the management of the cell's processes, and force the cell to produce more viruses identical to itself – rather than the crop yield we want! These new virus particles then spread through the plant to infect more cells. Each virus species causes a specific disease, for example the influenza virus causes flu in humans, the cassava mosaic viruses makes cassava plants sick, and the sweetpotato feathery mottle virus and the sweetpotato chlorotic stunt virus attack sweetpotato.

Common symptoms of virus infection in plants, including sweetpotato, are diminished growth so that the plants and leaves remain small, and chlorosis (pale, even white) of the leaf tissue. This chlorosis may be general or in a pattern, often either between the leaf veins in a mosaic or less well defined mottle, or along the veins to form a chlorotic network. Leaves may also be misshapen so they have an uneven appearance or are curled, and the leaves may become pigmented, often purple or yellow either generally or in spots or rings. Associated with these changes, there is generally a reduced production of sweetpotato storage roots. Severely affected sweetpotato plants can often be seen from a distance by their stunted growth and chlorotic leaves. Common viruses affecting sweetpotato are transmitted by aphids or whiteflies.

Witches' broom is not caused by a virus but is a disease caused by a mycoplasma-like organism (a phytoplasma). However, like many viruses, this group of plant diseases is transmitted from plant to plant by insects, in this case leafhoppers. Plants containing this organism show extreme dwarfing with an associated production of many small shoots, abnormal development of flowers and also extreme proliferation of fine fibrous roots. This disease is very common in south-east Asia but appears to be rare in Africa.

Witches broom Normal plant

Witches' broom dwarfing and irregular flowering

4.8.1 Viruses

A. Biology

Viruses affecting sweetpotato can be perpetuated and spread between cropping cycles by the use of foliar cuttings taken from infected plants. They are also transmitted from plant to plant by sap-sucking insects. So far, the only proven vectors of sweetpotato viruses are aphids and whiteflies. Furthermore, for any one virus species, only one of these insect groups can transmit it. Thus, sweetpotato feathery mottle virus (SPFMV) and the related sweetpotato virus 2 (SPV2) and sweet potato virus G (SPVG) are all transmitted (non-persistently) only by aphids whereas sweetpotato chlorotic stunt virus (SPCSV) and perhaps sweetpotato mild mottle virus are transmitted only by whiteflies, predominantly *Bemisia* spp. Most viruses affecting sweetpotato also have a fairly narrow host range even when transmitted experimentally and, although some weeds such as Morning Glories may harbour them, the only economically important source of infection is other infected sweetpotato plants.

SPFMV and SPCSV are together the most important viruses affecting sweetpotato in Africa and occur everywhere sweetpotato is grown on the Continent. Other viruses may be locally important, for example, SPV2 and SPVG seem to be important in southern Africa. By themselves, sweetpotato viruses may cause only mild or no obvious symptoms (though evidence is building up that such symptomless plants may still suffer a considerable reduction in yield). However, plants can be infected by more than one virus species and, when this happens, the viruses may help each other to multiply with the result that the disease is even more severe than the expected sum of the two diseases. This phenomenon seems unusually common in sweetpotato, SPCSV in particular synergising the multiplication of SPFMV and apparently of other viruses too, by a mechanism that is still being researched. This can severely affect the growth of the sweetpotato plants. The combination of SPCSV + SPFMV is the most important disease of sweetpotato in Africa and perhaps worldwide and is known as sweetpotato virus disease (SPVD). SPFMV is transmitted by a wide range of aphid species and is spread mainly by winged adults, even of species that do not colonise sweetpotato, flying from plant to plant. SPCSV is transmitted by the mobile adult form of whiteflies, especially *B. tabaci*, as they fly from plant to plant. Since it is the spread of SPCSV by whiteflies that synergises SPFMV, whiteflies are also usually the driving force behind the spread of SPVD.

