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GUEST EDITORIAL

Pests and integrated pest management in western Equatoria, southern Sudan

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Abstract. Southern Sudan has tremendous agricultural potential, particularly in the high rainfall green belt of western Equatoria that borders the Democratic Republic of the Congo. A wide range of tropical and semi-tropical crops is grown there in a variety of complex cropping systems. Although a long civil war severely disrupted agriculture in the region, there is now hope that the recent peace accord will return stability and agriculture will remain a mainstay of a revived economy in western Equatoria. The environment supports crop production, but pests and diseases also thrive, although very little has been recorded about them. This article represents the sole record of an agricultural insect pest collection and disease notes assembled at Yei over several years in the early 1980s, but which were destroyed during the civil war. It is hoped that these notes will be useful in addressing biotic constraints to rehabilitation of agriculture in western Equatoria. Traditional methods of pest and disease management will be particularly important given the poor state of the economy, the need to produce crops for subsistence farming and the relative geographical isolation and poor communications that characterize southern Sudan.

Key words: agriculture, diseases, pests, integrated pest management, southern Sudan

Résumé. Le sud du Soudan offre d'énormes potentialités de développement agricole, en particulier dans la ceinture verte humide de la région Ouest de l'Equateur qui borde la République Démocratique du Congo. Une large gamme de cultures tropicales et subtropicales y est cultivée selon une grande variété de systèmes culturaux complexes. Bien qu'une longue guerre civile ait sévèrement perturbé l'agriculture de la région, il y a maintenant un espoir que les accords de paix récemment signés rétablissent la stabilité et que l'agriculture puisse constituer la base d'un renouveau économique dans l'Ouest de l'Equateur. L'environnement est favorable á la production agricole, mais également au développement des ravageurs et des maladies, bien que nous ayons très peu d'informations. Cet article constitue une source unique d'informations sur les insectes ravageurs et les maladies des cultures répertoriées pendant plusieurs années au début des années 80 dans la région de Yei, mais dont les notes ont été détruites pendant la guerre civile. On espère que ces notes seront utiles pour identifier les contraintes biotiques et permettre la réhabilitation de l'agriculture dans l'Ouest de l'Equateur. Les méthodes traditionnelles de gestion des ravageurs et des maladies seront particulièrement importantes compte tenu du mauvais état de l'économie, du besoin de produire des

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cultures de subsistance, du relatif isolement géographique et des mauvaises communications qui caractérisent le sud du Soudan.

Mots clés: agriculture, maladies, ravageurs, gestion intégrée des cultures, sud Soudan

Introduction

Sudan became independent from Egypt and Great Britain in 1956, but shortly afterwards, civil conflict between the north and the south erupted. The troubles have continued more or less unabated over the past 47 years (Salopek and Olson, 2003). Given the optimism following the recent peace negotiations, there could be an opportunity for the south to realise its potential for agricultural production and for agriculture to contribute to development of the region.

Several agricultural rehabilitation projects operated in southern Sudan in the 1980s during a lull in the conflict. The Equatoria Region Agricultural Project, based in the green belt at Yei (4°N, 30.2°E), was one such project. Over several years an agricultural insect pest collection was built up; many specimens were identified by experts in specialist institutions. This author rehabilitated the collection in 1984, drew the species and recorded notes on them (Robinson, 1985). Notes were also made on the major plant pathogens in the region. The Equatoria Region Agricultural Project was evacuated in 1986 and the pest collection and disease notes that remained there were lost during the upsurge in hostilities. This article is based on copies of the notes that were retained. If agriculture is to be rehabilitated again in western Equatoria, these notes and observations will be useful, given that no readily available information exists on pests and diseases of the region since those published by Tothill (1948) and Schmutterer (1969). This article discusses the principal biotic constraints to crop production in western Equatoria in relation to crop management.

The environment

There are three major ecological zones in southern Sudan: tropical rainforest, along the border with the Democratic Republic of the Congo; tropical moist forest, along the borders with the Central African Republic and Uganda; and tropical dry forest, from the Chad border in the west across to the Ethiopian border in the east. There are also areas of tropical scrubland and tropical mountain forest. Cloud forest is present along rivers; depression forest also exists and large areas of swamp surround the Nile. Wickens (1991) described the natural vegetation of the region in greater detail. 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 ranging from around 600 mm pa to over 1300 mm pa. Rainfall is bimodally distributed in the extreme south, resulting in a >250-day cropping season, permitting two main crops a year to be grown. Mitchell (1991) described the soils of the region and Walsh (1991) the hydrology.

Agriculture in southern Sudan

The standard text on agriculture in Sudan remains Tothill (1948). De Schlippe (1956) described the cropping systems of the Zande in the green belt area bordering the Democratic Republic of the Congo, but mainly from a sociological perspective. Dickie (1991) described farming systems of southern Sudan, but little mention was made of biotic constraints to production.

