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69

Okra

Abelmoschus esculentus, A. caillei, A. manihot, A. moschatus (Malvaceae)

S. Hamon
Institut Française de Recherche Scientifique
pour Développment en Coopération, BP 3045
Montpellier, France

and

D. H. van Sloten
International Board for Plant Genetic Resources,
Via delle Sette Chiese 142, 000145 Rome, Italy.

Introduction

Okra is a very popular, tasty, gelatinous vegetable. Tender green pods 3–5 days old are used as a vegetable, generally marketed in the fresh state but sometimes in canned form (USA, Turkey). In dry areas, fruits are cut into slices, dried in the sun and stored for long periods (Sahel in Africa, India). They are relished because of their high mucilage content.

Four species are cultivated. The main crop (*Abelmoschus esculentus*) is an annual vegetable, grown from seed, in tropical, subtropical and mediterranean climatic zones. In West and Central Africa it is cultivated, in association with *A. caillei* where the former, which flowers earlier, is known as 'the rainy season okra', and the latter, which has a longer cycle (up to 1 year), is known as the 'dry season okra'. Plants of *A. manihot*, whose pods are too prickly to be consumed and have sometimes lost their flowering ability, are only cultivated in Papua New Guinea for their leaves. *Abelmoschus moschatus* has seeds which are used as musk mallow (ambrette). This species is sometimes used in several animism practices in West Africa (south Togo and Benin).

Okra has a relatively good nutritional value and is a good complement in developing countries where there is often a great alimentary imbalance. Moisture (89.6 per cent), K (103 mg), Ca (90 mg), Mg (43 mg), P (56 mg), vitamin C (18 mg) are found in 100 g of fresh fruit. Metals such as iron and aluminium are found between 500 and 4000 ppm, the nitrogen percentage is 16 per cent dry weight; the amino acids Asp and Arg are each present at nearly 10 per cent (Markose and Peter, 1990).

Cytogenetic background

Okra, originally included in the genus *Hibiscus*, section *Abelmoschus*, is now accepted as a distinct genus on the basis of the caducous nature of the calyx. A synthetic view, integrating the relationships between the different classifications that have been adopted, is given in Table 69.1. The taxonomic work of van Borssum-Waalkes (1966) is the most complete study. From fourteen species previously described (Hochreutiner, 1924) six were retained. This classification remains, however, incomplete in at least three points:

1. *Abelmoschus moschatus* and *A. manihot*, considered as 'wide species' need to be studied in more detail to rationalize infraspecific categories;
2. *Abelmoschus caillei* Chev. Stevels (1988), discovered by Chevalier (1940), is not taken into account and is often considered in some papers as a form of *A. manihot*;
3. *Abelmoschus tuberculatus*, must be considered as a species, not as a wild form of *A. esculentus*.

A summary of the taxonomic key is reported in Table 69.2.

Very little work has been carried out on the chromosome complement. The most detailed studies

Table 69.1 The systematics of the genus *Abelmoschus*.

Hochreutiner (1924)	Van Borssum-Waalkes (1966)	Today recommended
A. crinitus	*A. crinitus*	*A. crinitus*
A. ficulneus	*A. ficulneus*	*A. ficulneus*
A. angulosus	*A. angulosus*	*A. angulosus*
A. esculentus	*A. esculentus*	*A. esculentus*
	A. tuberculatus	*A. tuberculatus*
A. haenkeanus		
A. moschatus	*A. moschatus*	
var. *genuinus*	spp. *moschatus*	*A. moschatus*
var. *multiformis*	var. *moschatus*	
var. *betulifolius*	var. *betulifolius*	
var. *rugosus*		
A. todayensis	spp. *tuberosus*	*A. rugosus*
A. rhodopetalus		(*A. tuberosus*)
A. brevicapsulatus		
A. sharpei		
A. biankensis	spp. *biakensis*	
A. manihot	*A. manihot*	*A. manihot*
var. *genuinus*	spp. *manihot*	
var. *timorensis*	(cultivated)	
var. *tetraphyllus*	spp. *tetraphyllus*	*A. tetraphyllus*
var. *luzoensis*	(wild)	
var. *mindanaensis*	var. *tetraphyllus*	
var. *pungens*	var. *pungens*	
var. *caillei* Chev. (1940)		*A. caillei*
		(Stevels, 1988)
A. ficulneoides		

Table 69.2 Taxonomic key to the species of *Abelmoschus*[a].

