A Guide to IPM in Brassicas Production

in Eastern and Southern Africa

by
Ana Milena Varela
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Disclaimer

Where specific pesticides have been mentioned in the text, these are generally given as examples and should not be regarded as being exclusive of others. Mention of specific pesticides or trade names in the text 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, it is advisable to check local regulations before purchase or use.

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CTA's tasks are to develop and provide services that improve access to information for agricultural and rural development, and to strengthen the capacity of ACP countries to produce, acquire, exchange and utilise information in this area. CTA's programmes are organised around four principal themes: developing information management and partnership strategies needed for policy formulation and implementation; promoting contact and exchange of experience; providing ACP partners with information on demand; and strengthening their information and communication capacities.

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Introduction

Brassicas constitute the majority of cultivated Cruciferae in eastern and southern Africa. The main brassicas grown in the region include cabbage (*Brassica oleracea* L. var. *capitata*), kale or choumolea (*B. oleracea* L. var. *acephala*), Chinese cabbage (*B. campestris* L. var. *chinensis*/*B. campestris* L. var. *pekinensis*), cauliflower (*B. oleracea* L. var. *botrytis*) and rape (*B. carinata* (indigenous) and *B. napus* (an exotic type). Other brassicas grown in the region are broccoli (*B. oleracea* L. var. *italica*), Brussels sprouts (*B. oleracea* L. var. *gemmifera*), kohlrabi (*B. oleracea* L. var. *gongylodes* L.), savoy (*B. oleracea* L. var. *sabauda*), swede (*B. napus* L. var. *napobrassica*) and turnip (*B. campestris* L. var. *rapa*). Other crucifers grown in the region include radish (*Raphanus sativus* L. var *hortensis*) and horseradish (*Armoracia rusticana* Gaertn.)

These vegetables are grown mainly for the local market and for domestic use. They are valuable as sources of vitamins and minerals, as well as a source of cash for smallscale farmers in rural and peri-urban areas. However, production is often constrained by damage caused by a range of pests (insects, diseases, nematodes and weeds). The range of pests attacking the different brassicas is similar, but the relative importance of individual pest species varies between the different crops.

The pest constraints of brassicas in the region were identified during a planning workshop held in Malawi in May 1995 with participants from seven countries (Kenya, Malawi, Mozambique,

South Africa, Uganda, Zambia and Zimbabwe), and revised in a second meeting held in Kenya in May 1998. The main pests were identified as insects: the diamondback moth (DBM), cabbage aphids, the headborer *Hellula* and *Bagrada* bugs. The most important diseases are blackrot and Turnip Mosaic Virus (Table 1).

Farmers in Africa currently depend solely on the use of pesticides for pest control. The control of pests is becoming increasingly difficult and uneconomical, as well as environmentally harmful. Pesticides are often applied on a calendar basis. Important pests such as DBM have developed resistance to a wide range of the pesticides commonly used. Furthermore, the incidence of Turnip Mosaic Virus, which is transmitted by aphids, has increased in the region in recent years. Consequently, many farmers have resorted to the application of insecticide cocktails, as well as increased spraying frequency. This has led to much higher levels of contamination of the farm environment, high pesticide residues in the produce, and increasing health risks to farm workers, as well as higher production costs. There is therefore urgent need for alternative control options in order to become less dependent upon synthetic pesticides. For instance, several countries in Asia have developed and implemented a biocontrol-based IPM approach for control of DBM. A similar attempt, coordinated by ICIPE, is underway for the eastern and southern Africa region.

This manual provides descriptions and photos of the major pests and diseases of brassicas, and symptoms of damage, to aid in their identification. Available control options are summarised and wherever possible, IPM solutions suggested as a means of safer and more sustainable crop production.

Table 1. Regional priority pest problems of brassicas in eastern and southern Africa

Major insect pests	Major diseases	Others
Diamondback moth *(Plutella xylostella)*	Black rot (*Xanthomonas campestris* pv. *campestris*)	
Aphids: The mealy cabbage aphid (*Brevicoryne brassicae*), the false cabbage aphid (*Lipaphis erysimi*), the green peach aphid (*Myzus persicae*)	Turnip Mosaic Virus (TuMV)	
Cabbage web-worm/ headborer (*Hellula undalis*)		
Bagrada bug (*Bagrada* spp.)		
Minor insect pests	**Minor diseases**	**Others**
Sawfly (*Athalia* spp.)	Softrot (*Erwinia* spp.)	Root-knot nematodes (*Meloidogyne* spp.)
Cabbage moth *(Crocidolomia binotalis)*	Downy mildew *(Peronospora parasitica)*	Weeds
Cutworms (*Agrotis* spp.)	Leafspot (*Alternaria brassicae*)	Snails
Cabbage looper *(Trichoplusia ni)*		
Termites		
Thrips		
White grubs		
African bollworm (*Helicoverpa armigera*)		

Source: GTZ-IPM Horticulture Project; Brassica Planning Workshop for Eastern and Southern Africa Region. Lilongwe, Malawi. 15th–18th May, 1995.

Integrated pest management for brassicas

Integrated pest management (IPM) is an approach that focuses on the use of as many compatible methods as possible with minimal pesticide input to manage arthropod pests, diseases and weeds. IPM is based on the economics of external inputs being less than the expected returns. When deciding on a method or technique for management of a particular problem, special attention should be given to its possible effects on other organisms (pests, natural enemies, pollinators, etc.) in the environment. When combining several methods, the possible interference or synergism among them should be taken into account. This means that pesticide use must be minimal and applied only when it is needed.

A key tool in IPM is scouting. Scouting is field observation on a regular basis during the crop production cycle for pests, diseases, weeds, and also paying attention to crop health (nutrition and water needs). Proper field observations give information about the status of the crop and enables decision-making on the appropriate intervention(s) to be taken, for example fertilisation, irrigation or pest/disease/weed control.

The complex of brassica pests varies from one area to another: some are pandemic or of worldwide distribution, for example diamondback moth, while others are restricted to smaller areas or localities within a continent and/or a country. A good example of the latter case is club-root. IPM cannot be transplanted, but the principles

and techniques can be adapted to local conditions (Figure 1). Knowledge of the pest–host plant relationship is vital for the development of an IPM programme. Before making any intervention, it is very important for growers to correctly identify the arthropod pest, disease or weed causing the damage, the extent of the damage, and the stage of the crop. Figure 2 presents the major arthropod pests and diseases of brassicas in the eastern and southern African region and their probable occurrence during the growing cycle of the crop.

Management methods for arthropod pests and diseases used in IPM for brassicas

Biological control

Biological control refers to the use of a living organism to control pests. It is implemented through conservation, augmentation and importation of natural enemies such as predators and parasitoids, as well as use of pathogens and antagonists. For more information on natural enemies see page 12.

Mechanical control

Mass trapping: This refers to the use of traps to catch a large proportion of the pest population. Traps used for monitoring (pheromone, coloured sticky traps, etc.) can also be used as a control method when pest densities are low. Several types of pheromone traps have been developed for monitoring and for mass trapping of Lepidoptera adults (moths).

Use of screening materials: Screens and muslin or polypropylene tents can be used in nurseries to prevent the transmission of non-persistent virus by insects. However, increase of sun scorching and fungal diseases have been observed when the tents are used for a long period. Due to the costs involved, these methods are probably useful for large-scale farmers only.

Hand picking or removal of pests by hand is practical in small plots.

Deep ploughing kills pests in the soil such as pupae of caterpillars and thrips by exposing them to the sun and natural enemies.

Use of plant resistance

Plant breeding for increased genetic resistance to pest damage can be an important component of IPM programmes. Breeding for resistance to diseases has been an essential part of commercial breeding programmes. Attention is now also being given to resistance to pests.

Cultural methods

Managing the habitat or the way a crop is grown prevents or reduces arthropod pest and disease damage. Cultural methods include:

Mixed cropping systems: 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). However, acceptance of the system by the farmers is essential.

Pest/disease avoidance: Pests can be avoided by regulating the timing of planting. Whenever possible, grow crops when conditions are favourable for the crop but not for arthropod pests and diseases. For example, growing cabbage and kale during the dry season under furrow irrigation would minimise the incidence and severity of black rot, downy mildew and ring spot diseases. However, arthropod pests and diseases require different weather conditions and therefore attack brassicas during different seasons. This is why it is not possible to escape all of them.

Creation of proper conditions for growing healthy crops that can withstand pests and diseases better. For instance, ensuring good soils; good nursery management to start the crop with healthy, vigorous seedlings; adequate spacing; proper irrigation; and proper fertilisation.

Sanitation: Destroying sources of infestation such as crop residues (stems, leaves, etc.) and timely weeding. Crop residues can be composted, buried underground or burned.

Crop rotation can help to reduce build up of soil pests and diseases such as root-knot nematodes and black rot. Use crops/plants belonging to families other than brassicas (e.g. onions and cereals).

Solarisation: The soil is covered with clear or transparent polyethylene sheets (mulch), for a period of 2 to 3 months depending on the amount of sunshine. The successful application of this technique will depend on enough sunshine, good land preparation, soil moisture and land

availability. It is more suitable for nursery beds and small plots, but can also be used in the field.

Procedure:

- Prepare the land (plough, harrow, irrigate).
- Apply the mulch. Make sure the mulch is properly tacked in to prevent heat and moisture loss.
- Do not remove the mulch until the process has completed the 2–3 months' duration. The minimum time is 2 months in semi-arid areas.

Advantages of solarisation:

- Reduces soil-borne pests (insects, diseases, nematodes and weeds).
- Increases the range and effectiveness of soil-inhabiting antagonists, which compete or inhibit microorganisms causing soil-borne diseases.
- Improves soil condition.
- Reduces soil salinity by preventing upward capillary movement of the soil water and salt concentration due to evaporation on the surface.

Use of pesticides

Pesticides (insecticides, fungicides, acaricides, nematicides and bactericides), particularly synthetic pesticides, should be considered for use as a last resort. They should be used only when other measures are inadequate in maintaining arthropod pests and diseases at acceptable economical levels.

When pesticides are needed, preference should be given to 'soft', selective pesticides. Some of these are IPM-compatible and have no or little effect on natural enemies. These include

biopesticides (pesticides whose active ingredient is a living organism such as the microbial pesticide *Bt*) and botanical pesticides derived from plants.

