ISSN 1479-2621

Plant Genetic Resources 2(2); 85–97
DOI: 10.1079/PGR200438

After the conflict: plant genetic resources of southern Sudan

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Received 8 March 2004; Accepted 2 April 2004

Abstract

Southern Sudan has a low population density, abundant land and tremendous agricultural potential. A large number of domesticated crops are grown in the region in a range of cropping systems. There are also numerous useful wild plant genetic resources. Little collecting work has been done in the region, there are few accessions from southern Sudan stored *ex situ* and publications on the actual and potential plant genetic resources for agriculture are sparse. The region has been a centre of civil conflict with little respite since independence in 1956. The farmers' fields and natural environments represent *in situ* genebanks, which following the cessation of hostilities will become extremely important for the rehabilitation of subsistence agriculture, the promotion of cash crop production and the revitalization of the regional economy. Several wild plant species are highly nutritious and merit the attention of plant scientists. This article describes some of the domesticated, semi-domesticated and wild plant genetic resources of the area, and suggests why these are important for agricultural rehabilitation following implementation of a peace accord.

Keywords: agricultural biodiversity; conflict; neglected species; Sudan; underutilized species

Introduction

Civil conflict between the North and the South erupted when Sudan became independent from Egypt and Great Britain in 1956 and has been described as the oldest civil war in the world (Salopek and Olson, 2003). There has been little respite in hostilities over the past 47 years, but recent peace negotiations represent an opportunity for the South to realize its potential for agricultural production and for agriculture to contribute to development of the region. Wickens (1991) stated that there was once a hope that Sudan would become the 'breadbasket' of Africa, but regrettably it was more likely to become the 'dust bowl'. This paper argues that the plant genetic resources of southern Sudan (for these purposes the region below 9°N, incorporating mainly Equatoria and Bahr el Ghazal provinces) are extensive but poorly recorded and their importance underappreciated outside the region. It is suggested that there remains considerable opportunity to develop sustainable agriculture and revitalize the economy of the region based on both indigenous and introduced agricultural species if the proposed peace accord works.

The larger animal resources of southern Sudan have undoubtedly suffered considerably in terms of numbers and species during the course of the wars in Sudan and its neighbouring countries. The plant genetic resources, however, are likely to have largely remained intact and the war could have benefited the natural environment where it has kept people out of large areas, as has been the case in the Democratic Republic of the Congo (Draulens and van Krunkelsven, 2002; Anon., 2004). Some southern Sudanese farmers became refugees and fled into neighbouring countries, but many have lived and farmed in the region during the hostilities. Crops have been produced despite hostilities and cross-border trade has continued. The wild plant resources have

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remained and probably assumed greater significance in the face of periodic food shortages resulting from crop failure and lost opportunities to harvest.

The environment

Southern Sudan comprises three major ecological zones: tropical rainforest along the border with the Democratic Republic of the Congo, tropical moist forest stretching from the border with the Central African Republic to Uganda and tropical dry forest from the Chad border in the west across to the Ethiopian border in the east. Tropical scrubland is present along the Kenyan and southern Ethiopian borders with tropical mountain forest up to 3000 m above sea level in the Imatong and Dongotona mountains and Didinga hills on the Uganda border. Cloud forest is present along rivers, depression forest also exists and large areas of swamp surround the Nile. Andrews (1948), and more recently Wickens (1991), described the natural vegetation of the region. The climate ranges from humid, on ferrosol and nitosol soils, to sub-humid on luvisol and vertisol soils, tropical rainy to tropical wet–dry, with reliable rainfall (20th percentile, 1951–1980) ranging from over 1300 mm per year to around 600 mm per year. Rainfall is bimodally distributed in the extreme south, where it translates into a >250-day cropping season that allows two main crops to be grown in a year. Soils were described by Greene (1948) and Mitchell (1991) and hydrology by Ireland (1948) and Walsh (1991).

The agriculture

Tothill (1948) is a seminal work on the agriculture of southern Sudan with that of de Schlippe (1956), who specifically described the cropping systems of the Zande in the green belt area bordering the Democratic Republic of the Congo. Dickie (1991) briefly described farming systems of the region. The agricultural systems of southern Sudan are complex and differ according to site and the many tribes of the region. Cattle are a major feature of the Dinka, Nuer and Shilluk farming systems in the northern areas of southern Sudan, while towards the southern Bari-speaking areas only goats and fowl are common. Farming is almost exclusively of the smallholder, subsistence, shifting-cultivation type, where small areas of land are cleared of their natural or secondary vegetation using hand hoes (*toria*). The trees dominating the vegetation (often *Combretum* L. spp. and *Terminalia* L. spp.) are cut and used for house (*tukl*) construction (poles from introduced teak, *Tectona grandis* L., are also much used for house construction) and a range of crops sown to meet the needs of food security and income generation. After several seasons, during which the soil becomes exhausted and weeds become a problem, especially spear grass (*lalang*, *Imperata cylindrica* (Anderss.) C. E. Hubbard), a common thatching grass, and the parasitic weed striga (*buda*, *Striga hermonthica* (Del.) Benth.; eight additional species in the region), new areas are opened up.

