

DISCOVERY

through

DIAGNOSIS

A manual of practical exercises and pest data sheets to promote better pest management. Experiences from a pilot project in Bolivia

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CABI BIOSCIENCE • CIAT SANTA CRUZ • PROINPA

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The original version of this manual included Spanish and English versions of data sheets and exercises. The current version produced in October 2003 has only the English versions.

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Foreword

Integrated Pest Management (IPM) and Integrated Crop Management (ICM) strategies are recognised as key components in the move towards more sustainable and environmentally friendly approaches to crop production. In many developing countries however, these knowledge intensive strategies have not been widely adopted by farmers. To address this concern, participatory approaches to knowledge transfer are fast gaining acceptance.

Effective pest management depends on accurate disease diagnosis through pest identification and knowledge of the pest ecology. The basic idea behind discovery learning exercises is that farmers gain more knowledge of their pest problems and, through experimentation, are better able to optimise their pest management strategies. Exercises are therefore designed for diagnosis, understanding biology and ecology, and management.

This manual is the result of a project that addressed the need for making scientific knowledge more accessible to local extension staff and farmers. The project developed, validated and documented discovery learning exercises dealing with major pest problems as an uptake pathway for local / international plant health clinic services. The ultimate goal was to effectively disseminate to extension staff and farmers the information generated through diagnostic and advisory systems in-country and externally.

The manual draws on both scientific information resources, such as the CABI Crop Protection Compendium, and field experiences in designing and validating farmer participatory exercises that facilitate the knowledge transfer to IPM practitioners in the field. The manual consists of two major parts: Part 4* provides the technical background on some selected major key pests of potato, peach and tomato in Bolivia; Parts 5* and 6* contain a set of validated and illustrated farmer participatory exercises. The selected information aims to provide the inspiration for continued development of similar materials for use in extension and farmer training.

The comprehensive project output, which yielded resource materials for coffee and banana in Uganda as well, is presented in the form of a CD-ROM, which is enclosed at the back of this manual. The main project report presents the various steps in the project implementation and the appendices present all the outputs of the project.

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Future development

Modifications and additional materials are requested for future resource material distribution.

The manual was designed and formatted by Eric Boa.

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Organisation of manual

The pest datasheets and exercises were originally written in English and then translated into Spanish. The datasheets on peach leaf curl and peach aphids were prepared for the Tree Health Bolivia project (funded by DFID through the Crop Protection Programme) and published previously in their Spanish version as part of the *Guía Práctica de Plagas y Enfermedades de Arboles Agrícolas en Bolivia.*

The datasheets provide general information on the pests and diseases that were addressed by the project. They include diseases of tomato, a crop which we were unable to examine as part of the present pilot project. The validated exercises (see foreword for more information) appear in two separate chapters, one for peach and one for potato.

The Spanish versions of the datasheets and exercises appear first (Sections 1–3) and are followed by the English versions (Sections 4–6).

1 *Pest Datasheets* • potato, peach, tomato

Brotes Grandes

Peach Leaf Curl

Peach Aphid

Bacterial Wilt

Tomato Fusarium Wilt

Tomato Verticillium Wilt

Root Knot Disease

Brotes Grandes
Phytoplasma

common names
Potato big bud, potato stolbur. SPANISH: brotes grandes.

host range
Potato (*Solanum tuberosum*). No secondary hosts known.

geographic distribution
Only known from Bolivia (e.g. Comarapa, Santa Cruz and Toralapa, Cochabamba), but similar symptoms have been reported from North America and Europe.

affected plant parts
GROWTH: Vegetative, flowering. PARTS: Whole plant, axilliary buds.

symptoms
Little is known about the timing of symptom appearance. Symptoms are typified by the appearance of tuber-like growths in the axils of the leaves. These vary in colour from dark red to black and in size from 2-15mm in diameter or more, depending on the growth stage of the plant. There may be adventitious shoots from the terminal eye of the big bud.

