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The potential benefits of weeds with reference to small holder agriculture in Africa

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Weed control is one of the most important crop protection activities undertaken in both intensive and low-input farming systems. However, even under intensive systems, crop protection which is less dependent on pesticides may require that weeds be managed to obtain a balance between crop and non-crop vegetation to encourage an increase in natural enemies of crop pests. In the low-input farming systems which sustain much of the rural population of Africa, weed control is usually done by hand and 'clean weeding' is often beyond the labour resources of the farming family. The vegetational diversity of peasant agriculture in Africa to which weeds make their contribution, helps to decrease the risk of disease and pest epidemics. In addition to the pest control benefits of a diverse agroecosystem, weeds contribute to the resource base of the rural community, providing a source of secondary foods, medicines and insecticides. Weed control within an integrated crop protection system appropriate to the needs of the resource-poor farmer, requires that weeds are managed in such a way that their biodiversity is maintained and the more useful species retained within the field or field margin. Those weeds with high food potential or which have pesticidal or medicinal properties might be deliberately encouraged within the crop or field margins. Certain weed species may harbour important pests or diseases of local crops and therefore should be selectively removed. The paper reviews and discusses the literature on the beneficial and deleterious effects of weeds and argues for a weed management strategy which balances the effects of weed competition on crop production with the ethnobotanical and pest control attributes of individual weed species and weed communities.

Keywords: Africa; diseases; ethnobotany; insect pests; natural enemies; weeds.

Introduction

Weed control is often the most important crop protection activity undertaken on the farm. Uncontrolled weed growth, especially in the early stages of crop establishment, can greatly decrease final crop yield through competition effects between crop and weed populations. All farmers undertake weed control to one degree or another and it is one of the most labour intensive activities for the small scale farmer, especially in areas where high temperatures and regular rainfall encourage rapid weed growth. There has been much written about the problems of weed management in the tropics and there will be no further reference in this review to direct competition between weeds and crop plants and methods of preventing it. Until recently, the approach by crop protection researchers to weed control in small-holder agriculture has often been to adapt methodologies appropriate to intensive agriculture with an emphasis on the weed as a pest which should be eradicated at the first possible opportunity. Failure to remove weeds is often explained either as poor husbandry or a result of labour shortage. While it is clear that under certain circumstances either or both of these factors may operate, a broader, socio-biological view can be taken which places the weed in its ecological context and takes greater account of the relationship between the strictly cultivated plants and the surrounding vegetation as a whole. It is not a new idea to view weed control from an ecological perspective in the context of vegetation management, but for agriculture in the tropics, these ideas have perhaps been explored more fully in Latin America (Altieri *et al*., 1977) than they have in Africa. To design integrated crop protection systems appropriate to the small-farmer in Africa and to manipulate the agroecosystem to increase farm productivity, without destruction of the environment and further loss of biodiversity, weed management practice should take account of the positive as well as the negative contribution that weeds make to crop production and to the rural environment. This review examines weeds from an integrated crop protection perspective and considers their ethnobotanical value and their relationship with other pests, both as reservoirs of biocontrol agents and as alternative hosts for pests and diseases. While the value of weeds as famine foods and as sources of bioactive metabolites is relatively well documented for Africa, there has been little work done on the role of weeds in ecological pest control. The literature from Europe and North America on weeds in relation to natural enemy populations is reviewed , the principles of which can be applied to African agriculture and it is hoped that this work may help to stimulate some much needed research on ecologically-based IPM in Africa.

Domestic uses of weeds

There are only about 250 plant species which are sufficiently troublesome universally to be regarded as weeds (Altieri and Liebman, 1988) and agriculture has been a major factor influencing their evolution. World-wide exchanges of planting material of major crop plants has been a factor allowing the introduction of many of these weeds into all cultivated areas of the world which have the required ecological conditions. Some have been cultivated in the past as crops and others are progenitors of, or closely related to, wild progenitors of crop plants. Some are sufficiently close genetically to their crop relatives that introgression is common and contributes to the diversity of the crop species population, while selection for uniformity in crop species results in a loss of genes, and the consequent increasing instability of agroecosystems. Weed relatives of crop species may remain as a reservoir of genes and should be conserved as they may be needed in the future (Harlan, 1965).