Bemisia tabaci adults, the whitefly vectors of SPCSV

SPVD-affected plant (on left)

B. Damage

SPFMV by itself is generally symptomless in sweetpotato in Africa (although it may cause vein clearing and purple ring spots on leaves of susceptible varieties). SPCSV by itself causes some dwarfing of plants and also either a purpling or yellowing of lower leaves. Both viruses appear to cause some yield loss when infecting plants. In China and South Africa, yield increases of more than 30% have occurred as a result of planting virus-free planting material. Symptoms of individual infection by other viruses are poorly described, though they generally appear to be mild, notably a slight loss of vigour and perhaps a mild mottle. However, when a sweetpotato plant is infected with both SPCSV and SPFMV, the symptoms become very severe (SPVD). Symptoms of SPVD include severe stunting of the plant and small malformed leaves, often with either a chlorotic mottle or vein clearing. Often these symptoms are most apparent in young plants as they get established, but plants can be infected at any age. Plants affected by SPVD usually produce only small storage roots, generally of an unusable size, resulting in a massive reduction in the yield of individual plants. However, unless an entire crop is affected, yield losses are not proportionate as the sprawling indeterminate growth habit of most sweetpotato varieties can allow unaffected neighbours to make compensating increases in yield.

Yield losses associated with SPVD in sub-Saharan Africa: comparisons between yields in plots of diseased and unaffected plants

Country	Root yield loss	Cultivar	Comments
Uganda	66%	Bitambi	Severely diseased plants.
Uganda	70-99%	7 clones	Virus-free clones as negative control.
Uganda	57%	Kyebandula	Some controls became diseased.
Nigeria	76-78%	TIS1499	
Nigeria	60%	TIB 4	Low level of resistance to SPVD.
Cameroon	0 - 90%	8 Clones	Losses varied between clones and field trials

C. Management

Because viruses spread quickly through the vascular system of a plant to infect the whole plant, any portions of an infected plant that are used as planting materials (vines or roots), are almost always diseased themselves. This then carries the disease to the next generation of plants and is a quarantine risk. So:

- **Make sure cuttings are collected for new crops from healthy plants** and, if possible, from healthy plants in crops in which few other plants have the disease. Then there is also less chance of taking cuttings from plants that have just been infected. It may be better to avoid collecting cuttings from very old crops both because SPVD may have built up in these crops and because sweet potato virus disease is less easy to see in old plants than in vigorously-growing crops.

Furthermore, such cutting-derived infection becomes strategically located amongst other young plants and can act as a major source from which new infection can spread to infect the whole crop. So:

- **Remove any diseased plants as soon as they appear in young crops** (plants infected when young wouldn't have yielded much anyway, the neighbouring plants will soon fill up the space and you can replant cuttings if you wish in young crops [this is something farmers might want to test]).

- **Avoid planting new crops where you grew sweet potato last season** because roots and cuttings from old diseased plants surviving in the soil will produce diseased plants from which infection will easily spread to your new crop.

Neither SPFMV nor SPCSV are transmitted persistently by their aphid or whitefly vectors, rates of transmission drop within a few minutes for SPFMV and within a few hours for SPCSV. Consequently, neither of these viruses are often carried long distances by their vectors.

- **Plant your new crop away from old crops** so it is difficult for whiteflies and aphids to reach your new crop.

Other forms of crop hygiene such as ensuring that the trash foliage from harvested crops is completely destroyed (it can be fed to livestock) and that that all the roots (especially the small ones which may come preferentially from diseased plants), are destroyed.

However, often the best and certainly the most convenient means of controlling SPVD is to plant varieties of sweetpotato which have resistance to virus diseases. This can often provide control at no effective cost to the farmer. There has been a problem that some (but not all) resistant traditional varieties have often been low yielding and late maturing; however, high yielding resistant varieties have been bred, in West Africa by IITA and in East Africa by national agricultural research programmes. Where they are available and acceptable, farmers can use these varieties to produce a crop in areas of high SPVD pressure.

Finally, all the management practices work better if they are done on areas as large as possible, so if communities can work together to manage SPVD they will all benefit.

4.8.2 Fungal pathogens causing foliar disease

4.8.2.1 Alternaria

A. Biology

This is the most damaging fungal pathogen affecting sweetpotato foliage in Africa. The fungus survives in the soil and in plant debris. The airborne spores are spread through: infected planting material; wind; splashing rain and water. During the rains the increased humidity often leads to high levels of infection. The disease incidence and lesion size increase in wetter, high altitude areas.

B. Damage

The disease is first observed as small, brown/grey/black oval lesions with a typical bulls' eye appearance of concentric rings, on leaves, stems and petioles. On the lower side of the leaf, blackened veins are observed. As the disease progresses, the lesions become necrotic usually surrounded by a wide yellow halo; soon after the whole blade turns chlorotic and drops. Bases and middle sections are more affected than the vine terminals. Death of vines can occur. The ground under affected vines is often carpeted with blackened leaf debris.