Epicalyx				Capsule			Species
Number of segments	Length of segments (mm)	Shape of segments	Caducity	Relative size	Length (cm)	Shape	
10–16	25–50	Linear, filiform	Persistent	≤epicalyx	3.5–6	Ovoid, globular	*A. crinitus*
6–10[b]	5–20	Lanceolate	±	>epicalyx	15–25	Long, fusiform; short peduncle	*A. esculentus*
7–10 (plus)	8–20	Linear to lanceolate	±	>epicalyx	8	Ovoid, oblong; long peduncle with hairs	*A. moschatus*[c]
4–8	4–12	Linear to lanceolate	Caducous	—	3–3.5	Ovoid, 5-angled	*A. ficulneus*
4–8	20–35	Oval (adnate at the base)	Persistent	≥epicalyx	3–5	Ovoid, oblong	*A. angulosus*
4–8	10–30	Oval	Persistent	>epicalyx	3.5–6	Oblong, ovoid, pentagonal	*A. manihot*
7–9	10–35	Oval	±	>epicalyx	—	Oblong, long, ovoid	*A. caillei*[d]

[a] According to van Borssum-Waalkes (1966).
[b] Up to 15 (Siemonsma, 1982a,b).
[c] *A. moschatus* subsp. *moschatus* var. *moschatus* – epicalyx segments linear (8–15 × 1–2 mm), hairy stem; *A. moschatus* subsp. *moschatus* var. *betulifolius* – epicalyx segments lanceolate (17–25 × 2.5–5 mm), glabrous stem; *A. moschatus* subsp. *biakensis* – epicalyx segments lanceolate (15–20 × 3.5–4 mm), coriaceous capsule with long peduncle; *A. moschatus* subsp. *tuberosus* – tuberous root, non-enveloping epicalyx, white or pink flowers.
[d] According to Stevels (1988).

have been performed on *A. esculentus*. The chromosomes are short, mostly with median or submedian primary constrictions, a few have secondary constrictions. Eight chromosome types (A to H) were recorded (Datta and Naugh, 1968). The genus appears as a regular series of polyploids with $x = 12$. The genus constitutes a polyploid complex where varying chromosome numbers, from 14 to 97, have been reported (Table 69.3). Basic genomes are respectively called: (T) *A. tuberculatus*, $n = 29$; (M) *A. moschatus*, $n = 36$; (F) *A. ficulneus*, $n = 36$. A synthetic diagram of the cytological relationships between species is reported in Fig. 69.1. Polyploid series are found within the semi-wild 'wide sense' species: *A. moschatus (A. tuberosus* $n = 19$, *A. moschatus* $n = 38$, *A. betulifolius* $n = 140$) and *A. manihot (A.* subsp. *manihot* $n = 30–34$, *A. tetraphyllus* $n = 65–66$). With respect to the two major species, *A. esculentus*, $n = 65$ is presumed to be of allopolyploid origin with $E = T' + Y$ where T' is slightly different from T and Y similar to F (Joshi and Hardas, 1956). It has been suggested that there are two levels of ploidy in this species, one with 60–70 chromosomes and the other with 120–130. *Abelmoschus caillei* has a very high chromosome number ($n = 92–99$) and is thought to be of amphiploid origin from *A. esculentus* ($n = 62–65$) and *A. manihot* ($n = 30–34$) (Siemonsma, 1982a, b). For a review consult Charrier (1984).

Early history

Abelmoschus species have hermaphrodite flowers. They are self-compatible and show variable levels of cross-fertilization. For *A. esculentus* 0–69 per cent has been reported (Martin, 1983). More precisely, the structure of the flower, in accordance with Cruden's index based on the log (pollen/ovule), gives mean values of 2.0 (*A. esculentus, A. caillei*)

Table 69.3 Variation of chromosome numbers in the genus *Abelmoschus*[a].

