Promoting the conservation and use of underutilized and neglected crops. 5.

N i g e r

Guizotia abyssinica (L. f.) Cass.

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Contents

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

Niger (*Guizotia abyssinica* (L. f.) Cass., Compositae) is an oilseed crop cultivated in Ethiopia and India. It constitutes about 50% of Ethiopian and 3% of Indian oilseed production. In Ethiopia, it is cultivated on waterlogged soils where most crops and all other oilseeds fail to grow and contributes a great deal to soil conservation and land rehabilitation.

The genus *Guizotia* consists of six species, of which five, including niger, are native to the Ethiopian highlands. It is a dicotyledonous herb, moderately to well branched and grows up to 2 m tall. The seed contains about 40% oil with fatty acid composition of 75-80% linoleic acid, 7-8% palmitic and stearic acids, and 5-8% oleic acid (Getinet and Teklewold 1995). The Indian types contain 25% oleic and 55% linoleic acids (Nasirullah *et al.* 1982). The meal remaining after the oil extraction is free from any toxic substance but contains more crude fibre than most oilseed meals.

Niger is indigenous to Ethiopia where it is grown in rotation with cereals and pulses. The African and Indian genepools have diverged into distinct types. On both continents niger germplasm has been collected and evaluated, and is mostly conserved and documented at the Biodiversity Institute of Ethiopia and the Indian National Bureau of Plant Genetic Resources (including zonal centres). The Ethiopian germplasm is collected from farmers' fields and does not include breeding lines.

In this monograph the major germplasm characterizations and evaluations at Holetta, Ethiopia and Jabalpur, India are summarized. Available recent literature on niger genetic resources is reviewed, and the prospects and constraints of niger production are indicated.

1 Taxonomy and names of the species

1.1 The position of niger in plant systematics

The genus *Guizotia* belongs to the family of Compositae, tribe Heliantheae, subtribe Coreopsidinae. A taxonomic revision of the genus based on the morphological traits was presented by Baagøe (1974). She reduced the number of species within the genus *Guizotia* to six: *G. abyssinica* (L. f.) Cass.; *G. scabra* (Vis.) Chiov. subsp. *scabra* and subsp. *schimperi* (Sch. Bip.) Baagøe; *G. arborescens* I. Friis; *G. reptans* Hutch; *G. villosa* Sch. Bip. and *G. zavattarii* Lanza. *Guizotia scabra* contains two subspecies, *scabra* and *schimperi*. *Guizotia scabra* subsp. *schimperi*, known locally as 'mech,' is a common annual weed in Ethiopia. There is a controversy on the taxonomical category of *G. abyssinica* and *G. scabra* subsp. *schimperi* (Murthy *et al.* 1995). *Guizotia abyssinica* and *G. scabra* subsp. *schimperi* are morphologically very similar, they are both annuals, and are attacked by the same pests and diseases. Both species have $2n$=30 chromosomes with a similar karyotype. The hybrid between *G. abyssinica* and *G. scabra* subsp. *schimperi* is fertile and forms 15 bivalents in 95% of the pollen mother cells. Indeed, *G. scabra* subsp. *schimperi* is closer to the *G. abyssinica* than to the perennial *G. scabra* subsp. *scabra*. On the basis of cytological evidence, Murthy *et al.* (1995) proposed that the two species *G. abyssinica* and *G. scabra* subsp. *schimpri* be merged into one species. However *G. abyssinica* was described by Cassini in 1829 and *G. scabra* in 1841 and the International Rules of Botanical Nomenclature would not support the inclusion of *G. scabra* subsp. *schimperi* as a subspecies of *G. abyssinica*. Since *G. scabra* subsp. *schimperi* is a wild species, it is unlikely that a wild species was derived from a cultivated species. Therefore, for the time being the original description by Baagøe (1974) of cultivated niger as *G. abyssinica* (L. f.) Cass. should be retained. Other taxa within the genus *Guizotia*, such as the 'Chilulu' population (Dagne 1994b) and *G. bidentoides* Oliver and Hiern (Murthy 1990), were mentioned in the literature.

1.2 Accepted botanical name of the species and synonyms

The accepted botanical name of the species and synonyms according to Baagøe (1974) and Schultze-Motel (1986) are:

Guizotia abyssinica (L. f.) Cassini in Dict. Sci. Nat. 59 (1829) 248. - *Polymnia abyssinica* L. f., Suppl. (1781) 383; *Verbesina sativa* Roxb. ex Sims, Bot. Mag. 25 (1807) t. 1017; *Polymnia frondosa* Bruce, Trav. ed. 3, Atlas (1813) t. 52; *Parthenium luteum* Spr., Neue Entdeck. (1818) 31; *Heliopsis platyglossa* Cass. in Dict. Sci. Nat. 24 (1822) 332; *Jaegeria abyssinica* Spr., Syst. 3 (1826) 590; *Guizotia oleifera* DC., Sept. note Pl. rar. Jard. Genève, Mém. soc. hist. nat. Genève 7 (1836) 5, t. 2; *Veslingia scabra* Vis. in Nuovi Saggi Accad. Sc. Padova 5 (1840) 269; *Ramtilla oleifera* DC. in Wight, Contrib. 18 (1834).

Typus: *Guizotia abyssinica* (L. f.) Cassini.

Family: Compositae (Asteraceae).

Niger is an oilseed crop which has been under cultivation in Ethiopia and India for millennia. The species became known in Europe as a result of James

Bruce's expedition to Ethiopia in 1774 (Baagøe 1974). He presented seed samples of niger to French naturalists who studied the plant. The earliest name given to this plant was *Verbesina oleifera*. The first botanical description of niger was *Polymnia abyssinica* L. The Linnaean herbarium in London holds a specimen matching the description with the name *Polymnia bidentis* with a note *abyssinica*. Another description by Cassini (1821) was *Heliopsis platyglossa*, probably based on samples of Bruce. Eight years later, Cassini (1829) realized that *Heliopsis platyglossa* and *Polymnia abyssinica* were identical and designated a new name, *Guizotia abyssinica* Cass. The name *Guizotia* is from the French historian François Pierre Guillaume Guizot.

Botanists working in India, unaware of the African flora, used various names. *Verbesina sativa* was the first name used for the taxon. The taxon *Jaegeria abyssinica* was also used. De Candolle (1836) described the taxon with the name *Ramtilla oleifera*. Two years later he realized that his description and Cassini's *Guizotia abyssinica* Cass. were the same and proposed a new name, *Guizotia oleifera* (DC). In 1905 following the Vienna botanical congress, the name *Guizotia* was conserved, and in 1930 at the Cambridge botanical congress the name *Guizotia abyssinica* (L. f.) Cass. was proposed as the correct name.

1.3 Common names of the species

Common names of the species according to Chavan (1961), Patil and Joshi (1978), Patil and Patil (1981) and Seegeler (1983) are:

English	niger, niger-seed, niger-seed oil, ramtil oil
Ethiopian	
(Amharic)	nog, nuk, nook, noog (the plant), nehigue (the oil)
(Tigrinya and Sahinya)	neuk, nuhk, nehug, nehuk
(Orimigna, Galignya)	nuga, nughi
(Kaffinya)	nughio
(Gumuzinya)	gizkoa
French	Guizotia oléifère, niger
German	Gingellikraut
Indian	
(Assamese)	sorguja
(Bengali)	sarguza
(Oriya)	alashi
(Telugu)	verrinuvvulu
(Tamil)	payellu
(Kannada)	hechellu
(Marathi)	karale or khurasani
(Gujarati)	ramtal
(Hindi)	ramtil or jagni
(Punjabi)	ramtil
Medical name	*Semen guizotiae oleiferae*

2 Brief description of the crop

2.1 Botanical description

Niger is an annual dicotyledonous herb. Germination is epigeal and seedlings have pale green to brownish hypocotyls and cotyledons (Seegeler 1983). The cotyledons remain on the plant for a long time. The first leaf is paired and small and successive leaves are larger. The leaves are arranged on opposite sides of the stem; at the top of the stem leaves are arranged in an alternate fashion. Leaves are 10-20 cm long and 3-5 cm wide (Fig. 1.1). The leaf margin morphology varies from pointed to smooth and leaf colour varies from light green to dark green, the leaf surface is smooth.

The stem of niger is smooth to slightly rough and the plant is usually moderately to well branched. Niger stems are hollow and break easily. The number of branches per plant varies from five to twelve and in very dense plant stands fewer branches are formed. The colour of the stem varies from dark purple to light green and the stem is about 1.5 cm in diameter at the base. The plant height of niger is an average of 1.4 m, but can vary considerably as a result of environmental influences and heights of up to 2 m have been reported from the Birr valley of Ethiopia.

The niger flower is yellow and, rarely, slightly green. The heads are 15-50 mm in diameter with 5-20 mm long ray florets. Two to three capitulae (heads) grow together, each having ray and disk florets. The receptacle has a semi-spherical shape and is 1-2 cm in diameter and 0.5-0.8 cm high. The receptacle is surrounded by two rows of involucral bracts. The capitulum consists of six to eight fertile female ray florets with narrowly elliptic, obovate ovules. The stigma has two curled branches about 2 mm long. The hermaphrodite disk florets, usually 40-60 per capitulum, are arranged in three whorls (Figs. 1.1 and 1.2). The disk florets are yellow to orange with yellow anthers, and a densely hairy stigma.

The achene is club-shaped, obovoid and narrowly long (Seegeler 1983). The head produces about 40 fruits. The achenes are black with white to yellow scars on the top and base and have a hard testa. The embryo is white.

Niger is usually grown on light poor soils with coarse texture (Chavan 1961). It is either grown as a sole crop or intercropped with other crops. When intercropped it receives the land preparation and cultivation of the main crop. In Ethiopia it is mainly cultivated as a sole crop on clay soils and survives on stored moisture. A more detailed description on the agronomy of niger is presented under **Agronomy**.

2.2 Mode of reproduction

Flower development, the extent of cross- and self-pollination, and the time at which fertilization occurs are important criteria for conducting breeding work. In Ethiopia capitulum buds open approximately 2 months after planting (Seegeler 1983). Flower anthesis begins early in the morning at about 6.00 hours and dehiscence of pollen begins 2 hours later and continues up to 10.00 hours under conditions at Holetta, Ethiopia (Teklewold, unpublished). The style emerges covered with pollen but the receptive part rarely or never comes in contact with that pollen, a phenom-

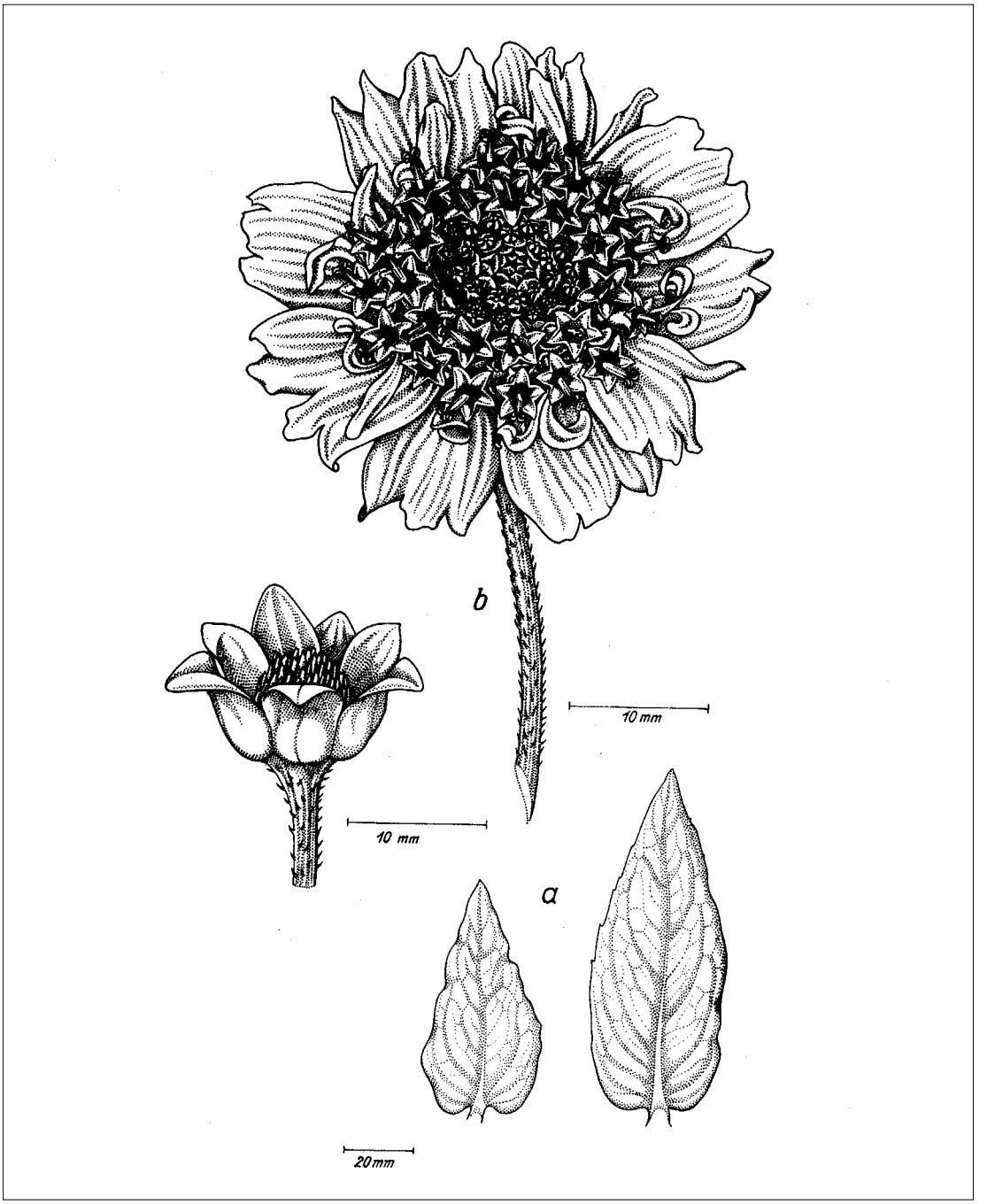

Fig. 1.1. *Guizotia abyssinica* (L. f.) Cass. (a) leaves, (b) flower heads.

