



# Descriptions of 16 potato pests in South Africa

June 2017



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## **Proposed reference**

Potatoes South Africa. 2017. Descriptions of 16 potato pests in South Africa. [www.potatoes.co.za/research/fact-sheets](http://www.potatoes.co.za/research/fact-sheets).

## **Acknowledgements**

- 1. Text** extracted or adapted from Final report: Potato pest survey to determine the status of potential arthropod pests in all the potato production regions of South Africa. Dr Diedrich Visser, ARC-Vegetable and Ornamental Plants (Roodeplaat).
- 2. Photographs** by Dr Diedrich Visser, ARC-Vegetable and Ornamental Plants (Roodeplaat).

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## INTRODUCTION

The composition of pest complexes is known for most crops in Africa. This publication was compiled following the first survey on potatoes in South Africa conducted by Dr Diedrich Visser of the ARC-Vegetable and Ornamental Plants (Roodeplaat). Interviews were conducted with a total of 116 commercial farmers in all 16 potato production regions. Farmers were asked to identify the most common pests (insects, mites and nematodes) encountered during the past five years. Farmers not accustomed to all pests were supplied with a visual database with more than 100 colour photographs to enable them to identify pests. After the farmer had compiled a list, he or she was then asked to rank the pest status according to three classes: High (always a serious problem), medium (sometimes a serious problem) and low (seldom a problem) according to the experiences and perceptions of the farmer.

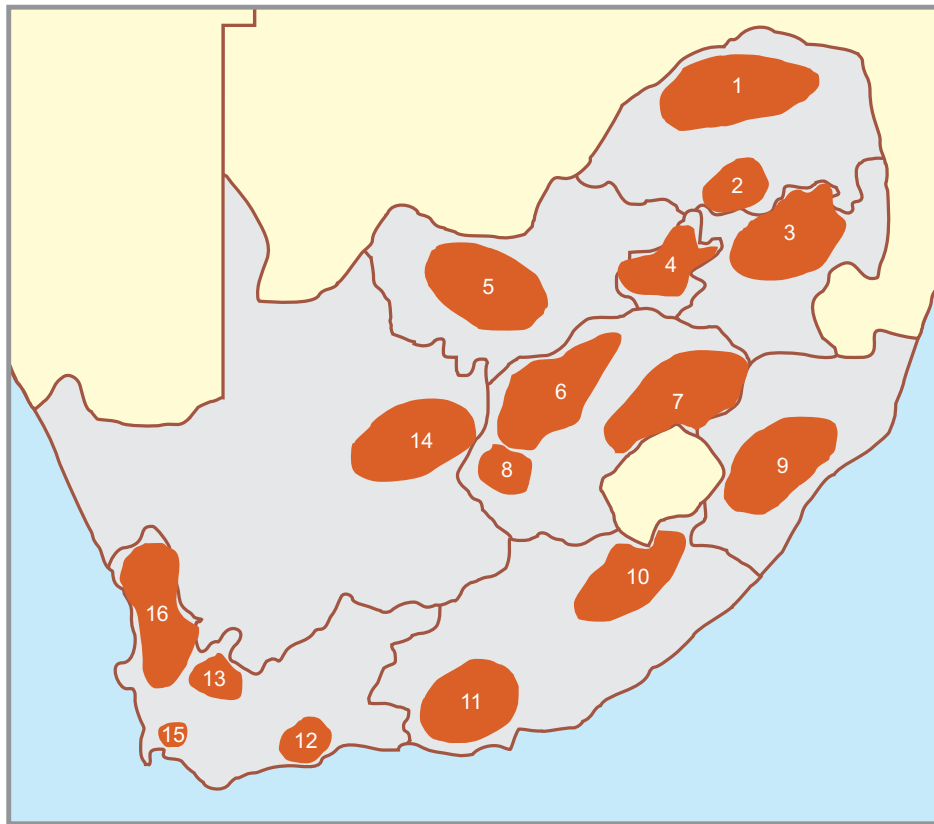
Of the 60 pest species known to attack potatoes in South Africa, four were classified as a problem in most production regions, viz: potato leaf miner (*Liriomyza huidobrensis*), potato tuber moth (*Phthorimaea operculella*), nematodes (*Meloidogyne* & *Pratylenchus* spp) and aphids (various spp.).

Climate change will undoubtedly shift pest complexes, and if we are not familiar with the pests we are dealing with, there may be catastrophic consequences for the potato industry (commercial and small-scale farmers) in future. A well-established and organised potato industry should know what insect problems are prevalent in which production areas, and also be aware of all potential pests on a regional as well as a national scale. This project was aimed at addressing these issues.

This publication aims to provide the potato farmer and pest specialist with detailed information on the most important pests occurring in potato fields in South Africa. The photos included were all taken by Dr Visser; they are of exceptional quality and will be of immense value in identifying pests.

Dr Visser has published two books, numerous scientific reports and many popular articles on various pests occurring on potatoes in South Africa. Certain sections and/or information in this booklet have been extracted from Visser, D. (2009). *A complete guide to vegetable pests in South Africa*. Pretoria: ARC-Vegetable and Ornamental Plants (Roodeplaat), 316pp.

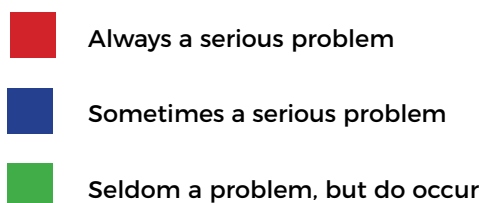
## POTATO PRODUCTION REGIONS IN SOUTH AFRICA



	<b>Region</b>	<b>Production season</b>	<b>Irrigated/Dryland</b>
1.	Limpopo	Winter	Irrigated
2.	Loskop Valley	Winter	Irrigated
3.	Mpumalanga	Summer	Irrigated
4.	Gauteng	Summer	Irrigated
5.	North West	Summer	Irrigated
6.	Western Free State	Summer	Irrigated
7.	Eastern Free State	Summer	Irrigated and dryland
8.	South Western Free State	Summer	Irrigated
9.	KwaZulu-Natal	Summer	Irrigated and dryland
10.	North Eastern Cape	Summer	Irrigated and dryland
11.	Eastern Cape	Winter	Irrigated
12.	Southern Cape	Summer	Irrigated and dryland
13.	Ceres	Summer	Irrigated
14.	Northern Cape	Summer	Irrigated
15.	South Western Cape	Summer	Irrigated
16.	Sandveld	Summer and winter	Irrigated

## STATUS OF PESTS IN POTATO PRODUCTION REGIONS

**Tabel 1.** Vergelyking van die status van plae in aartappelproduksiestreke. Let wel: Slegs tien plae word per streek gerapporteer. Die term ruspes word gebruik vir die kompleks van bolwurm, valslantermeter en Afrikabolwurm.

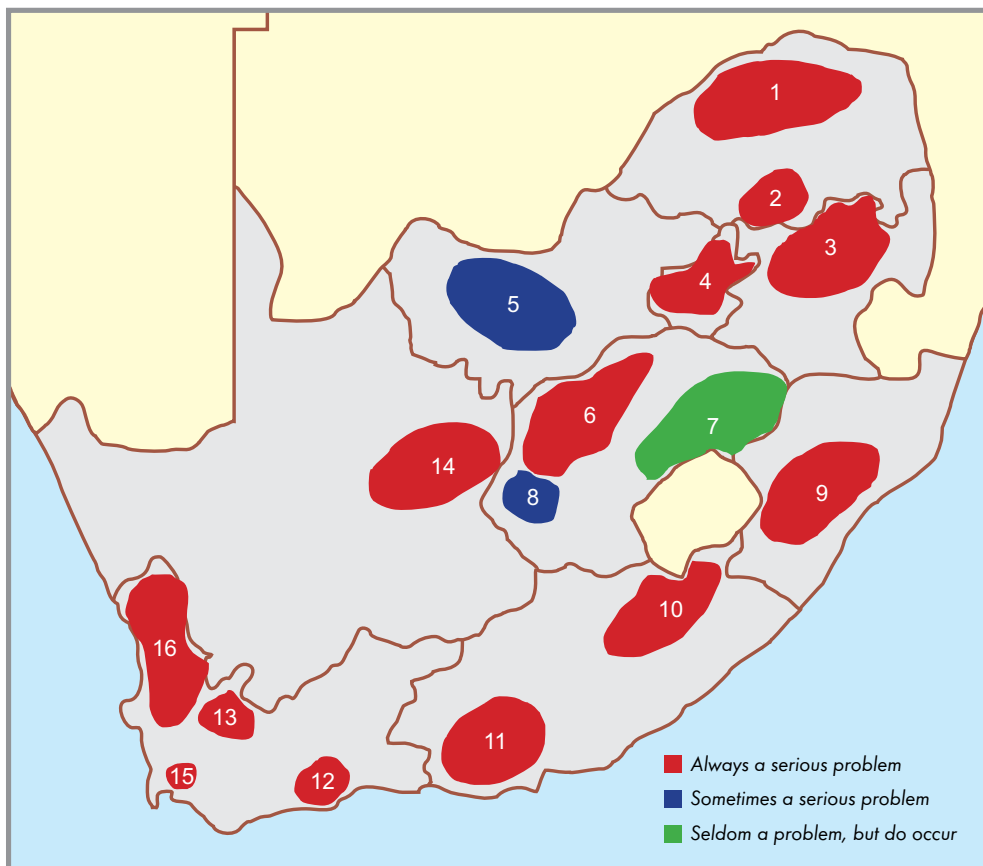


	Loskop Valley (2009)	Limpopo (2010/11)	Eastern Free State (2011/12)	North Eastern Cape (2012/13)	KwaZulu-Natal (2012/13)	Western Free State (2013/14)	North West (2013/14)	Eastern Cape (2014/15)	Mpumalanga (2014/15)	Northern Cape (2014/15)	South Western Free State (2014/15)	Sandveld (2015/16)	Ceres (2015/16)	Southern Cape (2015/16)	South Western Cape (2015/16)	Gauteng (2015/16)
Leafminers	Red	Red	Green	Red	Red	Red	Blue	Red	Red	Red	Blue	Red	Red	Red	Red	Red
Potato tuber moth	Blue	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Red	Blue	Blue	Blue
Nematodes	Red	Green	Blue	Blue	Blue	Red	Red	Red	Red	Red	Green	Red	Red	Green	Blue	Blue
Aphids	Green	Green	Blue	Red	Red	Red	Blue	Blue	Blue	Red	Green	Red	Red	Blue	Green	Green
Caterpillars	Green	Green	Green	Blue	Green	Green	Green	Blue	Blue	Blue	Blue	Blue	Green	Green	Blue	Blue
Cutworms	Green	Green	Green	Blue	Green	White	Green	Blue	Blue	Green	Green	Blue	Green	Blue	Blue	Green
Black maize beetle	White	White	Blue	Green	Green	Green	Green	Green	Blue	Green	Green	Green	Green	Blue	Green	Green
White grubs	Blue	White	Green	White	Blue	Green	Green	White	White	Blue	Green	Green	Green	Green	Green	Green
Red spider mites	White	Green	White	White	White	Blue	Blue	Green	Green	White	White	Green	White	White	Blue	Green
Snout beetle	White	White	Green	Blue	Blue	Green	White	Green	Green	White	White	White	White	White	White	White
Millipedes	Green	White	Green	Green	Green	White	Green	Green	Blue	Green	Green	White	White	White	White	Green
Sucking bugs	White	Green	White	White	White	White	White	White	White	White	Blue	White	Green	Green	White	White
Thrips	White	White	White	White	White	Green	White	White	White	White	White	White	Green	Green	Blue	White
Whiteflies	Green	Green	White	White	White	White	White	White	White	Blue	White	White	White	White	White	White
Wireworms	White	White	White	White	White	White	White	White	White	White	White	Green	White	White	White	White
Grasshoppers	White	White	White	Green	White	White	White	White	White	White	White	White	White	White	White	White

## LEAFMINERS

### Background

The genus *Liriomyza* contains more than 300 species worldwide, of which 23 are economically important to crops (Parrella 1987). *Liriomyza huidobrensis* (potato leafminer) is a relatively new introduction into the country (in the year 2000), while *Liriomyza trifolii* (American leafminer) has been present in South Africa since the 1970s. The potato leafminer was introduced into many new countries in the 1990s, including Canada, Indonesia, Israel, Taiwan and countries in Europe (Scheffer et al. 2001). It is also present in China, India and the USA. It presumably originated in South America. The American leafminer originated in North America and, except for Australia and some parts of eastern Asia, is distributed worldwide. Both *Liriomyza* leafminers have extensive host ranges – nearly all vegetables and many weeds are attacked. They are also severe pests of cultivated flowers.