The range of cultivated species in some of the cropping systems of southern Sudan is daunting. Myers (Tothill, 1948) recorded 68 crops from a single Zande settlement and it is not unusual to see 10–15 crops in a single field, excluding the wild food species associated with agriculture. Major intercropping systems can be discerned and are specific to particular soil and climate conditions and tribal practices. Robinson (1997a, b) reported the results of intercropping experiments done at Yei (4°N, 30.2°E), but little experimental work has been done in the area and therefore little has been published in journals.

The plant genetic resources

Table 1 represents a list of the major domesticated plant species grown for human consumption and income generation in southern Sudan, with their local Arabic name and an indication of the numbers of wild relatives growing in the region. Table 2 contains data on non-domesticated useful species, neglected and underutilized species, famine foods and potentially useful species. The information in both tables is not restricted to food plants, but includes other commodity groups. Very little plant breeding has been done to develop crops adapted to the conditions of southern Sudan and the plant genetic resources available in terms of wild relatives of domesticated species have been little used to develop adapted cultivars for other places. *Ex situ* conservation of the plant genetic resources is difficult to assess, but Mohammed (1991) reported that 100 okra (*Abelmoscus esculentus*) (L.) Moench) accessions from central, west and north Sudan were kept at Wad Medani in the Horticultural Research Section of the Agricultural Research Corporation (ARC) of Sudan. These were collected during several missions, along with other domesticated vegetable species (Hassan *et al.*, 1983, 1984; Geneif *et al.*, 1986), but there was no collectiing mission made in southern Sudan. Ahmed and Mohammed (1997) listed other horticultural accessions held by the ARC.

Southern Sudan is rich in genetic resources of forgotten and underutilized crops and species that have potential for being developed into crops. Little has been collected from the region and traditional knowledge on the use of wild plant genetic resources from southern Sudan is scarce, although Andrews (1950–1956), Crowfoot

Table 1. Major domesticated plant species cultivated in southern Sudan with local names (Arabic unless stated otherwise), commodity groups and existence of related species in the region indicated

Species	Common name	Local name	Commodity group	No. of related species	Comments
**Sorghum bicolor* (L.) Moench	Sorghum	*Dura*	Cereal	8	The major cereal of the region
**Pennisetum glaucum* (L.) R. Br.	Pearl millet	*Dukhn*	Cereal	9	
**Zea mays* L.	Maize	*Esh er rif*	Cereal	0	
**Eleusine coracana* (L.) Gaertn.	Finger millet	*Telabun*	Cereal	1	*E. indica* (L.) Gaertn. is a major weed
**Oryza sativa* L.	Rice	*Ruz*	Cereal	5	Several species harvested wild
**Manihot esculenta* Crantz	Cassava	*Bafra*	Tuber, leaf	0	Semi-naturalized
**Ipomea batatas* (L.) Lam.	Sweet potato	*Bambei*	Tuber, leaf	28	Several edible species, *I. hederacea* (L.) Jacq. (*milgat*), medicinal seeds
**Dioscorea alata* L.	Yam		Tuber	9	More than one edible species
**Colocasia esculenta* (L.) Schott	Taro	*Qulqas*	Tuber	0	
**Xanthosoma sagittifolium* (L.) Schott	Tannia		Tuber	0	
**Solanum tuberosum* L.	Potato	*Batata*	Tuber	10	Including *S. aethiopicum* L., garden eggs
Arachis hypogea L.	Groundnut	*Ful sudani*	Oil	0	
Sesamum indicum L.	Sesame	*Simsim*	Oil	2	*S. radiatum* Schumach. eaten as vegetable
Hyptis spicigera Lam.	Hard sesame	*Kino, kindi* (Bongo)	Oil	1	
Elaeis guineensis Jacq.	Oil palm	*Nakha al zayt*	Oil	0	Possibly indigenous
Ricinus communis L.	Castor	*Khirwa*	Oil	0	Cultivated and semi-naturalized
**Vigna subterranea* (L.) Verdc.	Bambara	*Ful abu ngawi*	Pulse	14	Wild and cultivated
Cajanus cajan (L.) Millsp.	Pigeon pea	*Ads sudani*	Pulse	0	
**Canavalia ensiformis* (L.) DC.	Sword bean	*Lubia el fil*	Pulse	0	
**Vigna unguiculata* (L.) Walp. ssp. *unguiculata*	Cowpea	*Lubia helu*	Pulse, fibre, vegetable	14	Wild and cultivated
**Phaseolus vulgaris* L.	Bean	*Fasulia, janjaro*	Pulse	2	
**Vigna mungo* L. Hepper	Black gram	*Balilla*	Pulse	14	
**Vigna radiata* (L.) Wilczek	Green gram	*Balilla*	Pulse	14	
**Phaseolus lunatus* L.	Lima bean	*Fasulia arida*	Pulse	2	
Coffea canephora Pierre ex Froeh.	Coffee	*Bun*	Stimulant	4	Wild and cultivated robusta coffee and possibly *C. arabica* L.
Camellia sinensis (L.) Kuntze	Tea	*Shai*	Stimulant	0	
Nicotiana tabacum L.	Tobacco	*Tombak*	Stimulant	1	*N. rustica* L. widespread

