



Integrated Pest Management for Brassica Production in East Africa

A Guidebook

A.A. Seif and Brigitte Nyambo



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Produced by

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Where specific pesticides have been mentioned in the text these are generally given as examples and should not be regarded as exclusive of others. Furthermore, mention of certain pesticides does not imply any preference or advantage over similar compounds not mentioned by name. Since some countries have restrictions on the use of certain pesticides, check local regulations before purchase or use. While every effort has been made to ensure the accuracy of the information in this booklet at the time of printing, the authors accept no responsibility for any damage that may arise as a consequence of using information in this guide.

Integrated Pest Management for Brassica Production in East Africa: A Guidebook

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Introduction

Many of the important agricultural and horticultural crops cultivated worldwide belong to the genus *Brassica*.


The main brassicas grown in East Africa are cabbage (*Brassica oleracea* L. var. *capitata*); kale, also called choumolea (*B. oleracea* L. var. *acephala*); Chinese cabbage (*B. campestris* L. var. *sinensis*); cauliflower (*B. oleracea* L. var. *botrytis*); broccoli (*B. oleracea* L. var. *botrytis*); and Brussel sprouts (*B. oleracea* L. var. *gemmifera*).

These vegetables are grown mainly for local markets and domestic use. They are valuable sources of vitamins and minerals, as well as a source of cash for small-scale farmers in rural and peri-urban areas. However, production is often constrained by damage caused by a range of insects, diseases, nematodes and weeds. The range of pests attacking brassicas is similar, but the relative importance of individual pest species varies between the different crops and among countries. The major insect pests of brassica include diamondback moth (DBM), cabbage aphids, cabbage webworm, cabbage cluster caterpillar and Bagrada bugs. Black rot, turnip mosaic virus and bacterial soft rot constitute the main diseases.

Farmers in East Africa depend overwhelmingly on the use of pesticides—often applied on a calendar basis—for pest control. The control of these pests is becoming increasingly difficult, uneconomic and environmentally damaging. Important pests such as the DBM have developed resistance to a wide range of commonly used pesticides. Furthermore, the incidence of turnip mosaic virus, which is transmitted by aphids, has increased in East Africa in recent years. As a result many farmers have resorted to the application of insecticide cocktails, as well as spraying more often. This has led to an increase in the level of contamination of the farm environment; high pesticide residues in the produce; health risks to farm workers and consumers; and increased cost of production. There is therefore urgent need for alternative control options, in order to become less dependent on synthetic pesticides.

Several countries in Asia have developed and implemented biocontrol-based integrated pest management (IPM) approaches for the control of DBM and cabbage aphids. In East Africa, an IPM programme coordinated by ICIPE has been successfully implemented in Kenya, Tanzania and Uganda.

This guide provides a practical reference for the preliminary identification of common brassica insect pests and diseases, as well as beneficial insects (natural biological control agents) in East Africa. Photographs and descriptions for most of the insect pests and diseases are presented in the guide to aid their identification. The guide



also covers some salient aspects of good agricultural practices (GAP) for cabbage production, such as ecological requirements, varieties commercially available in the region, land preparation and management, propagation, intercropping, harvesting and nutrient deficiencies. The latter can sometimes be confused with diseases and also can have a significant impact on crop yield and quality.

The use of this guide in conjunction with regular crop scouting (monitoring) can enable early detection of insect pests, diseases and disorders, thus making possible early implementation of control measures. Where in doubt, confirmation of diagnoses can be obtained by contacting local horticultural field offices and/or research centres.

Since chemical control recommendations change from time to time, they have not been included in the guide – consult your local horticultural field officer and/or chemical supplier for the most effective IPM-compatible registered products.

Cabbage Production

ECOLOGICAL REQUIREMENTS

Cabbage is a biennial plant that grows best under full sunlight. The optimum mean temperature for growth and quality head development is 15-18°C, with a minimum temperature of 4°C and a maximum of 24°C. Generally, young plants are more tolerant to heat and cold than plants nearing maturity.

Cabbage grows well on a wide range of soils with adequate moisture and fertility. Soil pH in the range of 6.0-6.5 is preferred, but cabbage will tolerate a soil pH range of 5.5 to 6.8. Cabbage is a heavy feeder, so to get good yields, proper fertilisation is necessary.

To maintain growth, cabbage requires a consistent supply of moisture, and should as a general rule receive a minimum of 2.5 cm of water per week. Larger quantities may be required when cabbage is grown on sandy soils or when evapotranspiration is high.

VARIETIES

Many cabbage varieties are commercially available in Eastern Africa and many more are being introduced into the market. Choice of a variety will depend on the production environment, market demand and preferences. Some examples of cabbage varieties grown in the region and their characteristics are given below. Variety information is derived from websites of seed companies. As far as possible, select a variety with attributes suitable to your local environment and with tolerance/resistance to prevalent insect pests and diseases.

Hybrid varieties

Baraka F1

A high yielding variety with bluish-green round heads. Head weight is 4-6 kg. It matures in about 75 days from transplanting. It has a good field holding capacity and is highly tolerant to black rot, ring spot and Fusarium yellows.

Blue Dynasty F1

Adapted to a wide range of agro-ecological zones. It is heat tolerant. Maturity is about 80-85 days after transplanting. Head is blue-green and weighs about 4-6 kg. It is resistant to black rot, ring rot and diamondback moth. It transports well.

CPI

A hybrid cabbage with round green heads. Head weight is 3-5 kg. It matures in 70-80 days after transplanting. It has a good field holding capacity since it does not burst easily. It has a sweet flavour and therefore ideal for salads. It is tolerant to Fusarium and black rot.

Globe Master F1

A high yielding hybrid cabbage with wide adaptability to different conditions. It is blue-green in colour and globe shaped with a short core. It is highly tolerant to black rot and Fusarium yellows. The head grows to 2.5 kg in 75 days after transplanting.

Gloria F1

It is a proven F1 hybrid for fresh market and processing. It is well adapted to various climatic conditions and withstands high temperatures. It is a mid-early maturing variety, ready for harvesting 90 days after transplanting. Head weighs about 4 kg with solid blue-green colour and thick waxy layer. Has strong rooting and moderate resistance to Fusarium yellows. It has good resistance to splitting and keeps well after harvesting.

Green Coronet F1

It is medium-large, semi-upright and grows well in medium hot to cold areas. Deep green, oblate head weighing up to 4 kg under optimum conditions. It is a medium-to early-maturing variety (about 75-80 days after transplanting). It has excellent field holding capacity and will last long in the field before bursting.

Field Winner F1

It takes about 80 days from transplanting to harvest. Head is semi-flat and weighs about 4 kg. It is resistant to black rot and has a sweet taste.

Oxylus F1

It is adapted to a wide range of agro-ecological zones. It has compact heads weighing about 4-5 kg each. It matures uniformly in about 70-75 days from transplanting. It is heat resistant and also resistant to alkalinity. It transports well.

Pruktor F1

It takes about 80 days from transplanting to harvest. Head is high and round and weighs about 5 kg. It has high resistance to black rot. It has shown considerable resistance to diamondback moth.

Quisor F1

A sweet, soft cabbage that is ideal for salad preparation. It has a compact, round head weighing 3-4 kg. It takes 75-80 days from transplanting to reach maturity. It is resistant to Fusarium yellows and tolerant to black rot. It is also drought-tolerant and is able to form heads under high temperatures.

Riana F1

An all-round variety that is heat- and cold-tolerant. It produces round, blue-green compact heads weighing about 2.5 kg. It does well both in temperate, subtropical and tropical zones. It is tolerant to black rot and tip burn. It matures in 90-100 days after transplanting and has excellent non-bursting quality.

Red Dynasty F1

It is high in anthocyanin and has a compact head weighing about 4-5 kg. It is early-maturing, taking about 70-75 days from transplanting. It is resistant to black rot and diamondback moth. It transports well.

Ruby Perfection F1

A vigorous, easy growing and heavy yielder with a deep red head weighing about 2 kg. It is very uniform in maturity, is late busting therefore has a long harvest period. It has strong tolerance against heat and cold with ability to form heads at low temperatures. It matures in about 80 days after transplanting.

Santar F1

It has a very firm compact, globe-shaped head, which is blue green in colour. The head weight is 4-6 kg. It matures within 80-90 days after transplanting. It has good resistance, especially to black rot and diamondback moth. It transports well.

Star 3317 F1

It matures within 80-90 days after transplanting. Heads are semi-globe and weigh about 2-3.5 kg each. It has medium resistance to black rot.

Super Master F1

A widely adaptable hybrid that produces a round to flat-round, bluish green compact head weighing about 4-5 kg. It has excellent field holding capacity and can stand in the field for long without bursting. It matures in about 80-85 days after transplanting. It is resistant to Fusarium yellows, Alternaria, and has medium to high resistance to black rot and diamondback moth.

Victoria F1

Widely accepted in various markets. It is fast-growing with maturity period of about 70-75 days from transplanting. It matures uniformly. It has compact heads each weighing between 4-5 kg. It transports well.

White Cabbage Landini F1

It is a light red skin variety. It matures in 90-120 days after transplanting. It is adapted to a wide range of climatic conditions. It has a round head weighing 4-5 kg. It has a shelf life of 4-5 months, and is resistant to Fusarium yellows and black rot.

Open pollinated varieties

Copenhagen Market

It is the most popular amongst the ball-headed cabbages and a great favourite for both home and market gardeners in East Africa. The heads are uniformly round, firm, medium sized and weighing about 2-3 kg. The plant is short-stemmed and rather small, and can be spaced closer. It is early maturing, approximately 60-70 days after transplanting. It is rather sensitive to splitting and should not be left in the field for too long after maturity. It is a highly dependable and productive variety.

Glory of Enkhuizen

An attractive variety that is presently very popular in East and Central Africa. The plant is low and relatively wide. The heads are medium large, flat round, green, firm and sweet (sweeter than any drumhead type). It matures about 12 weeks (84 days) after transplanting with the head weighing about 3.5 kg. Harvesting is spread for about 3 weeks thus market supply can be prolonged.

Prize Drumhead

A very late-maturing variety. It takes 18-19 weeks (126-133 days) after transplanting to mature. The heads are flat, solid, reaching about 30 cm in diameter, and can weigh more than 5 kg. Plants are spreading type and very large, A hardy variety which produces high yields.

Sugar Loaf

It takes about 75 days from transplanting to harvest. Head is conical and weighs about 2 kg. It prefers cool conditions. It is suitable for areas with well distributed moderate to heavy rainfall. It should be planted in well drained soils.

LAND PREPARATION AND MANAGEMENT

Prepare land well before transplanting and avoid field operations when it is wet. This will help to prevent the inadvertent spread of diseases from plant to plant and movement of infested soil within and outside the field. Keep fields free of weeds. Especially, weeds of the brassica family are potential alternative hosts of insect pests and diseases and are nutrient competitors. Ensure optimal fertilization (see below).

NURSERY MANAGEMENT

Raise seedlings on seedbeds or in wooden trays containing a mixture of compost and top soil or forest soil. Site the beds on land not previously under brassicas, and preferably away from old brassica fields. Raised beds (1-metre wide and of any desired length) are recommended for wet areas, especially those with heavy soils, while sunken beds are better for dry areas and/or dry seasons. Sterilize the soil before seeding by heating the soil in the seedbed: place plenty of crop trash or straw and burn for at least 30 min, and after cooling, mix the soil with compost in equal proportions. Use certified disease-free seed of pest resistant/tolerant varieties. If using own seeds of open-pollinated varieties, treat seeds with hot water for 30 minutes at 50°C and dress the seeds with fungicides. Seed rate is about 300 g/ha. Mulch the seedbed. Do not overwater seedlings in the seedbed; water them early in the morning. Excessive watering is conducive to damping-off diseases, and extended wetness of seedlings favours the development of foliar diseases. Thin out seedlings to avoid plant congestion in the seedbed. Healthy, vigorous seedlings should be transplanted when they are 10-12 cm high and about 4-6 weeks old.

MANURE AND FERTILIZER REQUIREMENTS

It is important to have the soil tested to determine the soil nutrient status before planting. If the soils are low in organic matter, 1-2 handfuls per planting hole (up to 20 t/ha) of manure or good compost should be applied. A basic dressing of phosphate (46% P_2O_5) at 200 kg/ha is recommended for soils low in phosphorous. In acidic soils, dolomite limestone should be applied at a rate 500-1000 kg/ha. Diammonium phosphate (DAP) should not be used in acidic soils. Instead, use rock phosphate, double superphosphate (DSP) or triple superphosphate (TSP). The plants should be top dressed with a nitrogen fertilizer at the rate of 100 kg/ha when seedlings are established and a second top dressing applied at the rate of 200 kg/ha when leaves start to fold.

INTERCROPPING

Intercrop brassica with trap crops or repellent plants, to reduce pest infestation. Tomato, when planted 14 days before cabbage, reduces the incidence of and damage

by diamondback moth by repelling the moth, and Indian mustard acts as a trap crop. Intercropping brassicas with spinach, beans or dill reportedly reduces aphid infestation.

Intercropping with tomato, coriander or garlic, combined with the application of neem seed kernel extract, also protects cabbage from diamondback moth in the field. Indian mustard, Chinese cabbage and radish are good trap crops for controlling cabbage webworm, flea hopper, and mustard aphid when planted in every 15 rows of cabbage. The mustard row is either the outermost or the middle row to avoid caterpillars being blown by wind into the cabbage plants. To control cabbage head caterpillar, Indian mustard should be planted 12 days before transplanting cabbage. Do not plant cabbage where members of the cabbage family have been grown for 3 consecutive years, so as to avoid serious problems of pests and diseases (especially soil-borne diseases).