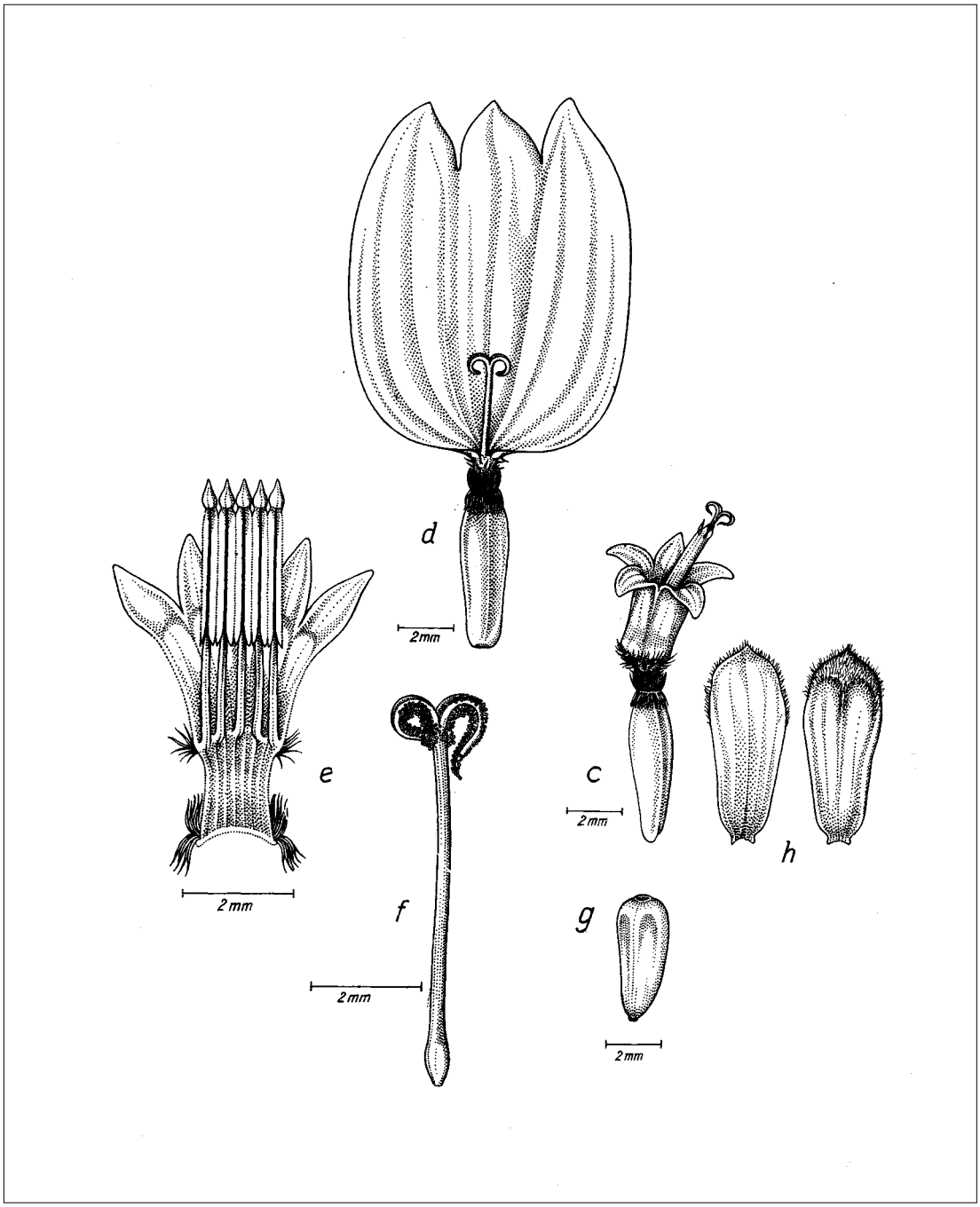

Fig. 1.2. (c) hermaphrodite disk floret, (d) pistillate ray floret, (e) upper part of disk floret tube (laid open) with stamens, (f) pistil, (g) achene, (h) sepals (Figs. 1.1 and 1.2: R. Kilian in Schultze-Motel 1986; reprinted with permission of the Gustav-Fischer Verlag, Jena).

enon that favours cross-pollination. A single head or capitulum takes 8 days and a field will require 6 weeks for completion of flowering (Seegeler 1983).

Niger is a completely outcrossing species with a self-incompatibility mechanism (Chavan 1961; Mohanty 1964; Shrivastava and Shomwanshi 1974; Sujatha 1993) and insects, particularly bees, are the major agents of pollination (Ramachandran and Menon 1979). The self-incompatibility nature of niger complicates the production of selfed seed. At Holetta, 600 accessions were tested for their ability to produce selfed seed using muslin cloth bagging (Riley and Belayneh 1989). Twenty-two out of the 600 accessions produced approximately 1 g of selfed seed per plant, indicating that niger germplasm with some level of self-compatibility exists within the Ethiopian genepool.

For crossing of niger, the disk florets which are hermaphroditic are removed from the capitulum, after 1-3 days of opening and the female ray florets are dusted with pollen from the selected second parent (Mohanty 1964; Naik and Panda 1968; Teklewold, unpublished). Pollination after the third day does not result in any seed set. After dusting, the capitulum is covered with a bag for 1 week to exclude any foreign pollen. This procedure produces a good quantity of crossed seed.

2.3 Cytology

The species of the genus *Guizotia* are diploid with 2*n*=30 chromosomes (Richharia and Kalamkar 1938; Murthy 1990; Hiremath and Murthy 1992; Dagne 1994a). The karyotype and chromosome relationships of 10 Indian niger varieties were studied by Patel *et al.* (1983). Chromosome length varied from 26.66 to 63.05 µm. Individual chromosomes showed considerable variation in arm length ratios ranging from 0.48 to 1.00. On the basis of arm length ratios, chromosomes were classified as median, submedian and subterminal. The karyotype of *G. abyssinica*, *G. scabra* subsp. *schimperi* and *G. villosa* was symmetrical and that of *G. scabra* subsp. *scabra*, *G. zavattarii*, and *G. reptans* asymmetrical (Hiremath and Murthy 1992; Dagne 1994a). The karyotypes of *G. abyssinica* and *G. scabra* subsp. *schimperi* were identical with close similarity to *G. villosa*. *G. abyssinica* showed karyotype heterogeneity in terms of number of satellite chromosomes and median and submedian chromosomes (Dagne and Heneen 1992; Hiremath and Murthy 1992). The number of median chromosomes ranged from 18 to 26 and that of submedian chromosomes from 2 to 10.

Interspecific crosses between species within the genus *Guizotia* were studied by Dagne (1994b) and Murthy *et al.* (1993). Hybrid plants (F_1) were produced between crosses of *G. abyssinica* with *G. scabra* subsp. *schimperi*, *G. scabra* subsp. *scabra* and *G. villosa* in both directions (Dagne 1994a). Dagne also reported that in all crosses involving *G. abyssinica*, hybrid seed set was greater when *G. abyssinica* was used as a male. The F_1 plant from the *G. abyssinica* x *G. scabra* subsp. *schimperi* cross showed 15 bivalents in 95% of pollen mother cells, with 4% univalents and no multivalents (Dagne 1994a). The F_1 between *G. abyssinica* x *G. scabra* subsp. *scabra* showed 15 bivalents in 69% of pollen mother cells and univalents at metaphase I. He observed

15 bivalents in 89% of pollen mother cells from the cross *G. abyssinica* x *G. villosa*. The F_1 between *G. scabra* subsp. *scabra* x *G. villosa* showed 15 bivalents in 89% of cells, univalents and no multivalents. Pollen viability (stainability) of F_1 plants between *G. abyssinica* with *G. scabra* subsp. *schimperi*, *G. scabra* subsp. *scabra* and *G. villosa* was 81.5, 46.6 and 30.6% respectively. The F_1 plant from the cross between *G. scabra* subsp. *scabra* x *G. villosa* had 49.3% viable pollen. From these cytological investigations it can be concluded that the small genus *Guizotia* consists of closely related species.

3 Origin and centre of diversity

Baagøe (1974) describes the distribution of the genus *Guizotia* in Africa. The distribution of *Guizotia* species in Africa as presented in the distribution map by Hiremath and Murthy (1988), in contrast to that reported by Baagøe (1974), is incorrect. In Africa, *G. abyssinica* is largely found in the Ethiopian highlands, particularly west of the Rift Valley (Fig. 2). Niger is also found in some areas in Sudan, Uganda, Zaire, Tanzania, Malawi and Zimbabwe, and the West Indies, Nepal, Bangladesh, Bhutan and India (Weiss 1983).

Fig. 2. Geographic distribution of *Guizotia abyssinica* (reprinted from Baagøe 1974, with permission).

The genus *Guizotia* is native to tropical Africa (Baagøe 1974). *Guizotia villosa* is concentrated in the northern and southwestern highlands of Ethiopia. *Guizotia zavattarii* is endemic around Mount Mega in southern Ethiopia and the Huri hills in northern Kenya. *Guizotia arborescens* is endemic to the southwest of Ethiopia and Imantong mountain areas on the border between Sudan and Uganda. *Guizotia scabra* subsp. *scabra* is distributed from Ethiopia to Zimbabwe in the south and to the Nigerian highlands in the west, dissected by the Sudanese desert and Congo rainforest. *Guizotia reptans* is endemic to Mount Kenya, the Aaberdares and Mount Elgon region in East Africa and is the only taxon which is not reported from Ethiopia (Dagne 1994b). Baagøe (1974) raised four points about the origin of niger: first, the highest concentration of *Guizotia* species is in Ethiopia; second, *G. abyssinica* can also be collected from the natural habitat; third, the similarity of the distribution of niger with that of other cultivated crops, and fourth, the historical trade between Ethiopia and India. This would suggest that niger is not native to India and may have been taken from Ethiopia to India by traders.

It is believed to have been taken to India by Ethiopian immigrants, probably in the third millennium BC along with other crops such as finger millet (Dogget 1987). It is important to note that its wild relatives were not taken with it. According to a legend, an Ethiopian Queen occupied a vast territory of India in the remote past (Seegeler 1983), and made Ethiopians emigrate to India. Even today there are people in Jaferabad, Kathiawar who consider themselves of Ethiopian origin. The truth of this legend is not known.

India is the largest producer and exporter of niger (Chavan 1961). It is cultivated in Andra Pradesh, Madhya Pradesh, Orissa, Maharashtra, Bihar, Karnataka, Nagar Haveli and West Bengal states of India of which Madhya Pradesh is the largest. During 1938 to 1948 India exported up to 6968 tonnes of niger annually to western Europe, eastern Europe and North America. Chavan (1961) also indicated that niger is important in inter-state trade.

Niger was also tested in Russia, Germany, Switzerland, France and Czechoslovakia during the 19th century (Weiss 1983). In Russia it was tested in 1926 following Vavilov's visit to Ethiopia but the low seed yield made it unprofitable.

4 Properties

The chemical composition of niger is indicated in Tables 1 and 2. The oil content of niger seed varied from 30 to 50% (Seegeler 1983). Niger meal remaining after the extraction of oil contains approximately 30% protein and 23% crude fibre. In general the Ethiopian niger meal contains less protein and more crude fibre than the niger meal grown in India (Chavan 1961; Seegeler 1983). The oil, protein and crude fibre contents of niger are affected by the hull thickness and thick-hulled seeds tend to have less oil and protein and more crude fibre.

Niger oil has a fatty acid composition typical for seed oils of the Compositae plant family (e.g. safflower and sunflower) with linoleic acid being the dominant fatty acid. The linoleic acid content of niger oil was approximately 55% in seed grown in India (Nasirullah *et al.* 1982) and 75% in seed grown in Ethiopia (Seegeler 1983; Getinet and Teklewold 1995; Table 1).

Table 1. Ranges of fatty acid composition (%) of Indian and Ethiopian niger oil.