Table 1. *Continued*

Species	Common name	Local name	Commodity group	No. of related species	Comments
Cannabis sativa L.	Indian hemp	*Bangi*	Stimulant, fibre	0	Illegal narcotic
Hibiscus sabdariffa L.	Roselle	*Kerkade*	Beverage, fibre, vegetable	22	Wild and cultivated
Saccharum officinarum L.	Sugarcane	*Qassab sukar*	Confection	1	
Gossypium L. spp.	Cotton	*Qutn*	Fibre	2	
Hibiscus cannabinus L.	Kenaf	*Til*	Fibre	22	Wild and cultivated
**Musa* L. spp.	Banana	*Moz*	Fruit	1	*Ensete ventricosum* (Welw.) Cheese.
Mangifera indica L.	Mango	*Manga*	Fruit	0	
Ananas comosos (L.) Merrill	Pineapple	*Ananas*	Fruit	0	
**Citrus* L. spp.	Citrus, orange, lime	*Bortugan, limun*	Fruit	0	
Psidium guajava L.	Guava	*Gawafa*	Fruit	0	
Carica papaya L.	Papaya	*Babaia*	Fruit	0	
Lycopersicon esculentum Mill.	Tomato	*Tematim*	Vegetable	0	
Abelmoscus esculentus (L.) Moench	Okra	*Bamia, weika*	Vegetable	22	Wild and cultivated. Leaves eaten (*sabarok*)
**Solanum melongena* L.	Aubergine	*Bedingan*	Vegetable	10	
Capsicum frutescens L.	Chillie	*Shatta*	Vegetable	0	Cultivated and naturalized
Corchorus olitorius L.	Jew's mallow	*Melukhiya*	Vegetable, fibre	3	

* Genera included in the International Treaty on Plant Genetic Resources for Food and Agriculture.

Table 2. Selected non-domesticated, neglected, underutilized, forgotten, famine food and potentially useful plant species of southern Sudan. Local names are indicated (Arabic unless stated otherwise) (indigenous, exotic and naturalized species are included)

Species	Common name	Local name	Commodity group	Comments, additional species in the genus[a]
Adansonia digitata L.	Baobab	*Tebeldi*	Vegetable, fibre, fruit	Not in the wetter areas
Aframomum luteoalbum (K. Schum.) K. Schum.	Grains of paradise		Spice	3 spp., indigenous cardamom substitute
Agave sisalana Perrine	Sisal		Fibre	
Amaranthus caudatus L.	Amaranth	*Bedibedi*	Vegetable	Wild and cultivated
Annona senegalensis Pers.	Custard apple	*Qishta*	Fruit	
Asystasia gangetica (L.) T. Anders.			Vegetable	
Azadirachta indica A. Juss.	Neem		Insecticide	Also *Melia aradirach* L. (Persian lilac)
Balanites aegyptiaca (L.) Del.	Desert date	*Lalob, heglig*	Fruit	
Basella rubra L.			Vegetable	Cultivated and wild
Bidens pilosa L.	Blackjack		Vegetable	6 spp., common weed
Borassus aethiopium Mart.		*Doleib*	Fruit, fibre	
Boscia senegalensis (Pers.) Lam. Ex Poir.		*Mokhet*	Fruit, medicine	
Canarium schweinfurthii Engler.	Incense tree		Fruit	Seeds edible when cooked
Capparis decidua (Forsk.) Edgew.	Caper	*Tundub*	Fruit	5 spp., including the edible *C. sepiata* L. var. *fischeri* De Wolf.
Carissa edulis (Forsk.) Vahl.			Fruit	
Ceiba pentandra (L.) Gaertn.	Kapok		Fibre	Young leaves eaten in Nigeria
Celosia argentea L.	Lagos spinach	*Danab el kalb*	Vegetable	4 spp., including *C. trigyna* L., also edible
Chrysophyllum albidum Don.			Fruit	
Citrullus L. spp.	Melon		Fruit	
Cleome gynandra L.	Cat's whiskers	*Tamaleika*	Vegetable	4 spp., common weed
Conyza aegyptica (L.) Ait.			Vegetable	
Cordia L. spp.		*Inderab, gimbil*	Fruit	5 spp.
Crassocephalum rubens (Juss.) S. Moore.			Vegetable	5 spp.
Crateva adansonii DC.		*Dabkar*	Fruit, medicine	
Crotalaria juncea L.	Sann hemp	*Til hindi*	Fibre	
Cucumis L. spp.	Cucumber		Vegetable	4 spp. and other *Curcurbitaceae*
Cyperus rotundus L.	Tiger nut	*Seid*	Vegetable	Widespread, serious weed. Numerous spp.
Dactyloctenium aegyptium Beauv.		*Umm asabi*	Cereal	