NUTRIENT DEFICIENCIES

Nitrogen deficiency

Symptoms of nitrogen deficiency in cabbage include:

- Restricted growth of both tops and roots. Growth is upright and spindly.
- Leaves are pale yellow-green in the early stages and later develop a distinctive yellow colour.
- Red or purplish tints can develop in pale leaves.

To correct nitrogen deficiency, incorporate material with a high carbon : nitrogen ratio into the soil (e.g. sawdust, straw, or woody residues), which will temporarily lock up soil nitrogen. However, too much nitrogen can cause excess vegetative growth, decrease storage life and increase the crop's susceptibility to diseases. Remember that nitrogen is required in large amounts relative to other essential elements, but is readily leached as nitrate, particularly in sandy soil types. Waterlogging can also result in loss of nitrogen.

Phosphorous deficiency

- Slow growth and stunted plants.
- Leaves, leaf veins and stems develop a dark purple colour. In severe cases, older leaves turn yellow.
- Deficiency symptoms are enhanced by low temperatures.

To correct phosphorous deficiency, use ground rock phosphate or diammonium phosphate at planting. However, excess phosphorous can induce zinc deficiency.



Nitrogen deficiency in cabbage
(Courtesy of James Walworth, Dept. of Soil,
Water & Environmental Science,
University of Arizona, USA)



Phosphorous deficiency in cabbage
(Courtesy of Thomas Wallace:
<http://customers.hbci.com>)



Potassium deficiency in cabbage
(Courtesy of Carol Rossi:
<http://hubpages.com>)



Boron deficiency in cauliflower
(Courtesy of <http://sikkimagrisnet.org>)



Molybdenum deficiency in cauliflower: whiptail
symptom (Courtesy of L.R. Evans:
<http://www1.agric.gov.ab.ca>)



Calcium deficiency in cabbage
(Courtesy of David B. Langston,
University of Georgia, Bugwood.org)

Potassium deficiency

- Scorching of leaf edge and/or interveinal region.
- Scorched area can be light brown to black and is often preceded by yellowing.
- Leaves may curl backwards or leaf margins may be scorched and turned sharply forward.

To correct potassium deficiency, the application of potassium-amended fertilisers (e.g. NPK) is generally essential, as most brassicas have a high demand for potassium. Potassium enhances plant resistance to diseases.

Boron deficiency

- Tissues can become brittle, crack and split easily, and stems may be hollow.
- Brown corky lesions on stems and midribs both internally and externally.
- Bronze cauliflower curds.
- Often develops after a long wet period is followed by a dry spell.

Where a deficiency is known to exist, use boron-amended fertilisers at transplanting or sowing. Foliar application may be effective if symptoms are not severe. Compost and well rotted animal manures are good sources of most micronutrients, including boron. Note, also, that heavy use of lime reduces boron uptake.

Molybdenum deficiency

- Drastic thinning of leaf blade with leaf distortion resembling a whiptail.
- Outer leaves yellow, margins of smaller leaves die.
- Cauliflowers are very susceptible to molybdenum deficiency.

Where a deficiency is known to exist, molybdenum-amended fertilisers should be used at transplanting or sowing. Liming soil to increase pH to about 6.5 will increase the availability of molybdenum in the soil. Foliar application may be effective if symptoms are not severe. Compost and well rotted animal manures are good sources of most micronutrients, including molybdenum.

Calcium deficiency

- Tips of leaves in heads turn brown then black (known as tip burn).
- Young leaves suddenly get water soaked, turning black rapidly.
- Death of leaf tissue usually along leaf margins, including the interior of cabbage heads, and Brussels sprout buttons form.

To correct calcium deficiency, use dolomitic limestone.

HARVESTING

Cabbage is often hand-harvested when heads are firm to the touch but before cracking begins. With hand harvesting, a field is harvested 2 to 4 times to obtain heads of uniform size and maturity. Only 1 to 3 harvests of hybrid varieties are required because of their greater uniformity. Use of uniform transplants and consistent growing conditions also helps reduce the number of harvests. Yields will vary with the season of production, cultivar, and production system used. With proper management, cabbage can produce 10-12 tons per acre. Generally, most fresh produce markets in East Africa prefer heads that weigh on average 1-2.5 kg. For processing into coleslaw or sauerkraut, or for long-term storage, larger-headed varieties are preferred.





Integrated Pest Management for Brassicas

The Food and Agriculture Organization of the United Nations (FAO) defines IPM as: *“A system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques in as compatible a manner as possible, and maintains the pest populations at levels below those causing economic injury”*.

The definition implies that IPM is a pest management strategy that focuses on long-term prevention or suppression of pest problems through a combination of techniques. These include encouraging biological control, the use of resistant or tolerant varieties, and adoption of cultural practices to make the habitat less conducive to pest and disease development. It basically means that we integrate as many methods as possible to minimize problems caused by arthropod pests, nematodes, diseases and weeds. These methods include cultural, mechanical, physical, environmental, pesticidal (bio-pesticides and synthetic molecules) and biological control (the use of natural enemies of arthropod pests).

IPM does not forbid the use of pesticides. However, it advocates the use of pesticides only when it is absolutely necessary and on basis of scouting information. Using less pesticides and only when there is a need leads to reduced production costs, and reduces the risks of:

- Farm workers being exposed to toxic chemicals
- Pesticide residues on/in produce
- Environmental contamination/pollution
- Killing beneficial insects such as pollinators, natural enemies, and aquatic organisms such as fish
- Occurrence of pesticide resistance and pest resurgence.

CROP SCOUTING

A key tool in IPM is scouting, also called crop monitoring. Its objective is to detect problems before we execute any intervention or before the problems get out of control. Only after a thorough scouting of the field are we able to say which problem exists and to what extent. Proper scouting gives us information about the status of the crop and enables us to make informed decisions about the need to control any occurring pests, diseases and weeds, as well as for fertilization and irrigation.

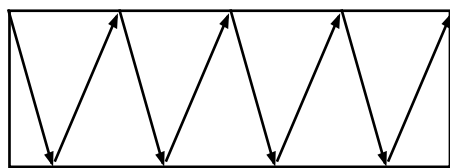
Crop scouting must be regular; at least once a week. This helps to detect a problem in the crop early and to take action before serious damage occurs. Regular scouting also helps in the assessment of previous interventions related to control measures and overall management of the crop (i.e. whether they were effective or not, and if not, to understand what went wrong).

Crop scouting methods include plant sampling, the use of insect traps (e.g. light traps, sticky yellow traps, or pheromone traps) and indicator plants (plants that are very susceptible and attractive to particular pests). To scout a crop you need to survey the crop area to get an overview of the major problems and the general condition of the crop. This is achieved by methodical inspection of the crop, picking plants at random at sampling sites and recording the observations.

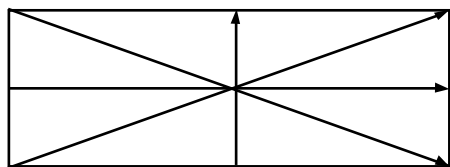
Examine the sample plants from soil and roots to the top of the newest shoot, both the upper and lower sides of all leaves, flowers and fruits. Different sampling sites should be chosen each time the crop is inspected. The number of sampling sites on each stretch will depend on the crop and the size of the field. However, there is no fixed approach or protocol that is suitable for all crops and field sizes or shapes. As a guideline, try one of the patterns below and select the best one for the crop and field. Remember, scouting should be done on a regular basis, and more often after an infestation is detected.

Examples of sampling techniques include the zigzag, multi-bisectoral and 'W' patterns (Figure 1).

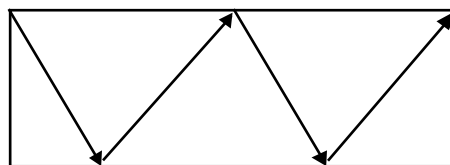
Figure 1. Examples of scouting patterns



Zigzag pattern



Multi-bisectoral pattern



'W' pattern

PROBLEM RECOGNITION

For proper management, it is important for a farmer to know what a healthy crop looks like, and to be familiar with normal crop development in order to recognise the typical damage from pests and diseases during the various stages of crop development. It is also important to be able to differentiate a pest or disease damage symptom from a nutritional problem, a chemical burn, weather damage or physiological disorders.

RECORD KEEPING

Proper record keeping is important. A logbook or record sheet should be kept of the problem type, locality and abundance or any other disorder observed. A record of all remedial measures taken should also be kept. If a pesticide is applied, all its details must be recorded (name, dosage, sprayer type, crop sprayed, target pest or disease, application date, weather conditions and name of the person applying the product). Such records are important in determining the effectiveness of interventions and will also be of long-term benefit in understanding the trends or patterns of arthropod pest and disease development in relation to weather conditions. In the short term, the records serve as the basis for decision-making on strategies for managing production problems.

DECISION-MAKING TO OPTIMIZE PRODUCTION

Once the field has been inspected, the farmer has to decide what to do to optimize production. To make a valid, informed decision, the farmer has to consider the following:

- Prevailing weather conditions
- Crop growth stage
- Yield potential
- Pest or disease stage
- Pest or disease damage
- Previous field records
- Results of interventions already implemented
- Presence and activity of beneficial arthropods such as bees, ladybird beetles, predatory mites, etc.
- Available potential management options

MANAGEMENT OF INSECT PESTS AND DISEASES

Biological control

Biological control refers to the use of a living organism to control insect pests and diseases. It involves conservation, augmentation or importation of natural enemies such as predators, parasitoids, pathogens and antagonists.

Although natural enemies cannot always prevent economic damage, they are important for pest management. Often, the effectiveness of natural enemies in regulating pest populations is reduced by unsustainable farming practices such as the use of broad-spectrum pesticides.

Conservation and encouragement of natural enemy populations are important elements of pest management. One way of preserving existing natural enemies is to avoid or reduce the use of pesticides, particularly broad-spectrum types that kill a wide range of insects. If pesticides must be used, selective pesticides that target specific pests are preferable. For example, insect pathogens (also known as biopesticides) such as commercial products based on *Bacillus thuringiensis* (Bt) have been used alone or in combination with parasitoids and predators to control caterpillars.

The effectiveness of natural enemies can be improved by cultural or environmental manipulation, such as augmentation of food sources. This can be done, for instance, by providing flowering plants as nectar sources or by providing artificial food sources. For example, ants and lacewings could also be attracted with sugar baits to the crops. A mixture of yeast, sugar and water has been found to increase the numbers and fecundity of lacewings. Application of compost improves the soil's condition and the effectiveness of soil microbes that inhibit the buildup of plant pathogens in the soil.

Natural enemies can be attracted to crops by encouraging the growth of plants that are attractive to them (by overlapping different crops on adjacent plots) or by intercropping. These measures may involve changes in the pattern of planting and would require knowledge on parasitoid–pest–crop interaction. In some cases where locally occurring natural enemies cannot control pests, commercially produced natural enemies may be released. This is known as **augmentative biocontrol**.

Mechanical control

Mass trapping

This method makes use of traps to capture large proportions of the pest population. The traps used for pest monitoring (pheromone, coloured sticky traps, etc.) can be used for trapping when pest densities are low. Yellow sticky traps have been used for controlling leafminers and whiteflies, and have been fairly effective in catching migrating insects in greenhouse vegetables. Several types of pheromone traps have been developed for monitoring and mass trapping of Lepidoptera adults (moths) on several crops.

Mass trapping is predominately used for crops in protected environments. It is possible to use traps for monitoring brassica fields, but such traps must be available and affordable to smallholder brassica growers, which at present is not the case in East Africa.

Use of screening materials

Screens and muslin or polypropylene tents can be used in nurseries to prevent transmission of viruses by insects. However, higher rates of sun scorching and fungal diseases have been observed when tents are used for a long period. Due to the high costs involved, this method is probably more useful for large-scale farmers. Small-scale farmers can use screens in nurseries.

Hand picking

Removal of pests by hand can be practical and effective in small plots. This could be done for bollworm eggs and caterpillars. But farmers must be able to distinguish between pests and their natural enemies.

Ploughing

By exposing them to the sun and to their natural enemies, ploughing can control pests in the soil such as pupae of caterpillars, thrips and cutworms, as well as weeds.

Use of plant resistance

The choice of crop variety is a crucial decision, since it can determine whether pests and diseases become serious problems. Some varieties have natural resistance to pest or disease attack. They may produce chemical toxins or repellants to pests or have physical structures which discourage pests: hairs on the leaves or sticky substances on leaf and stem surfaces, for example. Other varieties produce chemicals which suppress disease pathogens.

Cultural methods

These involve changing the way a crop is grown or its habitat in order to prevent and/or reduce pest damage. Some cultural methods are described below:

Mixed/intercropping systems

Mixed cropping involves planting two or more crops in a field. Opinions differ as to the value of mixed cropping in arthropod pest and disease control, but it can definitely have other benefits. Intercropping involves planting alternate rows of two or more crops in a field. Mixed cropping of brassicas (e.g. cabbage and kale) with tomatoes and/or onions has been shown to reduce infestation by the diamondback moth (DBM).

Pest and disease avoidance

Pests can be avoided by controlling the timing of planting. Whenever possible, crops should be grown when conditions are favourable for them and unfavourable for pests and diseases. For example, growing cabbage and kale during the dry season under furrow irrigation minimises the incidence and severity of black rot, downy mildew and ring spot diseases. However, different arthropod pests and diseases require different weather conditions and therefore attack brassicas during different seasons. This is why it is not possible to avoid all pests and diseases.