Many plants among the indigenous flora are used by local communities both as food and as traditional medicines, the knowledge of which is handed down orally through the generations and may be knowledge carried-over from the pre-agricultural era of hunter gatherers. It is only relatively recently that attempts have been made to document these. Conventional agricultural research focuses on relatively few crops among those consumed by rural communities. In western Kenya the agricultural system of Bungoma is dominated by maize cultivation, yet one study revealed that at least 100 different species of vegetable and fruit were consumed which were drawn from 70 genera belonging to 35 families (Juma, 1989). Although most of the weeds commonly found in cultivated land are introduced species, there are few which do not have culinary, medicinal or other domestic uses (Table 1). Rahmato (1988) noted that wild foods are an important component of peasant survival in Ethiopia. Among other wild plants, the weed species *Portulacca oleracea* and *Amaranthus* spp. were important in helping the people of Wollo to cope with the 1984 drought. Although in most cases where weed species are used for human consumption their use is confined to periods of food shortage, this is by no means always the case. Some species are highly prized as green leaf vegetables and grains and some are more productive than their crop equivalents. For instance the grain yield obtained from the wild grass *Panicum laetum*, (known as 'fonio') in the valley of the Malian Gourma, is higher than that from the local millets (Maiga *et al*., 1991). Sometimes valuable 'weed' species such as *Solanum nigrum*, may be taken into cultivation in home compounds, as has been documented in Uganda (Tallantire and Goode, 1975) and western Kenya (Juma, 1989). More often they are accidental colonisers and can be in competition with the main crop, although some may be actively encouraged and are deliberately not removed from the crop during weeding. This is seen in East Africa with weeds such as *Gynandropsis gynandra* which is much favoured as a relish or 'spinach'. *Commelina* spp. are common weeds throughout eastern and southern Africa where the leaves, young shoot and rhizome are consumed during times of famine. In the Machakos district of eastern Kenya for instance, *Commelina* sp. was reported as the most popular wild vegetable (Maundu, 1987). One study in Tanzania recorded that wild plants appeared in 32% of all meals consumed by villagers (Fleuret, 1979). *Bidens* spp. are among the most common early colonisers of cultivated land in Africa and the leaves are widely consumed. Although regarded as a famine food due to its rather aromatic flavour, Ogle and Grivetti (1985a) reported that in Swaziland, *Bidens* was the most frequently consumed wild leaf vegetable and eaten by more than 70% of the adult population. Other weeds such as *Commelina* and *Sonchus oleraceus* were also important (Ogle and Grivetti, 1985b). Bush plants and edible weeds often play an important role in maintaining the nutritional status of rural communities (Ogle and Grivetti, 1985c; Grivetti, 1987). Huss-Ashmore and Curry (1989) reported that the transition to more intensive farming with more cash crops and increased use of herbicides was marked by the virtual disappearance of *Bidens pilosa* and *Corchorus* spp. They attributed poorer nutritional status of the villagers in part to the elimination of these species as a source of wild food. In Ethiopia also, it has been recorded that wild foods are an important component of peasant survival strategies and it is mainly the women who are particularly knowledgeable about the most useful species (Rahmato, 1988). Zmarlicki *et al*. (1984) analysed the nutrient composition of some of the wild plants used for human consumption in the Transkei of South Africa. They found many potentially useful plants among the weed flora and suggested that the cultivation of weeds such as *Sonchus asper*, *Chenopodium album*, *Amaranthus* spp. and *Galinsoga parviflora* could be encouraged in multiple crop farming systems. In other studies where the nutrient value of weed species has been measured some have been found to compare favourably with cultivated species. Sreeramulu (1982) tabulated the nutrient status of 22 cultivated and wild vegetable plants. The weed species *Gynandropsis gynandra*, *Solanum nigrum* and *Celosia argentea* contained high levels of protein. Ogle and Grivetti (1985c) found that the protein content of edible wild plants ranged from 1.3% to 7.5% of fresh weight and in Swaziland, wild vegetables were eaten with maize porridge in 39% of all meals. As these leaves were high in lysine which is deficient in maize, they represent an important supplement to a diet based on maize. *Bidens pilosa*, *Amaranthus* spp. and *Corchorus* spp. all had a higher content of protein, calcium and iron than spinach.

Table 1. Some of the most common weeds of cultivated land in eastern and central Africa and their domestic uses

Weed species	Domestic use
Ageratum conyzoides	*Medicinal* – leaves pounded to treat wounds. Popular with the Luo in Kenya as a haemostatic. Also known as a remedy for stomach pains.
Amaranthus spp.	*Food* – Leaves of several species of *Amaranthus* eaten as a relish throughout E. Africa, often mixed with salt and groundnut paste. Seed can be roasted and pounded to produce flour used in preparation of bread and biscuits. *A. caudatus* in Ethiopia is mixed with flour of Tef to make 'injera'.
	Other uses – *A. hybridus* can be used to make a red dye.
Argemone mexicana	*Other uses* – Seeds are narcotic and used in Tanzania to make traditional beer more intoxicating. Seeds have insecticidal properties. Can be poisonous to livestock.
Bidens pilosa	*Food* – leaves and shoots are edible. It is one of the weeds most widely used as a famine food due its abundance, rather than its taste which is rather aromatic.
	Medicinal – Leaves can be made into a poultice to treat wounds and the juice used to treat eye complaints. Roots and stem used to treat diarrhoea and abdominal pains.
Boerhavia diffusa	*Medicinal* – Occasionally, leaves pounded and used medicinally.
Celosia spp.	*Food* – leaves and inflorescence used as a vegetable and in soups and stews.
Chenopodium spp.	*Medicinal* – *C. ambosioides* leaves applied to face to treat convulsions in Zimbabwe. Also powdered leaf mixed with oil and applied to skin to treat ringworm.
	Other uses – Believed in some parts of Malawi to repel snakes.
Cleome monophilla	*Food* – Said to be edible when leaves and flowers are cooked and pounded with groundnut and tomato but is bitter and not much liked.
Commelina spp.	*Food* – in times of famine leaves and young shoots used either fresh or boiled as a vegetable. Rhizome can also be eaten.
	Medicine – *C. africana* used to treat leprosy, eye problems and colds.
Corchorus spp.	*Food* – One of the most valuable local vegetables in hot, arid regions. Often cooked with potash. In Senegal the leaf is used with steamed millet to prepare 'm'boum'. Eaten by women, children and invalids in many parts of Africa.
	Medicinal – *C. olitorius* used as a tonic and to treat toothache, stomach and bladder complaints.
	Other uses – fibres can be woven to make course cloth.
Crotalaria spp.	*Food* – leaves and flowers of some species can be cooked and eaten as a relish but it is often mixed with groundnut to make it more palatable.
Cynodon dactylon	*Medicinal* – known in Malawi as a remedy for indigestion and heartburn.
	Other uses – pasture grass.
Cyprus esculentus	*Food* – Tubers are rich in starch and oil and it is a good source of phosphorous and iron, although protein content is relatively low, it is twice as high as in cassava. Tubers eaten raw or can be roasted to make 'coffee', in Zambia and Zimbabwe used to make porridge.
Datura stramonium	*Medicine* – In Zimbabwe leaves burned and smoke inhaled as a treatment for asthma. Leaves and seed contain the alkaloids hyoscine and atropine and are crushed and mixed with ghee to make an ointment for treatment of ringworm. Crushed leaves used as insect repellent.
	Other uses – in Malawi it is believed that the leaves sprinkled around the house repel cockroaches. *Datura* spp. used as a rat poison in stored grain.
Eleusine indica	*Food* – seed can be pounded into flour; eaten as a famine food in Zambia and Ethiopia. Other uses – straw used for bedding.
	Medicinal – reputed in Malawi to be effective as a remedy for coughs and blood complaints.
Euphorbia heterophylla	*Medicinal* – an infusion of leaves and root used as a remedy for headache.
Euphorbia hirta	*Medicinal* – Used to treat wounds by covering with fresh leaves. Common name of asthma weed but this may be because it is believed to induce asthma. The latex is sometimes used in Malawi to treat eye complaints such as conjunctivitis.
Galinsoga parviflora	*Food* – leaves eaten as a relish in some areas.
	Medicinal – Stem/leaves pounded and juice squeezed into wound.
Gynandra gynandropsis	*Food* – One of the most popular sources of relish in E. Africa. The young shoot and leaves are cooked and often mixed with pounded groundnut.
	Medicinal – leaves are reputed to be a remedy for pneumonia in Malawi.
Hibiscus cannabinus	*Food* – in times of famine may be eaten as a relish; the leaves have to be pounded with potash.
Imperata cylindrica	*Medicinal* – known in Malawi as a treatment for digestive complaints.
Leucas martinensis	*Medicinal* – leaves and bracts boiled in salt water and the infusion drunk to cure throat infections.
Ocimum spp.	*Medicinal* – widely use as medicinal plants to remedy fevers and the whole plant of infusion of the leaves is used as a mosquito repellent.