Species	Numbers(2*n*)	Authors
A. esculentus	±66	Ford (1938)
	72	Teshima (1933); Ugale *et al.* (1976); Kamalova (1977)
	108	Datta and Naugh (1968)
	118	Krenke in Tischler (1931)
	120	Krenke in Tischler (1931); Purewal and Randhawa (1947); Datta and Naugh (1968)
	122	Krenke in Tischler (1931)
	124	Kuwada (1961, 1966)
	126–34	Chizaki (1934)
	130	Skovsted (1935); Joshi and Hardas (1953); Gadwal *et al.* (1968)
	131–43	Siemonsma (1981)
	132	Medvedeva (1936); Roy and Jha (1958)
	±132	Breslavetz *et al.* (1934); Ford (1938)
	144	Datta and Naugh (1968)
A. tuberculatus	58	Joshi and Hardas (1953); Kuwada (1966, 1974); Gadwal *et al.* (1968); Joshi *et al.* (1974)
Abelmoschus sp. (Ghana)	194	Singh and Bhatnagar (1975)
Abelmoschus sp. 'Guinean'	185–98	Siemonsma (1981)
A. manihot	60	Teshima (1933); Chizaki (1934)
	66	Skovsted (1935); Kamalova (1977)
	68	Kuwada (1966, 1974)
A. pungens	138	Gadwal in Joshi and Hardas (1976)
A. tetraphyllus	130	Ugale *et al.* (1976)
	138	Gadwal in Joshi and Hardas (1976)
A. moschatus	72	Skovsted (1935, 1941); Gadwal *et al.* (1968); Joshi *et al.* (1974)
H. coccineus	38	Skovsted (1935)
A. ficulneus	72	Gadwal *et al.* (1968);
	78	Joshi *et al.* (1974); Skovsted (1935, 1941)
H. grandiflorus	38	Skovsted (1941)

[a] According to Siemonsma (1982b).

and 2.2 (*A. manihot*, *A. moschatus*). So the breeding system is intermediate between obligate and facultative autogamy. However, the observed variability in outcrossing, partly due to differences in local ecology – insects (nature, mobility and density – is correlated with allopollen arrivals (Hamon and Koechlin, 1991a,b).

The geographical distribution of cultivated and wild species is shown in Fig. 69.2. *Abelmoschus esculentus* is found all around the world from mediterranean to equatorial areas. Cultivated and wild species clearly show overlapping in Southeast Asia, which is considered as the centre of diversity. The spread of the other species is the result of their introduction to America and Africa. There are two hypotheses concerning the geographical origin of *A. esculentus*. Some authors, arguing that one putative ancestor (*A. tuberculatus*) is native to Uttar Pradesh (north India), suggest that the species originated from this geographic area. Others, on the basis of ancient cultivation in East Africa and the presence of the other putative ancestor (*A. ficulneus*), suggest that the area of domestication is north Egypt or Ethiopia, but no definitive proof is available today. For *A. caillei*, only found in West Africa, it is difficult to suggest an origin outside. Its origin by hybridization with *A. manihot* is difficult to accept even if its presence, mentioned in the *Flora of West Africa* (Hutchinson and Dalziel, 1958), was not recently confirmed in this area and herbarium samples are lacking.

Recent history

The cultivation of *A. esculentus* is based mainly on traditional cultivars. Okra varieties are classified on the basis of plant size, pod shape and pod colour. F. W. Martin *et al.* (1981) and Hamon and van Sloten (1989) comparing a large collection of cultivars from south Europe, Asia and Africa, conclude that few, if any, characteristics distinguished those from the principal countries, where cultivation is very old and from where the collection was drawn. Only samples from West Africa are distinct and show wider morphological and phenological variability than in other areas. The global diversity is increased in West Africa by the presence of another species. Meanwhile, data show that separate cultivation and genetic