### Description

Adult *Liriomyza* leafminers are small, yellow and black flies approximately 1.5–2 mm in length. In both species males are smaller than females. The American leafminer is also slightly smaller and more yellow in colour than the potato leafminer. The legs of the potato leafminer are dark, whereas those of the American leafminer are yellow. Both species have red eyes and a distinct yellow dot on the upper thorax between the wings. American and potato leafminers live for approximately one and two weeks respectively (Capinera 2001) and may lay up

to 400 eggs. Eggs hatch in about three days and the emerging larvae (maggots) tunnel between the upper and lower leaf surfaces. The cream-coloured to orange larvae are legless and are never found outside their tunnels within the leaves. While feeding, the larvae pass through three instars in as few as four days. At maturity, the third instar cuts a slit in the leaf surface after which it exits the leaf mine. The larvae may then fall to the ground and pupate there, but often it pupates on the surface of a leaf. The pupae are orange to brown, but turn dark brown to black just before eclosing into flies. It takes approximately ten days for the adult fly to emerge from the pupa. An interesting observation is that the larvae of *Liriomyza* leafminers on potato can only survive on older plants or plants/leaves that grow more slowly (e.g. the lower leaves). Younger potato plants, although attacked and punctured by females, usually never harbour high numbers of larvae. The onset of damage is therefore nearly always sudden and dramatic towards the latter part of the growing season (when plants are senescent). This dramatic “invasion” of leafminers is exacerbated by the extremely short life cycle of the larvae, which may be as short as four days. This phenomenon of “delayed but sudden attacks” on potato has not been observed in other vegetables.

### Damage

The origin of the first flies in a crop is in some cases still a mystery. Occasionally, newly planted crops are attacked by scores of flies and in some cases swarms cover entire plants. It is thought that these flies enter potato fields in large numbers from surrounding areas, even though there are seemingly no alternative host plants nearby. Wind may play a role in fly migrations, but this has not been proven. However, in most cases fly numbers build up within a field without being noticed. The tiny flies are inconspicuous and reproduction may continue on the lower leaves where they are not detected. One female fly can lay up to 400 eggs, and with a life cycle as short as 21 days, a single female may give rise to a huge population in less than two months. Females are capable of puncturing leaf surfaces with their ovipositors (the egg-laying apparatus at the end of the abdomen). These puncture marks (shallow holes) are distinct and sometimes cover entire plants. One female may produce up to 1 000 leaf punctures (Capinera 2001).

Although these marks usually do not affect the plant negatively, very young plants may be stressed, and the wounds may serve as entry points for pathogens. Female flies lay their eggs in these punctures (10-20% of holes contain eggs), and they also consume plant sap that oozes from fresh punctures. The larvae make long, thin tunnels while feeding between the upper and lower leaf surfaces. On potatoes the physical structure and position of the mines differ between the two *Liriomyza* species. The American leafminer has no preference for a particular area on the leaf, but seldom attacks the midrib area. On the other hand, the potato leafminer prefers the midrib or vein areas, always fanning out from there to the rest of the leaf. Compared with the American leafminer, more potato leafminer larvae are found inside a single leaf, resulting in mines that later merge to form large chlorotic areas. The potato leafminer sometimes also tunnels into leaf stems when moving down from the leaf area. Feeding by larvae results in leaves, and sometimes entire haulms/stems, dying-off. Affected growth also looks poor and may resemble diseased plants. Plants usually die-off a month earlier than would be normal during senescence. This premature dying-off causes the yield loss associated with this pest on potato. Potatoes plants need the latter part of the season to grow or fill the tubers formed during the first half of the season. The result is that mostly small and medium-sized tubers are produced. Reduction in yields of up to 70% has been reported.

### Control

For potatoes preventative spraying is necessary before plants go into senescence. Most insecticides used against other pests will not control *Liriomyza* leafminers. Most cultural practices are ineffective, but a few parasitoids are known to reduce leafminer numbers under favourable conditions. More than eleven insecticides (active ingredients) are registered for use against leafminers on potatoes in South Africa ([www.croplife.co.za](http://www.croplife.co.za)).



Females make punctures into leaf surfaces with their ovipositors. In some of these punctures the female lays eggs.



Pupae are formed on the leaf surface, but easily drop to the ground, where most of the pupae are usually found.



Potato leafminer damage to potato leaves. As the damage escalates entire leaves, and later haulms/stems, may die.



Damage by the potato leafminer begins near the midrib of the leaf and later an entire leaf area may be destroyed.



The American leafminer (*L. trifolii*) does not make mines near the midrib, and usually fewer mines are found per leaf.

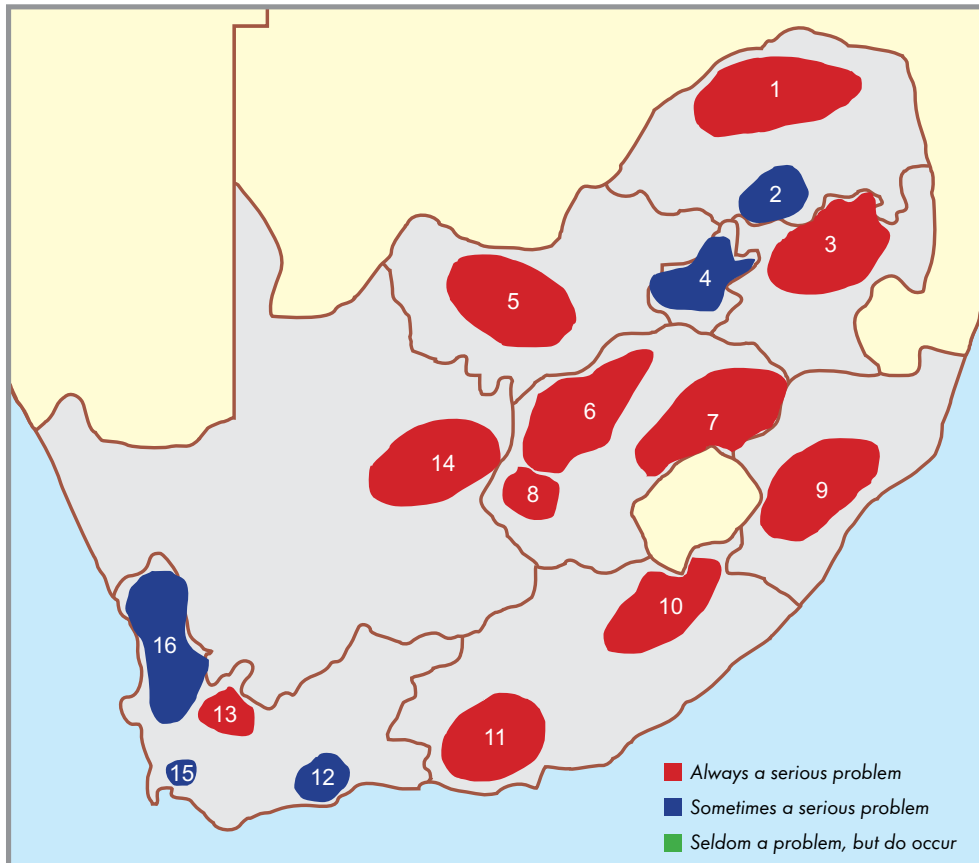


Potato leafminer damage to the border area of a potato field where the one side of the insecticide applicator did not reach.

## POTATO TUBER MOTH

### Background

The potato tuber moth, *Phthorimaea operculella* (Zeller), belongs to the order Lepidoptera, family Gelechiidae. It is a non-indigenous pest that originated in South America and has been present in South Africa for more than a century. At the moment it occurs wherever potatoes are cultivated. It is especially destructive where potatoes are grown under dry conditions in the warmer seasons. It also attacks tobacco, tomato, eggplant, Cape gooseberry and certain broad-leaved weeds.



### Description

The moth (8 mm in length) lays her eggs on foliage or on the ground near plants. In warm weather conditions, the eggs hatch in 4–5 days. The tiny (less than a millimetre) first instar larvae are very active and immediately after hatching start searching for an available plant. They mine into leaves by tunnelling between the upper and lower leaf surfaces. In this process, a “window-like” patch is formed (blotch leaf mine). The larvae occasionally also mine into growth points/tips. The larvae usually remains in the protective area within leaves or growth points. After feeding for about two weeks, the larvae are fully-grown and ready to pupate.

The mature larva is approximately 10 mm long. It is greenish, sometimes grey-brown or pinkish. It has a black head with a distinct pink thorax (behind the head). It exits from the feeding site and moves to the soil surface – upwards when it was feeding on tubers and downwards when it was feeding on leaves. It wiggles itself into loose soil at ground level while producing fine silk threads from glands in its mouthparts. By incorporating small sand and dust particles into the lining, a strong cocoon is formed around the larva. In the absence of sand or dust, the larvae spin cocoons of silk only. Inside the cocoon, the larva changes within two days into a pupa.

After approximately seven days, the moth ecloses from the cocoon. Male moths find females by tracing pheromone plumes produced by the females. Mating takes place almost immediately and most eggs are laid within 2-3 days. One female can lay up to 200 eggs. Moths live for approximately one week and do not feed. They do, however, survive a few days longer if they have access to water or honeydew.

### Damage

Damage due to mining into foliage during the season usually does not cause yield losses. However, if moth numbers are very high early in the season, very young or small plants may be adversely affected. In the case of potatoes, the foliage-feeding stage is crucial in the life cycle of the moth because it is then that reproduction and multiplication take place while tubers are still forming in the ground. Four to five overlapping generations are usually produced on the foliage per growing season. At the end of the potato growing season, the foliage becomes sparser while the moths keep on laying eggs on dead and dying leaves. Millions of larvae may then be moving about in fields in search of foliage. At this time, some larvae move down minute cracks in the ground, thereby finding and attacking the tubers. After reaching the tubers, the larvae may tunnel just below the potato skin, causing distinct mines, but sometimes deeper mining also occurs.

Tubers in storage are attacked by larvae of moths that fly in from surrounding areas or by populations originating from larvae in infested tubers that had been transported to the storage areas. Damage symptoms in stored tubers differ slightly from those of subterranean tubers because the eyes of the tubers are attacked first. Mines under the skin of the potato are less obvious than those damaged in the field, but characteristic excreta are discharged from entry points on the surface of infested stored potatoes. Depending on the severity of the initial infestation in stored tubers, the contents of an entire potato store may be destroyed within two months by the progeny of the emerging moths.

### Control

Insecticide application is currently the most widely used and most effective control strategy against the potato tuber moth. However, under certain conditions even insecticides may not control it. This is usually when environmental conditions favour a very high reproductive rate. Eggs (Findlay 1975) and the protected pupae usually escape the effect of insecticides and under certain circumstances, this results in huge population "explosions". This normally happens in seasons when warm and dry conditions have prevailed for more than two weeks.

It is not uncommon for a farmer to experience a 40% yield reduction following a year in which the yield reduction was less than 5%. This has been noticed on several farms in the Free State where all production practices were the same in consecutive seasons, with only the weather differing greatly. During the year with widespread drought and high ambient temperatures, the damage increased six-fold. Unfortunately, warm and dry seasons cannot be predicted accurately.