C. Management

Good sanitation practices are the main management strategies for this disease: infected crop materials should be destroyed and burnt, clean planting materials used, and new crops of sweetpotato should not be planted in fields which have recently had a sweetpotato crop grown in them. Some varieties of sweetpotato are more susceptible to *Alternaria* disease than others; planting material from more resistant varieties could be selected. In other crops fungicides are used against *Alternaria* diseases, however there is no information about using fungicides to control the disease in sweetpotato.

4.8.2.2 Phomopsis leaf spot (Phomopsis ipomoea-batatas)

A. Biology and lifecycle

The fungus survives in crop debris and is not known to have other hosts. Spores spread through infected planting material, wind, splashing water and possibly insects. The disease usually appears late in the growing season developing mainly in mature leaves.

B. Damage

Whitish to brown irregularly shaped lesions, usually less than 10 mm in diameter, form on the upper and lower surfaces of older leaves. The lesions usually have a dark brown or purple margin and a few pinhead-like black to brown structures in the centre.

C. Management

Good sanitation practices are the main management strategies for this disease: as the fungus survives on infected crop debris between planting seasons infected crop materials should be destroyed, moved away from the field and burnt; and clean planting materials used.

4.8.3 Root rots

Several fungi and bacteria cause root rots. Once rotting starts it cannot be reversed. Infected plants must be destroyed to prevent further spread of the disease. Planting material should not be obtained from fields where there are many rotten roots. Since the fungi and bacteria that cause root rots can survive in the soil for a long time, sweetpotato should be planted in rotation with other crops in order to avoid a build-up of disease. Cuttings should be taken from vine sections that have not been in contact with the soil.

Black rot (*Ceratocystis fimbriata*) is a dry root rot caused by a fungus. Sunken greyish-black lesions form on the surface of the storage root. Black spine-like structures of the fungus sometimes protrude from the lesions. A smell of alcohol like that of fermenting fruit is often present. In severe infections, yellowing, wilting, stunting and death of affected plants can occur. The disease can also be serious on young sprouts and adult plants. Infected sprouts develop black sunken necrotic lesions or cankers at the point of attachment to the mother root. Affected shoots are girdled at soil level. In the field infected plants are stunted and chlorotic due to the cankers present in the underground stem.

The use of planting material infected by the black rot fungus perpetuates the disease. Cuttings taken from plant parts in contact with the soil surface may be infected or contaminated with fungal spores. The black rot fungus can survive in the soil for 1-2 years. The spread of black rot at harvest time is a particular problem since spores from infected roots are easily transferred to hands, tools, vehicles and other equipment, from which they can spread far and wide. The sweetpotato weevil also spreads black rot. Females can infect roots as they puncture the surface to feed and lay eggs. Weevils can also spread black rot spores to the foliage. Any sort of wounding increases the possibility of infection.

Bacteria also cause root rots, disease transmission routes and management strategies are similar to those of black rot. On storage roots, small brown lesions with black margins can be observed on the surface, but more frequently the rotting is internal with no evidence outside. Affected tissue becomes watery. There is often a peculiar smell produced in infected tissues due to the invasion of saprophytes that live on decomposed organic matter.

Bacterial rot on storage root

4.8.4 Nematodes

A. Biology

Nematodes are microscopic worms, which can be parasitic or beneficial to crops (as well as other organisms). Depending on the plant parasitic nematode species, nematodes infect sweetpotato roots by either entering the roots and feeding on tissue from within the root (endoparasites), or by migrating through the soil and feeding externally on tissue from the soil (ectoparasites). They feed by piercing cells with their needle-like stylets, damaging roots by injuring the cells they feed on, stealing nutrients, distorting root growth and by enabling other pathogens and pests to enter root tissues. Nematodes reproduce by laying eggs. When the juvenile hatches from the egg it finds a feeding site on or in fresh root tissues and grows and moults until it reaches adulthood. Eggs are deposited in the soil or plant tissues where the nematode lives, or accumulate in a gelatinous mass attached to the female or in a hard egg casing.