Table 1. (*Continued*).

Oxygonum sinnuatum	*Food* – occasionally cooked with potash to make a relish. *Medicinal* – widely used as a medicine. Leaves crushed and rubbed into the eye to treat eye complaints. Infusions of the root can be drunk to treat menstrual problems.
Physalis angulata	*Food* – fruit can be consumed an is rich in vitamin A and C. *Medicinal* – to improve female fertility.
Potulacca olerecea	*Food* – contains high levels of oxalic acid. May be eaten in salads and soups particularly in Mozambique and Malawi. Large leaved types cooked as a vegetable. *Medicinal* – as a snake bite remedy.
Schkuhria pinnata	*Medicinal* – Leaf decoction taken orally in Zimbabwe to treat gonorrhoea.
Solanum nigrum	*Food* – the unripe fruit are poisonous but in many parts of Africa the leaves are cooked as a relish. *Medicinal* – Juice from the fruit has antibacterial and antifungal properties and is used to treat skin infections including ringworm.
Tagetes minuta	*Medicinal* – crushed in oil and applied to skin to treat wound maggots.
Tribulus terrestris	*Food* – leaves, shoots and fruits rich in calcium, iron and vitamin C. Leaves used as salad and seed can be pounded to make flour. Fruits may be gathered in times of severe food shortage.
Trichodesma zeylanicum	*Medicinal* – powdered tuber of *T. physaloides* Fengl. said to have aphrodisiac properties. An infusion of the roots and leaves is used to treat intestinal worms.
Tridax procumbens	*Medicinal* – the leaves are mixed with other herbs to treat coughs and chest complaints.
Triumfetta spp.	*Medicinal* – in Zimbabwe, *T. weliwitschii* (Mat.) powdered root used to prevent abortion. *T. rhomboidea* used in Zimbabwe to treat circumcision wounds by squeezing juice from the root into the wound.
Vernonia spp.	*Medicinal* – leaves contain alkaloids and can be used to treat wounds. In Zimbabwe infusions prepared from the root used to combat infertility. Leaves rubbed on body as insect repellent and to protect against body lice.

Sources: Banda and Morris (1986), FAO (1988), Kokwaro (1976), Fox and Norwood-Young (1982), Drummond (1984), Ivens (1967), Johns *et al*. (1990), Johns and Kokwaro (1991).

The morphological similarity between crop species and related wild species is perhaps most obvious in the Gramineae with many wild species used as a source of grain, especially in areas prone to drought. In parts of the Sahel, the collection and consumption of wild grains, such as *Echinocloa colona* and *Panicum laetum* is an important part of the pastoral production system. (Scoones *et al*., 1992). In the Sahara and sub-Saharan regions, the grain from many wild grasses, some of them common weeds in crops of sorghum and millet such as *Eragrostis* spp., are collected and sometimes sold, often being regarded as more flavoursome than the cultivated species. The wild rices *Oryza barthii* and *O. longistamata* are harvested in swampy areas when rice yields are low. In addition, the stem of *Echinochloa stagnina* can be processed into sugar (Harlan, 1989).

In addition to their value as a food resource, weeds and the natural vegetation are also used as animal fodder (Lambers *et al*., 1996) and to provide other domestic products such as brooms, but particularly medicines used in traditional remedies and for insect repellents in the home (Table 1).

Weeds and ecological pest control

From a strictly crop protection perspective, weeds are normally regarded as undesirable, having negative competitive effects on the crop and attention has been concentrated on methods of controlling them, either chemically or culturally. However, it has long been recognised that insect pest pressure tends to increase in agro-ecosystems as they become less diverse. It is almost 70 years since Wolcott (1928) first drew attention to the possibility that the destruction of weed communities in the tropics might increase crop damage by insect pests and insect transmitted disease. For intensive agriculture, the view has been expressed by Way and Cammell (1981) that insect communities in and around agroecosystems have been affected more by herbicides than by insecticides. The importance of field margins as conservation areas for flora and fauna is well established in Europe and for some pests they may act as reservoirs of beneficial insects (Marshall, 1988). In the USA Altieri and Whitcomb (1979a,b) have documented the association of beneficial insects with the weed flora. The beneficial role of weeds in contributing to the diversity and stability of insect populations has rarely been considered in the design of pest control programmes in Africa. Three factors have provided the impetus for change in this respect. The first is overproduction of crop commodities in the developed world and an increase in uncropped land with the introduction of 'set aside' policies which encourage farmers to allow portions of their land to return to sub-climactic natural vegetation. The second is the concern over erosion of biodiversity in plant communities with consequent loss of potentially valuable genes from the pool. The third is the need to develop pest control systems which rely on minimum use of agrochemicals in order to protect the environment and to delay the development of pesticide resistance in target pest populations. The resource poor farmer in the tropics requires in addition, crop protection systems which are compatible with his farming practice and do not require expensive chemicals, particularly those which are highly toxic.