Some botanical pesticides are good alternatives to synthetic pesticides in IPM programmes. For instance, neem-based pesticides are effective for management of a broad spectrum of pests (insects, mites, fungal diseases, nematodes) and are least harmful to natural enemies. However, products based on neem oil have more and stronger side effects on non-target organisms than oil-free products.

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 pesticides deter feeding in many insects. This is particularly important in the case of vectors of virus diseases such as aphids and whiteflies. Amending the soil with neem leaves or neem cake is commonly used against root-knot nematodes. Since neem products do not have 'a knock-down effect' and take longer to kill the insect or prevent damage, compared to synthetic pesticides, many smallscale farmers perceive them as not effective. Therefore, farmers should be informed about the mode of action of neem products.

When using pesticides, the instructions on the label must be strictly followed. This includes using the right product for the target problem; safe handling and storage; use of protective clothing; equipment properly calibrated and maintained; right dosage and application frequency; careful record keeping; proper disposal of containers and (though not stated in

the labels) regular medical checkups for persons dealing with pesticides. Children, expectant and breast-feeding mothers must NOT *be allowed to handle pesticides.*

The amount of pesticide used can be reduced by:

- Avoiding preventive sprays whenever possible. Decisions on spraying should be based on regular scouting of the crop.
- Avoiding blanket application. Preferred application methods include seed treatment, use of granules, baits or spot treatment.

The indiscriminate use of pesticides has resulted in the development of resistance by pests such as the diamondback moth and other caterpillars to the major classes of insecticides in many countries. Repetitive use of synthetic pyrethroids, particularly when they are used for several consecutive seasons, can result in development of resistance and an increase in pest pressure. In addition, it can also prompt hitherto minor pests becoming major pests. Development of resistance to pesticides can be avoided or delayed through rotation of pesticide groups to minimise selection pressure for resistance. Preventive applications and applications of dosages lower than recommended should be avoided, since this may also lead to development of resistance.

A list of some of the relatively less toxic pesticides available in the region is given in Table 2 on page 74.

Natural enemies as biological control agents

Natural enemies (living organisms that feed on crop pests) are usually present in any crop. These include predators, parasitoids and pathogens. A fair number of natural enemies are usually present in brassica fields.

Predators

Predators often feed on various stages of the pest: eggs, larvae, pupae, and adults. A predator feeds on several prey individuals to reach maturity. The main predators include:

Ladybird beetles: Adult ladybird beetles are small, oval to nearly spherical in shape, and with short antennae. They are often brightly coloured with black markings, black with bright spots, or shiny black (Plate 1). Larvae are soft-bodied, and usually long and thin in shape. Their colour varies from black to dark brown with various types of markings. Some larvae are covered by wax resembling mealybugs (Plate 2). Adults and larvae of most ladybird beetles are important predators of aphids and are commonly found on brassica crops.

Predatory bugs: Adults and nymphs of the predatory anthocorid bug (*Orius* spp.) are important predators of thrips, aphids and of eggs of moths (Plate 3).

Hoverflies: Adults are usually brightly coloured with yellow-brown or black stripes. They feed on nectar of flowering plants and can often be seen floating in the air. The larvae resemble maggots

and are usually greenish (Plate 4). The larvae feed on aphids and small caterpillars and are commonly found in aphid colonies on brassicas.

Cecidomyiid flies and chamaemyiid flies: The adults are minute flies (about 3 mm). Cecidomyiid flies are usually slender with long legs and antennae while chamaemyiid flies resemble tiny houseflies. Larvae are yellow maggots, and some species are predaceous on aphids and mealybugs. However, most species of cecidomyiid larvae are plant feeders, causing galls on plants.

Lacewings: The wings of the adults are usually greenish (green lacewings) or brownish (brown lacewings). Eggs are laid at the end of tiny stalks, usually on the foliage. The larvae have long sickle-shaped mandibles (jaws) (Plate 5). Adults feed on nectar and sugary substances such as honeydew produced by aphids. The larvae feed on soft insects such as aphids, thrips, small caterpillars and insect eggs.

Other predators such as spiders, ants, and praying mantis, which feed on many different types of insects, are also important in natural control of pests.

Parasitoids

Most of the parasitoids are parasitic wasps. Their immature stages (larvae) live on (external parasitoids) or in (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 (caterpillars).

Several species of parasitic wasps attack caterpillars and aphids on crucifer crops. Parasitic wasps found parasitising DBM in the region include *Apanteles* species (Plate 6), *Diadegma mollipla* (Plate 7), *Oomyzus sokolowskii* (Plate 8) and *Itoplectis* species. However, the overall average parasitisation rate is generally low. Surveys of unsprayed fields in six countries of eastern and southern Africa showed parasitisation rates lower than 15%.

Aphids are also attacked by several parasitic wasps. *Diaeretiella rapae* (Plate 9), 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 aphids' abdomen in a few days (Plate 9).

Pathogens

The pathogens include fungi, bacteria and viruses. They are naturally found attacking pests in the field. However, naturally occurring pathogens generally occur too rarely or too late to serve as important control agents. There are a few commercially available microbiological pesticides. For example, commercial products based on *Bacillus thuringiensis (Bt)* have been successfully used for control of caterpillars and are available in many countries. *Bt* formulations have the advantage of being specific; that is, they

affect only caterpillars, and do not harm natural enemies. In brassicas, *Bt* is used for control of caterpillars such as DBM, cabbage looper, cabbage webworm and others. However, as with synthetic pesticides, microbiological pesticides must be rationally used. Resistance to some *Bt* formulations, particularly those based on the *Bt kurstaki* strain has been observed in some DBM populations. *Bt* should be applied when larvae are small. Larvae must eat *Bt*-treated foliage for these insecticides to work, so thorough coverage of the leaves and use of a sticker is advisable. Larvae stop feeding within a few hours after eating *Bt*-treated foliage and die within a couple of days.

When not commercially available, farmers can produce their own homemade biopesticides by collecting the diseased larvae, crushing and mixing them with water in a blender. Large tissue clumps are then filtered out, and the liquid is sprayed onto the crop. The pathogen will infect other pests in the crop and kill them.

Conservation of natural enemies

Natural enemies are important elements in pest mortality. However, they cannot always prevent economic damage. Often the effectiveness of existing natural enemies in regulating pest numbers is affected by incorrect farming practices (e.g. use of broad-spectrum pesticides). Thus, conservation and encouragement of existing natural enemy populations is very important in order to optimise their role in pest management.

One way of preserving existing natural enemies is avoiding or reducing the use of

pesticides, particularly broad-spectrum pesticides. Whenever possible, selective pesticides such as *Bt* formulations are preferred. The effectiveness of existing natural enemies can be improved by cultural or environmental manipulations, such as providing or augmenting food sources (e.g. flowering plants as nectar sources) and/or provision of artificial food sources. For instance, ants and lacewings could also be attracted to crops with sugar baits. Mixtures of yeast + sugar + water increase numbers and fecundity of lacewings. Application of compost improves soil condition and facilitates the effectiveness of soil microbes that inhibit the build-up of harmful pathogens in the soil.

Natural enemies can also be attracted to crops by encouraging plants that are attractive to them and by overlapping of different crops on adjacent plots or by intercropping. These measures involve changes in cropping practices, which must be acceptable to the farmer.

Introduction of natural enemies

In cases where locally occurring natural enemies are not able to control pests, parasitoids and predators can be released into the system in the hope they will multiply and become established. An alternative approach is through the use of mass rearing and supplementary releases. In the latter case, high quality natural enemies must be economically produced in large numbers. To achieve satisfactory control, enough parasitoids need to be released at the right time; repetitive releases may be needed. The timing of introductions of the natural enemies can be determined by monitoring the presence of pests

through crop scouting and/or by traps.

The exotic DBM parasitoid *Diadegma semiclausum* (Plate 10), which has been successfully used in biocontrol programmes for DBM in highland growing areas in many parts of Asia, was recently introduced into Kenya, and is being mass-reared at ICIPE. This wasp has been released in several pilot sites in Kenya and Tanzania. The parasitoids have established in all the regions of release with an average parasitism of 36 and 40% being recorded in Tanzania and Kenya, respectively, one year after release. The results so far show that the number of DBM per plant has gone down, and the level of damage on the crop has also been drastically reduced.

When using introduced natural enemies, as with locally existing natural enemies, care should be taken when selecting other methods/ techniques for pest management. Particular attention should be paid to the selection of pesticides. Whenever possible, selective pesticides are preferred. For instance, in Trinidad, the cabbage looper *Trichoplusia ni* has been controlled by the introduction of the parasitoid *Cotesia marginiventris* combined with applications of a biological pesticide, the Nuclear Polyhedrosis Virus of *T. ni*.

Principles and options of IPM for cabbage (Figure 1)

- Site seedbeds on land not previously under crucifers and, preferably, away from old crucifer fields. (Wooden trays can be used to raise seedlings. Use compost, a mixture of compost and top soil or forest soil for raising seedlings.)

- Heat 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 resistant/ tolerant varieties. (Always buy seed from reputable seed dealers and consult seed dealers on right choice of varieties.)
- Dress the seed with a fungicide and an insecticide prior to sowing. (Seed treatment will protect seedlings against damping-off and early season pests. Use only registered products at the recommended rates shown on the label.)
- Mulch seedlings in the seedbed, if possible.
- Do not overwater seedlings in the seedbed; water seedlings early in the morning and thin out seedlings to avoid plant congestion in the seedbed. (Excessive watering is conducive to damping-off diseases, and extended wetness of seedlings favours development of foliar diseases.)
- Rogue out weak-looking seedlings from the seedbed.
- Avoid siting a new cabbage field next to an old crop of crucifers.
- Prepare land well before transplanting. (Tilling and ploughing kill existing cutworms.)
- Do not transplant seedlings on land that was previously under crucifers. Transplant only healthy, robust seedlings on well-prepared land preferably late in the afternoon to minimise transplanting shock and desiccation. In areas prone to club-root disease, lime the plot well before transplanting and delay transplanting by about 2 weeks (older seedlings are more tolerant to the disease).