Farming systems in southern Sudan are complex and differ across the region according to environment and tribe. In western Equatoria livestock is mainly limited to goats (*Capra hircus* L.) and shifting, crop-based agriculture is the norm. The presence of tsetse fly *Glossina moristans* Westwood (Diptera: Glossinidae) in the region restricts cattle ownership. Farming is almost exclusively done by subsistence-level smallholders. Excess yield is marketed locally to generate income. Small parcels of land are cleared of vegetation by hand and a range of crops sown. After several seasons, during which the soil becomes exhausted and weeds become a problem, new areas are opened up.

The cropping systems of southern Sudan are based on a wide range of domesticated species. Myers (Tothill, 1948) recorded 68 crops from a single Zande settlement and frequently 10–15 crops are intercropped in a single field. The intercropping systems are designed to suit particular soil and climate conditions and tribal practises. Robinson (1997a,b) reported on the results of intercropping experiments done at Yei and on the plant genetic resources of the area (Robinson, 2004). One of the principal features of the intercropping systems is that they represent an insurance against crop failure from abiotic and biotic stresses. In this respect there is a solid appreciation of the consequences of pests, diseases and weeds.

Crops grown during the first rains include maize (*Zea mays* L.) and groundnuts (*Arachis hypogea* L.), which are sown in March–April. Long-season sorghum (*Sorghum bicolor* (L.) Moench) and cassava (*Manihot esculenta* Crantz) can be sown until September. Short-season sorghum (3 months), sesame (*Sesamum indicum* L.), upland rice (*Oryza sativa* L.) and finger millet (*Eleusine coracana* (L.) Gaertn.) are second-rains crops. Cowpeas (*Vigna unguiculata* (L.) Walp. ssp. *unguiculata*) and beans (*Phaseolus vulgaris* L.) are sown throughout the season. Dickie (1991) provided more details of cropping patterns in the region. Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is confined to the drier areas of the north and west. The effects of staggered sowing and harvests are to reduce the damage done by pests, diseases and weeds; intercrops are generally sown into a main crop at the first or second weeding. Cash crops, including tobacco (*Nicotiana tabacum* L.) and coffee (*Coffea canephora* Pierre ex Froeh.), were grown in the past on a larger scale and production could be resumed when there is greater stability in the region.

Fruit crops are common in the region and include mango (*Mangifera indica* L.), *Citrus* spp., guava (*Psidium guajava* L.), banana (*Musa* spp.), papaya (*Carica papaya* L.) and pineapple (*Ananas comosos* (L.) Merrill). Many vegetable crops are also grown around the homesteads (Robinson, 2004). Cotton (*Gossypium* spp.) was formerly a major cash crop of western Equatoria and was host to numerous important pest species, many of which are associated with other crops cultivated in the region.

Biotic constraints to crop production

Biotic constraints to agricultural production in western Equatoria include insect pests (the main group), plant pathogens and weeds. All crops are to various extents affected by representatives of all three categories, but the damage that they cause largely depends on additional factors such climate and crop management. Examples of the pests, diseases and weeds present in southern Sudan were described by Kranz *et al.* (1978), while Schmutterer (1969) described some of the insect pests.

Arthropod pests

A list of the most prevalent and important pests (all but one are insects) of the major crops grown in western Equatoria is given in Table 1. The list is based on the collection made at Yei that was lost during civil disturbances in the area after 1985. The pests included many polyphagous species and others that fed only on particular host species.

Many crop pests were present throughout the year. Pest build-up on first-rains crops might have resulted in carry-over to the second rains crops, however, as the cropping patterns during the second rains do not generally duplicate those of the first in species compositions, it was usually only the generalist pests that had a greater effect during the second rains. The termites *Macrotermes bellicosus* (Smeath.) and edible grasshoppers *Homocoryphus nitidulus vicinus* (Walker), both polyphagous pests that can cause substantial damage to a range of crops, are valuable sources of protein in the human diet. The grasshoppers arrived in November, as sorghum grain was maturing, and were enthusiastically harvested and consumed. The termites were similarly harvested during their nuptial flights in May and eaten. Harvesting these two pest species did not have a significant impact on their deleterious effects on crops. Through their feeding on developing grains, of sorghum in particular, the grasshoppers allowed infection by many fungal pathogens. Various species of grasshopper fed on finger millet foliage, which was otherwise less affected by pests than other crops.

There were many Homoptera crop pests in western Equatoria. Scale insects and mealybugs were present on a range of crops, particularly citrus and coffee, where they were extremely damaging. Some virus diseases were spread by Homoptera including maize streak virus by *Cicadulina mbila* Naudé. Aphid species were numerous, although only the four most common are listed in Table 1. Citrus was usually infested with aphids and in common with other fruit trees suffered also from feeding of a range of scale insects and mealybugs (Table 1). The groundnut aphid, *Aphis craccivora* Koch, was particularly problematic as the vector of groundnut rosette, the most serious disease of groundnuts in the region. *Bemisia tabaci* (Gennadius) was a cosmopolitan pest species found on a range of crops, especially vegetables, but caused most damage as a vector of cassava mosaic virus disease, the most widespread and important disease of cassava in western Equatoria.

