CHAPTER 4

WEED AND VEGETATION MANAGEMENT

Namibian Organic Association
Enabling Sustainable Organic Agriculture

IFOAM SOUTHERN AFRICAN NETWORK

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DEUTSCHE ZUSAMMENARBEIT

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WEED AND VEGETATION MANAGEMENT

4.1. Prevention

4.1.1. Introduction

Weeds can be one of the most significant problems in many farming systems.

There are numerous methods to manage weeds. Currently the use of herbicides is the main weed control strategy in non-organic agriculture. This has replaced the range of methods used in the past. Those management systems were far broader than just tillage, however much of this knowledge has been lost to the current generations of chemical farmers.

There are a range of new methods being used to manage weeds that are based on the current understanding of plant physiology and Eco Functional Intensification (EFI). These systems use applied ecology in increasing bio-diversity to manage weeds.

It is important to understand that organic farming is about weed management, rather than weed eradication. Organic farmers develop an approach to minimise weed problems so that they do not adversely affect the cash crop and integrate weed management into the farming system as part of their farm management.

4.1.2. Weeds – friends or foe?

There are many definitions of a weed. Probably the most common one is: "A plant in the wrong place".

In agriculture a better definition is: "A plant that adversely affects the production of the crop".

Generally it is assumed that any plant, other than the crop, is a weed because it competes for soil moisture, nutrients, light or it harbours pests etc. The current 'normal' solution is the removal of these through herbicides, tillage, fire etc.

Weeds however can have many benefits such as preventing soil erosion, increasing soil fertility, correcting poor soil structure, indicating poor drainage, mineral deficiencies and pH imbalances and as host plants for beneficial insects and animals.

Multiple benefits of weeds are:

1. Prevent soil loss

Loss of topsoil is one of the most significant problems in nearly all farming areas in every country on this planet. Nutrient rich healthy topsoil is the basis of high yielding sustainable farming, yet many farming practices squander this precious resource.

Inappropriate tillage practices, herbicide use, poor irrigation methods and allowing soil to remain bare of plant cover are some of the major causes of soil loss. Ironically the loss of this valuable resource results in degradation of downstream aquatic environments, due to these systems being overloaded with nutrients and a lack of light due to turbidity of the water.

Having a groundcover of weeds will minimise or prevent soil loss. The tops of plants help cushion the impact of rain or wind on soil while the roots help to hold the soil together.

2. Carbon gift *(see section 4.1.5.)*

If soil nutrient levels are optimal and the weed management methods ensure that the nutrients they use are recycled into the soil – weeds can actually increase soil fertility through the gift of carbon and nitrogen fixation.

3. Insectaries

Weeds can be used as insectary species to attract beneficial insects and other animal species to suppress insect pests.

4. Nutrient storage

Weeds can help to take up excess soluble nutrients in wet periods, stopping them from leaching, running off-farm and eutrophying water.

They can be very useful in preventing leaching of soil minerals especially anions like nitrogen, boron and sulphur. They can take up and store the soluble ions that are in excess to the needs of the cash crop. Later when the weeds are managed, microorganisms will break down the residues and release a steady flow of these nutrients back into the soil for the cash crops to use.

As plants get around 95% of their nutrients from the air, sun and water, the correct management of weeds can increase soil fertility and help the crop, rather than stunt and compete with the crop.

5. Nitrogen fixation

Weed legumes can fix significant amounts of plant available nitrogen per hectare and make it available for the main crop.

6. Disease suppression

The microorganisms associated with many weeds can be effective in suppressing diseases in crops.

4.1.3. Weed characterisation and monitoring

Weed management strategies

Weeds mostly cause problems by:

1. Competing for sunlight
2. Competing for soil nutrients
3. Competing for soil water
4. Hosting pests and diseases and
5. Contamination of crops with weed residues

Weed management priorities

When deciding on strategies for managing weeds it is important to analyse weeds using the following four criteria.

1. Competing for sunlight

Competing for sunlight is the most important of all negative attributes of weeds. Apart from some crops such as cocoa, coffee and salaks *(Salacca zalacca)*, most plants need all the sunlight they can get.

Photosynthesis is the basis of most crops. They are living solar energy collectors. Given that 95% of the biomass of plants comes from the products of photosynthesis, optimising the crop's sunlight is critical to achieving good outcomes.

Weeds that reduce the amount of solar energy collected during photosynthesis by the crop will reduce its yield.

It is important that weed management strategies ensure that weeds are kept below the leaves of the crop.

2. Competing for soil nutrients

Good soil nutrition is essential to ensure that weeds do not take up nutrients and leave the crop deficient.

As an example: *if the weeds take up a significant proportion of a trace element such as boron to the point where there is not enough for the crop, the crop will not be able to properly set seeds or utilise calcium. Calcium is essential for the uptake and movement of many other minerals within plants. This deficiency will lead to a poor crop and possible pest and disease problems.*

The correct strategies are:

- To ensure luxury levels of soil nutrients that will supply enough for both the crop and the weeds
- To regularly return the weed nutrients to the soil through slashing, grazing, tillage etc. The constant decay of weed organic matter will ensure a steady release of nutrients back to the soil

The correct strategies will ensure the weeds are always returning the nutrients that they use; however with the carbon gift they should really be returning more nutrients and feeding the crop.

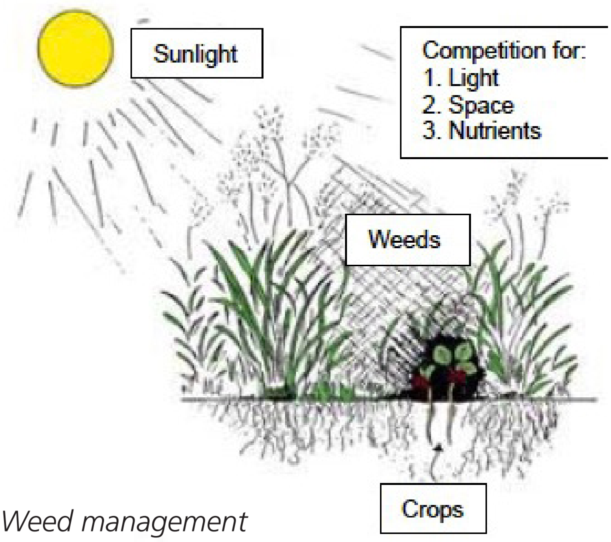
3. Competing for soilwater

It is important that adequate water is provided for both the weeds and the crop. In some instances such as dry land farming, this is not possible due to limited soil moisture. When water is limited it is important to eliminate or reduce weeds.

Slashing and using the residue for mulch to retain soil moisture can be one of the best strategies. However, grazing or very shallow tillage before sowing the crop can also reduce weed induced water loss.

In areas where there is ample water, this competition can be used to the advantage of the crop. In some areas with wet winters and dry summers, weeds can use excess winter water to produce mulch to increase the water holding capacity of the spring and summer crops.

Similarly in areas with heavy summer monsoon rains, weeds can be used to store water and nutrients as dry season mulches.



Weed management

4. Host for pests and diseases and contamination of crop with weed residues

These are the weed species that should be concentrated on to be eradicated and/or replaced with beneficial species. Weeds that can contaminate crops with seeds or extraneous matter can be eliminated, kept small or prevented from seeding.

4.1.4. Key issues in weed/ groundcover management

Timing

Timing is critical to control weeds efficiently. This does not mean a 3-monthly or other calendar based spray programme.

It is important to know the flowering times of all weeds and to ensure they are controlled before they set seeds. Over time, this strategy will lessen the weed load by lowering the germination rates, a result of the fewer seeds.

There is an old farmers saying: *"One year's seeding; seven years' weeding".*

Many weeds are much easier to control when they are young, especially a few days after germination. Tillage, hoeing, flame weeding and steam weeding are very effective control methods at this stage.

Working with the correct seasons

Most weeds are easier to control in cooler, drier seasons than in the warmer, wetter months when they are in active growth. Quite often control methods have been largely ineffective during the active growth periods. Some weeds have the energy to recover from the damage caused by herbicides, grazing, slashing, tilling and will regrow very quickly.

Sometimes it is better to work with the right seasons rather than waste valuable time, resources and money on failed strategies that do not achieve any useful weed control.

4.1.5. The carbon gift – how plants increase soil carbon and soil fertility

It is estimated that between 30% to 60% of the atmospheric carbon dioxide (CO_2) absorbed by plants is deposited into the soil as organic matter in the form of bud sheaths that protect the delicate root tips and as a range of other root excretions.

The best way to understand the amount of organic matter that is shed by plant roots is to look at the amount of plant biomass that is above the ground. The amount of biomass on the top of a plant is similar to the amount of biomass in the roots. Plant roots also shed or secrete about the same amount of biomass that is above the ground.

Root biomass according to plant development stages

These complex carbon compounds contain the complete range of minerals used by plants and are one of the ways in which minerals are distributed throughout the topsoil. They feed billions of microbes – actinomycetes, bacteria and fungi that are beneficial to plants. This complex of living organisms is called the soil food web.

The greatest concentrations of microorganisms are found close to the roots of plants because of all the organic carbon compounds that are shed or secreted by the roots. This important area is called the rhizosphere. These organisms perform a wide range of functions from helping to make soil minerals bio-available to protecting plants from disease *(see Chapter 2).*

Plant roots put many tonnes of complex carbon molecules and bio-available minerals per hectare into the soil every year and this is the most important part of the process of forming topsoils and good soil structure.

This means that well managed weeds and groundcover plants can put more bio-available nutrients into the soil than they remove from it. Also, the nutrients they put into the soil are some of the most important to the crop, to beneficial organisms and to the structure and fertility of the soil.

4.1.6. Managing weeds and groundcovers to increase soil organic matter

Managing weeds and groundcovers needs to be looked at from the perspective of the carbon gift. Rather than only concentrating on the 5% of a plant biomass that comes from the soil, it is also extremely important to concentrate on the 95% that is produced via photosynthesis from water and CO_2.

This means that the priorities in weed and groundcover management should be for the cash crop to have priority access to sunlight and water.

If the weeds and groundcovers are managed properly and their residues are allowed to return to the soil, their nutrient removal from the soil is zero. In fact, because they add between 30% to 60% of the organic compounds that they create through photosynthesis into the soil, they actually increase soil fertility.

Simply removing weeds because the perception is that they cause one or more nutrients to be deficient is in reality ignoring the real problem. Actually, weeds can ameliorate soil nutrient deficiencies as their extensive root systems tend to "mine" these nutrients from soil depths which are deeper than most crop roots can utilise. Good nutrient management means that the levels are high enough to support appropriately managed weeds/groundcovers and the cash crop.

Studies of weed/pasture fallows and the microorganisms that they feed, show that they help with increasing the bio availability of the minerals that are locked into the soil. Soil tests show an increase in soil fertility after weed/pasture fallows and when plants are grown as green manures.

It is one of the reasons why groundcover fallows restore soil health. They return tonnes of organic matter into the soil, feed the microorganisms that make nutrients bio available and reduce soil pathogens.

The important thing is to ensure that the soil has adequate levels of all the minerals and moisture necessary for growth and that the vegetation management practices allow the cash crop to be the dominant plants *(see Chapter 2).*

Managing groundcovers to feed the cash crop

Techniques where weeds/groundcovers are cut, rolled down, pulled or grazed, so that their residues are returned to the soil, means they will feed the cash crop. Cutting and grazing plants will result in significant percentages of roots being shed off, so that the weed or cover crop plants can re-establish equilibrium between their leaf and root areas.

Soybeans ground cover under emerging asparagus bed

Plants feed themselves via their leaves through photosynthesis. When the amount of leaf area is reduced through grazing or slashing, the amount of sugars and amino acids needed to feed the plant, especially the roots, is significantly reduced. The plant can only feed the roots in direct proportion to the amount of these photosynthesis products. They cast off the roots that they cannot feed to ensure that they are in balance otherwise all the roots will be starved and the plant will die.