Table 2. *Continued*

Species	Common name	Local name	Commodity group	Comments, additional species in the genus[a]
Digera arvensis Forsk.	Amaranth	*Lablab ahmar*	Vegetable	
Dioscorea bulbifera L.	Aerial yam			9 spp.
Dolichos biflorus L.	Horse gram		Pulse	5 spp. including *D. lablab* L.
Echinocloa colona Link.		*Difra*	Cereal	
Ficus thonningi Bl.	Wild fig		Fibre	Cloth and fruit from many *Ficus* spp. (*qammaz*)
Funtumia elastica (P. Preuss) Stapf.	Lagos rubber		Exudate, fibre	
Garcinia buchanani Bak.			Fruit	1 spp. Related to *G. mannii* Oliv. (chewing stick), *G. kola* Heckel (bitter cola) of West Africa and mangosteen, *G. mangostana* L.
Gardenia erubescens Stapf. & Hutch.			Fruit	5 spp. *G. jovis-tonantis* Hiern. also edible
Grewia tenax (forsk) Fiori.		*Gaddem*	Fruit	7 spp. *G. mollis* Willd. (*basham*), fibre
Guizotia scabra (Vis.) Chior.			Oil	Niger wild relative
Haematostaphis barteri Hook. f.			Fruit	
Hydnocarpus wightii Blume			Essential oil	Leprosy treatment
Hyparrhenia edulis C. E. Hubbard		*Penze* (Zande)	Cereal	
Irvingia barteri Hook. f.			Fruit	1 spp. Related to African mango, *I. gabonensis* var. *excelsa* (Mildbr.) Okafor
Jatropha curcas L.	Physic nut		Oil	6 spp.
Lagenaria siceraria (Molina) Standl.	Bottle gourd	*Kpagu* (Zande)	Vegetable, utensil	Seeds used for flour
Landolphia owariensis P. Beauv. var. *tomentella* Stapf.	Zande rubber		Exudate, fruit	5 spp. of rubber-producing vine
Leianiodiscus cupanioides Olanch. Ex Benth.			Fruit	
Luffa cylindrica (L.) M. Roem.	Luffa	*Lif*	Vegetable, utensil	1 spp.
Momordica charantia L.	Bitter gourd	*Jereh*	Vegetable	7 spp.
Mondora myristica (Gaertn.)	Calabash-nutmeg		Fruit, spice, medicine	2 spp. Edible seeds and pulp. Ghana exports
Moringa oblongifolia (Forsk.) A. Rich.	Horseradish tree		Vegetable	
Mucuna pruriens (L.) DC.	Velvet bean		Pulse, fibre	1 spp.
Nauclea latifolia Sm.		*Karamadoda*	Fruit, medicine	
Nymphaea lotus L.			Vegetable	Seeds eaten
Oryza L. spp.	Wild rice	*Ruz el wadi*	Cereal	5 spp.
Phoenix reclinata Jacq.			Fruit	Date palm wild relative

Table 2. *Continued*

Species	Common name	Local name	Commodity group	Comments, additional species in the genus[a]
Piper guineense Schumach.	Bush pepper		Vegetable	2 spp.
Portuluca oleracea L.	Purslane	*Rigla*	Vegetable	An ancient widespread leafy vegetable
Pseudospondias microcarpa (A. Rich.) Engler.			Fruit	
Psophocarpus palmettorum Guillem. & Perrott			Pulse	Winged bean, *P. tetrogonobolus* (L.) DC., wild relative
Pycnanthus angolensis (Welw.) Excell.	African nutmeg		Spice	Ghana exports
Salvadora persica L.	Toothbrush tree	*Arak*	Fruit, medicine	
Sanseviera Thunb. spp.	Bow-string hemp		Fibre	2 spp.
Sclerocarya birrea (A. Rich.) Hochst.	Marula	*Homeid*	Fruit	
Solanum nigrum L.	Nightshade		Vegetable	10 spp.
Sphenostylis stenocarpa (Hochst.) Harms.	African yam bean		Pulse, tuber	1 spp. Eaten in SW Nigeria (*otili*)
Sterculia setigera Del.	Kataya gum		Gum	
Strychnos spinosa Lam.			Fruit, gum, medicine	3 spp.
Syzygium guineense (Willd.) DC.			Fruit	
Tamarindus indica L.		*Tamar al hind*	Fruit	
Trichilia emetica Vahl.		*Umm shara*	Oil	3 spp.
Urena lobata L.	Congo jute		Fibre	
Vernonia L. spp.	Bitterleaf		Vegetable	25 spp. Favoured leafy vegetable in West Africa
Vigna vexillata (L.) Benth.	Zombi pea	*Babun*	Pulse, tuber	14 spp.
Vitellaria paradoxa C.F. Gaertn.	Shea	*Lulu*	Oil	
Vitex madiensis Oliv.			Fruit	Also *V. doniana* Sweet., fruit and medicine
Ximenia americana L.		*Kalto*	Fruit	
Zanha golungensis Hiern.			Fruit	
Ziziphus Mill spp.	Jujube	*Nabaq*	Fruit	5 spp. Several edible

[a] Additional species in the genus are often useful and represent the interspecific genetic resources available for crop improvement.

(1928), El Amin (1990) and Tothill (1948) provided information on edibility of some species. Davis *et al.* (1994) reported that there were over 1400 plant species in the Imatong mountains, representing nearly half the entire flora of Sudan. Friis and Vollensen (1998) reported on vascular plants of the Sudan–Uganda border east of the Nile and Sommerlatte and Sommerlatte (1990) on the trees and shrubs of the Imatong mountains of Sudan.