Species of Heteroptera were numerous and many, such as *Nezara viridula* Linnaeus, are polyphagous. Some, including *Stencoris southwoodi* Ahmad, were found mainly on a single crop, in this case rice, but fed on numerous weeds associated with crops. It is likely that many of these bugs transferred fungal pathogens, including *Nematospora* spp., or at least through their feeding allowed fungal pathogens to infect damaged plants. The andat bug (*Agnoscelis pubescens* Thonn.) of sorghum was present and was capable

Table 1. Major arthropod pests of western Equatoria, southern Sudan

Order, family	Species	Common name	Comments+
Isoptera			
Termitidae	*Macrotermes bellicosus* (Brug.)	War-like termite	Polyphagus but particularly problematic on maize and sorghum, eating through base of stalks. Swarming adults eaten in May.
Termitidae	*Microtermes thoracalis* Sjöst.	Cotton soil termite	Common and serious pest of groundnuts.
Orthoptera			
Gryllotalpidae	*Gryllotalpa africana* Pal. Beauv.	Mole cricket	Pest of seedlings and tuber crops.
Tettigoniidae	*Homocoryphus nitidulus vicinus* (Wlk.)	Edible grasshopper	Favours sorghum grain during November; cut surfaces colonized by grain moulds. Valued food source.
Acrididae	*Nomadacris septemfasciata* (Serv.)	Red locust	Polyphagus, but particularly problematic on cereals.
Acrididae	*Zonocerus variegatus* (L.)	Elegant grasshopper	Pest of seedlings, particularly cassava.
Hemiptera			
Aphididae	*Aphis craccivora* Koch	Groundnut aphid	Polyphagus, but transmits groundnut rosette virus among several other viruses.
Aphididae	*Aphis gosypii* Glov.	Cotton aphid	Infests a large range of crops.
Aleyrodidae	*Bemisia tabaci* (Genn.)	Tobacco whitefly	Pest of tobacco, tomato, sweet potato and cassava. Vector of cassava mosaic virus.
Diaspididae	*Chyrsomphalus ficus* Ashm.	Florida red scale	Found on leaves of most fruit trees, but particularly citrus, mango and guava.
Cicadellidae	*Cicadulina mbila* Naudé	Maize leafhopper	Transmits maize streak virus.
Coccidae	*Coccus* spp.	Soft scales	Several species found on coffee, mango and citrus. Further problem caused by *Oecophylla* spp. (Hymenoptera: Formicidae) that farm them.
Pseudococcidae	*Dysmicoccus brevipes* (Ckll.)	Pineapple mealybug	Pest of pineapple, but particularly important pest of groundnuts.
Coccidae	*Gascardia brevicauda* (Hall)	White waxy scale	Present on citrus and coffee.
Monophlebidae	*Icerya aegyptica* (Dgl.)	Egyptian fluted scale	Present on citrus, coffee and guava.
Cercopidae	*Locris affinis* (Haglund)	Red leafhopper	Sucks sap from a wide range of crops, including rice, maize and sorghum.
Aphididae	*Melanaphis sacchari* (Zhnt.)	Dura aphid	Common on sorghum.
Delphacidae	*Peregrinus maidis* (Ashm.)	Maize leafhopper	Common on maize.
Pseudococcidae	*Planococcus citri* (Risso)	Citrus mealybug	Serious pest of citrus and coffee.
Cercopidae	*Poophilus costalis* (Wlk.)	Brown froghopper	Pest of maize and sorghum.
Aphididae	*Toxoptera citricidus* (Kirk.)	Citrus aphid	Common on all citrus.
Coccidae	*Unaspis citri* (Comst.)	Citrus snow scale	Serious pest of citrus.
Coreidae	*Acanthomia* spp.	Spiny brown bugs	Serious pest of pulses, which become colonized by fungal pathogens following feeding.
Pentatomidae	*Acrosternum* spp.	Spiny green bugs	Feed on developing seeds of numerous crops.
Pentatomidae	*Agnoscelis pubescens* (Thunb.)	Cluster (andat) bug	Serious pest of sorghum, sunflower and sesame.
Coreidae	*Anoplocnemis curvipes* (F.)	Twig wilter	Feeds on terminal shoots of many crops, but a particular pest of pigeon pea.
Pentatomidae	*Aspavia armigera* (F.)	Three-spot shield bug	Extremely common on many crops, year round.

