Promoting the conservation and use of underutilized and neglected crops. 11.

Cat's whiskers

Cleome gynandra L.

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Foreword

Humanity relies on a diverse range of cultivated species; at least 6000 such species are used for a variety of purposes. It is often stated that only a few staple crops produce the majority of the food supply. This might be correct but the important contribution of many minor species should not be underestimated. Agricultural research has traditionally focused on these staples, while relatively little attention has been given to minor (or underutilized or neglected) crops, particularly by scientists in developed countries. Such crops have, therefore, generally failed to attract significant research funding. Unlike most staples, many of these neglected species are adapted to various marginal growing conditions such as those of the Andean and Himalayan highlands, arid areas, salt-affected soils, etc. Furthermore, many crops considered neglected at a global level are staples at a national or regional level (e.g. tef, fonio, Andean roots and tubers etc.), contribute considerably to food supply in certain periods (e.g. indigenous fruit trees) or are important for a nutritionally well-balanced diet (e.g. indigenous vegetables). The limited information available on many important and frequently basic aspects of neglected and underutilized crops hinders their development and their sustainable conservation. One major factor hampering this development is that the information available on germplasm is scattered and not readily accessible, i.e. only found in 'grey literature' or written in little-known languages. Moreover, existing knowledge on the genetic potential of neglected crops is limited. This has resulted, frequently, in uncoordinated research efforts for most neglected crops, as well as in inefficient approaches to the conservation of these genetic resources.

This series of monographs intends to draw attention to a number of species which have been neglected in a varying degree by researchers or have been underutilized economically. It is hoped that the information compiled will contribute to: (1) identifying constraints in and possible solutions to the use of the crops, (2) identifying possible untapped genetic diversity for breeding and crop improvement programmes and (3) detecting existing gaps in available conservation and use approaches. This series intends to contribute to improvement of the potential value of these crops through increased use of the available genetic diversity. In addition, it is hoped that the monographs in the series will form a valuable reference source for all those scientists involved in conservation, research, improvement and promotion of these crops.

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Introduction

In the past, traditional societies have exploited edible wild plant resources to obtain their nutritional requirements (Richards and Widdowson 1936; Beemer 1939; Quin 1959; Jelliffe *et al.* 1962; Woodburn 1968; Keller *et al.* 1969; Lee 1969; Scudder 1971; Korte 1973; Newman 1975; Abe and Imbamba 1977; Gomez 1981; Chweya 1985). Recent studies on the agro-pastoral societies of Africa indicate that these plant resources still play a significant role in nutrition, food security and income generation (Tallantire and Goode 1975; Grivetti 1976; Johnson and Johnson 1976; Fleuret 1979a, 1979b). Their nutritional composition has not been well documented, but it could be comparable to, or, in some instances, even superior to the introduced cultivars (Fox and Weintraub 1937; Platt 1965; Fox 1966; Wehmeyer 1966; Leung 1968; Schmidt 1971; Imbamba 1973; Calloway *et al.* 1974; Okigbo 1980; Martin 1984; Ruberte 1984; Chweya 1985). It is worthwhile to note therefore that the incorporation or maintenance of edible wild plant resources could be beneficial to nutritionally marginal populations, or to specific vulnerable groups within populations, especially in developing countries.

In such countries, the emphasis of agricultural development is firstly on subsistence crops and wild plant species, and secondly on the cultivation or utilization of a wide range of food crops whose total number of species is large (Leaky and Wills 1977; Martin 1984). However, dietary utilization of non-domesticated plants has received little attention, and a dramatic narrowing of the food base has occurred in many traditional societies. While thousands of edible wild and domesticated plants are documented globally (Tanaka 1976), as few as 150 species are traded internationally, and only 15 constitute the main sources of human food energy (Wilkes 1977). In the event of crops being destroyed by drought, diseases and pests, the narrowing of the range of domesticated species poses a risk to food security (Turton 1977). Domestication and cultivation of wild edible plants is, therefore, essential in broadening the food base in developing countries. This will lead to diversification, which will ensure a dietary balance and the intake of micronutrients.

Edible wild leafy vegetables play an important role in the African agricultural and nutritional systems (Keller *et al.* 1969). Okigbo (1980) gives a list of over 160 endemic vegetables used in one small area in West Africa, while Chweya (1985) and Juma (1989) list several leafy vegetables used in Kenya. Ogle and Grivetti (1985) and Ogle *et al.* (1990) give lists of traditional/indigenous leafy vegetables used in Swaziland and Zambia, respectively. Tallantire and Goode (1975), Fleuret (1979a), Getahun (1974) and Johnson and Johnson (1976) have indicated plant species used as leafy vegetables in Uganda, Tanzania, Ethiopia and Nigeria, respectively. Owing to the lack of figures available on their total yields and sales, the traditional leafy vegetables have been regarded as minor crops, and have been given low priority in most agronomic research and development programmes (Brown 1983; Ruberte 1984; Brush 1986; Altieri and Merrick 1987; Prescott-Allen and Prescott-Allen 1990).

Little is known about the indigenous cultivation techniques, knowledge and utilization, the extent and structure of genetic variation, and the potential for crop improvement through domestication, selection and/or breeding. Very few systematic studies have been conducted on these species, and little, if any, systematic germplasm collecting has been done (Martin 1984). Some of these vegetables are treated as weeds in different parts of the world, and as indigenous/traditional vegetables in others.

The cat's whiskers (*Cleome gynandra* L./*Gynandropsis gynandra* (L.) Briq.) is one such vegetable, which grows as a weed in most tropical countries, but is a semi-cultivated popular tropical leafy vegetable in many parts of sub-Saharan Africa, especially in most countries in eastern and southern Africa. This monograph gives information on its genetic resources.

1 Taxonomy

Cat's whiskers (*Cleome gynandra* L.)1 belongs to the botanical family Capparaceae (formerly Capparidaceae), subfamily Cleomoideae. The family contains about 700-800 species, divided into 45 genera (Kuhn 1988; Kokwaro 1994). The genus *Cleome*, with over 200 species (Iltis 1967; Bruinsma 1985), consists of highly polymorphic herbaceous plants. Native African *Cleome*, of which there are more than 50 species, are all spineless (Gilg and Benedict 1915; Iltis 1960, 1967). Box 1 gives a taxonomic key for determination of the weedy *Cleome* species (Kuhn 1988).

Box 1. Key for the determination of weedy *Cleome* species (Kuhn 1988)

All leaves simple	*monophylla*
Lower leaves digitately compound Androgynophore longer than 5 mm	*gynandra*
Androgynophore absent, or at most 3 mm long Gynophore about 4 cm in flower, up to 8 cm in fruit	*spinosa*
Gynophore shorter than 2 cm or absent 6 stamens; flowers slightly zygmorphic, ovary on a short gynophone	*rutidosperma*
8 stamens or more; flowers actinomorphic, ovary sessile	*viscosa*

The genus is a phylogenetic near relative of the Cruciferae (Brassicaceae) family (Bremer and Wannorp 1978). The species are mainly found in the tropics and subtropics, and are well represented in Africa. They are common in dry areas.

Synonyms of *Cleome gynandra* L. (Sp. Pl. (1753) 671) are: *Gynandropsis gynandra* (L.) Briq., in Ann. Conserv. et Jard. Bot. Genève 17 (1914) 382; *Cleome pentaphylla* L., Sp. Pl. ed. 2, 2 (1763) 938; *Pedicellaria pentaphylla* (L.) Schrank in Roem. et Usteri, Mag. Bot. 3 (1790) 11; *Gynandropsis pentaphylla* (L.) DC., Prodr. 1 (1824) 238; *G. denticulata* DC., l. c.; *Cleome acuta* Schum. et Thonn., Beskr. Guin. Pl. (1827) 293 (Hammer 1986). Table 1 lists some of the local names for *C. gynandra* in the various countries in which it grows.

The diploid number of chromosomes as determined in young flower buds during diakinesis of pollen mother cells is 20 (2*n*=20), although 18, 22, 32 and 34 have been reported, and polyploidy has also been shown to occur (Darlington and Wylie 1955; Hanumantha-Rao *et al.* 1978; Raghavan and Kamble 1979; Koshy and Mathew 1985).

1 *Gynandropsis* DC. and *Gynandropsis gynandra* (L.) Briq. are considered synonyms of *Cleome* L. and *Cleome gynandra* L., respectively. Thorough taxonomic investigations may reveal further differences between *Gynandropsis* and *Cleome*; however, especially in their androgynophore, there is a possibility that *Gynandropsis gynandra* may be reinstated as the valid name (Kers, unpublished). Hammer (1986) accepted the name *Gynandropsis gynandra* (L.) Brig. However, until now, both scientific names have been widely used all over Africa. For simplicity, *Cleome gynandra* L. is used in this monograph.

Table 1. Common and local names of cat's whiskers.