Fatty acid	India[1]	India[2]		Ethiopia[3]	
	Range	Range	Mean	Range	Mean
Palmitic	8.2-8.7	6.0-9.4	8.2	7.6-8.7	8.2
Stearic	7.1-8.7	5.0-7.5	6.7	5.6-7.5	6.5
Oleic	25.1-28.9	13.4-39.3	28.4	4.8-8.3	6.5
Linoleic	51.6-58.4	45.4-65.8	56.0	74.8-79.1	76.6
Linolenic	–	–	–	0.0-0.9	0.6
Arachidic	0.4-0.6	0.2-1.0	0.6	0.4-0.8	0.5
Behenic	–	–	–	0.4-1.5	0.7
Number of lines	10	5		241	

[1] Nasirullah *et al.* 1982.
[2] Nagaraj 1990.
[3] Getinet and Teklewold 1995.

Dutta *et al.* (1994) studied the lipid composition of three released and three local cultivars of Ethiopian niger. Most of the total lipid was triacylglycerides and polar lipids accounted for 0.7-0.8% of the total lipid content. The amount of total tocopherol was 720-935 µg / g oil of which approximately 90% was α-tocopherol, 3-5% was γ-tocopherol and approximately 1% was ß-tocopherol. As α-tocopherol is an anti-oxidant, high levels of α-tocopherol could improve stability of niger oil. The total sterol consists of ß-sitosterol (38-43%), campesterol (~14%), stigmasterol (~14%), Δ5 avenasterol (5-7%) and Δ7 avenasterol (~4%).

The amino acid composition of niger protein was deficient in tryptophan (Table 2). The protein quality of Ethiopian niger was evaluated using chemical score and essential amino acid requirement score (Haile 1972). Using chemical score and whole

egg protein as a standard, methionine, lysine, cystine, isoleucine and leucine were considered as limiting amino acids. When essential amino acids were used as a reference, lysine was the limiting amino acid. A lipoprotein concentrate was isolated from niger seed using hot water / ethanol sodium chloride solution extraction (Eklund 1971a, 1971b). The lipoprotein contained 4% moisture, 12% ash, 46% protein, 20% fat, 7% crude fibre and 11% soluble carbohydrate. From the amino acid composition Eklund (1971a, 1971b) calculated a nitrogen to protein conversion ratio of 5.9. The energy content of the niger lipoprotein concentrate was 400 kcal / 100 g.

Table 2. Amino acid composition of whole niger flour, niger seed lipid concentrate, high temperature soluble (HTS) fraction concentrate, Indian niger cake, and Ethiopian niger meal.

Amino acid	Whole niger seed flour[1]	Niger seed lipid-protein concentrate[1]	HTS fraction[1]	Niger cake[2]	Niger meal (% of protein)[3]
Isoleucine	307	341	201	349	4.66
Leucine	388	505	308	589	6.99
Lysine	294	279	199	335	4.74
Methionine	109	125	216	148	2.06
Cystine	177	97	537	138	1.40
Phenylalanine	327	385	130	378	4.80
Tyrosine	185	225	138	197	–
Threonine	237	263	112	278	3.73
Tryptophan	54	85	65	–	–
Valine	362	397	273	428	5.76
Arginine	621	627	734	889	9.36
Histidine	162	192	97	190	–
Alanine	281	290	132	335	4.06
Aspartic acid	619	673	427	823	9.49
Glycine	375	357	295	502	5.53
Proline	262	270	222	354	3.86
Serine	347	390	390	456	6.19

[1] Eklund (1974), samples from Ethiopia (mg/g N).
[2] Mohan *et al.* (1983), based on samples from India (mg/g N).
[3] Haile (1972) based on samples from Ethiopia (% of protein).

5 Uses

The niger plant is consumed by sheep but not by cattle, to which only niger silage can be fed (Chavan 1961). Niger is also used as a green manure for increasing soil organic matter.

Niger seed is used as a human food. The seed is warmed in a kettle over an open fire, crushed with a pestle in a mortar and then mixed with crushed pulse seeds to prepare 'wot' in Ethiopia (Seegeler 1983). 'Chibto' and 'litlit' are prepared from crushed niger seed mixed with roasted cereals, and is the preferred food for young boys. In Ethiopia, niger is mainly cultivated for its edible oil. The pale yellow oil of niger seed has a nutty taste and a pleasant odour. The traditional method for extraction of oil from niger in Ethiopia is through a combination of warming, grinding and mixing with hot water followed by centrifugation in an 'ensera' (a container made of clay). After an hour of centrifugation by hand on a smooth soft surface the pale yellow oil settles over the meal. Niger is also crushed in small cottage expellers and large oil mills. The small, electrically powered cottage expellers are manufactured as different brands with varying capacities in Addis Abeba and Nazreth in Ethiopia. The meal remaining after extraction of the oil using Ethiopian expellers contains 6-12% oil depending on the expeller. Many expellers are found in the provinces of Arsi, Bale, Gojam, Gonder, Shoa and Wellega of Ethiopia.

In India the oil is extracted by bullock-powered local 'ghanis' and rotary mills (cottage expellers) or in mechanized expellers and hydraulic presses in large industrial areas. The niger oil is used for cooking, lighting, anointing, painting and cleaning of machinery (Chavan 1961; Patil and Joshi 1978; Patil and Patil 1981). Niger oil also is a substitute for sesame oil for pharmaceutical purposes and can be used for soap-making.

The meal remaining after the oil extraction contains about 24% protein and 24% crude fibre (Seegeler 1983). Niger meal from India contains higher protein (30%) and lower crude fibre (17%) levels than meal from Ethiopia. Niger cake replacing linseed cake at levels of 0, 50 and 100% was fed as a nitrogen supplement for growing calves (Singh *et al*. 1983). No significant differences in growth rate, feed efficiency and dry matter digestibility were noticed between niger and linseed cake and it was concluded that niger cake can replace linseed cake in calf rations (Singh *et al.* 1983). Similarly, four levels of niger cake (0, 50, 75 and 100%) replacing groundnut cake were fed to large White Yorkshire pigs for 9 weeks (Roychoudhury and Mandal 1984). There was no significant difference in weight gain between rations containing either niger or groundnut cake. Niger lipoprotein concentrate was fed to growing rats as a sole protein source for 90 days and no negative effects on growth rate were observed (Eklund 1971b).

A niger-based agar medium can be used to distinguish *Cryptococcus neoformans* (Sant) Vaill, a fungus that causes a serious brain ailment, from other fungi (Paliwal and Randhawa 1978). There are reports that niger oil is used for birth control and for the treatment of syphilis (Belayneh 1991). Niger sprouts mixed with garlic and 'tej' are used to treat coughs.

6 Genetic resources

6.1 Collecting

The niger germplasm in India was collected after 1973 from the states of Madhya Pradesh, Orissa, Bihar, Andhra Pradesh and Karnataka which represent the major niger-growing states. The collections represent landraces and selected breeding lines. Almost all the material except five exotic lines from Ethiopia is indigenous.

In 1981 the Ethiopian government established oilseed research projects in close collaboration with the Plant Genetic Resource Centre / Ethiopia (PGRC / E), now named the Biodiversity Institute. Oilseed-collecting missions were jointly carried out by oilseed breeders and PGRC / E staff in major oilseed-growing regions in Ethiopia, particularly in the Central highlands (Plant Genetic Resource Centre / Ethiopia 1986; Abebe 1991). During November and December in 1981-83, collecting missions for niger, linseed and oilseed Brassicas were carried out in Wello, Wellega, Gojam, Gonder and Shoa. The less-secure areas of northern Ethiopia, which are now known as Eritrea and Tigre, were included as much as possible. The standard random sampling procedure and PGRC / E collection sheet was used. PGRC / E retained the active collection sample and the oilseeds project benefited greatly from these collections in their breeding programme.

The Ethiopian germplasm of niger was mostly collected from Gojam, Gonder, Shewa, Wellega and Wello regions (Fig. 3). The region from Dejen to Bahar Dar in Gojam and the Fogera plain in Gonder are the major niger-growing areas. In Wellega, niger is the only oilseed crop known in that province. Niger was found growing from altitudes of <1000 to almost 3000 m asl. Most of the accessions were collected within elevations of 1500 to 2500 m (Figs. 4 and 5).

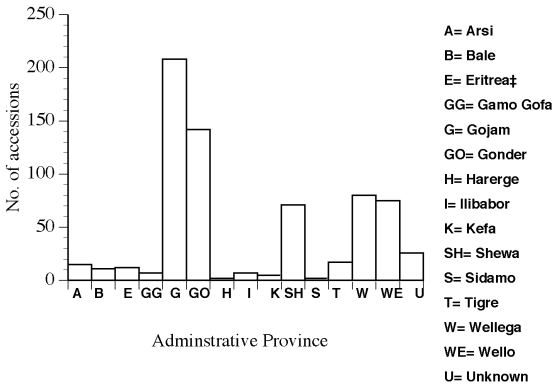

Fig. 3. Distribution by administrative regions in the Ethiopian niger collection.

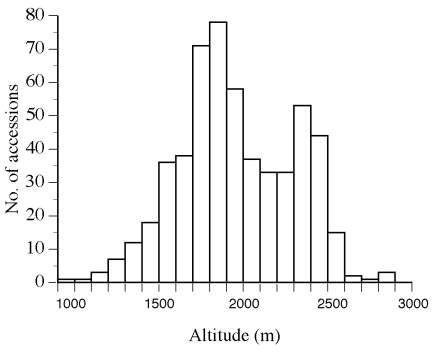

Fig. 4. Frequency of occurrence of niger by altitude in the Ethiopian collection.

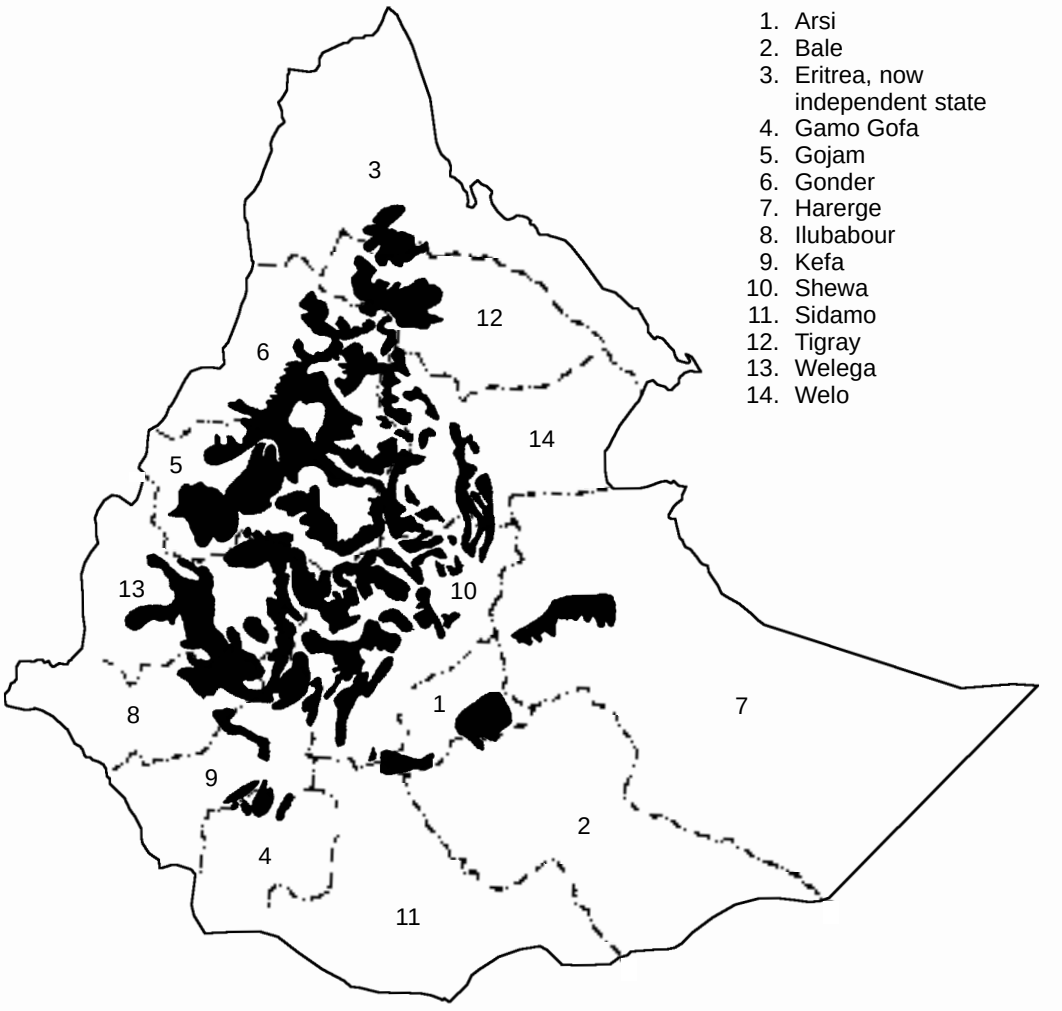

Fig. 5. Niger-growing areas in Ethiopia and Eritrea (from Belayneh and Getinet 1989, unpublished monograph).