Non-crop vegetation can affect insect populations in a number of ways. Field margins and natural vegetation can provide a habitat for beneficial arthropods where they can find physical shelter, the polyphagous species can find alternative hosts, a diverse flora may provide pollen, nectar or water and perhaps a more favourable microclimate than is available within the cropped area, especially if it is a monocrop (Dyer and Landis, 1997). Some predators (van Emden, 1963) and parasites (Syme, 1975) are particularly dependent on certain weed species to maintain their populations.

The non-crop vegetation provides a refuge for beneficials from pesticides applied to the crop. Herbivorous pest species may also be protected from pesticide spray while feeding on alternative hosts in field margins. The natural vegetation then holds a reservoir of insects which have not been exposed to insecticide and are able to restore pesticide sensitivity to the pest population when they return to the crop and interbreed with pesticide-resistant individuals. Indirectly the natural vegetation may assist in pest control by providing nesting sites for birds which feed on insect pest species.

The disastrous effects of virtually weed-free monocropping over vast acreages has been experienced in the cotton-growing areas of Australia where ever increasing numbers of sprays were required to control bollworms as they rapidly became resistant to synthetic pyrethroids during the 1980's. There are many studies which demonstrate clearly that insect pests are fewer in number in weedy than in weed-free crops. However usually the competitive effect of the weeds decreases crop yield by more than is gained by the decrease in pest numbers. One such study from Nigeria for instance, found that in cowpea fields infested with weeds mainly of the species *Syndrella hybidum*, *Eleusine indica* and *Amaranthus hybridus*, populations of the leafhopper, *Empoasca dolichi* and the fleabeetle, *Ootheca mutablis* were lower than in weed-free cowpea plots. However, yields were higher from the weed-free plots (Ofunya, 1989).

Weeds may act as alternative hosts for the insect pest. Sometimes the weed can be more attractive to the crop pest than the crop itself. Where this is the case, pest population on the host can be decreased due to the dilution effect of the weed. This situation provides the potential for the weed to be exploited as a trap crop. In Uganda, the common weed *Cissus adenocaulis* Steud. was found to be a preferred host for the cotton pest, *Taylorilygus vosseleri* Popp. although it has not been exploited as a trap crop. Exploitation of weeds to manage pests in this way has been long advocated (Altieri and Letourneau, 1982; Markovitch, 1935), but Andow (1988) states that he knows of no examples of the successful use of weeds as trap crops. However, Altieri and Trujillo (1987) describe the use of weeds as trap crops in Mexico, where farmers encourage the growth of *Lupinus* spp. in their maize fields to attract the scarab beetle (*Macrodactylus*) away from the crop.

Weeds and natural enemy populations

Van Emden (1965) reviewed the role of uncultivated land in the biology of crop pests and their predators. Since then policies adopted in Europe and north America to foster sustainable agricultural systems and reduce farm surpluses and pesticide use, have stimulated research on the role of field margins and natural vegetation corridors on populations of beneficial arthropods (e.g. Feber *et al*., 1995; Morris and Webb, 1987; Southerton, 1985). Field margins and the surrounding natural vegetation can provide a habitat where beneficial arthropods may find refuge, alternative hosts, water, overwintering sites, favourable microclimate and escape from pesticides applied to the crop. *Eriborus terebrans* for instance, is an abundant parasitoid of the European cornborer (*Ostrinia nubilalis* Hub) in Mitchigan. More females were found in surrounding vegetation than in the cornfield itself (Dyer and Landis, 1997). Non-crop habitats bordering agricultural fields in Europe have been found to have a favourable effect on a number of other beneficials such as spiders (Maeflait and de Keer, 1990), Cochinellidae (Perrin, 1975) and Syrphidae (Pollard, 1971). In the UK field margins provide an important overwintering habitat for some beneficials to survive during the non-crop period. The rove beetle, *Tachyporus hypnorum* F. and the ground beetle, *Demetrias atricapillus* L. are important aphid predators (Dennis and Wratten, 1991) overwintering specifically in field boundaries of arable land (Thomas *et al*., 1991). The exclusion of herbicides from field margins was shown to increase densities of predatory arthropods, especially polyphagous species and their alternative prey (Chiverton and Southerton, 1991). Weedy field margins are not always the most suitable type of non-cultivated habitat for beneficials and European cornborer was found to be more abundant in woodland close to cereal fields than in herbaceous edges or in the cornfield itself (Dyer and Landis, 1997). Strips of woodland or hedgerows joining natural habitats have been shown to increase the activity of predatory arthropods in nearby crop fields (Mader, 1988). Both the type of field boundary vegetation and the way it is managed can impact on the abundance of beneficials (Southerton, 1985; Feber *et al*, 1995). Manipulation of the vegetation in and around agricultural land has been advocated as a way of increasing natural biological control of crop pests (e.g. Altieri and Letourneau, 1982; Dennis and Wratten, 1991; Thomas *et al*., 1991, 1992).