America	
Bermuda	Small spider flower
Cuba	Volantin
Martinique	Acaya blanc, mouzambe à fleurs blanches
Puerto Rico	Small spider flower, white massombee, jasmin del rio, volantines de cinco hojas
USA	African spider flower, spider flower (Hawaii)
Europe	
France	Mouzambe à fleurs blanches, Cleome, Gynandro
Germany	Senfkapper, Benzoinbaun, Fieberstrauch
Great Britain	African spiderflower, cats' whiskers, spider flower, Bastard mustard
The Netherlands	Kattesnor
Asia and Oceania	
Australia	Wild spider flower, African spider flower
China	pe hua tsai
India	kurhur, karaila
Indonesia	Babowan, enceng-enceng, mamang, langsana, merah, boboon, ent jengent, leug-lengan
Malaysia	Maman, langsana merah
Philippines	Cinco-cinco, silisihan, tantandok, balabalansyan, hulaya, apoiapoian
Thailand	Phak sian, phak sian khaao, phak som stan
Africa	
Angola	Musambe, Muzambue, Kasangu
Botswana	Rothwe, lothnue
Cameroon	Gorbwa, worba, kinaski
Egypt	Abu quarn, arareeg, tamaleekah, tokshangeth
Ethiopia	Boekbeha, gargama
Kenya	Chinsaga, saget, keyo, mkabili, mwangani, mwianzo, mukakai, sake, thagiti, isakyat, isoget, tsisaka, esaks, chisoka, lisaka, dek, alot-dek, deg-akeyo, lemba-e-nabo, olmuateni, oljani-lool tatwa, munyugunyungu, isakiat, suriyo, suriya, karelmet, bakeria-dahan, sakiantet, sabai, iasaitet, jeu-gurreh, kisiat, echaboi, akio Luni, nsila, mutaka
Malawi	Brede caya, pissat des chiens
Mauritius	Lerotu, erotho, spider flower, spider wisp, bastard mustard,
Reunion	Aija

Table 1 (continued).

Somalia	Palmbossie, vingerblaartee
South Africa	Tamaleika, akaki, agyiri, ziri
Sudan	Mgagani, mwage-nazi
Tanzania	Ejjoboyo, isaga, akeyo, eshogi, eyobyo, ekiau, ekaboi, ecaboi, ekeyo, tegeri, jirri, eshoje
Uganda	Gasaya, nasege, kinaski, ngor si bidar
West Africa	Boanga, mugole, muhole, isogi, lubanga, mangayamangaya
Zaire	Suntha, lyuniyi, lubanga, sishungwa, chishugwa, shungwa
Zambia	Spider flower, nyevhe, tsinga, ulude, bangara, ulede, rumi,
Zimbabwe	nyeuhe, elude

Sources: Ivens 1967; Kokwaro 1976; Thomo and Kwapata 1984; Schultze-Motel 1986; Terry and Michieka 1987; FAO 1988; Kuhn 1988; Juma 1989; Chigumira 1995; Madisa and Tshamekang 1995; Maundu *et al.* (unpublished); Mingochi and Luchen 1995; Nekesa and Meso 1995; Rubaihayo 1995; Swai 1995; Van den Heever 1995; Opole *et al.* 1995.

2 Botanical description

Cat's whiskers is an erect herbaceous annual herb, which is branched and rather stout. Depending on environmental conditions, it can grow up to 1.5 m in height, and is usually 0.5-1.0 m tall. It has a long tap root, with a few secondary roots with root hairs. Stems and leaf petioles are thickly glandular and rarely glabrous (Figs. 1, 2a).

They exhibit variable pigmentations, from green to pink, or violet to purple. Leaves are alternate, digitately palmate and petiolate. Each leaf has 3-7 leaflets, but most commonly 5 (rarely 3-4), which are pinnately dissected and sessile (Figs. 1, 2b). They vary from obovate to elliptic in shape, and are usually 2-10 cm long and 2-4 cm wide. They are sparsely hairy, but this is variable, and they have finely toothed margins or round ends. The petioles are 3-23 cm long, the cotyledonary leaves have single leaflets, and leaves are oppositely arranged on the stem.

Inflorescence is quite showy, and is usually up to 30 cm in length. It has terminated and axillary determinate racemes, bearing flowers with long pedicels, which arise singly in the axils of small sessile and trifoliate-to-simple bracts (Figs. 1, 2c). The bracts are much smaller than the leaflets. The flowers measure 1-2.5 cm in diameter, and have 4 sepals, 4 narrow clawed petals, and 6 stamens with long purple filaments, arising from a much elongated receptacle. The sepals are ovate to lanceolate, measuring up to 8 mm in length, and are glandular. The petals are white, pale, pink or lilac, and the floral formula is $K_4C_4A_6G(2)$.

The fruit is a long-stalked, dry, dehiscent silique, which is a spindle-shaped capsule measuring up to 12 cm long and 8-10 mm wide (Figs. 1, 2d). The capsules are green, turn yellow when ripe, and dehisce easily when dry, to release seeds. Seeds are small, suborbicular and sharply tuberculate, with many concentric ribs and irregular cross-ribs. They are rough and greyish-to-black in colour. The seed cleft is narrow. Each seed measures 1.0-1.5 mm in diameter. The seedling has oblong petiolate cotyledonary leaves, and petiolate trifoliate almost elliptical leaflets, the terminal one being larger than the lateral ones. The petioles are often hairy.

Reproductive biology

Although the pollination characteristics of *C. gynandra* have not been determined, it has been observed that plants in the species can be both self- and cross-pollinating. Observations on populations indicate uniformity for most characters (Omondi 1990). Such uniformity can only arise from a predominantly self-pollinating species. It is therefore possible that *C. gynandra* is predominantly self-pollinating, although this needs to be quantified. There is likely to be a high rate of outcrossing, owing to diverse phenotypic variability, and the phenomenon of anthers dehiscing when flowers have been open for a long time and their stigmas exposed (Omondi 1990). Pollinators may include insects (especially honey bees), spiders and the wind.

The flowering of *Cleome* spp. has been reviewed by Bruinsma (1985). However, most studies on flowering have been carried out with florist species of *Cleome*, notably *C. hassleriana* (Chodat). Owing to similarities in floral morphology, observations from such studies could be used to illustrate the behaviour of other species, including

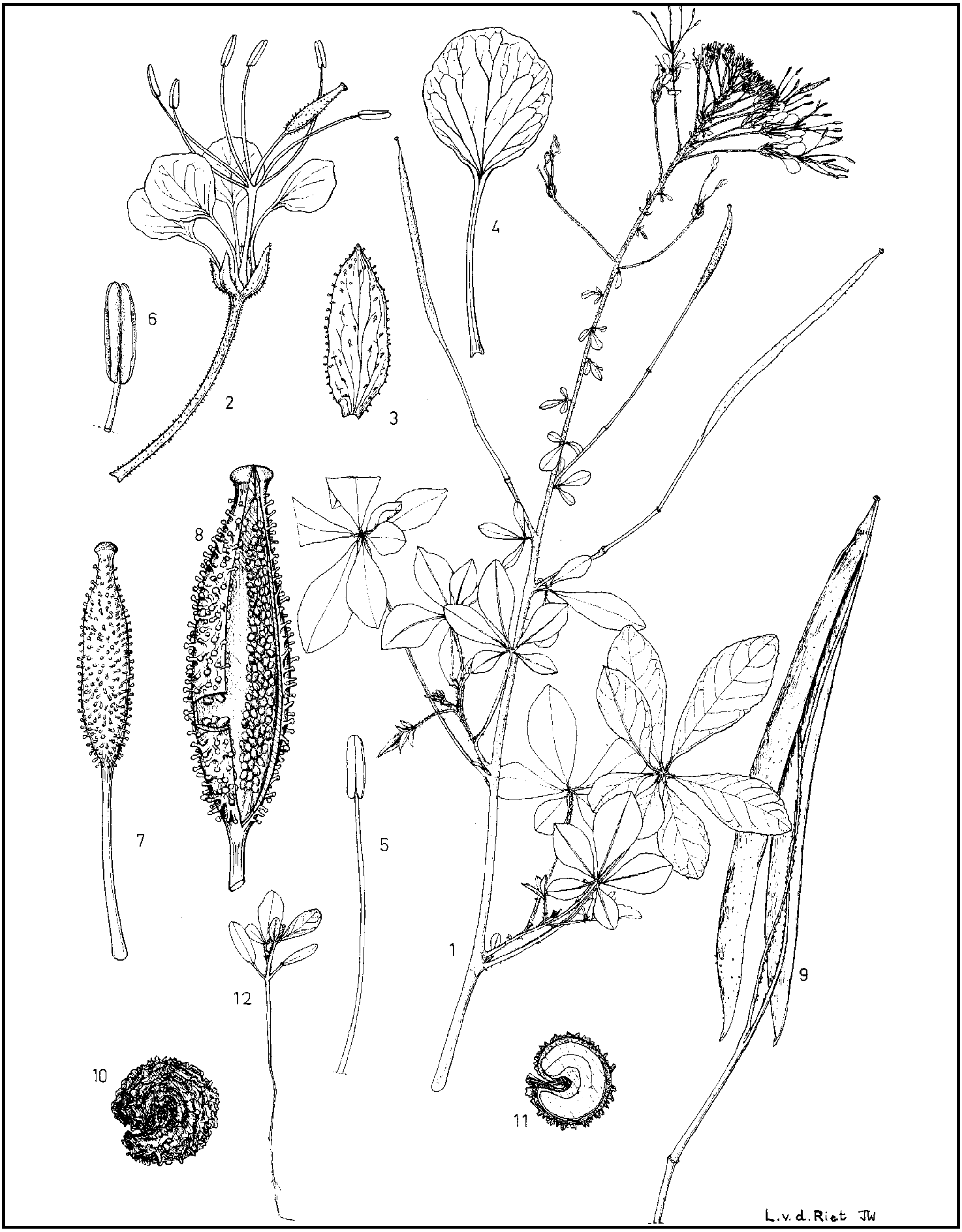
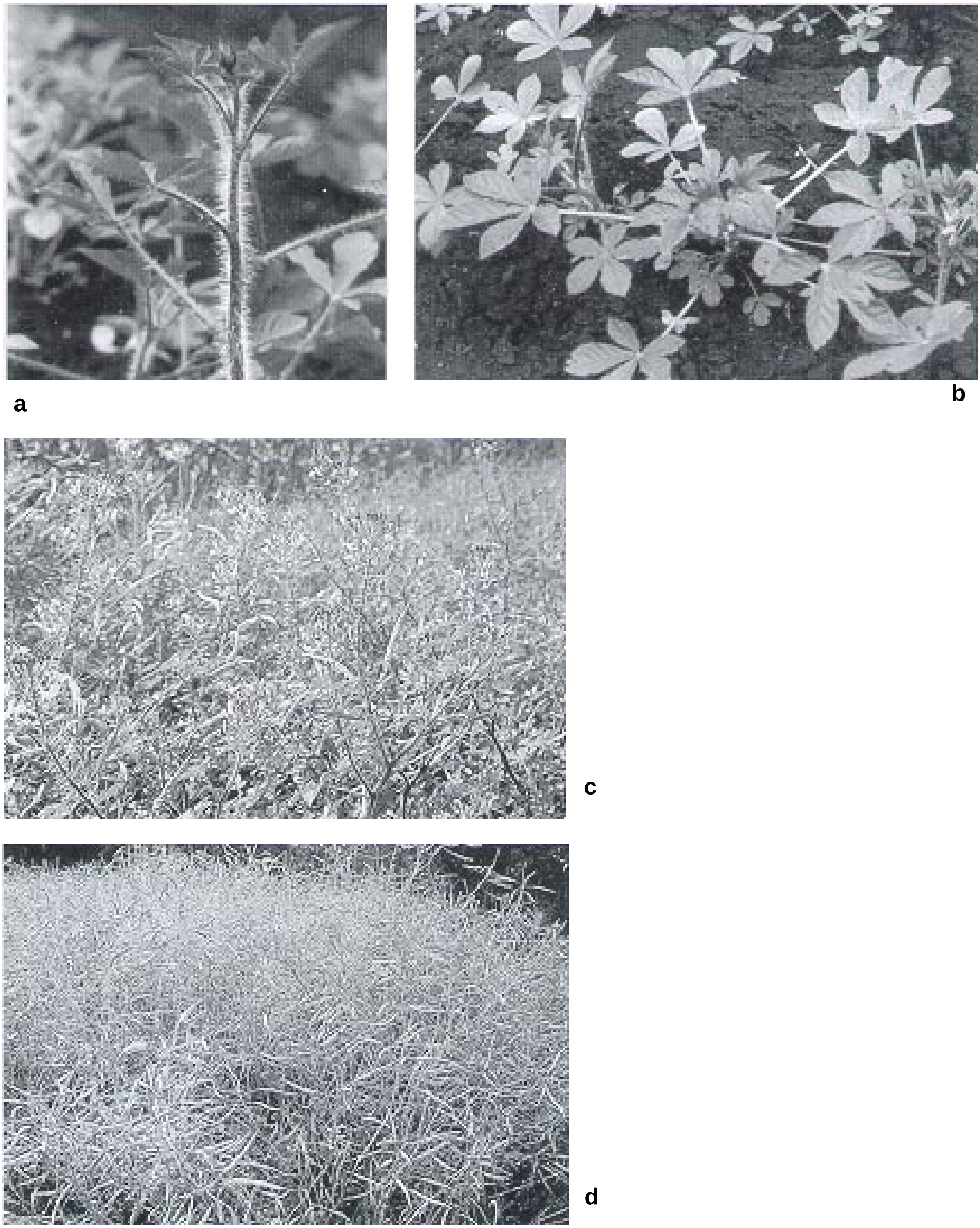