These cast-off roots from the weeds/ groundcovers not only add carbon and feed the soil microorganisms, they release nutrients to the crop and significantly lower nutrient and water competition. This addition of nutrients encourages the cash crop roots to grow deeper into the soil, below the weed roots, resulting in larger crop root systems and better access to water and soil nutrients.

This has become the basis of the emerging organic no-till and minimum-till systems where crops are planted into pastures or previously-sown cover crops. The critical issues in these systems are the choice of the right species for the pasture and cover crops, and the management of these so that they do not compete with the crop for sunlight, water and nutrients. Rolling, grazing or cutting can usually achieve this. These techniques can leave a thick cover of mulch that will suppress weeds, conserve water and encourage beneficial microorganisms.

These techniques also increase the efficiency of the farm surface area, capturing sunlight and using photosynthesis to make the carbon based molecules that eventually result in the fertile soils that feed plants.

The light, not intercepted by the leaves of the cash crop is intercepted by cover crop to provide carbon, nitrogen and attract beneficial insects. The cover crop is cut to act as a living mulch in the drier seasons to conserve water, increase soil carbon and to add nutrients to the cash crop. The other concept is a perennial cover crop. Cover crops do not have to be annuals or ploughed into the soil to return nutrients in the soil. They can be periodically cut or grazed to achieve this.

The nutrients that are lost to the farm, either through selling the crop, through soil leaching or erosion need to be replaced every year. Good fertilisation should always ensure that the soil has the optimum level of all the necessary minerals. If the management system does not replace the minerals that are removed from the soil by the crop, the system is mining the soil and running it down.

One of the reasons why good organic farmers notice that weeds do not become a problem in their systems is because they ensure they have excellent soil nutrition and health by using weed/cover-crop management techniques that build up the soil. The process becomes one of effective weed and groundcover management rather than weed eradication.

4.1.7. Examples of using the carbon gift in successful farming systems

There is a growing list of successful farming systems, using these principles to produce low input high yielding systems.These systems have the ability to increase the profitability of agricultural systems by significantly lowering the costs of production and increasing the output from the systems.

Rodale no/low-till systems – Cover cropping

The Rodale trials are excellent examples of these principles. They had a reduction of fossil fuel input of up to 75% and significant increases in yield.

These systems work through a combination of low-till and no-till in the crop rotation sequence in farming. All organic annual cropping systems must incorporate a crop rotation system. Continuous monocultures of the same crop year after year are not permitted.

The basis of these systems is to choose a suitable, fast growing cover crop such as vetch, rye, and oats. These are generally planted in the season prior to the season for the cash crop or early in the season. Farmers around the world are successfully modifying and adapting the timing and choice of cover crops to their specific climates.

In the Rodale system a specially designed crimping roller that flattens and suppresses the cover crops is used instead of spraying with synthetic herbicides or ploughing in the crop. The current system has the roller on the front of the tractor and the seeder on the back so the crop is planted in one pass.

Rolling the vetch and seeding the corn in one pass

"The resulting living-mulch mat acts as a barrier against weeds, conserves moisture, protects the soil, provides an extensive rhizosphere (root zone) for beneficial microorganisms, and – in the case of leguminous cover crops such as hairy vetch – provides a source of nitrogen to the cash crop" (Rodale, 2008).

"Rodale Institute's organic rotational no-till system can reduce the fossil fuel needed to produce each no-till crop in the rotation by up to 75%, compared to standard-tilled organic crops" (LaSalle and Hepperly, 2008).

Energy used in different corn production systems expressed in litres of diesel per hectare

Non-organic tillage	231 litres per hectare
Non-organic no-till	199 litres per hectare
Organic tillage	121 litres per hectare
Organic no-till	77 litres per hectare *(Pimentel et al., 2005)*

"The 2006 trials resulted in organic yields of 160 bushels an acre (bu/ac) compared to the Country average of 130 bu/ac. […] The average corn yield of the two organic no-till production fields was 160 bu/ac, while the no-till research field plots averaged 146 bu/ac over 24 plots. The standard-till organic production field yielded 143 bu/ac, while the Farming Systems Trial's (FST's) standard-till organic plots yielded 139 bu/ac in the manure system (which received compost but no vetch N inputs) and 132 bu/acin the legume system (which received vetch but no compost). At the same time, the FST's non-organic standard-till field yielded 113 bu/ac. To compare, the Berks County average non-organic corn yield for 2006 was 130 bu/ac, and the average yield for South-eastern Pennsylvania was 147 bu/ac" (Rodale, 2006).

Plans for the roller and for more comprehensive information on the various cropping systems are available on the Rodale Institute website: ***http://www.rodaleinstitute.org***

The book by Jeff Moyer *(Moyer, 2011)*, *"Organic no-till farming, Acres USA"*, Texas, USA, is a very useful manual of how to get the best results.

Pasture cropping – Annuals in a perennial system

A very successful variation of cover cropping is pasture cropping. This is where the cash crop is planted in a perennial pasture instead of planting it into an annual cover crop. This was first developed by Colin Seis in Australia. The principle is based on a sound ecological fact. Annual plants grow in perennial systems. The key is to adapt this principle to the appropriate management system for the specific cash crops and climate.

The pasture is first grazed or slashed to ensure that it is very short. This adds organic matter in the form of manure, cut grass and shed roots. The crop is directly planted into the pasture.

According the Colin Seis: *"It was also learnt that sowing a crop in this manner stimulated perennial grass seedlings to grow in numbers and diversity, giving considerably more tonnes/hectare of plant growth. This produces more stock feed after the crop is harvested and totally eliminates the need to re-sow pastures into the cropped areas. Cropping methods used in the past require that all vegetation is killed prior to sowing the crop and while the crop is growing.*

From a farm economic point of view the potential for good profit is excellent because the cost of growing crops in this manner is a fraction of non-organic cropping. The added benefit in a mixed farm situation is that up to six months extra grazing is achieved with this method, compared with the loss of grazing due to ground preparation and weed control required in traditional cropping methods. As a general rule, an underlining principle of the success of this method is 'One hundred percent groundcover – one hundred percent of the time'".

The seedlings emerge from the dead vetch

Oats & pasture

"[…] A 20 Ha crop of Echidna oats was sown and harvested in 2003 on…'Winona'. Thiscrop's yield was 4.3 tonnes/Ha (31 bags/acre). This yield is at least equal to the district average where full ground disturbance cropping methods were used".

Harvesting oats

"This profit does not include the value of the extra grazing. On Winona it is between US$50 to US$60/ha because the pasture is grazed up to the point of sowing. When using traditional cropping practices, where ground preparation and weed control methods are utilised for periods of up to four to six months before the crop is sown, then no quality grazing can be achieved.

Other benefits are more difficult to quantify. These are the vast improvement in perennial plant numbers and diversity of the pasture following the crop. This means that there is no need to re-sow pastures, which can cost in excess of $150 per hectare and considerably more should contractors be used for pasture establishment.

Independent studies at Winona on pasture cropping by the department of land and water have found that pasture cropping is 27% more profitable than non-organic agriculture. This is coupled with great environment benefits that will improve the soil and regenerate our landscapes".

Building soil fertility without synthetic fertilisers

Dr Christine Jones has conducted research at Colin Seis' property showing that in the last 10 years 168.5 t/ha of CO_2 was sequestered.

- The sequestration rate in the last two years (2008 to 2010) has been 33 tonnes of CO_2 per hectare per year
- This increase occurred during the worst drought in recorded Australian history

The following increases in soil mineral fertility have occurred in 10 years with only the addition of a small amount of phosphorus

- Calcium 277%, magnesium 138%, potassium 146%, sulphur 157%, phosphorus 151%, zinc 186%, iron 122%, copper 202%, boron 156%, molybdenum 151%, cobalt 179% and selenium117%
  (Carbon that Counts: ***www.ofa.org***).

Conventional - pasture cropping

Pasture cropping and cover cropping in horticulture

These systems have been used very successfully in horticulture with numerous advantages. A good groundcover will suppress weeds, add nitrogen, conserve water and give nutrition to the cash crop from organic matter that comes from the shedding of roots and decay of the leaves and stems.

Onions grown in rye grass (Lolium sp.)

A good example here is onions grown in rye grass *(Lolium spp.)*. The rye grass is mowed down as short as possible. The onions are then seeded into small ploughed strips. The grass is regularly mowed with a side throw lawn mower. The mowed grass clippings act as a mulch to suppress weeds and conserve water. The discarded roots of the rye grass are broken down by microorganisms to provide a range of complete nutrients to the cash crop.

Perennial horticulture

The concept of groundcovers has been used extensively in perennial horticulture, especially in orchards and vineyards. Plantings of swards of legumes, grasses and flowering plants can provide nitrogen, organic matter, and mulch and attract beneficial insects.

In most perennial systems there is a season that gets the most rainfall. In many temperate climates, especially Mediterranean climates, this is in winter when there is not much growth from the cash crop. Planting winter growing groundcovers such as vetch is a way of capturing the sunlight and rainfall not used by the crop to improve the farming systems. The cover crops can add nitrogen and carbon and provide valuable mulch for water conservation in the drier and hotter summer months.

In tropical climates the groundcovers can do the same and provide mulch for the drier winter months. There is the added advantage that they protect the soil from erosion during the intense tropical downpours and prevent nutrient leaching by taking up the nutrients in the biomass. These nutrients are released to the cash crop when the cover crop is cut down at the beginning of the dry season.

Letting the groundcovers grow tall and mature properly, will improve their content in lignin, and consequently, the quantity of carbon rich organic matter in the soil. The general rule is, the taller the plant, the deeper the roots. This will increase the depth of the carbon rich topsoil.

Consequently tall, mature groundcovers are better for deepening and improving the stable carbon levels in soils.

4.2. Curative weed treatments

4.2.1. Mechanical control

Tillage

Tillage is one of the oldest and most effective weed control methods. Unfortunately, it is also one of the most abused methods resulting in severe soil loss and damage when used incorrectly.

One of the important methods used to control weeds is to turn over the weeds to expose them and be desiccated by the sun.

Another is to turn them into the soil as a green manure. It is important not to do this too deeply, as occurs in some practices where the topsoil is turned under the subsoil, as this will reduce soil fertility instead of improving it.

Freshly turned soil encourages weed seeds to germinate and these can later be exposed to the sun with shallow cultivation to lessen the weed seed load.

A large range of methods can be used to control weeds in the rows between crops.

Rotary hoes are very effective. However the hoeing operation should be kept very shallow at around 25mm to avoid destroying the soil structure.

Various spring tynes, some types of harrows, star weeders, knives and brushes can be used to pull out young weeds without disturbing the crop.

Disking the inter-row and hilling the crop with soil will destroy most of the weeds in-between the crop rows and smother many of the weeds growing in the crop row.

There are several cultivators with guidance systems that ensure precision accuracy for controlling weeds. These can be set up with a wide range of implements and can be purchased in sizes suitable for small horticultural to large broad-acre farms.

Organic farmers in the USA, Europe and Australia are using these to get excellent control over weeds in their crops. In Namibia, farmers will have to order tailor made equipment from local manufacturers.

Tillage and soil erosion

Organic farmers are criticised for using tillage for weed control with critics stating that this leads to more soil erosion and loss of soil organic matter.

The published science shows that correct tillage *(see tillage section 4.2.1.)* in organic systems does not cause either.

"We compare the long-term effects (since 1948) of organic and non-organic farming on selected properties of the same soil. The organically farmed soil had significantly higher organic matter content, thicker topsoil depth, higher polysaccharide content, lower modulus of rupture and less soil erosion than the non-organically farmed soil. This study indicates that, in the long-term, the organic farming system was more effective than the non-organic farming system in reducing soil erosion and, therefore, in maintaining soil productivity"(Reganold et al., 1987).