AERIAL TUBERS APPEAR AT THE LEAF AXIL – THE JUNCTION BETWEEN THE LEAF STALK AND THE STEM.

biology and ecology
This disease was originally known as 'Rhizoctoniosis' but this is incorrect. Investigations have consistently failed to isolate *Rhizoctonia* from affected plants. A phytoplasma has been detected and its presence is clearly associated with symptoms. A phytoplasma is a bacterium-like organism that does not have a cell wall and lives in the phloem sieve tubes, where it can be found in potatoes with *brotes grandes*. Symptoms are caused by alterations in the hormones of the host caused by the growth of the phytoplasma. Transmission can occur in the field from infected to healthy plants where the leafhopper vector is present. Tubers from infected plants are likely to be a source of infection and are probably the main pathway for its spread. It is important that farmers do not save seed from crops infected with brotes grandes.

detection and inspection
Detection is simple: look for aerial tubers in the axils of the leaves.

economic impact
Up to 90% infection has been observed in fields. Yield loss assessments are ongoing but the impression is that significant yield loss can result from the disease.

control
There is no information about varietal resistance in potato.

GROSS SYMPTOMS IN POTATO AFFECTED BY BROTES GRANDES.

Prepared by John Bridge and Julian Smith

Peach Leaf Curl
Fungus: *Taphrina deformans*

host range
Primary hosts: Prunus persica (peach), Prunus persica var. nucipersica (nectarine).
Secondary hosts: *Prunus armeniaca* (apricot), *Prunus dulcis* (almond).

common names
English: peach leaf curl; leaf blister of peach; leaf curl of peach; leaf blister
Spanish: verrucosis del durazno; lepra del melocotonero; abolladura del melocotonero; arrufat (melocotonero)

geographic distribution
Peach leaf curl is known to be co-extensive with peaches and nectarines, so one can assume it will be present wherever peaches are grown, except perhaps in the tropics as the disease is not favoured by high temperatures. However, even subtropical regions now grow low-chill varieties, and leaf curl is likely to occur during the cooler months of the growing season.
SOUTH AMERICA: Argentina; Bolivia; Brazil [Minas Gerais, Rio Grande do Sul, Sao Paulo]; Chile; Colombia; Ecuador; Peru; Uruguay; Venezuela;

affected plant parts
GROWTH: Vegetative, flowering and post-harvest. PARTS: Whole plant, leaves, stems, growing points, inflorescence, and fruits/pods.

symptoms
Symptoms appear about 1 month after flowering starts. Leaves are thickened and distorted (puckered, curled) and green to bright red, depending on variety. Whole shoots are affected when the infection becomes systemic in the growing tip, causing lateral shooting or 'witches broom'. Flowers and fruit surfaces may be similarly affected, with heavily diseased trees having a dramatically different appearance to healthy trees. When diseased leaves are about to release ascospores their surfaces develop a silvery-white 'bloom'. Later these leaves turn black, die, fall and are replaced by new leaves. Leaf blackening coincides with higher daytime temperatures. Areas of bark are also blackened where systemic shoot infection was present. Fresh leaf curl symptoms can reappear on new autumn shoot growth in vigorous varieties.

biology and ecology
T. deformans survives both high summer temperatures as ascospores on tree foliage, and low winter temperatures as conidia derived from ascospores by budding (blastospores). By successive budding during moist conditions a film of resistant bud-conidia eventually covers twigs and buds. In spring these conidia are splashed onto emerging leaves where they germinate by germ tube at the usual point of budding and penetrate either leaf surface directly through the cuticle. Infection is favoured by cool spring temperatures, with the most penetration occurring at 10°C, and new infection cycles may occur during cool wet spells after ascospore maturation later in the spring. Severe outbreaks of leaf curl occur when extended periods of cool, moist conditions occur during blossom to shuck fall, probably by slowing down leaf growth. If the infection period is shortened by resumption of warm condi tions, small leaf blisters may occur which never develop to the 'white bloom' stage of ascus maturation. In this case faster leaf growth appears to interfere with normal fungus growth and symptom development.

detection and inspection methods
Detection is easy. Look for foliage malformations: abnormal curling, thickening, puckering and yellow to red coloration of the leaves, flowers and fruit surface; also thickened, grotesque shoots or 'witches broom' effects.

economic impact
If spraying is not carried out, total yield loss can occur due to extensive defoliation, with eventual tree debilitation, stunting and death.

control
No host immunity is known, resistance is present in a few varieties and susceptibility varies between varieties, but varietal resistance is not currently used to control leaf curl. Chemical control is very effective if sprays are applied at leaf fall and/or just before bud break. A single spray after leaf fall is used in drier peach growing regions, but in wetter regions, several leaf-fall copper-based sprays (copper oxychloride, cupric hydroxide, Bordeaux mixture) and one or two bud-movement sprays of ziram, thiram, copper-based compounds and other fungicides are used to effectively control the disease. Resistance to copper-based fungicides has been found.

