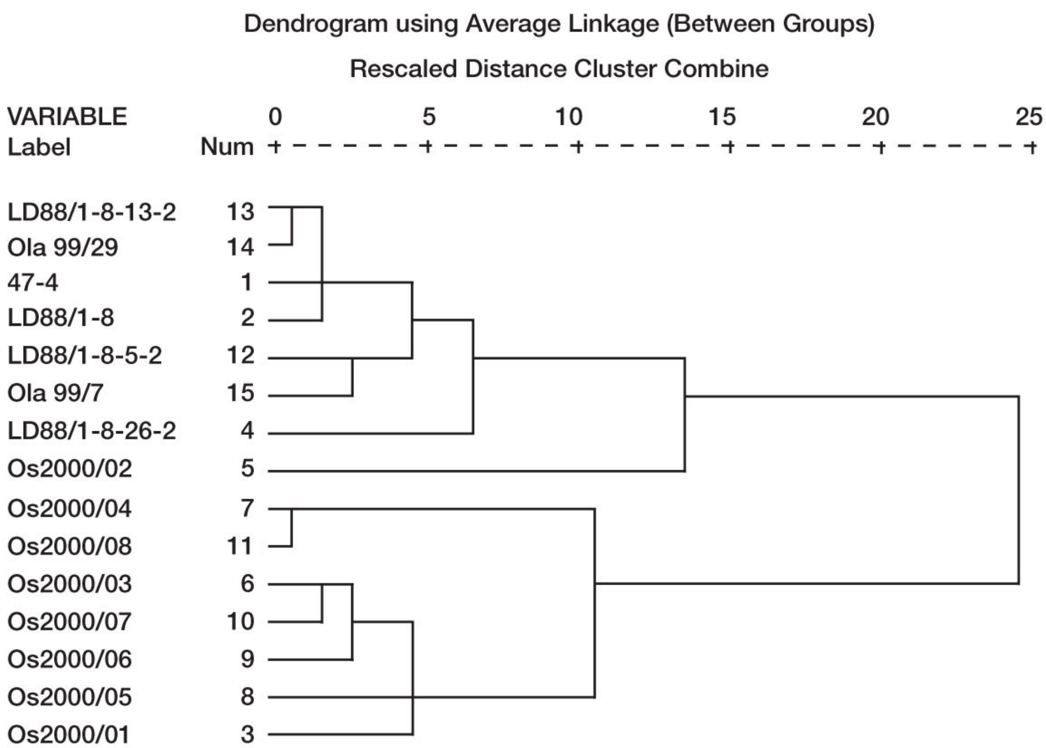
Although a longer fruiting period does not necessarily imply higher yield, it is, however, most suitable for the ecogeographical conditions, subsistence agriculture and the home garden system, where year-round production is required. However, the profuse branching recorded for *A. callei* points to a high yield potential, as branches are production sites and hence the higher their number, the greater the potential yield.

Cluster analysis

The degree of intraspecific variation differs for the two groups of accessions. *Abelmoschuscallei* accessions formed two clusters: Os2000/03, Os2000/07, Os2000/01, Os2000/06, Os2000/04 and Os2000/08 form a cluster; and accession Os2000/02 forms a single cluster (**Figure 1** and **Table 3**). The grouping of most of the *A. callei* accessions in one cluster indicates a high degree of morphological similarity within the species. Nevertheless, the separation of the single cluster (Os2000/02) shows a considerable degree of morphological variation within the species. Conversely, the *A. esculentus* accessions formed five clusters: LD88/1-8-5-2 forms a single cluster; LD88/1-8-13-2, Ola 99/29 and LD88/1-8 form a cluster; and the accessions Ola 99/7, LD88/1-8-26-2 and 47-4 each formed single cluster. This shows that there is wide morphological variation among the *A. esculentus* accessions. This greater degree of intraspecific variation is probably indicative of the cultivated state of *A. esculentus*, in contrast with the predominantly wild state of *A.caillei*.

Table 3. Cluster membership

Cluster number	List of accessions
1	Os2000/03, Os2000/07, Os2000/01, Os2000/06, Os2000/05, Os2000/04, Os2000/08
2	LD88/1-8-5-2
3	LD88/1-8-13-2, Ola 99/29, LD88/1-8
4	Os2000/02
5	Ola 99/7
6	LD88/1-8-26-2
7	47-4



At a higher Euclidian distance, three distinct clusters are formed. This is indicative of interspecific morphological dissimilarity between the two groups of accessions. However, the clustering of Os2000/02 with the *A. esculentus* accessions and of accession LD88/1-8-5-2 with the *A. callei* accessions shows a considerable level of interspecific similarity, hence the placement of the two species under the section *Abelmoschus*.

Conclusion

The degree of morphological variation recorded among the accessions indicates wide differences that may require further evidence, probably molecular, to clarify. These variations represent a vast genetic pool for breeding and improvement of the species as a whole.

Acknowledgments

We are very grateful to the Director of NIHORT for providing the *A.esculentus* material, and Dr Ogbe for supervision.

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