6.2 Characterization and evaluation

Ethiopia

As one of the objectives of the programme, local accessions of niger were characterized during the main season of June to December at the Holetta Research Centre. Holetta is situated at 2300 m asl, 50 km northwest of Addis Abeba. The centre has both light red and heavy clay soils. In 1982 and 1983, 243 and 127 accessions, respectively, were characterized for 29 descriptors. Experimental plots were 6 m long, with two rows spaced at 30 cm. Fertilizer (both N and P_2O_5) was applied at the rate of 23 kg / ha at the time of planting. Plants in each plot were isolated for sib pollination with large muslin bags for the basic collection. Plots were harvested at 50%

capitulum moisture and stacked to dry in the sun before threshing. In 1992, 241 accessions and the cultivar Fogera-1 were planted at the Ghinchi research farm 90 km west of Addis Abeba. Agronomic traits such as maturity duration, disease reaction and plant height were recorded in the field. After harvest the oil content of the seed was determined using wide line Magnetic Resonance Spectroscopy. Fatty acid composition of the oil was determined using gas chromatography according to the method of Thies (1971).

The accessions evaluated in 1982 and 1983 showed wide variability for morphological and agronomic traits (Table 3). Figure 6 shows the results of various characters evaluated in 1982, 1983 and 1992. The 236 accessions evaluated for days to 50% flowering in 1982 fell into one major flowering group (Fig. 6a), whereas the 127 accessions characterized in 1983 fell into three flowering groups: 75-90 days (early group), 90-105 days (medium group) and 105-120 days (late group) (Fig. 6b). The 241 accessions evaluated in 1992 at Ghinchi showed continuous distribution (Fig. 6c).

The distribution of days to 50% maturity followed a similar pattern to that of 50% flowering. In 1983, the accessions fell into three maturity groups (Fig. 6b). The early maturing group of 22 accessions matured in 120-130 days, and the 60 accessions of the midmaturity group matured in 140-150 days. The third group of 45 accessions were late maturing and required 175-185 days to full maturity. Similarly, the accessions tested in 1992 fell into two maturity groups. The first group of 119 accessions matured within 130-150 days and the second group of 122 accessions matured within 150-170 days (Fig. 6c).

The results of the investigations on maturity groups carried out in 1983 are in agreement with previous classifications of niger into three maturity groups. These are referred to as 'abat' (medium to late maturity), 'bungne' (early maturing) and 'mesno' (late but frost tolerant). 'Abat' niger is grown within altitudes of 1500 to 2500 m on heavy black clay waterlogged soils with adequate rainfall. It is grown in the mid- and high-altitude regions of Gojam, Gonder, Shoa and Wellega and probably also in Arsi and Bale. On the other hand, 'bungne' niger is grown in lowland and highland areas with low rainfall on shallow soils. It is grown from the end of June to October. 'Bungne' in Amharic means light and easily blown away by wind while sifting. Accessions from Abay Gorge, the lowlands of Wello, and Tigre (regardless of altitude) were all of the 'bungne' type. 'Abat' niger is higher yielding and has a longer growing season than 'bungne' and 'mesno' niger, and the oil content of 'abat' types is also higher than that of 'bungne' types.

Plant height of niger accessions evaluated in 1982 showed a bimodal distribution (Fig. 6a). The short-stature group consisted of 74 accessions varying in height from 70 to 130 cm with a mean of 104 cm; the taller accessions of the second group of 162 accessions varied in height from 131 to 220 cm with a mean of 162 cm (Fig. 6a). Plant height evaluations in 1983 produced similar results. However, the plant height of accessions characterized at Holetta in 1983 and at Ghinchi in 1992 were normally distributed (Figs. 6b and 6c). Plants were shorter in 1992, probably because no fertilizer was applied.

Table 3. Frequency of leaf and flower characteristics of 236 niger accessions (1982) and 127 accessions (1983) characterized at Holetta Research Centre Ethiopia.

Trait	Characteristic	Number of accessions	
		1982	1983
Flower size	1. very small	0	0
	2. small	4	6
	3. medium	105	60
	4. large	77	60
	5. very large	50	1
Head size	1. very small	0	0
	2. small	13	0
	3. medium	178	52
	4. large	26	71
	5. very large	1	4
Synchrony of maturity	1. no difference	36	0
	2. little difference	148	0
	3. some difference	45	25
	4. great difference	7	72
	5. very different	0	30
Leaf colour	1. very light green	2	0
	2. light green	45	0
	3. green	100	73
	4. deep green	72	54
	5. dark green	17	0
Leaf size	1. very small	6	0
	2. small	57	34
	3. medium	85	71
	4. large	67	22
	5. very large	21	0
Leaf width	1. very narrow	4	0
	2. narrow	43	0
	3. medium	76	25
	4. broad	93	72
	5. very broad	20	30
Angle of branching	1.very erect	1	0
	2. erect	65	0
	3.horizontal	105	17
	4. nearly horizontal	65	61
	5. hanging	0	49

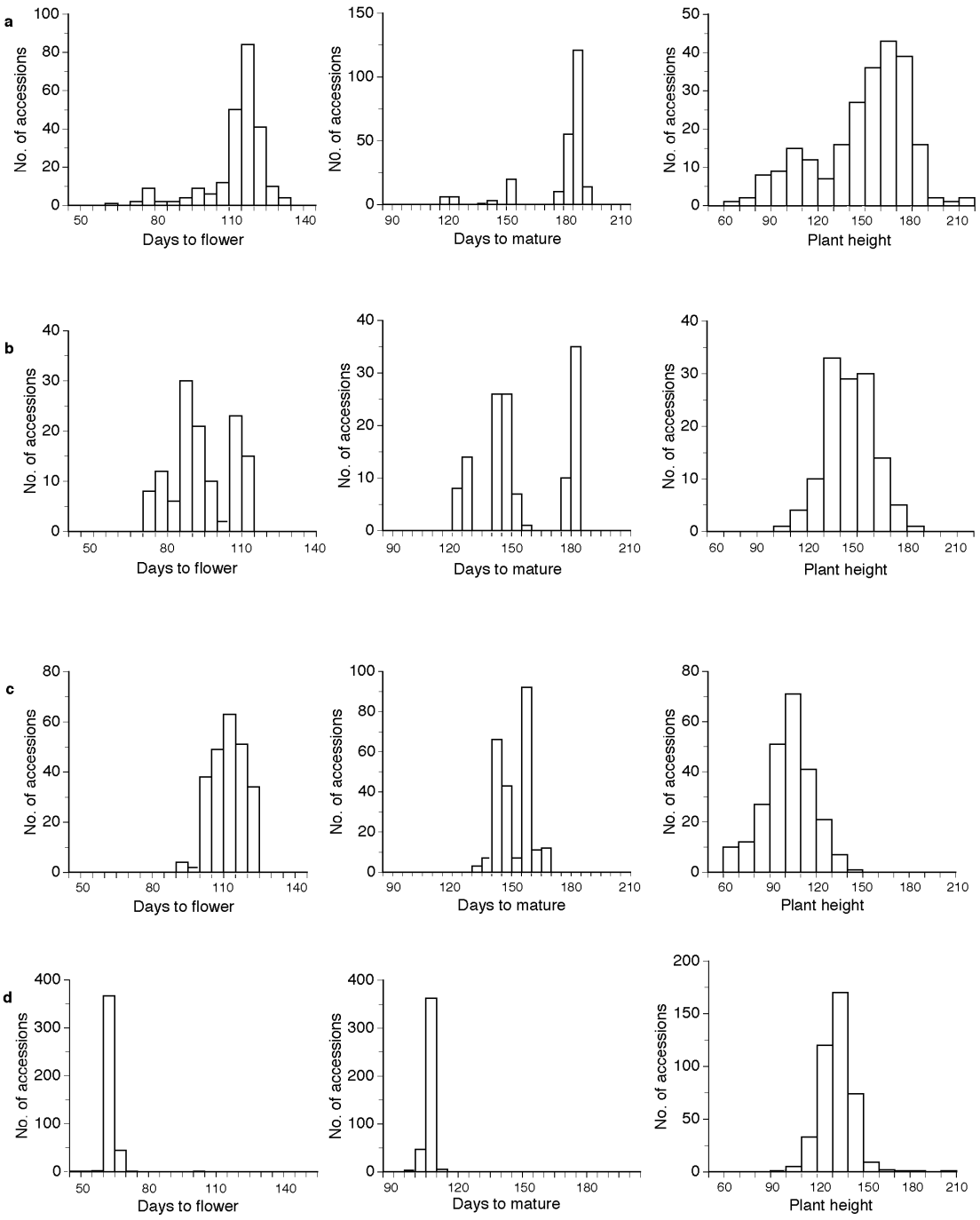

Fig. 6. Frequency distribution for days to 50% flowering, days to maturity and plant height of accessions evaluated at Holetta, Ethiopia in (a) 1982 and (b) 1983, (c) Ghinchi, Ethiopia in 1992, and (d) at Jabalpur, India.

Source: Institute of Agricultural Research (1966-1994).

The niger germplasm studied in 1983 included accessions collected from the lowlands of Wello, northern Shoa and Abay Gorge. Some of the germplasm tested originated from mid- and highland areas. The 1982 and 1983 germplasm characterization had no accessions in common. The characterization / evaluation at Ghinchi in 1992 included 57 accessions characterized at Holetta in 1982 and 32 of those characterized in 1983. The rest were collected since 1983. Ghinchi is situated at a lower altitude than Holetta. Therefore, the different frequency distributions result from different sample composition and environmental effects.

The fungal diseases of leaf spot (*Alternaria* sp.), stem and leaf blight (*Alternaria* sp.) and Sclerotinia wilt were observed on niger. Leaf spot affects the leaves and has the potential to reduce the photosynthetic leaf area of the plant. However, the niger

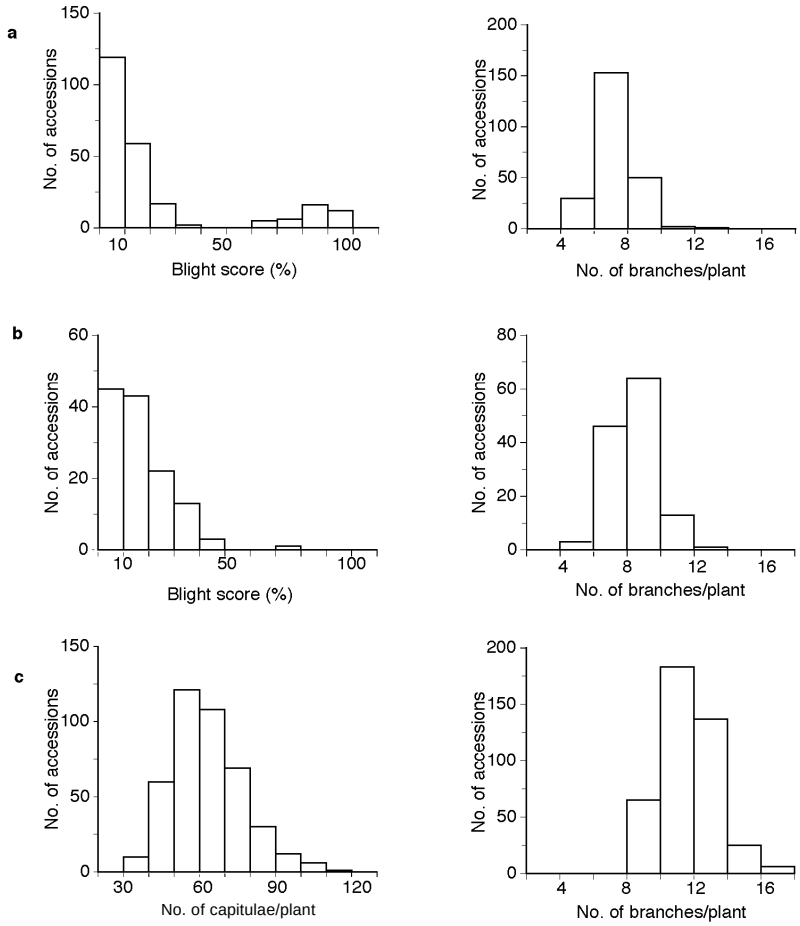

Fig. 7. Frequency distribution for niger blight, number of capitulae per plant and number of primary branches per plant of accessions characterized/evaluated at Holetta, Ethiopia in (a) 1982 and (b) 1983, (c) at Jabalpur, India.

accessions tested probably had more leaves than the plant needed to nourish the flower sinks (Yitbarek and Truwork 1992). Niger stem and leaf blight is a recent record and is very devastating for early maturing accessions, particularly during wet seasons. The mid- and late-maturing 'abat' accessions had probably escaped the disease onset. The disease affects the leaves, branches and flower buds of early accessions and causes dieback. The mode of transmission of the disease is not known but seed and stubble are suspected to be the major sources of the inoculum. The early and late blight score distributions were similar and hence only the late score is shown (Figs. 7a and 7b). The accessions characterized in 1982 fell into two disease reaction classes. The first group of 197 accessions had low leaf and stem blight scores ranging from <10 to 30% with the majority of accessions having scores of <10%. The second group of 39 accession was more susceptible to blight. The leaf