- Avoid overhead irrigation in areas where bacterial black rot disease is endemic; mulch the crop if feasible. (Water splash facilitates spread of the disease and can also spread many other foliar diseases.)
- Avoid field operations when it is wet. (This will help prevent inadvertent spread of diseases from plant to plant and movement of infested soil within and outside the field.)
- Keep fields free of weeds. (Weeds are potential alternative hosts of insect pests and diseases, and are nutrients competitors.)
- Ensure optimal fertilisation. (Cabbage has a very shallow root system and is particularly responsive to phosphorus.)
- Monitor fields regularly for pest and disease occurrence. (Early detection of pests and diseases is important. Manual collection and destruction of larvae at light infestations are useful for control of pests such as cutworms and sawflies.)
- Scout for caterpillar presence. (Feeding damage and caterpillar excrement give an indication of their activity. Scouting can be done by walking in a zigzag pattern through the field.)
- Check for aphids and whether parasitised aphids (mummies) and natural enemies such as ladybird beetles and lacewings are present. Since aphid populations are often clustered, all portions of the field should be checked.
- Avoid unnecessary use of pesticides. Do not practise calendar spraying. Pesticides should be used as a last resort; use only registered products at the recommended dosage and observe pre-harvest intervals as indicated on

the label. Buy pesticides from reputable dealers.

- Avoid using broad-spectrum pesticides. Whenever available, use selective pesticides such as microbial pesticides (e.g. *Bt* products) for control of caterpillars, or products which are less (or not harmful at all) to natural enemies such as neem-based products which control aphids, caterpillars and sawflies.
- Intercrop brassica crops with trap crops or repellent plants, to reduce pest infestation. (Tomato reportedly repels DBM, and Indian mustard acts as a trap crop. Intercropping brassicas with spinach, beans, or dill reportedly reduces aphid infestations.)
- Remove crop refuse from the field immediately after harvest and dispose of volunteer plants.
- Practise crop rotation with unrelated crops (non-crucifers).
- Avoid overlapping crucifers between seasons.

Arthropod pests

Diamondback moth

(Plates 11–13)

Plutella xylostella (L.) (Lepidoptera: Plutellidae [Yponomeutidae])

Status and distribution: The diamondback moth is a serious pest of brassicas and attacks all *Brassica* spp. It is very common and widespread. It is completely cosmopolitan, tolerating tropical, subtropical and temperate climates, extending as far north as the Arctic Circle in Europe. It is considered a major pest in all countries of the eastern and southern Africa region.

Description and biology: The adult is a small greyish-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 (Plate 11). Eggs are tiny, white, flat and oval-shaped. They are laid on the upper surface of leaves, either singly or in small groups. A single female can lay more than 400 eggs. The incubation period is 3 to 8 days depending on the environment (e.g. temperature). Larvae are pale green, and widest in the middle part of the body (Plate 12) and measure 12 mm when fully grown. Larvae are active, and when disturbed wiggle violently and drop to the ground, remaining suspended only by a silken thread. The total larval period varies from 14–28 days. There are four larval instars. 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 a brown colour as the moth develops. It remains visible to the naked eye within the cocoon (Plate 12). The pupal period lasts 5–10 days. The adult lifespan is 16–17 days. In the tropics, breeding is continuous, with as many as 15 generations a year.

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 (Plate 13). DBM infestations tend to be serious in the dry months. Rainfall has an adverse effect on DBM populations; thus DBM is less likely to be a problem in wet years and during rainy seasons.

Control 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 also 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. Surveys of unsprayed fields in six countries of eastern and southern Africa showed parasitisation rates lower than 15%.

Attempts at parasitoid introductions have been made elsewhere and successful biological control has been achieved in highland growing areas in many parts of Asia. Similar efforts are now under way for Africa, and the exotic parasitoid *Diadegma semiclausum* is being mass-reared and released in the region *(see section on natural enemies)*. Conservation of these natural control agents is very important. Thus, avoiding the use of broad-spectrum insecticides early in the season when DBM are present in low numbers and when crops can tolerate moderate damage, may preserve parasitoids that can help keep DBM and aphid populations under control later in the season.

Chemical control is becoming ineffective due to the ability of the DBM to quickly develop resistance against all groups of pesticides. Alternative products such as bioinsecticides and botanicals are available. For instance, *Bt* (*Bacillus thuringiensis* var. *kurstaki*) 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. Since the action of neem is relatively slow, 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 brassicas with trap plants such as Indian mustard, and repellent plants such as tomato, reportedly reduces DBM infestation on cabbage. In the case of 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

reportedly especially effective when it is practised where a sprinkler irrigation system is used. When applied at dusk, the sprinkler irrigation disrupts the DBM flight activity and oviposition. It also results in run-off of DBM larvae, increasing their mortality. However, use of sprinkler irrigation *may* lead to increase of diseases such as black rot and downy mildew.

Resistant varieties are not yet available; however, dark green glossy-leafed species of *Brassica* tend to be less susceptible.

An integrated and ecologically compatible approach incorporating the use of parasitoids, combined with cultural methods and a more judicious use of insecticides, constitutes a more sustainable management strategy for DBM. Parasitism by released or locally-occurring native populations of the larval parasitoids, coupled with DBM sex pheromones, sprays of *Bt* and implementation of overhead sprinkler irrigation can provide effective integrated control of DBM.

Aphids
(Plates 14–20)

Brevicoryne brassicae (L.), the cabbage aphid or mealy cabbage aphid (Plates 14, 15);
Lipaphis erysimi (Kaltenbach), the false cabbage aphid, turnip aphid or mustard aphid (Plate 16);
Myzus persicae (Sulzer), the green peach aphid or peach-potato aphid (Plate 17) (Homoptera: Aphididae)

Status and distribution: Aphids are considered a major pest in all countries of the region. Three different species are of importance on brassicas.

The mealy cabbage aphid is virtually restricted to members of the Cruciferae. It is a serious pest of cabbage, cauliflower and Brussels sprouts and less serious on other cruciferous crops. Turnips are relatively immune. It is found in tropical, subtropical and temperate climates, although in the tropics it is confined to higher altitudes. In South Africa the cabbage aphid is a cold season aphid, being particularly numerous in winter and relatively scarce in spring and summer. In East Africa it is particularly serious during dry months of the year.

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, onion, soybean, cucumber and potatoes. It is found virtually worldwide.

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

abundant in temperate regions than in the tropics. In South Africa the green peach aphid is usually present in considerable numbers in summer, autumn and winter months, but is scarce in spring to early summer.

These three aphids are important virus vectors.

Description and biology: Aphids occur in colonies. Adult aphids are small- to medium-size. They can be winged or wingless. Wingless forms are the most prevalent. Normally, females give birth to living young. Cabbage aphids are usually found in colonies on the underside of leaves. Mixed colonies of the cabbage aphid and the false cabbage aphid are occasionally found.

Adults of the **mealy cabbage aphid** 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 (Plates 14 and 15). 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 back of the abdomen. Under laboratory conditions, fecundity averages 14.9 and 86.4 nymphs per female, at 30 °C and 15 °C, respectively. Adult lifespan varies from 8 days at 30 °C to 28 days at 10 °C. Four nymphal instars and 39 generations have been observed. Survival is least at temperatures above 30 °C. Mortality is lowest at 20 °C, which is also the optimum temperature for its development.

Adults of the **false cabbage aphid** 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 because they are not covered or only slightly covered by wax (Plate 16). 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; extremely high numbers are found during the warm season, becoming scarce in the cool season. Heavy rainfall adversely affects its reproduction and development.

Adults of the **green peach aphid** are 1.2–2.3 mm long. Wingless forms are usually uniformly green in colour with a darker thorax (Plate 17). 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, discoloration, stunted growth and even death of the infested plants. Seed set is also reduced. In heavy infestations, copious amounts of honeydew are produced on which sooty mould fungus grows. This reduces the quality of the crop.

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

Broccoli and cauliflower can tolerate fairly high numbers of aphids during the period from

thinning or transplanting to flowering or curd formation, unless plants are under other types of stress. Cabbage is more sensitive to aphid damage before heading due to the possible distortion of the heads.

Control options: Aphids are naturally controlled by parasitic wasps (of the families Aphidiidae and Aphelinidae), predators (ladybird beetles, rove beetles, hoverflies, chamaemyiid flies, cecidomyiid flies, anthocorid bugs and lacewings) (Plates 1–5), and pathogens (*Entomophthora* spp.). The most important parasitoid of the cabbage aphid and the false cabbage aphid is the braconid *Diaeretiella rapae* (Plate 9) 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. These natural enemies frequently keep the pest in check. *(See also the section on natural enemies.)*

Destruction and removal of crop residues immediately after harvesting minimises the spread of aphids to adjacent crops.

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

Mealy cabbage aphids are difficult to control due to the waxy covering which repels water.

However, pyrethroids such as cypermethrin*, deltamethrin and lambdacyhalothrin have given good control. Some pesticides such as acephate and pirimicarb have been reported to be relatively safe to natural enemies. Neem oil and neem seed extracts have reportedly given effective control of the three aphid species. Insecticidal soaps can be effective in controlling aphids and do not seriously affect natural enemies.

Early detection and monitoring of initial aphid infestation build-up is important. Spraying should be considered if seedlings or transplants are at risk when heavy infestations occur. To prevent contamination at harvest, spot-spray the aphid-infested plants and observe the pre-harvest intervals to avoid pesticide residues.

*For mention of a few common trade names, see Table 2 on page 74.

Cabbage webworm

(Plates 18 and 19)

Hellula undalis Fabricius (Lepidoptera: Pyralidae): oriental cabbage webworm; cabbage centre grub or cabbage headborer; cabbage headworm

Status and distribution: *Hellula undalis* is an important pest of brassicas in many parts of the world. It occurs in many countries of North, Central and South Africa, in the Near and Middle East, East Asia and Australia. In the E/S Africa region, *H. undalis* is considered a major pest in Malawi and Mozambique.

Description and biology: Adult moths are greyish-brown in colour, small and rather delicate with a wing span of approximately 10 mm. Each front wing has a black spot and zig-zagging pale brown lines. The eggs are small and are laid on the surface of leaves or on younger parts of the plant. Adult lifespan is about 4 days. At temperatures between 25–29 °C, a single female lays as many as 153 eggs which hatch in 4–5 days. There are 5 larval instars over the larval period of 10 days. Larvae are creamy white with brown stripes and have a black head. Larvae measure 15 mm when fully grown (Plate 18). 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 in a year. Eggs do not hatch at 10 °C and larvae fail to pupate at 15 °C.