Critics of organic systems point to non-organic no-till production systems as superior to organic systems because the organic systems use tillage. There is only one published study comparing non-organic no-till with organic tillage systems. The researchers found that the organic system had better soil quality.

"[...] the OR [organic] system improved soil productivity significantly as measured by corn yields in the uniformity trial [...] These higher levels of soil C and N were achieved despite the use of tillage (chisel plough and disk) for incorporating manure and of cultivation (low-residue sweep cultivator) for weed control". "Our results suggest that systems that incorporate high amounts of organic inputs from manure and cover crops can improve soils more than non-organic no-tillage systems despite reliance on a minimum level of tillage" (Teasdale et al., 2007).

Slashing

Cutting weeds with tractors and slashers, lawnmowers and brush-cutters or by hand with scythes, sickles, cane knives and machetes etc. are all very useful tools to control weeds. These methods ensure that the weeds still hold the soil together to prevent soil loss and return nutrients and organic matter to the soil. The cut weeds can also provide valuable mulch.

Constant mowing/slashing will favour the more prostrate species. This can eliminate some of the worst weeds; however it is important not to limit the groundcovers to one or two low growing grass species.

Ongoing research since the 1930s has shown that limiting bio-diversity through constant mowing will promote pest species. It is better to encourage a high bio-diversity, especially of flowering plants to encourage beneficial species. The aim should be to produce a lush meadow style rather than a city park look.

Flame weeding

Flame weeders are used to quickly sear weeds with a naked flame. The aim is not to burn the weed, but to make most of its cells burst and blister through boiling the cell liquid. Many plants shoot back and recover from a complete burn; however they usually die if enough cells are injured through heat.

Flame weeders come in a range of forms from back pack or hand trolley mounted forms for small orchards and horticultural crops to large tractor pulled implements.

The flame is surrounded by a shroud to ensure that the crop is not burnt. The burners and the shrouds are adjusted to the row widths and the farmer quickly passes down the rows searing the weeds.

The advantage is that it is very quick. The major disadvantage is that it cannot be used when the weeds are drying out as it can burn the crop – and the district.

Steam weeding

Steam weeding works on the same principles as flame weeding except that high pressure steam is used instead of a flame.

The major advantage is that it will not cause a fire. Most steam weeding systems are still in prototype stages however it will become one of the major replacements for herbicide use due the ease of use and safety to the environment.

There are several commercial models that are readily available from broad-acre to hand use.

A practical way to develop a steam weeder in horticulture is to buy a normal steam cleaner and modify it for the farm. There are many models available. Look for ones that are portable and can be used with a small portable electrical generator.

Hand weeding - Pulling, hoeing and cutting

Hand weeding is one of the most effective and efficient methods of weed control but has become a lost art due to mechanisation and chemical spraying. In these days of factory style production, it is not considered an economically viable option.

However when done properly and systematically as part of an overall weeds management strategy, many commercial organic farmers regard these methods as very efficient and cost effective.

Usually these methods are confined to the difficult-to-reach areas or for the worst weeds.

The correct, well maintained tools are important in hand weeding. Usually these are the traditional tools that farmers have used for centuries. These tools have been repeatedly refined and improved by each generation and are now tried and proven as very effective. Examples of these are hoes, sickles, scythes, cane knives and machetes. It is important that blades of these instruments are kept razor sharp so that the blade and the weight of the tool does the work. Each tool has a correct method of use that allows the user to weed a large area quickly and efficiently with the minimum of effort.

In Germany the word Morgen ("Morning" in English) is used as the unit of measurement for about an acre of land. (One hectare = 2.5 acres). A Morgen was the area that a farmer could slash with a scythe in the morning. This clearly shows that the correct forms of handweeding are economically viable and practical in most family sized horticultural farms.

Skilled farmers can easily keep many hectares well maintained through hand weeding methods. Given that most of the world's farmers only have around two hectares, hand weeding is the obvious and most cost effective solution to weed management.

Farmers should learn these techniques and practice them, in order to avoid back injuries and other repetitive strain injuries.

Crop rotations

Crop rotation can be used very successfully to suppress weeds. Dense crops of canola can be used before a crop, such as soybeans, as the canola tends to smother weeds. High density plantings of grain, such as oats, wheat and sorghum, can be used to shade out weeds for the following crops of vegetables or lucerne and other legumes. These crops can be planted in the stubble of the harvested grain crop.

Crop rotations break weed cycles, smothering and/or disrupting their germination and seeding cycles.

4.2.2. Physical control

Cover crops

Cover crops suppress weeds by out-competing them and also when used later as living or dead mulches.

The advantages of this method are that the sward (the upper layer of soil; especially when covered with grass) can provide useful nitrogen, suppress weeds, retain soil moisture through mulching and also protect the soil from wind and water erosion. This method also increases the organic matter levels and fertility of the soil.

In orchard situations, useful groundcovers can be selected to suppress weeds and replace them with beneficial plants. The aim is to change the groundcover balance from negatives that compete with crop to positives such as soil stabilisation, nitrogen fixation, habitat for beneficials, mulch and organic matter for trees and soil. Examples of this are introducing legumes, such as pinto peanut, hairy vetch *(Viciavillosa)*, barrel clover *(Medicagotruncatula)* and lucerne as groundcovers.

Legumes such as clover, alfalfa, desmodium, and pinto peanut make ideal groundcovers. They are prostrate, suppress many weeds, provide nitrogen and the flowers function as insectaries for beneficial insects.

Insectary plant species, especially flowering plants can be used as groundcovers to suppress unwanted species and to encourage beneficial arthropods and higher animal species.

Tractor mounted slasher for weed control

Mulching

Mulching is a very effective way of suppressing weeds. The weeds are completely covered by the mulching material, resulting in death due to lack of light. Mulches are very beneficial in retaining soil moisture, preventing soil loss and as they biodegrade they provide organic matter and stimulate soil organisms.

Harvested weeds can be used as mulch to suppress other weeds, however it is important to ensure that they are used before they seed – otherwise they could lead to later weed problems. Harvested weeds with seeds should be composted at temperatures above 70°C to destroy most of the seeds.

Living mulches

Groundcovers can be used as living mulches. Correctly selected groundcovers can help conserve soil moisture as well as suppress weeds and diseases, increase soil fertility and act as insectary plants to attract beneficial species. The system captures the solar energy not captured by the cash crop – increasing the efficiency of the farming system and lowering input costs.

Sheet composting

Sheet composting can be a very effective method of suppressing weeds, as well as improving the soil and feeding the crop. A thin layer of fresh manure is put over the weeds. Covered with a thick layer of organic mulch to shade the weeds and trap the ammonia gas, being careful that the manure or green compost does not burn the crop.

Shade as weed control

Competition for sunlight is the most important of the interaction between crops and weeds. Reversing the situation so that the crop shades the weeds is one of the most useful situations.

High density planting of crops will control many weeds by shading them out. This can be used very successfully in crops like sugar cane, corn and many vegetable crops, where good control of weeds while the crop is small, will ensure minimal weeds once the crop begins to reach the size where it shades the soil.

Selecting crop varieties with large leaves that hang over the soil which creates shade will suppress the emergence of weeds.

There are techniques with vine crops that utilise Y shaped trellises or complete canopies to shade out the majority of weeds.

Dense large canopies on fruit trees will do the same in orchards.

This will not work with all weeds. There are several weed species that tolerate shade and some vine weeds can still find their way to the top of the crop, including tall fruit trees.

Soil Solarisation

Soil solarisation proves to be a simple, cheap and highly efficient method to control weeds effectively. Some of the most persistent weeds have been eradicated using this method. In soil solarisation the only price input involved is that of plastic sheets and labour. To solarise the soil, the soil must be moist and covered with at least 0.125mm thick black polyethylene sheet (ideally 500 micron, so it can be re-used many times) for 4 to 6 weeks.

The sheet should be properly laid out with the edges buried in the soil to hold it in place or weighed down with sand bags. Due to solar radiation, the soil under the plastic sheet heats up to a temperature of around 45° to 50°C. Due to the heat, weeds and weed seeds present under the polythene cover are destroyed.

The effect of this soil solarisation depends mainly upon the exposure time of the soil and soil temperature that is maintained. In addition to weed control the other advantages of soil solarisation are that it controls plant diseases, it alters some of the physical and chemical properties of the soil to promote better crop yield.

Benefits of soil solarisation:

- It completely eradicates soil pathogens
- It strengthens the root system of follow-up crops
- It enhances the growth and health of plants
- It modifies the physical and chemical properties of the soil atmosphere and increases the availability of essential nutrients, thereby improving the soil fertility
- It enhances the resistance of the soil against pests and diseases
- It improves the soil productivity

For persistent plants, like couch and kikuyu grass, it has proven of great value to cell-graze pigs in moveable electric fence pens over the area and any stolon's and roots left will be 'ploughed out' by the animals.

Organic herbicides

There are a range of natural compounds that can be used as herbicides in organic systems.

Acetic acid (vinegar)

USDA research shows that 9% acetic acid will kill all weeds after repeated applications. 3% is effective for soft weeds.

Pine oils

It is effective in hot dry conditions but ineffective in hot humid conditions.

Essential oils, emulsified oils, soaps

Mixed results – work well in some circumstances

Home-made herbicide mixture

Consisting of 3,8 litres vinegar, 2 cups Epsom Salts, ¼ cup liquid soap.

Simply mix the spray and spray weeds in the morning after all dew has evaporated. It will kill any plant that you spray it on so be careful not to spray plants you want to keep.

If there are any really stubborn weeds, you can always use a stake or garden fork, poke a whole down the middle of the weed a few centimetres down to expose the roots, and spray right down into the root system.

All of these work as burn down herbicides similar to paraquat. They do not poison the weed, just burn down the stems and leaves. The weeds will shoot up again, so effective control will mean regular applications until the plants burn out their starch reserves.

The major advantage of these compounds is that farmers can use their existing spray equipment.

Most organic organisations are not very supportive of the concept of organic herbicides due to the concern that the farmers who use them will just become substitution farmers, with farming systems that are almost identical to non-organic farms, only using non-toxic inputs. Some organic certifiers will not allow them for this reason.

There is a role for organic herbicides when they are just one part of a well-designed multifunctional weed management system rather than the only method.

Quarantine

It is important to have systems to stop the introduction of new weeds, especially noxious weeds.

One strategy is not to allow any vehicles on the farm fields apart from dedicated farm vehicles. Do not allow visitors to drive on the farm road or past the sheds and house. This will make it easy to monitor these areas for new weed introductions. It is usually easy to eradicate a small patch of weeds, before they take over large areas.

If stock feeds or mulches are being brought onto the farm, it is important to be vigilant for any new weeds that might come up in the manure or the mulch beds. Where possible, hot-compost all vegetative material (hay, mulch etc.) brought onto the farm to destroy most of the weed seeds.

Ensure contractors clean all heavy machinery used on the farm. This is one of the most common ways of spreading weeds.

4.2.3. Biological control

General biological control

Organic agriculture does have several very good methods of bio-control of weeds and these involve integrating animals and weed competitive beneficial plants into the farming system.

These are good examples of Eco Function Intensification (EFI) where the system uses applied ecology to manage the weeds. It is the opposite of the complete eradication of all plants other than the crop with herbicides which is the dominant paradigm of non-organic agriculture. These organic systems actively increase the functional bio-diversity of the system rather than reducing it through the use of poisons.

Building a healthy and bio-diverse rich farm ecology will ensure that many weeds will also have their natural bio-control agents.

The world's worst weeds are plants that have been taken from their native countries without their natural bio-controls. In a limited number of cases, their insect or disease bio-controls have been introduced into the new regions and these have been effective in significantly reducing the weed problem.