There are now a large number of studies from Europe and North America showing that natural enemy populations are greater in more diverse vegetational communities

(Altieri and Letouneau, 1982; Morris and Webb, 1987; Coll and Bottrell, 1996) and the beneficial insect population associated with particular weed species has been surveyed by Altieri and Whitcomb (1979a,b) and by Perrin (1975). Of 31 species of predators and 28 species of parasitoids listed by Andow (1988), 16 predators and 25 parasitoids were consistently more numerous in weedy than non weedy systems and 6 more of the predators were occasionally more numerous in the weedy systems. However, there are few studies which show that this is linked to increased predation and even fewer which show a decrease in pest damage and a related increase in crop yield. In one such study conducted in Germany, weed strips were planted within a field of wheat and compared with a field without weed strips. Predatory arthropods such as spiders, Nabidae and Dolichopodae were found in larger numbers near the weed strips than in the middle of the filed. Furthermore, enhanced activity of beneficials was observed adjacent to the strips and this was associated with a decrease in the number of insect pest species recorded (Hausamann, 1996). In China, planting of *Ageratum conyzoides* and other weeds in citrus orchards has been used as an ecological approach to the control of the citrus red mite, *Panonychus ctri* (Weiguang-Liang and Mingdu-Huang, 1994).

The dynamics of the trophic interactions between pests and their natural enemies in diversified vegetation are complex which make them difficult to study quantitatively and difficult to generalise on the mechanism of enhanced natural enemy activity. Weeds may be hosts to herbivores which serve as alternative prey for natural enemies. Flaherty (1969) for instance, reported that in the USA, *Sorghum halepense* supported an alternative prey for *Metaseilus occidentalis* which controlled the Willamette mite (*Eotetranychus willamettei*) on the nearby grape crop. In one example from the UK, Aveling (1981) found that the population of *Anthocoris nemorum*, a hemipterous predator, increased on *Utrica diotica* by consuming the nettle aphid and then transfers onto hop where it helps to control *Phorodon humuli*. Andow (1988) cautions that these studies do not make it clear if increased parasitism or predation occurred due to lower overall host populations, higher natural enemy populations, or both. Nevertheless it is clear that alternative hosts among the weed flora and natural vegetation are important in the life cycle of many natural enemies (van Emden, 1963). There are a number of reports that outbreaks of certain pest species are more frequent in weed-free fields than in fields with a diverse weed population (Pimental, 1961; Dempster, 1969; Altieri *et al*., 1977).

If it has proved difficult in advanced economies to design experiments to demonstrate the benefits of encouraging vegetation diversity in agroecosystems through weed management, rather than weed eradication, then it is all the more difficult in Africa where much of the agriculture is small scale and fields tend to be surrounded by large uncultivated areas. One of the few studies of this type conducted in Africa was carried out in Ivory Coast, where it was shown that the activity of predatory ground spiders was increased when rice fields were hand weeded between 28 and 63 days after emergence, compared to fields which were treated with herbicide. Also, the number of spiders was greater when weed trash was left in the field, rather than removed. However, none of the treatments which increased predator activity could be shown to have a significant effect on the numbers of insect pests (Afun *et al*., 1995). These results reflect the difficulty of this type of work in low-input, small-scale farming systems where there is probably a stable equilibrium between insect pests and beneficials due to a high ratio of non-crop to crop vegetation and experimental plot size can rarely be large enough to overcome the problem of beneficials migrating into the trial from the surrounding vegetation.

Weeds as alternative hosts for pests and pathogens

Insects

For non-specialised (polyphagous) insect pests the presence of alternative hosts to the crop is usually regarded as undesirable, allowing the pest to build-up its population on the alternative host before moving to the crop. Bendixen and Horn (1981) listed more than 70 families of arthropods affecting crops which were primarily weed-associated. Under some circumstances there may be crop protection benefits to the presence of a weed which is an alternative host for a major insect pest of the nearby crop species but this can also be a disadvantage, depending often on the relative timing of the growth stage of each which is most attractive to the insect and to the host range and feeding preference of the insect. The separation of effects on pest populations of diverse vegetation and diverse natural enemy population is artificial because insect pests, beneficials, crops and weeds all interact to produce a complex matrix and the effect on crop damage of altering one component is difficult to predict. Andow (1988) has pointed out that there is scarce evidence to prove that pests move from the alternative host in sufficient numbers to cause significant crop damage, even in the case of pests such as some of the aphids which are obliged to alternate between hosts to complete their life cycle. It is often assumed that if population build-up of a particular pest is observed on a weed prior to their appearance in the crop then the weed population was the source of the infestation. Andow (1988) sites examples where the pest performed poorly on the weed hosts which therefore play only a minor role in pest population dynamics. The risk that the pest population will move in large numbers from the weed to the crop is greater if the weed is as good a host as the crop. The alternative host may however, attract the pest away from the crop, depending on the timing of the growth stage of crop and weed which are most attractive to the pest. The knowledge that in Ethiopia, the grass species *Pennisetum purpureum* and *Sorghum verticilliformum* are major hosts of *Busseola fusca* (Gebre-Amlak, 1988) does not necessarily enable us to predict that the presence of these grasses close to a maize field will always lead to increased stalk borer attack in the maize crop. Usually the farmer cannot take the risk of waiting to find out if a pest is going to move from the wild host to his crop and in the case of *B. fusca*, it is a standard recommendation in areas where this stalkborer is a problem, to remove thick-stemmed grass weeds from the viscinity of the crop. Nyambo (1988) reported that in Tanzania, *Cleome* sp. was an alternative host for the bollworm (*Helicoverpa armigera*) and assisted in the biological control of the pest in two ways; firstly by providing a source of insects which were not pesticide resistant, having escaped the spray applied to the cotton crop and also in supporting a more diverse parasitoid population. It was confirmed that parasitism of *H. armigera* was greater on the weed than on cotton (Nyambo, 1990). High infestations with the variegated grasshopper, *Zonocerus elegans* were associated with the presence of *Eupatorium odoratum* in Nigeria (Page and Richards, 1977). In the Sudan, eradication of *Abutilon* spp. and *Solanum dubium* L. is encouraged by legislation as part of the management programme for cotton pests. Malvaceous shrubs are often preferred over cotton as a food source for *Earias* spp. and they migrate to nearby cotton crops only in drier areas where natural vegetation is sparse.