Table 1. *Continued*

Order, family	Species	Common name	Comments[+]
Pentatomidae	*Atelocera spinulosa* (Pal. Beauv.)	Spiny legged bug	Pest of sesame.
Pentatomidae	*Bagrada* spp.	Harlequin bugs	Feed on leaves of *Brassica* spp., groundnuts and okra.
Pentatomidae	*Calidea* spp.	Blue bugs	Present on sorghum and sesame.
Pyrrhocoridae	*Dysdercus* spp.	Cotton stainers	Pests of sorghum and millet.
Miridae	*Helopeltis schoutedeni* (Reut.)	Cotton helopeltis	Many tree crops and legumes damaged.
Coreidae	*Mirperus jaculus* Thunb.	Bean bug	Feed on legume pods and tender growing points.
Pentatomidae	*Nezara viridula* (L.)	Green stink bug	Var. *smaragdula, torquata* and *viridula* present. Pest of numerous crops.
Lygaeidae	*Oxycarenus hyalipennis* (F.)	Cotton seed bug	Severe pest of okra.
Coreidae	*Spilostethus rivularis* (Germar)	Red and black bug	Suck sap from developing grains of sorghum and millet.
Coreidae	*Stencoris southwoodi* (Ahmad)	African rice bug	Feed on developing grain and shoots of rice, but present in large numbers on wild *Amaranthus* spp.
Lygaeidae	*Taylorilygus vosseleri* (Popp.)	Lygus bug	Pest of virtually all crops.
Lepidoptera			
Pyraustidae	*Antigastra cataunalis* (Dup.)	Sesame leaf roller	Frequent pest of sesame.
Noctuidae	*Busseola fusca* (Full.)	Maize stalk borer	Common pest of maize and sorghum.
Sphingidae	*Cephonodes hylas* L. *virescens* Wall.	Oriental bee hawk moth	Larvae feed on coffee foliage.
Crambidae	*Chilo partellus* (Swin.)	Spotted stalk borer	Larvae cause dead heart of all cereals grown in the region.
Galleriidae	*Ephestia* spp.	Warehouse moths	Larvae are common pests of stored grains, particularly sesame.
Noctuidae	*Earias biplaga* Wlk.	Spiny bollworm	Serious pest of okra.
Noctuidae	*Heliothis armigera* Hb.	American bollworm	Larvae infest a range of crops including maize, tobacco, legumes and vegetables.
Sphingidae	*Herse convolvuli* (L.)	Sweet potato hawk moth	Larvae defoliate sweet potatoes.
Pyralidae	*Lamprosema indicata* F.	Bean web worm	Larvae eat bean and cowpea leaves.
Pyraustidae	*Maruca testulalis* (Geyer)	Bean pod moth	Larvae bore into pods of several pulse crops.
Noctuidae	*Othreis* spp.	Fruit piercing moths	*O. fullonia* Clerck, *O. materna* L., *O. divitiosa* Wlk. present. Adults pierce a range of fruits, including guava, citrus and mango.
Papilionidae	*Papilio demodocus* Esp.	Orange dog	Larvae are serious pests of young citrus trees.
Lyonetiidae	*Phyllocnistis citrella* Stnt.	Citrus leaf miner	Common pest of citrus.
Yponomeutidae	*Plutella xylostella* (L.)	Diamondback moth	Larvae infest a wide range of vegetable crops.
Noctuidae	*Rhaguva albipunctella* De Joanis	Millet head worm	Larvae are serious pests of millet, destroying the heads.
Gelechiidae	*Sitotroga cerealella* (Oliv.)	Angoumois grain moth	Larvae are pests of all stored cereal grains.
Noctuidae	*Spodoptera exempta* (Wlk.)	African armyworm	Larvae are extremely destructive, destroying cereals, particularly finger millet.
Coleoptera			
Curculionidae	*Alcidodes leucogrammus* Erichs.	Cowpea gall weevil	Larvae are pests of cowpea and bean plants. Galls form in the stems.