Peach aphid

Insect: *Myzus persicae* (Order: Hemiptera: Family: Aphididae

notes on taxonomy and nomenclature

There has been much confusion about the correct identification of this aphid. *At* least 39 names have been recorded, including species in the genus *Aphis*, *Myzodes* and *Rhopalosiphum*. The name *M. persicae* is used here to refer to a complex of species and host plant races. It is a highly variable species; strains, races and biotypes have been distinguished by morphology, colour, biology, host-plant preference, ability to transmit viruses and insecticide resistance. More has been published on *M. persicae* than for any other aphid species.

common names

ENGLISH: green peach aphid; peach curl aphid; cabbage aphid; peach aphid; tobacco aphid; potato aphid; green sesame aphid; peach-potato aphid.
SPANISH: áfido verdoso; pulgón verde; áfido amarillo del tabaco; áfido verde; pulgón verde del melocotonero

host range

Primary host has two meanings for the peach aphid. It is used here to refer to the main winter host, where the aphid has to over-winter to survive.
The primary host is usually *Prunus persica* (peach), including nectarines, though *P. nigra* is also used in the USA. Other possible primary hosts include *P. tenella*, *P. nana*, *P. serotina*, *P. americana* and peach-almond hybrids. The sexual part of the life cycle is thought to be completed only on *P. persica* and *P. nigra*.
M. persicae feeds on a wide range of plants in summer. These include over 40 different plant families, including Brassicaceae, Solanaceae, Poaceae, Leguminosae, Cyperaceae, Convolvulaceae, Chenopodiaceae, Compositae, Cucurbitaceae and Umbelliferae. On some of these plants the peach aphid is also a major source of damage.
Selected economically important examples have been used to illustrate the wide host range.

MAJOR HOSTS: *Arachis hypogaea* (groundnut); *Brassica*; *Cajanus cajan* (pigeon pea); *Capsicum annuum* (bell pepper); *Carica papaya* (papaw); *Citrullus lanatus* (watermelon); Citrus; *Coriandrum sativum* (coriander); *Cucumis* (Cucumber); *Cuminum cyminum* (cumin); *Daucus carota* (carrot); *Fragaria chiloensis* (Chilean strawberry); *Hordeum vulgare* (barley); *Lactuca sativa* (lettuce); *Lycopersicon esculentum* (tomato); *Malus domestica* (apple); *Nicotiana tabacum* (tobacco); *Phaseolus* (beans); *Prunus armeniaca* (apricot); *Prunus persica* (peach); *Raphanus sativus* (radish); *Saccharum officinarum* (sugarcane); *Solanum tuberosum* (potato); *Spinacia oleracea* (spinach).; *Triticum* (wheats); *Zea mays* (maize).
The peach aphid causes less significant damage on over 40 other plant hosts.

geographic distribution

M. persicae is probably of Asian origin, like its primary host plant (*Prunus persica*), but now occurs everywhere in the world except where there are extremes of temperature or humidity.
SOUTH AMERICA: Argentina; Bolivia; Brazil; Chile; Colombia; Ecuador; Peru; Uruguay; Venezuela.

affected plant parts

GROWTH: Flowering, seedling, vegetative and post-harvest. PARTS: Whole plant, leaves, stems, growing points, and flowering parts.

symptoms

Aphid populations tend to be dispersed on summer hosts. *M. persicae* usually feeds on older senescing leaves, often along the leaf veins. The effect of infestation depends greatly on host plant and especially any viruses that are transmitted. Aphid infestations on peach cause severe leaf curl and shoot distortion. Honeydew production is less than for many other aphids because dense colonies are not formed less mould fungi develop on leaves. On crops such as potato and brassicas, *M. persicae* occurs at low densities, particularly on older leaves.
Winged females are attracted to many summer hosts, although they have a preference for yellow and yellow-green surfaces. Accumulation of aphid populations occurs because the departure rate is lower on favoured hosts.