Providing conditions for growing healthy plants to better withstand pests

This includes ensuring good growing conditions for the crop, such as good soils; good nursery management to produce healthy, vigorous seedlings; proper spacing; and proper water management and fertilisation.

Sanitation

This involves destroying sources of infestation, such as crop residues (stems, leaves, fruits, etc.) and weeds. Crop residues can be composted, fed to livestock, buried or burned.

Avoiding dense planting

Proper spacing should be used, as dense planting creates a humid microclimate that is conducive to the development of foliar diseases.

Early planting

Avoid late sowing. Early planting is a good tactic for managing some pests (e.g. aphids, bollworms, thrips and whiteflies). It also means that the crop matures early, escaping damage by late-season pests.

Crop rotation

Rotation can help reduce the build-up of soil pests and diseases such as black rot, cottony rot and *Rhizoctonia*. In the rotation, use crops belonging to dissimilar families, such

as cereals and onions. Rotation is also related to soil fertility improvement: planting different crop types (shallow, deep rooted or legumes) provides a good measure of nutrient uptake from different soil depths and/or replenishment of nitrogen when legumes are used.

Mulching

Covering the surface of the soil with material such as compost or plant residues conserves soil moisture and maintains good soil structure and health. Mulching can reduce soil pests such as cutworms and thrips, and diseases like black rot. It also prevents surface crusting of the soil, and allows rain or irrigation water to soak in rather than run off and be lost. It also reduces transmission of diseases caused by rain splash and suppresses weed growth. However, care must be taken that mulching material does not harbour diseases or become a source of weed seeds.

Solarisation

After irrigating the soil, it is covered with a clear or translucent polyethylene sheet for 2-3 months, depending on the intensity of sunshine. Successful solarisation results from adequate sunshine, good land preparation and land availability for rotation and fallowing for up to 6 weeks. Solarisation is more suitable for nursery beds and small plots but can also be used in the field.

To solarise the soil:

- Prepare the land by ploughing, harrowing and irrigating.
- Apply mulch then polyethylene sheeting, making sure that it is properly tucked in to prevent heat and moisture loss.
- Retain the mulch until the defined period is completed.

Solarisation has several advantages:

- It reduces soil-borne pests (insects, diseases, nematodes and weeds).
- It increases the range and effectiveness of soil-inhabiting antagonists that compete with or inhibit microorganisms causing soil-borne diseases.
- It improves plant health, vigour and yield.
- It improves soil condition.
- It reduces soil salinity by preventing the upward capillary movement of soil water and its concentration through evaporation.

Pesticides

Pesticides (insecticides, fungicides, miticides, bactericides and nematicides) should only be used as a last resort, when other measures have failed to maintain pests at acceptable levels.

When pesticides are needed, preference should be given to IPM-compatible selective pesticides that have little or no effect on natural enemies. These include biopesticides

(pesticides whose active ingredient is a living organism) such as microbial pesticides (e.g. Bt) and botanical pesticides (those derived from plants such as the neem tree).

Neem-based pesticides are effective for the control of a broad range of pests (insects, mites, fungal diseases and nematodes) and are not usually harmful to natural enemies. However, products based on neem oil have stronger side effects on non-target pests than do oil-free products. Amending the soil with neem leaves or neem cake is a common method used against root-knot nematodes.

Good control of brassica pests, particularly aphids, diamondback moth and caterpillars has been shown with neem products alone and/or in combination with other pesticides. Neem-based products deter feeding in many insects. This is particularly important in the case of vectors of viral diseases such as aphids and whiteflies. Since neem products do not have a “knock-down effect” and take longer to kill insect pests compared with synthetic pesticides, many small-scale farmers perceive them as not being effective. Therefore, farmers should be informed about the mode of action of neem products.

When using pesticides, the instructions on the product label must be strictly followed. This includes using the right product for the target problem; safe handling and storage of pesticides; use of protective clothing when spraying; use of equipment properly calibrated and maintained; use of the right dosage and application frequency; proper record keeping; and proper disposal of pesticide containers. Children, and pregnant or breastfeeding mothers must not be allowed to handle pesticides.

The amount of pesticide to be used can be reduced by:

- Avoiding preventive spraying whenever possible; decisions on spraying should be based on the outcome of regular scouting of the crop.
- Avoiding blanket application; the preferred application methods include seed treatment, use of granules or baits, and spot treatment.

In many countries, the overuse and careless use of pesticides has resulted in the development of resistance to the major classes of insecticides in brassica pests such as diamondback moth, leafminers and whiteflies. Repetitive use of synthetic pyrethroids, particularly using them for several consecutive seasons, can result in the development of resistance and increased pest pressure. The development of resistance to pesticides can be avoided or delayed by rotating pesticide groups (different chemical types) to minimise selection for resistance. Preventive (routine/blanket) spraying and application of lower-than-recommended dosages should be avoided since this, too, may lead to resistance.

NATURAL ENEMIES AS BIOLOGICAL CONTROL AGENTS

Natural enemies (living organisms that thrive on crop pests and antagonists that attack disease-causing organisms) are usually present in brassica fields. They include predators, parasitoids and pathogens.

Predators

Predators often feed on various stages of the host (pest): eggs, larvae, pupae and adults. Each predator requires a number of prey individuals to reach maturity. Major predators include ladybird beetles, lacewings, hoverflies, cecidomyiid and chamaemyiid flies, and predatory bugs. Others are various ant species, chameleons and spiders.

Ladybird beetles



Ladybird beetle adult



Ladybird beetle eggs



Ladybird beetle larva



Ladybird beetle pupa

Adult ladybird beetles are small, oval to nearly spherical in shape, with a short antenna. They are often brightly coloured with black markings, black with bright spots, or shiny black. The eggs of ladybird beetles are elongated, usually yellow to orange in colour. They are normally laid in groups near aphid colonies. The larvae are soft-bodied and usually long and thin. Their colour varies from black to dark brown with various types of markings. The adults and larvae of most ladybird beetles are important predators of aphids, scales and mites. However, they are most abundant when prey populations are large, by which time the crop may have been damaged. Several species of *Cheilomenes* and *Hippodamia* are commonly found on aphid-infested okra plants.

Note: there are several species of plant-feeding ladybird beetles (particularly beetles of the subfamily Epilachninae). Both the larvae and the adults feed on leaves and fruits, and can be pests of crops such as tomatoes, potatoes and cucurbits.

Lacewings



Brown lacewing adult



Green lacewing adult



Lacewing egg



Lacewing larva



Lacewing larva covered by aphid scales



Lacewing pupa

The wings of the adults are usually greenish (green lacewings) or brownish (brown lacewings) and semi-transparent. The eggs are laid at the end of tiny stalks, usually on foliage. The larvae have long, sickle-shaped mouth parts. The pupae are whitish and spherical and can be confused with spider egg sacs. The larvae feed on aphids, insect eggs and small caterpillars, while the adults feed on nectar from flowers and other sugar sources such as honeydew.

Hoverflies



Hoverfly adult



Hoverfly eggs



Hoverfly larva



Hoverfly pupa

Hoverfly adults are usually brightly coloured with yellow-brown or black stripes. The eggs are white, cylindrical and 1-2 mm long. The larvae are usually greenish or brown with one to three white stripes along the body. They resemble maggots and are often mistaken for caterpillars although they do not have a distinctive head or legs as do caterpillars. The pupae are pear-shaped and may be green or brown. The adults feed on nectar of flowering plants and can often be seen floating in the air. The larvae feed on aphids and small caterpillars.

Cecidomyiid and chamaemyiid flies

The adults are minute flies (about 3 mm). Chamaemyiid flies resemble tiny houseflies whilst cecidomyiid flies (midges) are usually slender, mosquito-like flies with long legs and antenna. Larvae of chamaemyiid flies are small, yellow-orange maggots and some species are predaceous on aphids and mealybugs. They are commonly found feeding on aphids on brassicas. Most species of cecidomyiid larvae are plant feeders, causing galls on plants. However, the aphid midge, *Aphidoletes aphidimyza*, is an effective predator of aphids. This midge is available commercially in the United States and Europe, where it is an important component of bio-control programmes for greenhouse crops.

Predatory bugs



Anthocorid bug



Nymph of anthocorid bug



Assassin bug

The main group of predatory bugs includes anthocorid bugs, nabid bugs and assassin bugs. Other families of bugs that include many plant-feeding bugs, such as lygaeid bugs, mirid bugs and shield bugs also contain predatory species. The nymphs of bugs are similar to the adults in shape, but are smaller and may vary in colour. Young nymphs are wingless, but wings develop gradually and wing pads can be seen as the nymphs develop. Anthocorid bugs, or pirate bugs, are tiny insects (up to 2-3 mm long). The nymphs are brown, black or orange, while the adults are black with black and white patches on their wings. The adults and nymphs of *Orius* and *Anthocoris* spp. are important predators of thrips, mites, aphids, insect eggs and small caterpillars.

Predatory mites



Predatory mites

Predatory mites eat plant-feeding mites, thrips and insect eggs. They may be red, dark or even translucent, depending on the species and the growth stage. They are distinguished from spider mites by their larger size, longer legs and faster movement.

Praying mantis



Praying mantis

Praying mantis nymphs and adults have characteristic forelegs that assume a praying posture—hence their common name—that are used for grasping the prey. The nymphs resemble the adults but are smaller and initially have no wings. The wings develop gradually as nymphs grow older. The eggs are laid in a sac containing hardened foam. Both nymphs and adults feed on moths, flies, crickets, etc.

Other predators

Other predators, including spiders, ants, predatory wasps, and ground and rove beetles, which feed on many different types of insects, are important in the natural control of pests. Non-specific predators with good searching ability such as carabid and staphylinid beetles are particularly useful for keeping pests at low numbers, and are good complements to other predators such as ladybird beetles, which are more common when pest numbers are high.



Maji moto ants



Ants preying on a caterpillar



Chameleon



Rove beetle



Crab spider

Parasitoids



Cotesia plutella
(DBM parasitoid)



Diadegma semiclausum
(DBM parasitoid)



Apanteles sp.
(DBM parasitoid)



Diglyphus sp.
(whitefly parasitoid)



Diaeretiella rapae (aphid
parasitoid)



Oomyzus sokolowskii (DBM
parasitoid)

Most parasitoids are parasitic wasps. Their immature stages (larvae) live on (external parasitoids) or inside (internal parasitoids) the host (pest). They complete their development (egg to adult) on a single host, killing it. Parasitic wasps are important natural enemies of leafminers, aphids, and eggs and larvae of moths and butterflies (as caterpillars).

Several species of parasitic wasps attack caterpillars and aphids on brassica crops. Parasitic wasps found parasitizing DBM in East Africa include *Apanteles* species,

Diadegma mollipla, *Oomyzus sokolowski* and *Itopectis* species. However, the overall parasitisation rate is generally low. Surveys of unsprayed fields in six countries of eastern and southern Africa showed parasitisation rates lower than 15%. ICIPE implemented a successful biocontrol-based IPM programme covering Kenya, Tanzania and Uganda against the DBM using *D. semiclausum* and *Cotesia plutellae* introduced from Asia and South Africa, respectively.

Diaeretiella rapae is among the major parasitoids associated with aphids (particularly the cabbage aphid) on brassicas worldwide. The larvae of this parasitic wasp feed on the internal organs of the aphid, causing a cessation in reproduction, retarded development and finally death. When the parasitic larvae pupate, the parasitised aphids turn brown and hard and remain stuck to the leaves. They are known as 'mummies' and can be easily recognised. The parasitic wasps emerge through a round hole in the abdomen of aphids.

Pathogens

Pathogens include fungi, bacteria and viruses. They attack pests in the field. Naturally occurring pathogens are often too rare to serve as important control agents, or occur when the damage is already done. A few of them, such as the bacterium *Bacillus thuringiensis* (Bt) and the fungus *Trichoderma viride*, are commercially available in many countries, including Kenya. Bt is used for controlling caterpillars, and *T. viride* for controlling soil-borne pathogens. The larvae must eat Bt-treated foliage for these insecticides to work, so thorough coverage of the leaves and the use of a sticking agent are advisable. Bt should be applied when the larvae are small. The larvae stop feeding within a few hours after eating Bt-treated foliage and die within a couple of days. Bt formulations have the advantage of being specific, that is, they affect only caterpillars and do not harm natural enemies.

Farmers can produce homemade bio-pesticides by collecting diseased larvae, crushing and mixing them with water in a blender, then filtering out the large tissue masses to obtain a liquid for spraying the crop. The pathogen in the liquid will infect other pests in the crop and kill them.

IPM OPTIONS FOR BRASSICAS

A guide to IPM options in brassica production is given in the flow diagram overleaf. It covers the whole production cycle from site selection to harvesting. It also gives specific management recommendations for the major insect pests (diamondback moth and aphids) and disease (black rot and turnip mosaic virus).

Brassicas are principally grown in cool highland areas with supplementary irrigation during the dry season. Some of them, such as cabbages and kales, are grown in semi-arid areas under continuous irrigation.

Steps in IPM for brassica production in East Africa

Before you get started, Check on following...