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Table 1. *Continued*

Order, family	Species	Common name	Comments^{+}
Chrysomelidae	*Asbecesta* spp.	Leaf beetles	Pests of legumes and sesame in the main.
Chrysomelidae	*Aspidomorpha* spp.	Tortoise beetles	Common pests of sweet potatoes and coffee.
Chrysomelidae	*Aulacophora africana* Wiese	Red melon beetle	Very common leaf beetle with *Asbecesta* and *Ootheca* spp.
Bruchidae	*Bruchidius atrolineatus* (Pic.)	Pulse bruchid	Very common and destructive pest of stored pulses.
Nitidulidae	*Carpophilus hemipterus* (L.)	Dried fruit beetle	Pest of stored grains but also present on maize and groundnuts in the field.
Meloidae	*Coryna* spp.	Pollen beetles	Common pests of okra, roselle and kenaf (*Hibiscus cannabinus* L.). Flowers including anthers eaten. Several elytra patterns.
Tenebrionidae	*Cryptolestes pusillus* (Schonerr.)	Rust-red grain beetle	Secondary pest of stored grains.
Curculionidae	*Cylas puncticollis* Boh.	African sweet potato weevil	Larvae eat into sweet potato tubers and adults eat the leaves.
Meloidae	*Epicauta aethiops* (Latr.)	Grey blister beetle	Pest of vegetables and pulses.
Coccinellidae	*Epilachna similis* Thb.	Scarifying ladybird	Adult scarifies cereals leaves, particularly maize.
Scarabaeidae	*Gnathocera trivittata* Swed.	Scarab	Pest of sorghum. Transfers from *Hyparrhenia* spp. to sorghum heads, where it eats grains.
Tenebrionidae	*Goncephalum simplex* F.	Dusty brown beetle	Adult cuts through the stems of tobacco, cereals and legumes and ring-barks coffee. Larvae can be serious pests of groundnuts.
Halticinidae	Several, including *Podagrica* spp.	Flea beetles	Numerous species infest a range of vegetables. Particularly damaging on okra.
Meloidae	*Lagria villosa* F.	Metallic blister beetle	Pollen and flowers of legumes eaten, especially of *Phaseolus* beans.
Chrysomelidae	*Megalognatha rufiventris* (Baly.)	Maize tassel beetle	Destroys maize silks.
Meloidae	*Mylabris* spp.	Blister beetles	Serious and widespread pest of all legumes, particularly pigeon pea. Flowers eaten. Several different elytra patterns and colours.
Curculionidae	*Nematocerus* spp.	Shiny cereal weevils	Pests of cereals, vegetables, legumes and coffee.
Chrysomelidae	*Ootheca mutabilius* (Shalb.)	Brown leaf beetle	Serious pest of cowpeas and beans. Vector of cowpea mosaic virus. Various elytra colours and patterns.
Tenebrionidae	*Oryzaephilus surinamensis* L.	Saw-toothed grain beetle	Secondary pest of stored grains.
Cetoniidae	*Pachnoda marginata* (Drury)	Scarab	Adults eat fruit, particularly guava.
Cetoniidae	*Rhabdotis sobrina* (Gory & Perch.)	Scarab	Adults often found with *P. marginata* on guava.
Curculionidae	*Sitophilus oryzae* (L.), *S. zeamais* Motsch.	Rice, maize weevil	Common pests of stored grains.
Tenebrionidae	*Tribolium castaneum* (Hbst.)	Red flour beetle	Pest of stored grains.
Diptera			
Cecidomyiidae	*Asphondylia sesami* Felt.	Sesame gall midge	Often a serious pest of sesame capsules.
Muscidae	*Atherigona soccata* Rond.	Sorghum shoot fly	Common and often serious pest of sorghum seedlings.
Cecidomyiidae	*Contarinia sorghicola* (Coq.)	Sorghum midge	Very common and destructive pest of developing sorghum grain.

Table 1. *Continued*

Order, family	Species	Common name	Comments+
Diopsidae	*Diopsis thoracica* Westw.	Stalk-eyed fly	Larvae common pest of rice and sorghum, causing deadheart.
Agromyzidae	*Ophiomyia phaseoli* (Try.)	Bean fly	Common and often serious pest of legume seedlings.
Acarina			
Tetranychidae	*Mononychellus tanajoa* (Bondar)	Cassava mite	Common and serious pest of cassava.

+Notes on the crops affected and the type and degree of damage were compiled from 1982–1985.

of causing severe damage to sorghum, sesame and sunflower (*Helianthus annuus* L.). Pigeon pea, *Cajanus cajan* (L.) Millsp., was particularly prone to insect damage. It was a favourite host plant of *Anoplocnemis curvipes* (Fabricius), which damaged the growing points and in combination with blister beetles (*Mylabris* spp.) and pod borers (*Maruca testalis* (Geyer)), sometimes decimated the crop.

Larvae of many Lepidoptera fed on crops in western Equatoria, both in the field and in storage. Adult fruit piercing moths of the genus *Othreis* also damaged mango, guava and papaya. Although finger millet was largely resistant to pests and diseases in comparison with many other crops of the area, it was susceptible to *Spodoptera exempta* Walker, however severe infestations were not frequent. Leaf miners, the larvae of monotrysian moths (*Phyllocnistis citrella* Stainton), were also often observed on citrus and coffee, although the most obvious pest of citrus was *Papilio demodocus* Esper Some of the moth larvae represented the greatest biotic constraints to cereal production in the region. They included *Busseola fusca* (Fuller), *Chilo partellus* (Swinhoe), *Spodoptera exempta* (Walker) and *Helicoverpa armigera* Hübner.

There were many beetle pests of crops in the region. The most visible were *Mylabris* spp., which fed on flowers of legume crops and okra (*Abelmoscus esculentus* (L.) Moench). Schmutterer (1969) reported eight species to be present in Sudan. Pollen beetles of the genus *Coryna* were also very destructive on okra and roselle (*Hibiscus sabdariffa* L.). A range of leaf-eating beetles defoliated many crops. Other Coleoptera pests included cetoniids, such as *Rhodopsis* and *Pachnoda* spp. on fruit, and cerambycids on fruit trees. Grain crops are stored in mud-wicker constructions, which are not optimal for keeping grain pest-free, and which were invariably infested with several species of storage pests as listed in Table 1. Bruchids, of which *Bruchidius atrolineatus* (Pic) appeared the most common, infested stored pulses. A gall weevil, *Alcidodes leucogrammus* Erichs, also frequently affected cowpea in the field. Finger millet had few storage pests.

Fly pests were particularly damaging on crops in western Equatoria, and the five most important ones are listed in Table 1. *Contarinia sorghicola* (Coquillet) was arguably the most serious, by rendering a sorghum crop completely grainless when occurring in large numbers. Severity of damage was, however, dependent on environmental conditions and cultivar, which was also the case for many of the other insect pests. Introduced cultivars were generally more susceptible to pests and diseases than local cultivars. A range of tephritid flies, including *Ceratitis* spp. damaged fruits.