The use of alternative control strategies may reduce damage if implemented on a seasonal basis. These include cultural methods, of which ridging is the most important. Ridging ensures that enough soil is available to avoid exposure of tubers and to prevent cracks from forming while tuber bulking is taking place. Potato tuber moth larvae cannot reach tubers if the tubers are covered with a layer of soil of more than 5 cm. The only means by which infestation can take place is through minute cracks in the ground that lead to tubers. Soils can still crack when ridging is performed, but the incidence of cracks and therefore the infestation potential will be reduced. Frequent rain or irrigation may seal some cracks, but this is not always the case. It is surprising that potatoes planted in sandy soils that are supposed to be less prone to cracking, may still suffer severe losses due to the potato tuber moth. The main reason that larvae still reach tubers, even when conditions do not favour cracks, is that only minute or microscopic cracks are needed as passageways for the very small larvae. Larvae are only 0.2 mm in diameter in their first instar, and (unnoticeable) cracks of that size form easily in soils when tubers are bulking or when wet soils dry out.

Other practices that may help to reduce the incidence of potato tuber moth damage include planting cultivars that are not sensitive to deeper planting or those that do not produce shallow tubers, the use of pheromone traps to monitor the incidence of male moths in fields, the use of narrow-range insecticides that will not kill their natural enemies, and the use of several insecticides in different groups to prevent the build-up of resistance. Sanitation plays an important role, e.g. the elimination of piles of culled potatoes and regular destruction of volunteer potato plants and solanaceous weed hosts. Sanitation is aimed at reducing moth numbers in off-seasons when potato plants in cultivated fields are not available to the pest. Practices that may directly lead to tuber infestations include: leaving heavily infested foliage in the fields after vine-pull and leaving harvested potatoes in fields overnight. The postponement of harvesting after vine-kill will result in a higher incidence of damage. In South Africa, the only cultivar that seems to be less preferred by moths is Vanderplank with a lower percentage pupation compared to other cultivars.

Natural enemies may reduce tuber moth numbers in fields by a staggering 98% (Visser 2007). It is mainly two imported parasitoids, *Copidosoma koehleri* and *Apanteles subandinus*, that are responsible for potato tuber moth mortality in fields. However, a high incidence of parasitism is not always related to low levels of damage, and parasitoids are not always present in fields.

Synthetic pheromones are available to monitor potato tuber moths in fields and in storage. These pheromones are so potent that it is not uncommon to find a string of moths on the wing following a person walking through a field with one of these lures in his or her pocket. Custom-made water pan traps work as effectively as commercial traps. It must be remembered, however, that only male moths are attracted and mass-trapping will therefore not be very effective. Mass-trapping and mating disruption, however, may be an option in potato stores.

A naturally occurring granulose virus is known to kill potato tuber moth larvae under favourable conditions. This virus infects populations when stress levels are high, e.g. when both ambient temperatures and humidity levels are high. Although studies have been carried out to evaluate the effect of this virus on potato tuber moth larvae under field conditions (references in Capinera 2001 and Visser 2004), its obvious potential has unfortunately not led to the production of commercial products. The main reason is that infected larvae do not die before they reach the pupal stage, and damage is therefore not preventable in the treated generation.

Genetically modified potatoes that are completely resistant to attacks by the potato tuber moth have been tested in South Africa. Although such potatoes will eliminate the use of insecticides (or any other control strategy) against this pest, they have not been released.



The potato tuber moth is a small brownish moth, 8 mm in length.



Tuber moth pupae are formed inside silken cocoons that are strengthened with soil particles or debris. In potato fields, they use the soil below plants, and the cocoons are therefore not easily noticed.



A blotch leaf mine in leaves is a clear indication of potato tuber moth infestation.



Leaf damage by the larvae potato tuber moth is usually only visible as brown marks on leaves.



When potatoes are harvested that were previously attacked in the field, clear tunnels or mines are visible on the surface of affected tubers.



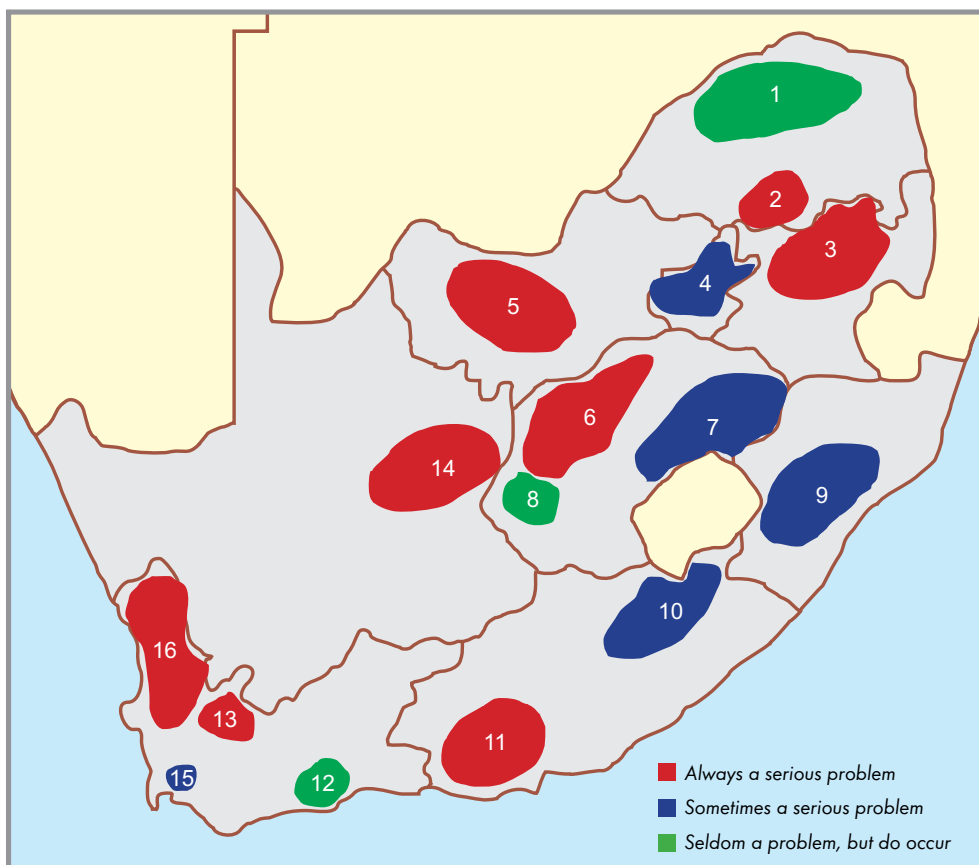
When stored tubers are attacked, excreta are clearly visible protruding from feeding sites.

## NEMATODES

### Background

Nematodes are microscopic, roundworms that live in soil, water and plant tissues. Many nematodes are not pests but feed on fungi, bacteria, other nematodes and insects. However, some nematodes are specialised to live on plant roots or on underground plant tissues. They may cause considerable damage by negatively influencing the water/nutrient transport channels of plants or by damaging their underground vegetative reproductive organs and roots.

Nematodes often occur in a symbiotic relationship with fungal diseases like *Verticillium* and other wilting diseases. Nematodes occur worldwide and are transported within plant material and in soil adhering to roots (Kleynhans et al. 1996). The most important ones that attack potato include *Globodera rostochiensis*, *Meloidogyne* spp., and *Pratylenchus* spp. The golden/potato cyst nematode, *Globodera rostochiensis*, is a quarantine pest found in isolated areas of South Africa.



### Description

Most nematodes have a simple life cycle consisting of an egg, four larval stages and the adult male and female. The first-stage larva usually remains inside the egg. Second-stage larvae that hatch from the egg search for plant roots to infest. The larvae use the capillary forces in moist soils to move distances of up to a metre to reach susceptible plant roots. Depending on the species, nematodes may either feed on root surfaces or penetrate the root tissue to establish permanent feeding sites. The second-stage larva then moults three times, after which it turns into a male or female. Depending on the species, females may lay 50-2 000 eggs. Under favourable environmental conditions, the life cycle may be completed in 4-8 weeks, depending primarily on ambient temperature.

**Root-knot nematodes, *Meloidogyne* spp.** The most common nematodes that attack potatoes in South Africa are the root-knot nematodes. They have a very wide host range, attack most crops and occur worldwide. Most species in this genus prefer hot climates and lighter (sandy) soils. They hibernate in uncultivated soils as eggs in gelatinous egg masses produced by the females. In soils, these eggs remain viable for many years and will only hatch when a new host is grown close-by.

When root-knot nematodes infest roots and tubers, visual symptoms may be dramatic, with galls covering entire surfaces. The tubers form these galls in response to salivary secretions of the feeding nematodes. Growth of potato plants may become stunted when infestations are severe - yellowing, wilting and dying off may occur. When cutting open infested potato tubers, females and egg masses may be observed up to 20 mm below the skin. At low ambient temperatures, these eggs can survive for as long as two years within the tubers. Contamination of new soils is, therefore, possible when planting infested tubers.

Nearly all vegetables are susceptible to root-knot nematode attack, especially tomato and potato. Sweet corn, however, is tolerant and is usually not damaged.

**Lesion nematodes, *Pratylenchus* spp.** The lesion nematodes are less common than root-knot nematodes, but injury by these nematodes can be severe enough to cause economic losses, especially at ambient temperatures above 20°C. Damage symptoms include necrotic lesions on roots that are visible as darkened or brown areas at the sites of invasion, and in underlying feeding sites within the root cortex. Later more extensive necrosis and root rot may occur, resulting in poorly developed and brownish root systems.

Above-ground symptoms are often confused with malnutrition or disease. Yellowing of plants and reduced foliar growth may be observed in patches in a field. In potatoes, infested tubers may show a variety of symptoms. They generally look unhealthy, with purple-brown pimples, pustules or wart-like protuberances. Sometimes lenticels are infested, resulting in dead, corky cells.

**Potato/golden cyst nematode, *Globodera rostochiensis*.** This is currently the only pest occurring on potatoes in South Africa that requires quarantine measures. At present, it occurs only in some areas (Western and Eastern Cape provinces, and a few isolated areas elsewhere) and when encountered, has to be reported to the Department of Agriculture. Above-ground symptoms are similar to those of the other two nematode species. Control is extremely difficult because the protected eggs are encased in tough cysts.

### **Control**

Nematodes may be controlled by soil nematicides, crop rotation, early harvesting, fallow cultivation or planting of resistant cultivars. For crop rotation to be effective, crops that are not hosts to nematodes must be used in the rotation sequence. Suitable non-hosts include grasses like Bahia grass and Bermuda grass. It is, however, important to remove all weeds growing among the grasses that may serve as hosts.

Where nematodes are known to be problematic, crops must be harvested as early as possible. A fallow period of at least two years, with no susceptible host, may decrease nematode populations greatly. However, if the soil is reworked (disked) every two weeks in summer, even a one-year fallow period will reduce nematode numbers greatly. Crop residues, i.e. stems with roots, must be removed from soils as soon as possible after the final harvest. The best strategy is to remove all nematode food sources from the soil.



Typical symptoms on roots attacked by the root-knot nematodes (*Meloidogyne spp.*) These nematodes get their name from the familiar “knots” that they induce on the roots of plants. Such deformed roots are severely restricted in their ability to transport water and nutrients, resulting in the wilting or death of plants. Infected tomato roots are shown here.



Egg masses of the root-knot nematode may be found up to 20 mm below the skin of a potato. At low temperatures, the eggs can survive for many months within such tubers.



The circled area indicates a control block (5 x 5 meters), which were not treated with a nematicide. The result is dying, diseased looking potato plants.