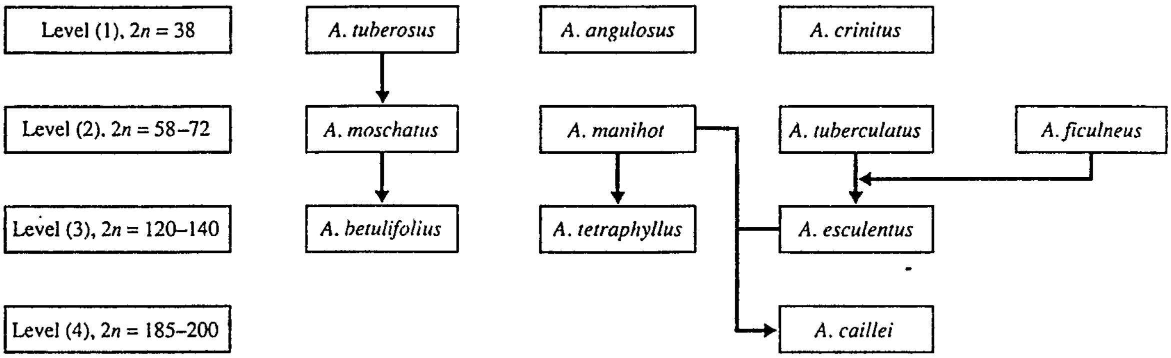

Fig. 69.1 Cytogenic relationships between *Abelmoschus* species.

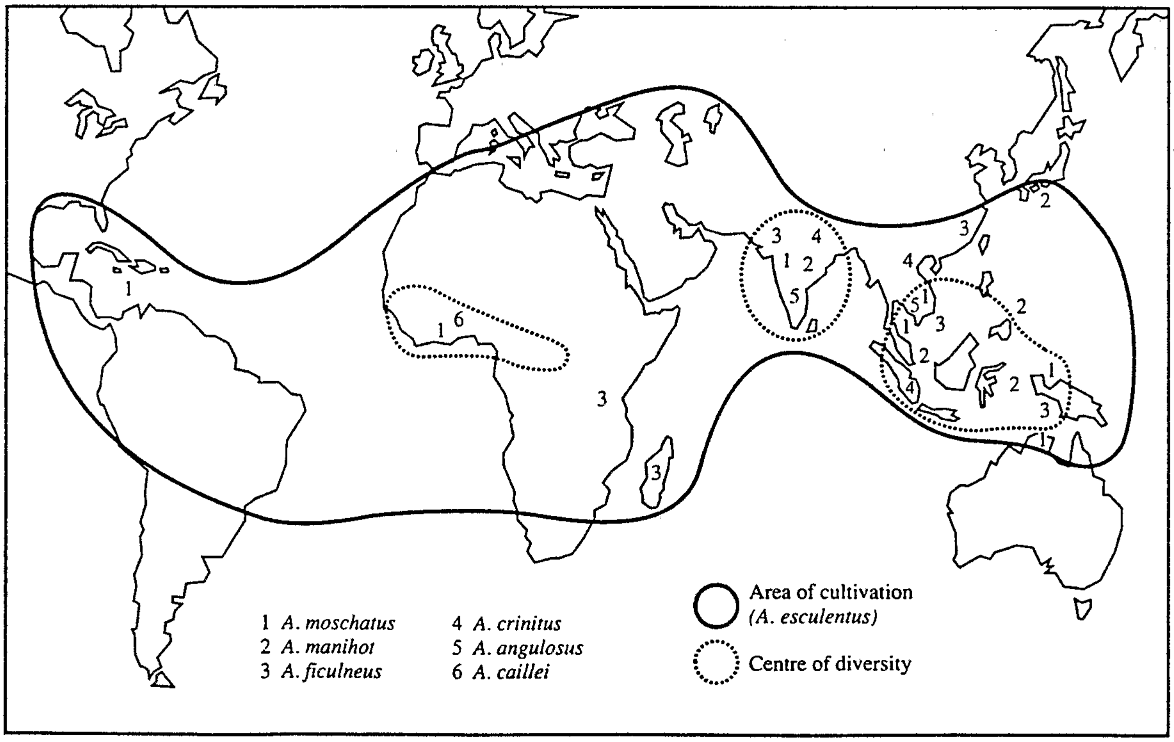

Fig. 69.2 Geographical distribution of *Abelmoschus* species modified from Charrier (1984).