One additional arthropod pest, the green mite *Mononychellus tanojoa* Bondar, was widespread and at times a serious pest of cassava. Doubtless other mites occurred in the area (Schmutterer, 1969), but their effects, even if significant, were not as marked as for this mite, which was not reported by Schmutterer (1969), but was suggested to be in southern Sudan by Girling *et al.* (1978).

The species listed in Table 1 do not represent a comprehensive account of the insect pests of the region, but the major species recorded over several years are included. Many other occasional and minor pests such as thrips damaged crops, for instance. However, most were of minor significance.

Other animal pests

Some non-insect pests were important in the region. These included domestic livestock (goats), various weaverbirds, molluscs (*Limicolaria kambeul* (Brug.)), rodents, monkeys, wild pigs (*Potomochoerus porcus* (L.)) and other mammals. Several attempts were made to identify nematode pests of crops in the area (although they probably occurred, Schmutterer (1969) mentioned *Meloidogyne javanica* (Treub.) on tobacco), only fungal-feeding types were found and there was no evidence of root-knot nematodes on any of the crops studied.

Diseases

The climate of southern Sudan is very conducive to phytopathogen infections. Some of the most common diseases of the principal crops of the region are given in Table 2. The crop species of the area have adapted to the environment; even exotic crops including maize, beans and groundnuts from the Americas have been cultivated for a long time in southern Sudan. Consequently, those cultivars that did not stand up to infestation and infection sufficiently well have disappeared. Moreover, farmers have always selected the best individuals from their fields to save as propagating material and there has therefore been selective pressure exerted on the germplasm of all domesticated crops. Although crops did sometimes succumb completely to a pest or disease, the accompanying intercrops were able to compensate to some extent for the loss. Inspection of the information provided in Table 2 indicates that most crop diseases were associated with sorghum. Sorghum is the main staple of the area and there is considerable intraspecific diversity in the crop. Many of the diseases listed for sorghum in Table 2 are recorded on modern varieties imported into the region, including Serena, a three-month variety bred and released from Serere in Uganda. When present on the local sorghums, many diseases developed late in the season and appeared not to depress yield to any significant extent. Many plant diseases, which were present on the modern cultivars, were not obviously associated with significant reduction in crop yield.

Diseases of the principal cash crops included *Cercospora coffeicola* Berk. & Cooke on coffee and anthracnose, *Colletotrichum gloeosporoides* Penz., common on mango. Tobacco was not particularly affected by foliar pathogens. Hard sesame, *Hyptis spicigera* Lam., and roselle were notably free of pests and diseases and finger millet was largely disease-free with the exception of an occasional blight infection. Sesame was occasionally affected by phyllody, possibly caused by a leafhopper-transmitted mycoplasma as indicated in Kranz *et al.* (1978). Wild plant species, which are very important in the area as food sources, were not obviously seriously affected by diseases; although some weeds associated with agriculture, including *Amaranthus* spp., supported large insect pest populations.

Some diseases in the area, however, were associated with significant, widespread and frequent damage. These were covered kernel smut (*Sphacelotheca sorghi* (Link) Clinton) on sorghum, downy mildew (*Sclerospora* spp.) of maize, blast of rice (*Pyricularia oryzae* Cavara), cassava mosaic virus and bacterial blight of cassava, and groundnut rosette. An unidentified seedling blight of sorghum also caused serious crop loss. Many diseases followed in the wake of insect infestation, with bugs and beetles respectively introducing pathogens and exposing tissues through feeding that were colonized by fungal pathogens. Bacterial and viral diseases were evident, though with the exception of the two diseases already mentioned for cassava and groundnut rosette, seldom serious, possibly with the exception of maize streak virus. Storage diseases included a range of rots and moulds on grains that reduced yield quantity and quality. Sesame and finger millet generally stored well. The growth of *Aspergillus flavus* Link on stored groundnuts represented a particular hazard for food safety through production of aflatoxins (Elamin *et al.*, 1988).

Weeds

Three weeds were found to be of particular importance in western Equatoria and were major determinants of agricultural practices. The parasitic witchweed, *Striga hermonthica* (Del.) Benth., was present throughout the region and affected cereal crops, especially maize, sorghum and rice. It also parasitized some wild grasses and was able to survive off-farm. It took a heavy toll on cereal yields

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and required that land be abandoned to cereal production for a considerable time as it produces numerous long-lived seeds. A related species, *Striga gesneroides* (Willd.) Vatke., was seen to occasionally infest cowpeas and tobacco, but did not constitute a serious threat to production. Speargrass, *Imperata cylindrica* (Anderss.) C.E. Hubbard, was another weed of major consequence. This species invades agricultural land easily and is extremely difficult to remove; the solution was usually to open up new land and to leave the infested land to fallow. Deep ploughing to remove speargrass was generally not possible in the region as cultivation was done with hand-held implements. A third weed, *Eleusine indica* (L.) Gaertn., represents a particular problem in fields of finger millet because during its early