- **Soil fertility:** take samples for analysis of macro- and micro-nutrients before planting
- Availability and quality of **water for irrigation:** take water samples for analysis of salt content before planting
- **Pest and disease history** of the farm: if the farm has a long history of soil-borne diseases such as black-leg, club root and yellows, opt for other crops (for identification refer to relevant sections of this manual)
- **Suitable varieties** to cater for existing or expected pest and disease problems and also for the agro-ecological zone
- **Market** trends for the produce.



Standard recommendations in management of pests and diseases

Dos and Don'ts

Nursery management

- Site nursery on land not previously under brassicas and away from old brassica fields (wooden trays may be used to raise seedlings away from the field)
- Heat soil in the seed-bed: place plenty of crop trash or straw and burn for at least 30 minutes, and after cooling, mix the soil with compost in equal proportion
- Use certified disease-free seed
- Mulch seedlings in the seed-bed
- Avoid over-watering the seedlings (excessive watering is conducive to damping-off diseases, and extended wetness of seedlings favours the development of foliar diseases). water seedlings early in the morning.
- Rogue out poor looking seedlings and thin out seedlings in the seed-bed
- Drench or spray seedlings with appropriate products when pests and diseases are first observed
- Constantly check your nursery and remove weak and unhealthy looking plants.

Dos and Don'ts (continued)

Transplanting and field operations

- Do not site a new field on land that was previously under brassicas and ensure it is not next or near an old crop of brassicas
- Prepare land well before transplanting (tilling and ploughing can kill soil-borne pests such as cutworms)
- Transplant only robust, healthy seedlings, preferably late in the afternoon, so as to minimize transplanting shock and desiccation. In areas prone to club root disease, lime the soil before transplanting and delay transplanting by 2 weeks (older seedlings are more tolerant to the disease)
- Keep newly planted fields weed-free (weeds are potential alternative hosts of insect pests and diseases, and they compete for nutrients)
- Avoid field operations when it is wet (this will help prevent the inadvertent spread of diseases from plant to plant and movement of infested soil within and outside the field)
- Inspect plants for pests and diseases regularly and keep records of the same throughout the crop cycle
- Ensure proper identification of pests and diseases prior to taking any intervention; if in doubt after consulting this manual, consult a qualified crop protection professional.

Cropping season and harvest

- Use pesticides only when needed; use only registered products; avoid broad-spectrum insecticides. Strictly follow the instructions on the label—use only indicated dosage and observe pre-harvest intervals
- For crops that are continuously harvested such as kale, divide the field into plots, and when application of pesticides is justified, spray a plot at a time in order to comply with pre-harvest intervals of the various products
- Avoid damaging the crop during harvest and handling
- Place the harvested produce in a cool shaded area immediately after harvest
- Remove crop debris from the field after harvest
- Avoid overlapping of brassica crops
- Practice rotation with crops not related to brassicas: these include bell peppers, brinjals, carrots, cereals, chillies, cucurbits, fodder grass, karella, legumes, okra, onions, potato, Swiss chard and tomato.



Pests and diseases

Because of differences in cropping systems and environmental conditions, particularly weather, the complex of major and minor pests and diseases of brassicas is variable over seasons and areas. Therefore, it is important to consider these factors when planning pest and disease management measures.

The major pests and diseases of brassicas in semi-arid and cool highland areas

Semi-arid areas	Cool highland areas
<ul style="list-style-type: none">• Diamondback moth• Aphids• Turnip mosaic virus• Black rot• Powdery mildew• Thrips	<ul style="list-style-type: none">• Diamondback moth (dry season)• Aphids (dry season)• Black rot• Downy mildew• Thrips

Other pests and diseases that attack brassicas

The below-listed pests and diseases can occur in any of the two agro-ecological zones depending on weather conditions. However, most of the pests prefer hot conditions while for most diseases the critical weather condition is rainfall.

<u>Pests</u>	<u>Diseases</u>
Cabbage webworm	Viruses
Bagrada bug	Cottony rot
Cabbage sawfly	Soft rot
Cabbage moth	Ring spot
Cabbage looper	Alternaria leaf spot
Leafminers	Club root
Cutworms	Black-leg
	Wirestem
	Yellows wilt
	White blister rust

Proper identification of pests and diseases is the first and most important step in their management. A wrong diagnosis will lead to mismanagement and to increased losses and costs. If in doubt after consulting this manual, check with a qualified crop protection professional.



Specific management measures for diamondback moth, aphids, black rot and Turnip mosaic virus



Diamondback moth

- Use **tolerant/resistant varieties**. Dark green glossy varieties are less susceptible. Examples of cabbage varieties with moderate to high resistance to DBM include Blue Dynasty F1, Pruktor F1, Red Dynasty F1, Santar F1 and Super Master F1.
- Plant border rows with a **trap crop** such as Indian mustard and apply direct control measures at the trap crop. Alternatively, intercrop with repellent crops like tomato. The main crop should be planted 30 days after tomato.
- **Scout** for caterpillars (where viable, monitor moth populations using sex pheromones); In dry seasons or in semi-arid areas, when you observe more than one diamondback larva per plant on 20 plants sampled, corrective action must be taken. In rainy seasons, the threshold is five larvae per plant on 20 plants sampled. Check weekly for the larvae.
- Use **overhead sprinklers** at dusk to disrupt moth flight and oviposition; overhead irrigation will also wash down the young caterpillars, thus increasing their mortality.
- If control is necessary, **spray with IPM-compatible products** such as neem-based or Bt products. However, avoid continuous use of Bt products as they can induce development of resistance.
- Use **natural enemies**: Parasitoid releases (*Diadgema semiclausum* in highlands; *Cotesia plutellae* in lowlands; *Oomyzus sokolowski* in both highlands and lowlands), where viable, together with aforementioned measures, will provide effective control of the diamondback moth.

Aphids

- **Seed dress or drench seedlings** with an appropriate insecticide (consult field officer or research centre)
- Weekly, apply a **mineral oil** (1%) solution in the seedbeds and on young plants; this will act as a protectant and prevent build up of aphid populations in the crop. Do not apply oil in full sunlight when temperatures exceed 25° C, as it may burn the crop
- **Intercrop** with beans, dill or spinach
- **Check regularly** for aphid infestation; green aphids do not normally require control measures
- If control is necessary, **spot spray** aphid-infested plants with IPM-compatible products such as neem oil, neem seed extracts, insecticidal soaps or selective aphicides that are relatively safe to natural enemies of aphids. Use products that are registered and observe the pre-harvest interval indicated on the product label. Intensive and indiscriminate use of broad-spectrum insecticides like pyrethroids might induce resistance development in aphids and will eliminate natural enemies.

Black rot

- Use **tolerant/resistant varieties**. Examples of cabbage varieties having tolerance/resistance to black rot are Blue Dynasty F1, CPI, Field Winner F1, Globe Master F1, Pruktor F1, Red Dynasty F1, Santar F1 and Super Master F1.
- Use certified disease-free **seed**
- **Mulch** the crop
- Keep the field **free of weeds**, particularly of the brassica family
- **Check** regularly for initial symptoms; if traces of black rot are detected, apply copper sprays (once the disease is established copper sprays will not help)
- Avoid overhead irrigation
- Avoid field operations when wet
- Dispose of crop debris promptly after harvest
- Practice a two-year **rotation** with non-brassicac (refer to Standard Recommendations).

Turnip mosaic virus

- Locate seedbeds away from production fields
- Keep the seedbeds and production fields **free of weeds**; remove brassica weeds from crop borders and crop residues in nearby areas before crop is planted
- Weekly, apply a **mineral oil** (1%) solution in the seedbeds and on young plants; this will act as a protectant and prevent aphids from transmitting the virus. Do not apply oil in full sunlight when temperatures exceed 25°C, as it may burn the crop
- Field equipment should be used in new fields first and then in older fields to avoid mechanical transmission of the virus
- Take care not to damage plants when working in the field, and wash field tools to prevent transmission of the virus from diseased to healthy plants



Review what went wrong, but more importantly what went right. Did the control measures work? Compare pest and disease activity before and after treatment. What needs to be improved? Keep records of what you do and what you observe.



Major Insect Pests of Brassicas

DIAMONDBACK MOTH

(*Plutella xylostella*)



Diamondback moth adult



Diamondback moth eggs



Diamondback moth larva



Diamondback moth pupa



Healthy (left) and parasitized (right) diamondback moth pupa



Cabbage damaged by diamondback moth larvae

Description and biology: The adult is a small grayish-brown moth, about 8-mm in length, with a wingspan of about 15 mm. It has a characteristic diamond pattern on its back which can be seen when its wings are closed at rest, hence its common name.

Eggs are tiny, creamy yellow, and cigar-shaped. Larvae are pale green, and widest in the middle part of the body. They measure 12 mm when fully grown. Larvae are active, wiggle violently, and when disturbed drop to the ground, remaining suspended only by a silken thread. Pupation takes place inside a silken gauze-like cocoon that measures about 9 mm long, which is stuck to the underside of the leaf. The pupa is greenish at first and changes to brown as the moth develops. It remains visible to the naked eye within the cocoon.

A single female can lay more than 400 eggs. Female moths glue their eggs to the upper surface of leaves, either singly or in small groups. Incubation period is 3-8 days depending on temperature. The total larval period varies from 14-28 days. There are four larval instars. The pupal period lasts 5-10 days. Adult life-span is 16-17 days. In the tropics, breeding is continuous with as many as 15 generations a year. The whole life cycle is temperature-dependent, with more generations produced in hotter areas.

Damage: Feeding by larvae causes damage to leaves. Newly hatched larvae feed on the underside of the leaf, penetrating the epidermis and mining through it. Later instars also feed on the underside of the leaf except that they either cut round holes through it, making the leaf appear 'windowed', or they scratch off the tissue leaving the epidermis of one side untouched so that attacked leaves appear skeletonised. DBM infestations tend to be serious in the dry months. Rainfall has an adverse effect on DBM populations; DBM is less likely to be a problem in wet years and during rainy seasons.

Management options: Insect species parasitising DBM are numerous, although not all are effective. In general, larval parasitoids have the greatest potential for control of DBM. Important natural enemy species are found in the genera *Cotesia*, *Diadegma*, *Diadromus* and *Oomyzus*. All of these are known from Africa and some species are reported to effect excellent control of DBM elsewhere. In contrast, parasitisation rates in the region seem to be low. Introductions have been made in East Africa where a successful biological control programme was achieved in highland growing areas in Kenya, Tanzania and Uganda. Conservation of these natural control agents is very important. Thus, when DBM are present in low numbers, avoiding the use of broad-spectrum insecticides early in the season (when crops can tolerate moderate damage) may preserve parasitoids that can help suppress DBM and aphid population later in the season.

Chemical control is becoming ineffective due to the DBM's ability to quickly develop resistance against all groups of pesticides. Alternative products such as bio-insecticides and botanicals are available. Thus, Bt (*Bacillus thuringiensis*) is widely used. At weekly sprays and a rate of 0.5 kg/ha, Bt provides effective control of this pest. However, continuous use of Bt can induce development of resistance. Neem-based products

give good control of DBM, and are relatively harmless to natural enemies and non-toxic to warm-blooded animals. The action of neem is relatively slow, thus the larvae may survive for a few days after application, but their growth and feeding is inhibited and the larvae do not cause further damage to the crop.

Intercropping brassica with trap plants such as Indian mustard, and repellent plants such as tomato reportedly reduces DBM infestation on cabbage. In the case of the Indian mustard, control measures are directed at DBM on the trap crop. When intercropping with tomato, the cabbage crop is planted 30 days after tomato. This method is reported to be effective especially when it is practised together with sprinkler irrigation system. Applied at dusk, the sprinkler irrigation disrupts flight activity and oviposition. It also results in run-off of DBM larvae, increasing their mortality.

Dark green glossy varieties of cabbage are less susceptible to DBM. Examples of cabbage varieties with moderate to high resistance to DBM include Blue Dynasty F1, Pruktor F1, Red Dynasty F1, Santar F1 and Super Master F1.

An integrated and ecologically compatible approach incorporating the use of DBM tolerant/resistant varieties, biological control (conservation of locally occurring native populations or introduced agents) combined with cultural methods and judicious use of IPM-compatible insecticides constitutes a sustainable management strategy for DBM.

APHIDS

Brevicoryne brassicae (cabbage aphid or mealy cabbage aphid).

Lipaphis erysimi (false cabbage aphid, turnip aphid or mustard aphid).

Myzus persicae (green peach aphid or peach-potato aphid).



Cabbage aphids



False cabbage aphids



Green Peach aphids



Parasitised aphids
(mummies – brown in colour)



Cabbage damaged by the cabbage
aphids



Kale damaged by the cabbage
aphids

Description and biology: Aphids occur in colonies. Adult aphids are small to medium-sized. They can be winged or wingless. Wingless forms are the most prevalent. Reproduction is by living young. No eggs are produced. Cabbage aphids are usually found in colonies on the underside of leaves. Mixed colonies of the cabbage aphid and the false cabbage aphids are occasionally found.

Damage: These three aphids are important virus vectors. The cabbage aphid and the false cabbage aphids are important vectors of viruses that cause diseases such as cabbage black ring spot, cabbage ring necrosis, and mosaic diseases of cauliflower, radish and turnip. The green peach aphid transmits well over 100 viruses in over 40 different plant families including brassicas, beans, sugarcane, potato, citrus and tobacco.

Mealy cabbage aphid

This aphid is virtually restricted to brassicas. It is a serious pest of cabbage, cauliflower and Brussels sprouts. Other cruciferous crops are less severely attacked. Turnips are relatively immune. It is found in tropical, subtropical and temperate climates, although it is confined to higher altitudes in the tropics. In East Africa, it is particularly serious during dry months of the year.