Fig. 1. *Cleome gynandra* L.: 1 – flowering and fruiting branch (x0.6); 2 – flower (x2); 3 – sepal, external view (x8); 4 – petal, internal view (x4); 5 – stamen (x4); 6 – anther (x6); 7 – gynoecium (x6); 8 – ovary, longitudinal section (x10); 9 – dehiscent fruit (x1.2); 10 – seed (x8); 11 – seed, opened with embryo (x8);



a b c d

Fig. 2. *Cleome gynandra* L.: (a) pubescence of stems; (b) 5-week-old plant; (c) flowering plants, partly with capsules; (d) mature plants with capsules.

C. gynandra.

Because of its tropical origin, Iltis (1967) considered *Cleome* to be daylength-insensitive. Koevenig (1973a) showed that under an 8-hour daylength, 31 leaves were formed, before flowering occurred, while under a long day regime (14 hours), only 18 leaves formed before flowering occurred. Plants flowered under either long or short-day regimes, after a minimum number of palmately compound leaves had been produced. For this reason, *C. hassleriana* was classified as a quantitative or facultative long-day species. In other species, e.g. *C. spinosa*, Astie (1972) observed that under short day, or in continuous light, plants may flower abnormally.

Over 2-3 months, up to 200-400 perfect flowers developed acropetally, in a tight spiral on a terminal inflorescence, with several flowers at approximately the same developmental stage, throughout the flowering period (Koevenig 1973a).

Axillary branches develop and terminal flowers occur, extending the flowering period to 6-12 months. It takes 2 weeks for a flower to develop. First sepals develop and elongate fully, followed by petals, stamens, pistils and gynophores. The pedicels elongate throughout floral development, reaching up to 40 cm at anthesis. Gynophores elongate to about 7 cm, before seed development starts, and reach a length of 8 cm, as the seeds mature over several weeks. Stamen filaments elongate to 25 mm, before buds open, which takes 10-20 days. The filaments then elongate, reaching 6.5 cm within 24-48 hours. Their maximum length and elongation time depend on environmental conditions, position of the flower on the inflorescence, and other factors. A flower may have long or short stamens, and long or short gynophores, thus zones of 10-40 long stamens alternate with 10-60 short gynophores, but do not correlate with zones with long and short stamens. For this reason, *Cleome* flowers resemble a ‘spider’, hence its common name ‘spider flower’. The cause of this zonation is unknown, but may have something to do with the intermittent endogenous hormonal changes that occur.

Flowers with unelongated gynophores lack normal seeds in the ovary. Short stamens have abnormal pollen, and stamen elongation within any zone is relatively uniform. Stamens abscise after stamen filament elongation and anther dehiscence, but short filaments with aborted pollen abscise 5 days earlier.

Gynophores abscise if seeds do not develop, and the stamens have abscised. Petals abscise just prior to stamen abcission. If (and only if) seeds do not develop and gynophores abscise, flowers abscise following stamen and filament elongation.

Comparison of length of floral organ in 235 buds showed a high correlation between lengths of various floral organs and the buds (Koevenig 1973a). Correlation of bud length and logarithm of filament length was usually high for buds within one long filament zone.

Owing to the abundance of large flowers over long periods, the occurrence of flowers at different stages of growth and the rapid growth of floral parts (especially stamen filaments), *Cleome* flowers have been found useful in floral development studies involving hormone transport. Thus, Koevenig (1973b) revealed that the transport of cytokinin is not polar in any of the organs, and that more cytokinin moved in stamen filaments and gynophore sections from mature than from young buds. Koevenig and Sallix (1973) showed that the anther controls filament growth by supplying Indole Acetic Acid (IAA). Other floral organs exert influence on filament elongation during early development, suggesting acropetal movement of IAA. The movement of IAA was strictly polar and basipetal at all stages of floral development, except in open flowers, just before stamen abscission, when both acropetal and basipetal movement were equal. The amount of IAA moved depended on stage of flower development, the amount drastically declining after stamens reached maximum elongation. Just before stamen abscission, there was an insignificant amount of acropetal IAA movement. The control of stamen filament elongation and abscission is thought to be regulated by IAA (de Jong and Bruinsma 1974a, 1974b, 1974c).

Although anther removal reduces filament and androgynophore growth in *C. rutidosperma* (Dathagupta and Datta 1976), auxin restores growth, even *in vitro*. Gibberelic acid (GA) determined the growth of the gynophore and pistil in a number of species, including *C. iberidella* (de Jong and Bruinsma 1974a) and *C. spinosa* (de Jong and Bruinsma 1974b).

Upon flower opening, the anthers and stigma are exposed. Many *Cleome* species are protandrous and are therefore cross-pollinated. Self-compatibility has been shown for a number of species (Iltis 1967), an important aspect in single-seed dispersal and establishment, as observed by Baker (1955). *Cleome* exhibits ‘super dioecy’ (Stout 1923; Murneek 1927), in which flowers on the same inflorescence can be male sterile, have pistil abortion, or become complete.

Fruits occur in zones at the inflorescence stalk, alternating with non-fruited sterile zones, hence *Cleome*’s other common name of ‘cat’s whiskers’. The non-fruited zones are caused by pistil abortion during the development of a group of flowers, which thereby become infertile (Stout 1923). Poor nutritive conditions aggravate this phenomenon (de Jong and Bruinsma 1974c, 1974d), whereas removal of pistils, or of young fruits, allows for the subsequent formation of complete fertile flowers (Murneek 1927). Restoration of fertility results from the timely removal of ovules from subadjacent ovaries, their sink activity coinciding with a high auxin peak in the ovules. It has been shown by de Jong and Bruinsma (1974a, 1974b, 1974c, 1974d) that extracts from the young flower buds contain some essential factors for pistil development. Pistil growth is not limited by nutrient deficiency, but by lack of specific cytokinin when cultured *in vitro*. The intermittent formation of zones of perfect and male flowers can thus be ascribed to the periodic withdrawal of root-produced cytokinins by developing fruits (de Jong and Bruinsma 1974a, 1974c, 1974d).

Propagation is by seed. Viable seeds germinate within 4-5 days. Seed germination is erratic, occurring over an extended period, during the rainy season. Yepes (1978) planted freshly harvested seed at monthly intervals, for 13 consecutive months. It was determined that seeds have a rest period (latency) that extends to the 5th month after collection. Active germination starts 6 months after harvest, and increases to 88% in 3 months. Highest germination occurs after 12 months of storage, but this finding requires investigation, as the authors have observed that seeds from dry capsules germinate immediately after harvest. Vegetative growth is very fast, and a plant may reach a height of 60-90 cm before flowering, if it is given favourable growing conditions, such as adequate soil moisture, high light intensity and temperatures of 18-25°C. Growth is rhythmic, and highest growth rates occur between the 5th and 6th weeks of growth (Yepes 1978). Leaves exhibit strong rhythmic circadian movements, which follow the direction of the sun. These movements are increased by high light intensity and temperatures. This characteristic probably influences the photosynthetic efficiency of the species. The species is a C_4 plant (Imbamba *et al.* 1977), and can therefore produce 3-5 times more dry matter per unit leaf area than C_3 plants.