An example of this is the water hyacinth (Eichhornia crassipes) which was widely introduced around the world as an ornamental waterplant from its home in the upper reaches of the Amazon. It quickly spread and choked out river and lake systems in the warm temperate to the tropical regions of the world. In some places it formed mats that were so dense that it stopped boats and killed much of the native aquatic species due to out competing them for light and oxygen. The introduction of several of the water hyacinth's bio-controls has cleared it from most tropical areas, although this has not been as successful in subtropical and warm temperate regions.

However, the general principle of building high bio diversity into the farming systems, especially by incorporating insectaries, will ensure that there will be some of the natural weed bio-controls in the systems.

These are generally not sufficient on their own to control the problem weeds and it is always necessary to use a range of strategies in an integrated whole-farm system.

Grazing

Many of the most aggressive weed species in cropping and orchard systems were introduced for the grazing industries. The characteristic that makes a fast growing pasture also makes it hard to control weeds.

Grazing is one of the most effective methods of weed control, and when done sustainably will also increase soil fertility by increasing humus and soil nitrogen.

Grazing is a very effective form of weed control

The microorganisms in the guts of grazing animals break down cellulose into glucose and also fix air nitrogen to synthesise proteins and other important organic compounds. Most of these compounds are utilised by the animal and the rest is excreted as valuable plant food and soil improver. Research shows correct grazing will increase exchangeable soil minerals including nitrogen.

Grazing improves the efficiency of the system. It is a way of value adding fertility and increasing production.

Traditional cultures have always used grazers and foragers – such as geese, ducks, chickens, guinea fowl, pea fowl, goats, sheep, cattle, llamas, yaks, water buffalo, rabbits, and guinea pigs to turn weeds into food and fertiliser. Poultry also eat many of the weed seeds and destroy them.

Geese can be very useful in managing weeds. Young Chinese Geese and Indian Runner Ducks can be trained to eat specific weeds by feeding these weeds to the fowl when they are very young and just starting to graze on plants. They develop a taste for these weeds as their preferred forage and will actively seek them out and graze on them.

Cell grazing

One of the most successful methods of controlling weeds in pastures is called Cell or Controlled Grazing. In many current grazing systems, the animals tend to concentrate on the species that they prefer and continuously feed on them. This leaves the weeds to proliferate.

The cell grazing system confines the stock to smaller paddocks for several days forcing them to thoroughly graze all the edible plants. The higher stock density also ensures the weeds are crushed and trampled and that the manure is kicked and well scattered across the ground. The animals are then moved to another cell and the process is repeated. There is a continuous rotation of controlled grazing in the cells with the animal returning to the original cell when the feed has regrown.

Some of the most successful examples use multiple species in succession such as cattle, followed by sheep, followed by poultry as each will tend to eat different species.

Cell grazing has been shown to significantly reduce weeds, increase bio-diversity and improve productivity in Australia, Africa and the USA *(see Savoury Institute for more information).*

Poultry and pigs eat weeds and weed seeds. They are very effective in reducing the load of weed seeds in the soil.

Out-competing weeds with beneficial plants

One of the most effective ways to reduce weeds is to plant beneficial species that will out-compete them. Some good examples are useful legumes such as soya beans, desmodium, and pinto peanut planted in the rows between the crops in orchards and vegetable plots. This is the same concept of the living mulch and cover crops *described in section 4.2.2.*

The correct choice of species will not only out-compete the weeds for sunlight and nutrients, they should be beneficial for the cash crop by adding nitrogen, conserving water and capturing the sunlight not used by the cash crop to produce useful organic matter. Their flowers should also be able to attract beneficial insects to help with pest control.

This is a relatively new area of organic farming and more research is needed to work out the best combination of plant species and the methods to use them effectively.

It is worthwhile to experiment on different species. Do a few small areas first to ensure that the introduced legumes are effective at suppressing weeds and can be effectively managed.

It is important to ensure that there are adequate nutrients and moisture for both the cash crop and the living mulch and that the cash crop has access to the sunlight.

4.3. Use a whole-farm approach

4.3.1. Use multiple integrated strategies

Research shows that the best organic farmers use multiple integrated strategies for weeds and achieve very good control.

It is important to look at weeds from the four criteria *listed under section 4.3.2*. In most cases the first three strategies apply. By ensuring that the weeds do not shade the crop, that there is enough nutrition and water for the weeds and the crop, the weeds are usually helping rather than hindering the crop. In these cases it is counter productive to kill or remove them.

For some crops, growers are penalised for delivering products with extraneous matter, especially if these are weed seeds. Strategies like preparing a weed bed to encourage germination and ploughing this in before planting will reduce the weed load. This should be followed by dense planting to encourage early shading and various methods of cultivating or steaming the inter row to remove all weeds. Several people on hoes can be used to remove the few weeds remaining in the rows.

Good organic farmers find that their weed loads significantly reduce over the years. Many of the worst weeds seem to disappear and tend to be replaced with softer, easier to manage species.

Weeds are not always bad and should not be removed because they are not part of the crop. A good organic farmer develops a series of management strategies that minimise the negative aspects of weeds and enhance the positive aspects. By doing this, the farmer ensures that weeds increase the productivity of the agricultural system.

There is no such thing as a weed problem. There are only management problems and these can be solved.

4.3.2. Weed management plans

Good organic farmers manage weeds rather than just try to destroy them. Effective management means good planning and the best way to do this is to prepare a plan.

Example of a generic weed plan for a fruit orchard:

Firstly consider the four criteria for management strategies:

1. *Competing for sunlight*
2. *Competing for soil nutrients*
3. *Competing for soil water*
4. *Host for pests and diseases and contamination of crop with weed residues*

Short term strategies

Slashing/mowing will work effectively for all the weeds in an orchard, especially those in categories 1, 2 & 3. This will ensure they do not compete for light and by cutting them down, they will shed roots and this will severely reduce their competition for nutrients and water.

Category 4 weeds generally need extra treatments. Regular slashing/mowing treatments are needed to stop them from regenerating. This will see them die when they use all their starch reserves. Cutting them out with a sharp hoe is a very effective way to deal with them.

Only ever slash part of the orchard at one time and leave other areas untouched until later in the season. Never remove all the weeds from one section of the orchard, as it is necessary to encourage small flowering plants as hosts for beneficial insects, fungi etc. These plants should be managed as insectaries.

Depending on the size of the orchard, the weeds between the rows can be controlled with a tractor and slasher, lawn mowers, scythes and grazing from small animals and poultry. Once or twice a year use a cane knife, sickles or machetes as well hoeing and hand pulling under the trees to clear plants missed by the slashing and grazing.

Long term strategies

Bio-diversity is essential to healthy environmental systems. The more complexity built into the system means fewer spaces in that system for pathogens (diseases, insect pests, and noxious weeds) to colonise. This is achieved by having other species out-compete them for space, directly predate them or actively aid the crop species through symbiosis.

The aim is to change the groundcover balance from negatives that compete with the crop to positives such as soil stabilisation, nitrogen fixation, habitat for beneficials, mulch and organic matter for trees and soil.

Examples of this are introducing prostrate legumes, such as pinto peanut, clovers, etc. as a groundcover. These low-growing species spreads by runners and adds nitrogen to the soil. It chokes out many of the weed species, stabilises the soil and builds humus.

Some of other legumes such as centro, mimosa, calopo and stylo are usually considered as weeds by non-organic farmers; however the use of geese and other fowls will graze on them so they do not choke the trees. Use chicken feed to direct the poultry to areas of orchard where they are needed to work. Every morning scatter the feed under the trees in the area of the orchard where they are needed. After a week or so take them to another area so that it can be grazed and the previous area rested.

Poultry also eat many of the weed seeds and insect pests as well as fertilise the soil.

Use shade as weed control. The canopy of the fruit trees shade out many weed species. The marginal areas should be steadily planted out with taller species and native flowering trees. These will shade out the worst weeds such as tall grasses, while providing wind breaks, food and shelter for useful insect, bird, mammal, reptile and amphibian species.

The aim is to produce a lush meadow style rather than a city park look. This will be a robust system that requires very little maintenance, provides nitrogen and other nutrients to the cash crops, works as an insectary attracting beneficial species, protects and builds up the soil health, retains soil moisture and reduces pests and diseases.

Control of specific weeds

Weeds are generally divided into two major categories:

- Annual weeds (e.g. purple witchweed/ *Striga*)
- Perennial weeds (e.g. couch grass and sedges)

Management practices depend on which type is predominant in the field.

Annual weeds

These are the weeds germinating from seed along with every crop and going through a full lifecycle from germination to flowering to setting and dropping seeds in one season. All healthy topsoils have myriads of different types of weed seed and every time the soil is disturbed a new lot germinates in order for the ground to keep itself covered. If we leave these weeds to grow unchecked, the crop we are trying to cultivate will not do well as there is too much competition.

1. Edible weeds

Many weeds are useful, some are edible and very nutritious (e.g. amaranth, mustard, etc.) and in traditional gardens some of these are often left to grow and harvest for family meals. Improved varieties with bigger leaves have been developed commercially and these are planted as traditional vegetables for market and home use and show a much better nutritional content than the normal commercial vegetables. Mustard plants also contain compounds that will combat such soil diseases as bacterial wilt and nematodes *(See also bio-fumigation in the Pest control section).*

2. Medicinal weeds
Other weeds such as blackjack, Mexican marigold and many others (normally the smelly ones) have plant protection properties and yet others have medicinal properties, which can be very valuable in a self-sufficient farming system and provide medicine for animals and people.

If you have any useful tips to share with other farmers through this website please send us a note about it. We will contact you and quote you by name on this site.

3. Nitrogen fixing weeds
Weeds such as various clover varieties, desmodium and other legumes fix nitrogen from the air and help improve soil fertility. When the legumes become too vigorous, they can be cut and used as animal feed or mulch for other crops.

Weeds such as *Tithonian* (wild sunflower), also help improve soil fertility when the leaves are incorporated into the soil as green manure.

Many farmers complain about white clover, which is a powerful growing legume. It falls in between an annual and a perennial plant, as it produces seed in the first season, but plants do not die and continue into the next season if moisture levels permit. It is a creeper which when left undisturbed develops large patches of dense clover. Farmers say it gives cattle bloat. This can be true if animals are allowed to graze while the leaves are wet (same as for any other high protein legume). However dried clover leaves mixed with grass are a protein rich feed for all livestock. Clover can also be cut and dried as hay along with grasses.

Clover overpowers other weeds including couch grass, many other grasses and sedges and as such can be used to control them. In Europe clover is used in grass mixes for pastures for grazing, and hay and silage making. A good mixture of clover grass can fix over 300 kg/ha of nitrogen in one season (6 months). Clover is a versatile plant, which can survive being shaded by maize plants. It is a groundcover on walking paths and non-utilised patches of crop land – there is always that corner where nothing else grows. It can be of great help in preventing soil erosion by protecting the soil from the sun and the rain.

Farmers, should not kill the clover and other nitrogen fixing legumes, but experiment with them to improve the fertility of the soil. Patches that are too big should be dug up so that some of the plants can be transferred to areas that have no legumes. Taller plants are not affected by clover, but small plants with superficial root systems need to be given space for their own initial root development.

Perennial weeds

These are weeds with a root system that survives the dry seasons and stay alive for two or more seasons. If not controlled, perennials can completely crowd out crops, in some cases by sending a dense network of underground roots and stolons in all directions. They are very difficult to control as the roots go deep and a very small piece of root or stem can re-grow after weeding and create new networks.

Perennials such as couch grass and sedges have a function though; they help the soil restore aeration and natural life in the patch of ground where they grow. They also protect the soil from erosion, being carried away by water or wind and the grasses provide fodder for livestock. If these perennial weeds cover unproductive corners of the farm or steep hillsides they are not harmful, so far they do not invade the crop area.

Sedges *(Cyperaceae)* have smooth leaves and triangular flower stems. The clustered seed heads differ according to the numerous species growing in southern Africa. They have underground bulbs, stolons or tubers, which can remain dormant for long periods of time. They are often only minor problems in farms with a mixed weed population.