Damage: Young larvae mine the leaves while older larvae feed on the underside of rolled leaves within spun webs (Plate 18 (right). Last

instars feed on leaves as well as midribs and petioles, stalks, growing points and roots. Feeding by larvae on young plants frequently causes death of the plants, especially when the larvae feed on the growing point (Plate 19 left). In older plants, new shoots are produced and the attacked plants produce several small heads of little value. Caterpillar feeding after heading may cause head stunting. In addition, insect feeding and the presence of caterpillars and/or their excrement reduce the market value of the produce (Plate 19 right).

Control 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) such as teflubenzuron have been shown to be highly effective. Insecticides that are effective include permethrin, trichlorfon and malathion. Alternatives to synthetic pesticides are biopesticides such as the microbial insecticide *Bacillus thuringiensis (Bt)*, and botanicals, especially neem-based insecticides which give good control of the cabbage headworm. 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

(Plates 20 and 21)

Bagrada spp. (Hemiptera: Pentatomidae): Bagrada bug, harlequin bug or painted bug

Status and distribution: *Bagrada hilaris* (Burm.) and *Bagrada cruciferarum* (L.) destroy the leaves of cultivated crucifers by their sucking activity. Alternative hosts include groundnuts and potato. Maize, sorghum and pearl millet can also be attacked. *Bagrada* spp. are major pests of cruciferous crops in many parts of the world. *Bagrada hilaris* is found throughout East and southern Africa, Egypt, Zaire, Senegal, Italy, Iran, Iraq, Pakistan, India, Sri Lanka, Burma and Afghanistan. *Bagrada cruciferarum* occurs in East Africa, India, Sri Lanka, Pakistan, SE Asia, and Afghanistan. It is a major cabbage pest in Malawi, Zambia and Zimbabwe.

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 (Plate 20). 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 a period of 2–3 weeks. The incubation period is 5–8 days. The nymphs look like adults but are smaller and at first have no wings. Nymphs pass through 5 stages, gradually developing wings. The life cycle lasts 3–4 weeks and several generations may occur in a year.

Damage: Feeding by sucking by both adults and nymphs causes damage to leaves, which wilt and later dry. Feeding by the bugs causes small puncture marks on the leaves (Plate 21). A heavy attack on young plants generally results in death of the plant.

Control options: Crop hygiene, including destruction of weeds of the family Cruciferae prevents population build-up. Bugs can be removed by hand and destroyed. Harlequin bugs are controlled by insecticides such as fenitrothion, trichlorfon and malathion.

Cabbage sawfly
(Plates 22 and 23)

Athalia spp. (Hymenoptera: Tenthredinidae)

Status and distribution: Host plants are restricted to Cruciferae including its wild members, which act as alternative hosts. It is a sporadic but serious pest. *Athalia* occurs in tropical, subtropical and temperate climates in various parts of the world including Great Britain, Europe, Japan and Asia, North-, East- and South Africa and South America. Sawflies constitute a major pest of brassicas in Tanzania.

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 (Plate 22). 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 (Plate 23). They characteristically drop to the ground at the slightest disturbance. *Athalia* larvae bear a close resemblance to caterpillars except that they possess 6–9 pairs of prolegs on the abdomen (most caterpillars have 5 pairs or less). They measure 25 mm when fully grown, after which 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 such that leaves appear skeletonised with just the main veins remaining (Plate 23).

Control options: Destruction of wild members of the Cruciferae family in the vicinity of the crop and ploughing in of volunteer plants at the end of the season help reduce field populations. In light infestations, manual collection and destruction of larvae can provide a fair amount of control.

Sawflies are generally very susceptible to insecticides and infestations are often controlled by treatments targeting caterpillars and aphids.

Chemicals such as malathion and trichlorfon provide satisfactory control of sawflies.

Cabbage moth

(Plates 24–26)

Crocidolomia binotalis Zeller (Lepidoptera: Pyralidae): cabbage caterpillar, large cabbage-heart caterpillar, cabbage cluster caterpillar or cabbage webworm

Status and distribution: *Crocidolomia binotalis* Zeller is primarily a pest of brassicas and is occasionally an important pest of cabbage. The moth is found in several countries of Asia, in the Pacific islands and in parts of southern, western and eastern Africa. It is an important pest in Kenya and Uganda.

Description and biology: Adult moths are light brown with a wingspan of about 20 mm (Plate 24). Eggs are laid in batches on leaves and have a brown furry appearance. Larvae are dark green with a light brown head. They measure about 20 mm in length when fully grown (Plate 25). Young larvae are gregarious and are often found in clusters near the egg mass. Pupation takes place in earthen cells in the ground. The female moth lays as many as 240 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 to pupate.

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 damaging it entirely (Plate 26). In addition to the feeding damage, host plants are often completely soiled with larval excrement.

Control options: There are few reports of natural enemies of the cabbage moth.

Insecticides reported to be effective include pyrethroids such as fenvelerate, permethrin, deltamethrin and cypermethrin, and other pesticides such as trichlorfon, fenitrothion and acephate. Neem extracts reportedly give a significant degree of protection against *C. binotalis*. Insect growth regulators like teflubenzuron, flufenoxuron and chlorfluazuron have also provided effective control of the pest under experimental conditions. Adequate control has also been achieved with microbial pesticides based on *B. thuringiensis (Bt)*.

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.

Cutworms
(Plate 27)

Agrotis spp. larvae (Lepidoptera: Noctuidae): *A. ipsilon* and *A. segetum*

Status and distribution: Cutworms are larvae of certain moths, and are cosmopolitan pests, occurring in all continents. *Agrotis* spp. occurs in Africa from the Cape to the Mediterranean coast. It can attack a wide range of plants, but the common host plants are tobacco, cotton and crucifers.

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 greyish-brown with black lines or kidney-shaped markings along the side margins. Hindwings are pearly white with dark brownish margins and veins (Plate 27 inset). A single female may lay up to 2000 eggs. These are ribbed and globular; they start off 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, grey, dark green to brown or black and with shiny, greasy-looking skin in which the hair tubercles are not conspicuous (Plate 27). 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 with two dark spines at the tip of the abdomen. The life cycle can be completed in 6 weeks under warm conditions.

Damage: The mature larvae cause the most damage. These hide during daytime in the soil near the plants and first cut the stem below the soil surface, then nibble at it, and later leave it to attack another plant. The injured plant wilts and withers. Young caterpillars feed on the leaves, leaving perforations. 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. Cutworms tend to be more frequent in soil with plenty of decaying organic material or where organic manure has been applied.

Control options: Cutworm damage is usually minor and does not warrant control measures. When damaged plants are detected, the cutworms normally can be found near the damaged plant and removed by hand. This is particularly helpful at the beginning of infestations. 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 the daytime and thus become exposed to predators and adverse environmental conditions.

Tilling and ploughing soil is necessary to kill existing cutworms.

Numerous parasitoids and some predators of cutworms have been recorded worldwide. The parasitic wasp *Cotesia (Apanteles) ruficrus* Haliday, an important natural enemy in India and Egypt, has also been used in biological control programmes elsewhere. Several bird species (including hens) are important predators of larvae and pupae. Ashes are reported to deter cutworms when spread on seedbeds, around plants, or mixed with the soil in the planting holes.

In situations of severe infestation, chemical intervention may be needed. The amount of insecticide can be minimised by spraying or pouring around the base of each plant in the evening. Baits consisting of flour and water and containing microbial insecticides such as *Bt*, or other insecticides, are recommended. Baits are more effective when other food is limited. Checking for cutworms in the field is recommended before sowing or transplanting, or applying the bait, if needed.

Cabbage looper
(Plate 28)

Trichoplusia ni (Hb.) (Lepidoptera: Noctuidae)

Status and distribution: The cabbage looper is widely distributed in the tropics and subtropics of the New and Old Worlds, and in some areas in the USA and Mediterranean basin. It is polyphagous, but a serious pest of cruciferous crops. It also attacks other important crops such as tomato, lettuce, potatoes, sweet potatoes, cotton, cucurbits, etc.

Description and biology: The adult is a mottled, greyish-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 (Plate 28 inset). 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 from 300 to 1600 eggs. The eggs are laid singly or in small groups, usually on the underside 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 larvae have three pairs of legs near the head and three pairs of prolegs near its rear. As it moves, the middle section of its body becomes arched or humped (Plate 28). 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 by making irregular holes of variable shapes while feeding on the leaves of host plants. On cabbage they eat into the heads. As a result, marketability of the produce is lowered.

Control options: A wide range of natural enemies attacks *T. ni.* Egg and larval parasitoids and pathogens have been shown to play a very important role in regulating populations. Due to the regulatory effect of natural enemies, control measures are not often needed. Cabbage looper infestations often increase after use of broad-spectrum pesticides due to the elimination of natural enemies. Chemical control is also difficult due to the development of resistance. Regular field monitoring, applying control measures only when needed, helps avoid the overuse of insecticides and the potential for the build-up of insecticide resistance, and helps to conserve natural enemies. Caterpillars can be detected by scouting the crop, while adults can be monitored by using light- or pheromone-baited traps.

When chemical intervention is necessary selective pesticides should be used. Biopesticides such as *Bt*- and Nuclear Polyhedrosis Virus (NPV)-based products give good control of medium and large larvae. Neem-based pesticides are reported to control cabbage looper infestations by interfering with the growth of young larvae.

Leafminers

(Plate 29)

Liriomyza spp. (Diptera: Agromyzidae)

Status and distribution: *Liriomyza* species are serious pests of vegetables and ornamental plants worldwide. They are occasional pests of brassicas. *Liriomyza brassicae* is cosmopolitan. In Africa it is reported from Egypt, Ethiopia, Kenya, Mozambique, Zimbabwe, Cape Verde and Senegal. Host plants are primarily crucifers.

Description and biology: Adult leafminers are tiny flies. *Liriomyza brassicae* has a shiny black body, yellow legs and antennae. 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, greenish-white and the frass (excrement) produced by the larvae is seen as more or less connected threads (Plate 29). The larvae are bright yellow, up to 4 mm long. Pupation takes place on the ground or on the upper leaf surface. The pupa is pale and yellowish-orange (Plate 29).

Damage: Feeding and egg-laying by female insects result in white puncture marks on the leaves (Plate 29 left), but this is not of much significance. Small, individual leafminers also do not produce much damage, but when larvae occur in large numbers, entire leaves can be eaten out. 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 dying off of young plants.

Control options: Leafminers are usually reasonably well controlled by the existing natural enemies, particularly parasitic wasps. However, this balance can be disrupted by the use of non-selective pesticides.