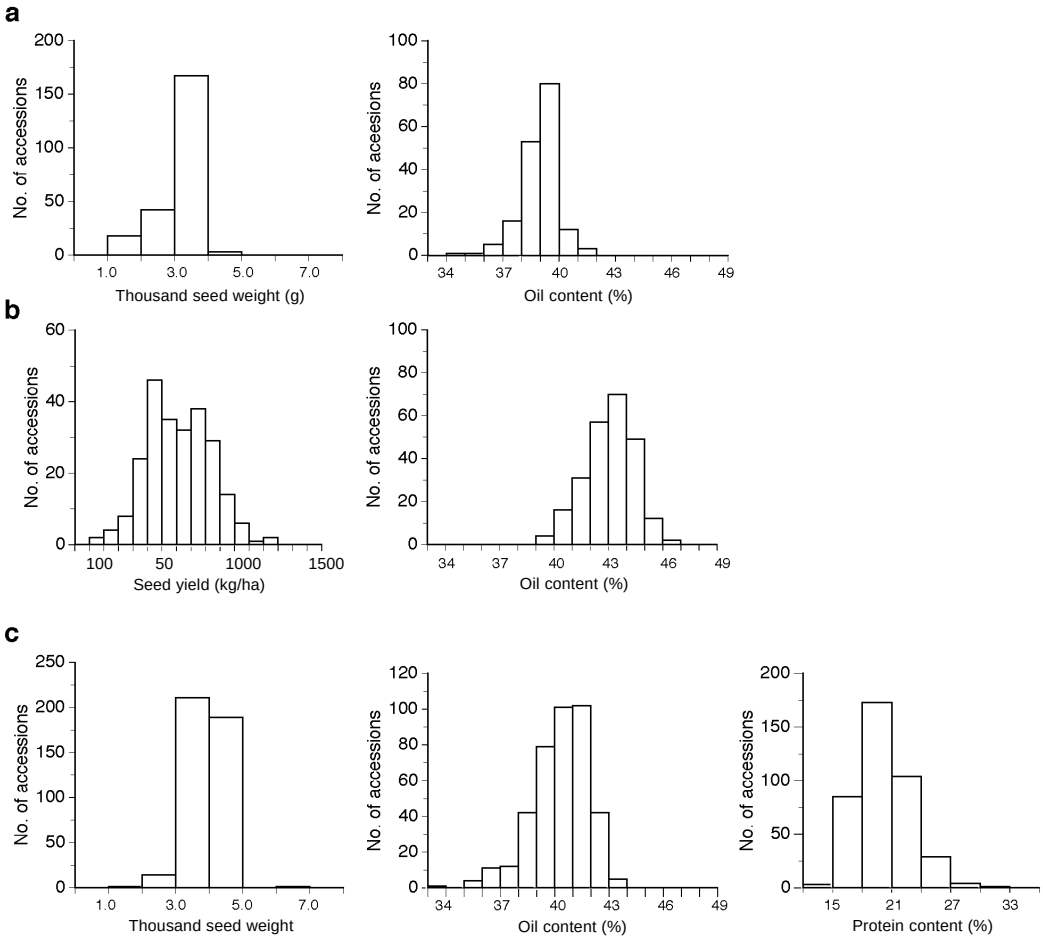

Fig. 8. Frequency distribution for 1000-seed weight, seed yield, oil and protein contents of accessions characterized/evaluated at (a) Holetta, Ethiopia in 1982, (b) Ghinchi, Ethiopia, and (c) at Jabalpur, India.

and stem blight scores of niger accessions characterized in 1983 were low and the distribution was skewed towards lower disease scores. Obviously, a more severe disease score was observed during the wet season of 1982 than in 1983 (rainfall data not shown). The correlation between stem and leaf blight score and days to maturity was –0.78*** in 1982 and -0.67*** in 1983.

The number of branches / plant was narrowly distributed in both 1982 and 1983 (Fig. 7). The seed yield of the accessions evaluated at Ghinchi ranged from 100 to 1400 kg / ha (Fig. 8b).

The oil content of niger accessions tested at Holetta in 1982 ranged from 27.2 to 40.4% with a mean of 38.9% of moisture-free seed, whereas the oil content of the 241 niger accessions tested at Ghinchi in 1992 varied from 39.6 to 47.0% (Fig. 8) (Getinet and Teklewold 1995). The variability in oil content of niger seed was significant. This variability could be utilized for the breeding of high oil content niger cultivars. Increases in oil content of at least 5% or more could easily be achieved through selections for high oil content within the existing germplasm, thereby significantly increasing the value of the crop. Oil content is affected by growing altitude and / or temperature, which would make selection for oil content difficult (Westphal and Kelber 1973). Oil content of niger is also affected by the hull thickness of seeds (Getinet and Belayneh 1989). The hull thickness of 25 accessions of niger grown at Holetta ranged from 13.5 to 36.6% with a mean of 25.6% of the total seed weight. Seeds of 'abat' seeds contained less hull and higher oil in the seed and, higher protein and less crude fibre in the meal.

The fatty acid composition of oil from the accessions characterized at Ghinchi was analysed using gas chromatography. Linoleic acid ranged from 74.8 to 79.1% with a mean of 76.6% (Table 1). Contents of other fatty acids were palmitic acid (7.8-8.7%), stearic acid (5.8-7.4%) and oleic acid (trace amounts, 0.5-1.5%).

Genet (1994) studied a random sample of 179 niger accessions, representing collections from the entire country, at Adet, for days to 50% flowering, days to maturity, leaf colour, leaf width, stem hairiness, stem colour, angle of branching and plant height. He arbitrarily divided the country into four regions consisting of provinces. These were the northern region (Tigre, Wello and Gonder), the western region (Gojam, Gonder, Wellega and Illubabor) the southern region (Gamo Gofa, Sidamo and Bale) and the central region (Shoa, Arisi and Hararghe). Genet (1994) calculated phenotypic diversity indexes according to Shannon-Weaver which indicates the diversity of characteristics of a species across geographical regions (Jain *et al.* 1975). The phenotypic diversity index (H') of niger accessions was 0.61 for western, 0.41 for eastern and central and 0.51 for northern regions. Province-wise, the phenotypic diversity (H') was 0.58 for Wellega, 0.54 for Shoa and Gojam, and 0.52 for accessions from Gonder. The phenotypic diversity value for the entire nation was 0.55. Based on the limited number of 179 accessions evaluated, the centre of diversity for niger appeared to be in Wellega, Gojam, Shoa and Gonder. He concluded that further niger germplasm collecting should be concentrated in these provinces.

India

The variability of niger in India has been reported by several authors. Chavan (1961), Nema and Singh (1965), Nayakar (1976) and Mathur and Gupta (1993) recorded observations on the number of florets, duration of flowering, etc.

Chavan (1961) reported the number of florets per capitulum, duration of flowering, and capituluae per plant in niger populations (Table 4). The number of disk florets varied from 25 to 60 with a mean of 43. The capitulae per plant ranged from 34 to 170 with a mean of 92 and the duration of flowering was only 15 days for 25 populations. Nema and Singh (1965) studied niger accessions collected from Madhya Pradesh, Maharashtra and Gujarat for seven quantitative traits. Nayakar (1976) characterized 18 niger accessions collected at Karnataka, Gujarat and Maharashtra at Raichaur in Karnataka, for days to flowering, plant height, number of primary branches, number of capitulae per plant, 1000-seed weight, and seed yield per plant. Mathur and Gupta (1993) characterized 35 niger accessions which were collected based on geographical representation for 18 traits in Rajasthan.

Table 4. Observations on number of florets, duration of flowering and number of capitulae per plant in Indian niger populations.

Trait	Range	Mean	SD	No. of populations
No. of disk florets/capitulum	25-60	43	0.96	50
Duration of flowering (days)	15-30	22	0.97	25
No. of capitula/plant	34-170	93	6.89	25

The most comprehensive evaluation of niger in India was carried out by S.M. Sharma, G. Nagaraj and R. Balakrishnan, where a total of 417 accessions (lines) was evaluated at Jabalpur during July to October of 1991 (Sharma *et al.* 1994). Plot size was single row, 3 m long with 30-cm spacing between rows and 10 cm between plants in two replications. Five plants were randomly selected, tagged and the following data were recorded: days to 50% flowering, days to 50% maturity, plant height, number of capitulae per plant, number of branches per plant, seed yield per plant, 1000-seed weight, oil content and protein content. Oil content was determined using Nuclear Magnetic Resonance Spectrometer and protein content was determined using the Biuret method.

The results of the Indian characterizations / evaluations are summarized in Table 5. Several of the characters measured by Sharma *et al.* (1994) can be compared with the Ethiopian evaluations (Figs. 6 to 8). Differences between Ethiopian and Indian niger will be discussed in **section 6.3**. The days to 50% flowering of the materials studied by Nayakar (1976) ranged from 37 to 82 days with a mean of 41 days. The days to 50% flowering of the 35 accessions studied by Mathur and Gupta in 1993

ranged from 53 to 97 days with a mean of 72 days and the 417 lines characterized at Jabalpur (Sharma *et al*. 1994) had a range of 40-70 days with a mean of 62 days. The days to maturity of the 417 lines characterized in 1994 ranged from 90 to 111 days with a mean of 106 days. The plant height ranged from 45.5 to 75.5 cm in the material studied in 1965, 42.3-95.8 cm for accessions characterized in 1976, 62-116 cm for 35 accessions characterized in 1993 and 100-197 cm for the 417 lines studied at Jabalpur in 1994. All studies were carried out under optimum conditions, and therefore the observed variation indicated the wide variability existing for plant height.

Table 5. Range, mean and standard deviation of eight quantitative traits of Indian niger.

Trait	Range, mean, SD	Nema and Singh (1965)	Nayakar (1976)	Mathur and Gupta (1993)	Sharma *et al.* (1994)
Days to 50% flowering	range	–	37-82	53-97	40-70
	mean	–	41	72	62
	SD	–	0.6	–	1.9
Plant height (cm)	range	45.5-75.5	42.3-95.8	62.3-116.0	100-197
	mean	60.9	52.3	90.3	142
	SD	8.5	2.2	–	10.2
No. of primary branches/plant	range	3-12	6-18	9-19	3-17
	mean	7	9	14	11
	SD	4	1	–	1.7
No. of capitulae/ plant	range	7-42	17-64	–	30-110
	mean	23	28	–	62.7
	SD	31	2.9	–	14
No. of seeds/ capitulum	range	13-47	–	9-24	–
	mean	31	–	17	–
	SD	10.9	–	–	–
1000-seed weight (g)	range	2.4-5.6	0.8-4.4	2.5-3.8	1.6-6.0
	mean	3.5	2.3	3.3	3.8
	SD	0.9	0.5	–	0.5
Yield/plant (g)	range	0.5-4.1	0.8-4.4	–	0.7-7.3
	mean	1.8	2.3	–	2.6
	SD	2.1	0.5	–	0.9
Oil content (% dry seed)	range	39.0-47.2	–	28.8-43.3	30.0-43.2*
	mean	42.3	–	34.7	40.2
	SD	1.2	–	–	1.6
No. of accessions tested		ND**	18	35	417

* No. of samples = 399.
** ND = no data provided.

The range for the number of branches per plant and seeds per capitulum was

similar for all the studies (Table 5). The 1000-seed weight showed the highest variation in 1994, ranging from 1.6 to 6.0 g with a mean of 3.8 g.

The mean oil content was 42.3% in materials studied in 1965, 34.7% in 1993 and 40.2% in 1994 (Table 5). The protein content of the 399 lines characterized in 1994 ranged from 10.0 to 30.0% with a mean of 21.0%; however, this was lower than what was reported by Seegeler (1983).

Sharma *et al.* (1994) presented correlation coefficients among 10 quantitative traits recorded from 399 lines. As expected, days to flowering and maturity were positively correlated (Table 6). Seed yield per plant was positively and significantly correlated with plant height, number of branches per plant and number of capitulae per plant. The number of branches per plant was positively correlated with days to flowering, days to maturity and plant height, indicating that tall plants had more branches per plant, more capitulae per plant and mature late. Oil content was not strongly correlated with any of the traits. This was in contrast to the Ethiopian niger where oil content was positively correlated with days to maturity and strongly and negatively correlated with protein content.

Table 6. Correlations among ten quantitative characters (N= 399) (Sharma *et al.* 1994).

	1	2	3	4	5	6	7	8	9
1									
2	–0.0490								
3	–0.0654	0.4633							
4	0.2680	0.2242	0.1931						
5	0.2390	0.2340	0.2689	0.2583					
6	0.3321	0.1456	0.1139	0.2478	0.5442				
7	–0.0067	–0.0964	–0.1724	–0.0890	–0.1849	–0.1784			
8	0.0346	0.0186	–0.0021	0.0548	0.0338	0.0923	–0.0922		
9	0.0144	–0.1075	–0.0908	–0.0032	0.0016	0.0321	0.0483	0.0811	
10	–0.1233	0.0832	0.1390	0.0631	0.0251	–0.0201	–0.0097	–0.0497	–0.0695

1 = seed yield/plant (g), 2 = days to 50% flowering, 3 = days to maturity, 4 = plant height (cm), 5 = no. of branches/plant, 6 = no. of capitulae/plant, 7 = 1000-seed weight (g), 8 = oil content (%) dry seed weight, 9 = protein content (%) defatted dry meal, 10 = sugars (%) defatted dry meal.