Apical dominance is very weak, as axillary buds start breaking between the 2nd and 3rd week of plant growth. Plants tend to flower very early, within 4-6 weeks of growth. Yepes (1978) observed that, under Colombian conditions, the first flowers appear around 30 days after sowing. Fruit development and maturation take the longest time (3-4 months), and flowering may last for at least 2 months. During the reproductive phase, vegetative growth declines and leaves senesce very quickly, starting with oldest ones. When capsules are mature and dry, seeds are released through dehiscence of the capsules.

Cultivation

Cat's whiskers is still regarded as a weed, or 'volunteer' crop. Its leaves are gathered for use, and some ethnic groups in Africa do cultivate the crop as a vegetable in home gardens, or near homesteads. The plants thrive, in both pure stands and mixtures. Seeds from the previous crop are broadcast, or drilled on well-loosened fertile soil, and the plants can be grown on raised or flat beds. Seeds germinate within 4-5 days. Seedlings are thinned about 3 weeks later, and the thinnings are used as a vegetable. Topping and removing inflorescences as soon as they appear are practices that increase leaf production for harvesting. After several successive leaf harvestings from the plants, these are left to flower and produce capsules. The capsules ripen, dry up and shatter, releasing seed for the next season. Growers also harvest the ripe capsules at the end of rainy season, to save seed for the next crop. In Asia, plants are cultivated for seed oil.

3 Origin and centre of diversity

The species is thought to have originated in tropical Africa and Southeast Asia, and to have spread to other tropical and subtropical countries in the Northern and Southern hemispheres (Kokwaro 1976). It is spread by birds, and by seed dispersal, owing to capsule dehiscence. The *Cleome* genus is widely distributed in the drier parts of the tropics and subtropics, but occurs mostly in Africa. It is also found in countries in Asia, Africa and the Americas (Iltis 1960, 1967; Kuhn 1988), where it grows and is regarded as a weed. These countries could therefore constitute important centres of diversity. Other than local landraces, there are no known described botanical varieties or cultivars.

Geographic distribution

The natural habitat of *C. gynandra* is wasteland and arable land with annual species as well as grasslands. Imbamba and Tieszen (1977), Naidu *et al.* (1980), Rajendrudu and Das (1982a, 1982b), Kumar *et al.* (1984) and Rao and Rejendrudu (1989) have determined the species to have a C_4 photosynthetic pathway, an adaptational mechanism that enables it to survive in drier and hot environments. It grows well up to about 1000 m asl in semi-arid, subhumid and humid climates, and is adapted to many soil types, but grows luxuriantly around rubbish dumps and soils supplied with organic manure.

The species is native to the following regions/countries (Anonymous 1956a, 1956b; Williamson 1956; Anonymous 1973; Hutchinson 1974; Holm *et al.* 1976; Thomo and Kwapata 1984; By and Wittern 1988; Mnzava 1989; Stevels 1990; Benhura and Chitsiku 1991; Shaban *et al.* 1991; Humphry *et al.* 1993; Agnew and Agnew 1994; Nzioka 1994; Abbiw 1995; Rubaihayo 1995):

? Northern Africa – Egypt, Mauritania
? Western Africa – Cameroon, Ghana, Guinea, Côte d'Ivoire, Mali, Niger, Nigeria, Sierra Leone
? Central Africa – Angola, Burundi, Zaire
? Eastern Africa – Ethiopia, Kenya, Somalia, Sudan, Tanzania, Uganda
? African Islands – Madagascar, Mauritius, Reunion, Seychelles
? Middle East – Oman, North Yemen
? Far East – Afghanistan
? Asia – Borneo, India, Java, Malaysia, Moluccas, Philippines, Sri Lanka, Sumatra, Sulawesi, Thailand
? Australasia – Fiji

The species has been introduced to such Caribbean islands as the Bahamas and Bermuda, Cuba, southeastern USA (Florida, Kentucky and Louisiana), southern, midwestern and southwestern USA, Mexico, Puerto Rico, Colombia, Venezuela, Bolivia, Peru, Brazil, Paraguay, Argentina, Uruguay, Chile, the Iberian Peninsula, Italy, France, Central and Northern Europe (including Great Britain), the former USSR, China, Japan, Korea, Philippines, Australia, New Zealand and the Pacific islands (Kuhn 1988).

4 Properties

Nutritional

Some studies have been conducted to investigate the nutritional composition of the raw leaves of *C. gynandra*. Table 2 summarizes the findings of these studies to date.

The plant's nutritional value may vary with soil fertility, environment, plant type, plant age and the production techniques used (Chweya 1995). The amount of ascorbic acid lost increases with cooking time, and can reach 81% if the vegetable is cooked for 15 minutes in 8 volumes of water (Mathooko and Imungi 1994). Another study reports the proportion of ascorbic acid lost after cooking to be as high as 82% (Sebit 1995).

Table 2. Nutritional and chemical composition of *Cleome gynandra* leaves (% or mg/100 g edible parts).

Nutrient	Range of values
Moisture content (%)	81.8 - 89.6
pH	5.8
Crude protein (%)	3.1 - 7.7
Crude fibre (%)	1.3 - 1.4
Carbohydrates (%)	4.4 - 6.4
Ether extract (%)	0.4 - 0.9
Total ash (%)	2.1 - 3.0
Potassium (mg)	410
Calcium (mg)	213 - 434
Magnesium (mg)	86
Sodium (mg)	33.6
Phosphorus (mg)	12
Iron (mg)	1 - 11
Zinc (mg)	0.76
Copper (mg)	0.46
β-carotene (mg)	6.7 - 18.9
Ascorbic acid (mg)	127 - 484
Oxalate (mg)	8.8
Total phenolics (mg)	520 - 910

Source: Gomez 1981; Sreeramulu 1982; Mathooko and Imungi 1994; Arnold *et al.* 1985; Malaise and Parent 1985; Waithaka and Chweya 1991; Mathooko and Imungi 1994; Chweya 1995; Opole *et al.* 1995; Sebit 1995.

Seeds of *C. gynandra* have been analyzed for crude protein and fatty acid content (Mnzava 1990). The crude protein composition varies from 17.9% (green-stemmed plants) to 31.4% (purple-stemmed plants). The lipid content varies from 25.1% (green-stemmed plants) to 29.6% (purple-stemmed plants). Oleic and linoleic acids account for about 81% of total fatty acids, but linoleic acid is the most abundant (accounting for 59% of total fatty acids) (Table 3). Lipids have a high degree of unsaturation, as is shown by the high iodine and saponification numbers (123 and 192, respectively). Cultigens exhibit slight variation in the proportion of fatty acids and generally have lower stearic than palmitic acid contents.

Table 3.Fatty acid composition (% of total fatty acids) of selected *Cleome gynandra* seeds (Mnzava 1990).

Fatty acid	Purple stem	NIRS-2	NIRS-3	Green stem	Mean
Palmitic (16:0)	11.5	10.7	11.2	11.7	11.2
Palmitoleic (16:1)	0.3	0.4	0.3	0.3	0.3
Stearic (18:0)	6.4	7.6	6.1	6.1	6.6
Oleic (18:1)	19.5	23.9	21.5	22.2	21.8
Linoleic (18:2)	61.1	56.3	59.7	58.6	58.9
Arachidic (20:0)	0.1	0.2	0.2	0.2	0.2
Eicosenoic (20:1)	0.1	0.1	0.1	0.1	0.1

Amino acid analysis of defatted meal has indicated that glutamic acid content is highest, followed by arginine, aspartic acid, lysine, tyrosine and histidine. As can be seen from Table 4, the composition is comparable to that of leguminous oilseeds.

Table 4.Amino acid composition (g/100 g crude protein) of selected Zambian *Cleome gynandra* seed, compared with leguminous seed (Mnzava 1990).

Amino acid	Purple stem	NIRS-2	NIRS-3	Green stem	Mean	Peanut	Soybean
Glutamic	16.4	17.9	18.6	16.8	12.9	12.6	15.7
Arginine	10.2	11.0	11.1	9.0	10.3	7.1	5.6
Aspartic	7.6	8.2	9.3	8.6	8.4	7.2	20.4
Leucine	5.6	6.1	6.3	5.5	4.4	4.2	6.2
Valine	5.4	5.7	5.9	5.5	5.8	2.9	4.1
Glycine	5.0	5.3	5.7	5.3	5.3	2.7	4.3
Proline	4.8	4.9	5.1	4.9	4.9	3.8	3.9
Phenylalanine	4.2	4.4	4.5	4.0	4.3	3.4	3.3
Isoleucine	4.0	4.3	4.4	3.9	4.2	3.5	3.7
Threonine	3.0	6.1	3.7	3.5	4.1	2.1	5.2
Alanine	3.8	3.9	4.1	3.8	3.9	1.1	3.8
Serine	3.4	3.6	4.1	3.9	3.8	1.2	3.9
Lysine	3.3	3.3	3.4	3.0	3.3	2.5	4.1
Tryosine	2.4	2.5	2.4	2.3	2.4	1.4	2.1
Histidine	2.2	2.2	2.5	2.4	2.3	2.5	2.9

Analyses have not been carried out yet to isolate the various important active ingredients that give the species its various medicinal and industrial properties (described in section 5).