## APHIDS

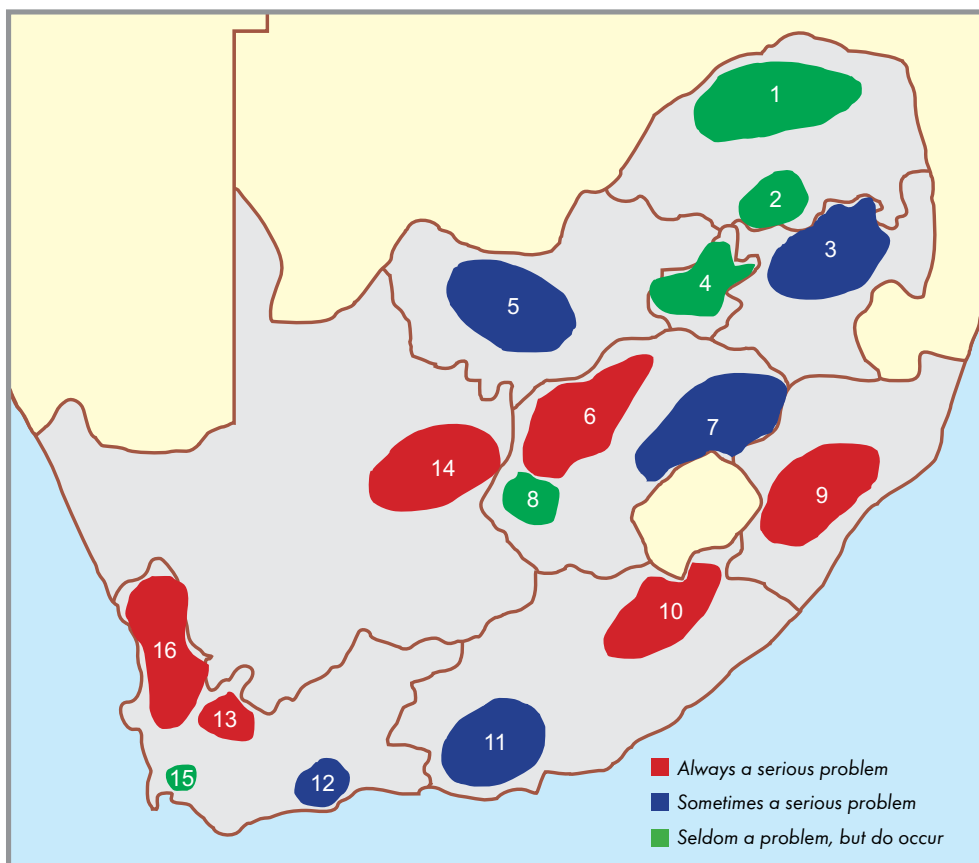
### Background

Aphids have piercing-sucking mouthparts with which they extract plant sap from the phloem (nutrient-carrying canals) in plants. They are small, less than 4 mm in length, and are usually found feeding together in groups on plant tissue. They suddenly appear on crops and multiply very rapidly. They usually do not cause visible or dramatic damage symptoms on most plants, but their presence alone is unacceptable to most growers. Under certain conditions, however, severe crop losses may be experienced, e.g. when they act as virus vectors.

The biology of aphids varies considerably between species. To add to the confusion different scientists report different developmental rates for the same species. In general, using the five most common species that occur in South Africa, and averages in Capinera (2001), nymphal development takes 5-10 days, females live for 20-40 days, one female produces 50-100 offspring and there may be between eleven and 35 generations per year. Aphids give birth to young at an average rate of 2-5 per day. Most start producing young at the age of ten days. Most aphids live for another week after given birth to their last young.

The lower and upper ambient temperature thresholds for development range between 4°C and 37°C. The optimal developmental temperature varies greatly among species. All aphid species can lay eggs. Eggs are usually only produced as a survival strategy in areas with freezing winters. Because potatoes are annual crops, egg production would be of no use to the aphid (the eggs will perish with the crop). Aphids, therefore, make use of a primary host for egg-laying. This is usually a woody perennial plant, e.g. the green peach aphid utilises peach trees, and the potato aphid rose trees. Other aphid species utilise other hosts, and sometimes an aphid species may use more than one host plant species.

In areas with freezing winters and under normal conditions, aphids start producing both female and male winged forms in autumn. This phenomenon is triggered when prevailing ambient temperatures start to fall and when day



lengths shorten. These forms migrate from potatoes to their primary host. Females arrive first and start producing wingless, egg-laying forms. The migrating, winged males produced on the secondary host (potatoes), are attracted to these females (on the primary hosts) by pheromones released by the females. One male arriving in such a colony may mate with several females. The fertilised female then lays her eggs on these primary hosts (trees). The eggs are very small and are deposited in concealed and protected places like crevices in and near buds. During cold winters all aphids may succumb, but when spring arrives the eggs hatch to give rise to new populations. A few generations may develop on the primary hosts, but after some time winged forms are produced that migrate to the summer secondary host (potatoes). In areas with moderate winters the adults overwinter on the secondary host (e.g. volunteer potatoes). Reproduction may, however, continue on warmer days, and in protected areas such as greenhouses, actual overwintering may not occur.

Nearly 40 aphid species are known to attack vegetable crops in South Africa (Millar 1994). The following nine aphid species are reported to use potatoes as a host on which it can reproduce (Visser 2009).

1. *Aphis gossypii* (cotton aphid, melon aphid)
2. *Aphis nasturtii*
3. *Aulacorthum solani* (greenhouse potato aphid, foxglove aphid)
4. *Macrosiphum euphorbiae* (potato aphid)
5. *Myzus ornatus*
6. *Myzus persicae* (green peach aphid, peach-potato aphid)
7. *Rhopalosiphoninus latysiphon* (potato clamp aphid)
8. *Smynthurodes betae* (potato tuber aphid, bean root aphid)
9. *Uroleucon compositae*

More species may be found in potatoes (Blackman & Eastop 2000; Kruger et al. 2014). Of the nine listed above, the three most common aphids on potatoes in South Africa are the green peach aphid, the potato aphid, and the cotton aphid. These are discussed in more detail hereunder.

### Descriptions and host ranges of the three most common aphids on potatoes

***Myzus persicae* (green peach aphid, peach-potato aphid).** Distribution: worldwide. Host plants: potato, tomato, green pepper, eggplant, carrot, beetroot, lettuce, crucifers, with peach as primary host (Myburgh 1988). Capinera (2001) adds (international hosts): artichoke, asparagus, bean, broccoli, Brussels sprouts, cabbage, cauliflower, celery, corn, cucumber, fennel, kale, kohlrabi, turnip, mustard, okra, parsley, parsnip, pea, radish, spinach, squash, watercress, watermelon and various weeds. Winged and wingless forms are approximately 1–2 mm in length. Wingless forms vary in colour: whitish green, pale-yellow-green, grey-green, mid-green, pink, red or almost black. Under colder conditions, populations tend to become more deeply pigmented green to purple-red. Winged forms have a black central patch on the upper side of the abdomen. Immatures of the winged forms are often pink or red, especially in autumn populations.

Except for curling young leaves of peach trees in spring these aphids usually prefer older or senescent leaves of plants. They will therefore mostly be found on the lower third of plants. However, during long periods of cool, cloudy weather, the aphids may move to the upper parts of the plants (University of California 1986). They will also be more abundant on, and will peak sooner, on cultivars with a short growing season (Minks & Harrewijn 1987). Nearly all plants are attacked (more than 40 plant families). This aphid is considered by many as the most important aphid virus vector worldwide, transmitting more than 100 plant viruses. It is the most important vector of the Potato leafroll virus (PLRV) on potato.

***Macrosiphum euphorbiae* (potato aphid).** Distribution: worldwide. Host plants: potato, tomato, cucurbits (Myburgh 1988). Capinera (2001) adds (international hosts): spinach, lettuce, asparagus, beet, celery, chicory, corn, cucumber, eggplant, horseradish, kale, mustard, pea, parsnip, pepper, pumpkin, rhubarb, sweet potato.

watercress and various other field and fruit crops as well as flowers and various weeds. These aphids feed on over 200 plant species.

They are large aphids, approximately 2–4 mm. Wingless forms are spindle- or pear-shaped. They are usually green, but sometimes yellow, pink or purple-red, often shiny. Eyes are distinctly reddish. Legs and tube-like protrusions on the back of the body (siphunculi or cornicles) are usually the same colour as the body (siphunculi may be darker at the ends). Immatures are rather long-bodied, paler than adults, with a dark spinal stripe and a light dusting of whitish grey wax. This aphid (especially the pink forms) prefers the upper parts (Minks & Harrewijn 1987) of potato plants (upper third) and sometimes may infest apical growth points severely (Annecke & Moran 1982). Infested leaves take on a distorted appearance on some plants. In potatoes the leaf edges turn downwards in contrast to the upward-turning of leaves when plants are infested with Potato leafroll virus. Leaf deformities are less apparent on plants like tomato, pepper and eggplant, but the flowers of these plants are readily attacked.

The primary host (overwintering host) is the rose tree, but in temperate climates, females overwinter on secondary hosts (potatoes). Eggs may occasionally be found on vegetables (Capinera 2001). They may be very abundant on cool-weather vegetables, but favour potatoes in warmer weather. This aphid is a vector of more than 40 non-persistent and five persistent viruses. It is less important than *Myzus persicae* in transmitting PLRV to potatoes. One of the reasons for this could be that it is capable of transmitting PLRV in a non-persistent manner, losing the virus soon after acquiring it (University of California 1986; Van Oostrum 2002).

***Aphis gossypii* (cotton aphid, melon aphid).** Distribution: worldwide. Host plants: more than 700 plant species have been recorded as hosts, including potato and cucurbits (Myburgh 1988). Capinera (2001) adds (international hosts): asparagus, pepper and eggplant; also citrus, cotton and hibiscus. Host-specific races exist. Winged forms (0.9–1.8 mm) are variable in colour. Large specimens are dark green to black, but adults produced in crowded colonies at high ambient temperatures may be less than 1 mm in length and very pale yellow to almost white. Nymphs may be covered in white wax. Usually, the aphids are an uneven green colour (dark and pale green colours on the same individual). Pale individuals prevail in summer, while the darker individuals are more common in winter. Tube-like protrusions on the back of the body (siphunculi or cornicles) are dark.

Cotton aphids feed on the underside of leaves or growth tips. They are notorious for leaf distortions, causing the leaves to curl and becoming chlorotic. They also secrete vast amounts of honeydew. They are known to transmit more than 50 different plant viruses.

### Damage

Aphids may attack any part of a plant, depending on the aphid species and the host plant. When attacking leaves, most aphids prefer the underside of leaves. However, in crowded conditions, they may be found all over the plant.

Aphids may damage potatoes in three different ways. Normal feeding may affect plants negatively, viral transmission may make plants sick, and the honeydew produced by aphids may influence plants negatively. Some aphids are known to inject toxins into plants when feeding, but this has not been studied in detail. Most aphids tend to reproduce rapidly and reach high numbers on plants that are growing actively. Under normal conditions, when plants are not stressed or deprived of nourishment, aphid feeding will not necessarily result in crop losses. However, when plants are stressed, or when large numbers of aphids have been feeding unrestricted for extended periods of time, plants may wilt and sometimes die. This is especially the case when plants are small and young.

Symptoms of aphid feeding include curling of leaves and stunted plants. Feeding by some aphids produce different symptoms, e.g. the green peach aphid rarely causes leaf distortions on its secondary hosts (e.g. potatoes), while others like the cotton and potato aphids cause severe leaf curling in some plants.

Most aphids are vectors of plant viruses. Viruses are micro-organisms, smaller than bacteria, that can only survive and reproduce within living organisms. Most plant viruses need a vector (transmitter) to spread the virus from a diseased to a healthy plant. Aphids are some of the most effective plant virus vectors (others include thrips). In

certain situations, insect plant-virus interactions may be complex. For example, some viruses need a particular aphid species to act as its vector and sometimes certain viruses need to incubate inside the body of an aphid before it becomes infectious (e.g. Potato leafroll virus). These types of viruses stay active in that aphid for the rest of the aphid's life (persistent virus). Other viruses do not survive inside aphids, but they are usually transmitted immediately when an infected aphid inserts its "contaminated mouthparts" into plant tissue (non-persistent or stylet-borne viruses, e.g. PVY).