Chemical control is usually not warranted. Early treatment of seedlings can be an advantage in producing a healthy crop, but continued application of pesticides on mature plants is not advised in view of the limited damage caused to older plants. Moreover, frequent use of some pesticides may lead to the development of resistance. Field hygiene can play an important role in reducing leafminer damage: hand-picking and destroying leaves with mines; removing and destroying crop debris after harvest, etc. Hoeing and preparing the soil before planting a new crop exposes the pupae which may be killed by natural enemies and sunlight.

Whiteflies

(Plate 30)

Aleyrodes proletella (Linnaeus), the cabbage whitefly
Bemisia tabaci (Gennadius),the tobacco whitefly or the sweet potato whitefly
Trialeurodes vaporariorum (Westwood), the greenhouse whitefly (Homoptera: Aleyrodidae)

Status and distribution: *Aleyrodes proletella* is common on many brassicas in Europe. In Africa it has been reported in Angola, Egypt, Ethiopia, Mozambique and Kenya. *Bemisia tabaci* and *T. vaporariorum* are cosmopolitan in distribution and have been reported feeding on a very wide range of wild and cultivated plants, including brassicas. Whiteflies are not considered serious pests of brassicas in the eastern and southern Africa region.

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 (Plate 30 top right). They are often found in 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. The eggs are elliptical, tiny (about 0.2 mm long) and are attached vertically to the leaf surface by a short stalk. They are normally laid in an arc or circle comprising 20–40 eggs (Plate 30 top right) and hatch in about 7 days. Nymphal instars are greenish-white in colour, oval in shape with a flattened scale-like body. The first instar nymphs move about, but all other further nymphal stages are immobile. The last instar ('puparium') is about

0.7 mm long, and becomes more bulky and darker shortly before the adult emerges (Plate 30 bottom right). The life cycle in warm weather takes 3–4 weeks to complete.

Adults of *B. tabaci* have a narrow (triangular) appearance. *Trialeurodes vaporariorum* and *A. proletella* have a flattened appearance. *Bemisia tabaci* and *T. vaporariorum* are all white but the cabbage whitefly has dark flecks on its wings (Plate 30 bottom right).

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

Honeydew excreted by whiteflies may completely cover the leaves, which may turn black in colour due to the growth of black sooty mould. This may affect respiration and photosynthesis.

Some whiteflies are important virus vectors. *Bemisia tabaci* transmits serious virus diseases on cassava, cotton, tobacco, tomato and beans. There are reports in the USA of a new virus in cabbages, similar to Cabbage Leaf Curl Virus, which is transmitted by whiteflies. There are no reports of *A. proletella* as a vector of viruses.

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 effect on plant growth. 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.

Control options: In East Africa whitefly populations on brassicas usually do not build up to such an extent that control measures are required. Natural enemies such as ladybird beetles, predatory mites, lacewings, and in particular parasitoids (e.g. *Eretmocerus* spp. and *Encarsia* spp.) can play an important role in reducing whiteflies numbers. However, these natural enemies are harmed by pesticide applications. The application of high doses of nitrogen fertiliser favours development of the pest. Hand picking of the pest off infested leaves is possible 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 the pest. 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 by experimenting on small plots or individual plants.

Whiteflies develop resistance to insecticides very quickly. Insecticides such as buprofezin or chinomethionat, imidacloprid and pymetrozine afford good control of whiteflies. The selective action of buprofezin and pymetrozine makes them especially useful in IPM programmes. Applications of neem-based insecticides control young nymphs, inhibit the growth and development of older nymphs, and reduce egg laying by adult whiteflies.

Proper timing of spraying is important. Pesticides should be applied early in the morning when adult whiteflies are not very active. It is important to cover all of the lower surface of the leaves.

Thrips
(Plate 31)

Frankliniella spp.
Thrips spp., e.g. *Thrips tabaci* Lind., the onion thrips
(Thysanoptera: Thripidae)

Status and distribution: *Frankliniella* species feed on a wide variety of plants including brassicas. The onion thrips is a cosmopolitan species that attack onions, tomato, tobacco, beans and many other plants. It is found outdoors in warm climates and in greenhouses in colder areas. It has been reported as a pest of cabbage in America, Europe and Asia. Thrips attacks are not common on brassicas in the eastern and southern Africa region.

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 are tied dorsally along the back of the body (Plate 31 right). The female inserts single eggs into the plant tissue that are white or yellowish in colour, and cylindrical in shape. The eggs hatch within a few days to give the first two larval stages that are small, wingless and active feeders (Plate 31 left). These are followed by two to three pre-adult instars, the prepupa 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 lifespan is two to three weeks. Thrips migrate actively between different hosts.

Adult thrips of the genus *Frankliniella* and of the onion thrips are small (0.9–1.2 mm in length) and pale brownish-yellowish in colour (Plate 31 right).

Damage: Thrips, both nymphs and adults, puncture the lower surface of leaves and suck the exuding sap. Attacked leaves frequently have a silvery sheen and they 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 causes rough, bronzed blisters on leaves inside cabbage heads. These lesions may penetrate many layers into the cabbage head. Attack by the onion thrips on brassicas has been observed when onions are interplanted with brassicas. Some species of *Frankliniella* thrips are reported to cause discoloration of flowers in rape.

Control options: Thrips attacks are not common on brassicas in the region, and their populations are seldom large enough to warrant control measures. Ploughing and harrowing before transplanting can be useful in reducing thrips attacks by killing pupae in the soil. Natural enemies, particularly predators, are important in the natural control of thrips. The main predators include predatory bugs, predatory mites and other species of predatory thrips. Conservation of these natural enemies is important *(see page 12)*.

Thrips are difficult to control with insecticides due to their secretive habits. Some species of *Frankliniella* thrips are known to develop resistance to pesticides very rapidly. The onion thrips can be controlled with broad-spectrum pyrethroids (e.g. lambdacyhalothrin, alpha-cypermethrin; bifenthrin), but since the eggs and the pupae in the soil are not easily reached by the chemicals, repeated applications are needed to achieve satisfactory control. However, use of these pesticides should be minimised since they adversely affect natural enemies.

Bacterial diseases

Bacterial black rot

(Plates 32 and 33)

Causal agent: *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson

Symptoms: The plant can be affected at any growth stage. On seedlings, cotyledon margins turn black and later shrivel and drop off. On true leaves, small, yellow, V-shaped areas develop on the margins (Plate 32). 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 (Plate 33). 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 in infested soil. Seed-borne bacteria can be disseminated long distances. Many cruciferous 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, blowing of detached leaves or handling of 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 wounds made by chewing insects. They then move through the water vessels to the stem and the head. The optimum temperature for the disease is 26–30 °C. Water, in form of either rain or persistent dew, is required for disease development.

Control options: Use certified disease-free seed. Direct seeding should be used where feasible. Plant in seedbeds free of cruciferous crops for at least 2 years. Seedlings should not be crowded in the nursery. Transplants should not be dipped in water before transplanting. Mulching of the field crop, where feasible, is highly recommended. Avoid overhead irrigation. Field operations during wet weather should be discouraged. Keep the field free of weeds, particularly of the crucifer family. After harvest, prompt disposal of crop debris should be done. A crop rotation based on at least a 2-year break in cruciferous crops is advocated.

It should be noted that fungicidal sprays do not control black rot disease. However, copper sprays might reduce the disease spread if traces of black rot are detected early in the fields. Use of resistant/tolerant varieties, where commercially available, provides the most effective control of the disease.

Bacterial soft rot
(Plate 34)

Causal agent: *Erwinia carotovora* var. *carotovora* (Jones) Dye

Symptoms: A soft mushy decay of the heads with a very offensive odour is seen (Plate 34). 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 which 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, spread occurs by water splash and field tools. In transit and storage, it occurs by contact and bacterial ooze dripping from diseased leaves. Often, cutting knives used on diseased heads serve to spread the bacteria to subsequent heads.

Control 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 those residues decompose as quickly as possible. Handle produce carefully and store in a cool, well-ventilated area.

Fungal diseases

Alternaria leaf spot
(Plate 35)

Causal agent: *Alternaria brassicae* (Berk) Sacc.; *A. brassicicola* (Schw.) Wiit

Symptoms: A minute dark spot develops on the seedling stem immediately after germination. The spot causes damping-off or stunting of the seedling. Such diseased seedlings do not attain the normal size nor do they yield well when transplanted in the field. Spotting of broccoli, cabbage heads and cauliflower is another symptom and a destructive phase of the disease. 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 (Plate 35). The disease can also occur on seed pods in seed fields.

Disease cycle: The *Alternaria* spp. produce many spores that can be wind-blown, water-splashed or carried by tools, animals and humans throughout fields. The mycelium is frequently under the seedcoat 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.

Control options: Use certified disease-free seed. Treat seed with fungicides before planting. Rotate with crops unrelated to crucifers and

eradicate cruciferous weeds. Remove and destroy crop debris after harvest. Chlorothalonil, iprodione or mancozeb provide good control of the disease.

Blackleg

Causal agent: *Phoma lingam* (Tode) Desmazieres

Symptoms: All parts of the plants above or below ground may be affected from seedbed to harvest. The earliest noticeable 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 on prematurely killed seedlings. These spores are able to cause secondary infections in the seedbed.

Inconspicuous, somewhat circular, light brown to greyish spots appear on the leaves. They gradually become well defined with ashen-grey 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 come to the surface only in moist weather. Diseased leaves wilt but tend to remain attached to stems. On the stems, elongated, light brown, sunken areas (lesions) with purplish margins form 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 gradually is destroyed, although plants may survive in damp soil when new roots develop.

Plants grown for seed purposes may have their pods and seed infected. Such seed may carry dormant mycelium over to the next season. The presence of pycnidia on cotyledons, leaves,

stems and roots distinguishes blackleg from other crucifer diseases.

Disease cycle: The fungus can survive for at least 3 years in crop debris in the soil, in manure, and can be carried on in seed. The disease starts from infection of young seedlings by the fungus from infected seed or from trash in the soil. Conidia are produced on diseased plant parts and they are exuded when wet or water-splashed. The conidia are then blown to other plants, where they can germinate and cause new infections. Humid, rainy weather is essential for an epidemic. Conversely, the disease is relatively rare in dry growing areas.