biology and ecology

The life cycle of *Myzus persicae* is complicated and can involve alternate hosts, sexual and asexual reproduction and a number of different insect forms. Some of these are wingless while others can move to new food sources (hosts).
There are two distinct types of life-cycle.
Type 1 occurs where active forms cannot survive throughout the year. Sexual reproduction occurs. The aphid overwinters as eggs. The aphid develops on alternate peach and summer plant hosts.
Type 2 occurs where peach is absent and a mild climate allows active stages to survive throughout the year. The aphid always reproduces through live young from virgin females. No winged forms are produced. This is most common in the tropics and sub-tropics.
The following is a condensed account of the Type 1 life-cycle:
Pregnant females lay 4-13 eggs, usually in crevices around and in axillary buds of peach. They require a period of chilling to develop. They are very resistant to

cold temperatures, surviving as low as -46°C. The average number of eggs found on a peach tree is 4000, but there is considerable variation up to a maximum of 20,000 eggs.
The eggs from the previous season hatch into female aphids which can give birth to live young. The first generation feeds off swelling peach flower buds. Large numbers of these female aphids may die. The live young produced by the females then feed on opened buds, flowers and soft shoots of the peach tree. The second generation of female aphids are winged and can move to the summer host plants. Production of wingless females may continue for several generations. As the nutritional value or attraction of the peach tree declines so more winged females are produced which can look for new food sources.
Winged females known as gynoparae are produced as the growing season progresses, the daylength reduces and temperatures lower. These move back to peach and close relatives and produce mating females that feed and develop on peach leaves. Males are produced after the gynoparae appear. They return independently to peach and fertilise the mating females.
Up to 25 generations of peach aphid are possible in a growing season, depending on the host and other conditions. Higher growth rates have been observed on virus-infested plants.

natural enemies

The natural enemies which are important against *M. persicae* depend on the crop being attacked, the circumstances under which it is grown and the climate. Aphid natural enemies are restricted by habitat and not by host. Aphid parasites often use aphid honeydew to locate their hosts. *M. persicae* produces relatively little honeydew. *M. persicae* is attacked by over 30 species of primary parasitoid. Most of these parasitoids also attack a range of other aphid species. *Aphidius colemani* is an important natural enemy in North and South America.
These lists include a selection of species generally considered as most important.
PARASITOIDS (number of species): *Alloxysta* (1); *Aphelinus* (4); *Aphidencyrtus* (1) ; *Aphidius* (8), including *Aphidius colemani* (nymphs, Chile, Peru) and *Aphidius matricariae* (nymphs, introduced to Peru and Chile); *Asaphes* (1); *Diaeretiella* (1); *Ephedrus* (2) ; *Neoephedrus* (1): *Praon* (1); *Trioxys* (1).
PREDATORS: Adults and larvae of several coccinellids are important predators worldwide, particularly species of *Adonia*, *Coccinella*, *Hippodamia* and *Scymnus*. Important syrphid larvae predators worldwide include *Episyrphus balteatus*, *Ischiodon scutellaris*, *Metasyrphus corollae* and *Scaeva pyrastri*.
ENTOMOPATHOGENS: at least 14 species are known. Virulence of some is greatest when humidity is high. All attack nymphs and adults. The fungus *Verticillium lecanii* is effective against peach aphid in a wide range of crops.

economic impact

M. persicae is the most important aphid which transmits viruses in plants. Over 100 plant viruses are able to multiply in the aphid (persistent transmission) and these affect many major crops. Many more viruses are transmitted by the non-persistent method and include cucumber mosaic cucumovirus, pepper veinal mottle potyvirus, plum pox potyvirus and lettuce mosaic potyvirus. The impact of these plant viruses can be huge and plant production losses usually greater than the direct feeding effects of the aphid. However, direct feeding damage coupled with the toxic effects of aphid saliva can be of economic importance in some crops.
M. persicae is a major pest everywhere potatoes are grown. The relationship between *M. persicae* on peach and *M. persicae* on potato in Bolivia is not known. On potato, it is the most important vector of potato leafroll virus. This causes potato leaf roll and tuber rot necrosis. Seed potatoes have low tolerance for the virus and low aphid populations can be very damaging. No virus diseases on peach have been reported though unpublished observations suggest that the possible symptoms of virus attack are present in some regions.