Adult mealy cabbage aphids measure 1.6-2.8 mm in length. They are greyish-green or dull mid-green in colour and are covered with a fine waxy grey mealy powder. Cornicles are short and dark and there are irregular dark bands on the abdomen under the powdery wax covering. Winged forms have a dark head and thorax and black transverse bars on the dorsal abdomen. Under laboratory conditions, at constant temperatures of 30°C and 15°C, fecundity averages 14.9 and 86.4 nymphs/female, respectively. Adult life-span varies from 8.1 days at 30°C to 28.2 days at 10°C. Four nymphal instars and 39 generations have been observed. Survival is lowest at temperatures above 30°C. Mortality is lowest at 20°C, which is also the optimum temperature for this aphid's development.

False cabbage aphid

The false cabbage aphid is a major pest of brassicas, and a minor pest of other important crops such as beans, beet, spinach, pea, celery, onions, stock, soybeans, cucumber and potatoes. It is found virtually worldwide.

Adults are 1.4-2.4 mm long. Wingless aphids are yellowish green, pale green, grey green or olive green in colour, and can be distinguished from the cabbage aphid by the absence of a mealy cover. Winged aphids have a dusky green abdomen with conspicuous dark lateral sclerites, and dusky wing veins. The nymphal stage lasts 5-7 days. Adult lifespan varies between 7-35 days and as many as 158 young can be produced per female. Temperature appears to be an important factor in the seasonality of the aphid, increasing to extremely high numbers during the warm season period and becoming scarce in the cool season period. Heavy rainfall adversely affects its reproduction and development.

Green peach aphid

It has a wide range of host plants, including very many economically important crops such as peach and potato. Among the brassicas, turnip seems to be a particularly favourite host, but the aphid is considered to be a very important pest of cabbage. Alternative hosts include capsicums and other solanaceous plants. It is virtually cosmopolitan, but it is more abundant in temperate regions than in the tropics.

Adults are 1.2 - 2.3 mm long. Wingless forms are usually uniformly green in colour with a darker thorax. Antennae are two-thirds as long as the body. Cornicles are fairly long.

Damage: Damage is by direct feeding and by virus transmission. Direct feeding by aphid colonies causes leaf curl, discolouration, stunted growth and even death of the infested plants. Seed set is also reduced. In heavy infestation, copious amounts of honeydew are produced on which sooty mould fungus grows. This reduces the quality of the crop.

Aphid management options: Aphids are naturally controlled by parasitic wasps of the families Aphididae and Aphelinidae; predators (ladybird beetles, rove beetles, hoverflies, Chamaemyiid *Leucopis* sp., cecidomyiid flies, anthocorid bugs and lacewings); and pathogens (*Entomophthora* spp.). The most important parasitoid of the cabbage aphid and the false cabbage aphid is the braconid *Diaeretiella rapae* with a wide geographical distribution. It has been reported in several countries in the region. A fungal disease caused by *Zoophthora aphidis* has been reported infecting cabbage aphids in South Africa.

Intercropping brassicas with other crops such as clover, spinach, beans, dill or grass reduces cabbage aphid infestation. Resistant varieties are not yet available; however, glossy green-leafed cabbage lines with a low wax tend to be less susceptible. Indian mustard, *Brassica juncea*, is moderately resistant to *L. erysimi* and *M. persicae*. Other varieties reported with resistance include the turnip “Shogoin” and the Brassica species, *B. alba* (white mustard), *B. carinata* and *B. hirsuta*.

There are many insecticides that provide effective control of aphids. Use only those registered and proven friendly to natural enemies. However, continuous use of insecticides can induce development of resistance in aphids. Neem oil and neem seed extracts have reportedly given effective control of the three aphid species.

Early detection and monitoring of initial aphid infestation build-up is important. Spraying should be carried out only when heavy infestations occur since natural enemies, especially parasitic wasps and ladybird beetles, frequently keep the pest in check.

CABBAGE WEBWORM

(*Hellula undalis*)

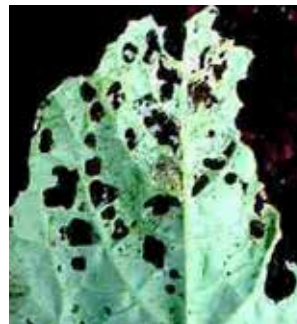
(Other names: oriental cabbage webworm; cabbage centre grub or cabbage headborer)



Webworm adult



Cabbage webworm larvae on cabbage head



Leaf damage by larvae of cabbage webworm

Description and biology: Adult moths are grey-brownish in colour, small and rather delicate with a wing span of approximately 10 mm. Eggs are small and are laid on the surface of leaves or on younger parts of the plant. Larvae are creamy white with brown stripes. The head is black. Larvae measure 15 mm when fully grown. They feed by mining and boring on plant parts. Young larvae mine the leaves; older larvae feed on the underside of rolled leaves within spun webs. Last instars feed on leaves as well as midribs and petioles, stalks, growing points and roots. Adult life span is about 4 days. At temperatures between 25-29°C, a single female lays as many as 153 eggs. Incubation period is 4-5 days at 26°C. There are 5 larval instars. The larval period lasts 10 days. Pupation occurs in leaf tissue, in tunnels made by the feeding larvae. The pupal period lasts 7 days. Five to eight generations can be produced. Eggs do not hatch at 10°C and larvae fail to pupate at 15°C.

Damage: Feeding by larvae on young plants frequently causes death of the plants, especially when the larvae feed on the growing point. In older plants new shoots are produced and the attacked plants produce several small heads of low market value.

Management options: Natural enemies of *H. undalis* include braconid, ichneumonid and chalcidoid parasitic wasps.

There has been considerable research done on chemical control of *Hellula*. Insect growth regulators (IGRs) have shown to be highly effective. Consult your field officer or a research centre for registered insecticides that are effective against cabbage webworm. Alternatives to synthetic pesticides are bio-pesticides such as microbial insecticides (*Bacillus thuringiensis*), and botanicals (namely neem-based insecticides), which give good control of the cabbage head borer. It is important to start control measures early, when larvae are still young and have not yet penetrated plant tissue.

General field sanitation, such as uprooting and burning of cabbage stalks and crop rotation, are important to reduce field populations.

BAGRADA BUG

(*Bagrada* spp.)

(Other names: Bagrada bug, harlequin bug or painted bug).



Bagrada bug adult



Bagrada bug eggs



Bagrada bug nymph



Cabbage leaves damaged by bagrada bugs

Description and biology: The adult bug is typically shield-shaped, 5-7 mm long and 3-4 mm at its widest area. The upper surface has a mixture of black, white and orange markings, which gives the insect its common name. The bug lays its eggs in clusters on leaves or on the soil underneath cabbage plants. Eggs are initially white, turning orange with age. A single female can lay as many as 100 eggs within 2-3 weeks. The incubation period is 5-8 days. There are 5 nymphal instars, and a life cycle lasts 3-4 weeks. Several generations may occur in a year.

Damage: Feeding by sucking by both adults and nymphs damages leaves, which wilt and later dry. A heavy attack on young plants generally results in death of the plants.

Management options: Crop hygiene, including destruction of weeds of the brassica family, prevents population build-up. Harlequin bugs can be controlled by insecticides. Consult your field officer or a research centre on registered products in the market.

CABBAGE SAWFLY

(*Athalia* spp.)



Adult sawfly



Leaf damaged by sawfly larva

Description and biology: The adult insect is a wasp. The head and thorax are dark, and the abdomen is bright yellow with two pairs of membranous wings. The basal two-thirds of the wings are dark and the front edge of the forewings is black. Adults are often found flying slowly above the crop. Eggs are laid singly in a space the adult sawfly excavates inside the leaf. Larvae are oily black or greenish in colour with rows of fleshy warts along the body, and there is a swollen part just behind the head, which makes them appear humped. They characteristically drop to the ground at the slightest disturbance. *Athalia* larvae bear a close resemblance to caterpillars except that they have 6 pairs of prolegs on the abdomen instead of the usual four. They measure around 25 mm when fully grown. They burrow into the soil and spin a tough silken cocoon to pupate. Pupae are yellowish in colour.

Damage: Larvae eat the leaf blades away so leaves appear skeletonised with just the main veins remaining.

Management options: Destruction of brassica weeds in the vicinity of the crop and ploughing in of volunteer plants at the end of the season helps reduce field populations. In light infestations, manual collection and destruction of larvae can provide a fair amount of control. Sawflies can also be controlled by insecticides. Consult your field officer or a research centre on registered products in the market that provide satisfactory control.

CABBAGE MOTH

(*Crociodolomia binotalis*)

(Other name: cabbage cluster caterpillar).



Adult of cabbage moth



Larvae of cabbage moth



Cabbage damaged by
cabbage moth

Description and biology: Adult moths are light brown with a wingspan of about 20 mm. Eggs are laid in batches on leaves. They have a brown furry appearance. Larvae are dark green with a light brown head. They measure about 20 mm in length when fully grown. Young larvae are gregarious and often found in clusters near the egg mass. Pupation takes place in earthen cells in the ground. The female moth lays as many as 241 eggs in batches of 1-4. The egg, larval and pupal stages last 4-8, 10-23, and 9-15 days respectively. Larvae go through 5 instars before pupating.

Damage: Young larvae chew off top leaf surfaces. Older larvae feed under a web of silk on young leaves, petioles and growing points of the plant, often entirely damaging it. In addition to the feeding damage, host plants are often completely soiled with larval excrement.

Management options: There are few reports of natural enemies of the cabbage moth. Neem extracts reportedly give a significant degree of protection against *C. binotalis*. Adequate control has also been achieved by microbial pesticides based on *B. thuringiensis*.

Trap-cropping cabbage with Indian mustard in a planting pattern of 15 rows of cabbage followed by mustard rows has been shown to reduce attack on cabbage. Intercropping cabbage with tomato, which acts as a repellent, can also reduce attack on cabbage. The cabbage crop is planted 30 days after tomato.

There is a range of insecticides and insect growth regulators that provide satisfactory control of cabbage moth. Consult your field officer or nearest research centre on registered products in the market.

CUTWORMS

(*Agrotis* spp.)



Cutworm moth



Cutworm caterpillar



Cutworm pupa

Description and biology: The adult of *Agrotis* is a medium-sized moth, about 22 mm long with a wingspan of 40-50 mm. The forewings are grey-brown with black lines or kidney-shaped markings along the side margins. Their hindwings are pearly white with dark brownish margins and veins. A single female may lay up to 2000 eggs. These are ribbed and globular, cream coloured and turn reddish-yellow to blackish before hatching. Eggs are laid singly or in small groups on moist soil, on weeds or on leaves of host plants. The young larvae are pale, yellowish green with a blackish head. Their body is covered with dusky tubercles. Fully grown larvae are 40-50 mm long, gray, dark green to brown or black and with shiny, greasy-looking skin in which the hair tubercles are not conspicuous. The newly hatched larvae feed on the leaves and later on the stems. They are nocturnal, hiding in the daytime in the soil. The larvae moult six times and become fully-grown in 18 days at 27°C or 65 days at 15°C. The larvae pupate in an earthen cell in the soil. The pupa is about 15 mm long, smooth and shiny reddish brown. It has two dark spines at the tip of the abdomen. The life cycle can be completed in 6 weeks under warm conditions.

Damage: The main damage is caused by the mature larvae. These hide during daytime in the soil near the plants and first cut the stem below the soil surface, nibble at it for a time, and then leave it to attack another plant. The injured plant wilts and withers. Young caterpillars feed on the leaves, leaving perforations on them. The larvae also cut down more plants than they normally eat and small bits of plants are commonly found scattered on the soil surface. The nature of the soil and the ecological conditions of the field have a large influence on the rate of infestation. Crops on heavy soils are usually more infested than those on sandy soils; irrigated fields are more visited by the ovipositing moths than non-irrigated ones. Moths are more attracted to fields with a dense growth of weeds than to fields with sparse vegetation. Cutworms tend to be more frequent in soil with plenty of decaying organic material or where organic manure has been applied.

Management options: Cutworm damage is usually minor and does not warrant control measures. When damaged plants are detected, the cutworms can be normally found near the damaged plant and removed by hand. Early destruction of weeds is important, as they are very attractive to ovipositing females. Flooding of soils induces caterpillars to leave their hiding places during daytime and thus become exposed to predators and adverse environmental conditions. Hand removal of larvae may be also done at the beginning of infestation. Tilling and ploughing soil is necessary to kill existing cutworms. *Apanteles ruficrus* is an important parasitoid of cutworms. Many *Apanteles* may develop in the body of a single cutworm larva. Several bird species are important predators of larvae and pupae.

CABBAGE LOOPER

(*Trichoplusia ni*)



Adult of cabbage looper



Caterpillar of cabbage looper



Cabbage damaged by caterpillars of cabbage looper

Description and biology: The adult is a mottled, grayish-brown moth, about 2.5 cm long, with a wingspan of 4 cm. The front wings have two small silvery spots, one small and round, the other U-shaped (resembling an “8”), near the middle part of the wing. The hind wings are pale brown. Cabbage looper moths are strong fliers and are primarily nocturnal. During the day the moths can be found resting in foliage or in crop debris. A female moth can lay 300 to 1600 eggs. The eggs are laid singly, usually on the undersides of leaves. They are round with ridges, and silvery white in colour. There are five larval instars. Young larvae are white and almost clear with a black head. Older larvae are pale green with four white stripes (a thin white line along each side of the body and two other white lines on the dorsum). The larva has three pairs of legs near the head and three pair of prolegs near the rear. As it moves, the middle section of its body becomes arched or humped. Mature larvae reach 3 to 4 cm in length. Larvae pupate in white loose cocoons attached to the underside of leaves, or in a folded webbed leaf or between two webbed leaves. Development from egg to adult takes about 4 to 6 weeks.