Sedges are not real grasses and most livestock only eat them if there is nothing else available.

The most common species of *Cyperus* includes *C. longus* with underground stolons like couch grass and no visible "nuts". *C. rotundus*, more common in hot areas, has underground nuts and thin connecting stolons.

"Watergrass" is a troublesome sedge especially for non-tillage farmers. They are small plants with a tiny underground "nut" and produce seeds prolifically.

Sedges (including nutsedges and watergrass) release chemicals that reduce the growth of other plants near them, which is why most crops grow very poorly in the presence of sedges.

Among the many weeds we see everyday some do not seem to have any function that we know of. But this does not mean they are useless. However, *Oxalis spp.* in spite of its tiny size has been found to reduce the yield of maize up to 24% *(Terry, 1984)*.

If you look carefully, most of these perennial weeds are most serious where the soil is compacted, waterlogged or has generally become infertile, or on mechanised farms where annual weeds have been killed by herbicides.

Weeds and soil fertility

In studying the relationship between weeds and soil fertility, a clear connection appears. Of all the seeds stored in the topsoil, those suited to the soil status, will be the ones germinating. Certain weeds will germinate on very poor and damaged soil and very different ones will grow on a soil in good fertility.

Weeds, as any other plants, take up nutrients from soil and air and return them to the soil when they die. Weeds that grow on poor soils are those that are able to extract or fix nutrients, which the more demanding plants are not able to take up under the same conditions. These poor fertility plants/weeds, if left to do their job, will enrich the soil and slowly improve it. High fertility weeds left to do the same on fertile soils will improve the soil even faster as they take up/fix higher amount of nutrients.

Too many weeds reduce yields, but not much research has been carried out on retaining some weeds for soil protection but keeping them down to a manageable level, so as not to interfere with the main crop.

On slopes there are many recommendations for strip cropping in order not to lose valuable top soil. The grass strips then become soil conservation measures. However, very good results have been achieved by The Conservation Agriculture research team on replacing weeds as groundcover with legumes, both as far as yields and reduced workload for the farmers is concerned *(IIRR, 2005)*.

4.5. A selection of notorious weeds and their possible control

4.5.1. Broomrape

4.5.1.1. Scientific and common names

Broomrape, Orobanche spp.
Lamiales

Broomrape about to flower

Broomrape in carrot field

Broomrape in tomato

Broomrape on carrot

4.5.1.2. What it is

Broomrape is a root parasitic weed.

Root parasitic weeds are a serious problem in many agricultural production systems. Unlike "normal" weeds that merely compete with the crop plants for nutrition and possibly harbour diseases, root parasitic weeds damage the crops by attaching their own roots to the roots of the crop plant and taking their nutrition and water from it. They are especially hard to control because they cannot be treated as a separate plant and they also inflict damage before emerging above ground. Of all root parasites, *Orobanche* (broomrape) and Striga (witchweed) cause the most damage to agricultural crops.

Broomrape *(Orobanche)* is a genus of over 200 species of parasitic herbaceous plants in the family *Orobanchaceae*, native to the Mediterranean region (North Africa, the Middle East and southern Europe) and western Asia. Their range extends to similar climates in Africa, Asia, Australia and North and South America where they cause significant crop damage. It is broadly estimated that it affects over a million hectares of agricultural land with average yield losses as high as 40% in some areas. The extent of economic damage caused by *Orobanche* is unknown.

The broomrape plant is small, from 10cm to 60cm tall depending on species. It is recognised by its yellow-to-straw coloured stems. They lack chlorophyll and bear yellow, white or blue, snapdragon-like flowers. The flower shoots are scaly, with a dense terminal inflorescence (spike) of 10 to 20 flowers in most species. The leaves are merely triangular scales. The seeds are minute, tan-to-brown and blacken with age. These plants generally flower when weather conditions are cool to moderately warm. When they are not flowering, no part of these plants is visible above the surface of the soil.

Because they have no chlorophyll, they are totally dependent on other plants for nutrients. Broomrape seeds remain dormant in the soil, often for many years, until stimulated to germinate by certain compounds produced by living plant roots. Broomrape seedlings put out a root-like growth, which attaches to the roots of nearby hosts. Once attached to a host, the broomrape robs its host of water and nutrients.

Biology and Ecology of Broomrape

Life cycle

Root parasites like *Orobanche* are difficult to control, partly due to their complex life cycle. *Orobanche* produces numerous dust-like seeds, 0.15 to 0.5mm long. A medium-sized *O. aegyptiaca* plant, for example, can develop 400 flowers or more, each producing about 500 seeds. Thus, a single plant in the field can produce 250,000 seeds (about 184 000 seeds per gram) and a single *Orobanche* plant is therefore capable of heavily infesting the field, rapidly increasing the seed bank in the soil. The seeds remain viable in soil for over 15 years. When shed, the seeds are dormant and require a period of after-ripening, which is usually completed before the end of the dry season. At the start of the rainy season the seed will absorb water, but it is still unable to germinate. This "conditioning" period lasts for 5 to 21 days at a suitable temperature (15° to 20°C). Conditioned seeds are capable of germinating but a chemical stimulus is needed to trigger *Orobanche* germination. This stimulus normally comes from host roots. Therefore *Orobanche* normally germinates only when a host root is nearby. However, a moist environment is required for several days together with suitable temperatures in order to render the mature seed responsive to germination stimulants. This preparatory period is known as conditioning or preconditioning. Conditioned seeds remain responsive to germination stimulants for several months. Their ability to respond to germination stimuli fades gradually when the seeds dry and they then remain dormant until re-conditioned. Once the parasite makes contact with the host root, it develops a root-like structure known as haustorium. It has three functions: attachment, penetration of the host root and nutrient acquisition from the host. When a successful connection has been made with the host, the parasite can grow rapidly using water and nutrients taken from the host, causing yellowing of leaves, stunting and wilting of the host plant. After emergence, the parasite will grow until it flowers, produces seed and dies. The complete cycle takes 10 to 15 weeks.

Vectors and dispersal

The very small seeds may very easily be moved from one field to another by water, wind, animals and man. The seeds remain viable even after passing through the alimentary system of animals; therefore manure may be contaminated with viable *Orobanche* seeds. Agricultural products of various crops may carry *Orobanche* seeds if harvested in an infested field. Agricultural tools should always be cleaned after being used in an infested field to avoid transfer of *Orobanche* seeds or contaminated soil to non-infested fields.

Habitat

Most of the noxious weedy *Orobanche* species are native to the Middle East and are adapted to soils of generally high pH. They occur to some extent in wild vegetation but the weedy species are mostly associated with the crops which they attack. *O. ramosa, O. aegyptiaca* and *O. cernua* require relatively high temperatures for optimum germination and growth and occur especially in irrigated crops grown under hot conditions, while *O. minor* and *O. crenata* are more temperate in distribution, require lower temperatures for germination and occur mainly in crops grown during cool conditions or non-irrigated crops.

Host range

Members of the genus *Orobanche* parasitize roots of broad-leaf plants, causing damage to vegetables and other field crops. Some species are relatively specific in their host selection, while other species have a very wide host range. The most important species and their hosts are:

- *O. aegyptiaca* (Egyptian broomrape): Tomato, potato, tobacco, eggplant, bell-pepper, pea, vetch, faba bean, carrot, celery, parsley, cumin, cabbage, cauliflower, rape, mustard, turnip, hemp, sunflower, spinach. In some areas, e.g. southern Russia, sweet melon and water melon are also hosts. Also parasitizes ornamentals like Chrysanthemum and Gazania
- *O. ramosa* (Branched broomrape or hemp broomrape): Hemp, potato, tobacco and tomato; also on groundnut, cowpea and chilli pepper. *O. ramosa* was also recorded on aniseed, basil, fennel and a range of ornamental species
- *O. crenata* (Bean broomrape): An important pest of legumes: faba bean, pea, lentil, chickpea, vetch and clover. Also attacks carrot, parsley, celery, cumin, safflower (*Carthamus)*, eggplant, tomato, lettuce, geranium and verbena
- *O. cernua* (Nodding broomrape): Mainly attacking solanaceous crops: tomato, potato, tobacco and eggplant
- *O. cumana* (Sunflower broomrape): An important pest of sunflower and also parasitizes safflower. May in certain cases parasitise tomato, when growing in soil previously cropped with sunflower. It is also known to attack caraway *(Carum carvi)*
- *O. minor* (Common broomrape): It attacks red and white clover, lucerne, tobacco, carrot, lettuce, sunflower and many other crops and ornamentals on a local basis

In order to determine the host, it is necessary to check which plant's roots are connected to the parasite. There are some erroneous reports based on observations of neighbouring plants rather than of connected hosts. Sometimes the detection of a host is very difficult, especially when a field is used simultaneously for more than one crop, or when the field is loaded with weeds.

4.5.1.3. The damage caused

Symptoms

Infested plants exhibit symptoms such as leaf yellowing, water stress, stunting and wilting

Affected plant stages

Vegetative, growing stage and flowering stage

Affected plant parts

Whole plant, leaves and roots

4.5.1.4. Cultural practices to prevent its occurrence

Sanitary methods

Phytosanitation is aimed at preventing the spread of viable seeds by minimising the movement of infested soil by farm machinery and vehicles, preventing grazing on infested plant material, treating manure (e.g. composting) and avoiding the use of hay made of *Orobanche*-infested plants. One should also avoid the use of *Orobanche*-infested crop seeds.

Hand weeding

Orobanche flowering stems should be weeded as early as possible. The stems should immediately be discarded and must not remain in the field because they can continue developing flowers and spreading seeds even without being connected to the host. Hand weeding is very important especially when only a few *Orobanche* plants develop in a field. This can prevent further spread of the parasite and avoid damage.

Avoidance

Avoidance of infestation by either delaying the sowing of crops or early sowing, as with sunflower, thereby reducing infestation and damage by *O. cumana*.

Another way to avoid infestation is to grow non-host crops in the infested field. It is necessary to know the host preferences of the particular *Orobanche* population in the field and it should be remembered that *Orobanche* seeds remain viable in soil for many years, sometimes up to 15 to 20 years!

Trap crops and catch crops

Both are used to promote extensive germination of *Orobanche* in soil, in order to deplete the seed reserve. Trap crops promote *Orobanche* seed germination but do not support parasitism; catch crops support parasitism but are destroyed prior to *Orobanche* flowering. Examples of trap crops for *Orobanche* include flax, mung beans, maize and sorghum. A catch crop that has been effective in Egypt is berseem *(Trifolium alexandrinum)*, harvested repeatedly for forage to prevent full development and seeding of the parasite.

Even though this method sounds promising and in some cases proved successful to a certain extent, the use of trap and catch crops has not gained an important role in the control of root parasites anywhere in the world, for two reasons: (a) local strains of the parasites may differ in their response; and (b) it takes several years of trap or catch cropping to reduce parasite seed populations to non-damaging levels.

Solarisation

Soil solarisation, based on mulching soil with transparent polyethylene sheets for several weeks under solar irradiation, kills *Orobanche* seeds in the upper soil layers. This is effective only where sunshine is sufficient.

Host-Plant Resistance
Breeding resistant genotypes of host plants is one of the most promising approaches to reducing losses due to infestation by *Orobanche*. Resistant sunflower cultivars were selected in Russia and Spain many years ago and have been used successfully for decades. However, host-plant resistance was lost in many countries due to selection in the *Orobanche* populations towards more aggressive biotypes adapted to the newly introduced cultivars. This could also be the cause for the very limited practical success of introducing genetic resistance against *Orobanche* in other crops, such as faba bean, lentil and tomato.

4.5.1.5. Remedies

Biological Control
The broomrape-fly *Phytomyza orobanchia* was widely used for *Orobanche* control in the Soviet Union and some East European countries. No outstanding success has so far been achieved using this biological agent, mainly because of some hyperparasites *(e.g. Opius occulisus)* that attack *Phytomyza*.