5 Uses

Leafy vegetable

Investigations of the nutritional composition of cat's whiskers (Gomez 1981; Chweya 1985; Mwajumwa *et al.* 1991; Mnzava 1990; Opole *et al.* 1995), and some studies on genetic enhancement (Chweya 1995; Swai 1995) of *Cleome gynandra* L. have been conducted. Results indicate that the leaves of the species could be more nutritious than most exotic leafy vegetables. Furthermore, the results further indicate that the species responds positively to increased soil fertility, although the harvest index is reduced. Increased soil fertility also increases crude protein, but decreases β-carotene, ascorbic acid and iron content of the leaves. Increased soil fertility has no effect on the phenolic compounds, or on the calcium and sodium content of the leaves.

Throughout Africa, the tender leaves or young shoots, and often the flowers as well, are eaten boiled as a pot herb, tasty relish, stew or side dish. The leaves and shoots are gathered from the wild or are cultivated. In East Africa, fresh leaves are used as ingredients in other mashed foods, and the dried leaves are ground and incorporated in weaning foods (Mathenge 1995). The usefulness of these preparations has not yet been established, however. The leaves are rather bitter, and for this reason are cooked with other leafy vegetables such as cowpea (*Vigna* spp.), amaranths (*Amaranthus* spp.) and black nightshade (*Solanum nigrum* L.). To reduce the bitterness, milk may be added to the boiled leaves, and the mixture should preferably be left overnight in a cooking pot. In other areas, leaves are boiled briefly, the water is discarded, and they are then combined with other ingredients in a stew.

The leaves and tender shoots are boiled whole, or chopped, and may be mixed with other ingredients. In Zambia, for example, pounded groundnuts are often added to dishes to enhance flavour. The high fibre content of the leaves enables them to be dried and stored. The leaves may be blanched, made into small balls and sun-dried. These balls can be stored for more than 6 months, and are reconstituted by soaking in water before being used in cooking.

The vegetable is a rich source of nutrients, especially vitamins (A and C) and minerals (calcium and iron). It also contains some protein, and the leaves contain over and above the normal recommended adult daily allowance of vitamins A and C and the minerals calcium and iron (Arnold *et al.* 1985). Boiling the leaves may reduce vitamin C content by up to 81%, while drying reduces the vitamin content by 95% (Sreeramulu *et al.* 1983; Mathooko and Imungi 1994). The other component nutrients are not significantly affected by cooking or drying of the leaves.

Leaves do contain some antinutrients such as phenolic compounds, which give the vegetable an astringent taste. The phenolic compounds bind proteins and this may lower protein digestibility and quality. The leaves also contain glucosinolates.

In several African countries, the vegetable is an important food in rural areas (where over 80% of the total population of most of these countries lives). In some countries, only this leafy vegetable is available during the relish-gap period, and therefore plays a significant role in household food security during drought.

The vegetable is important as a leafy vegetable in the following African countries: Nigeria, Zaire, Malawi, Zimbabwe, Cameroon, Botswana, Namibia, Swaziland, Tanzania, Zambia, South Africa, Ghana, Uganda and Kenya. In India, it is eaten as a pot herb and a flavouring in sauces, and in Thailand it is consumed fermented in a product called ‘pak-sian-dong’ (FAO 1990).

Indigenous knowledge possessed by rural women in Kenya indicates that *C. gynandra* has several nutritional uses (Opole *et al*. 1995). Leaves may be crushed to make a concoction that is drunk to cure diseases such as scurvy. In many cultures, boiled leaves are regarded as a medicinal meal. In other communities, leaves are boiled and marinated in sour milk for 2-3 days and eaten as a nutritious meal, which is believed to improve eyesight, provide energy and cure marasmus. It is a highly recommended meal for pregnant and lactating women. However, in some communities, leaves boiled in water are believed to dry up a mother’s milk. Eating the vegetable is believed to reduce dizzy spells in pregnant women.

It is believed that regular consumption of the leaves by pregnant women will ease childbirth by reducing the length of their labour, and will help them regain normal health more quickly afterwards. In some communities, consumption of the vegetable by pregnant women is almost mandatory. The vegetable does not appear to be a popular infant meal (for babies of up to 10 months), but is given to children from toddler age upwards.

The seeds are oleiferous, containing a polyunsaturated oil, which is extracted by pressure and does not need refining. They are used as bird food. The seed cake has an excellent acid spectrum and can therefore be utilized in animal feeds.

Medicine

The leaves and seeds of cat’s whiskers are used in indigenous medicine in many countries (Purseglove 1943; Anonymous 1956a, 1956b; Kokwaro 1976; Baruah and Sarma 1984; Kumar and Sadique 1987; Opole *et al.* 1995). The following uses have been reported.

? Sap from leaves may be used as an analgesic, particularly for headaches.

? Sap from pounded young leaves is squeezed into ears, nostrils and eyes to treat epileptic fits and earache.

? A decoction or infusion of boiled leaves and/or roots is administered to:
- facilitate childbirth in pregnant women
- treat stomach-ache and constipation
- treat conjunctivitis
- treat severe thread-worm infection
- relieve chest pains.

? Arthritis is treated with the leaves.

? The leaves have anti-inflammatory properties.

? The bruised leaves are rubefacient and vesicant, and are used to treat headache, neuralgia, rheumatism and other localized pains. They are rubbed on the affected parts of the body, or applied as a poultice. Care must be taken to remove the application before it causes blisters, however.

? Bruised leaves are applied to boils, to prevent the formation of pus.
? An infusion from the leaves is used to treat anaemia.
? The leaves and roots are used to treat uterine complaints
? Sap from leaves is used to cure recurrent malaria.
? Drops of the juice of the leaves, on its own or mixed with oil, are applied to the ear to treat ear-ache. The juice produces a burning sensation and should be used with care.
? The leaves are rubbed onto the skin to relieve pneumonia.
? An infusion of the leaves can be used as an eyewash.
? The seeds and roots are anthelmintic, and are ingested for the expulsion of round worms, or a concoction is applied externally on the stomach as a counter-irritant.
? The seeds are applied as a poultice to maggot-infested sores.
? The seeds are mixed with oil and applied to the scalp to treat head lice.
? An infusion of seeds is administered to reduce coughing.
? The seeds are used by veterinarians, to treat stomach-ache in equines.
? The seeds can be used as a piscicide.

Plant protectant

Cleome gynandra plants have been observed to have insecticidal, antifeedant and repellent characteristics (Verma and Pandey 1981, 1987; Pandey *et al*. 1983a, 1983b; Singh 1983a; Chandel *et al*. 1987; Akhtar 1990; Malonza *et al*. 1992; Pipithsangchan 1993).

? The leaves have anti-tick properties. They also have repellent and acaricidal properties for larvae, nymphs and adult *Rhipicephalus appendiculatus* and *Amblyomma variegatum* ticks. Ticks may not be found for a distance of 2-5 m from the plant.
? The ethanol extract is toxic to insect pests, such as the painted bug (*Bagrada cruciferarum* Kirk) and the diamond back moth (*Plutella xylostella* L.) of cruciferous vegetables. The volatile oils permanently repel the diamond back moth larvae from treated cabbage leaves.
? The plant has an anti-feedant action against the tobacco caterpillar (*Spodoptera litura* F.).
? The extract from the mature seeds is toxic to brinjal aphid (*Aphis gossypii* Glov.), and the larvae of *Heliothis armigera* (bollworm).

The seeds contain phenolic compounds, which are natural products (Jain and Gupta 1985). Lipids from seeds could be used in soap manufacture (Gupta and Chakravarty 1957).

Forage

Bovines, camels, equines and game animals graze the leaves as forage.

Economic

In some African countries (e.g. Zambia, Zimbabwe, Botswana, Malawi, Uganda, Tanzania and Kenya), during periods of abundance, the leaves and young tender shoots are sold in rural and urban markets by gatherers and growers, who are mostly rural women. The vegetable can therefore provide a source of income for rural areas, especially for the poor and the unemployed.

6 Genetic resources

Range of diversity for major characteristics

Although the species is widely distributed in Africa and Asia, its range of genetic diversity has hardly been studied. Studies in Kenya (Chweya 1990; Kemei *et al.* 1995) indicate that there are phenotypic variations among plant populations for plant type, stem and petiole pigmentation, length of petiole, plant height, number of leaflets / compound leaf, leaflet size and shape, stem and leaf pubescence, day to flowering, stem diameter, branching habit, number of primary branches and leaf colour. There is also variation among plants for days to seedling emergence and vigour, flowering tendency, position of fruit, fruit length, disease susceptibility and plant lodging. Table 5 summarizes the range of variation for some characters / traits.

Table 5. Range of variation for some characters of *Cleome gynandra*.

Character	Range of variation
Days to seedling emergency	4 - 8
Seedling vigour	very strong - very weak
Days to 50 % flowering	17 - 35
Flowering tendency	low - high
Plant type	erect - semi-erect
Plant height (cm)	25 - 72
Stem colour	green, pink, violet, purple
Stem pubescence	glabrous - abundant
Branching habit	upright - spreading
No. primary branches	2 - 7
Leaf colour	green - brownish
Leaf length (cm)	3 - 23
No. leaflets/leaf	3 - 7
Shape of leaflet	elliptical - oval
Leaflet margin ends	sharp - round
Length of leaflet (cm)	1.7 - 10
Width of leaflet (cm)	0.8 - 4.0
Petiole colour	green, pink, violet, purple
Petiole length (cm)	3 - 23
Flower size (cm)	1.0 - 2.5
Position of fruit	Top of canopy - throughout plant
Fruit length (cm)	6.4 - 12.0
Disease susceptibility	medium - resistant
Pest susceptibility	medium - resistant
Lodging	none - nearly 100 %

Variations among populations due to seasonal differences in environmental conditions are significant. Branching of plants tends to be dictated by environmental factors. For example, good moisture supply at the early stages of plant growth promotes fast vegetative growth, with reduced branching, while plant stress promotes early branching. Plant populations from hot, semi-arid areas tend to have shorter leaves and lower dry leaf weights than those from high-rainfall areas. The plants may, therefore, adapt to shorter growing periods which may be accompanied by low biomass production. Variation in fruit (pod) shape, fruit colour (yellow), seed colour (black) and seed shape (round) is not significant.