control

Many of the successful examples of pest management refer to crops grown in greenhouse conditions.
CHEMICAL CONTROL: Control by insecticides has had only limited success. Resistance to a range of insecticides has developed world-wide. Resistance to older insecticides has led to the use of new ones such as imadocloprid. Neem products were effective against *M. persicae*. Antifeedants based on alarm pheromones [see below] are also being developed. Insecticidal soaps are useful. They have low toxicity to many beneficial organisms.
BIOLOGICAL CONTROL: The parasitoid *Aphidius matricariae* has been widely used as a biological control agent in greenhouses. Releases were often made in combination with the predatory aphid midge, *Aphidoletes aphidimyza*. *Aphidius gifuensis* has been successfully used in greenhouses in China. *Ephedrus cerasicola*, *Aphidius colemani* and *Aphelinus abdominalis* have also been used.
HOST-PLANT RESISTANCE: A repellent aphid alarm pheromone chemical is present in the microscopic hairs of wild potato. These hairs also release a sticky exudate which prevents aphids from moving and inhibits settling and probing. The hairs have been bred into resistant potato cultivars. Increased waxiness in brassica leaves decreases aphid colonization.
CULTURAL CONTROL: Recommended methods include early sowing, weed management and the use of certified seeds, known to be virus-free (for example, seed potatoes). In peach orchards good pruning procedures are an effective control against overwintering eggs. This practice is beneficial to peach and to nearby summer crops which are attractive to aphids.

Bacterial Wilt
bacterium: *Ralstonia solanacearum*

name of the bacterium
In 1996 the bacterial wilt bacterium known as *Pseudomonas solanacearum* was given a much needed review and was divided into *Ralstonia*, *Burkholderia* and *Pseudomonas* (in a very limited sense). *P. solanacearum* – the cause of bacterial wilt was renamed *Ralstonia solanacearum*.

common names
Bacterial wilt of potato; brown rot of potato; southern bacterial blight of tomato; granville wilt of tobacco; moko disease: banana; slime disease. SPANISH: marchitez bacteriana, podredumbre parda de la patata; marchitez del platano; vaquita de la papa; marchitez del tomate; moco del platano; marchitez bacteriana: tabaco

host range
MAIN HOSTS: *Lycopersicon esculentum* (tomato), *Nicotiana tabacum* (tobacco), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Musa* (banana), *Musa paradisiaca* (plantain), *Heliconia*. SECONDARY HOSTS: *Anthurium*, *Ricinus communis* (castor bean), *Zingiber officinale* (ginger), *Arachis hypogaea* (groundnut), *Capsicum annuum* (bell pepper), *Colocasia esculenta* (taro), *Curcuma longa* (turmeric), *Gossypium* (cotton), *Hevea brasiliensis* (rubber), *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava).

geographic distribution
SOUTH AMERICA: Argentina, Bolivia, Brazil, Chile, Paraguay, Peru.

EARLY SYMPTOMS OF WILT ON TOMATO

affected plant parts
STAGES: Vegetative growing stage. PARTS: Fruits, leaves, roots, seeds, stems, vegetative organs, and whole plant.

symptoms
POTATO: The first visible symptom is a wilting of the leaves at the ends of the branches during the heat of the day with recovery at night; eventually, plants fail to recover and die. As the disease develops, a streaky brown discoloration of the stem may be observed on stems up to 2.5 cm or more above the soil line, and the leaves have a bronze tint. A white, slimy mass of bacteria exudes from vascular bundles which are broken or cut. This slime oozes spontaneously from the cut surface of a potato stem in the form of threads, when kept in a beaker with water. Such threads are not formed by other bacterial pathogens of potato.

TUBERS: external symptoms may or may not be visible, depending on the state of development of the disease; furthermore, symptoms may be confused with those of ring rot due to *Clavibacter michiganensis* subsp. *sepedonicus*. *R. solanacearum* can be distinguished by the bacterial ooze that often emerges from the eyes and stem-end attachment of infected tubers. When this bacterial exudate dries, a mass of soil adheres to the tubers at the eyes. Cutting the diseased tuber will reveal a browning of the vascular ring and immediately surrounding tissues up to 0.5 cm each side of the ring. A creamy fluid exudate usually appears spontaneously on the vascular ring of the cut surface a few minutes after cutting. In the case of ring rot the tuber has to be squeezed in order to press out a mass of yellowish dissolved vascular tissue and bacterial slime. Plants with foliar symptoms caused by *R. solanacearum* may bear healthy and diseased tubers, while plants that show no signs of the disease may sometimes produce diseased tubers.
TOMATO: The youngest leaves are the first to be affected and have a flabby appearance, usually at the warmest time of day. Wilting of the whole plant may follow rapidly if environmental conditions are favourable for the pathogen. Under less favourable conditions, the disease develops less rapidly. Stunting may occur and large numbers of adventitious roots are produced on the stem. The vascular tissues of the stem show a brown discoloration and, if the stem is cut crosswise, drops of white or yellowish bacterial ooze may be visible.