Orobanche-specific *Fusarium oxysporum* was used to control the parasite in tobacco and in sunflower. This agent is still to be developed for worldwide biological control of the different *Orobanche* species.

A fungus, *Sclerotinia sclerotiorum forma orobanchae*, has been recorded in India causing a wet rot of the flowering stem without affecting host plants.

4.5.2. Couch grass

4.5.2.1. Scientific and common names

Cynodon dactylon
bermuda grass, bahama grass, common star grass, dhub grass, devil grass

Cynodon - USDA PLANTS Database

Cynodon flower

Cynodon infestation - Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org

4.5.2.2. What it is

Couch grass *(C. dactylon)* is thought to have originated in Africa, but now occurs worldwide in both tropical and subtropical regions.

The couch grass *(C. dactylon)* is regarded by Holm et al. (1977) as the second most important weed in the world after *Cyperus rotundus*, a status that is justified by its occurrence in virtually every tropical and subtropical country and in virtually every crop in those countries.

The weed is an alternate host of some plant diseases such as brown spot, leaf spot, early blight, stripe disease of rice, barley yellow dwarf, and lucerne dwarf and of nematodes. Couch grass is used as a cover crop to control erosion and for soil stabilisation, feed for livestock, lawn beautification and herbal medicine.

C. dactylon tolerates a wide range of temperatures, especially very high temperatures in near desert conditions. Freezing point ranges from -2° to -3°C. Growth is favoured by medium to heavy, moist, well-drained soils but *C. dactylon* will also grow in acidic and quite highly alkaline soils and the rhizome system can survive flood conditions and drought.

The stem creeps at full length along the ground. The leaves are small, linear and blue-green with rough margins. The undersides are smooth, but hairy on the upper surfaces. The flowering stalks bear many slender and purplish spikelets. The fruit is reddish-brown or orange-red. The seeds are flattened, oval and straw-coloured.

The weed can be spread through seeds, runners, rooting nodes or underground rhizomes. It is mat forming. A single plant can produce up to 720 seeds. It can endure both extensive flooding and drought.

Host Range:

The crops in which couch grass is most commonly a major problem are those of the subtropics that are planted in wide rows, for example, cotton, sugarcane, tobacco, citrus, olive, deciduous fruit, forestry and ornamental species and many vegetables, but also some closer-planted but less competitive crops such as rice, lucerne, lucerne and grass pastures, onion and jute.

4.5.2.3. Cultural practices to prevent its occurrence

Control Methods

- Proper selection of seeds (ensure that whatever seeds you plant are not contaminated with couch grass seeds)
- Thorough land preparation
- Regular plant monitoring
- Legumes or other cover crops are sometimes used for smothering *C. dactylon* since the weed does not tolerate deep shade. Vigorous crops and higher crop density may be important in reducing weed competition
- Traditional techniques of controlling *C. dactylon* rely very little on manual methods, as it easily survives shallow hoeing and positively thrives on mowing. However, the benefits of deep cultivation have been confirmed in Botswana and Zimbabwe where double ploughing, either after crop harvest or before the onset of the next season's rains, provided a high degree of control and was beneficial to crop yields

The main non-chemical approaches to control couch grass are deep tillage and shading/ smothering crops.

4.5.3. Dodder

4.5.3.1. Scientific and common names

Cuscuta spp
Devil's guts, devil's hair, devil's ringlet, gold-thread, hail-weed, hair-weed, hellbine, love vine, strangle-weed, witch's hair

Dodder

Dodder infestation

Dodder on capsicum

Dodder seeds

4.5.3.2. What it is

Cuscuta (dodder) is a genus of more than 200 species of obligate aerial parasitic plants in the morning glory family, *Convolvulaceae*. The genus is found throughout the temperate to tropical regions of the world, with the greatest species diversity in subtropical and tropical regions. *Cuscuta* species have a distinct appearance, consisting mainly of leafless, yellow or orange, hairless twining stems and tendrils, bearing minute scales in the place of leaves. It has very low levels of chlorophyll; some species such as *Cuscuta reflexa* can photosynthesise slightly, while others such as *C. campestris* are almost totally dependent on the host plants for nutrition. If a dodder plant is allowed to grow unchecked, it will form dense mats in and over the host plant. Dodder plants branch and re-branch, spreading from plant to plant until large areas may be infested. Stem growth of 7.5cm per day has been recorded. A single dodder plant may spread to a diameter of 3m or more. Important dodder species in Africa include *C. approximate* (alfalfa dodder), *C. epithymum* (clover dodder), *C. campestris* (field dodder), *C. reflexa* (common dodder), *C. kilimanjari, C. planiflora* and *C. somaliensis*.

Biology and Ecology of Dodder

Dodder flowers occur in white or greenish-yellow clusters. Each flower is capable of producing up to four seeds. Seeds are irregular in shape, rough-surfaced, about 1mm across. A proportion of the seeds do have a hard coat requiring gradual degradation or scarification, which reduces the danger of all seeds germinating at once in the absence of a host. Seeds can survive in the soil for 5 to 10 years.

Unlike the root parasites *Striga* and *Orobanche*, *Cuscuta* species do not require a germination stimulant provided by host roots. Dodder seeds sprout at or near the surface of the soil. While dodder germination can occur without a host, it has to reach a green plant quickly; dodder grows toward the smell of nearby plants. If a plant is not reached within 5 to 10 days of germination, the dodder seedling will die. Before a host plant is reached, the dodder, as other plants, relies on food reserves in the embryo. The seedling has only a rudimentary root for anchorage, while the shoot circumnutates, i.e. swings around anti-clockwise about once per hour, until it makes contact with any stem or leaf, around which it will coil before growing on to make further contacts.

After a dodder attaches itself to a plant, it wraps itself around it. If the host contains food beneficial to dodder, the dodder produces haustoria (root-like growths) that insert themselves into the vascular system (water and nutrient conducting tissues) of the host. The haustoria have three functions: attachment, penetration of the host stems and nutrient acquisition from the host. The original root of the dodder in the soil then dies.

The dodder can grow and attach itself to multiple plants. In tropical areas it can grow more or less continuously and may reach high into the canopy of shrubs and trees; in temperate regions it is an annual plant and is restricted to relatively low vegetation that can be reached by new seedlings each spring.

Dodder seed can be spread by irrigation water, in the manure of livestock that has fed on infested plants along with the seed of dodder and also through movement of contaminated seed of crops e.g. lucerne or onion.

Host range:
Medicago sativa (lucerne), *Guizotia abyssinica* (niger), *Beta vulgaris var. saccharifera* (sugar beet), *Daucus carota* (carrot), *Trifolium pratense* (purple clover), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Lycopersicon esculentum* (tomato), *Citrus spp.* (citrus), *Vigna radiate* (mungbean).

Wild hosts:
Convolvulus arvensis (bindweed), *Rumex abyssinica* (wild dock), *Rumex usambarensis, Bougainvillea spp.* (paper flower)

Dodder as a medicinal herb
It is recommended for people suffering from biliary disorder or gall bladder emptying-dysfunction. It can also be used as a poultice for slow healing wounds. Preparation and use of dodder as a medicine are given by *Pamplona-Roger (2000)*.

4.5.3.3. The damage caused

Dodder derives nutrients by penetrating the stem tissues of the host plant with its haustoria (specially modified root-like growths) and absorbing water, carbohydrates and minerals at the expense of the host plant. As well as "starving" the host plant, dodder is also implicated in the transmission of certain bacterial and viral diseases. It is most troublesome, where it is sown as a seed contaminant (e.g. lucerne, clovers, niger seed); where broad-leaved crops are grown as perennials or biennials (e.g. lucerne, clovers, citrus, sugar beet); and in horticulture where most crops in the rotation are broad-leaved (e.g. vegetables, ornamentals). Owing to its powerful metabolic sink effect, the damage to infested hosts can be severe, to the extent of total crop loss. Crop losses have rarely been measured, but there are estimates of 57% reduction in lucerne forage production over a two-year period and reductions of up to 40% in root weight and 3.5 to 4 tonnes of sugar per hectare in infested sugar beet. There is also further economic loss when crop produce, intended for export, is rejected or has to be cleaned expensively.

"Dodder is a true vegetal vampire. With its fine stems it sticks to its victims, then literally sucks the sap until killing the host." *(Pamplona-Roger, 2000).*

Symptoms

The presence of *Cuscuta* is always obvious from the twining stems and tendrils on a host plant. Infested plants show reduced vigour and, in particular, poor seed and fruit development. Leaves of infested plants are yellowed and eventually die. Severely infested plants wilt and die

Affected plant stages

Seedling stage, vegetative growing stage, flowering stage and fruiting stage

Affected plant parts

Whole plant, leaves and fruits/pods

4.5.3.4. Cultural practices to prevent its occurrence

Prevention

Many nations have laws prohibiting import of dodder seed, requiring crop seeds to be free of dodder seed contamination (Phytosanitary regulations). Use of clean crop seed is vital. Seed should be inspected and cleaned if necessary, or obtained from a source known to be reliable. Removal of highly favoured hosts such as *Convolvulus arvensis* from around field edges is also recommended.

Cultural control

The aim is to control before dodder sets seed by collection and deep burying of infested plants. This may have to be done repeatedly throughout the growing season as dodder seed germinates from the upper 3cm of the soil. Prevent livestock from grazing in infested areas after dodder has set seed and do not allow livestock that have grazed fields where dodder has set seed to move to other areas. Hand-pulling is suitable only for scattered infestations as the infested crop plants have to be removed with the parasite. Scattered infestations can also be controlled by heat, using a hand-held flame gun. More extensive infestations in lucerne are also sometimes treated with overall flaming, as the crop is able to recover. Close mowing is an alternative means of control in lucerne and clovers. Rotation with non-susceptible crops can be helpful. Examples of non-host crops include grasses and many other monocotyledons. Cereals are virtually immune, but some broad-leaved crops may also be sufficiently resistant, including soybean, kidney bean, squash, cucumber and cotton. Guar bean *(Cyamopsis psoraloides)* is not immune, but causes gross deformity and reduces the vigour of the parasite to the extent that it helps to protect a susceptible crop, mungbean *(Vigna radiata)*, when they are grown in mixture. There are no known resistant varieties of susceptible crop species. Deep shade suppresses the coiling and attachment of *Cuscuta* – encouraging a dense crop canopy is a valuable component of any integrated control programme.

4.5.3.5. Remedies

Biological Control

Attempts at biological control of *Cuscuta* spp. have mainly involved the agromyzid fly *Melanagromyza cuscutae* and the gall-forming weevils *Smicronyx spp*. Introduction of *M. cuscutae, Smicronyx rufivittatus* and *Smicronyx roridus* from Asia into Barbados for control of *Cuscuta americana* and *C. indecora* apparently failed, but *Smicronyx jungermanniae* and *Smicronyx tartaricus* have given encouraging results in eastern Europe when introduced from one region to another for control of *C. campestris*.

Among pathogens, *Alternaria cuscutacidae* is reported to have been used successfully on *C. campestris* in the former USSR and a form of *Colletotrichum gloeosporioides* has been used for many years in China as a mycoherbicide for control of *C. chinensis* and *C. australis* on soybean.

Integrated Control

Integrated methods involve the all-important use of clean seed; good field hygiene to eradicate scattered infestations before they get out of control; good control of other weeds which might act as reservoirs of infestation; timing of tillage and planting to maximise destruction of parasite seedlings before sowing; and optimum planting arrangement and growing conditions for a good crop canopy to suppress development of the weed.

4.5.4. Purple witchweed

4.5.4.1. Scientific and common names

Striga hermonthica
Purple witchweed

Purple witchweed damage

Purple witchweed flowers

Purple witchweed infestation

4.5.4.2. What it is

Striga hermonthica is a herbaceous annual plant 30 to 100cm high, the most robust forms occurring in Sudan and Ethiopia. Larger plants may be much branched. The root system is weak with little or no ability to absorb materials from the soil, but branches develop from lower nodes of the plant, ramifying and developing attachments on contact with other host roots.