Nematodes

Many of the common plant parasitic nematodes have wide host ranges and can invade and reproduce on crop and weed species (Table 2). Common weed species growing on farm land can serve as indicator hosts for nematodes which might affect the crop growing there or which may be grown there in the future (Hogger and Bird, 1976). The root-knot nematodes (*Meloidogyne* spp.) are the most damaging nematodes in tropical legume and vegetable crops. Several common weeds associated with their cultivation in Malawi, such as *Ageratum conyzoides*, *Galinsoga parviflora*, *Crotalaria* spp., *Nicandra physaloides* and *Corchorus olitorius* are also hosts for *Meloidogyne javanica* (Hillocks *et al*., 1995). Among these weed species, *A. conyzoides* was found to be a particularly good host for the population of *M. javanica* tested (Hillocks, *et al*., 1995) which appears to be the case also in Zimbabwe (Martin, 1959) and in Nigeria (Salawu *et al*., 1991). The extrapolation of results obtained from studies such as these to similar plants in other countries should be done with caution, as results obtained

Table 2. Some common weeds recorded as alternative hosts for nematodes and plant pathogens affecting crop species

Weeds species	Nematode or Plant Pathogens
Acanthospermum hispidum	*Meloidogyne javanica* (Hillocks *et al*., 1995)
Ageratum conyzoides	*M. javanica* (Hillocks *et al*. 1995; Madulu and Trudgill, 1993), *Verticillium dahliae* Hillocks, unpublished), *P. solanacearum* (Kelman, 1953)
Amaranthus hybridus	*Pratylenchus zeae* (Jones and Hillocks, 1995), *M. javanica* (Hillocks *et al*., 1995)
Amaranthus spinosus	*Rotylenchulus reniformis* (Inserra *et al*., 1989)
Bidens pilosa	*M. javanica* (Saka and Siddiqi, 1979), *R. reniformis* (Inserra *et al*., 1989)
Bidens schiperi	*M. javanica* (Martin, 1959)
Chenopodium murale	*M. incognita* (Meyer and van Wyk, 1989)
Commelina benghalensis	*Pratylenchus zeae* (Jones and Hillocks, 1995), *P. godeyi* (Gowen, unpublished)
Commelina diffusa	*R. reniformis* (Inserra *et al*., 1989)
Corchorus olitorius	*M. javanica* (Hillocks *et al*., 1995; Madulu and Trudgill, 1993)
Crotalaria incana	*P. zeae* (Jones and Hillocks, 1995), Bean common mosaic virus (Spence and Walkey, 1995)
Cynodon dactylon	*Sporisorium sorghi* (Marley, 1995)
Digitaria spp.	*P. zeae* (Jones and Hillocks, 1995)
Eleusine indica	*P. zeae* (Jones and Hillocks, 1995)
Euphorbia heteropylla	*R. reniformis* (Inserra *et al*., 1989)
Euphorbia hirta	*R. reniformis* (Inserra *et al*., 1989)
Galinsoga ciliata	*R. reniformis* (Inserra *et al*., 1989)
Galinsoga parviflora	*M. javanica* (Hillocks *et al*., 1995; Madulu and Trudgill, 1993)
Gisekia spp.	*M. javanica* (Madulu and Trudgill, 1993)
Nicandra physaloides	*M. javanica* (Hillocks *et al*., 1995)
Oxygonoum sinuatum	*M. javanica* (Madulu and Trudgill, 1993)
Portulacca oleracea	*P. solanacearum* (Quimio and Chan, 1979), *R. reniformis* (Inserra *et al*., 1989)
Ricardia scabra	*M. javanica* (Madulu and Trudgill, 1993)
Rottboellia exalta	*P. zeae* (Jones and Hillocks, 1995)
Sida acuta	*M. javanica* (Madulu and Trudgill, 1993)
Xanthium pungens	*Verticillium dahliae* (Evans, 1971)

from host range tests depend on a number of factors such as whether they were based on artificial inoculation or natural infection, the particular nematode population used, the temperature under which the tests were conducted and the host species. Also, it cannot be assumed that if one species is a good host it will be the case for all members of the genus. For instance, *A. conyzoides* is a good host for *M. javanica* but *A. houstonianum* is not (Hillocks *et al*., 1995). Similarly, Martin (1959) reported that he found no evidence of galling due to *Meloidogyne* on plants of *Bidens pilosa* which he examined but *B. schiperi* was a good host. In Malawi *B. pilosa* was reported as a host for *M. javanica* (Saka and Siddiqi, 1979). In South Africa several weed species were found to be hosts to both *M. javanica* and *M. incognita* and it was recommended that weeds such as *Chenopodium murale*, susceptible to the tobacco race of *M. incognita*, should be eradicated from tobacco fields (Meyer and van Wyk, 1989). One of the most common nematodes in maize-based cropping systems throughout eastern, central and southern Africa is the lesion nematode *Pratylenchus zeae*. This nematode reproduces best on maize, sorghum and millet but their populations can be sustained on grasses and some broad-leaved weeds. Of the weed species inoculated with a population of *P. zeae* from Malawi by Jones and Hillocks (1995), the best broad-leaved hosts were *Amaranthus hybridus*, *Commelina benghalensis* and *Crotalaria incana*. However, the preferred weed hosts for this nematode were the graminaceous species, *Rottboellia exalta* and *Digitaria* spp. In South Africa, *Crotalaria spaerocarpa* was found to be an good host for *P. zeae* (Jordaan and de Waele, 1988) while the best graminaceous weed host was *Eleusine indica*. The host status of many African weeds for nematodes other than *Meloidogyne* spp. and *Pratrylenchus zeae* is unkown. A number of weeds which are common in Africa, such as *Amaranthus spinosus* and *Bidens pilosa* were listed as hosts for the reniform nematode (*Rotylenchulus reniformis*) in Florida (Inserra *et al*., 1989).