The major staple crops

The staple diet of southern Sudan consists of a thick porridge (*asida*) made from sorghum (*Sorghum bicolor* (L.) Moench), pearl millet (*Pennisetum glaucum* (L.) R. Br.), maize (*Zea mays* L.) or cassava (*Manihot esculenta* Crantz), accompanied by a sauce for which a wide variety of vegetables and pot-herbs are used. The centre of origin of sorghum and pearl millet includes Sudan, and this is reflected in the large number of wild relatives and presumed progenitors in the region (eight and nine, respectively; Table 1). While pearl millet is confined to the lower rainfall areas and sandy soils, sorghum is grown on the heavier soils where rainfall is higher. There is a huge range of sorghum types in southern Sudan, from the fast-maturing, short-stature varieties (e.g. *Serena*, a modern cultivar from Serere, Uganda that matures in 3 months) to the extremely tall long-maturing types (e.g. *Jeri*, *Dongo*, *Jokwaje*) and ratoon types. Low-tannin cultivars are generally preferred, but are more susceptible to damage from grasshoppers (the edible *Homocoryphus nitidulus vicinis* Wlk.) and birds than the dark kernel, high-tannin cultivars. Sweet sorghum varieties are also grown and could represent an opportunity to develop ethanol production as outlined by Rains *et al.* (1993).

Considerable research was done on sorghum, at least around Yei, in the early 1980s using imported germplasm and this has spread in the region along with sorghum introduced through food aid. Sorghum diversity in the region is substantial and although some material has been collected and is maintained by the International Centre for Research in the Semi-Arid Tropics (ICRISAT) and the ARC of Sudan (Mahmoud *et al.*, 1995), it is likely that farmers' fields of the region represent valuable *in situ* genebanks in terms of domesticated and wild sorghum species. This is also the case for pearl millet, but to a lesser extent inasmuch as southern Sudan is concerned, in comparison with the central regions. Constraints to sorghum production in the region are mainly striga, birds (*Quelea quelea* (L.)), sorghum midge (*Contarinia sorghicola* (Coquillett)) and a variety of phytopathogens. Variation for resistance to pests and diseases exists in the local germplasm and could be developed through selection and breeding. This would represent an ideal opportunity to share responsibility with farmers and tap into traditional knowledge through a participatory breeding programme. There would, moreover, be opportunities to produce sorghum grain on a larger scale for export to neighbouring countries and for the regions of Sudan where the sorghum harvest is less reliable.

Maize is a popular introduced cereal in southern Sudan, often eaten boiled or roasted green. There are no wild relatives in the region and maize does not survive off-farm. Many white and yellow kernel flint open-pollinated varieties have entered the region from Kenya, Uganda and the Democratic Republic of the Congo, and from further afield. Cassava, like maize, is of American origin, but unlike maize has become semi-naturalized to the extent that there is considerable diversity in the crop in the field. Long-season and short-season types (*Karangwa*, a bitter type, being the most popular) are cultivated and there are bitter and sweet varieties. The leaves are a favoured pot-herb in addition to the tubers being eaten directly after boiling (sweet types) or processed into flour after retting to remove prussic acid (bitter types). Cassava is used as an insurance against failure of other staple crops as it can remain in the ground for extended periods. Major problems encountered in cassava production are Cassava Mosaic Virus and bacterial leaf blight (*Xanthomonas manihotis* (Arth.-Ber.) Starr.), but there is probably variation for resistance traits that could be exploited to produce better-adapted cultivars.

Upland rice (*Oryza sativa* L.) is grown in the wetter areas of the green belt and in the more central areas of the Nile flood plain, including its tributaries. Five wild relatives grow in the region (Table 2) and several are harvested from the wild and represent important sources of grain. Other grains harvested and consumed similarly to the wild rices include *Echinocloa colona* Link. (*difra*) and *Dactyloctenium aegyptium* Beauv. (*umm asabi*). These are particularly important as famine foods, but are also harvested outside of times of famine. Other grasses have edible seeds, although little has been recorded about them. De Schlippe (1956) reported that the Zande harvested seed of *Hyparrhenia edulis* C. E. Hubbard, termed *penze*. Accessions of some wild rice species from Sudan are maintained at the International Rice Research Institute (IRRI), but there remains a great deal of diversity in the *Oryza* gene pool *in situ*. Rice suffers from relatively few pests and diseases in the region, but blight (*Pyricularia oryzae* Cavara) does occur. The major constraint to upland rice is its labour-intensive management and lack of hulling facilities (grains are traditionally hulled in a *funduq*, a wooden pestle and mortar). Robinson (1997b) reported the superiority of introduced cultivars over a selection of farmers' cultivars.