B. Damage

Root-knot nematode causing distortion and necrosis

Internal necrosis of sweetpotato edible root caused by root-knot nematode

Necrotic lesions and cracks caused by Scutellonema bradys *(top) compared with unaffected root (bottom)*

The most destructive nematodes affecting sweetpotato are root-knot nematodes (*Meloidogyne* spp.) and reniform nematodes (*Rotylenchulus* spp.). Root-knot nematodes commonly cause gall-like swellings on roots and tubers of a wide range of crops. Reniform nematode damage is less obvious, but still affects a wide range of crops, making crop rotation difficult for management of the nematodes. Other nematode species also damage sweetpotato, but have not been studied much. Consequently, and particularly as sweetpotato expands in its geographical area of production, nematode species previously not known to cause damage are being found affecting the crop. For example stubby-root nematodes (*Paratrichodorus* spp.) have caused damage in South Africa and the yam nematode (*Scutellonema bradys*) affects sweetpotato in West Africa. Other nematodes likely to cause damage are lesion nematodes (*Pratylenchus* spp.).

Above-ground, there are no obvious, specific diagnostic symptoms. Nematode infected plants may exhibit general symptoms of malaise or poor growth associated with poor root growth, including stunting, chlorosis and a tendency to wilt early.

Below-ground, obvious swellings (galls) may be present on roots of plants affected by root-knot nematodes, although not all cultivars react in this way. Otherwise, symptoms on roots consist of necrosis, stunting, reduced mass and terminated root tips resulting in stubby, highly branched roots. On the edible roots nematodes typically cause cracking, which is also complicated (and mis-diagnosed) with drought effects, necrotic patches and blister-like swellings, which can result from most nematode attack. Cracks however, are very typical of reniform nematode parasitism, in particular, and also root-knot nematodes.

C. Management

Nematodes can survive in the soil between crops on decomposing plant material, on alternative crop or weed roots, or in some cases they may survive in a state of desiccation until favourable conditions return. Nematodes can also be spread between fields when soil is moved, for example, on farming tools, shoes, through infested planting material and irrigation water.

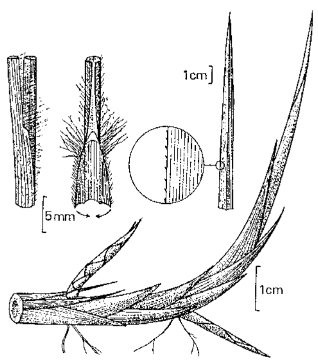
Serious nematode infections may reduce yields by over 50%, if unchecked, while cracking and necrosis reduces quality of tubers and predisposes them to secondary infection.

4.9 Weeds

Weeds are unwanted plants that may reduce the yield or value of the crop harvested. We usually think that they have no beneficial effects when they grow on cultivated land; however weeds are not always harmful. Weeds can be divided into three categories:

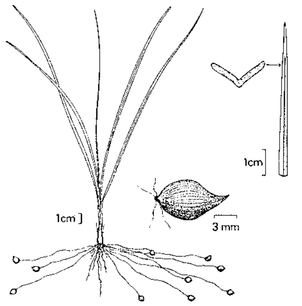
- Grasses
- Sedges
- Broad-leaved plants

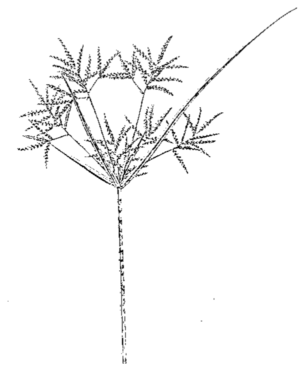
Grass



Imperata cylindrica
Mtimbi (Kiswahili), Ebiat (Ateso), Lalang, Lusanke (Luganda)

Sedges





Cyperus blysmoides *Cyperus esculentus*

Broad – leaved plants

Lantana camara
Akayuukiyuuki (Luganda), Magwagwa (Luo), Mukenia (Kikuyu), Omuhuuki (Ankole)

Solanum incanum
Entengotengo (Luganda), Mutongo (Kikuyu), Mtunguja mwitu (Kiswahili), Ochok (Luo)

Weeds can cause losses when:

- they compete with the sweetpotato crop for nutrients, light, water and growing space. This may result in smaller and fewer roots.
- their removal is time consuming or costly when labour is hired, and in the longer term as so many children have to help their parents to weed during school time missing hours and hours of school.
- they provide a refuge for insect pests allowing their survival during periods when there is no crop growing in the field, sweetpotato weevils can feed and survive on weeds from the same family (Convolvulaceae, morning glory) as sweetpotato such as *Ipomoea cairica* (sweet mile a minute vine) and *Convolvulus* spp (bindweeds).
- the roots of certain spear grasses penetrate and damage the sweetpotato root.