The fatty acid composition of the oil was reported by Nagaraj (1990) and Nasirullah *et al.* (1982). Linoleic and oleic acids were the two major fatty acids. Linoleic acid ranged from 45.4 to 65.8 and oleic acid 13.4 to 39.3% (Table 1). The palmitic acid values ranged from 8.2 to 9.4% and stearic acid ranged from 5.0 to 7.5%. The range in fatty acid composition shows that there exits a variability for fatty acid modification. However, the Indian niger oil was lower in linoleic and

higher in oleic acid than the Ethiopian (Table 1).

In India, more variability in niger occurs in central and eastern peninsular tracts. Some materials selected from Orissa possess bold seeds, compared with the medium seed types of Karnataka, which have a higher oil content (e.g. 40-43%; Mehra and Arora 1982). Cold-adaptable germplasm also occurs in the eastern hills, especially in Sikkim. Drought-tolerant germplasm occurs in central peninsular regions of India.

6.3 Differences between Ethiopian and Indian niger

The Ethiopian and Indian genepools differ in many respects as a result of geographical isolation. The Ethiopian niger has a tall plant, is later maturing and is a higher yielder. The Indian niger is earlier to flower and mature, and has a higher seed weight. The latest maturing Indian niger is earlier to mature than the earliest Ethiopian material (Fig. 6). Both genepools are similar in numbers of branches per plant and oil content (Figs. 7 and 8), but the fatty acid composition of the Ethiopian and Indian niger is quite different. The Ethiopian niger oil contains about 20% higher linoleic and 20% lower oleic acids than the Indian niger oil (Table 1). Although this characterization is based on the material grown in the respective regions, this was also the case when a limited number of lines were grown together in Ethiopia (Riley and Belayneh 1989).

6.4 Conservation and documentation

The Biodiversity Institute (formerly known as Plant Genetic Resources Centre / Ethiopia) and the Indian National Bureau of Plant Genetic Resources hold most of the niger germplasm (Table 7).

Table 7. Niger accessions conserved in genebanks.

Country[1]	No. of accessions	Passport data[2]	Storage[3]	Sample availability[4]
Bangladesh	2	–	M	–
Germany	4	A	L;M	F
Ethiopia	1071	P	L;M	F
India[5]	1528	A	–	–
Nepal	20	–	M	–
USA	15	A	M	F
South Africa	1	A	S;F	F

[1] For full addresses of institutions, see Appendix III.
[2] Passport data: A = available, P = partly available.
[3] Storage: S = short term, M = medium term, L = Long term, F = field collection.
[4] Sample availability: F = freely available.
[5] At various institutions, see Appendix III.
– No information available.
Sources: FAO 1995; PGRC/E 1995; Sharma, pers. comm..

The Biodiversity Institute holds 729 accessions with full passport descriptions. An additional 342 accessions were donated to the Biodiversity Institute from National Institutions, mainly the Institute of Agricultural Research. These accessions have been evaluated in the field but lack full passport data. The collection, characterization and seed-processing data are stored in desktop computers at the Biodiversity Institute. The Ethiopian niger collection is conserved *ex situ*, sealed in moisture-proof aluminium foil envelopes. Once an accession is collected from the field, a sample is given a registration number. The sample is fumigated with phosphine for 72 hours, then the amount of seed and the seed weight are recorded (Feyissa 1991). If the sample has 8000 seeds or more then it is sufficient for long term storage. Accessions with less than 8000 seeds are stored temporarily, at –4°C and 35% relative humidity, in paper bags. Seeds are dried to a 3-5% moisture level at 18-20°C and at 18% relative humidity prior to storage.

In India, the National Bureau of Plant Genetic Resources, New Delhi has developed facilities for conservation of germplasm. The niger base collection is being maintained at –20°C. Accessions are kept in laminated aluminium packets after viability testing and reduction of the moisture content of the seed to 4-5%. Apart from long-term storage, medium-term storage at 4°C is also used. The working collections which are regularly used by researchers are maintained by the project Coordination Centre at Jabalpur and are regularly regenerated to maintain viable seed stocks. *In vitro* and *in situ* conservation are not practised for niger. The germplasm in India at different research stations has been maintained by sibbing, that is bagging a group of plants to avoid intercrossing among accessions. The data on the genetic variability of the collections have been used in crop improvement programmes. A computerized database using Germplasm Resource Information System (GRINS) was done at the Directorate of Oilseeds, Research, Hyderabad. The total number of collections may include duplicates, where collections in part have been sent to different stations and are now maintained by them.

Niger has orthodox seed storage behaviour and, when properly dried, can be stored for many years without losing its viability (Hong *et al.* 1996). The method of on-farm conservation could be applied to niger. In Ethiopia at present, the on-farm conservation programme is only practised for crops with high genetic erosion such as durum wheat and barley. The replacement of local landraces by improved varieties in the farmers' fields is not widespread and therefore on-farm conservation of niger is not urgent (Zewdie 1995, pers. comm.).

7 Breeding

Niger production in Ethiopia is mainly based on local landrace populations. Four improved varieties – Sendafa, Fogera-1, Esete-1 and Kuyu – were released by the Institute of Agricultural Research, Holetta Research Centre, Addis Abeba (Table 8). Seed of these varieties was distributed to farmers through research and extension workers. In India, the niger breeding programme and seed production is much stronger than in Ethiopia. There are 11 improved varieties of niger of which N-5 was released in 1934 (Joshi 1990) (Table 9). Yields of niger are much higher in Ethiopia than in India.

Table 8. Agronomic characteristics of niger varieties in Ethiopia.

Variety	Maturity (days)	Height (cm)	Yield (kg/ha)	Oil (%)
Sendafa	145	133	780	40
Fogera-1	146	138	820	41
Esete-1	146	139	830	39
Kuyu	138	131	1060	41

Source: IAR 1966-94.

Table 9. Characteristics and adaptability and recommended niger varieties in India.

Variety	Maturity (days)	Yield (kg/ha)	Oil (%)	Recommended state
Ootacamund	110	500	43	Madhya Pradesh, Bihar
N-5	95-110	450	40	Bihar, Madhya Pradesh
IGP-76	105	470	40	Karnataka, Maharashtra, Orissa, West Bengal, Gujarat, Rajasthan
No. 12-3	110	450	40	Maharashtra
No. 71	95	475	42	Andhra Pradesh, Karnataka, Tamil Nadu, North-Eastern Hill region
Gaudaguda	95	570	39	Andhra Pradesh
Phulbanil	95-100	400	40	Orissa
RCR-317	90	500	40	All niger-growing areas of the country suitable for Gujarat
GA-5	120-125	400	39	Orissa, Bihar, West Bengal, Karnataka
GA-10	115-120	450	42	Orissa, Bihar, West Bengal, Karnataka

Source: ICAR 1992.

7.1 Breeding objectives

For niger to be competitive with other oilseed crops, its seed yield must be significantly improved. To achieve this objective, single-headed, dwarf types must be developed which have uniform maturity resulting in reduced shattering losses. The Ethiopian germplasm collection contains short-stature plants which could be used for the development of dwarf types. There also is genetic variation for number of heads per plant that could be utilized in breeding programmes to select single-headed types. The presently used normal-height niger material has many leaves and a low harvest index (Belayneh 1986). Reducing plant height would decrease the number of leaves per plant and result in a better harvest index. Shorter plants would be capable of utilizing fertilizer more efficiently in that seed yields could be increased through the application of fertilizer. Standard niger types respond to fertilizer application by increasing vegetative growth, which promotes lodging of the crop and in fact decreases rather than increases seed yield.

The second most important breeding objective in niger improvement is increasing the seed oil content. There exists great genetic variability for oil content in Ethiopian and Indian germplasm collections which could be used, in a breeding programme, to significantly increase oil content (Getinet and Teklewold 1995). An increase in oil content of 5 percentage points seems to be feasible.

7.2 Breeding method

A genetic improvement programme for niger must be based on its pollination behaviour. Because of its self-incompatibility nature, breeding procedures used in the improvement of cross-pollinating crops are the methods of choice for niger breeding (Doggett 1987). The standard breeding procedure for cross-pollinating crops is recurrent selection as described in standard plant breeding text books (Allard 1960). The resulting varieties are open-pollinated population varieties.

Mass selection is a powerful tool for crop improvement. In niger, this technique has been successfully employed for the development of an early to medium maturing, short plant type variety. The resulting variety (Kuyu) was 9 days earlier maturing, 10 cm shorter in height and significantly higher yielding than standard niger varieties.

The pollination behaviour of niger is similar to that of sunflower. Thus niger is an excellent candidate for hybrid variety development. The identification of genetic male sterility in India (Trivedi and Sinha 1986) and recently in Ethiopia (Teklewold, unpublished) has opened the way for the exploitation of heterosis in niger. Six hybrids based on genetic male sterility, their parents, and local and national check varieties were evaluated for seed yield in India (Singh and Trivedi 1993). The hybrids exhibited 10-30% heterosis for seed yield over the better parent and 15-55% over mid-parent yields. No heterosis was observed for oil content except in one hybrid combination.

A requirement for hybrid breeding is the availability of genetically diverse heterotic germplasm. It is anticipated that Ethiopian and Indian niger germplasm are

genetically very different and might express high levels of heterosis for seed yield. A preliminary evaluation of Indian niger at the Holetta Research Centre in Ethiopia has shown that Indian genotypes, when grown in Ethiopia, matured within 74 days compared with the 150 days of standard Ethiopian varieties. The Indian varieties also had higher seed weights than the Ethiopian varieties (Riley and Belayneh 1989).

Niger is attacked by a number of insects and fungal diseases. As modern high-yielding, genetically uniform cultivars are disseminated, threats from diseases will increase which will require increased emphasis on disease resistance breeding. Wild species of the genus *Guizotia* could serve as sources for disease resistance genes which could be introgressed into the cultivated species through interspecific crossing.

7.3 Biotechnology

Simmonds and Keller (1986) developed plant regeneration protocols of niger from leaf tissue. Efforts to develop dihaploids from ovule culture were unsuccessful. During the last 10 years modern techniques of plant tissue culture, doubled haploid technology and transformation are increasingly used by breeders for crop improvement. Protocols to regenerate plants from niger hypocotyl and cotyledon tissues and seedlings were developed in India (Sarvesh *et al*. 1993a, 1994b). Plant regeneration was dependent on genotype and media composition used. If niger is susceptible to *Agrobacterium tumefaciens* infection, then it will be a good candidate for gene transfer within the Compositae family.

Dihaploid plants of niger have been produced by anther culture (Sarvesh *et al* 1993b, 1994a). Self-compatible lines, dwarfs and single-headed doubled haploid plants were obtained from anther culture of niger in India. Anther- and microspore-derived dihaploids can be used to develop homozygous mutant types and inbred lines in a short time. Recessive, simply inherited and easily identifiable marker traits which are important for niger seed production to ensure genetic purity of varieties could be obtained through microspore culture technology.

8 Production areas

Niger is an important oilseed crop contributing 50-60% of the oilseed production in Ethiopia (Riley and Belayneh 1989) and 3% in India. The annual production in India is about 180 000 tonnes, whereas in Ethiopia it is estimated at about 7000 tonnes.

It should be noted that accurate statistics of crop production for Ethiopia are difficult to obtain; however, it is estimated that 90% of the niger is produced in Gojam, Gonder, Shoa and Wellega (Getinet and Alemayehu 1992). The remaining 10% is produced in Wello, Hararghe, Arsi and Bale.

In India, the niger crop is mainly cultivated in the states of Madhya Pradesh, Orissa, Maharashtra, Bihar, Karnataka and Andhra Pradesh, and to some extent in hilly areas of Rajasthan, Uttar Pradesh, Gujarat and Tamil Nadu and some parts of the northeastern hilly regions of the country. It is grown on about 600 000 ha (Table 10). The crop is mainly grown during the rainy season ('kharif') and to some extent as a winter crop (e.g. in Orissa). From 1989 to 1992, a total of 179 200 t of niger was produced. The productivity of niger ranges from 181 kg/ha in Karnataka to 479 kg/ha in West Bengal. The importance of niger cultivation and production in relation to other oilseed crops in India is shown in Table 11. In India, niger is usually planted on hillsides on poor shallow soils and seed yields in India are therefore lower than in Ethiopia.

Table 10. Area, production and productivity of niger in India, 1990-93.

State	Area (1000 ha)			Production (1000 t)			Productivity (kg/ha)		
	90-91	91-92	92-93	90-91	91-92	92-93	90-91	91-92	92-93
Andhra Pradesh	18.5	18.5	18.5	7.1	8.5	8.6	384	452	465
Bihar	32.7	28.7	25.9	16.1	12.5	10.9	492	435	421
Karnataka	53.0	51.0	42.2	9.3	9.1	7.4	175	178	175
Madhya Pradesh	223.7	212.0	207.7	47.6	28.2	33.5	213	134	161
Maharashtra	111.0	116.6	91.6	25.7	16.0	20.0	232	137	222
Orissa	165.4	206.3	197.0	77.1	101.7	97.7	466	493	496
West Bengal	6.6	6.8	6.8	3.3	3.4	3.4	500	500	500
All India	611.2	640.4	589.9	186.3	179.5	181.9	280	280	308

Source: Agricultural Situation in India.

In India about 75% of the niger crop is used for oil extraction. The remainder is exported as bird feed to the USA, Canada, UK, Italy, Netherlands, Spain, Germany, Belgium, Cyprus, Japan, Singapore, Sumatra and Australia (Table 12).