Newborn aphids are never infected through their mothers although they may acquire and transmit viruses when feeding for the first time. Of all aphid species, the green peach aphid is thought to be the most effective virus vector.

Production of honeydew by aphids may negatively influence some crops, sometimes severely so. Aphids excrete honeydew in the form of sticky droplets through the anus. In the absence of ants to collect this sticky nourishment directly from the aphids' anuses, entire plants may be covered in a sticky mass. Dust particles and aphids' cast-off skins adhere to these sticky surfaces, and often a non-pathogenic fungus, *Capnodium sp.*, grows on such surfaces. This fungus, also known as sooty mould, does not infect plants but produces a brown or black growth on leaf surfaces that may render plants incapable of photosynthesis.

### Control

Aphids are one of those groups of insects that have many registered insecticides for their control (see [www.croplife.co.za](http://www.croplife.co.za)). These insecticides usually work very well and can limit crop losses to a large extent. However, insecticides are not always effective in preventing the transmission of viruses to healthy plants and may, in fact, enhance viral transmission if sub-lethal doses are present on plant surfaces. Some of the stylet-borne viral diseases (e.g. PVY) are rapidly transmitted, and insecticides may not kill the aphids before virus transmission has occurred.

Seed potato growers use a monitoring system to inform them when aphid numbers are peaking or when aphids are migrating into their crops. During such times additional care is taken with regular insecticide applications in well-structured spraying programmes. Monitoring is carried out with yellow water pan traps, sticky traps, suction traps and regular scouting within fields. The persistent viruses, e.g. Potato leaf roll virus, however, can be controlled by killing the aphids with insecticides because these viruses are only transmitted when the aphid is allowed to feed unhindered for a few minutes.

Various alternative methods can be used to limit aphid numbers in crops. Where natural enemies are absent, weeds must be removed from an area demarcated for planting a crop a few weeks before planting commences. Weeds in the vicinity must also be removed. During periods between crop seasons, weeds play a critical role in keeping aphids surviving until the new season's crops arrive. Volunteer plants in a harvested field act as weeds and must always be removed and destroyed.

Naturally occurring fungi may play a major role in keeping aphid numbers down. Infected aphids usually turn brown and die. However, most of these fungi are only effective under certain optimal environmental conditions. Some need cool, moist conditions and others warm, moist conditions, whilst others need high aphid populations before they start making an impact on their numbers.

Other natural enemies include the following predators: lady beetles, lacewing larvae, assassin bugs, predatory mirids and syrphid fly larvae. Several parasitoids (very small wasps) are known to be very effective natural enemies. Most insecticides will also kill the beneficial natural enemies when applied against aphids or other pests.

As most aphids are weak fliers and are wind-blown to nearby fields easily, crops downwind from an infested crop may be susceptible to severe infestations. If possible, new crops should therefore not be planted downwind from a previous or other crops.

Other methods for aphid control that have been proposed over the years include the use of aluminium or plastic mulches, trap cropping, crop rotation, interplanting (intercropping), resistant cultivars, time of planting, providing hiding places and host plants for natural enemies, reducing nitrogen fertilisers, vegetable or mineral oils, pheromones, crop-free periods, whitewash sprays, coarse-net covers and destruction or spraying of overwintering hosts. Most of these methods, however, were found to be impractical, of short duration or not worth the effort. Barrier-cropping in Hawaii with sunn hemp or buckwheat has recently shown to be an effective means of providing a virus-sink (aphids feed on the barrier plants and lose the virus they bear on their stylets).



Green peach aphids, *Myzus persicae*.



Potato aphids, *Macrosiphum euphorbiae*.



Cotton aphids, *Aphis gossypii*.



A potato aphid giving live birth. During normal years this is the predominant way of reproducing.



A young potato plant infected with *Potato leafroll virus* (PLRV), one of the most serious viral diseases confronting the potato farmer.



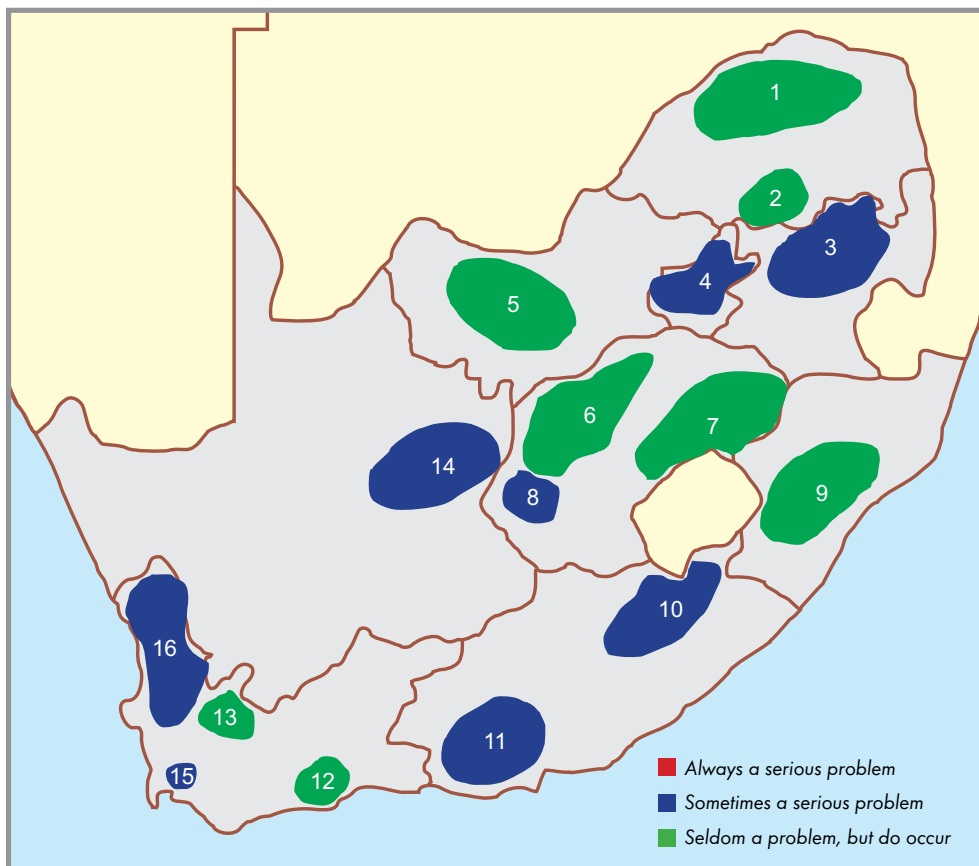
A colony of green peach aphids inside the curled-up leaves of a peach tree. Infested leaves curl characteristically.

## CATERPILLARS

### Background and description

Approximately 42 caterpillars are known to attack vegetables in South Africa. Of these, at least 25 species feed on potatoes. The most common caterpillars (moth larvae) that are usually reported on potatoes include the African bollworm (*Helicoverpa armigera*), the lesser armyworm (*Spodoptera exigua*) and the semi-loopers (mainly *Chrysodeixes acuta* and *Thysanoplusia orichalcea*).

Caterpillars feed on foliage and flowers of potatoes. The first symptoms are usually holes of varying sizes in leaves. Although feeding symptoms and the presence of caterpillars are alarming to the potato farmer, severe yield losses due to their feeding are rare. It is only when large numbers of caterpillars occur in fields with small plants, that control is warranted. Various insecticides are registered against different caterpillars on potatoes ([www.croplife.co.za](http://www.croplife.co.za)), but spraying programmes aimed at other pests usually keep their numbers low.





Lesser armyworm (*Spodoptera exigua*). One of the many colour variations.



Tomato semi-looper (*Chrysodeixis acuta*). They characteristically walk with a looping action.



African bollworm (*Helicoverpa armigera*). They characteristically fold their head area under their body when threatened.



African bollworm moth. One of the many colour variations. Like most moths, they are nocturnal and seldom seen during daytime.

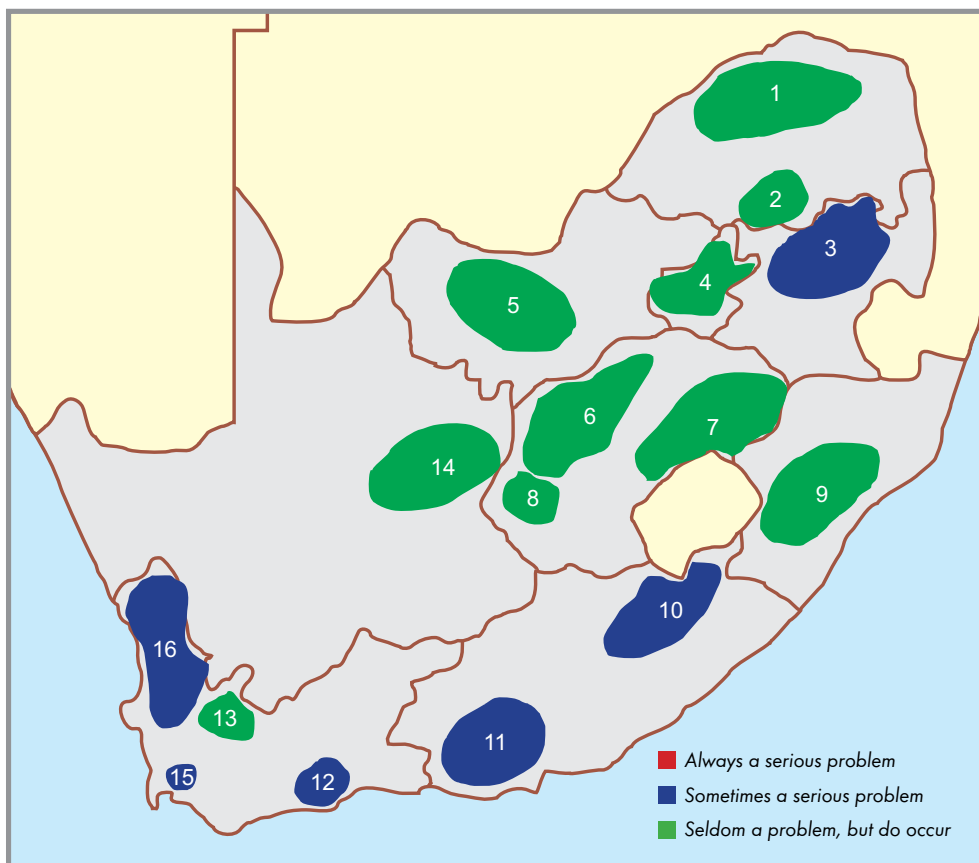
## CUTWORMS

### Background and description

Approximately seven cutworm species attack vegetables in South Africa. The three most common species on potatoes include the common cutworm (*Agrotis segetum*), the brown cutworm (*Agrotis longidentifer*), and the black cutworm (*Agrotis ipsilon*).

Most cutworms hide during the day and only appear from the soil after sunset. They roam the soil surface, eating, or cutting-off young tender stems at the base of plants. One cutworm may topple several plants, without eating the rest of the toppled plant. Although cutworms will not tunnel purposefully into soils to search for tubers, they will attack tubers when encountered.

Control of cutworms are mainly by insecticidal spraying of soil surfaces early in the season, but sanitation by removal of weeds a few weeks before planting may also reduce cutworm numbers at the beginning of the season.





Cutworms damage young potato plants by cutting-off stems of young plants (arrow). They usually do not feed on the plant itself.



Cutworms will also feed inside tubers under the soil surface when encountered.



Most cutworms characteristically curl up into a "C" when handled.