Clearly, weed species allow reproduction of some plant parasitic nematodes and can therefore sustain nematode populations during periods between crops. Weed hosts of parasitic nematodes, especially hosts of *Meloidogyne* spp., should be removed from fields where highly susceptible crops such as tobacco and common bean (*Phaseolus vulgaris*) or vegetable crops are to be grown.

Pathogens

Although better documented for Asia, there is little information from Africa on weeds or natural vegetation as alternative hosts for fungal or bacterial pathogens. The subject is better covered for the virus diseases but here too information is lacking. Conti (1981) has suggested that weeds may act as virus reservoirs which select new virus strains and gives the example of a strain of maize streak virus from *Eleusine* which became highly pathogenic towards some exotic maize cultivars when they were first introduced into Africa. Spence and Walkey (1995) isolated bean common mosaic virus (BCMV) from a range of wild legumes in the genera *Cassia*, *Crotalaria*, *Macroptilium*, *Rhynchosia* and *Vigna* and the virus was aphid-transmitted in either direction between the wild hosts and *P. vulgaris*. In one extensive survey of the tobacco-producing areas of South Africa, Swanepoel and Nel (1995) recorded the weed hosts of cucumber mosaic virus which included at least 15 species commonly found on cultivated land throughout eastern, central and southern Africa. Alegbejo (1987) reported that *Solanum nigrum* was a host of pepper veinal mottle virus and the virus could be transmitted from the weed to the pepper crop by four aphid species. Sunflower yellow blotch virus which is also responsible for causing groundnut streak necrosis, perpetuates in the absence of its crop hosts on the ubiquitous weed species, *Tridax procumbens* (Theuri *et al*., 1987).

From a crop protection viewpoint, the role of alternative hosts is most important where the pathogen has a wide host range and rotation is the main method of disease management. Alternative hosts for the pest among the weed flora then need to be removed if rotation with a non-host crop is to be fully effective as a control measure. Indigenous vegetation can be a reservoir for plant pathogens introducing them into newly cleared agricultural land. Some weed seeds can be carried long distances and in this way seed-borne pathogens may be spread into new areas. This was apparently the case with Verticillium wilt of cotton in Australia where the seed of the common weed *Xanthium pungens* was often found to be infected with the pathogen (Evans, 1971). *Ageratum conyzoides* is also a carrier host for *V. dahliae* and high incidence of verticillium wilt in cotton grown at a site in Zimbabwe where cotton had not been grown for 15 years, was attributed to a dense cover of *A. conyzoides* on the site (Hillocks, unpublished). Wood and Ebbels (1972) reported that many common weeds found in cotton fields in Tanzania could be infected with the fusarium wilt pathogen (*Fusarium oxysporum* f.sp. *vasinfectum*) by inoculation. Another important vascular wilt pathogen in the tropics is *Pseudomonas solanacearum* which causes bacterial wilt in a wide range of crops and has been isolated from several weed species, members of the Solanaceae and Asteraceae being relatively susceptible, often showing visible symptoms (Hayward, 1994). *A. conyzoides* is frequently reported as a host (Kelman, 1953) but usually shows latent infection, allowing the bacterium to survive, although no symptoms develop (Sunaina *et al*., 1989). This is the case also with *Portulacca oleraceae* in the Philippines (Quimio and Chan, 1979). Populations of the bacterium appear to increase in the rhizosphere of certain weeds such as *Bidens pilosa* L (Akiew and Trevorrow, 1994). As with the nematodes, it cannot always be assumed that a weed species which is host to a particular pathogen in one area will also be a host elsewhere, due to genetic differences in the host and pathogen population. A certain degree of host preference may be exhibited by isolates of *P. solanacearum*. For instance it was reported from Indonesia that the incidence of infection among weeds associated with wilt-infected cassava was particularly high in the Euphorbiaceous weed species (Machmud, 1986).

Weeds as a source of biopesticides

The production by plants of bioactive secondary metabolites is usually an evolutionary response to the threat posed to the species by herbivores, many of them insects. So it is not surprising that some of these compounds have been shown to be insecticidal. About 2000 plant species are reported to contain compounds with pest control properties (Secoy and Smith, 1983; see also Grange and Ahmed, 1988). Some of the more effective compounds such as nicotine, derris and pyrethrum have long been exploited commercially as agricultural and household insecticides. There are many others which are used traditionally in Africa but their use is rarely universal with particular plants being used as insect repellents in one area but neglected in another (Chimbe and Galley, 1996). Although the efficacy of extracts from most of these plants is poor compared to commercial synthetic pesticides, they can still contribute substantially to pest control when their use is integrated with other measures and often have the advantage of low human toxicity. Some of the plant extracts which are active against insect pests are also active against fungal and bacterial pathogens. *Datura stramonium* has been shown to provide some control of both Alternaria leaf spot (*Alternaria macrospora*) and bacterial blight (*Xanthomonas campestris* pv. *malvacearum*) on cotton (Bambawale *et al*., 1995).

Nicandra physaloides is a common weed in both the old and new worlds and is known to contain an antifeedant compound, nicandrenone. Its use as a household fly repellent is common in Peru (Bettolo, 1983) and its use for this purpose has been recorded in Africa. Secoy and Smith (1983) listed 664 plant species with pest control properties, some of which are common weeds. Most of the uses reported for these weeds, including *N. physaloides*, were as repellents against insects attacking the human body, *Datura* spp. are also used as rat poison in stored grain. Two noxious weeds which produce large quantities of biomass which could be exploited for pest control are the water hyacinth (*Eichornia crassipes L*) which decreased populations of plant parasitic nematodes when incorporated into soil (Siddiqi and Alam, 1989) and *Lantana camara* which produces an antimicrobial compound, umuhengen (Sharma and Sharma, 1990).