Table 2. Major diseases of the principal crops grown in western Equatoria, southern Sudan (1982–1985)

Crop	Disease	Species
Sorghum	Covered kernel smut	*Sphacelotheca sorghi* (Link) Clinton
	Loose kernel smut	*Sphacelotheca cruenta* (Kuhn) Potter
	Ergot	*Claviceps paspali* Stev. and Hall. (and associated *Cerebella* spp.)
	Bacterial leaf stripe	*Pseudomonas andropogoni* (E.F. Smith) Stapp.
	Downy mildew	*Sclerospora sorghi* (Kulk.) Weston and Uppal
	Crazy top	*Sclerophthora macrospora* (Sacc.) Thirum; Shaw and Naras.
	Oval leaf spot	*Ramulispora sorghicola* Harris
	Zonate leaf spot	*Gloeocercospora sorghi* Bain and Edgerton
	Grey leaf spot	*Cercospora sorghi* Ellis and Everhart
	Head smut	*Sphacelotheca reiliana* (Kuhn) Clinton
	Long smut	*Tolyposporium ehrenbergii* (Kuhn) Patouillard
	Rust	*Puccinia purpurea* Cooke
	Leaf blight	*Helminthosporium turcicum* Pass.
	Grain moulds	*Fusarium* spp.
	Seedling blight	
	Dwarf mosaic virus	
	Stunt virus	
Pearl millet	Downy mildew	*Sclerospora graminicola* (Sacc.) Schroet.
	Smut	*Tolyposporium penicillariae* Bref.
	Ergot	*Claviceps fusiformis* Loveless
	Rust	*Puccinia penniseti* Zimm.
	Long smut	*Tolyposporium ehrenbergii* (Kuhn) Patouillard
Maize	Downy mildew	*Sclerospora* spp.
	Leaf blight	*Helminthosporium maydis* Nisikado
	Ear rots	*Gibberella* spp.
	Maize streak virus	
	Rust	*Puccinia sorghi* Schw.
Finger millet	Blight	*Cochliobolus nodulosus* Luttrell
Rice	Blast	*Pyricularia oryzae* Cavara
Cassava	Bacterial blight	*Xanthomonas manihotis* (Arth.-Ber.) Starr.
	Mosaic virus	
Groundnut	Rosette virus	
	Rust	*Puccinia arachidis* Speg.
	Leaf spot	*Mycosphaerella arachidis* Deighton
Sesame	Phyllody	
	Angular leaf spot	*Cylindrosporium sesame* Hanf.
	Circular grey leaf spot	*Cercospora sesame* Zimm.
Pigeon pea	Pod moulds	
Cowpea	Rust	*Uromyces vignae* Barcl.
	Pod moulds	
Bean	Blight	*Xanthomonas phaseoli* (E.F. Smith) Dowson
	Leaf spot	*Cercospora cruenta* Sacc.
	Rots	*Colletotrichum* spp.
Banana	Black sigatoka	*Mycosphaerella fijiensis* Morelet

seedling stages it closely resembles the finger millet seedlings. Finger millet required careful and laborious weeding to remove *E. indica* and ensure that a good crop developed.

Integrated pest management

Southern Sudan is geographically isolated with a poor communications infrastructure. Many years of war in the south and in neighbouring countries have added to its isolation. Road communications, in any case sub-optimal, deteriorate in the long rainy season. For these reasons among many others, agricultural production, which will continue to be a mainstay of the local economy, will necessarily be based largely on traditional methods. It is likewise difficult to imagine that chemical control will become a major feature of crop management practices in the near future. This is partly due to the high cost of agricultural inputs and isolation, but also because subsistence farming will continue to be the first priority in the region and economics will rule against expensive inputs. Crop pest management, at least during the initial stages of the return of political stability, is likely to rely on an integrated approach founded on sound traditional practices and knowledge combined with exploitation of naturally occurring host-plant resistance present among the diverse plant genetic resources of the area.

Crop rotation and intercropping

Shifting cultivation and intercropping are universal features of farming systems in southern Sudan. In conjunction with crop rotation, the build-up of many pests and diseases is reduced. Such crop management, at least while there is not pressure for land, is set to continue and will be valuable in securing reliable yields. In addition to representing a crop insurance policy against abiotic stresses, intercropping can alter canopy structure in ways that ensure fast closure and deter pest and disease spread. Risch *et al.* (1983) suggested a general tendency for intercropping to reduce levels of specialist crop pests, and Gold (1993) detailed the beneficial effects of intercropping on reducing pests of cassava. Robinson (1997b) reported reduced levels of cassava mosaic virus in plots where cassava was intercropped with groundnuts compared to that in the monocrop. Nsiama *et al.* (1990) reported reduced cassava bacterial blight and *M. tanajoa* levels in addition to reduced cassava mosaic virus, following integrated management of cassava pests in Zaïre. Moreover, bitter cassava is generally intercropped with sweet cassava in southern Sudan to deter wild pigs from eating the latter.