Table 69.4 Genetics of quantitative and qualitative characters in *Abelmoschus esculentus*[a].

1. Quantitative characters

Characters	Mode of gene action	Reported by
Plant height	Monogenic (tall dominant to dwarf)	Jasim (1967)
Plant height	4–5 groups of dominant genes	Kulkarni *et al.* (1976)
Plant height and pods/plant	Additive gene action	Rao and Kulkarni (1977)
Earliness and more numerous fruits	Dominant and over dominant (1–3 groups of dominant genes)	Kulkarni *et al.* (1976)
More numerous fruits	Additive gene action with complete dominance	Kulkarni and Thimmappaich (1977)
Low fruit number	Incomplete dominance	Kulkarni and Thimmappaich
Days to flower, plant height and fruits/plant	Both additive and non-additive gene action	Rao (1972)
Yield/plant, branch number and plant height	Additive gene effects	Reddy *et al.* (1985)
Days to flower, plant height and fruits/plant	Additive × additive with epistatic action	Kulkarni *et al.* (1978)
Days to flower, yield/plant and fruits/plant	Additive gene action	Singh and Singh (1978)

2. Qualitative characters

Characters	No. of genes	Gene action
Leaf margin	Monogenic	Cut leaves dominant to lobed leaves
Pod colour	Monogenic	White fruit colour is dominant to green
Pod shape	Digenic	Angular dominant over round and epistasis was observed
Pod spininess	Monogenic	Spininess is dominant to non-spininess
Fruit hairiness	Monogenic	Fruit hairiness is completely dominant over smoothness
Stem colour	Monogenic	Purple stem colour is dominant over green

[a] According to Markose and Peter (1990).

barriers are enough to maintain the genetic integrity of both species (Hamon and Hamon, 1992).

The selection of modern cultivars has been undertaken only in a few countries (USA, Clemson Spineless, Perkins Long Pods; India, Pusa Sawani, Pusa Makhmali) – a complete list of Indian varieties is given by Thomas *et al.* (1990). Most breeding programmes follow the crossing scheme used for autogamous plants, pedigree selection using parents from populations chosen for their good combining ability. Heterosis has been reported in hybrids between cultivars from Malaysia and the USA for germination percentage, precocity, flowering period and plant height; F_1 hybrid vigour in intraspecific crosses can be used in some combinations but it is often variable and low. With respect to Indian accessions, strict additive gene action, sometimes with dominance, has been reported for the following quantitative characters: plant height, number of pods per plant, days to flower, branches per plant. General combining ability is greater than specific combining ability (SCA) for all characters. However, SCA is significant for 50 per cent flowering, branches per plant, fruit per branch, seed per fruit, diameter and length of fruits. Yield per plant has a significant positive association with the number of pods, number of nodes and plant height. Simple inherited characters are rare, these affect particularly the colour of different organs or pod characters. Light red petiole, petal blotch, petal venation, pod colour (multiallellism) show simple monogenic inheritance. Fruit hairiness, leaf lobing (with incomplete dominance) are also monofactorial, pod shape (angular/round) is digenic with angular dominant. In Table 69.4 a summary of the genetics of quantitative and qualitative characters is reported (Markose and Peter, 1990).

Okra, like other Malvaceae, is susceptible to a large variety of pests and diseases – insects, fungi, nematodes and viruses. In most cases insects and fungi can be controlled by suitable treatment twice a week. Nematodes (*Meloidogyne*) can be controlled by chemical treatment or prior planting of *Panicum maximum* for one year. No control is available for viruses which may completely destroy *A. esculentus* plants. The main fungal pests are: (1) pre/post emergence: *Fusarium solani, Phytophthora parasitica, Pythium*; (2) on leaves: *Cercospora malayensis* and *C. abelmoschi*, (3) on flowers and fruit: *Fusarium solani, Rhizoctonia solani*. The most serious diseases of okra are viruses: the yellow vein mosaic virus (YVMV) in India and the okra leaf curl (OLC) in Africa. Both are transmitted by a small white fly (*Bemisia tabaci*). *Abelmoschus caillei* and *A. tetraphyllus* seem more tolerant of these viruses than other species. Hybridization with *A. esculentus* has been carried out through a backcross breeding programme (Jambhale and Nerkar, 1981).