Niger is also grown in Bangladesh and Nepal. In Bangladesh, it is mostly grown in Comillo, Jamalpur and Faridpur districts and in different Char areas, and in Terai and the inner Terai areas of Nepal.

Table 11. Principal oilseed crops in India, 1992-93.

Crop	Area		Production		Yield
	(1000 ha)	(%)	(1000 t)	(%)	(kg/ha)
Groundnut*	8351	32.7	8854	46.7	1060
Rapeseed and mustard	6305	24.6	4872	24.0	773
Soybean	3627	14.2	3106	15.3	856
Sesamum	2364	9.2	853	4.2	361
Sunflower*	2093	8.2	1185	5.84	566
Linseed	879	3.4	268	1.3	305
Safflower	707	2.8	342	1.7	484
Castor seed	659	2.6	617	3.4	936
Nigerseed	590	2.3	182	0.9	308
Total	25575	100	20279	100	

* Sum of 'kharif' and 'rabi' seasons.
Source: Directorate of Economics and Statistics. Area and production of principal crops in India 1990-93.

Table 12. Export of niger seed from India.

Year	Quantity (tonnes)	Value (1000 Rs.)
1991-92	13 141	234 528
Apr. 1992 - Dec. 1992	13 108	240 589
1993-94	10 858	186 737

Source: Annual Statement of the Sea-Borne Trade of India, Director General of Commercial Intelligence and Statistics, Calcutta.

9 Ecology

In general, niger is a crop of the cooler parts of the tropics. The major niger-producing areas in Ethiopia are characterized by a moderate temperature ranging between 15°C and 23°C during the growing season.

Prinz (1976) studied the effect of temperature and daylength of Ethiopian and Indian niger in the field and phytotron at Göttingen, Germany. Ethiopian niger showed best flower induction at 18/13ºC day/night temperature and 12 hours daylength. Flowering was very delayed at daylengths of more than 12 hours and temperature of 23ºC. The Ethiopian types may not be induced at daylengths of more than 14.5 hours. Once flowering is induced it remains induced, even at longer photoperiods (Yantasath 1975). The Ethiopian types can be induced to flower at 11-12 hours daylength 7 weeks after planting. The influence of temperature on the flower induction of Indian niger was not observed. Longer daylengths increased vegetative growth and plant height in Ethiopian and Indian types, but more so in Ethiopian than in Indian. In summary, the Ethiopian types are short-day and the Indian types are quantitative short-day types.

In Ethiopia, niger is grown mainly in mid-altitude and highland areas (1600-2200 m asl). It is also cultivated in lower (500-1600 m) and higher (2500-2980 m) altitudes with enough rainfall. Niger is adapted to areas where rainfall does not exceed 1000 mm per year. A higher precipitation (1000-1200 mm and lower levels of about 500 mm may be suitable, depending upon the variety and the distribution of rainfall. In India, a rainfall between 1000 and 1300 mm is optimum but a well-distributed rainfall of 800 mm can produce a reasonable yield (Sharma 1990b). The growth may be depressed with rainfall of over 2000 mm, but the plants can withstand high rainfall during the vegetative phase. For this reason, niger is the most suitable crop for hill regions of high rainfall and humidity in India.

Niger will grow on almost any soil as long as it is not coarse-textured or extremely heavy. It is usually sown in areas with a rather poor soil or on heavy clay soil under poor cultural conditions. It grows well at pH values between 5.2 and 7.3. Niger tolerates waterlogged soils since it grows equally well on either drained soils or waterlogged clays. Niger is extraordinarily resistant to poor oxygen supply in soil because of its ability to develop aerenchymas under these conditions. The aerenchymas develop only when niger plants are grown under high waterlogging condition and transport oxygen within the cormus into the root system (Prinz 1976).

Rainfall during seed-setting and maturity leads to seed shattering and hence, low yield. Niger is salt tolerant (Abebe 1975) but flowering is delayed with increasing salinity. It has been observed that crops following niger grow well and inoculation of soil with soil in which niger was grown resulted in increased growth of the crop following niger (Yantasath 1975). A microorganism involved in mycorrhiza association, *Glomus macrocarpus*, has been identified.

10 Agronomy

Farmers in Ethiopia plant 'abat' niger in mid-May to early June and harvest in December, 'bungne' niger is planted in July and harvested in October and the growing season for 'mesno' niger is from September to February. Systematic research at the Holetta Research Centre showed that mid-June to mid-July was the optimum time of planting for the 'abat' niger (Belayneh *et al.* 1986). Planting too early should be avoided as rain in October can cause shattering and reduce seed yield. In India niger is planted as a rain-fed crop in 'kharif' and 'rabi' seasons (ICAR 1992). Generally it is planted from mid-June to early August for 'kharif', in September for the semi-rabi season and in December for 'rabi' season. The optimum sowing period varies from state to state. Niger is a small-seeded crop and seed rates vary from 5 to 10 kg / ha in Ethiopia and from 5 to 8 kg / ha in India. The crop compensates for lower seeding rates through increasing branching. In Ethiopia lower seed rate is preferred during early planting. In India the seed is treated with Thiram at a rate of 3 g / kg of seed to prevent soilborne diseases. In both countries it is often broadcast but it can also be sown in rows. In Ethiopia niger is mainly sown as a sole crop, usually in rotation with tef and maize. In some areas, particularly in Wello and Hararghe in Ethiopia and Maharashtra in India, niger is planted as a border crop around a cereal field to prevent animals from damaging the cereal crop. In Ethiopia farmers often report that niger is a good precursor for cereals and that crops following niger have less weed infestation. This was confirmed in crop rotation trials where high yields of cereals were obtained following niger. Preliminary investigations at Holetta showed that a water-extract substance from niger inhibited the germination of monocotyledonous weeds.

In India, niger is sown as a sole or mixed crop with finger millet, castor, groundnut, soybean, sorghum, mungbean, chickpea and even sunflower. Niger has a low response to nitrogen and phosphorus fertilizer. However, a rate of 23 kg N / ha and 23 kg P_2O_5 / ha is necessary for stand establishment. In India, both nitrogen and phosphorus and farm yard manure are applied. In Madhya Pradesh 10 kg N / ha and 20 kg P_2O_5 / ha at sowing and 10 kg / ha 35 days after sowing is recommended. In Orissa, 20 kg N / ha and 40 kg P_2O_5 / ha is applied during planting and 20 kg N is applied 30 days after sowing. In Maharashtra 4 t of farmyard manure and 20 kg N / ha are used during sowing. In Andra Pradesh 5 t of farmyard manure and 10 kg / ha N are used at sowing.

Correct timing of harvesting of niger is an important practice in reducing shattering. Traditionally, niger is harvested while the buds are still yellow and stacked to dry. Then the stack is taken up right over to the threshing ground. As niger seeds are loosely held in the head, threshing is easy. Research has shown that harvesting niger at a bud moisture content of 45-50% or when the buds turn from yellow to brown yellow is the optimum stage (Belayneh 1987). In India it is harvested when the leaves dry up and the head turns black (ICAR 1992). During harvesting, plants are kept in stacks and when dried they are taken to the threshing ground in an upright position to reduce shattering. The crop is then threshed using sticks.

The effects of cultural practices –sowing date, seed rate, fertilizer rate, weeding, improved variety – on seed yield of niger were studied. In Ethiopia, the plant developmental stage at harvest and the variety planted were found to be important factors contributing to high seed yields. In India, fertilizer application and variety contributed 68 and 51%, respectively, to increased yield (Sharma 1990a). Adoption of improved technology increased seed yield of niger by 40%.

11 Parasitic weeds, pest insects and diseases

The parasitic weed known as dodder (*Cuscuta campestris*) has become a serious threat of niger production throughout Ethiopia (Fessehaie 1992). Dodder was also a major threat to Indian production (Sharma and Sengar 1989). In Orissa, dodder (*Cuscuta chinensis* Damk) infestation caused stunted slow growth, inhibited branching, reduced number and size of flower heads and seeds per plant (Rath and Mahanthy 1986). Early infestations and infestation at 30 days after seeding and 45 days after emergence caused total yield losses. Tosh and Patro (1975) reported that dodder can be controlled by the application of the herbicide Chlorpropham as a granulate, at the initiation of dodder germination, and at a rate of 4 kg / ha. A 90% control of dodder was achieved using Propyzamide applied as a post-emergence, 20-25 days after sowing at a rate of 1.5-2.0 kg / ha with no phytotoxicity (Tosh *et al.* 1977, 1978). Dodder could also be controlled by sifting seed before sowing.

Table 13. List of niger pests.

Latin name	Common name	Reference
Achaea janata	Surface grasshopper	Sharma (1990b), ICAR (1992)
Agrotis ipsilon	Cut worm	Sharma (1990b)
Condica conducta	Caterpillar	ICAR (1992)
Eutretosoma sp.	Niger fly	Bayeh (1995), Bayeh and Gebrre Medhin (1992)
Piezotrachelus milkoi	Apionid weevil	Bayeh (1995), Bayeh and Gebrre Medhin (1992)
Meligethes sp.	Black pollen beetle	Bayeh (1995)
Haplothrips articulosus	Niger flower thrips	Schmutterer (1971),Bayeh (1995)
Synaptothrips sp.	Thrips	Bayeh and Gebrre Medhin (1992)
Medicogryllus spp.	Crickets	Bayeh and Gebrre Medhin (1992)
Taylorilygus pallidulus	Mirid bug	Bayeh and Gebrre Medhin (1992)
Decaria abolominalis	Chrysomelid beetle	Sharma (1990b), Bayeh (1995)
Dioxyna sororcula	Niger fly	Bayeh (1995), Schmutterer (1971), Jakhmola (1981)
Chrysodeixis circumflexa	Plusia worm	Bayeh and Gebrre Medhin (1992)
Trichoplusia orichalcea	Golden plusia	Bayeh and Gebrre Medhin (1992)
Gryllus bimaculatus	Cricket	Bayeh and Gebrre Medhin (1992)
Pemphigus sp.		Bayeh and Gebrre Medhin (1992)
Perigaea capensis	Caterpillar	Jakhmola (1981), Chavan (1961)
Diacrisia obliqua	Hairy caterpillar	ICAR (1992), Bayeh (1995)
Chrotogonus sp.	Surface grasshopper	Jakhmola (1981), Chavan (1961)
Prospalta capensis		Bayeh and Gebrre Medhin (1992)
Plusia orichalcea		Jakhmola (1981)
Luxus brachyrrhinus		Jakhmola (1981)
Sphaeroderma guizotae		Haile (1993)
Spilosoma obliqua	Caterpillar	ICAR (1992)
Liroleucon carhami	Aphid	ICAR (1992)

A total of 24 insects are recorded on niger in both Ethiopia and India (Table 13). Of these the niger fly (*Dioxyna sororcula* and *Eutretosoma* spp.) and black pollen beetles (*Meligethes* spp.) are the most important (Bayeh, unpublished). The niger fly is the

Table 14. List of niger diseases.

Pathogen	Disease	Distribution	Reference
Alternaria dauci	On seeds and leaf	Ethiopia	Stewart and Yirgu (1967)
Alternaria porri sp. *dauci*	Leaf spot	Ethiopia	Yirgu (1964)
Alternaria sp.	Stem and leaf blight	Ethiopia	Yitbarek (1992)
Aspergillus sp.		Ethiopia, India	Kolte (1985)
Bremia lactucae	Downy mildew	Ethiopia	Stewart and Yirgu (1967)
Cercospora guizoticola	Leaf spot	Ethiopia, India	Yirgu (1964)
Cladosporium sp.		Ethiopia, India	Yirgu (1964)
Emericella sp.		Ethiopia India	Kolte (1985)
Fusarium sp.		Ethiopia, India	Kolte (1985)
Ozonium taxanum var. *parasiticum*	Ozonium wilt	India	Kolte (1985)
Macrophomina phaseolina		Ethiopia, India	Chivan (1961), Yirgu (1964)
Phoma sp.	Stem lesion, wilting	Ethiopia	Yitbarek (1992)
Phyllosticta spp.	Tar spot	Ethiopia, India	Yirgu (1964)
Plasmopara halstedii	Downy mildew	Ethiopia	Yitbarek (1992)
Puccinia guizotiae	Rust	Ethiopia	Yirgu (1964)
Rhizoctonia solani	Root rot	Ethiopia	Yirgu (1964)
Rhizoctonia bataticola	Seed rot	India	Yitbarek (1992)
Sclerotium rolfsii	Seed rot	India	Kolte (1985)
Sphaerotheca sp.	Powdery mildew	India	Yirgu (1964)
Xanthomonas campestris pv. *guizotiae*	Leaf spot	Ethiopia	Yirgu (1964)
Anguina amsinckia	Leaf gall	Ethiopia	Stewart and Yirgu (1967)
Epicoccum nigrum		Ethiopia	Yirgu (1964)
Erysiphe cichoraceurum		Ethiopia	Yirgu (1964)
Coniothyrium sp.		Ethiopia, India	Kolte (1985)
Penicillium spp.		Ethiopia, India	Yirgu (1964)
Xanthomonas campestris pv. *guizota* var. *indicus*		India	Kolte (1985)
Septoria sp.		Ethiopia	Stewart and Yirgu (1967)

most serious insect pest of niger, both in Ethiopia and India. The flies start mating when the flower is blooming (Bayeh, unpublished). Eggs are laid within the disk florets, hence interfering with seed-set. The damaged flowers turn red brown and contain larvae or pupae. At maturity the damaged disc florets are stony and reveal pupae when dissected. The black pollen beetle is also reported from all niger-growing areas of Ethiopia. Although precise identification is lacking, five species are suspected. These insects feed on pollen grain, hence interfering in fertilization of ovules. The adult beetles are adapted to live within the disk florets. Some of the insect pests found in Ethiopia are not yet identified. In India, control measures for niger caterpillar, semilooper, hairy caterpillar and surface grasshopper have been developed (ICAR 1992).