Crop sanitation

Crop sanitation plays an important role in crop protection, and cassava mosaic virus infection in western Equatoria was reduced through a policy of encouraging propagation of cassava through cuttings taken from disease-free plants. Encouraging use of healthy seed for sowing to reduce the effect of seed-borne diseases, particularly the various head smuts, will also be beneficial. Given that land preparation and sowing are done by hand and that all crop husbandry is very labour intensive, it is probably unrealistic to suppose that removal of weeds harbouring large pest populations from around field margins would always be possible. However, removal of heavily infested alternative host plants might reduce pest and disease burdens of crops.

Biological control agents

Significant levels of naturally occurring biocontrol agents of insect pests were previously found in western Equatoria. Numerous entomophagous insects were present, including reduviid bugs, chrysopids, syrphids and chrysomelids; there were also predacious staphylinid beetles and mites. Anthocorid bugs, including *Orius* spp., preyed on pest species including *M. tanajoa*, as reported by Girling *et al.* (1978). In addition, braconid wasps parasitized many homopteran pests, while mason wasps (*Delta* spp.) preyed on caterpillars and entomophagous fungi were evident. *Phonoctonus* sp., a reduviid mimic, preyed on *Dyderscus* spp. and tachinid flies were noted to parasitize adults and nymphs of *Dyderscus* spp. Furthermore, humans consumed termites and some grasshoppers as food.

Storage practices

Storage pests could be kept in check through good sanitation practices and well-constructed grain stores. Seed for sowing the following season was frequently kept in the cooking hut where smoke eliminated pests and diseases. In the grain stores themselves, ash was often mixed with grain to deter insect pests.

Botanicals

Neem (*Azadirachta indica* A. Juss.) grows in the region and could be used as a source of azadirachtins. Other possibilities for insect pest management have been proposed based on naturally occurring compounds. Evans *et al.* (1985) reported on 2,5-dihydroxymethyl-3,4-dihydroxypyrrolidine, an insecticidal rotenoid effective against bruchids. Simmonds *et al.* (1989) reported

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the *Lonchocarpus/Millettia/Derris* (Leguminoseae) generic complex to be a source of such compounds. *Lonchocarpus laxiflorus* Guillem & Perrot. is a deciduous savanna tree of southern Sudan and *Millettia psilopetala* Harms. grows in Equatoria (El Amin, 1990). Further chemotaxonomic studies could reveal other useful plant species in the region, which might not only be useful for pest management, but might also represent new crops for the region.

Host plant resistance

Farmers in western Equatoria have been growing and selecting their crops for generations and partial resistance exists in many crops to many of the major pests and diseases. Naturally occurring host plant resistance probably represents the best and most environmentally suitable means for managing pests and diseases in the region. There is tremendous intraspecific diversity in the crop species and many crop relatives (Robinson, 2004) represent substantial interspecific diversity. Developing host plant resistance might be attempted through participatory schemes that build on the indigenous knowledge of the farmers, which largely remains unreported. To date there has been no formal plant breeding directed at developing cultivars specifically suited to the environment of southern Sudan. Exotic imported varieties used in the past were usually not adapted, even if they came from similar environments. Robinson (1997b), however, did report on the superiority of introduced rice varieties in comparison with local varieties in on-farm trials with respect to their higher resistance to rice blast.

Weed management

Striga represents a difficult management problem, as most intercropping combinations, except the common groundnut-cassava combination, included a susceptible cereal species. Differences in intra- and interspecific susceptibilities to striga might, however, be exploited to reduce its effects on cereal crop production. Timeliness of weeding is important. In well-managed cropping systems, bare ground, which allows for weed development, was kept to minimum by sowing intercrops immediately after weeding.

Chemical control

If cash crop production resumes in the region, for example of coffee and tobacco, the economics of production might allow chemical control to become a feature of the crop management programmes. It is likely that western Equatoria will remain relatively free of agrochemicals, however, which could conceivably bring benefits in the future through maintaining an unpolluted environment. As peace returns to the region and government again functions, policies directed at supporting agricultural production will need to include those addressed at pest and disease management. Legislation is likely to be a feature of an integrated pest management programme.

Conclusions

As peace returns to southern Sudan, there will be an opportunity to rehabilitate agriculture in the region. A large range of crops can be produced in western Equatoria. Pests, diseases and weeds will, however, take their toll on crop yields. If managed carefully however, subsistence agriculture could thrive, cash crop production could be revived, and agriculture could spur development in the region if it is based on traditional methods of crop husbandry in conjunction with application of modern management methods. Schmutterer (1969) suggested that more knowledge of natural enemies of pests is needed if appropriate biological control methods can be designed for southern Sudan. Agricultural research in the south has been neglected relative to other regions of the country and the long civil war has meant that little useful research has been done in the area for a long time. Peace will provide an opportunity to conduct agricultural research in southern Sudan and fill the gaps in the knowledge on pests and diseases there. This article, based on lost records from the region, represents a foundation for conducting such research.

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