On the basis of stem and petiole pigmentation, four different plant types can be recognized (Chweya 1990):

? green stems, green petioles
? green stems, purple petioles
? purple stems, green petioles
? purple stems, purple petioles.

The intensity of pigmentation varies from light to deep.

Collecting and conservation

There have been no organized collecting missions for *C. gynandra.* The species is still regarded as a wild, weedy or volunteer crop, or is semi-cultivated. In some eastern and southern African countries, collecting has been done locally, and germplasm is being conserved by various institutions in these countries. Table 6 gives a summary of the accessions they hold (Kemei *et al*. 1995; Madisa and Tshamekang 1995; Nkhoma *et al*. 1995).

Table 6. Accessions of *Cleome gynandra* in some eastern and southern African countries.

Country	Number of accessions	Remarks
Botswana	11, 6 other *Cleome* spp.	Stored in a genebank at the Department of Agricultural Research of the Ministry of Agriculture. Collecting missions planned to all districts.
Kenya	45	Stored at the Genebank of Kenya. Collected from plains and hilly regions between altitude 700 and 2300 m asl.
South Africa	Some collections	Kept in the Agricultural Research Centre’s genebank
Tanzania	1	Active collections at National Plant Genetic Resources Centre
Zambia	15	Active collections at National Plant Genetic Resources Centre, collected from Botswana

The conservation methods being used are well established in the various genebanks. These include long-term storage at –20 or –10°C, and seeds kept in hermetically sealed packs (aluminium foil or air-tight containers). For active collections, seeds are kept at temperatures of 12-15°C, at 40% relative humidity. However, because of a lack of funds and personnel, most accessions are at risk. Some researchers maintain accessions in paper bags, envelopes, glass bottles, tins, cups, on top of shelves and in refrigerators in offices or laboratories. This type of conservation leads to loss of viability and of accessions.

Some conservation is being done on-farm by users and growers. This is done through use. Growers harvest seeds at the end of the season and store the seed in their homes in special containers, in such places as above fireplaces. Plants growing wild or as weeds are protected by the community, in communal lands, shrines or sacred areas.

Characterization and evaluation

Characterization and evaluation of cat's whiskers have not been done systematically. Studies were conducted in Kenya between 1985 and 1989 (Chweya 1990), on germplasm collected from farmers' fields in Kenya, to determine any differences in plant characteristics and nutritive quality between seedlots collected from various areas. The results indicated that there were no significant differences between plant characteristics, leaf yield and the nutritive quality of plants from the various seedlots.

At the Genebank of Kenya, 13 accessions have been characterized (Kemei *et al.* 1995). Data were collected for plant, flower, fruit and seed characters, and accessions showed distinct variations in most characters. Only a few characters, such as fruit colour and shape, and seed colour and shape, were not variable.

Gaps in collections and constraints in conservation

Cleome gynandra has been neglected by the national agricultural research system, and by governments' agricultural development policies. There have been no specific missions to collect cat's whiskers from all the geographical areas in the various countries in which the diversity of the species exists. The few accessions held were collected during missions to collect important species found in these countries. There is a need, therefore, to organize specific collecting missions, especially in Africa, where the species is important as a vegetable and for its medicinal uses.

The main constraints in the conservation of cat's whiskers are:

? the scepticism of policy-makers, researchers and youth towards the species as a potential commercial crop

? a lack of funding and of strong, well-defined programmes for the crop

? inadequate personnel to conserve and maintain genetic resources (*ex situ*, *in situ* and on-farm).

7 Breeding

Farmers are using their own local selections / advances, and few genetic studies and breeding work on *C. gynandra* are reported in the literature. The findings of research done in Kenya (Omondi 1990) are inconclusive, but indicate that the characters of interest to any genetic improvement work will be higher leaf yield, plant uniformity, longer vegetative phase, late flowering and drought tolerance. Yield is polygenically controlled, is highly influenced by the environment, and therefore shows low heritability estimates. Yield therefore needs to be improved indirectly, via yield components (days to flowering, plant height, number of leaves, leaf length, fresh leaf weight and dry leaf weight). All components of vegetative yield, except days to flowering, show a positive correlation with dry leaf yield. Number of leaves could be the most consistent determinant of dry leaf weight. Broad sense heritability studies by Omondi (1990) and Omondi and Ayiecho (1992) indicate that most characters have low heritability estimates, and hence low expected selection gain, due to the genetic uniformity or factors concealing the limited genetic variation present. A high heritability estimate, however, was observed in days to flowering. Duration of vegetative growth could be significantly prolonged by selecting late-flowering genotypes in a population. More studies are needed in this area.

As is noted in section 2 above, *C. gynandra* plants could be both self- and cross-pollinated. It is possible, therefore, to produce hybrids. Although the specific mating system is not yet known, inbreeding is possible because the plants are self-pollinating. Interspecific crosses between *C. gynandra* and its relatives could be possible. However, no cytogenetic studies have been carried out. There is already a debate in the literature regarding the number of chromosomes. Koshy and Mathew (1985) report 2*n*=34, while Raghavan and Kamble (1979) report 2*n*=20. Polyploidy has also been shown to occur (Darlington and Wylie 1955; Hanumantha Rao *et al.* 1978). This situation represents a challenge to plant cytogeneticists and breeders.

8 Major and minor production areas

Cleome gynandra is not yet formally cultivated as a commercial crop. It is still regarded as a wild, weedy and volunteer crop, and is semi-domesticated in home gardens or on fertile land near homesteads in most African countries (Kenya, Uganda, Botswana, Zambia, South Africa, Zimbabwe, Malawi, Nigeria, Cameroon, Namibia, Swaziland, Tanzania and Ghana). It is therefore not easy to identify the crop's major and minor production areas. The seed crop is commercially cultivated, however, and in Zambia, a national seed company is marketing cat's whiskers seed. Production packages have been developed and the seed company is vigorously promoting the crop.

9 Ecology

The species is adapted to a wide range of environmental conditions. It grows well from sea level up to 2400 m asl, and tolerates high and low temperatures, but thrives from 18 to 25°C. Plants do not grow well under shade, as they require high light intensity. The species is a C_4 plant, and hence combines efficient water utilization with high photosynthetic capacity at high temperatures (Imbamba 1976). This allows it to grow in areas with short periods of useful rainfall. The species is not drought-resistant. However, water stress does influence leaf water potential, relative water content and net photosynthesis, until the 4th day after induction. Photosynthetic leaf area is high and leaf resistance is low. Transpiration rates are therefore high. The species tolerates some drought conditions, but water stress hastens maturity and senescence of the plants. Plants remain stunted and unthrifty under drought conditions.

The species does not appear to be sensitive to daylength, although leaves exhibit strong rhythmic circadian movements, following the direction of the sun. The movements are promoted by high light intensity and temperatures. This characteristic probably influences the photosynthetic efficiency of the plants.

The species requires soils with high organic matter content, with adequate mineral reserves. As a weed, plants are commonly found growing on fertile soils, especially in those previously mixed with animal manure, or with homestead refuse. Plants can grow on a wide range of soils, as long as they are deep and well drained, with a pH range of 5.5-7.0. The soil types range from sandy loam to clay loams.

10 Agronomy

Propagation

Cleome gynandra plants are propagated by seed. Seeds are sown directly in a well-prepared seedbed. Seedlings do not withstand transplanting, because their root systems consist of taproots with very few laterals. Production of new roots is slow; hence, transplanting will result in severe growth shock and is not recommended.

Seedbed preparation

Plants require a thoroughly prepared seedbed. After digging, the soil is harrowed to a fine tilth. Organic manure is applied and worked into the soil. The seedbed is then levelled before planting. Plants can be grown on flat beds or on traditional raised beds, which are normally 1 m wide. The appropriate bed length depends on the amount of the crop to be grown, but may not exceed 3 m. There are usually narrow pathways between the beds to facilitate weeding and harvesting. These pathways also act as drainage channels during the very wet season, as plants do not withstand waterlogging. When raised beds are used, application of organic manure is delayed until the beds have been dug.

Planting

The small seeds are broadcast or drilled in rows, spaced about 30 cm apart. Depth of sowing is crucial. Shallow seeding is recommended, as deep sowing will result in uneven seedling emergence and poor field stand. Seedlings emerge after 6-8 days. Thinning is done 3 weeks later, to leave 10-15 cm between plants, and the thinnings may be consumed as vegetables.

Nutrient requirements

Plants respond positively to increased soil fertility. For good yields, liberal application of nitrogenous fertilizers (organic or inorganic) is necessary. Where available, use of farmyard manure (FYM) or compost is recommended. Use of FYM has been observed to give better results than the use of inorganic nitrogenous fertilizers. Apart from adding nutrients to the soil, FYM also improves soil structure, cation exchange and water-holding capacities. Application of 20 kg FYM / m2 is recommended.

When FYM is not available, application of 200 g diammonium phosphate (46% P_2O_5, 18% N) / m2 at planting is recommended. This fertilizer gives better results than double or triple superphosphate, because the nitrogen in the diammonium phosphate gives the plants a good early start. It also promotes continuous vegetative growth, which results in good leaf yields.

At thinning stage, 3 weeks after seedling emergence, top-dressing with 100 g calcium ammonium nitrate (26% N) is recommended. Generous application of nitrogen delays flowering of plants and hence extends the harvesting period. The response to fertilizer N (ammonium nitrate) applied as split applications (at sowing and after two defoliations) on leaf and seed yield in Zambia is shown in Table 7. The optimum fertilizer rate is 120 kg/ha, and plants perform better in a rainy season. Seed yield is not responsive to N application. At higher N rates, stems become too succulent and regeneration is reduced, a disadvantage where plants are periodically harvested.