Control options: Certified disease-free seed should be used. If necessary seed can be treated with thiabendazole (24-hour soak in 0.2% solution) or with a slurry treatment (30 ml thiram/ 10 kg seed).

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. Blackleg is most destructive in wet soils, therefore fields and soil with good drainage are important. Seedlings should not be transplanted from seedbeds that have any diseased plants. Crucifer 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 crucifer fields. At least a 4-year rotation with non-cruciferous crops is recommended.

Cercospora leaf spot
(Plate 36)

Causal agent: *Cercospora brassicicola* Hennings

Symptoms: The fungus causes spots on cotyledons, leaves, petioles and seed pods. The spots are circular, grey to brown and usually have darkened margins (Plate 36). Severely affected seedlings die. When spots are numerous, affected foliage turns yellow and later drops off.

Disease cycle: The fungus is carried in a small percentage of seeds. It can survive in volunteer plants and perennial weeds. It can also survive part of the year in fallen diseased leaves. The fungus produces innumerable spores, which can be blown by wind or splashed by rain or overhead irrigation. Abundant moisture and a temperature range of 20–24 °C favour disease development.

Control options: Use certified disease-free seed. Treat seed with fungicides before planting. Site seedbeds away from windbreaks. Eradicate cruciferous weeds in and near seedbeds and in production fields. Remove and destroy crop debris after harvest. Chlorothalonil, mancozeb or propineb provide satisfactory control.

Club-root
(Plate 37)

Causal agent: *Plasmodiophora brassicae* Woronin (a slime mould 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 ball-like gall. When many infections occur close together, most of the root system is transformed into variously shaped malformations (Plate 37). After a time, the clubbed tissue is invaded by soft-rot 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 mould in the plant tissue is transformed into a mass of spores (zoosporangia) which contain zoospores that contaminate the soil when the host tissue disintegrates. These spores enter young roots of crucifers and initiate new infections.

Spores can be spread by movement of infested soil, in soil water and in contaminated manure. The slime mould 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.

Control options: Nurseries should not be sited where crucifers have been grown within the previous 8 years. The soil should be well drained. Crucifer weeds must be eradicated in and near seedbeds. Solarisation and soil amendments (3-weekly) with urban compost, of seedbeds and field plots are recommended. Surface water should not be allowed to flood over seedbeds nor should seedbeds be over-watered. No plants from a seedbed that has even a single club-root seedling should be transplanted into a new field. Transplanting of larger seedlings is recommended. Calcium nitrate should be used as a choice fertiliser.

Fungicides having some effect against the club-root fungus include fluazinam and PCNB (pentachloronitrobenzene). They can be applied as plant dips or in transplant water. Liming provides good control of the disease in heavy soils. It is not effective in light sandy soils or loose manure where airslaking occurs rapidly. The soil pH should be determined before application of hydrated lime. At pH 7.0, about 1.5 tonnes of hydrated lime is needed for one 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 they may be affected adversely by a high pH.

Cottony rot

Causal agent: *Sclerotinia sclerotiorum* (Lib.) deBy.; *S. minor* Jagger

Symptoms: A soft, light-brown, watery rot of leaves and heads with masses of white, cottony, fungal growths. 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, greyish-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 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 grows in dying or injured tissues. The disease is favoured by cool, showery weather, but fogs, mists, dews and overhead irrigation provide enough moisture for infection to take place. The optimum temperature range for disease development is 16–24 °C.

Control options: Plant in a friable soil that drains well. Rotate with resistant crops such as cereals, maize, onions or spinach. Iprodione provides good control of the disease.

Downy mildew

(Plate 38)

Causal agent: *Peronospora parasitica* (Pers.) Fr.

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 undersides of the leaves (Plate 38 right). Later, a slight yellowing appears on the corresponding upper side (Plate 38 left). Young leaves and cotyledons may drop off when yellow. 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 readily visible on the undersurface 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 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 the 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 growth and disease development. The fungus grows best and mildew develops most when night temperatures do not exceed 24 °C.

Control options: Control should be emphasised in nurseries since downy mildew is particularly damaging in the seedbed. Seedbeds should have well-drained soils and be sited away from hedges and windbreaks. The site should not have been under crucifers for at least the previous 2 years. Seedlings should not be excessively watered. Crucifer weeds should be eradicated in and near seedbeds and out in the production fields. During wet seasons with night and day temperatures of 16–24 °C respectively, it may be necessary to apply fungicides such as chlorothalonil, copper hydroxide, propineb or formulations containing cymoxanil + propineb or metalaxyl + mancozeb. After harvest, ensure crop residues are removed from the field.

***Mycosphaerella* ring spot**
(Plate 39)

Causal agent: *Mycosphaerella brassicicola* (Duby) Lindau

Symptoms: The disease can affect all aerial parts of the plant, although generally it occurs on older leaves resulting in premature defoliation. On leaves, circular brownish-grey spots up to 2 cm in diameter are formed; these spots consist of a series of delimited, black-speckled, concentric zones (Plate 39). Affected veins and petioles become hard and brown, and they can split lengthwise making the leaves twist and become distorted. On stems, the spots are oval. 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, pycnidia and perithecia, which usually occur together. The pycnidia produce one-celled colourless spores that do not cause infection directly. However, perithecia contain ascospores which shoot 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 overseasons in diseased plants, debris from diseased plants left in the field and seed. Seed infection can later initiate disease in seedlings.The optimum temperature range for disease development is 16–20 °C.

Control options: Certified disease-free seed should be used. Seedbeds and production fields

should be sited where crucifers have not been grown for 2 or more years to avoid early infection of young plants. Eradicate crucifer weeds in and near seedbeds and in the field. Crop residues should be removed from the field and destroyed. Potash fertilisers have been reported to suppress infection. In case of early infection, chlorothalonil could be applied. When using fungicides, ensure wetters (spreaders) are incorporated in the sprays.

Powdery mildew

(Plate 40)

Causal agent: *Erysiphe cruciferarum* Opiz ex L. Junell

Symptoms: The disease starts as circular yellowish-white spots on the underside of leaves. Later, a white powder-like deposit can be observed on the corresponding upper surface of the leaves (Plate 40). Severely affected leaves dry, turn brown and prematurely drop off. The disease seldom kills the plants.

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

Control options: Crop rotation, destruction of volunteer crucifer plants and eradication of crucifer weeds may reduce disease incidence. Fungicides such as dinocap, bupirimate or thiophanate-methyl could be used when young plants are infected. 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.

Rhizoctonia disease

(Plate 41)

Causal agent: *Rhizoctonia solani* Kühn [*Pellicularia filamentosa* (Pat.) Rogers]

Symptoms: In crucifers, this fungus causes damping-off and wirestem of seedlings in the seedbed; bottom rot and head rot in the field; and storage and root rot of horseradish, radish, rutabaga and turnip.

Damping-off: Seeds can decay in cold wet soils and stems can become light brown and water-soaked near the soil line. Such seedlings wilt, topple and die. Wet soils and temperatures at or above 24 °C favour disease development.

Wirestem: This is the most common and destructive phase of the disease. The stem above and below the soil line shrivels and darkens, and outer tissues slough off leaving a dark wiry and woody inner stem (Plate 41). 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.

Bottom rot: The disease occurs mid-season as a carry-over from wirestem seedlings and from new infections that occur when outer leaves come in contact with moist infested soil. Lower leaves wilt, decay and turn black, but do not drop off. Some plants may recover and produce heads, but usually bottom rot develops into head rot.

Head rot: A firm to slimy dark decay at the base of outer leaves and in cabbage heads develops during the period between head formation and maturity. The fungus grows up the main stem, passing between the leaf petioles. Foliage leaves die and drop off, thus exposing the stem beneath the head. Over the whole head surface, brown fungus mycelia and tiny brown resting fungal bodies (sclerotia) may develop and be visible over the head surface. Secondary rot bacteria usually invade the diseased tissue and turn the head into a slimy foul-smelling mass.

Root rot: It is usually dark brown, sunken and spongy. Infected tissues easily separate from advancing edges of the rot. A white to brown surface mould and irregular brown sclerotia distinguish this rot from other root rots. It mainly affects horseradish, radish, rutabaga and turnip.

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 mycelia produce sclerotia to complete the cycle. The

crucifer strain of the fungus grows at 9 to 32 °C; Cabbage can be infected between 12 and 32 °C, the optimum temperature being 25–27 °C. Optimum temperature range for the turnip-rotting strain is 18–25 °C.

Control options: Seedbeds and production fields should not have had crucifers for at least 3 years. At planting, seed should be treated with captan. All seedlings with wirestem symptoms should be discarded. After transplanting, the soil may be drenched with captan. During cultivation, care should be taken to avoid throwing soil into plant heads.

Yellows

Causal agent: *Fusarium oxysporium* f. sp. *conglutinans* (Sch. Ex Fr.) Snyd. & Hans.

Symptoms: Affected plants lose vigour and the lower leaves turn yellow. In half-grown plants, leaves tend to bend sideways with one side smaller and pale-yellow. 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 discoloration can be seen in stems, petioles and veins of leaves.

Disease cycle: The fungus may survive for a number of years in the soil. 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 is a warm-weather disease. The disease is most severe at temperatures between 26 and 29 °C.

Control options: Seed treatment, rotation and fungicide applications are useless for yellows control. In areas where the disease has not yet 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. (Check with your local seed dealer.)

White rust
(Plate 42)

Causal agent: *Albugo candida* (Gmelin) Kuntze

Symptoms: Although the disease probably affects all crucifers, it is serious only on radish. Small, circular, raised, yellowish-green spots develop on the upper surface of leaves. They later rupture the lower leaf surface under the spots, exposing masses of white, powdery spores in small circular cavities. Severely affected leaves are malformed and they wilt and die (Plate 42).

Disease cycle: The fungus is closely related to the downy mildew fungus. It is an obligate parasite and reproduces by conidia and oospores. It survives as mycelia or oospores on crop residues and on cruciferous weeds. Spores produced on the underside of diseased leaves are spread to neighbouring plants by wind, rain or insects. Moist cool weather favours disease development. The optimum temperature for the disease is 20 °C.

Control options: Remove crop residues from the field and destroy them. Eradicate crucifer weeds in and around the production fields. Rotate crucifers with unrelated crops.