biology and ecology
The bacterium has been divided into 5 biovars based largely on biochemical testing. The strains of a race do not necessarily belong to the same biovar. Race 1 has a very broad host range. Race 2 causes diseases on banana and plantain, while Race 3 is restricted to potato. The bacterium can spread in soil and irrigation (drainage) water. Transmission is mostly through infected vegetative plant parts.

detection and inspection
The bacterium may be obtained from infected tubers or stems by pressing a small portion of tissue onto a clean glass slide. Cut open potato tubers to look for symptoms. Tubers with suspected latent infection should be diagnosed in the laboratory.

control
Control is very difficult. Chemical control, including use of antibiotics has little or no effect. Biological control is being investigated but not yet available to farmers. Resistant and tolerant cultivars of potato and tomato are available but often only against specific races or strains and nematode infections may facilitate break-down of resistance. Grafting of tomato on resistant eggplant rootstocks has been proven effective. Crop rotation with non-hosts of 5-7 years or long fallow periods of at least 2 years are important. Use of healthy planting material, early detection and roguing of infected plants, crop rotation, control of weed hosts and volunteer plants, avoidance of surface water for irrigation are all key factors in managing bacterial wilt.

FINAL STAGES OF DISEASE (TOMATO)

economic impact

R. solanacearum can cause complete crop loss and is a serious obstacle to the cultivation of many solanaceous plants in both tropical and temperate regions. The greatest economic damage has been reported on potatoes and tomatoes in Brazil and Colombia. In Peru, about half the banana plantations are affected and the rapid spread of the pathogen threatens to destroy plantations in the Amazon region. Disease severity mostly increases if *R. solanacearum* is found in association with root nematodes.

Tomato Fusarium Wilt
fungus: *Fusarium oxysporum* f. sp. *lycopersici*

host range
MAIN HOST: tomato (*Lycopersicon esculentum*). SECONDARY HOSTS: other *Lycopersicon* species, and wide range of crops and weed hosts which do not show symptoms.

common names
Fusarium wilt of tomato, wilt of tomato, vascular tomato wilt. SPANISH: fusariosis del tomate, marchitez fusariana del tomate.

geographic distribution
Widespread where host occurs.

affected plant parts
STAGES: seedling, flowering, and fruiting. PARTS: whole plant, leaves and stems.

WILTING AND YELLOW YEAVES – EARLY SYMPTOMS

symptoms
Often occur on mature plants after flowering and at the beginning of fruit set. Initial symptoms can appear as slight wilting on part of the plant. Chlorotic symptoms begin to appear on one side of a leaf, then all leaflets become yellow on one-half of the leaf. As symptoms progress, wilting is often associated with one side of the plant. Wilt symptoms are more commonly observed during the warmest part of the day. A long cut at the base of the stem reveals a dark-brown to red discoloration in the xylem. As the disease becomes more severe, vascular discoloration occurs further up the stem, even extending into the leaf stalks. Seedlings can also become infected and, in addition to the symptoms described on mature plants, appear stunted with periodic wilting.

biology and ecology
F. oxysporum f.sp. *lycopersici* is a soilborne fungus. It can survive in soil for extended periods of time. The fungus infects and parasitises the root of a wide range of crop and weed species. On tomato, resting spores germinate in the presence of small feeder roots and infect the root cortex. The fungus then penetrates the vascular system, invading the xylem. Asexual spores then move passively upward via the vessel system to other parts of the plant. The plant responds to infection by producing tyloses, or plugs, which block the movement of water in the plant resulting in wilting of the tissue. The incorporation of infected plant material back into the soil increases the level of infection. Under conditions of high rainfall or high humidity, *F. oxysporum* f.sp. *lycopersici* can be disseminated through air. There are conflicting reports on potential interactions between fusarium wilt and root knot nematode (*Meloidogyne*), which claim that effectiveness of major gene resistance to fusarium wilt is affected through damage by root knot nematodes.

detection and inspection
Fusarium oxysporum f.sp. *lycopersici* can readily be recovered from infected plant material and identified using standard laboratory methods. Plant material with discolored vascular tissue should be collected from above the soil line.

economic impact
The fungus has the potential to severely affect tomato production and can cause complete yield loss under greenhouse and field conditions. Disease severity is influenced by many variables including the level of soil infestation, environmental conditions such as soil and air temperatures, soil moisture, cultivar and soil fertility.

control
Avoid planting tomatoes in fields with a known history of fusarium wilt. If unavoidable, resistant cultivars should be used. Although disease resistance might be the most economic method of control, the appearance of new races of the fungus and the lack of effective resistance in certain preferred cultivars show the need for additional alternative management practices. Rotations of up to 5-7 years can significantly reduce soil inoculum levels. In some soil types, adjusting the soil to a pH of 6.5-7 using lime can reduce the severity of disease. Several biological control agents, including bacteria and non-pathogenic strains of *F. oxysporum* have shown promise, however they have been more effective under controlled greenhouse conditions than in the field. Chemical control through fumigation can be effective, preferably products with lower mammalian toxicity to minimise risks when applying in open fields.