Storage pests are a major problem to smallholders in Africa where as much as 10% of their crop may be destroyed during storage (Schulten, 1975). In Malawi where maize is the dominant food crop, about 85% of production is stored on-farm in traditional granaries (Chimbe and Galley, 1996). Losses in store to insect pests, diseases and rodents are expensive to control with conventional pesticides and resistance in the target population has been known to develop towards some of the more commonly used insecticides such as malathion (Champ and Dyte, 1976). For these reasons and because compounds used on stored products must be of low human toxicity, storage pests are a particularly good target for natural pesticides. Natural products have shown some activity against two common pests of stored grain, *Sitophilum* spp. and *Prostephanus truncatus* (Chimbe and Galley, 1996; Abdallah *et al*., 1990; Tiertoniber, 1994). Fruits from *Datura* spp. or whole plants of *Leonotis africana* Briq. or *Ocimum canem* Sims are placed in the traditional store to protect the crop from pests (Secoy and Smith, 1983). Extracts from the leaves of *O. kilimanscharicum* were also shown to be insecticidal against common stored product pests (Jembere *et al*., 1995). Weaver *et al*. (1991) reported that linalol extracted from freshly milled *O. canem* was effective against stored product pests, protecting beans against *Zabrotes subfasciatus* in Rwanda. Another species of *Ocimum*, *O. suare* Willd. protected stored maize from maize weevils (*Sitophilus zeamais* Motchusky), the lesser grain borer (*Rhyzopertha dominica* Fabricus) and the grain moth (*Sitotroga cerealella* Oliver). Dried or ground leaves and essential oil extract was repellent to all three pests but particularly to *S. zeamais* (Hassanali *et al*. 1990; Bellele *et al*., 1996). Marigolds (*Tagetes* spp.) have long been known to produce root exudates with nematicidal properties (e.g. Daulton and Curtis, 1963) and floral and root extract of the common weed species in east Africa *T. minuta*, showed insecticidal activity against the adult Mexican bean weevils (*Epilachnai* spp.) (Weaver *et al*., 1994).

Weed management in integrated crop protection

A weed by definition is a plant growing where it is not wanted. It is clear from the works reviewed in this paper that the perception of whether a plant is wanted or not within the agroecosystem, depends on factors other than simply the competitive effect of the plant with the main crop species. For intensive agriculture with large areas planted to a single crop, the depressive effects of weed competition on crop yields would normally be expected to outweigh the pest management benefits. However, the benefits of practices which encourage a diverse flora in field margins or in islands of 'natural vegetation', within the cropped area, have been widely researched and discussed (e.g. Way and Greig-Smith, 1987; Thomas *et al*., 1991; Fry, 1994; Feber *et al*., 1995).

The situation is different for smallholders in Africa where some form of multiple cropping is often practised. Mixed cropping has advantages in terms of increased food security and land equivalent ratios can be higher than with monocrops. In this context, weeds which have culinary or other domestic uses may be included as part of the cultivated vegetational matrix. Zmarlicki *et al*. (1984) suggested that cultivation of culinary species such as *Amaranthus* and *Chenopodium* should be encouraged as a means of improving food security and nutrition. Provided weeds within the cropped area are controlled during the early stages of crop development when growth may be most affected by weed competition, then the increased activity of beneficial insects in weedy stands may contribute to integrated management of pest species (Afun *et al*., 1995). The difficulty here is the lack of knowledge on appropriate threshold levels for weeds within the crop stand, beyond which competitive effects outweigh the pest control benefits. Some weeds have pest control attributes such as the nematicidal effects of root exudates from *Tagetes* species. At the end of the growing season, cropped land in East Africa often becomes thickly colonised with weeds such as *Trichodesma zeylanicum* which is not known to have any beneficial effects. If instead a predominance of *Tagetes minuta* were to be encouraged on land infested with root-knot nematode, the weed cover might depress the nematode population.

As in more intensive agricultural systems, the natural vegetation surrounding the cropped areas can be managed by smallholders as part of an integrated approach to crop protection. A diverse flora will encourage beneficial insects but those species which serve as alternative hosts for important crop pests and pathogens may need to be actively removed from the system. Just as rational use of pesticides requires some knowledge of insect identification in order to carry out scouting activities, so vegetation management for integrated crop protection requires a knowledge of the attributes of different members of the weed and natural flora. Such knowledge is often indigenous but may have been partially lost through the generations. The wild basil *Ocimum canem* provides a good example of this in East Africa, where it is widely known to have insect repellent properties and is often burned in, or close to, dwellings to repel mosquitoes. However, in some areas it is not known as an insect repellent and in many areas where it is used for that purpose, its insecticidal properties have not been extended to use the plant as a protectant for stored grain.

Conclusions

The need to feed the increasing populations of the less developed nations and the aspirations of rural communities for a standard of living above that of mere subsistence, dictates that agriculture in these countries must become more productive. As the farming systems in the tropics become more intensified to meet this demand we must provide the technology to achieve this and ensure that increased productivity is sustainable, with the minimum of environmental degradation and loss of species diversity. Weed control will continue to play an important role in raising farm productivity in the tropics but there are some weeds and some situations in which more may be lost than gained by their eradication. Wilson (1989) has documented the increased dependancy on wild foods as a dietary supplement as population increases and agricultural land become scarce. As woodland areas are replaced by grassland and arable land there is an increase in species, including many annual weeds, which thrive in the new habitats. However, as areas of common property decrease, protection and privatisation of wild foods increases and attempts to domesticate wild species also occurs to ensure their supply. Other reports (e.g. Ogle and Grivetti, 1985c) have highlighted the importance of wild vegetables in the diet of rural communities in Africa. Clearly, the weed flora is an important resource and weed management projects, especially those advocating the use of herbicides should first evaluate the actual and potential domestic exploitation of the weed flora before designing a control strategy. The implementation and adoption of IPM programmes for smallholders in Africa requires the development and augmentation of indigenous knowledge which should include also knowledge of the uses and beneficial or deleterious attributes of the local weed and natural flora within and surrounding the cropped areas.

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