Finger millet, *Eleusine coracana* (L.) Gaertn., is a characteristic crop of southern Sudan. Although labour-intensive at the seedling stage due to the presence of its wild relative *E. indica* (L.) Gaertn., from which it is difficult to distinguish during its seedling stages, it is favoured for beer-making and pancakes (*kisra*), and in contrast to the other cereals is relatively resistant to storage pests and diseases. Many local types are grown under a variety of names (*Biringi* and *Giiru* being two), and the species generally thrives in the region when adequately weeded at the seedling stage. Other staples of the area include the yam *Dioscorea alata* L., and aerial yam (*D. bulbifera* L.) is also cultivated and harvested from the wild where it occurs with nine related species. Little is recorded about these. Taro, or old cocoyam (*Colocasia esculenta* (L.) Schott.), and tannia, or new cocoyam (*Xanthosoma sagittifolium* Schott.), are also cultivated but are introduced species without wild relatives in the region. Potato (*Solanum tuberosum* L.) was introduced into the higher areas and successfully cultivated, although it is the 10 wild *Solanum* species, including *S. aethiopicum* L. and *S. nigrum* L., that merit greater attention (Edmonds and Chweya, 1997) and for which indigenous germplasm could be developed. Africa is not the centre of origin of *Ipomea* L., but the genus is represented by 28 species in southern Sudan. Several of the lesser-known species are edible and some have medicinal properties. The inter- and intra-specific diversity in the genus represents a valuable reserve of germplasm for sweet potato improvement, development of new crops and a source of nutrition in its own right.

Pulses

Several major pulse crops are listed in Table 1. Cowpea, *Vigna unguiculata* (L.) Walp., is most important in the drier regions and common bean (*Phaseolus vulgaris* L.) in the wetter regions. Cowpea is a favoured pulse, serves as a leafy vegetable and its peduncles are used as a natural fibre. *Vigna* L. is represented by numerous species in the region, including bambara groundnut (*V. subterranea* (L.) Verdec.), which occurs wild and is cultivated. Zombi pea (*Vigna vexillata* (L.) Benth.) grows wild in the region and produces an edible pulse and tuber. Nearly 200 accessions of *V. vexillata* from Nigeria are maintained at the International Institute for Tropical Agriculture (IITA) in Nigeria, indicating its importance. The various *Vigna* species represent useful germplasm for plant breeding programmes and as with most plant genetic resources of the area merit greater study. Interestingly, winged bean (*Psophocarpus tetrogonobolus* (L.) DC.), often suggested to be the all-purpose crop of the tropics, has an edible wild relative in southern Sudan, *P. palmettorum* Guillem. & Perrott. Another high protein legume that produces a pulse and an edible, nutrient-rich (high lysine and methionine) tuber is *Sphenostylis stenocarpa* (Hochst.) Harms., the African yam bean, which grows wild in southern Sudan with its close relative *S. schweinfurthii* Harms. There was a call for germplasm collection of African yam bean with a view to its selection and improvement (National Academy of Sciences, 1979). More than 100 accessions are maintained at IITA, but none is from southern Sudan.

Oil crops

A range of introduced and indigenous oil crops occurs in the area, which represent great potential for oil crop production in general. Andrews (1950–1956) speculated that oil palm (*Elaeis guineensis* Jacq.), which was introduced into the area, was actually indigenous. It grows well and produces an oil rich in carotene (vitamin A precursor) and vitamin B that benefits the diet of those that consume it in the southernmost regions. *Vitellaria paradoxa* C. F. Gaertn., the shea nut tree, grows wild throughout the region and produces a highly valued oil-rich nut. It has not been consciously managed or selected in the area and there doubtless exists useful variation that could be exploited in selection programmes. Indigenous human populations have been associated for a very long time with such wild species and although it is unlikely that there has been positive selection for improved cultivars, there has no doubt been negative selection as undesired types have been neglected and in the case of trees, have gone to the fire.

The groundnut, *Arachis hypogea* L., is a widespread and important crop of the area. It is an introduced species, originally from Latin America, and does not have wild relatives in the region. However, the crop has been grown in the region for a long time and there is considerable diversity in germplasm that could still be exploited in selection programmes, particularly for adaptation to intercropping (Robinson, 1997b) as well as for oil production and disease resistance. Two indigenous crops, sesame (*Sesamum indicum* L.) and hyptis (*Hyptis spicigera* Lam.), are cultivated extensively in southern Sudan and both have several wild relatives. Mahmoud *et al.* (1995) suggested that Sudanese sesame genetic resources could be usefully used for crop improvement in Sudan and abroad. Within cultivated sesame there is considerable variation for many agronomically important traits, including seed colour, oil content and plant type. It is also likely that there exists variation for resistance to sesame's major pest in the area, gall midge (*Aspondylia sesami* Felt.). Hyptis is relatively

pest- and disease-resistant, although its oil is less appreciated than that of sesame. It might have medicinal properties, however, as does a related species (*Hyptis pectinata* L. Poit.) used as a medicine in Ecuador (Cragg *et al.*, 1993). *H. pectinata* is also native to Sudan, growing in the west-central area of the country.