Damage: The larvae interfere with plant growth and marketability by making irregular holes of variable shapes while feeding on the leaves of host plants. On cabbage they eat into the heads.

Management options: Cabbage looper is attacked by a wide range of natural enemies, which play a very important role in population regulation. Bio-pesticides such as Bt and nuclear polyhedrosis virus (NPV)-based products give very good control of medium and large larvae. Neem-based pesticides effectively control cabbage looper infestations by interfering with the growth of young larvae. Cabbage looper infestations often increase after the use of broad-spectrum pesticides. Insecticide applications must be based on scouting, and when chemical intervention is warranted selective pesticides should be used. Consult your field officer or nearest research centre on registered products in the market. Continuous use of insecticides may lead to development of resistance.

LEAFMINERS

(*Liriomyza* spp.)



Adult leafminer



Egg-laying punctures by leafminer



Pupa of leafminer



Leafminer mines on a cabbage leaf

Description and biology: Adult leafminers are tiny flies. *Liriomyza brassicae* has a shiny black body, yellow legs and antenna. Eggs are laid on leaves. Young larvae hatching from the eggs penetrate into the leaf either on the upper or lower leaf surface and mine under the epidermis. The mine is irregular, appearing whitish or greenish; the frass (excrement) produced by the larvae is seen as more or less connected threads. The larvae are bright yellow and up to 4 mm long. Pupation takes place on the ground. The pupa is pale and yellowish-orange.

Damage: Feeding and egg-laying by female insects result in white puncture marks on the leaves, but this is not of much significance. The small, individual leafminers also do not produce much damage, but when larvae occur in large numbers, entire leaves can be destroyed. In mature plants only the outer leaves are affected and this does not influence the growth of the plant. However, heavy attacks on seedlings weaken them, and may result in the death of young plants.

WHITEFLIES

Aleyrodes proletella (cabbage whitefly)

Bemisia tabaci (tobacco whitefly or sweet potato whitefly)

Trialeurodes vaporariorum (greenhouse whitefly)



Whitefly adult



Whitefly eggs



Whitefly nymphs



Whitefly adults and nymphs on lower surface of a cabbage leaf



Pupae of whitefly



Whiteflies on lower surface of a cabbage leaf

Description and biology: Adults are 1-3 mm long and have two pairs of wings, which are held over the body. The body and the wings are covered by a coating of white, powdery wax. They are often found in large groups on the underside of leaves and fly up in white clouds when disturbed. Adults can only fly short distances, but may be dispersed over large areas by wind. Females lay eggs on the lower surface of young leaves. Eggs are elliptical, tiny (about 0.2 mm long), and attached vertically to the leaf surface by a short stalk, which is inserted into the leaf tissue. They are normally laid in an arc or circle comprising 20-40 eggs. Eggs hatch in about 7 days. Upon hatching the tiny nymphs only move a short distance before settling down to feed on the underside of leaves. They insert their needle-like mouthparts into the plant tissues and suck their juices. Once feeding begins, nymphs do not move again. Nymphal instars are greenish-white in colour, oval in shape with a flattened scale-like body. They pass through three instars before pupation. The last instar (“puparium”) is about 0.7 mm, and it turns much bulkier and darker shortly before the adult emerges. The life cycle in warm weather takes 3-4 weeks to complete.

The three species of whiteflies can be distinguished at the adult stage and by details of the puparium. Adults of *B. tabaci* hold the wings over their body at a 45-degree angle to the leaf surface, which gives them a narrow (triangular) appearance. They are smaller than the other two species. *Trialeurodes vaporariorum* and *A. proletella* hold their wings almost parallel to the leaf surface, which gives a flattened appearance. *Bemisia tabaci* and *T. vaporariorum* are white. The cabbage whitefly has dark flecks on its wings and it is larger in size than the other two species.

Damage: Whitefly nymphs and adults suck sap from leaves. Infested plants may wilt, turn yellow and die when whitefly infestations are severe or prolonged. Damage may be accentuated when plants are under water stress.

White flies excrete a clear sugary liquid known as honeydew, which often completely covers the leaves during heavy infestations. Honeydew supports the growth of black sooty mould, and as a result, leaves may turn black, thus reducing the efficacy of

respiration and photosynthesis. Some whiteflies are important virus vectors. For instance, *B. tabaci* transmits serious virus diseases on cassava, cotton, tobacco, tomato and beans. There are reports of a new virus in cabbages, similar to cabbage leaf curl virus, transmitted by whiteflies in the USA. There are no reports of *A. proletella* as a vector of viruses.

In East Africa whitefly populations on brassicas usually do not build up to such an extent that control measures are required. Small numbers of whiteflies do not cause direct damage to the plant and therefore may not justify chemical intervention. Brassicas are reported to withstand large numbers of cabbage whiteflies, with little impact on plant growth. Routine removal of the outer leaves before marketing further reduces the economic significance of this pest. However, contamination of flower buds (in the case of cauliflower, broccoli, Brussels sprouts) and leaves (in the case of kales) by sooty mould can make them unmarketable.

Management options: Natural enemies such as ladybird beetles, predatory mites (e.g. *Amblyseius* spp. and *Typhlodromus* spp.), lacewings (*Chrysopa* spp.), and in particular parasitoids (e.g. *Eretmocerus* spp. and *Encarsia* spp.) can play an important role in reducing whitefly numbers. However, these natural enemies are adversely affected by pesticide applications. Moreover, whiteflies develop resistance to insecticides very quickly. Therefore, when chemical treatment is needed, it is essential to choose the product and the application method carefully in order to conserve natural enemies and to avoid or minimise the development of resistance.

Healthy plants are able to withstand pest attack, so it is important to provide adequate growing conditions (e.g. healthy soil and enough irrigation) to ensure strong, vigorous plants. The application of high doses of nitrogen fertilizer, however, favours the development of whiteflies. Hand-picking of infested leaves is feasible in small plots, when whitefly infestation is low.

Mineral oils alone or combined with some insecticides are reported to effectively control whiteflies. Spraying with soapy water solutions can also control whiteflies. However, the use of strong soaps, or soft soaps at high concentrations, may scorch leaves. Whenever possible soft soap made from potash should be used. The concentration should not exceed 1 part soap to 20 parts water. The right concentration can be found out by experimenting on small plots or individual plants.

Some insecticides afford good control of whiteflies. The selective insecticides are especially useful in IPM programmes. Consult your field officer or nearest research centre on registered products in the market. Applications of neem-based insecticides control young nymphs, inhibit growth and development of older nymphs, and reduce egg-laying by adult whiteflies.

Proper timing of the spray is important. Pesticides should be applied early in the morning when adult whiteflies are not very active. Good coverage of the lower surface of the leaves is important.

THRIPS

Frankliniella spp.

Thrips spp. (e.g. *Thrips tabaci*, the onion thrips)



Adult thrips (*Frankliniella* sp.) *Thrips tabaci*

Thrips damage on lower leaf surface of kale

Description and biology: Adult thrips are tiny (0.5-2.0 mm), slender and usually winged. The wings are long, narrow and fringed with long hairs, and at rest, tied dorsally along the body. The female inserts single eggs into the plant tissue. Eggs are white or yellowish, and cylindrical in shape. They hatch within a few days. The first two larval stages are small, wingless and active feeders. These are followed by two to three pre-adult instars, the pre-pupa and pupa, which usually have short wing pads, are inactive and do not feed. Pupation normally takes place in the soil or under fallen and decayed plant tissues near host plants. Thrips have a short generation time of 2-3 weeks in warm conditions. The adult life span is two to three weeks. Thrips migrate actively between different hosts. Adult thrips of the genera *Frankliniella* and *Thrips* are small (0.9-1.2 mm in length) and pale brownish-yellowish in colour.

Damage: Both nymphs and adults of thrips puncture the lower surface of leaves and suck the exuding sap. Attacked leaves frequently have a silvery sheen and show small dark spots of faecal material. When numerous, the pest may cause premature wilting, retardation of leaf development and distortion of young leaves. Heavy infestations may cause plant death, but this is not common on brassicas. Any environmental stress that weakens the plants makes them more susceptible to thrips attack.

Thrips tabaci is most common on brassicas and causes rough, bronzed blisters on lower leaf surface. Attack by onion thrips on brassicas has been observed when onions are interplanted with brassicas. Some species of *Frankliniella* thrips are reported to cause discolouration of flowers in rape.

Management options: Thrips attacks are not common on brassicas in East Africa, and their populations are seldom large enough to warrant control measures. Ploughing and harrowing before transplanting can be useful in reducing subsequent thrips attacks by killing pupae in the soil.

Natural enemies, particularly predators, are important in natural control of thrips. Main predators include predatory bugs, predatory mites and predatory thrips. Conservation of these natural enemies is important.

Thrips are difficult to control with insecticides due to their secretive habits. Some species of *Frankliniella* are known to develop resistance to pesticides very rapidly. Onion thrips can be controlled with a wide range of insecticides, but since the pupae in the soil are not controlled, repeated applications are needed to achieve satisfactory control. However, pesticide use should be minimised since it adversely affects natural enemies. Consult your field officer or nearest research centre on registered products in the market.

Major Diseases of Brassicas

Some 20 diseases have been reported on brassicas in East Africa. The most destructive are black rot, turnip mosaic virus and bacterial soft rot. Downy mildew, powdery mildew, black leg, club root, yellows and leaf spots are widespread throughout the region, albeit with local importance. It should be noted that all diseases of brassicas may affect other crucifers, and this is particularly important when considering disease management options such as rotations, disposal of crop residues and destruction of infection reservoirs.

DAMPING-OFF DISEASES

Causal agents: Over 40 species of fungi have been mentioned in the literature as possible causal agents of damping-off and seed rot in the nursery, amongst which several species of *Alternaria*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia* and *Sclerotinia* are considered important. Favourable factors for seed rot and damping-off include heavy soils, heavy seeding resulting in dense planting, excessive moisture and nitrogen, low light intensity, presence of weeds and careless handling of seedlings.

Symptoms: The injury from damping-off fungi is of two types: pre-emergence damping-off consists of a decay of the germinating seed or killing of the seedling before it can push through the soil. This injury is a common cause of poor stands, which are often erroneously attributed to inferior quality of the seed or seed not treated with fungicides. The other type is post-emergence damping-off, which occurs after the seedlings have emerged from the soil but while still small and tender. The roots may be killed, and affected plants show water soaking and shrivelling of the stems at the ground level and soon fall over and die.

Damping-off usually occurs in small patches at various places in the seed-beds. These diseased patches often increase in size from day to day until the seedlings harden. Seedlings are extremely susceptible for about two weeks after emergence; as the stem hardens and increases in size, the injury no longer occurs. Some seedlings are not killed at once, but the roots are severely damaged and the stem is girdled at the ground level. Such plants remain stunted and often do not survive transplanting.

Management options: The easiest and most effective control measure of seed rot and damping-off is to use healthy seed treated with both insecticide and fungicide, to plant in disease-free seedbeds, and to avoid excessive watering of seedbeds. If the air and the surface of the soil are kept as dry as is consistent with good plant growth, damping-off can be held in check. If the soil has sufficient moisture, it is advisable to wait 3 or 4 days after the seed is sown before water is applied to the soil. In addition,

the seed should be sown thinly enough in the bed so that later the plants will not be crowded. If soil in beds is heavy and slow drying, drainage can be improved by mixing it with a small amount of sand, and surface-drying can be improved by sprinkling sand over the surface. Seedlings should be watered in the morning and preferably on bright days. Heavy applications of water at long intervals are more desirable than are frequent light sprinklings. Stirring the surface soil after water application helps it to dry, thereby reducing the chance of damping-off.

BLACK ROT



'V'-shaped symptoms of black rot on cabbage leaves



Blackening of cabbage stem tissues due to black rot infection



Blackening of cabbage leaf veins due to black rot infection

Causal agent: *Xanthomonas campestris* pv. *campestris* (Bacterium)

Symptoms: The plant can be affected at any growth stage. On seedlings the margins of cotyledons turn black, and cotyledons later shrivel and drop off. On true leaves, initially small, yellow, V-shaped areas develop on the margins. Veinlets in the yellowish areas are dotted black when cut. As the disease progresses the yellowish areas enlarge, turn brown to black, and affected leaves drop prematurely. Petioles and veins of diseased leaves are dotted black. Affected stems, when cut crosswise, show a characteristic black ring. Heads are similarly affected and eventually turn black. During wet weather soft-rot bacteria may enter black rot lesions, move into the heads, and make the heads rot. Such heads exude an offensive odour and are not marketable.

Disease cycle: The bacteria survive in infected seed, in debris from diseased plants left in the field, and infested soil. Seed-borne bacteria can be disseminated long distances. Many brassica weeds can harbour the black rot bacteria. In a new field, black rot is usually introduced via infected seed or diseased transplants. Further spread is facilitated by water-splash, running water, by blowing of detached leaves or by handling infected plants. The bacteria enter the plant chiefly through water pores

(hydathodes) at the edges of the leaves. They can also enter through the root system and through wounds made by chewing insects. They then move through the water vessels to the stem and the head. Optimum temperature for the disease is 26-30°C. Water, in form of either rain or persistent dew, is required for disease development.