Many diseases have been reported on niger (Table 14). Of these, niger blight (*Alternaria* sp.) and leaf spot are the most serious. Control measures for cercospora leaf spot, powdery mildew, alternaria leaf spot, root rot and *Cuscuta hyalina* are being developed in India.

12 Limitations of the crop

The niger plant has an extremely low harvest index (Belayneh 1986) and inputs such as fertilizer promote vegetative growth rather than increase seed yield. Niger has an indeterminate growth habit. Lodging and shattering are the two most important causes of low seed yield. The self-incompatibility nature of niger causes serious difficulty for inbred line development and maintenance. The incompatibility nature of niger makes breeding work difficult. However, the application of population improvement techniques should result in steady genetic gain, and the self-compatable types located at Holetta might be used to produce high-yielding synthetic populations or possibly hybrids**.** Sib mating can be practised to develop inbreds. Therefore, the ability to set selfed seed is important (self-compatible types).

Insect attack on niger flowers causing severe seed set reduction has been reported in both Ethiopia and India. The niger fly is a serious insect pest which feeds on flower heads, interfering in seed-set and pollination (Schmutterer 1971; Jakhmola 1981; Bayeh, unpublished). Another serious insect which fed on flower heads, thereby reducing seed-set in Ethiopia, was black pollen beetles (Bayeh, unpublished). Most of the important niger insect pests known in Ethiopia have not been identified yet. Niger has fewer diseases than other oilseeds. However, as modern cultivars are distributed to farmers, diseases such as niger stem and leaf blight could be a problem. In India seedborne diseases such as *Aspergillus niger*, *A. flavus, Penicillium* sp., *Alternaria alternata, Rhizoctonia solani* and *R. bataticola* could cause a problem. Dodder has become a very serious problem in the niger-producing provinces of Ethiopia, namely Gojam, Gonder, Shoa and Wellega. Similar problems exist in India's Orissa state. *Orobanche minor* was also a problem in Ethiopia but serious damage was not reported.

Niger seed has a high fibre content and crushers and processors have reported that it has a lower oil recovery rate than other oilseeds. Although there is no known toxic or anti-nutritional factor in niger meal, it has been reported in Ethiopia that animals fed niger meal gain less weight than those fed meals from other oilseeds.

Cooperative programmes between Ethiopia and India should be encouraged. The Ethiopian niger research programme suffers from a shortage of resources.

13 Prospects

Niger is a good precursor for cereals, pulses and oilseeds because crops following niger have less weed infestation. It grows on heavy clay soil in Ethiopia, usually following one or two ploughings and without fertilizer or herbicide. It has fewer diseases and pests than other oilseeds. It contributes a great deal to soil conservation and land rehabilitation because of its mycorrhizal association and its potential as a biofertilizer. The oil extracted from the seed contains a high content of linoleic acid, an essential fatty acid for monogastric animals including humans. The meal remaining after the oil extraction is an excellent feed for animals. Niger seed oil extraction technology is well established and the oil and meal are widely accepted. The oil and the seed are completely free from any toxic substances. The potential of yield increase through plant breeding is very good, especially in view of the existing genetic variability. The biotechnology methods developed for niger could contribute to accelerating niger breeding programmes.

14 Research needs

The current niger accessions at the Biodiversity Institute were collected from relatively secure areas of the country accessible from major roads. Germplasm-collecting missions deep into villages and remote areas will be necessary (Tadesse, pers. comm.). Ethiopia has not had a peaceful administration since the late 1960s. The disputed regions of Welkayit, Tsegedey and Metema are known to be niger-producing districts. The areas in Gonder and Wello which were not covered previously by collecting missions should be given priority regarding 'abat' niger. Early 'bungne' types can also be collected from Tigre and Eritrea.

Niger germplasm apparently has only been collected from Ethiopia and India; there is no information regarding germplasm collecting from other countries. The niger landraces in Ethiopia, India and possibly other countries have been geographically isolated for a very long time and therefore may carry different valuable genes. Germplasm collecting in other countries such as Uganda and Zimbabwe should be carried out. Collecting of germplasm should include wild relatives within the genus *Guizotia.*

Characterization and evaluation of the germplasm should be standardized and descriptors should be developed. The valuable germplasm, particularly the Ethiopian genepool, was not characterized in one environment and needs thorough characterization and evaluation. Such germplasm evaluations would result in identification of valuable germplasm with high oil contents, high seed yield, and male sterile and dwarf lines. Documentation of the germplasm is also as important as the characterization. Documentation of the available germplasm needs, in addition to the present practice, a bar-coding system using desk top computers similar to what large plant breeding companies use. Germplasm exchange between Ethiopia and India, already a delicate issue, should be explored. However, the early Indian materials are too early to make use of the long Ethiopian growing seasons. Therefore elite lines, e.g. male sterile and dwarf lines, rather than accessions would be preferred for Ethiopia.

Striking genetic differences exist between the Ethiopian and Indian niger. These differences could be investigated using isozyme and molecular markers. It would be interesting to investigate which niger ecotype migrated to India. The variation among 'abat', 'bungne' and 'mesno' niger ecotypes could be differentiated using isozyme and molecular markers.

All species within the genus *Guizotia* are diploids with chromosome number of $2n=30$. Speciation within the genus *Guizotia* was not as a result of changes in chromosome number (Hiremath and Murthy 1992). The four species *G. abyssinica*, *G. scabra* subsp. *scabra*, *G. villosa* and *G. scabra* subsp. *schimperi* are not reproductively isolated (Dagne 1994a) so hybrids among these species could be obtained with ease. It would be very important to study the progenitor of niger using isozyme and molecular markers such as random amplified polymorphic DNAs. Comparison of chloroplast and mitochondrial DNA pattern could be studied to investigate the progenitor of niger. The solution to the problem of the phylogeny of the species

could come from molecular techniques.

It is often reported that niger has an allopathic and mycorrhizal association. It will be interesting to identify the substance associated with the weed-depressing effect of niger. It is very important to study the mycorrhizal association of niger further. Efficient genotypes and the possibility of biofertilizers should be investigated.

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Appendix I. Descriptors used to characterize and evaluate niger accessions in Ethiopia

1. Days to 10% flowering	
2. Days to 50% flowering	
3. Days to 90% flowering	
4. Days to 50% maturity	
5. Septoria (shot hole):	score 0= no disease, 5= leaves covered with holes
6. Sclerotinia wilt:	percentage wilted plants
7. Niger fly damage:	estimate percentage of florets with larvae
8. Thrips (black insect in flower)	
9. Stem colour:	G= green, P= purple
10. Number of nodes per plant:	average of 10 plants
11. Plant height (cm):	average of 10 plants
12. Number of primary branches	
13. Flower size:	1= very small, 5= very big
14. Leaf colour:	1= very light green, 5= very dark green
15. Angle of branching:	1= erect (acute) branches, 5= hanging branches
16. Number of heads per plant:	average of 10 plants
17. Head size score:	1= very small, 5= very big
18. Seed shattering score:	estimate shattering of plants just before harvest
19. Bird damage:	record percent loss due to birds (record only if birds are seen eating the seed)
20. Synchrony of maturity of heads:	1= all heads mature at the same time, 5= heads mature at different times
21. Leaf size:	1= very small, 5= very broad
22. Leaf width:	1 very narrow, 5= very broad
23. Leaf margin:	1= smooth, 2= rounded and 5= pointed
24. Lodging (%)	
25. Plot uniformity:	1= all plants uniform, 5= great differences from plant to plant
26. Sterility:	take 10 plants, divide into developed and aborted heads, record percent
27. Thousand seed weight (g)	
28. Oil content:	Wide Line Nuclear Magnetic Resonance Spectrometer reading
29. Fatty acid composition of the oil:	gas chromatography.

Appendix II. Current niger research

Scientist	Research field	Institute
Bangladesh		
Dr M.A. Khaleque Dr Dilruba Begam		Bangladesh Agricultural Research Institute (BARI), GPO Box 2235, Joydebpur, Gazipur Dhaka
Bhutan		
Dr Tayan Raj Gurung		Centre for Agricultural Research and Development, Department of Agriculture, Royal Government of Bhutan, Wangdiphodrang
Ethiopia		
Ato Adefris Teklewold	Breeding	Institute of Agricultural Research, Holetta Research Centre, PO Box 2003, Addis Abeba
Ato Bayeh Mulat	Entomology	
Ato Yitbarek Semeane	Pathology	
W/o Truwork Amongne	Pathology	
Dr Getinet Alemaw	Breeding	
Dr Mesfin Tadesse	Botany	Addis Abeba University, Department of Biology Faculty of Science, PO Box 1176, Addis Abeba
Dr Kefle Dagne	Genetics	
Ato Yeshanew Ashagre	Agronomy	Institute of Agricultural Research, Adet Research Centre, PO Box 8, Bahar Dar
Ato Tsege Genet	Breeding	
Dr Hirut Kebede	Characterization	Biodiversity Institute, PO Box 30726, Addis Abeba
India		
Dr S.M. Sharma	Genetic resources	All India Coordinated Research Project on Oilseeds, Jawaharlal Nehru Agricultural University, Jabalpur - 482 004 MP
Dr S.C. Hiremath	Genetics	Department of Botany, Karnataka University, Dharwad - 580 003 Karnataka

Dr R.K. Reddy	Breeding	Jawaharlal Nehru Agricultural University, Zonal Agricultural Research Station, Chhindwara - 480 008 MP
Dr R.A. Sheriff	Plant science	Department of Plant Breeding and Genetics, University of Agricultural Sciences, GKVK Campus, Bangalore - 560 065, Karnataka
Dr K. Giriraj		University of Agriculture Sciences, Dharwad - 580 003, Karnataka
Dr T.R. Loknathan		NBPGR Regional Station PKV Campus, Akola - 444 104, Maharashtra
Mr S. Venkata Rao	Breeding	Regional Research Station, Semiliguda PO Box 10, Sunabeda, Koraput 763 002, Orissa
Mr Sohan Ram	Breeding	Department of Plant Breeding and Genetics, Birsa Agricultural University, Kanke, Ranchi 834 006, Bihar

Nepal

Mr M.L. Jayaswal		National Oilseed Development
Dr Dilruba Begam		Programme, Nawalpur, Sorlahi, Janakpur Zone

Appendix III. Centres of crop research, breeding and plant genetic resources of niger

Bangladesh

Genetic Resources Center (2 accessions)
Bangladesh Agricultural Research Institute
GPO Box 2235
Joydebpur, Gazipur
Dhaka

Ethiopia

Institute of Agricultural Research
Research Centres at Holetta, Adet, Ghinchi and Bako
PO Box 2003
Addis Abeba

Biodiversity Institute (1071 accessions)
PO Box 30726
Addis Abeba

Addis Abeba University
Faculty of Science
Department of Biology
PO Box 1176
Addis Abeba

Germany

Institut für Pflanzengenetik und (4 accessions)
Kulturpflanzenforschung (IPK) - Genbank
Corrensstr. 3
06466 Gatersleben

India

All India Coordinated Research Project on Oilseeds (557 accessions)
J. N. Krishi Vishwa Vidyalaya
Jabalpur - 482 004 MP

Jawaharlal Nehru Agricultural University (254 accessions)
Zonal Agricultural Research Station
Chhindwara - 480 001 MP

Mahatma Phule Krishi Vidyapeeth (240 accessions)
Western Ghat Zonal Agricultural Research Station Itatpuri
Nasik - 422 403, Maharashtra

National Bureau of Plant Genetic Resources (205 accessions)
Regional Research Station
Akola - 444 104, Maharashtra

Birsa Agricultural University (178 accessions)
Kanke
Ranchi - 834 006, Bihar

Orissa University of Agricultural & Tech. (94 accessions)
Regional Research Station Semiliguda
PO Box 10
Sunabeda
Koraput - 763 002, Orissa

University of Agricultural Science
Dharwad, Regional Agricultural Research Station
Riachur - 584 104, Karnataka

Nepal
Central Plant Breeding & Biotechnology Division (36 accessions)
National Agricultural Research Council
PO Box 1135
Khumaltar

National Oilseed Research Programme
Nawalpur, Sorlahi

Pakistan
Pakistan Agricultural Research Council
PO Box 1031
Islamabad

South Africa
Grassland Research Centre (1 accession)
Dept. of Agricultural Development,
Private Bag X05, Lynne East
Pretoria

USA
Western Regional Plant Introduction Station USDA-ARS (15 accessions)
Washington State University
59 Johnson Hall
Pullman, WA 99164-6402