The morphological diversity of the cultivated species is very low, except in West Africa. The relatively simple inheritance of colour characters and pod shape, the breeding system, the local procedure for the management of varieties, could explain the rapid fixation of a large number of different phenotypes. An important question is, what is the real level of the genetic diversity of such an amphiploid species? Research on okra isoenzymic polymorphism is lacking; one reason could be the very low amount of genetic diversity. We have shown that *A. esculentus* and *A. caillei* are monomorphic for most of the systems studied (except shikimate dehydrogenase in East Africa for *A. esculentus*) and glutamate oxalo-acetate dehydrogenase (for *A. caillei*). These two species exhibit very similar patterns for most studied isozymic systems except malate dehydrogenase, phospho-glucose-isomerase and isocitric acid dehydrogenase. Preliminary results indicate that *A. moschatus* and *A. manihot* are more polymorphic.

Seed conservation is certainly the most convenient way to preserve okra genetic resources. Unfortunately, seeds are known to have a short longevity. J. A. Martin *et al.* (1981) showed that low temperature (5 °C) and low moisture content permit conservation for 11 years. Low oxygen and high content carbon dioxide levels maintained seed viability by reducing metabolic activity.

Prospects

With respect to improved varieties, breeders produced several years ago the well-known varieties Clemson Spineless and Pusa Sawani, which have not been replaced. It seems that selection for earliness and yield has been replaced by the search for virus-resistant varieties. The introduction of genes from wild species, as in any other genus, is very difficult and needs a good knowledge of sterility levels and the ways to overcome them.

The International Board of Plant Genetic Resources organized a workshop in New Delhi, India, in 1990 in order to produce a synthesis of current scientific knowledge on okra and to promote the formation of an *Abelmoschus* network (IBPGR, 1991). The main conclusions were that, compared to some other crops, very little work has been undertaken on okra and that the major part which has been done concerns *A. esculentus*. Among the recommendations were that:

1. Taxonomy needs clarification especially for the two broad species (*A. manihot* and *A. moschatus*) and *A. tuberculatus*
2. Phylogenetic and cytological relationships between species remain unclear not only for wild but also

for cultivated species (*A. esculentus* and *A. caillei*). Despite the fact that *A. esculentus* is the most studied species, no one could really say if the different chromosome numbers encountered are a reality or due to sampling errors.

3. A new standardized descriptor list will be proposed.
4. The core collection concept which was first applied to cultivated varieties must be applied to wild forms.

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Evolution of Crop Plants

Second Edition

Edited by

J. Smartt
School of Biological Sciences
University of Southampton

and

N. W. Simmonds
Formerly Edinburgh School of Agriculture
Edinburgh

Longman Scientific & Technical

Longman Scientific & Technical
Longman Group UK Limited
Longman House, Burnt Mill, Harlow
Essex CM20 2JE, England
and Associated Companies throughout the world

Copublished in the United States with
John Wiley & Sons, Inc., 605 Third Avenue, New York
NY 10158

First published 1976
Second edition 1995

British Library Cataloguing in Publication Data
A catalogue entry for this title is available from the British Library.

ISBN 0–582–08643–4

Library of Congress Cataloging-in-Publication data
Evolution of crop plants / edited by J. Smartt and
N. W. Simmonds. — 2nd ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-470-23372-9
1. Crops—Evolution. I. Smartt, J. II. Simmonds, N. W.
(Norman Willison), 1922– .
SB106.074E96 1995
631—dc20 94-25791
CIP

Set in 9/11½ Times by 5
Produced by Longman Singapore Publishers (Pte) Ltd.
Printed in Singapore