Table 7. Leaf and seed yield response of two *Cleome* accessions to fertilizer N during the rainy and cool seasons in Zambia (Mnzava 1986).

			N level† (kg/ha)				
Yield	Selection	Season	0	40	80	120	160
Leaf (t/ha)	Purple	Rainy	12.6	15.5	18.5	24.3	13.2
		Cool	9.1	12.8	12.5	14.7	14.2
	Green Stem	Rainy	14.8	19.4	33.8	33.8	38.4
		Cool	6.5	12.1	10.2	14.6	8.4
Seed (kg/ha)	Purple Stem	Rainy	360	220	330	220	530
	Green Stem	Rainy	110	360	420	420	530

† Ammonium nitrate.

A study was also conducted to show the effect of deflowering on the vegetative growth, leaf yield and quality of *C. gynandra* plants (Maumba 1993). The results (Table 8) show that deflowering significantly decreases plant height and increases number of branches per plant and leaf yield. Deflowering also significantly increases leaf ascorbic acid content, but has virtually no effect on leaf β-carotene and total phenolic contents.

Table 8. Effect of deflowering on the vegetative growth, leaf yield and quality of *Cleome gynandra*.

Character	Non-deflowered	Deflowered
Plant height (cm)	75	65
Petiole length (cm)	9	9
No. branches per plant	13	14
Leaf yield (t/ha)	7.2	9.5
Ascorbic acid (mg/100 g DM)	1056	1152
β-carotene (mg/100 g DM)	44.3	42.2
Total phenolics (mg/100 g DM)	5000	4966

The same study on the effect of plant age on leaf yield and quality of *C. gynandra* showed that weekly leaf yields increase with plant age until about the 7th week, when the yields decline. Furthermore, the results indicate that leaf ascorbic acid content significantly increases with plant age, while total leaf phenolics decrease. The β-carotene content of leaves increases and then decreases with plant age.

Weeding

Plants do not have dense foliage, and as such are unable to compete with weeds. It is therefore essential that seedbeds are kept weed-free at all times, but especially during the first 6 weeks. Shallow cultivation or hand-pulling of weeds should be practised. Damage on roots adversely affects the growth of plants, leading to reduced leaf yield and quality.

Watering

Seeds should be sown at the onset of rainfall. This ensures availability of adequate soil moisture throughout the growth period. Water stress reduces leaf yield and quality. When rainfall is inadequate, frequent watering is necessary during the vegetative growth period, with frequency depending on the water-holding capacity of the soil. Care must be taken not to over-water the plants, as they do not withstand flooding.

Pests and diseases

The plants can be attacked by the following pests: pentatomids (*Acrosternum gramineum* and *Agonoselis nubilis*) and their parasitoids; locusts (*Schistocera gregaria*); nematodes (*Meloidogyne* spp.); flea beetles (*Phyllotreta mashonana* Jacq.); green vegetable bugs (*Nezara* spp.); cabbage sawfly (*Athalia* spp.); cotton jassids (*Empoasca* spp.) and hurricane bugs (*Bagrada* spp.). The hurricane bug renders stand establishment virtually impossible. In Zambia, attack by these beetles is more prevalent during dry periods, and can be effectively controlled by spraying the plants with an appropriate insecticide such as Ambush, Ripcord or Rogor E. (Skaf 1978; Tawfik *et al.* 1980; Maundu, unpublished2; Velayudhan 1986; Dahiya *et al.* 1988).

Young seeds are eaten by weaver birds (*Quelea quelea*) and the plant is also host to mildew fungus (powdery mildews *Sphaerotheca fuliginea*, *Oidiopsis taurica* and *Cercospora uramensis)* (Atheya and Mathur 1966; Raghava and Purnachandra 1980; Singh 1983b).

Harvesting

Thinnings can be used as vegetables. When plants reach a height of about 15 cm, they can be harvested by uprooting whole plants, or by topping, cutting back to ground level, or picking individual leaves or leafy branches at frequent intervals. Frequent picking and deflowering encourages lateral growth, thus extending the harvesting period. Harvesting starts 4-6 weeks after seedling emergence and may last 4-5 weeks. Biweekly removal of tender leaves allows regeneration of branches.

2 Maundu, P.M., C.H. Kabuye and G. Wambui. unpublished. An Illustrated Guide to some Indigenous Food Plants of Kenya.

However, accessions studied in Zambia (Mnzava 1986) show marked differences in yield, due to varying abilities to regenerate. The 'purple stem' accession does not form a woody stem. It tends to dry up, and rot upon repeated decapitation, unlike the 'green stem' type. Old plants produce small bitter leaves.

Yields

Cumulative leaf yields of 30 t/ha per season may be obtained. Weekly leaf yields increase with plant age, until about the 7th week of growth, when they start declining. By the 10th week of growth, the yields would have decreased by about 90%. Seed yields are about 500 kg/ha at most.

Storage

No practices have yet been established for the storage of cat's whiskers. Some ethnic groups in Africa boil the leaves, sun-dry them and store the dried leaves in a well-ventilated place. The dried leaves can be stored up to 6 months, or sometimes longer, without any changes in quality (except loss of ascorbic acid). In Thailand, *C. gynandra* leaves are preserved as a fermented leaf product called *pak-sian-dong* (FAO 1990). This is made as follows: fresh leaves are washed and wilted in the sun. They are then mixed with water containing salt and raw cane or palm sugar; 1 kg of leaves requires 50 g salt and 60 g sugar, dissolved in a litre of water. The mixture is packed into tightly sealed jars and allowed to ferment for about 72 hours, until a pH of 3.9 is achieved. Both homofermentative and heterofermentative strains of lactobacilli have been isolated from the product.

11 Limitations of the crop

A number of factors currently constrain the cultivation and use of the species:

- its status as a wild and weedy, volunteer crop has caused it to be neglected by the National Agricultural Research Systems (NARS)
- young farmers perceive it as a vegetable for the poor
- its yield is low
- its phenolic contents adversely affect its palatability, especially to children
- it harbours pests (notably pentatomids, locusts and nematodes)
- it is a host to diseases such as powdery mildew.

12 Prospects

The uses of *Cleome gynandra* make it clear that the species has the following important characteristics that call for its conservation and utilization:

- it is a highly nutritious leafy vegetable (a rich source of vitamins A and C, and of calcium, iron and protein)
- it is known to rural populations, especially in Africa, where the vegetable is sold in rural and urban areas, providing a source of income
- it possesses insecticidal properties
- it has anti-tick properties (being used both as a repellent and as an acaricide).
- it has an anti-feedant action against insects
- it is a forage for bovines, camels, equines and game animals.
- it seeds are oleaginous, and have potential for use as edible oil and animal feed.

13 Research needs

The following initiatives are called for:

- A deliberate effort to collect and conserve *C. gynandra* germplasm. This will faciliate systematic evaluation and breeding / selection programmes, which are important for genetic enhancement of valuable nutritive traits.
- Undertaking of inventories of existing accessions, and gathering of existing passport and evaluation data.
- Proper information on the ecogeography of the species, and an assessment of its national and regional distribution.
- Crop improvement programmes, involving breeding for:
  (i) desirable traits, such as high leaf yield, longer vegetative growth period, late flowering, reduced lodging and reduced shattering of capsules
  (ii) a high-quality leaf that is less bitter and more palatable.
- Studies on:
  (iii) the reproductive biology of cat's whiskers, to overcome intermittent sterility, a feature which imparts low seed yield to the species
  (iv) methods of deferring the onset of flowering, thereby prolonging the vegetative phase and increasing leaf productivity
  (v) intercropping with field or other vegetable crops
  (vi) soil requirement.
- Selection of the genotypes best adapted to various agro-ecological zones.
- Identification of optimum planting dates and densities.
- Characterization of diseases and pests affecting the species.
- Post-harvesting handling of the crop, including methods of dehydration.
- Methods of storage.
- Development of production packages.
- Verification of existing local knowledge on production.
- Systematic comparison with other leafy vegetables, to establish its advantages.

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Appendix I. Scientists, researchers and institutions working on indigenous leaf vegetables in sub-Saharan Africa.

Angola

Ms I.M. Graça Agostinho Neto University CP 815 Av. 4 Fevereiro 7, 2° Andar Luanda Tel: +244-2-3314773	Plant genetic resources
Mr D.D. Kaholo Centro National de Investigação Scientifica Av. Revolução de Outubro Luanda Tel: +244-2-345034	Taxonomy

Botswana

Mr M.N. Mbewe Mr E. Tshamekang Thusano Lefatsheng Private Bag 00251 Gaborone Tel: +267-372273 / 399289 Fax: +267-305494	Germplasm collecting, cultivation
Mr F.W. Taylor Veld Products Research PO Box 2020 Gaborone Tel: +267-305522 Fax: +267-305522	Domestication, post-harvest handling

Burundi

Dr P. Ndabaneze Prof. Y. Cordier University of Burundi Dept. Technology / Agronomy PO Box 2940 Bujumbura Tel: +257-225556 Fax: +257-227967	Taxonomy, ecology, biochemistry

Cameroon

Dr M.N. Thomas Limbe Botanic Gardens Limbe 437 Tel: +237-332620 Fax: +237-332227	Utilization

Dr D. Tetio-Kagho Dept. Crop Science Faculty of Agronomy University of Dschang Dschang Tel: +237-451172 Fax: +237-451202	Agronomy

Côte d'Ivoire

Dr Christophe Kouame Institut des Savaries 01 BP 633 Bouakesoi Fax: +225-632045	Utilization