Castor, *Ricinus communis* L., once cultivated and now semi-naturalized, occurs throughout the region and is still a source of highly valued industrial oil (Brigham, 1993), although not in Sudan. Six wild relatives of the naturalized physic nut (*Jatropha curcas* L.), introduced from the Americas, also grow wild in the region and could merit research for their oil products and plant breeding potential. Heller (1996) quoted Rudolf Diesel, the inventor of the diesel engine, from 1911, saying 'it is generally forgotten that vegetable and animal oils can be used directly in diesel engines' and goes on to mention success with groundnut oil. Southern Sudan is isolated and has very poor communication systems. Fuel is likely to be a constraint to development for a long time. Substitute diesel production appears attractive. The author has experience with diesel engines in the area run on freshly pressed sunflower oil (*Helianthus annuus* L., successfully grown at Yei in the early 1980s), which is much easier to express than groundnut oil (requires heating the nuts). Although the oil crop niger, *Guizotia abyssinica* (L.f.) Cass., a member of the Compositae like sunflower, does not occur in southern Sudan (except possibly along the Ethiopian border), its wild relative *Guizotia scabra* (Vis.) Chior. does, and represents a part of the gene pool that Getinet and Sharma (1996) suggested be evaluated and used to improve niger. A substitute for diesel fuel would not only benefit transport and marketing in southern Sudan, but could also be used to power the all-essential grain hullers and mills that would provide an extra fillip to general economic development in the region.

Fruits and vegetables

Southern Sudan has climatic and soil conditions that allow cultivation of a wide range of introduced tropical and subtropical fruits and vegetables, as indicated in Table 1. Fruits of commerce include all the major species of *Citrus* L., mango (*Mangifera indica* L.), pineapple (*Ananas sativus* Schult.), various types of banana and plantain (*Musa* L. spp.), guava (*Psidium guajava* L.) and papaya (*Carica papaya* L.). In the Yei area there were isolated examples of avocado (*Persea americana* Mill.) and breadfruit (*Artocarpus altilis* (Park.) Fosberg). Although wild relatives of those exotic species do not grow in the region, with the exception of a wild relative of banana, *Ensete ventricosum* (Welw.) Cheese., the edible African breadfruit, *Treculia africana* Decne., does occur in the wild and there is a wild relative of the custard apple (*Annona* L. spp.), *A. senegalensis* Pers., which is common in the south. A close relative of the African mango, *Invingia gabonenesis* var. *excelsa* (Mildbr.) Okafor, *I. bateri* Hook. f., is also native to southern Sudan. Were roads and marketing systems developed, any one of the domesticated fruits could be grown for commerce and there could be potential markets for indigenous fruits.

What southern Sudan lacks in indigenous commercial fruit species it makes up for in wild species, some of which are listed in Table 2. Fruits such as marula, *Sclerocarya birrea* (A. Rich.) Hochst., have been established in Israel (Nerd and Mizrahy, 1993) and there are numerous multipurpose trees, including *Borassus aethiopium* Mart. and *Grewia* L. spp., both supplying fruit and fibre. For several genera, including *Grewia*, there are several related species about which little is recorded. Even date palm, *Phoenix dactylifera* L., has a wild relative (*P. reclinata* Jacq.) in the region. The shrub *Vitex madiensis* Oliv. and the tree *V. doniana* Sweet. both produce edible fruits. The natural vegetation contains numerous edible fruit-producing species, which are prized locally, but little appreciated outside the region. Wild blackberry, *Rubus steudneri* Schweinf., is found in abundance in the Imatong mountains. Wild species might be used in crop improvement, where related to commercial crop species. The wild species themselves doubtless contribute to food security and dietary diversity, but there may be real possibilities for developing and marketing new fruit crops, as has been attempted for marula.

Vegetables constitute the sauce that accompanies *asida* and are a major source of vitamins and nutrients that have a direct bearing on the health of the population. A large range of exotic naturalized and indigenous vegetables grow in southern Sudan. The major domesticated crop species are listed in Table 1, but only a small selection of the enormous numbers of indigenous leaf vegetables are listed in Table 2. There are numerous species in several genera that are important in the area, including those of *Hibiscus* L. and *Solanum* L., some of which are of importance beyond Africa. The genus *Hibiscus* contains species such as roselle (*Hibiscus sabdariffa* L.) and kenaf (*Hibiscus cannabinus* L.). Taylor (1993) suggested that kenaf represented an emerging new fibre crop industry. Species such as cat's whiskers, *Cleome gynandra* L., have attracted attention more recently with a view to diversification of leafy vegetables for improved human nutrition (Chweya and Mnzava, 1997). Knowledge of its related species, of which four grow wild in southern Sudan, will be important in any

future selection and breeding programmes. The same is true for many other species including bitterleaf, *Vernonia* L. spp. (Schippers and Budd, 1997), which is represented by 25 species in southern Sudan. For the vast majority of the traditional vegetables little has been recorded to date, but maybe it will be possible to rectify the situation if the region becomes accessible once again. The indigenous vegetable genetic resources are intrinsically bound with indigenous local knowledge of the vegetation and its uses, much of which has yet to be recorded and reported.