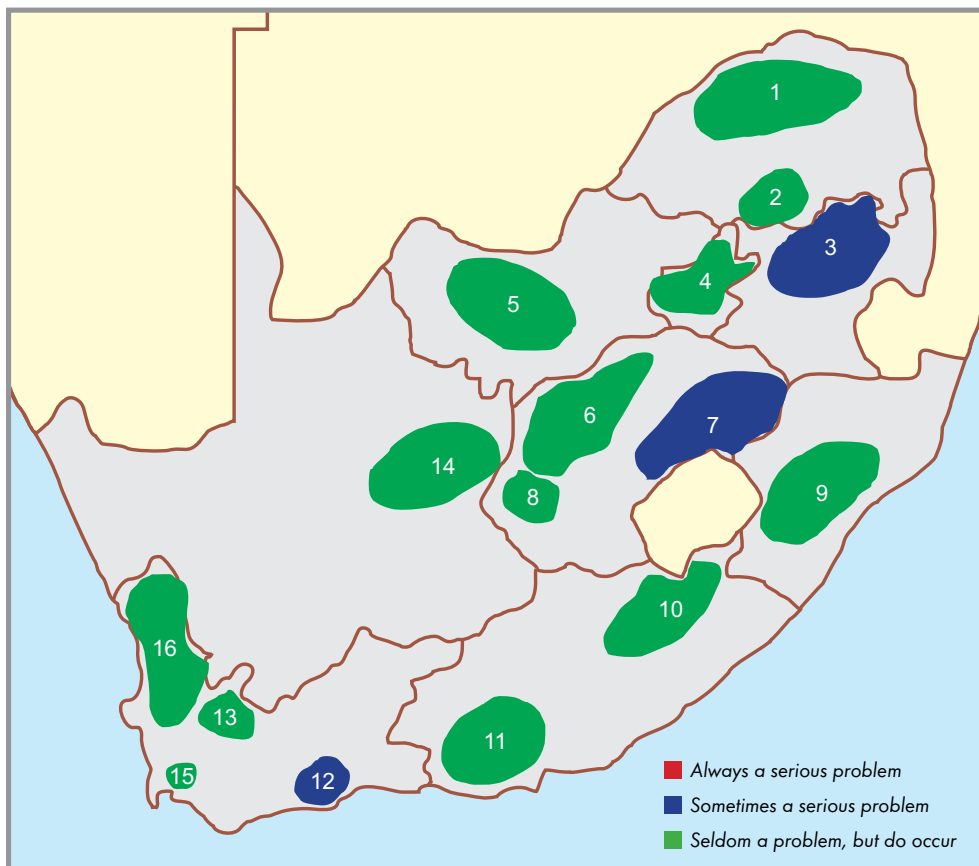
Brown cutworm moth (*Agrotis longidentifer*). They are mostly active at night.

## BLACK MAIZE BEETLE

### Background and description

The black maize beetle (*Heteronychus arator*) is a soil-dwelling pest, with all life stages occurring in the soil, except when the adults fly out to swarm. As its name indicates, the beetle is primarily a pest of maize, but it also attacks potato, pineapple, sugar cane, sorghum, and other plants. It is an indigenous African pest and in South Africa it occurs mainly in the eastern grassland areas and along the coast in the Eastern and Western Cape Provinces.

Beetles are 12-15 mm in length. Mating takes place in the soil and females lay their eggs down to 15 mm below the surface. The larvae do not gather under host plants (King 1977) because they only feed in humus-rich soils that contain old plant and organic matter. The larvae live and pupate in the soil, after which the emerging adults may move to new feeding sites. Adults are present year-round in low numbers, but peaks are found in October-December and then again in March-April. It is during these months that damage to potatoes can be expected. Larvae characteristically curl up in a C-shape when disturbed. Compared to most other vegetable pests, the black maize beetle has a long life cycle, taking up to one year to complete a life cycle. Usually, only one generation per year is produced, but in some parts of the country a second generation may be encountered.



Adult beetles chew holes into tubers and roots. However, they also often damage seedlings or young plants by gnawing into their stems just below the soil surface, much like the cutworms, but tend to shred the plant material. Of all vegetables, potatoes are the most vulnerable to attack. However, this only happens when a substantial source of beetles is located nearby. Because there is usually only one generation per year, build-up of numbers within fields does not occur. The beetles usually fly in from surrounding areas. When potatoes are planted close to maize fields, or when potatoes follow maize in the same field, damage to potatoes can be expected, especially in the Eastern Free State and Mpumalanga production regions. Although the larvae resemble white grubs, they do not attack tubers, and are not known to feed on roots of plants (Venter & Louw 1978).

Soil insecticides are available ([www.croplife.co.za](http://www.croplife.co.za)). Potatoes should never follow maize as a rotational crop because the larvae may survive in harvested maize fields for months. Reworking soils kills many pupae by exposing them to the elements.



Black maize beetle larvae do not feed on living plant material but live on organic matter in the soil.



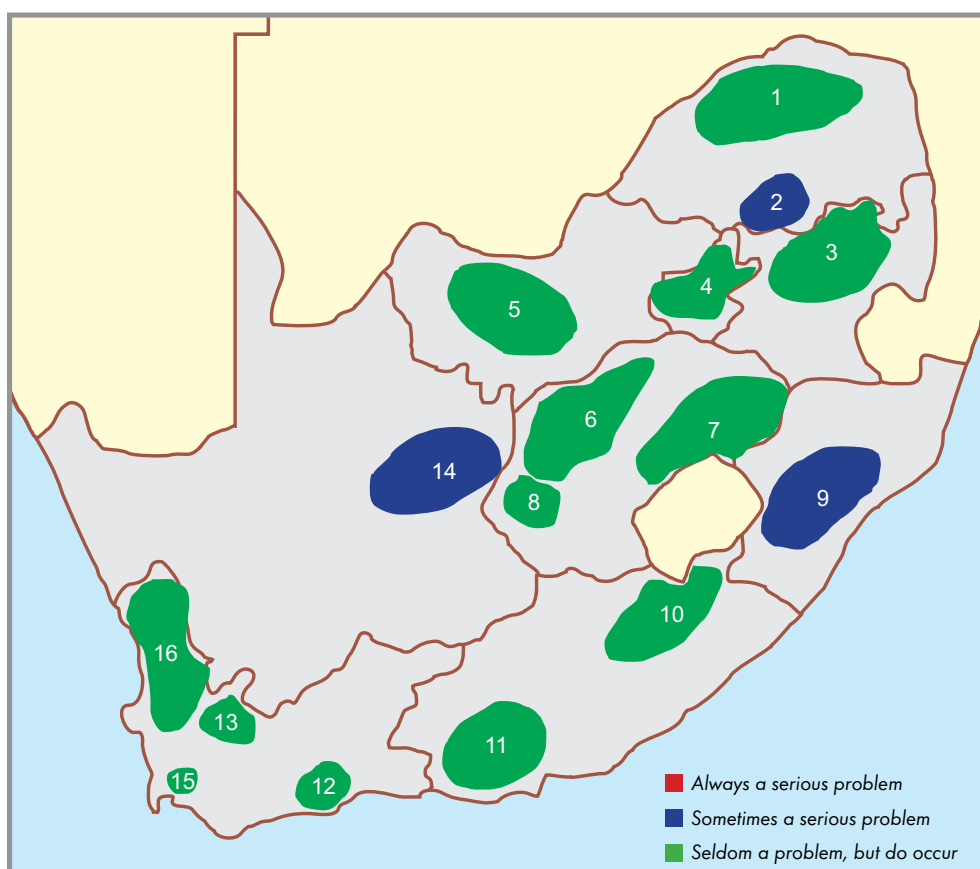
Adult black maize beetles may chew large irregular holes into potato tubers.

## WHITE GRUBS

### Background and description

Various white grub species have been reported to damage potatoes. However, only three species have positively been link to tuber damage. They are: *Anomala transvaalensis*, *Hypopholis sommeri* and *Temnorhynchus retusus*. Of the three species encountered in potato fields, it is only the large wattle chafer, *Hypopholis sommeri*, that is of economic importance.

*Hypopholis sommeri* is a stocky beetle, 18-20 mm in length with pale-brown elytra and a dark brown thorax. It is also commonly known as the large wattle chafer or rose chafer. The adult beetles are known pests of wattle, sugarcane, pine trees and roses. Larvae of two other beetle species are known to damage potato tubers, namely *Temnorhynchus retusus* and *Anomala transvaalensis*. *Temnorhynchus retusus* is approximately 18 mm long, a native black beetle that is abundant in the western parts of South Africa. Its larvae are white grubs capable of chewing large, irregular holes into potato tubers. *Anomala transvaalensis* is a brown scarab measuring approximately 14 mm in length. Its larvae chew large, irregular holes into potato tubers (Donaldson 1981).



All white grubs are soil-living larvae of various species of beetles belonging to the family Scarabaeidae (Skaife 1979). Young white grubs feed on soil rich in organic matter, while older individuals may also feed on roots and tubers. The roots of grasses are sometimes a preferred food source for some species. They may be serious pests of turfs and lawns. White grubs have limited mobility – they do not search for suitable host plants, but rather consume plant material (roots and soil) wherever they find themselves. Their distribution is therefore a function of the adult beetle's choice of oviposition sites. Potatoes are not known to be a preferred host plant. White grubs may therefore be incidental or secondary pests under most circumstances, but may become serious pests on occasion. When severe damage is experienced due to white grubs, it is usually when potatoes were planted in fields in which grasses were growing. The larvae then have little choice but to feed on roots or tubers. Young plants may be killed and older plants may be weakened when grub numbers are high.

No insecticide is specifically registered for white grub control on potatoes. Planting in fields in which grasses were growing must be avoided. Non-hosts such as lucerne can be used in a rotation programme. Shallow ploughing or reworking of soils will kill many white grubs. No-tillage or reduced tillage enhances white grub populations.



White grubs typically have a white body, orange head, well-developed legs and a dark abdomen.



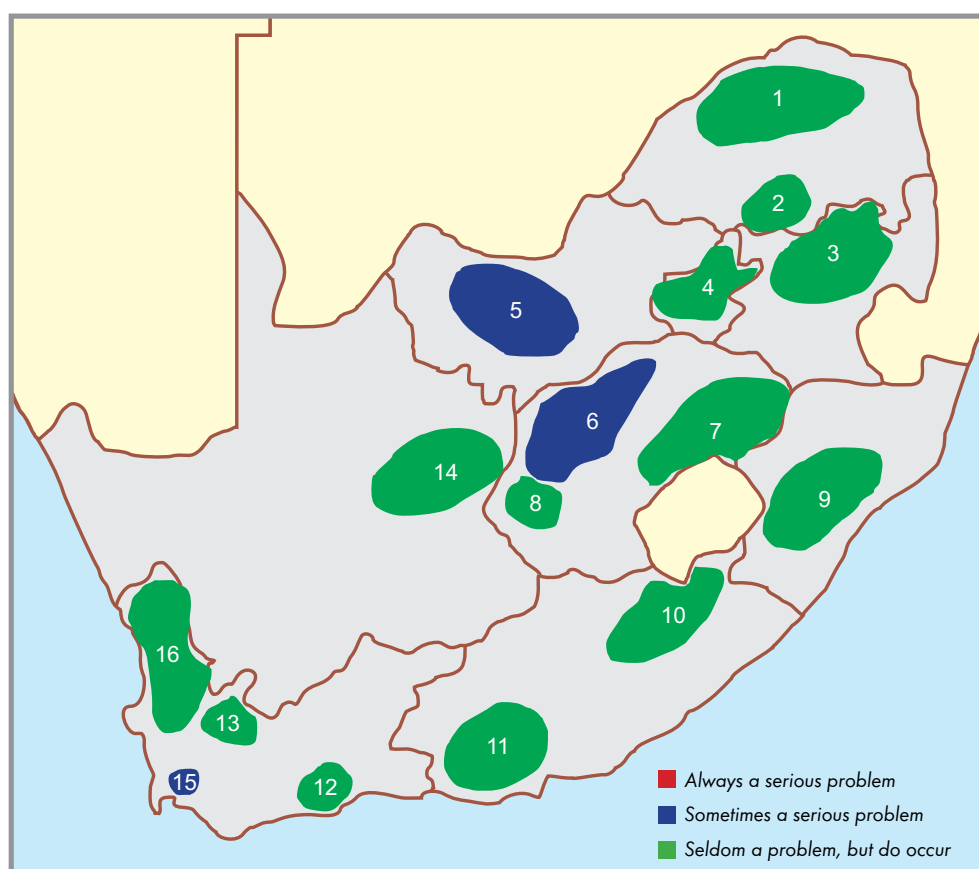
The large wattle chafer, *Hypopholis sommeri*, may severely damage potato tubers.