Viral diseases

Mosaic viruses

(Plate 43)

Causal agents: Cauliflower Mosaic Virus; Turnip Mosaic Virus

Symptoms: Mosaic, black speckling or stippling of cabbage heads at harvest or during storage can be caused by the Cauliflower Mosaic Virus or the Turnip Mosaic Virus occurring singly or together. Combined infection results in severe spotting. Symptoms can develop on inner leaves of the head as well as on outer wrapper leaves. Stored cabbage is affected most severely, since speckling on the leaves develops progressively with time. Early infection of cabbage by these viruses in the seedbed or soon after transplanting, can reduce yield by 75%, whereas late-season infection has little or no effect on yield.

Cauliflower Mosaic Virus: 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 the loss of green colour from the veins. On cabbage in storage, a black stippling develops on leaves throughout the head. The virus is transmitted by the green peach aphid (*Myzus persicae*) and the cabbage aphid (*Brevicoryne brassicae*). The virus is also transmissible by sap inoculation. It is not transmitted through seed.

Turnip Mosaic Virus: This virus can infect all crucifers as well as beets, spinach and tobacco. Infected plants are stunted, with leaves coarsely mottled and distorted (Plate 43). Black spots develop on leaves which prematurely drop. 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 and is readily transmitted mechanically.

Control options: Locate seedbeds away 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 outside rows in seedbeds. Aphicide sprays around and in seedbeds and in the field may reduce virus spread. Field equipment should be used in new fields first 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.

Table 2. Some commercial pesticides available in eastern and southern Africa

Common name	Representative commercial products
1. Insecticides	
acephate	Orthene®
alpha-cypermethrin	Bestox®, Fastac®
bifenthrin	Brigade®
buprofezin	Applaud®
chinomethionat	Morestan 25% WP®
cypermethrin	Ambush C®, Cymbush®
deltamethrin	Decis®
fenitrothion	Novathion®, Sumithion®
fenvalerate	Sunicidin®
imidacloprid	Confidor®, Gaucho®
lambdacyhalothrin	Karate®
malathion	Malathion®
permethrin	Ambush®
pirimicarb	Pirimor®
pymetrozine	Fulfill 50 WG®
trichlorfon	Dipterex®
2. Bactericides	
Copper-based	Kocide®, Cupravit®
3. Fungicides	
chlorothalonil	Daconil®, Bravo®
iprodione	Antracol®
mancozeb	Mancozeb®, Dithane M45®
thiabendazole	Thiabenzole®
thiram	Thiram®
propineb	Antracol®
fluazinam	Shirlan®
PCNB (pentachloro-nitrobenzene)	Terraclor®
copper hydroxide	Kocide 101®, Kocide DF®
copper oxychloride	Blitox®, Cobox®, Cupravit®, Cuprocaffaro®
cymoxanil–propineb	Milraz®
Metalaxyl–mancozeb	Ridomil®
dinocap	Karathane®
bupirimate	Nimrod®
thiophanate–methyl	Cercobin®
captan	Captan®

[a]See notes on safe pesticide use. Note that mention of specific pesticides or trade names does not imply any preference or advantage over similar compounds not mentioned by name.

Glossary

Alternate host: different type of plant on which a pest (insect or disease) can survive
Ascospores: microscopically small seeds of fungal diseases such as ring spot of cabbages
Brassicas: common name for crops such as cabbage, kale, mustard and rape
Bt: *Bacillus thuringiensis*
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
Cornicles: horn or horn-like growth on the rear part of the abdomen of aphids
Cotyledons: the first leaf or primary leaves of a growing plant embryo; seed-leaf
Crucifers: an alternative name for brassicas
Culls: plant removals
Curd: The edible portion of cauliflower
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)
Exuding: oozing out
Fruiting bodies: small structures of diseases containing disease spores or seeds
Gall: swellings on plants caused by pests (insects or diseases) such as those caused by root-knot nematodes on the roots

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: that portion of the stem below the cotyledons
Incubation: (of diseases): time between infection to appearance of symptoms
Inoculum: disease source
Instars: insect form between successive moults; the first instar is the stage between hatching and the first moult
Larvae: immature stage of an insect
Latent period: of a disease, the period between disease attack to the 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 legless
Morphology: form and structure of a plant, insect or organism
Mosaic: a pattern of greenish and yellowish shades in leaves
Mottled: leaves discoloured in patches
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
Oviposition: laying of eggs by insects
Parenchyma (palisade): cells under the leaf epidermis (leaf surface)

Parthenogenesis: form of reproduction in insects without need for males

Pathogen: any organism capable of causing disease

Perithecia: type of fruiting body from diseases such as powdery mildews

Petiole: leaf stalk

Phloem: nutrient- or food-conducting tissue in plants

Plumules: undeveloped shoots in a seed

Polyphagous: organisms or insects feeding upon a range of plants (hosts)

Prolegs: Abdominal legs of caterpillars and sawfly larvae; they are used for walking and clinging, as they have a set of minute hooks on the base

Prothorax: part of an insect body immediately behind the head

Pupa: an inactive and non-feeding stage between larva and adult in insects

Pupation: changing into a pupa is called pupation

Quiescent: dormant; inert; latent

Reticulate: having the appearance of or markings like a network

Roguing: physically removing unhealthy or unwanted plants from a crop

Root collar: where the root system begins (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 the plant sap

Saprophytic: organisms feeding on decaying organic matter

Sclerotia: hard lump of tissue formed by fungal diseases in some plants

Sooty mould: black mould on leaves or plants attacked by sucking insects such as aphids. 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 disease organisms produce spores or seeds

Stippled: dotted

Stomata: pores on the lower leaf surface

Translucent: allowing light to pass through, especially without being clearly visible (as opposed to transparent)

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

WFT: western flower thrips

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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NOTE: A complete reference list is available from the Horticultural Crops Sub-Division of ICIPE

Figure 1. A Guide to IPM in Brassicas Production

Before you get started

Check the following:

- **Soil fertility:** Take samples for analysis of macro- and micro-nutrients.
- Availability and quality of **water for irrigation:** Take samples for analysis of salt content.
- **Pest and disease history** of the farm: If the farm has a long history of soil-borne diseases such as blackleg, club-root and yellows, opt for other crops (see below).
- **Suitable varieties:** Choose the varieties to cater for existing or expected pest and disease problems and also for the agroecological zone.
- **Market trends** for the produce.

Standard recommendations for all production areas

Do's & don'ts

Nursery management

- Site nursery on land not previously under crucifers and away from old crucifer fields (wooden trays could be used to raise seedlings away from the field).
- Heat soil in the seedbed: Place plenty of crop trash or straw and burn for at least 30 minutes; after cooling, mix the soil with compost in equal proportions.
- Use certified disease-free seed, and when using own seed, treat it prior to sowing with a fungicide and an insecticide.

- Mulch seedlings in the seedbed.
- Avoid over-watering the seedlings and do not water late in the afternoon.
- Pull out weak-looking seedlings and thin out seedlings in the seedbed.
- 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.

Do's and don'ts contd.

Transplanting and field operations

- Do not site a new field on land that was previously under crucifers and ensure it is not next to or near an old crop of crucifers.
- Transplant only robust, healthy seedlings, preferably late in the afternoon.
- Keep newly planted fields weed-free.
- Avoid field operations when it is wet.
- 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

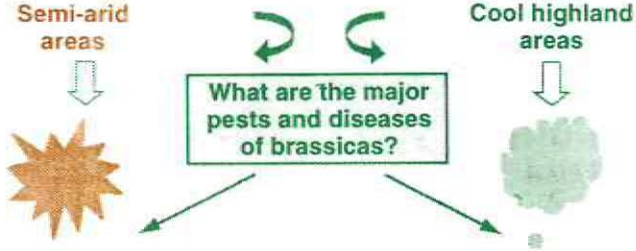
- Use pesticides only when needed; use registered products; avoid using broad-spectrum insecticides; and strictly follow instructions on the label. Do not use more or less than indicated and observe pre-harvest intervals.
- For crops which are continuously harvested such as kale, divide the field into 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 harvesting 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 crucifer crops.
- Practise rotation with crops non-related to crucifers. These include bell pepper, brinjals (eggplant), carrots, cereals, chillies, cucurbits, fodder grass, karela , legumes, okra, onions, potato, Swiss chard and tomato.

Where do you grow brassicas?

Brassicas are principally grown in cool highland areas with supplementary irrigation during the dry seasons. Some, such as cabbages and kales, are grown in semi-arid areas under continuous irrigation. Because of differences in cropping systems and in environmental conditions, particularly weather, the complex of major and minor pests and diseases is variable over the seasons. It is important to take into consideration these factors when planning pest and disease management measures.

Pests and diseases



Diamondback moth (p. 21)
Aphids (p. 25)
Black rot (p. 51)
Powdery mildew (p. 66)

Diamondback moth (dry season) (p. 21)
Aphids (dry season) (p. 25)
Black rot (p. 51)
Downy mildew (p. 62)

What other pests and diseases attack brassicas?

Insect pests

- Cabbage webworm (p. 30)
- Bagrada bug (p. 32)
- Cabbage sawfly (p. 34)
- Cabbage moth (p. 36)
- Cabbage looper (p. 41)
- Leafminers (p. 43)
- Cutworms (p. 38)

Diseases

- Viruses (p. 72)
- Cottony rot (p. 61)
- Soft rot (p. 53)
- Leaf spots (p. 58)
- Club-root (p. 59)
- Blackleg (p. 56)
- *Rhizoctonia* (p. 67)
- Yellows (p. 70)
- White rust (p. 71)

The given pests and diseases can occur in either of the two agroecological zones depending on weather conditions. However, most of the pests prefer hot conditions, while for most diseases, the critical weather condition is rainfall.

Always remember that proper identification is the first and most important step in controlling pest and disease problems. A misdiagnosis leads to mismanagement and to increased losses and costs. If in doubt after consulting this manual, check with a qualified crop protection professional.

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Specific management of major pests and diseases

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Diamondback moth

- Dark green glossy varieties are less susceptible.
- Plant border rows with a trap crop such as Indian mustard and use direct control measures at the trap crop. Also intercrop with repellent crops like tomato. The main crop should be planted 30 days after tomato.
- Scout for caterpillars (where possible, monitor moth population using sex pheromones). In the dry season 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 the rainy season, the thresholds are 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 away the young caterpillars and increase their mortality.
- If control is necessary, spray with neem-based or *Bt* products. However, avoid continuous use of *Bt* products as they can induce development of resistance.
- Parasitoid releases (*Diadegma semiclausum* in highlands; *Cotesia plutellae* in lowlands; *Oomyzus sokolowskii* in both highlands and lowlands), together with the above measures will provide effective control.