Tomato Verticillium Wilt

fungus: *Verticillium albo-atrum*

common names

Verticillium wilt, verticillium blight of tomato, verticillium wilt of tomato, wilt. SPANISH: verticiliosis.

host range

MAIN HOSTS: tomato, lucerne, potato, cotton and hop, and many other economically important crops. SECONDARY: pepper, cucumber, sugarbeet, yellow poplar and others.

geographic distribution

SOUTH AMERICA: Argentina; Brazil; Chile, Peru.

affected plant parts

STAGES: Vegetative growth. PARTS: whole plant, stems, leaves, shoots.

symptoms

Though referred to as a wilt, wilting may not be the main symptom seen. Indeed, there may be no observed wilting at all. The symptoms depend on the host, the resistance of the cultivar and the environmental conditions. The most extreme form of disease is an irreversible wilting of the whole plant followed by death. There could also be partial wilting (some shoots or leaves). Not uncommonly, sectorial chlorosis and/or necrosis of leaf tissue is the only external symptom. Symptoms are not usually seen until several weeks into vegetative growth. Vascular staining may be present. Often the only effect of disease is stunting, which may easily go unnoticed. Some infected plants show no symptoms at all.

VERTICILLIUM WILT OF TOMATO
PHOTO: TOM ZITTER, CORNELL UNIVERSITY

biology and ecology

Verticillium wilt of tomato is a systemic disease, which means that the pathogen invades the whole plant. It can be disseminated through infected planting material, including seeds. The pathogen occurs in irrigation water and can be spread by insects. In soil, the fungus survives as dark resting structures, associated with diseased crop debris. Farming tools can spread the pathogen. The fungus penetrates young roots of susceptible host plants and disseminates through the xylem vessels. The disease is favoured by moderate temperature and suppressed by high temperatures (above 25 °C). The impact of the disease may be exacerbated in the presence of plant-pathogenic nematodes.

economic impact

The diseases caused by the fungus are largely and effectively controlled through the use of healthy planting material, resistant cultivars, pathogen-free growing substrates and good husbandry practice. Nevertheless, because of the greater scope for spread with seed and in the field, *V. albo-atrum* continues to cause significant losses. A major hazard is the potential for the types of *V. albo-atrum* to evolve more virulent strains which can overcome the resistance in commercial cultivars or strains whose altered physiological characteristics extend their range into areas where crops may be unprotected by resistance.

control

Verticillium wilt is most commonly brought into disease-free areas by seed lots that contain internally infected seeds. Use only certified seed from reliable sources. The disease is controlled mainly through the use of resistant cultivars, by reducing inoculum and by limiting spread. Crop rotation is an important tool in controlling Verticillium wilt of tomato. The resting structures of the fungus loses viability fairly rapidly. Use of healthy planting material is also vital. Physical or chemical seed sterilisation is not effective with internal seed infections. There are no fungicides, including fumigants, which give adequate control under field conditions.

Root Knot Disease

nematode: *Meloidogyne incognita, M. javanica*

common names

M. javanica: root-knot nematode, javanese root knot nematode. SPANISH: nemátodo javanés, nemátodo javanés de quiste.

M. incognita: root-knot eelworm, southern root-knot nematode. SPANISH: rosario (Bolivia), nemátodo de los nódulos de las raíces, nemátodo de las agallas, anguilula de las raíces, nemátodo noédulador, nemátodo agallador, nemátodo sureño de quiste (Mexico).

host range

M. javanica: Infects more than 750 host species or varieties, including many weeds as well as crop plants e.g. many vegetables, fruit trees, cereals and ornamentals.