The purple witchweed *Striga hermonthica* threatens the lives of over 100 million people in Africa and infests about 40% of arable land in the savanna region, causing an estimated annual loss of $7 to 13 billion *(www.icipe.org)*. It is almost certainly responsible for more crop loss in Africa than any other individual weed species. Over 5 million ha of crops – mainly sorghum, millets and maize – are affected in six countries of West Africa alone, possibly 10 million ha in Africa as a whole. One plant of *S. hermonthica* per host plant is estimated to cause approximately 5% loss of yield (Parker and Riches, 1993) and high infestations can cause total crop failure. Overall yield losses are estimated at 21% of all sorghum in northern Ghana, 10% of all cereals in Nigeria, 8% in Gambia and 6% in Benin. Other countries seriously affected include Cameroon, Cote d'Ivoire, Burkina Faso, Niger, Mali, Senegal, Togo, Sudan, Ethiopia, Kenya, Uganda and Tanzania.

The damaging effect of *S. hermonthica* on the host plant derives not only from the direct loss of water, minerals, nitrogen and carbohydrate, but from a disturbance of the host photosynthetic efficiency and a profound change in the root/shoot balance of the host, leading to stimulation of the root system and stunting of the shoot. Young Striga seedlings are completely parasitic on the host while they are below the soil level and, at this stage, cause maximum damage to the host.

As *S. hermonthica* occurs mainly under conditions of low fertility. It is also associated with farming systems in Africa, in which farmers have few resources and very few options in terms of control measures.

Biology and Ecology of Purple Witchweed

The biology and ecology of *S. hermonthica* are described in detail by Parker and Riches (1993). It is an obligate hemi-parasite, with green foliage capable of photosynthesis and can at least partially support its own growth once established. Its minute seeds (about 0.2mm x 0.3mm) have inadequate reserves to establish without a host. Seeds are produced in enormous numbers and they are generally dispersed by wind, water, livestock and man.

Relatively high temperatures, 30° to 35°C, are optimal for germination and for growth. Dry conditions of soil and air are most favourable and *S. hermonthica* rarely occurs in irrigated cereals, though wet conditions can be tolerated for short periods. Neither soil type nor pH is critical for its growth – *S. hermonthica* occurs on almost all soil types from sandy acidic to alkaline clay soils, as in Sudan.

Habitat

S. hermonthica, as most other *Striga* species, is associated with low-fertility soils, especially those low in nitrogen. Unlike *Striga asiatica* it occurs not only on light, sandy soils but also on heavy clays and even on vertisols.

It is also favoured by low soil moisture and rarely occurs on irrigated soils, but can tolerate abundant moisture for short periods. It is a plant of the African savannah, almost invariably associated with cereal cropping and relatively uncommon in natural vegetation.

Host range

The natural host range of *S. hermonthica* is normally limited to *Gramineae (Poaceae)*, but weak attachment to groundnut, cowpea, lablab and soyabean was obtained in pots and there have been unconfirmed reports of infestation of groundnut and sesame fields in West Africa. Apart from the wild hosts listed above, *S. hermonthica* is occasionally observed on crowfoot grass *(Dactyloctenium aegyptium)*, Panicum walense, goose grass *(Eleusine indica)*, ricegrass paspalum *(Paspalum scrobiculatum)*, *Pennisetum violaceum* and on *Cynodon, Cymbopogon, Ophiuros* and *Brachiaria spp.*

Individual biotypes may have a narrower host range than the species. In particular, there are forms which attack sorghum but not pearl millet and vice versa.

4.5.4.3. The damage caused

S. hermonthica causes characteristic yellowish blotches in the foliage about 1cm long by 0.5cm wide. In later stages whole leaves may wilt, become chlorotic and die. Stems are shortened, though leaf numbers may not be reduced. Inflorescence development is delayed or prevented. Root systems, at least in early stages, may be stimulated and haustoria 1 to 2mm across appear like nodules.

Affected plant stages

Flowering stage, fruiting stage, pre-emergence, seedling stage and vegetative growing stage

Affected plant parts

Leaves, stems and whole plant

Symptoms by affected plant part

Leaves: Abnormal patterns; yellowed or dead
Stems: Abnormal growth
Whole plant: Dwarfing; early senescence

4.5.4.4. Cultural practices to prevent its occurrence

Detection and inspection methods

Infestation of a cereal crop by *S. hermonthica* may be apparent before emergence from the soil, by the chlorotic blotches on the crop foliage. Uprooting may confirm the presence of the haustoria and young parasite seedlings on the root.

Resistant/tolerant varieties

No completely immune cereal varieties have been developed, but many sorghum varieties show high levels of resistance, at least under local conditions. Selection and breeding programmes in India and Africa have led to the development and release of many lines with at least reduced susceptibility and these may be valuable as components of an integrated control approach.

However, traditional varieties in Striga-infested areas often show relatively high tolerance and these may yield well in spite of heavy infestation. Identified resistant cultivars of sorghum include 'N-13' from India, 'Framida' from South Africa and 'Serena'and 'SAR 29' from Tanzania. Among millets the following cultivars are considered resistant in Tanzania: 'Buruma', 'Shibe', 'Okoa' and 'Serere 17'.

In maize there are no effectively resistant varieties, though some show partial resistance, such as 'Katumani' in Kenya and some more tolerant lines have been developed by the International Institute for Tropical Agriculture. Work is now in progress to transfer high-level resistance into maize from wild relatives including *Zea diploperennis*.

Little progress has been possible with the out-crossing pearl millet, but there are promising results from work in progress to select and develop rice varieties with resistance to Striga species.

Characteristics/weaknesses in *S. hermonthica*, which may be exploited in cultural control measures include the following:

- Dependence on a susceptible host for establishment: Crop rotation avoiding a susceptible cereal will prevent new seeding and allow decline of the soil seed bank. In some areas, there may be alternative cereals, which are not attacked (e.g. sorghum in a millet-growing area, or vice versa). Among the non-cereal crops, many are known to exude germination stimulant, though they cannot be parasitised. These trap crops, such as cotton, groundnut, cowpea, sunflower and soya bean, are especially beneficial in causing suicidal germination and accelerating a decline in the soil seed bank. But they need to be sown at a time when Striga germination is likely to be high, usually early in the rainy season, before the onset of any secondary dormancy. Some of the catch crops are susceptible cereals which may be grown at the beginning of the season or in short rains prior to the main season, to stimulate germination of the Striga. However, they need to be destroyed before the weed can mature and set seed

- Preference for low nitrogen: Additional nitrogen fertiliser usually reduces Striga incidence, though not always, especially when applied as a single dose. However, improved soil fertility is a vital key to long-term control, whether by organic, inorganic or green manuring, rotation with legumes, or agroforestry techniques involving mulching

- Preference for dry conditions: Irrigation is rarely an option, but moisture conservation techniques may be beneficial. Any means of raising humidity will reduce Striga transpiration and its ability to draw nutrition from the host. Hence leafy crop varieties, dense, uniform planting and intercropping with legumes, all tend to suppress the weed.

None of the methods described above will, alone, provide complete control and without complete control there is the certainty that surviving Striga plants will mature and replenish the soil seed bank. It is therefore essential that manual and mechanical methods are used to destroy surviving Striga plants. Hand-pulling is the most common traditional technique, though a late hoeing or ridging may also be effective.

International Centre of Insect Physiology and Ecology (ICIPE) developed a habitat management strategy for effective control of Striga in cereal-based farming systems. It involves planting desmodium legume *(Desmodium uncinatum)* intercrop in maize fields. Roots of desmodium secrete chemicals (isoflavones) that stimulate Striga seed germination and also inhibit attachment of Striga to maize roots thereby causing suicidal germination of Striga seed and reducing its seed bank in the soil. The legume also maintains soil stability and improves soil fertility through nitrogen fixation. In addition it serves as a highly nutritious animal feed. This habitat management strategy is part of an integrated approach called "push and pull" for control of both maize stemborers and Striga (*www.icipe.org*).

4.5.4.5. Remedies

Biological Control

The reduction in seed production from gall-forming *Smicronyx spp.* is often substantial, but there has been no successful development of a biological control programme based on these weevils. Attempts to introduce *Smicronyx albovariegatus* (and the moth *Eulocastra argentisparsa*) from India into Ethiopia apparently failed. Meanwhile, conclusions from a mathematical modelling project have suggested that *Simicronyx spp.* would in any case be unlikely to have a significant impact on Striga population dynamics.

Other potentially useful organisms for Striga management include the following: a) the butterfly *Precis (Junonia)* species whose larvae feed on leaves, buds and capsules of many Striga species; and b) a range of fungal diseases including *Fusarium equiseti* that causes girdling of the stem, abortion of seed capsules or wilting and death of young Striga plants.

Integrated control

As virtually none of the treatments described above is likely to achieve complete control, integration of one or more is essential for any substantial reduction of the problem. Furthermore, such integrated treatments will almost certainly need to be repeated over a number of years for long-term control. Parker and Riches (1993) propose a range of programmes depending on the initial density of the problem, involving various combinations of rotation, varietal selection, soil fertility enhancement and intercropping with legumes, supplemented in all cases by hand-pulling.

4.5.5. Sedges

4.5.5.1. Scientific and common names

Cyperus spp.
Water grass, highland nut sedge, papyrus, yellow nut sedge, purple nut sedge

Nutgrass

Nutgrass

Yelllow nut sedge

Yelllow nut sedge

4.5.5.2. What it is

Sedges are grass-like plants widely distributed especially in the tropics and subtropics belonging to the genus *Cyperus* in the family *Cyperaceae*. The differences between sedges and grasses are:

1) grass stems are usually, but not always, round in cross section, while sedge stems are more or less triangular;
2) sedge leaves are spirally arranged in three ranks while grasses have alternate leaves forming two ranks; and
3) leaf sheaths (lower part of a leaf enclosing the stem) in grasses are split whereas leaf sheaths of sedges are not split.

Sedges are mostly found in moist areas such as wetlands, but are also common constituents of forest-margin vegetation. Like most tropical plants, they are sensitive to frost. Renewed attention is being given to these plants due to their critical role in wetland ecosystems.

Genus Cyperus comprises about 650 species. Some of the commonly occurring species in the region include:

- *C. blysmoides (C. bulbosus var. spicatus)* (Water Grass): It is a perennial sedge andis limited to the highlands (500 to 1800m). It is abundant as a weed in some upland crops such as coffee and wheat. It is propagated by bulbs (they are flattened stems bearing fleshy leaves and serve as organs of storage and vegetative reproduction)

- *C. rigidifolius* (Highland Nut Sedge): It is a perennial sedge that is widespread in the highlands (1200 to 3350m). It can be a problem in pastures and for pyrethrum and other crops, especially where there is little or no cultivation. It is propagated by rhizomes (a root-like underground stem) and tubers

- *C. teneristolon (C. transitorius; Kyllinga pulchella):* A perennial sedge localised in the uplands of Kenya and Tanzania. It is also present in Ethiopia. It is a weed of crops in the highlands. It is propagated by rhizomes and seed.