Aphids

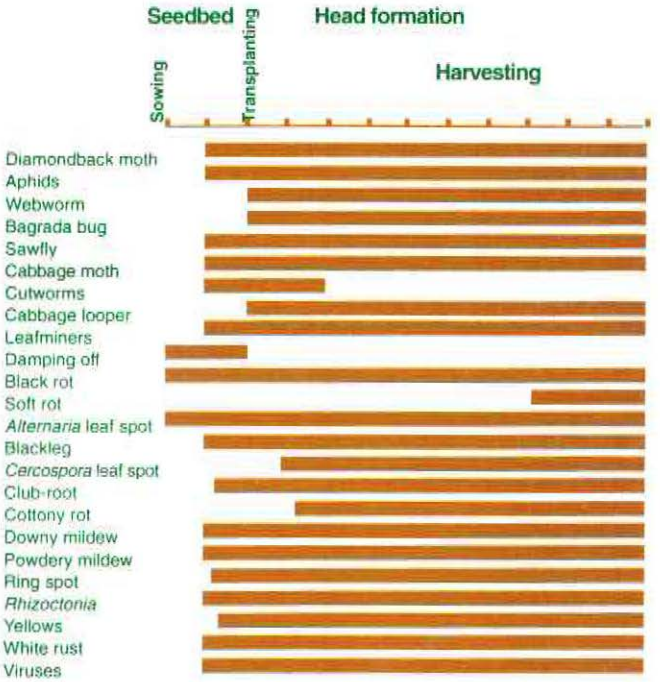
- Dress seed or drench seedlings with imidacloprid.
- Intercrop with beans, dill or spinach.
- Check regularly for aphid infestation; green aphids do not normally require control measures.
- If control is necessary, spot-spray aphid-infested plants with neem oil, neem seed extracts, acephate or pirimicarb. These products are relatively safe to natural enemies of aphids.

Black rot

- Use tolerant/resistant cabbage varieties (Field Lion and Predena are resistant; Field Mark, Field Force, Gladiator, Granadier, Krautman and St Pancras are moderately resistant.)
- Use certified disease-free seed.
- Mulch the crop.
- Keep the field free of weeds, particularly of the crucifer 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.
- Practise a two-year rotation with non-crucifers (refer to Standard Recommendations).

Always review what went wrong, but more importantly, what went right? Did the control measures work? Take a close look at the crop and compare pest and disease activity before and after treatment. What needs to be improved? Keep records of what you do and what you observe.

Figure 2. Cabbage growing cycle and the occurrence of major pests and diseases



Natural Enemies

Plate 1: Adults of the ladybird beetle

Plate 2: Eggs (left) and larva (right) of ladybird beetle

Plate 3: Nymph (left) and adult (right) of an anthocorid bug

Plate 4: Larva (left) and adult (right) of hoverfly. Note empty pupal case from which the fly emerged

Plate 5: Larva (top), adult (bottom left) and egg (bottom right) of lacewing

Plate 6: Diamondback moth (DBM) parasitoid: *Apanteles* sp.

Plate 7: DBM parasitoid: *Diadegma mollipla*

Plate 8: *Oomyzus sokolowskii* parasitising a DBM larva

Plate 9: Aphid parasitoid *Diaeretiella rapae* (inset) and parasitised aphids (mummies)

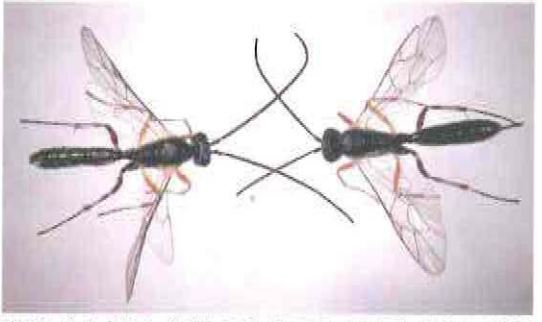


Plate 10: Male (left) and female (right) of the DBM parasitoid *Diadegma semiclausum*

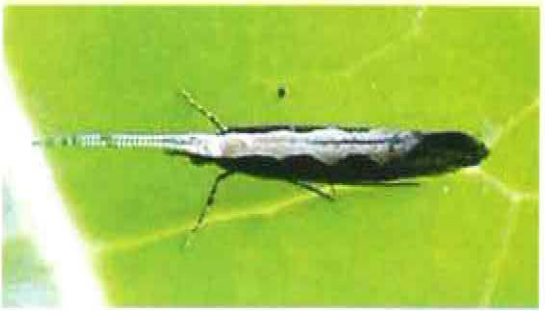


Plate 11: Diamondback moth, *Plutella xylostella*, adult

Plate 12: Diamondback moth larva and pupa (inset)

Plate 13: Cabbage plant damaged by diamondback moth larvae

Plate 14: The cabbage aphid *Brevicoryne brassicae*: note recently moulted aphids (green in colour) and some parasitised aphids (mummies), brown in colour

Plate 15: Cabbage plant damaged by the cabbage aphid; cabbage aphid (inset)

Plate 16: The false cabbage aphid, *Lipaphis erysimi*

Plate 17: The green peach aphid, *Myzus persicae*

Plate 18: Larvae of *Hellula undalis* (left) and damage on leaves caused by young larvae (right)

Plate 19: Damage on the growing point of a young plant (left) and on a cabbage head (right) caused by larvae of *Hellula undalis*

Plate 20: *Bagrada* adult bug on cabbage

Plate 21: Damage caused by the *Bagrada* bug

Plate 22: Adult sawfly, *Athalia sjostedti*

Plate 23: Sawfly larvae and damage caused on radish

Plate 24: Adult of the cabbage moth, *Crocidolomia binotalis*

Plate 25: Larvae of the cabbage moth, *C. binotalis*

Plate 26: Damage caused by *C. binotalis* larvae on cabbage

Plate 27: Larva and adult (inset) of the cutworm *Agrotis* sp.

Plate 28: Larva and adult (inset) of the cabbage looper

Plate 29: Punctures caused by feeding and egg-laying leafminer flies (left) and mines and a pupa on the upper leaf surface (right)

Plate 30: Kale infested with whiteflies (left). Adults and eggs (top right) and nymphs and adults (bottom right) of the whitefly *Aleyrodes proletella*

Plate 31: Larva (left) and adult (right) of the thrips *Frankliniella* sp.

Bacterial Diseases

Plate 32: Bacterial black rot: note v-shaped lesions on leaves

Plate 33: Bacterial black rot: note blackening of water-conducting tissues of the stem

Plate 34: Bacterial soft rot: note slimy rot of the centre of the head

Fungal Diseases

Plate 35: *Alternaria* leaf spot

Plate 36: *Cercospora* leaf spot

Plate 37: Club-root: note warty growth in the root system

Plate 38: Downy mildew: on upper (left) and lower (right) leaf surfaces

Plate 39: *Mycosphaerella* ring spot

Plate 40: Powdery mildew on cabbage (left) and kale (right)

Plate 41: *Rhizoctonia* disease: wirestem of seedlings: diseased plant (right), healthy plant (left)

Plate 42: White rust on kales

Plate 43: Turnip Mosaic Virus: affected kale plant (right), and healthy plant (left)

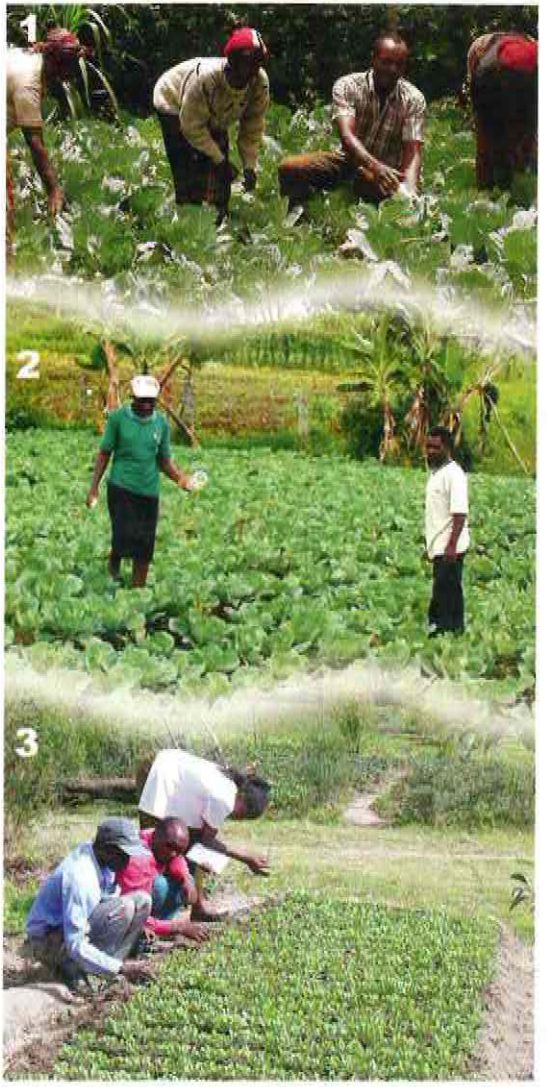


Plate 44: 1 and **2:** Releases of DBM parasitoids *(Diadegma semiclausum)* in cabbage fields in Kenya. **3:** IPM training on brassicas in Kenya

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Pest and damage in cabbage: cabbage aphid (a), Turnip Mosaic Virus (b), damage by DBM (c)

Front cover: From left: Diamondback moth, cabbage aphid, black rot and ring spot

Brassicas (the cabbage family) are popular and important crops in eastern and southern Africa. Grown mainly for the local market, they provide a valuable source of vitamins and minerals, as well as a source of cash income for smallholder farmers in rural and peri-urban areas.

A wide variety of pests and diseases attack cabbage, kale, cauliflower and other brassicas, but control of these is proving increasingly difficult. Important pests such as the diamondback moth (DBM) have developed resistance to most synthetic insecticides, and the incidence of Turnip Mosaic Virus (transmitted by aphids) is increasing yearly, for instance.

This manual describes the major pests and diseases of brassicas in the region, with photos and symptoms of damage indicated. Integrated pest management (IPM) options are presented as alternatives to synthetic pesticides whenever possible, as a means of making brassica farming more economical, safe and profitable.

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