## RED SPIDER MITES

### Background and description

The most common and best-known mite pests are the spider mites in the family *Tetranychidae*. The most common genus is *Tetranychus*, with eleven species in South Africa, of which eight attack vegetables (Meyer 1996; Meyer & Craemer 1999). On potatoes, it is usually *Tetranychus urticae* or *Tetranychus evansi* that sometimes occur in large numbers on foliage.

Most mites prefer the underside of leaves. However, at high population densities the same mites will occupy all plant parts on all sides, and will congregate on the highest areas to facilitate dispersal to new areas by wind or animals. This is especially true in the case of spider mites, which also spin elaborate webbing over entire plants to facilitate movement and dispersal. However, under normal population densities the same mites only spin “mat-like” webs on the underside of leaves under which they feed and reproduce.



Mites have piercing-sucking mouthparts. They first damage plant tissues with their stylets and then withdraw the cell contents. Leaves usually have a speckled appearance, with white and yellow spots gradually replacing the green colour of the leaf. Although most feeding takes place on the underside of leaves, the symptoms are also visible from the upper side. Later on this chlorotic stippling expands, and the leaves develop a scorched appearance. Such leaves quickly turn brown and die. Mites usually gather on the upper dead or dying leaves in masses, and it is usually only then that the culprits are noticed. By this time control is usually too late and most plants will die.

Mites are some of the most difficult pests to control. Only the application of certain pesticides results in adequate control on susceptible crops like tomato. Unfortunately, no pesticides have been registered for use on potatoes.

Weeds are important alternative hosts for mites, especially solanaceous weeds. An important route of infestation is by transport on humans, animals and implements. Mites are brushed off onto any moveable object in infested fields (or from weeds) and may drop off at any time, infesting new areas in the process. Movement in infested fields should be curtailed and should never be visited before moving to a non-infested field.



Red spider mites spin elaborate webbing between leaves when their numbers increase.



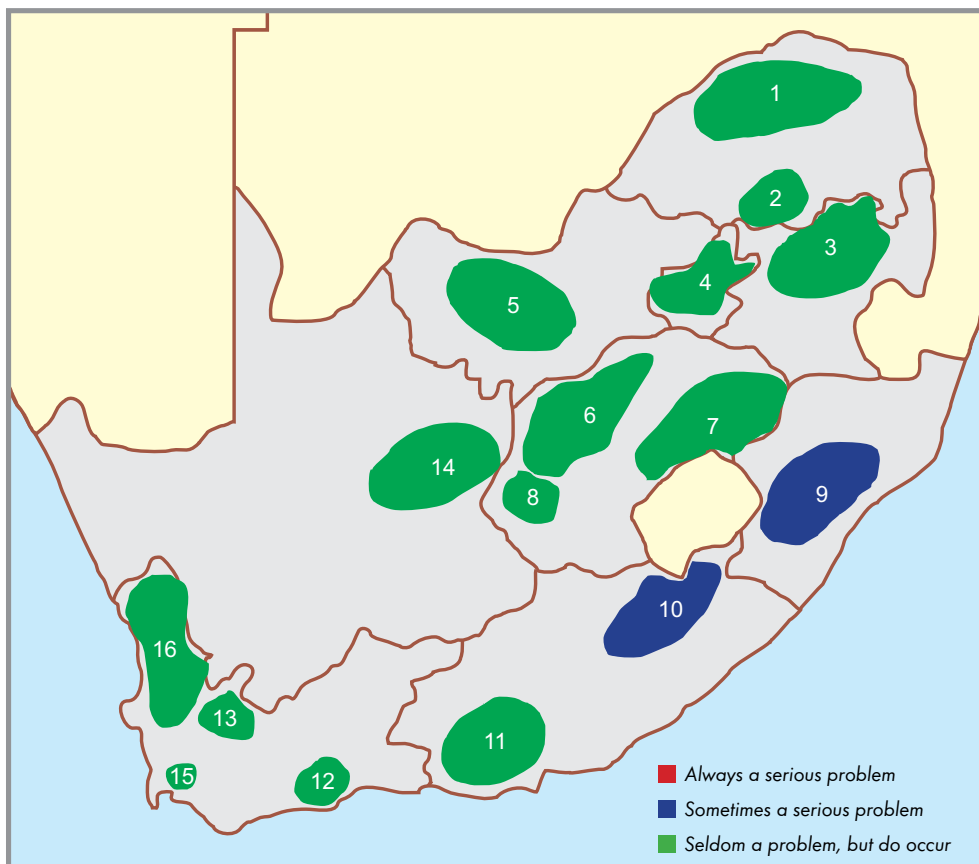
Infestations of red spider mites always start in isolated areas (e.g. the circled area).

## SNOUT BEETLES

### Background and description

Two species of weevils (snout beetles) attack potatoes in South Africa. The potato weevil (*Sciobius horni*) occur mainly in the eastern parts of the country, while the white fringed weevil (*Naupactus leucoloma*), mainly occur in the south-western parts of South Africa.

*Sciobius horni* was first noticed to damage potatoes in 1977 in the Free State Province (Venter & Schoeman 1978). The genus is endemic to Southern Africa. The beetle is dull to dark brown, 6-10 mm long and 3-4 mm wide. The larvae are typical snout beetle grubs - white, legless and usually curling into a C-shape when disturbed. The head is pale yellow to orange and the chewing mouthparts black. They grow up to approximately 10 mm in length and then leave the feeding area to pupate nearby in a cell constructed from soil particles. The pupa is whitish and remains in the protective cell until the adult beetle emerges. In areas where this pest has been troublesome, it was often found that at harvest the larvae had already left the tubers, making identification of the "culprit" difficult. The life cycle of this beetle has not been studied.



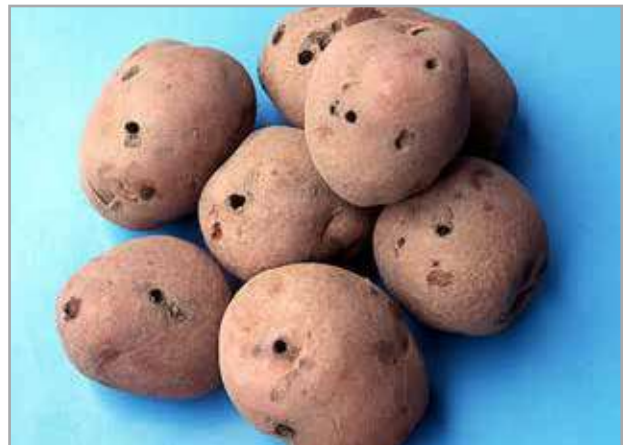
Originally from South America, the whitefringed weevil also occurs in the USA, Australia and New Zealand. It is a small (12 mm), grey, flightless beetle. The adults have a characteristic white band or “fringe” on the lower side of the wing covers, hence the common name. The larvae are legless, cream-coloured, and damage roots, below-ground stems and tubers.

The larvae of both weevils damage potato tubers, while the adults may chew on foliage. Shallow holes of up to 5 mm in depth and approximately 3–5 mm in diameter are eaten into tubers. Because these beetles cannot fly, damage usually occurs when crops are planted in infested soils. Although the adults are known to nibble on foliage, significant damage by them is unlikely. Serious damage by the larvae is uncommon, but do occur from time to time.

Crop rotation, clean cultivation and ploughing during off-seasons will greatly reduce potential damage by killing or exposing larvae hiding in soils. It is possible that these beetles may walk from an infested area to an adjacent newly planted field. In such cases furrows with poison or bait may be drawn between the two fields in an attempt to prevent the beetles from reaching the new crop. A few insecticides are registered against the potato weevil on potatoes ([www.croplife.co.za](http://www.croplife.co.za)).



A snout beetle larvae eating a hole into a potato tuber. These larvae can easily be recognized because they do not have any legs.



Typical damage symptoms of snout beetle larvae.

## MILLIPEDES

### Background and description

Millipedes are elongated creatures that move more slowly than most other arthropods. Millipedes vary significantly in colour, ranging from brown to black with yellow bands, to black with red bands to completely black. The giant millipedes of South Africa often reach lengths of between 20 and 30 cm (Lawrence 1983). One small species (3–4 cm) is also troublesome at times, especially in the western parts of South Africa.

Millipedes do not burrow purposefully into soils like other soil-dwelling insects. However, they may “push” away soil with their heads or wriggle themselves into loose soils or soils with a high organic content. They are often found under dead plant material or in moist places during the heat of the day. They are susceptible to loss of moisture and usually only move around early in the morning or on overcast days. In the summer rainfall regions, the larger millipedes hibernate in soil cells. They appear in large numbers after the first heavy summer rainfall, usually in October and November. After that they are abundant for a few weeks, but then their numbers dwindle. They are then usually only found under stones or plant debris during the day.

Millipedes are not known as a serious pest in commercial plantings. However, under certain conditions, small plantings or home gardens may be affected. They do not search for any particular crop because they are opportunists, feeding on any plant material encountered. In nature, however, they prefer rotting, decaying or even dried-out plant material (David & Celerier 1997). Small or young plants may well experience more damage while older plants with healthy, vigorously-growing foliage may not even be stressed.

Millipedes are quite often found inside a hollowed-out potato, the reason probably being that the inside of a rigid, damp substrate provides protection while feeding in a moist environment, rather than that they prefer potatoes as food. Some researchers emphasise the fact that damage to crops is usually a symptom of circumstances, e.g. planting in soils with too high an organic content, or other causes of original damage.

Because they are not insects, most insecticides are not very effective against millipedes. However, some of the snail baits available for use in home gardens are very effective. It is important to carefully read the labels on these baits before use, and to experiment as to which ones will control the millipedes in troubled fields. Shallow-bearing or exposed tubers are usually vulnerable. Regular ridging of potatoes is also recommended to cover exposed tubers. Millipedes do not reproduce inside fields because of their extremely long life cycle (at least one year). They are recyclers that help break down fallen leaves and foliage. They are truly beneficial creatures, in the same sense as earthworms.



Some millipedes are brightly coloured and others black.



Millipedes may nibble on potato leaves (arrow) but usually prefer decomposing or rotting leaves.

## SUCKING BUGS

### Background and description

Two sucking bugs are common in potato fields. They are the green vegetable bug *Nezara viridula*, and the tip wilters, e.g. *Anoplocnemis curvipes*. They are sometimes found in large numbers and may cause damage to potato foliage. As their name indicates, they suck the sap from foliage.

Green vegetable bugs are strong fliers, and can easily move from one host plant to another (Todd 1989). In winter the adults hibernate in sheltered areas like fallen leaves, under loose tree bark or any other protected place, including buildings. Adults are shield-shaped, 12–15 mm long.

Adult green vegetable bugs have a life span of several months. During this time, mated females may lay up to three egg batches, each containing between 30 and 130 eggs. Eggs are usually laid on the underside of leaves, but exceptions occur. They may also be laid on the upper side of leaves and on fruiting bodies. They are firmly glued together to the substrate in polygonal clusters. In cool months, eggs may take as long as three weeks to hatch. First instar nymphs are bright orange. During the last moult, wings develop to cover the abdomen of the adult bug. Nymphal development time is approximately one month in summer, but may be much longer in cooler areas or when the nymphs are forced to feed on less suitable food plants.