Weeds may be beneficial when:

- they are slashed but left on the land to form a covering layer over the soil (a mulch). Mulches protect the soil from the light that causes the loss of water and organic matter.
- they can be harvested to feed livestock.
- they are composted and then dug into the soil to supply nutrients and organic matter improving the soil structure.

4.9.1 Management of weeds

Weeding is easiest when there is no crop to avoid. Consequently, careful removal of perennial weeds, especially the roots, rhizomes and tubers of species including Imperata (spear grass), Cynodon (star grass), Cyperus (nut grass) and Digitaraia (couch grass), and burial of annual weeds is a key component of land preparation so that the weeds don't compete with the young sweetpotato planting materials. One aim of producing mounds or ridges should always be to invert the soil so weeds and seeds in the top layer of the soil are buried. Weeding should also be done during the first four to six weeks after planting before the sweetpotato vines cover the soil.

As land pressure limits long-term fallows, and labour shortage makes hand pulling and hoeing more problematic, what can small-scale farmers, who face the challenge of feeding themselves and their increasingly numerous urban compatriots, do in the future? Weed early. It is a common a sight to see farmers attempting to remove weeds that are well grown. By this stage not only have the weeds developed strong roots and stems, making it difficult to pull or to cut with a hoe, they have already compromised crop yield by their competition. If only the hoe could be applied to weeds when they are seedlings, they would be killed before they have become serious competitors, and the work would be done more quickly and with much less effort. Admittedly another flush of weed seeds will germinate and will have to be hoed in its turn but, if hoeing is done early; two quick and 'light' hoeings can take less time and energy than one delayed hoeing. Furthermore, weeds are killed long before they have a chance to set and disperse seed, reducing future weeding. Weeding early is a strategy that should prove advantageous for another reason: hoeing at the seedling stage should suit women and even children since they could use lighter hoes to do the work.

Reducing weed seed survival and germination

Weed seeds have a host of characteristics that assure their survival, they:

- are adapted to many types of disturbance and harsh climatic conditions;
- have several seed-dispersal mechanisms (often aided by humans) assuring wide distribution;
- produce seeds that can last a long time in the soil without rotting. Additionally, seeds can go dormant until favourable conditions come around again.

Weed seed distribution and density in agricultural soils are influenced by cropping history and the management of adjacent landscapes, and may be highly variable.

New weed species can enter fields by many routes. Equipment moved from one field to the next - especially harvest equipment - spreads weed seeds, as does grass brought from one farm to another. Crop seed is often contaminated with weed seed, and livestock transport weed seeds from one field to another in their digestive tracts and in their hair. Practical actions that can be taken to prevent the introduction and spread of weeds include the use of clean planting material, cleaning equipment before moving from one field to the next, and composting manures that contain weed seeds before applying them to the field.

Survival and germination of weed seeds in the soil depend on the weed species, depth of seed burial, soil type, and tillage. Seeds at or near the soil surface can easily be eaten by insects, rodents, or birds. Also, they may rot or germinate. Buried seeds are more protected from seed-eating animals and buffered from extremes of temperature and moisture. Some weed species are dependent on light for germination; some germinate in either light or darkness; others germinate only in the dark. Thus, there are no hard and fast rules for managing an overall weed population according to light sensitivity.

Manure application may stimulate weed germination and growth. Studies have shown that poultry manure does not contain viable weed seeds, yet weed levels often increase rapidly in pastures following poultry manure application. Since chickens and turkeys have a gizzard capable of grinding seeds, weed seeds are not likely to pass through their digestive systems intact. The weed germination is probably caused by effects of ammonia on the weed-seed bank already present in the soil. The effect varies depending on the source of the poultry manure and the weed species present. Manure from hoofed livestock (e.g. cattle, goats and sheep), on the other hand, may indeed contain weed seed that has passed through their digestive systems. Composted manure contains far fewer weed seeds than does raw manure because the heat generated during the composting process kills them.