Management options: Use certified disease-free seed. Direct seeding should be used where feasible. Seedbed must have been free of brassica crops for at least 2 years. Seedlings should not be crowded in the nursery. Seedlings should not be dipped in water before transplanting. Mulching of the field crop, where feasible, is highly recommended. Overhead irrigation should be avoided. Field operations during wet weather should be discouraged. Keep the field free of weeds, particularly of brassica family. After harvest prompt disposal of crop debris should be ensured. A crop rotation based on at least a 2-year break in brassica crops is recommended. It should be noted that fungicidal sprays will not control black rot disease. However, copper sprays may reduce the disease's spread if traces of black rot are detected early. Use of resistant/tolerant varieties provides the most effective control of the disease. Examples of cabbage varieties commercially available in the region with tolerance/resistance to black rot are: Blue Dynasty F1, CPI, Field Winner F1, Globe Master F1, Pruktor F1, Red Dynasty F1, Santar F1 and Super Master F1.

SOFT ROT



Cabbage head infected with soft rot bacteria: slimy rot on the head



Cabbage head infected with soft rot bacteria: blackening is due to secondary infection with other pathogens

Causal agent: *Erwinia carotovora* var. *carotovora* (Bacterium)

Symptoms: A soft mushy decay of the heads with a very offensive odour. Bacterial slime is often seen on affected areas. Although the disease is mainly a post-harvest problem, cabbage in the field sometimes shows a soft rot of the stem penetrating into the base of the head. Affected heads are unmarketable.

Disease cycle: The bacteria are commonly associated with decaying vegetable matter in the soil. They invade tissue that has been damaged, and are often secondary to other diseases. Hot weather favours the development of the rot, which may be particularly severe if it is wet. In the field, the disease is spread by water splash and field tools, while in transit and in storage, it is spread through contact and bacterial ooze dripping from diseased leaves. Often, cutting knives used on diseased heads serve to spread the bacteria.

Management options: Avoid harvesting when it is wet. Do not cut diseased heads. If one is cut inadvertently, wash the knife thoroughly in methylated spirit. Remove from the field or plough crops deeply immediately after harvesting so that residues decompose as quickly as possible. Handle produce carefully and store in a cool, well-ventilated area.

ALTERNARIA LEAF SPOT



Alternaria spots on cabbage leaf (Courtesy of Clemson University-
USDA Cooperative Extension Slide Series, Bugwood.com)

Causal agent: *Alternaria brassicae*; *A. brassicicola* (Fungus)

Symptoms: A minute dark spot develops on the seedling stem immediately after germination. The spot causes damping-off or stunting of the seedling. When transplanted, such diseased seedlings do not attain the normal size nor do they yield well. Spotting of broccoli, cabbage heads and cauliflower is another symptom and is a destructive phase of the disease, rendering them unmarketable. Leaf spots are common on old lower leaves and vary in size from pinpoints to 5-7 cm in diameter. They are nearly circular, often zonate and are various shades of brown to black. The disease can also occur on pods in seed fields.

Disease cycle: *Alternaria* spp. produces many spores that can be wind-blown, water splashed or carried by tools, animals and humans throughout fields. The fungus

mycelium is frequently seed-borne under the seed coat and thus can be disseminated with seed to new fields. The fungus also survives in susceptible weeds or perennial crops. Optimum temperature range for disease development is 24-28°C. Rain or dew that persists for more than 9 hours is essential for infection to take place.

Management options: Use certified disease-free seed. Treat seed with fungicides before planting. Rotate with crops unrelated to brassicas and eradicate brassica weeds. Remove and destroy crop debris after harvest. Consult your field officer or the nearest research centre on registered fungicides that provide good control of the disease.

BLACK LEG



Kale infected with black leg



Black leg lesions on kale stem
(close-up)

Causal agent: *Phoma lingam* (Fungus)

Symptoms: From seedbed to harvest, all parts of the plants above and below ground may be affected. The earliest conspicuous symptoms often occur in the seedbed 2 or 3 weeks before transplanting. Cotyledon infection usually causes seedlings to die early. This loss is often overlooked in the nursery. The fungus produces many spores (pycnidiospore or conidia) on hypocotyls and cotyledons of prematurely killed seedlings, and these are able to cause many secondary infections in the seedbed. Spots on leaves start off as inconspicuous, somewhat circular, light brown to grayish. They gradually become well defined with ashen-gray centres, in which large numbers of black dots are irregularly scattered; the black dots are fruiting bodies (pycnidia) of the fungus within which conidia are formed, and exude to the surface only in moist weather. Diseased leaves wilt but tend to remain attached to stems. On stems, elongated, light brown, sunken areas (lesions) with purplish margins forms near the soil line. Lesions gradually extend upward and downward, and eventually stems are girdled and turn black. Numerous pycnidia soon form in diseased areas. Affected

plants often wilt suddenly and die or they topple over later as the heads enlarge. The fibrous root system is gradually destroyed, although plants may survive in damp soil when new roots develop. Plants grown for seed purposes may have their pods and seed infected, and such seed may carry dormant mycelium over to the next season. The presence of pycnidia on cotyledons, leaves, stems and roots distinguishes black-leg from other brassica diseases.

Disease cycle: The fungus can survive for 1-4 years in crop debris in the soil, in manure, and can be carried on and in the seed. The disease starts from infection of young seedlings by fungus from infected seed or from trash in the soil. Conidia are produced on diseased plant parts and they are exuded when wet, or are water-splashed or blown to other plants, where they can germinate and cause new infections. Humid, rainy weather is essential for an epidemic; as such, in dry areas the disease is relatively rare.

Management options: Certified disease-free seed should be used. Seed infection can be controlled by hot water treatment. If necessary, seed can be treated with fungicides. Consult your field officer or the nearest research centre on registered fungicides. Plantings should be direct-seeded whenever feasible. Nurseries should be established in soil that has never been planted to cabbage or related crops. Nurseries should not be behind hedges or windbreaks. Black leg is most destructive in wet soils, so fields and soil with good drainage are important. Seedlings should not be transplanted from seedbeds that show any diseased plants. Brassica weeds should be eradicated. After harvest promptly dispose of crop debris. Diseased plant parts should not be fed to farm animals if manure is to be used on brassica fields. At least a 4-year rotation with non-brassica crops is recommended.

CLUBROOT




Wilting of cabbages due to clubroot infection



Distortion and thickening of roots due to clubroot infection

Causal agent: *Plasmodiophora brassicae* (Fungus)



Symptoms: As club-root affects only the below-ground parts of the plant, it may run part of its course after infection without causing any noticeable symptoms above ground. Such symptoms, when they appear, are likely to be in the form of slowly reduced growth, sometimes temporary wilting, and occasionally premature death. When affected plants are pulled out of the ground, various types and stages of root enlargement and malformation are found. The club may consist of a fleshy enlarged root in the shape of a spindle or it may consist of a spheroid gall. When many infections occur close together, most of the root system is transformed into variously shaped malformations. The clubbed tissue after a time is invaded by soft-rotting organisms.

Disease cycle: The fungus enters plants through fine hairs on young roots or through wounds in secondary roots or in the stem. After the root enlarges, the slime mold in the plant tissue is transformed into a mass of spores (zoosporangia, which contain motile zoospores); these contaminate the soil when the host tissue disintegrates. These spores enter young roots of brassicas and initiate new infection. Spores can be spread by movement of infested soil, in soil water and in contaminated manure. The slime mold is not seed-borne. It can survive in the soil for at least 10 years. Cool, wet, acidic soils (pH less than 7.0) favour disease development. The optimum temperature range for disease development is 20-25°C.

Management options: Nurseries should be sited where brassicas have not been grown for at least 8 years. The soil should be well drained. Brassica weeds must be eradicated in and near seedbeds. Soil solarisation and soil amendments with compost of seedbeds and field plots are recommended. Surface water should not be allowed to flood over seedbeds and seedbeds should not be overwatered. No plants from a seedbed that has even a single club-root seedling should be transplanted into a new field. Transplanting of bigger seedlings is recommended. Calcium nitrate should be used as a choice fertiliser. Liming provides good control of the disease in heavy soils. It is not effective in light sandy soil or loose muck, where air-slaking occurs rapidly. Soil pH should be determined before application of hydrated lime. At pH of 7.0, about 1.5 t of hydrated lime is needed per hectare. Planting should be done 6 weeks after lime application. Soil pH should again be tested before planting other vegetable crops in the limed field, as these may be adversely affected by a high pH.

COTTONY ROT (WHITE MOULD)



White mould on kale stem



White mould on broccoli

Causal agent: *Sclerotinia sclerotiorum*; *S. minor* (Fungus)

Symptoms: A soft, light-brown, watery rot develops on leaves and heads, with masses of white, cottony, fungal growth. Small, hard, dark-brown to black, irregular-shaped resting bodies (sclerotia) of the fungus later form in the rotting tissues. Crops grown for seed can be affected on their stems. Stem lesions (spots) are long, gray-white, and may girdle the plants. The fungus can invade the pith and cause death before seeds are produced; this phase is called white blight.

Disease cycle: The sclerotia formed in affected tissues enable the fungus to survive for many years in the soil. Those near the surface germinate in moist weather to produce, at the soil surface, small, cream, “mushroom-like” fruiting bodies (apothecia) containing large numbers of spores (ascospores). These are forcibly ejected and may be carried by wind over long distances. However, the fungus cannot infect healthy tissues directly and first colonises dying or injured tissues. The disease is favoured by cool, moist weather but fogs, mists, dews and overhead irrigation provide enough moisture for infection to take place. Optimum temperature range for disease development is 16- 24°C.

Management options: Plant in a friable soil that drains well. Deep cultivation and crop rotation with resistant crops such as cereals, maize, onions or spinach are recommended. Consult your field officer a research centre on registered fungicides that provide effective control of cottony rot.

DOWNY MILDEW



Downy mildew on lower leaf surface of cabbage



Downy mildew symptoms on upper leaf surface of cabbage

Causal agent: *Peronospora parasitica* (Fungus)

Symptoms: Plants can be infected at any time during their growing period. In seedbeds, the cotyledons and first leaves are invaded. The white mildew is mostly found on the undersides of leaves. Later, a slight yellowing appears on the corresponding upper side. Young leaves and cotyledons, when yellow, may drop off. Thus the disease can cause severe damage to seedlings in the seedbed. Older leaves usually remain attached, and affected areas enlarge, turning tan and papery. When the disease is severe, whole leaves die. When the foliage is wet, the downy white fungus mycelium is clearly visible on the under surface of leaves. As infection progresses, the tissues become light brown and parchment-like. The fungus may also cause numerous sunken black spots on heads. Soft rot bacteria may enter head lesions and cause damage in transit and storage. In cauliflower, the infection is evident as brown to black streaks in the vascular system of the upper portion of the main stalk and branches leading to the florets.

Disease cycle: The fungus survives between crops and over-seasons as thick-walled sexual resting spores (oospores) in roots or in old diseased plant parts. When new roots begin to grow, the fungus grows and is carried above ground on new shoots, where it sporulates in abundance. The fungus mycelium penetrates leaves through stomata. Conidia are produced on fungal branches that grow to the surface of lesions and become visible. The conidia are readily carried by air currents and float long distances in cool moist air. Late in the season oospores form in stems, roots, and in other fleshy host parts. Heavy fogs, drizzling rains or extended dews favour the fungus's growth and disease development. The fungus grows best and mildew develops most when night temperatures do not exceed 24°C.

Management options: Control emphasis should be placed in nurseries, since downy mildew is particularly damaging in the seedbed. Seedbeds should have well-drained

soils and sited away from hedges and windbreaks. The site should not have been under brassicas for at least 2 years. Seedlings should not be excessively watered. Brassica weeds should be eradicated in and near seedbeds, and from the production fields. During wet seasons with night and day temperatures of 16 and 24°C, respectively, it may be necessary to apply fungicides. Consult your field officer or the nearest research centre on registered fungicides that provide satisfactory control. After harvest, ensure crop residues are removed from the field.

RING SPOTS



Ring spots on cabbage leaf

Causal agent: *Mycosphaerella brassicicola* (Fungus)

Symptoms: The disease can affect all aerial parts of the plant, although it generally occurs on older leaves, resulting in premature defoliation. On leaves, circular brown-gray spots up to 2 cm in diameter are formed; these spots consist of a series of delimited, black-speckled, concentric zones. Affected veins and petioles become hard and brown, and they can split longitudinally, making the leaves twist and become distorted. On stems, spots are oval in shape. On stored cabbage, the disease can penetrate deep into the heart, thus requiring considerable trimming before sale.

Disease cycle: The fungus produces two types of spore fruiting bodies, which usually occur together. The fruiting bodies are pycnidia and perithecia. The pycnidia produce one-celled colourless spores that do not cause infection directly. However, perithecia contain ascospores in asci; ascospores are shot into the air and can be blown by wind to other plants. On susceptible plants, infection can take place if moisture occurs on the foliage. Heavy dews favour infection. The fungus over-seasons in diseased plants, in debris from diseased plants left in the field, and in seed. Seed infection can later initiate disease in seedlings. Optimum temperature range for disease development is 16-20°C.

Management options: Certified disease-free seed should be used. Seedbeds and production fields should be sited where brassicas have not been grown for 2 or more years. Seedbeds should be sited away from brassica fields to avoid very early infection of young plants.