- *C. papyrus* (Papyrus, Papyrus Sedge or Paper Reed): It is a stately aquatic member of the sedge family. It is a herbaceous perennial native to Africa. This tall, robust, aquatic plant can grow 4m to 5m (13ft to 16ft) high. It forms a grass-like clump of triangular green stems that rise up from thick, woody rhizomes. Each stem is topped by a dense cluster of thin, bright green, thread-like stems around 10cm to 30cm (4 in to 10 in) in length, resembling a feather duster when the plant is young. Greenish-brown flower clusters eventually appear at the ends of the rays, giving way to brown, nut-like fruits. Papyrus sedge (and its close relatives) has a very long history of use by humans, notably by the Ancient Egyptians'. It is the source of papyrus paper, parts of it can be eaten and the highly buoyant stems can be made into boats. It is now often cultivated as an ornamental plant. *C. papyrus* grows in full sun, in wet swamps and on lake margins throughout Africa, Madagascar and the Mediterranean. In deeper waters it is the chief constituent of the floating, tangled masses of vegetation known as "sudd". Papyrus ranges from subtropical to tropical desert to wet forests, tolerating annual temperatures of 20°C to 30°C and a pH of 6.0 to 8.5. Papyrus flowering prefers full sun to partly-shady conditions. Like most tropical plants, it is sensitive to frost. The "feather-duster" flowering heads make ideal nesting sites for many social species of birds. As with most sedges, pollination is by wind, not insects. Mature nut-like fruits are distributed by water

- *C. esculentus* (Yellow Nut Sedge, Earth Almond, Tiger Nut Sedge or Chufa Sedge): *C. esculentus* is a light green perennial sedge growing to about 1m in height with solitary stems growing from a tuber. The stems are triangular in section and bear slender leaves 3mm to 10mm wide. The flowers of the plant are distinctive, with a cluster of flat oval seeds surrounded by four hanging leaf-like bracts (modified leaves from where flowers arise) positioned 90 degrees from each other. The plant foliage is very tough and fibrous and is often mistaken for a grass. It is present in over 20 African countries. It is widely distributed in arable land and irrigated areas.

  It can be a serious weed of coffee, cotton, groundnut, maize, pineapple, rice, sisal, soybean, sugarcane and vegetables. If left unchecked, *C. esculentus* can cause a yield loss of over 40% in maize and soybean.

  It produces tubers, which are nearly spherical, about 10mm in diameter, dark brown in colour. Tubers are edible with a slightly sweet, nutty flavour. It is commercially grown for these tubers in some countries (e.g. Burkina Faso, Ghana, Mali, Nigeria and Spain). The tubers are quite hard and are generally soaked in water before they can be eaten, thus making them softer and giving them a better texture. They are eaten as vegetables, made into sweets or used to produce the famous "Horchata de chufas" (a creamy white drink) of the Valencia region in Spain. They have excellent nutritional qualities with a fat composition similar to olives and a rich mineral content, especially phosphorus and potassium. The oil of the tuber was found to contain 18% saturated (palmitic acid and stearic acid) and 82% unsaturated (oleic acid and linoleic acid) fatty acids. "Horchata de chufas" can be useful in replacing milk in the diet of people intolerant to lactose to a certain extent. Since the tubers contain 20 to 36% oil, C. esculentus has been suggested as potential oil crop for the production of biodiesel.

  Seed and tubers are an important means of dispersal of this species.

- *C. rotundus* (Coco-grass, Purple Nut Sedge or Red Nut Sedge): *C. rotundus* is a perennial plant that may reach a height of up to 40cm. The names "nut grass" and "nut sedge" (shared with the related species *Cyperus esculentus*) are derived from its tubers, that somewhat resemble nuts, although botanically they have nothing to do with nuts.

As in other *Cyperaceae*, the leaves sprout in ranks of three from the base of the plant. The flower stems have a triangular cross-section. The flower is bisexual, reddish-brown to purplish-brown. The fruit is a three-angled achene (small, dry, not opening when ripe, one-seeded).

The root system of a young plant initially forms white, fleshy rhizomes. Some rhizomes grow upward in the soil and then form a bulb-like structure from which new shoots and roots grow and from the new roots, new rhizomes grow. Other rhizomes grow horizontally or downward and form dark reddish-brown tubers or chains of tubers.

It is a species of sedge native to Africa, southern and central Europe (north to France and Austria) and southern Asia. *C. rotundus* is one of the most invasive weeds known, having spread out to a worldwide distribution in tropical and temperate regions. It has been called *"the world's worst weed"* as it is known as a weed in over 90 countries and infests over 50 crops worldwide.

Life Cycle of Purple Nut Sedge (Cyperus rotundus)

The typical life cycle of *C. rotundus* starts with growth of the apical bud of a tuber. As the tuber shoot extends, it swells to form a basal bulb (sometimes called a corm), usually near the soil surface, from which an aerial shoot and roots are produced. Up to three or four rhizomes develop from each basal bulb, extending 5 to 30cm before turning up to form a further basal bulb and, in more mature plants, these rhizomes may form dormant tubers, without any aerial shoot. Further branch rhizomes develop, however, from lateral buds on the tuber and eventually, branched chains of rhizomes and tubers become an extensive, underground network. Meanwhile, the new shoots grow and produce flowers within 3 to 8 weeks of emergence if stimulated by short photoperiods of 6 to 8 hours. Most seeds of *C. rotundus* are not viable.

Tuber dormancy is high on undisturbed sites and may last for at least 7 years. A growing tuber exerts dormancy on others in the same rhizome/tuber chain and fragmentation of the network by cultivation breaks this dormancy. Hence, cultivation stimulates the growth of *C. rotundus*. Large populations of shoots and tubers can develop from a single tuber; as many as 600 plants have been produced in a single year. It has been reported that 2 to 3 million tubers per hectare per week can be produced during active growing periods, yielding 30 to 40 million tubers per hectare. Forty tonnes of underground organs have been produced on one hectare in a year, giving *C. rotundus* a phenomenal capacity for vegetative reproduction. Most tubers are found in the upper 15cm of soil but they can grow down to 30cm or more in favourable conditions.

It has low tolerance of shade, a property that can be exploited in controlling this weed by crops with dense canopies. Temperature has a marked effect on the germination of tubers. Sprouting has been reported at temperatures of 13°C to 43°C but the range varies with biotype. Desiccation kills tubers but the duration and temperature of the drying period affects this process. The critical moisture level for tuber germination seems to be in the region of 11.5% to 15%.

Dispersal of *C. rotundus* occurs when tubers are moved by tillage equipment or other farm machinery. Flood water may also carry the tubers. Contaminated soil in nursery stock is an avoidable but common method of dispersal. Under natural conditions, a population of *C. rotundus* extends its boundary by a few metres in a year. Spread by seed is generally regarded as being unimportant.

C. rotundus is widespread in the tropics and subtropics, growing in almost every soil type, elevation, humidity, soil moisture and pH, but not in soils with a high salt content. Its range at increasing latitudes and altitudes is limited by cold temperatures. It occurs in cultivated fields, fallow land, neglected areas, road and rail sides, banks of irrigation canals and streams, edges of woods and sand dunes. Generally, it does not tolerate shade.

Good use

It is claimed that *C. rotundus* is an important medicine in India and China and noted for its use by pharmaceutical companies to produce diuretics, anthelminthics and treatments for coughs, bronchial asthma and fever. It makes a poor fodder but has value in binding together soil. However, its negative attributes as a weed far outweigh its usefulness.

4.5.5.3. The damage caused

C. rotundus is considered the worst weed based on its occurrence in 52 crops in 92 countries and its capacity to cause substantial yield losses. Examples of crop loss caused by *C. rotundus* include 35 to 89% in vegetables, 30% in cotton and 75% in sugarcane harvest. Even the growth of tree crops can be reduced, for example, mulberries in Japan, citrus in Israel and coffee in Kenya. Much of this can be attributed to the capacity of *C. rotundus* to remove nutrients from the soil and store them in its tubers, making them unavailable to crops. Adding nitrogen to a crop can actually improve the competitiveness of *C. rotundus*, causing even greater crop loss than where no fertiliser is added. *C. rotundus* undoubtedly competes with crops for water but also for light when it grows tall enough. There is evidence that extracts from *C. rotundus* suppress the growth of plants but it is difficult, under field conditions, to separate the effects of allelopathy (the roots releasing substances harmful to other plants) from competition.

4.5.5.4. Cultural practices to prevent its occurrence

Tillage has little effect on *C. esculentus* when tubers are dormant during the off season: the tubers are then less susceptible to desiccation than those of *C. rotundus*. Conversely, when tubers have sprouted and before new stolons and tubers are formed, it is much more susceptible than *C. rotundus* to disturbance and desiccation by tillage. Hence, pre-sowing cultivations prior to late sowing of crops can cause useful reductions and inter-row cultivation in the crops (e.g. maize, soybean etc.) can also be effective at an early growth stage when the reserves of the parent tuber are newly depleted. Other measures that may help in suppression of *C. esculentus* include shading, improved drainage and crop rotation.

It is extremely difficult to remove *C. esculentus* completely from fields. It is considered an intrusive weed. This is due to the plant having a stratified and layered root system, with tubers and roots being interconnected to a depth of 50cm or more. The tubers are connected by fragile roots that are prone to snapping when pulled, making the root system difficult to remove intact. The plant can quickly regenerate if a single tuber is left in place.

Mechanical control of C. rotundus

Successful cultivation depends on destroying the tubers of *C. rotundus* by exposing them to desiccation or by exhausting the food reserves. This can be especially effective under hot dry conditions, but requires the necessary power to disturb rhizomes and cut roots to at least 15 and preferably 20 to 25cm depth. Repetition may be needed. Under moist soil conditions, a single cultivation may only serve to spread and aggravate the problem and it is essential that tillage is repeated as necessary to prevent re-establishment from fragments of the rhizome/tuber system. This could necessitate cultivating every 2 to 3 weeks until the crop forms a canopy to suppress further growth of the weed. In practice this consumes much time and energy and could be detrimental to soil structure.

Organic mulch made from crop residues provides temporary suppression of *C. rotundus* but a film of 1000-gauge polyethylene is an effective barrier to growth which can be used in nurseries and high value field crops.

Solarisation with black plastic is not completely successful, as tubers deeper in the soil survive and sprout, piercing the plastic as they emerge. With clear plastic, however, the sharp shoots become leafy in the light as they emerge and since they are trapped under the plastic are killed by the high temperature.

Phytosanitary control

The main phytosanitary risk is *C. rotundus* tubers attached to farm machinery or on the roots of crop plants moved from place to place. Introduction is limited by prohibiting the import of plants with soil around their roots and by cleaning farm equipment before transporting to other sites.

4.5.5.5. Remedies

Biological control

It is questionable whether a cosmopolitan weed like *C. rotundus* with a huge regenerative capacity would be a good target for biological control but it is claimed that several fungi are promising candidates for classical biocontrol including *Puccinia conclusa, P. philippinensis* and *Phytophthora cyperi* and they warrant evaluation as possible mycoherbicides.

Arthropod herbivores of *C. rotundus* that have been investigated as biological control agents include *Athesapeuta cyperi, Chaetococcus australis, Bactra minima, B. venosana* and *B. verutana*.

Solarisation followed by cell-grazing pigs in moveable electric-fence pens over the area will remove the majority of plant parts surviving in the soil.

Management of sedges:

- Groundcovering legume plants and mulches can play a very important role in both improving the soil fertility and combat perennial weeds. Clover and other leafy and strongly growing legumes planted in sedge infested land will both overpower the sedges and enrich the soil. In the case of watergrass or nut sedges, harrowing only makes the problem worse, as the root nuts will be separated from the stems and given the opportunity to send out many new shoots

- Solarisation: Covering a sedge infested piece of land with black polythene after wetting it and leaving it exposed for some days to hot sunshine, will completely eliminate any of the sedge species. However plastic is expensive, so if it cannot be afforded try the first option, viz. groundcover with legumes

- Mulching: *C. rotundus* has been successfully controlled with heavy mulching. Initially the weeds grow prolifically, but after a wet period they are easy to remove by careful hand pulling making sure the "nut" does not stay in the soil. This does not work on hard un-mulched soils

- Hand digging: Very careful hand digging with a knife ensuring all the little underground bulbs are removed can give a small reduction in Oxalis populations (annual or perennial), but is very time consuming and bound to leave a few bulbs here and there, which will waste no time in germinating.