Fertilisation practices can also affect weed germination. Where fertiliser is broadcast, the entire weed community is fertilised along with the crop. Where fertiliser is banded in the row, it is mainly the crop that gets fertilised.

Mulching
In general, typical levels of cover crop residues, when left on the soil surface as a mulch, can be expected to reduce weed emergence significantly. As these residues decompose, the weed suppression effect will decline also. Residues that are more layered and more compressed will be more suppressive. Small-seeded weeds that have light requirements for sprouting are most sensitive to cover crop residue. Larger-seeded annual and perennial weeds are least sensitive to residue. Effective management strategies include growing cover crops that produce high amounts of residue, growing slower-decomposing cover crops, packing the mulch down with implements that compress it, and using methods other than cover crops to control large-seeded annual and perennial weeds. With enough mulch, weed numbers can be greatly reduced.

In some countries where sweetpotato is planted on ridges, farmers often temporarily move the soil down from the sides of the ridges at about five weeks after planting, in order to remove weeds, aerate the plant roots and provide a place for side dressing of fertiliser. The weeds are then left in the field as green mulch.

Crop rotation
Crop rotations limit the build-up of weed populations and prevent major weed species shifts. Weeds tend to prosper in crops that have requirements similar to the weeds. Fields of annual crops favour short-lived annual weeds, whereas maintaining land in perennial crops favours perennial weed species. In a crop rotation, the timing of cultivation, fertilisation and harvesting changes from year to year. Rotation thus changes the growing conditions from year to year - a situation to which few weed species easily adapt. Rotations that include clean-cultivated annual crops, tightly spaced grain crops, and grazed perennial grass crops create an unstable environment for weeds. Additional weed control may be obtained by including short-season weed-smothering crops. Crop rotation has long been recognized for this ability to prevent weeds from developing to serious levels.

Intercropping
Intercropping (growing two or more crops together) can be used as an effective weed control strategy. Having different plant types growing together enhances weed control by increasing shade and increasing crop competition with weeds through tighter crop spacing. Where one crop is relay-intercropped into another standing crop prior to harvest, the planted crop gets off to a weed-free start, having benefited from the standing crop's shading and competition against weeds. Such is the case when beans are interplanted into standing maize - the maize competes well with weeds while the beans are getting started.

Weeder Geese
Weeder geese have been used successfully. They are particularly useful on grass weeds (and some others, too) in a variety of crops. Chinese or African geese are favourite varieties for weeding purposes. Young geese are usually placed in the fields at six to eight weeks of age. They work well at removing weeds between plants in rows that cannot be reached by cultivators or hoes. If there are no trees in the field, temporary shade will be needed. Supplemental feed and water must be provided as well. Water and feed containers can be moved to concentrate the geese in a certain area. A 24- to 30-inch fence is adequate to contain geese, but costly and dogs and other predators need to be kept away. At the end of the season, geese can be brought in for fattening on grain. Carrying geese over to the next season is not recommended, because older geese are less active in hot weather than younger birds. Geese have been used on the following crops: cotton, tree nurseries, maize, fruit orchards, tobacco, potatoes, onions, sugar beets, other small fruits, and ornamentals.

Tillage
Tillage and cultivation are the most traditional means of weed management in agriculture. Both expose bare ground, which is an invitation for weeds to grow. Bare ground also encourages soil erosion, speeds organic matter decomposition, disturbs soil biology, increases water runoff, decreases water infiltration, damages soil structure, and costs money to maintain.

Herbicides

In the past, farmers had limited options for weed control, and many still do: uproot, hoe, transplant crops from nursery beds to give them a growth advantage over weeds, or abandon weed infested land and clear fresh ground. Herbicides may appear to offer other options but, while they have been widely and successfully used on commercial farms and on estates or plantations, they have had little appeal for small-scale farmers because of their cost, and because of the challenges of accurate and timely application.

Herbicides such as Round-up (glyphosphate) can provide easy and effective control of most of the problem weeds encountered in sweetpotato fields. A good practice is to dig planting ridges or mounds two to three weeks prior to planting. Then spray any weeds that emerge the day before planting vines. This will ensure control of perennial weeds for the first four to six weeks after planting. The vines of sweetpotato grow slowly at first and it is essential to make sure the land is weed free until the crop is well established and is growing strongly.