*Anoplocnemis curvipes* is known as the large black tip wilter. The males have prominent hind legs, sometimes armed with spines. They are strong fliers and may fly in from adjacent areas. One female lays an average of 55 eggs in clusters of approximately 15 over a two-week period. Eggs hatch after approximately one week and similar to the green stinkbug, first instar nymphs aggregate, but disperse after the first or second moult.

Sucking bugs feed by sucking sap from plant tissue with their elongated beaks, also called the rostrum or proboscis. While feeding, these bugs inject digestive enzymes to enhance sap flow through their thin stylets. When young shoots are attacked, the distal parts toward the tips may wilt and perish. This is usually due to feeding (extraction of sap), but is also due to the enzymes secreted by the bug.

No insecticides are registered for control of green vegetable bug and tip wilters on potatoes. However, spraying with contact insecticides for other pests may suppress their numbers. Some success has been obtained by planting trap crops near a susceptible crop. These trap crops, e.g. leguminous plants are then monitored and sprayed before the bugs develop wings and move to the potato plants. Other factors that keep populations down include excessive rainfall, low humidity, and desiccation of first instar nymphs on hot days.



The green vegetable bug, *Nezara viridula*.



*Anoplocnemis curvipes*, also known as the large black tip wilter (female).

## THRIPS

### Background and description

Thrips are minute insects rarely seen with the naked eye. At least six thrips species are known to attack vegetables in South Africa. The one of concern to the potato industry is the kromnek thrips, *Frankliniella schultzei*.

Immature thrips are wingless, while adults may be winged or wingless. Pupation usually occurs in the soil and sometimes in leaf debris. Before a female thrips lays her eggs in plants, she cuts a slit in the foliage. She then deposits eggs just below the epidermis with one end of each egg protruding slightly. In warmer climates, eggs usually hatch within three days. Development time is usually three weeks, but may be as short as 10–15 days under optimal conditions, and up to ten generations may be produced in one year (depending on the species).

Overwintering is usually in the adult or nymphal stages on alternative host plants, e.g. winter crops and weeds, or sometimes on leaf debris or in the soil. In areas with warmer winters or in greenhouses, reproduction may continue throughout the year. Thrips can reproduce without mating, but males usually form part of a colony, although in lower numbers than females.

Thrips have an unusual combination of rasping, piercing and sucking mouthparts. They physically damage plant surfaces without making holes or visible openings. Damage symptoms on leaves vary between crops, but thrips feeding usually results in silvery to darker areas, with small brown to black spots (thrips excreta) visible inside these areas. Infested leaves on some crops may have chlorotic to dead areas, especially the edges and tips of leaves.

Thrips are known to transmit more than twelve viral diseases in Southern Africa (Scholtz & Holm 1985). However, the most notorious virus transmitted is the tomato spotted wilt virus (TSWV). This virus is acquired by thrips during the larval stage, whereafter the thrips remain infectious for life. No other insect is capable of transmitting this virus. Thrips, on the other hand, do not transmit any of the other important potato viruses.

Placing yellow or blue sticky traps close to plants before they are transplanted will reveal thrips infestations (Wright 1992). Screening material to exclude thrips from a protected crop is not always effective because some thrips will enter through holes as small as 185 microns (Capinera 2001). Low barriers to prevent thrips movement and dispersal under field conditions may be a control option (Yudin et al. 1991). No insecticides are registered against thrips on potatoes.



Thrips are minute insects, approximately 1 mm in length, and not easily noticed on plants. Most hide in leaf axils or in flowers.



Thrips damage to potato leaves. Silvery areas with black spots are a clear indication of the presence of thrips.

## WHITEFLIES

### Background and description

Whiteflies belong to the same insect order as the aphids, Hemiptera. All whiteflies have piercing-sucking mouthparts and belong to the insect family Aleyrodidae. Worldwide there are approximately 1 200 whitefly species (Byrne & Bellows 1991). In South Africa, only 16 species have been recorded. Two of the species attack potatoes, namely *Bemisia tabaci* and *Trialeurodes vaporariorum*.

*Bemisia tabaci* is referred to as the sweet potato whitefly, cotton whitefly or the tobacco whitefly, while *Trialeurodes vaporariorum* is known as the greenhouse whitefly. Although certain vegetables are preferred by whiteflies, alternative hosts (including potatoes) will be attacked if the favoured crop is not available. Favoured crops include bean, cabbage, cucurbits, eggplant, lettuce, sweet potato and tomato. Plants in greenhouses are particularly susceptible, especially cucumber, eggplant, potato and tomato. The origin of whiteflies is uncertain, but it is thought that the greenhouse whitefly originated in the Americas and *Bemisia* in Asia. The two species are pests worldwide, especially in areas with moderate climates and in greenhouses.

Nymphs and adults suck sap from plant parts, usually on the underside of the uppermost leaves. However, most crops can tolerate the removal of sap to some extent when they are not stressed. Crops like potato may be covered with dense masses of whiteflies on the foliage without obvious adverse effects. However, some plants may be more sensitive to whitefly feeding, resulting in yellowing, wilting and leaf-drop.

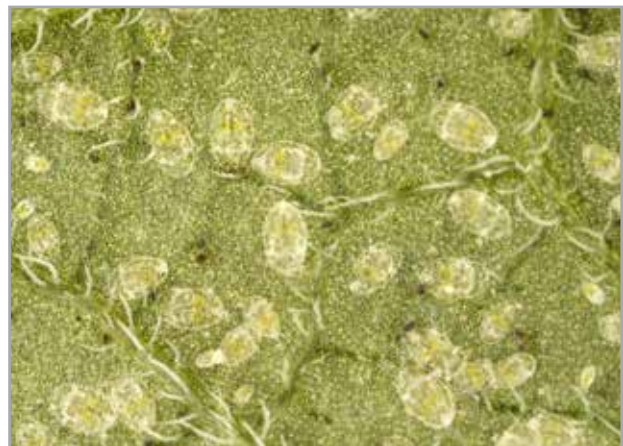
A secondary effect of whitefly feeding is related to the copious amounts of honeydew produced. Both adults and nymphs excrete the sticky, sweet substance that drops onto the lower leaves. Wherever the honeydew lands, black sooty mould (*Capnodium sp.*) usually grows. This mould is not a disease but a saprophytic fungus that grows superficially on surfaces that contain honeydew. It is unsightly on fruit and may kill leaves or even plants when they become smothered.

Whiteflies may cause serious damage by transmitting viral diseases to tomatoes, e.g. tomato *yellow leaf curl virus* (TYLCV), and *tomato curly stunt virus* (ToCSV) (Visser 2014). However, whiteflies are not known to transmit these viruses to potato, neither any of the potato viruses, and is therefore not included as a potato virus vector.

No insecticides are registered for whitefly control on potatoes. Mass-trapping by yellow sticky traps may be an option in small plantings (Gerber 2006). Removal of weeds around fields or greenhouses will reduce the infection rate in newly planted crops. Generally, a cleared area of 3–6 metres around greenhouses should suffice.



Greenhouse whiteflies on the underside of a leaf. Eggs can be seen on the surface of the leaf.



Whitefly nymphs become immobile, flat and translucent from the second instar onwards.

## WIREWORMS

### Background and description

Wireworms are the larvae of beetles belonging to the family Elateridae (click beetles), or Tenebrionidae (darkling beetles and toktokkies) (Picker et al. 2002). False wireworms (Tenebrionidae) are most often encountered in potato fields, but true wireworms (Elateridae) have also been reported to damage vegetables. They are serious pests of potatoes in other countries. The false wireworms include (Myburgh 1988): *Rosochrus tristis*, *Gonocephalum simplex*, *Herpiscius sp.*, *Mesomorphus spp.*, *Psammodes spp.*, *Somaticus spp.*, and *Zophosis boei*. True wireworms include *Heteroderes spp.*

Larvae of *Gonocephalum spp.* (dusty surface beetles) are widespread and damage most plants that they encounter. Adults are about 8-10 mm long, with an oval, flattened body. The beetles are dull greyish black with soil or dust usually adhering to their bodies. The larvae are yellow-brown. They may reach 18 mm in length and have smooth, shiny and sclerotized bodies. They have a tough and leathery appearance. *Somaticus*, *Psammodes* and *Herpiscius* are the larvae of toktokkie beetles and are larger than the other species (up to 38 mm in length). Wireworms have a unique leathery appearance that is unlike that of any other potato pest.

Wireworms are opportunistic feeders that search for plant material on or just below the soil surface. They usually feed on organic matter in soils, but when conditions become unfavourable (e.g. in dry soils), they may turn to plant foliage as a source of moisture. They are also known to eat the contents of germinating seeds. They are usually active at night and hide superficially in soils or under clods/leaf litter during the day. They will consume leaves and fruit of most vegetables that touch the ground. Both the larvae and the adults chew small areas into leaves and fruit and the larvae may also chew small holes into stems of seedlings just below ground level. Young plants may die as a result, similar to cutworm damage. When seedbeds are infested, several plants may be killed in a single evening. However, their numbers seldom increase to damaging levels. Wireworms also chew small, round holes into potato tubers situated close to the soil surface. However, it is known that in dry soils the larvae burrow deeper down in search of moisture. They may then encounter tubers or roots while doing so.

Although various insecticides are registered for use against wireworms on many crops, no insecticide is registered on potatoes. Planting in well-prepared moist soils can reduce damage. However, damage by wireworms is usually insignificant.



Wireworms are leathery larvae of several different species of beetles.



Wire worms may chew small holes into tubers, but also stems of potato plants (arrow).

## GRASSHOPPERS

### Background and description

Grasshoppers are usually not listed as potential pests in potato handbooks in South Africa. However, grasshoppers and katydids are frequently encountered in potato fields, although no species is known to be a serious potato pest.

Grasshoppers (and locusts) are generally broad-range feeders and attack many plants. They represent many families, of which members of the Acrididae (short-horned grasshoppers) are the most common. Some species, for example the brown locust, *Locustana pardalina*, is a major agricultural pest that, when swarming, can destroy crops rapidly (Smith 1964). These locusts usually feed on grasses, but also attack cereals, and when they swarm, and grasses and cereals are not available, they may destroy potato fields overnight. Fortunately, swarming phases occur only sporadically, every 7-11 years. When not swarming, they occur singly and are then usually not serious pests. Most other grasshoppers found in potato fields are not swarm-forming and only damage plants superficially.

Most grasshoppers lay eggs in egg pods in the soil. The eggs usually hatch after rain. Young grasshoppers are wingless and usually green. Older grasshoppers vary in colour but are usually brown. The katydids (family Tettigoniidae) are characterised by their long antennae and uniformly green colour (they are sometimes called long-horned grasshoppers). They are common in potato fields, but are seldom noticed owing to their green camouflage and leaf-mimicking behaviour. They chew holes into leaves, but seldom occur in large enough numbers to cause serious damage. Most katydids lay their eggs within plant material.

Grasshoppers and katydids are not serious pests of potatoes. However, when plants are very young and high numbers of these insects enter fields, plants may be stressed or killed, or feeding may render them susceptible to various plant diseases. Emerging plants are particularly susceptible to damage by grasshoppers and katydids. They are seldom identified as the culprits that chew small to medium-sized, irregular holes into leaves/leaf margins because they jump or move away when approached.

No insecticides are registered for grasshopper control on potatoes as control is rarely necessary. Adjacent grassy areas must be scouted before planting potatoes to estimate potential invasions. The destruction of adjacent grassy areas must be avoided when high population densities are noticed as infestations will shift to potato fields. Insecticidal control in such grassy areas is recommended when necessary. Some insects, e.g. the CMR beetles prey on grasshopper eggs in soils.



Grasshoppers lay eggs in soil. They and their nymphs feed on many crops, including potatoes.



Long-horned grasshoppers (also known as katydids), are common in potato fields.

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