Ethiopia

Dr Z. Asfaw Faculty of Science Addis Ababa University PO Box 1176 Addis Ababa Tel: +251-1-550844 Fax: +251-1-522112 Email: biology@padis.gn.apc.org	Utilization, food preparations

Gabon

Dr A. Blandine International Centre for Bantu Civilization Dept. Traditional Medicine and Pharmacopoeia BP 770 Libreville Tel: +241-739650 Fax: +241-739717	Medicinal uses, ethnobotany

Ghana

Prof. I. Addae-Mensah Dept. Chemistry University of Ghana PO Box 25 Legon Accra Tel: +233-21-667706	Medicinal uses
Prof. Bede N. Okigbo The United Nations University Institute for National Resources in Africa Private Mail Bag Accra Tel: +233-21-775396 Fax: +233-21-775792	Home gardens

Mr G. Tuani Dept. Chemistry University of Science and Technology University Post Office Kumasi Tel: +233-51-5351	Insecticidal activities
Dr Daniel K. Abbiw Dept. Botany University of Ghana PO Box 55 Legon Tel: 233-21-63322 Email: balme@ug.gn.apc.org	
Kenya	
Mrs L. Mathenge Mrs B. Busolo Kenya Energy and Environmental Organization PO Box 48197 Nairobi Tel: +254-2-749747 / 748281 Fax: +254-2-749382	Utilization and conservation
Mr P. Maundu Mrs C.S. Kabuye National Museums of Kenya Herbarium PO Box 40658 Nairobi Tel: +254-2-742161-4 Fax: +254-2-741424 Email: biodive@tt.gn.apc.org.	Ethnobotany, taxonomy
Prof. James A. Chweya Dr Florence Olubayo Dept. Crop Science University of Nairobi PO Box 29053 Nairobi Tel: +254-2-632175 / 632037 Fax: +254-2-631956	Germplasm collecting, evaluation, characterization, genetic enhancement, agronomy, pests
Prof. Jasper K. Imungi Dept. Food Science and Technology University of Nairobi PO Box 29053 Nairobi Tel: +254-2-631956 Fax: +254-2-630172	Nutritive value, processing

Ms Monica Opole Centre for Indigenous Knowledge Systems and By-Products PO Box 29226 Nairobi Tel: 254-2-444424 Fax: 254-2-444424	Utilization, conservation, indigenous knowledge
Mr John Wanjau Njoroge Mr Nehemiah Mihindo Kenya Institute of Organic Farming PO Box 34972 Nairobi Tel: 254-2-732487 Fax: 254-2-581178	Cultivation
Dr C.O. Omondi Dept. Horticulture Jomo Kenyatta University of Agriculture and Technology PO Box 62000 Nairobi	Genetic resources
Mr Paul Osero Mr Patrick Nekesa Organic Matter Management Network PO Box 39042 Nairobi Tel: 254-2-521482	Utilization, seed production
Mrs G.N. Thitai National Council of Science and Technology PO Box 30623 Nairobi Tel: 254-2-748281 / 749747	Ethnobotany, utilization diversity
Mr E.N. Seme Mr J.K. Kemei National Genebank of Kenya PO Box 781 Kikuyu Tel: 254-154-32880 / 1 / 2 Fax: 254-154-32587	Collecting, characterization, evaluation, conservation
Mrs D. Mwamba Mr Obiero Mrs M. Onyango Kenya Agricultural Research Institute PO Box 57811 Nairobi	Agronomy

Madagascar	
Mr Manitra Rakatoarisoa Dept. Agronomic Research PO Box 1444 Antananarivo	Surveys, utilization
Malawi	
Dr M.B. Kwapata Dept of Crop Science University of Malawi PO Box 219 Lilongwe	Germplasm collecting, improvement and production
Mr Moses Maliro University of Malawi Bunda College of Agriculture PO Box 219 Lilongwe	Agronomy, conservation, utilization
Mauritius	
Dr C. Ricaud Mauritius Sugar Industry Research Institute The Mauritius Herbarium Reduit Tel: +230-4541061 Fax: +230-4541971	Ethnobotany, taxonomy
Prof. I. Fagoonee Dept. Chemistry University of Mauritius Reduit Tel: +230-4541041 Fax: +230-4549642	Botany, taxonomy, phytogeography
Namibia	
Ms Gillian Maggs National Botanic Research Institute Private Bag 13184 Windhoek Tel: +264-61-2022196 Fax: +264-61-233459	Conservation, utilization, agronomy
Nigeria	
Dr C.O. Ajakaye Dept. Biological Sciences Ahmadu Bello University Zaria, Kaduna State Tel: +234-62-50581 X 108	Germplasm storage

Dr Y.Y. Karatela Dept. Biological Sciences Bayero University PMB 3011 Kano Tel: +234-61-660036	Surveys, ethnobotany
Dr B.M.B. Ladu Dept. Biological Sciences Federal University of Technology PMB 2076 Yola Tel: +23434-200090	Medicinal properties
Mr O.A. Bakare Ecology Division Forestry Research Institute of Nigeria PMB 5054 Ibadan Tel: +234-22-410771 Fax: +234-22-417715	Taxonomy, herbarium collections, ethnobotany
Prof. A.E. Akingbohungbe Dept. Natural History Obafemi Awolowo University Ile-Ife, Osun State Tel: +234-36-230290 / 1 1-9x2651	Inventory
Dr J.O. Okafor FAME Agricultural Centre PO Box 3856 Enugu Tel: +234-42-335060 Fax: +234-42-250611	Medicinal properties, utilization
Prof. A. Sofowora Dept. Pharmacognosy Ile-Ife, Osun State Tel: +234-36-230290 Fax: +234-36-36231733	Ethnobotanical surveys
Prof. A.I. Ahianzu Dept. Food Science and Technology Rivers State University of Science and Technology PMB 5080 Portcourt Tel: +234-84-300368	Production techniques, nutritional evaluation

Prof. A. Egunyoni Dept. Botany University of Ibadan Ibadan Tel:+234-22-400550x 1403	Ethnobotanical surveys
Dr O.A. Denton National Horticultural Institute PMB 5432 Ibadan Tel: +234-22-412490 / 412296 Fax:+234-22-2413121 Email: c / o D.Ladipo@cgnet.com	Utilization
Rwanda	
Dept. Vegetables National University of Rwanda Tel: +250-30716	Extracts against pests and diseases
Senegal	
Dr Meissa Diouf Centre pour le Développement de l'Horticulture Institut Senegalais de Recherches Agricoles BP 219 Dakar Tel: +221-352506 Fax: +221-322127 / 350610	Utilization
Dr Abdoulay Seck TROPICASEN BP 999 Dakar Tel: +221-320505 Fax: +221-320536	Surveys, utilization
South Africa	
Dr R.D. Heinsohn ACER (Africa) PO Box 276 Mtunzuni, 3867 Tel: +27-353-401799 / 402715 Fax: +27-353-402232	Indigenous plant cultivation
Mrs Erika van den Heever Vegetable and Ornamental Plant Institute Agriculture Research Council Private Bag X293 Pretoria 001 Tel: +27-12-8419611	Utilization, diversity

Fax: +27-12-8080844	
Dr D.B. Arkcoll Dept. Crop Production Elsenburg Agricultural Development Institute Private Bag Elsenburg 7607 Tel: +27-2231-94620 Fax: +27-2231-94226	Identification of new crops
Mr T. Arnold Dept. Data Management National Botanical Institute Private Bag X101 Pretoria, 0001 Tel: 27-12-8043200 Fax: 27-12-8043211	Database of indigenous South African plants
Prof. M.A.T. Poswal Dept. Agronomy University of Fort Hare Private Bag X1314 Alice 5700 Tel: +27-404-22232 Fax: 27-404-31740	Sources of natural or botanical pesticides
Sudan	
Dr El Tair I. Mohamed Sudan Natural Centre for Plant Genetic Resources PO Box 126 Wad Medan	Cultivation, utilization, conservation
Tanzania	
Mr R.E.A. Swai Ministry of Agriculture Tengeru Horticulture Research & Training Institute PO Box 1253 Arusha Tel: Deluti 94 Fax: +255-57-8254	Conservation, utilization, agronomy, seed production
Dr. N.A. Mnzava Horticulturist Consultant PO Box 1371 Arusha	Agronomy, seed production, nutritive value

Uganda

Mrs J. Ochola Botanical Gardens c/o NARO PO Box 295 Entebbe	Utilization
Ms E.K.Z. Kakudidi Dept. Botany Makerere University POB. 7062 Kampala Tel: +256-41-542803	Ethnobotany
Mrs E. Rubaihayo Dept. Horticulture Kawanda Agricultural Research Station POB. 7065 Kampala Tel: +256-41-567648 Fax: +256-12-21070	Germplasm collecting, conservation, seed multiplication and distribution

Zambia

Mr G.P. Mwila National Plant Genetic Resources Centre Mt. Makulu Research Station P/B 7 Chilanga Tel: +260-1-278263	Inventory and collecting
Dr D.S. Mingochi Dept. Agriculture National Irrigation Research Station Private Bag S-3 Mazabuka Fax: +260-32-248028	Agronomy, utilization, conservation
Dr Godwin Mkamanga SADC Plant Genetic Resources Centre Private Bag CH6 ZA-153 02 Lusaka Tel: +260-1-230511	Germplasm conservation

Fax: +260-1-241927 / 290440

Zimbabwe

Dr J.E. Jackson Dept. Research and Specialist Services Horticultural Research Institute Private Bag 3748 Marondera Tel: +263-79-24122	Development of indigenous leafy vegetables
Mr Fabeon Chigumira Horticultural Research Centre Private Bag 3748 Marondera Tel: +263-79-24122 Fax: +263-4-791223	Utilization
Mr Andrew Mushita Community Technology Development Association PO Box 7232 Harare Tel: +263-4-732360	Conservation, cultivation