Cash crops

Southern Sudan was once a major grower of cotton, *Gossypium* L. spp., which was produced for export. Other cash crops have included coffee, *Coffea canephora* Pierre ex Froeh., which with its wild relatives occurs in some the forests of the region, and tea, *Camellia sinensis* (L.) Kuntze., which was grown in the Imatong mountains and at a single site south of Yei (Iwatoka). Tobacco, *Nicotiana tabacum* L., is grown on a small scale, but prior to hostilities there was a national corporation growing it on a larger scale in the south. The civil war disrupted these enterprises, which theoretically in the case of coffee, tea and tobacco could be revived under stable conditions. Interestingly, the region contains germplasm of formerly important cash crops, including Zande rubber (*Landolphia owariensis* var. *tomentella* Stapf.), Lagos rubber (*Funtumia elastica* (P. Preuss) Stapf.), kapok (*Ceiba pentandra* (L.) Gaertn.) and Congo jute (*Urena lobata* L.). Three species related to the cardamom substitute, grains of paradise, *Aframomum melegueta* (Roscoe) K. Schum., once a commercial crop, grow in southern Sudan. If nothing else, these species represent the past potential of the area and may one day become important sources of germplasm should there be a revival in the fortunes of some of these former crops. The amount of genetic diversity for these indigenous and naturalized species has never been gauged, but is probably considerable.

Germplasm collection, recording indigenous knowledge and crop development and improvement

As southern Sudan has been a war zone for more than 40 years, it has not been possible to undertake thorough species inventories, let alone collect there. With the exception of project reports, often unpublished, and if published largely unavailable, little detailed work on plant genetic resources of the region has been undertaken since pre-independence. Not only is detailed botanical information lacking, but the accompanying indigenous knowledge is also generally absent. Ethnobotanical research will be necessary to unlock oral knowledge of indigenous use of plant resources. This will be needed not only for food plants but also for medicinal and toxic species. Such knowledge will assist in efforts to establish sustainable agriculture and stimulate development in the region. There is currently tremendous interest in neglected and underutilized plant species, as evidenced by several publications referred to in this paper. If there is a halt to the war it will present a timely opportunity to undertake such work.

It will be useful to record species distributions and get an appreciation of the diversity in germplasm of important and potentially important plant species in southern Sudan. Some localized species, those of coffee for example, which form part of the gene pool of a globally significant crop, might be threatened (or even extinct) as their environments, cloud and gallery forests, are encroached on and damaged. The effect of human impact on fragile environments needs to be known to design effective conservation strategies. Draulens and van Krunkelsven (2002) reported the considerable impact of war on forest-dwelling animals of the Democratic Republic of the Congo, but indicated that commercial logging often came to a halt in times of war. Despite decades of war failing to have an impact on Salonga, the world's second largest tropical rainforest, in the Democratic Republic of the Congo, it is peace, allowing commercial logging, which represents the greatest threat to biodiversity (Anon., 2004). Southern Sudan is similar to the Democratic Republic of the Congo, with which it shares a border, in many respects.

Sudan is a signatory of the United Nations Convention on Biological Diversity, which aims to conserve biological diversity, promote sustainable use of its components, and encourage fair and equitable sharing of benefits from using genetic resources. This should help ensure that the precious plant genetic resources of southern Sudan are conserved. Moreover, Sudan has ratified the International Treaty on Plant Genetic Resources for Food and Agriculture. When this comes into force, it will provide a globally agreed mechanism for exchange of and benefit sharing for selected crops vital to agriculture and food production. Several of the crops and their wild relatives included in Table 1 will become accessible through a multilateral system of germplasm exchange and could become available to researchers and plant breeders to improve food security in Sudan and elsewhere. The overriding assumption is that conservation of biodiversity through use (of plant genetic resources) will be compatible with economic development. This can only be gauged retrospectively.

Conclusion

This article has touched on a fraction of the plant genetic resources of southern Sudan that could be important for sustainable agricultural development in the region and beyond. Virtually nothing has been said about the timber resources, forages, medicinal plants, ornamentals and plants of cultural value, but these too represent rich sources of genetic diversity that could be included in any future research and development programmes. Mahmoud *et al.* (1995) listed numerous plant species from various commodity groups for the whole of Sudan, some of which occur in the south. Regarding ornamentals alone, there are more than 20 orchid species in southern Sudan, a cycad (*Encephalartos septemtrionalis* Schweinf.), tree ferns (including *Cyathea deckenii* Kuhn), attractive shrubs and trees, and a variety of other potentially commercially interesting plants. *Lophira alata* Banks ex Gaertn. f., which grows in southern Sudan, was found to contain two compounds that inhibited Epstein-Barr virus, one of which blocked tumour promotion (Murakami *et al.*, 1992). *Erythrophleum guineense* G. Don., the ordeal tree or sassy bark, produces an analgesic alkaloid (Davis *et al.*, 1994) that has been used in dentistry and is used locally. There are likely to be other indigenous plant species in southern Sudan that have potential in medicine.

Given the abundant plant genetic resources, ample land, relatively low population density and favourable environment, there is no reason why southern Sudan should become the 'dustbowl of Africa', as feared by Wickens (1991) for Sudan in general, and not still become the 'breadbasket'. Even if this is an over-optimistic scenario, when the war is truly over, southern Sudan should be able to develop an effective agriculture-based economy built on the existing wealth of plant genetic resources.

Acknowledgements

The author lived and worked in southern Sudan (Yei) between 1982 and 1985. Much of the information contained in this article draws on that experience. Many Sudanese colleagues contributed to crop research in the region and to the author's opportunity to gather information on plant genetic resources. The war destroyed their lives and their work. They are sincerely thanked.

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