Eradicate brassica weeds in and near seedbeds, and in the field. Crop residues should be removed from the field and destroyed. Potash fertilizers have been reported to suppress infection. In case of early infection, fungicides could be applied. Consult your field officer or the nearest research centre on registered fungicides that provide satisfactory control. When using fungicides, ensure wetters (spreaders) are incorporated in the sprays.

POWDERY MILDEW



Powdery mildew on cabbage



Powdery mildew on kale: infected leaf (left); healthy leaf (right)

Causal agent: *Erysiphe cruciferarum* (Fungus)

Symptoms: The disease starts as circular yellowish-white spots on the underside of leaves. Later, on the corresponding upper surfaces of the leaves a white powder-like deposit can be observed. Severely affected leaves turn brown and prematurely drop off. The plants are seldom killed by the disease.

Disease cycle: The disease is usually encountered in dry seasons. The powdery deposit on the leaves consists of a mass of fungal mycelium and spores (conidia). The conidia can be wind-blown to neighbouring crops or fields, which on landing on susceptible hosts germinate and initiate new infections. High humidity and temperature of about 28°C are required for spore germination. Conidia do not germinate in free-flowing water.

Management options: Crop rotation, destruction of volunteer brassica plants and eradication of brassica weeds may reduce disease incidence. Fungicides could be used in case young plants are infected. Consult your field officer or a research centre on registered fungicides which provide effective control of the disease. However, there is always a risk that the fungus may develop resistance to systemic fungicides when they are used often or over a long period.

WIRESTEM



Wirestem symptoms on cabbage seedlings

Causal agent: *Rhizoctonia solani* (*Pellicularia filamentosa*) (Fungus)

Symptoms: Wirestem is the most common and destructive phase of the disease. The stem above and below soil line shrivels and darkens, and outer tissues slough off leaving a dark wiry woody inner stem. Such plants do not fall over, but assume an unhealthy stunted appearance. Some may die, but most survive and do poorly when transplanted to the field. When moisture is adequate, plants may produce a small poor quality head.

Disease cycle: The fungus is common in moist soils. Under favourable environmental conditions it attacks susceptible hosts. It persists indefinitely in soil and survives unfavourable conditions as tiny brown sclerotia, which are resistant to cold, heat, drought and most chemicals. During favourable conditions the sclerotia germinate by forming delicate threads that spread through the soil and invade roots or leaves of susceptible plants. Infection can take place through intact tissues, wounds or natural openings when moisture is present. Once inside, the fungus continues to develop and causes decay regardless of external moisture. Later as food in the tissue becomes exhausted or conditions become unfavourable, the mycelium produces sclerotia to complete the cycle. The brassica strain of the fungus grows at 9 to 32°C; cabbage can be infected between 12° and 32°C with optimum temperatures of 25-27°C. Optimum temperature range for the turnip-rotting strain is 18-25°C .

Management options: Seedbed and production fields should not have had brassicas for at least 3 years. At planting, seed should be treated with fungicide. All seedlings with wirestem symptoms should be discarded. After transplanting the soil may be drenched with fungicide. Consult your field officer or the nearest research centre on fungicides registered for seed dressing and drenching. During cultivation care should be taken to avoid throwing soil into plant heads.

YELLOWS WILT



Yellows wilt on cabbage
(Courtesy of M.E. Bartolo, Bugwood.org)

Causal agent: *Fusarium oxysporium* f. sp. *conglutinans* (Fungus)

Symptoms: Affected plants lose vigour and the lower leaves yellow. In half-grown plants, leaves tend to be bent sideways with one side retarded in growth and pale-yellow in colour. Symptoms may show on one side of the plant only. Affected leaves drop prematurely. When a plant is cut crosswise, a yellow to dark brown discolouration can be seen in water-conducting vessels in the stems, petioles and veins of leaves.

Disease cycle: The fungus may survive for a number of years in the soil without being associated with host parts. Occasionally, it can be carried in the seed. It enters rootlets, but it can also enter through wounds in older roots at transplanting. In the root tissues it moves in the water vessels to all plant parts. After the fungus becomes established in a locality, it spreads rapidly with soil particles. Rain, floodwater, tools and infected seedlings introduce the disease to neighbouring and new fields. Yellows wilt is a warm-weather disease. The disease is most severe at temperatures between 26° and 29°C.

Management options: Conventional control measures such as seed treatment, rotation, and fungicide applications are useless for yellows control. In areas where the disease has not appeared, extreme care must be taken to exclude infected seedlings. Once the disease is present the only effective control is to use yellows-resistant varieties. Some examples of cabbage varieties that are tolerant or resistant to Yellows wilt are Baraka F1, CPI, Globe Master F1, Gloria F1, Quisor F1, Super Master F1 and White Cabbage Landini F1.

WHITE BLISTER RUST



White blister rust on kale
(yellowish-green spots on upper leaf
surface)



White blister rust on kale (blister-like
white lesions on lower leaf surface)

Causal agent: *Albugo candida* (Fungus)

Symptoms: Small, circular, yellowish-green spots develop on the upper leaf surface. On the corresponding underside of the leaves white, circular, blister-like lesions develop. These lesions later rupture exposing masses of white powdery spores in their cavities. Severely affected leaves are malformed, wilt and die.

Disease cycle: It survives as mycelia or spores on crop residues and brassica weeds. Spores are spread to neighbouring plants by wind, rain or overhead irrigation, or insects. Moist cool weather favours disease development.

Management options: Remove crop residues from the field or deep bury the residues. Eradicate brassica weeds in and around the production fields. Rotate brassicas with unrelated crops such as cereals, legumes or onions.

MOSAIC VIRUSES

Turnip mosaic virus



Turnip mosaic virus in cut cabbage head: black necrotic spots



Turnip mosaic virus on kale leaf: yellow ring spots on lower leaf surface



Turnip mosaic virus on kale leaf: yellow ring spots on upper leaf surface



Turnip mosaic virus on cut cabbage head: black necrotic spots (close-up)

Symptoms: Turnip mosaic virus can infect all brassicas as well as beets, spinach and tobacco. Infected plants are stunted with leaves coarsely mottled and distorted. Black spots develop on leaves, which drop prematurely. In stored cabbage, black sunken spots develop on leaves throughout the head. The spots are considerably larger than those caused by cauliflower mosaic virus. It is also transmitted by aphids but in a non-persistent manner (without a latent period). It is readily transmitted mechanically.

Management options: Locate seedbeds far from weedy fields. Weeds and volunteer plants should be eliminated from seedbed areas and preferably from production fields. It may be helpful to discard plants from the outside rows of seedbeds. Aphicide sprays around seedbeds, in seedbeds and in the field may reduce virus spread. Field equipment should be used first in new fields and then in older fields. In areas where mosaic is serious and endemic, growing of Danish cabbage varieties should be considered. These varieties have been reported to have some resistance to mosaic viruses.

Cauliflower mosaic virus



Cauliflower mosaic virus symptoms on kale

Symptoms: The virus infects only members of the cabbage family. Several strains are known. Cabbage plants are rarely stunted even when leaf symptoms appear. Leaf mottling and sometimes warty overgrowths appear along the veins on the lower surface, but the characteristic symptom is clearing of the veins. On cabbage in storage, a black stipple develops on leaves throughout the head. The virus is transmitted by aphids and particularly by green peach aphid (*Myzus persicae*) and cabbage aphid (*Brevicoryne brassicae*) in a semi-persistent mode. The virus is also transmissible by sap inoculation, but is not seed-transmitted. Early infection of cabbage, in the seedbed or soon after transplanting, can reduce yield by 75%, whereas late-season infection has little or no effect on yield.

Management options: Same management options as with turnip mosaic virus.

Glossary

Alternate host	Different type of plant that a pest (insect or disease) can survive on
Arthropod	An animal, usually very small, with a hard skin, segmented body and jointed legs. It includes insects, millipedes, mites, spiders and ticks
Ascospores	Microscopically small seeds of fungal diseases such as ring spot of cabbages
Broad spectrum pesticides	Pesticides that kill many different types of pests
Canker	A dead area on a plant caused by a disease
Caterpillar	The wingless larval stage of a moth or butterfly. This is usually the pest stage, due to its feeding on leaves and other plant parts
Chlorosis	Yellowing of leaves
Chlorotic	Blanched or yellowed
Concentric	Round in shape or pattern
Conidia	Seeds of fungal diseases such as Alternaria leaf spot and downy mildew
Cotyledons	The first leaf or primary leaves of a growing plant embryo; seed-leaf
Culls	Plant removals
Damping-off	Disease causing seed to rot before emergence from the soil or seedlings to die after emergence
Defoliation	Removal or shedding of leaves
Defoliators	Insects that eat leaves
Elytra	Thickened forewings of beetles
Endemic	Established in a defined area (locality or country).
Entomophagous	Organisms that feed on or attack insects
Exuding	Oozing out.
Fruiting bodies	Small structures containing disease spores or seeds
Frass	Droppings or waste left by feeding insects.
Gall	Swellings on plants caused by pests (insects or diseases) such as those caused by root-knot nematodes on the roots
Girdling	Constriction around the stem caused by pest or disease damage
Globular	Spherical shape.
Grubs	Immature stages of beetles, often thick-bodied and six legged
Honeydew	Sugary liquid discharged by some insects such as aphids, scales, mealybugs and whiteflies.
Hydathodes	Water pores on leaves
Hypocotyl	Portion of stem below cotyledons
Incubation	Time between infection to appearance of disease symptoms.
Inoculum	Disease source.

Instar	Insect form between successive moults; the first instar being the stage between hatching and the first moult.
Larva	Immature stage of an insect
Latent period	The period between disease attack to time when the disease produces spores (seeds)
Lateral	Sideways
Lesion	Damaged area of a plant due to insect or disease attack
Maggots	Immature stages (larvae) of flies; often whitish, without a distinct head and legs
Morphology	Form and structure of plant, insect or organism
Mosaic	A pattern of greenish and yellowish shades in leaves
Mottled	Leaves patchily discoloured
Mulch	Any material laid on the soil surface to reduce erosion, weed growth or to conserve soil moisture.
Mycelium	Fungal growth in or on leaves such as fungal growth of powdery mildew on leaf surface
Necrosis	Death of part of a plant
Necrotic	Dead part of a plant
Nymph	One of the stages in life cycles which exhibit incomplete metamorphosis. Nymphs usually look very similar to the adults but do not have wings
Oviposition	Laying of eggs by insects or mites
Parenchyma (palisade)	Cells under leaf epidermis (leaf surface)
Persistent	Long lasting. It can refer to a pesticide which remains active for a long time after spraying, or a disease which can survive a long time in the soil after an infected crop has been growing in the field
Parthenogenesis	Form of reproduction in insects without males
Pathogen	Any organism capable of causing disease
Perithecia	Type of fungal fruiting body containing fungal spores (seeds) from diseases such as powdery mildews
Petiole	Leaf stalk
pH	A measure of acidity/alkalinity in the soil. The pH of 7.0 is neutral, lower than 7.0 is acidic and higher than 7.0 is alkaline
Pheromones	Chemicals produced by insects that attract individuals of the same species
Phloem	Nutrient- or food-conducting tissue in plants
Plumules	Undeveloped shoots in a seed
Polyphagous	Organisms or insects feeding upon a range of hosts
Prolegs	Abdominal legs of caterpillars and sawfly larvae. They are cylindrical, not segmented and have a set of minute hooks on the base. They are used for walking and clinging
Prothorax	Part of an insect body immediately behind the head

Pupa	An inactive and non-feeding stage between larva and adult in insects (changing into a pupa is called pupation)
Quiescent	Dormant; inert; latent
Resistant	A plant able to withstand attack by a pest or disease, or a pest not killed by a pesticide
Reticulate	Having the appearance of or markings like network
Roguing	Physically removing of unhealthy or unwanted plants from a crop
Root collar	Where the root system forms (just below soil level)
Sap	Plant juices containing water and nutrients (plant food)
Sap inoculation	When a virus disease is introduced into a plant through plant sap
Saprophytic	Organisms feeding on dead organic matter
Sclerotia	Hard lump of tissue formed by fungal diseases in some plants when conditions are not favourable for fungal development
Seed-borne	A disease carried in or on the seed
Selective	Relates to pesticides which kill only a narrow range organisms
Soil-borne	Pests or diseases which can survive and infest/infect crops from the soil in the field
Sooty mould	Black mould on leaves or plants attacked by sucking insects such as aphids, scales and whiteflies. The mould feeds on honeydew produced by sucking insects
Spores	Asexual reproductive structures (seeds) of varied shapes and sizes produced by fungi and some bacteria
Sporulate	When fungi produce spores or seeds
Stippled	Dotted
Stomata	Pores on the lower leaf surface
Susceptible	Capacity to be affected (e.g. a plant which can be infected by a disease)
Symptom	A visible sign of damage by pest or disease
Translucent	Allowing light to pass through [without being transparent]
Tolerant	Capacity to withstand a particular disease or diseases without major damage or yield loss
Tubercles	Raised growths bearing hairs on insect bodies
Vectors	Arthropods which carry and transmit disease agents (e.g. viruses)
Vegetative period	Growth period of a plant from germination till flowering (before production of flowers and fruits)
Volunteer plants	Plants growing from seed or debris left over from the previous crop in the field
Wirestem	A type of disease symptom where the root is hard like wire
Zonate	Round or circular in shape or pattern
Zoosporangia	Structures of some fungi that produce spores or seeds
Zoospores	Spores or seeds produced by zoosporangia that are capable of swimming in soil water.

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