M. incognita: potato, tomato and peach.

geographic distribution

In South America: Argentina, Bolivia, Brazil, Chile, Paraguay, Peru (*M. icognita* only).

affected plant parts

Roots, tubers and whole plant.

symptoms

Poor growth with stunting and chlorosis of the aerial parts and a reduced and galled root system. The below-ground symptom of the root knot nematode is the presence of galls or knots on roots. A few small galls can be seen on young seedlings, at transplanting time of tomato for example, but become more obvious as the crop develops. The size of the root system can be very reduced if many nematodes are present.

MELOIDOGYNE INCOGNITA GALLS ON TOMATO ROOTS

biology and ecology

Eggs and juvenile of root knot nematodes survive in upland soils and in plant roots left in the ground after harvest. Root knot nematode can not survive in permanently flooded soil. Without host plant roots on which to feed, the number of nematodes in the soil gradually declines, particularly if the soil is moist and warm. Nematodes do not disperse themselves more than a few centimetres, but they can be spread in a number of ways, for example by moving infested soil, or infected plants, or in flood and irrigation water. Within the field, nematodes are spread by cultivation which transfers and mixes soil. Juvenile worms move through the soil to invade the roots of growing plants. The juvenile worm enters the root and develops into a female after about 28 days. As the female develops the root swells around her, forming a root gall or knot. A gall can contain several females and each female lays about 250 eggs, which are ready to hatch after a few days releasing thousands of juveniles to re-invade the root. Root knot nematode reduces the size of the root system and its ability to take up water and nutrients from the soil.

detection and inspection

Above ground, infected plants are usually smaller, perhaps with yellowing leaves and may wilt rapidly in direct sunlight. Very often, not all the plants in a field will be affected to the same degree giving a patchy distribution typical of a root knot nematode infection. Infected root systems show characteristic knots or galls, the severity of which varies with the degree of nematode infection and species and crop cultivar. Identification of *Meloidogyne* species requires specialised taxonomic services.

economic impact

Root-knot nematode is probably the most widely distributed and economically important plant parasitic nematode in tropical and subtropical regions. Yield reductions can be very high e.g. up to 80% for eggplant, 80-100% for tomato. Plant growth reductions of over 40% for chickpeas and over 60% are estimated for soyabeans. Yield losses are most serious on vegetable crops: in particular, solanaceous crops. *Meloidogyne* spp. can make some plants more susceptible to wilt fungi e.g. fusarium wilts or *Rhizoctonia solani* on various crops, including tomato, cotton, chickpea and tobacco.

control

It is impossible to completely eradicate root knot nematode from a field. But it is important to reduce infection to a tolerable level. The amount of galling on roots (root knot rating) at harvest will show just how serious the problem is and whether applied control is working. Avoid planting infected potato tubers. Raise strong, uninfected, healthy tomato seedlings as these are then more tolerant of future infection through positioning the seed bed in an uninfested or solarised area or by using a raised bed in a previously flooded paddy field. Remove infested roots of previous crops and weeds while rotating with poor or non hosts, such as amaranthus, garlic, groundnuts, maize, mustard, onion, rice, watermelon, wheat. Resistant cultivars have been developed and should be used, if available, in infested fields. Fallows and organic amendments are useful to a certain extent through among other things, the promotion of natural enemies in the soil. Botanical pesticides can be used such as neem, mustard or linseed in the form of oil cakes and incorporated into the soil. Where costs justify their use, nematicides can be applied, but care must be taken to select only those that have low mammalian toxicity. Nematicides are likely to destroy a large amount of the soil flora and fauna inclusive of useful organisms.

2 *Exercises* • potato

1. Living soils
2. Nematodes vs. Rhizobium
3. Root knot nematodes in tubers
4. Nematodes in the roots: observation of rosary bead nematodes with a microscope
5. *The Glass and the Paper*: identifying potato cyst nematodes
6. Bioassay in a plastic bag
7. Crop Rotation (for the control of nematodes)
8. *Cigarette Smoke*: identifying bacterial wilt
9. *Warm bag*: identifying bacterial wilt
10. Testing in the market: identifying bacterial wilt
11. Potatoes in Pots: the life of bacterial wilt
12. *Coffee and Water*: an analogy of the spread of disease by insect vectors

Potato 1

LIVING SOILS

Objective: Discover that the soil is alive, and that its diversity reflects the stability of the agro-ecosystem.

This exercise does not deal with nematodes specifically, but it is important that people realise that the soil contains living organisms, including nematodes. Microscopes and magnifying glasses help, even if just to observe the different forms of micro-fauna in the soil, not necessarily to identify them. This exercise works quite well in communities, but is difficult to do in fairs or markets.

◊ MATERIALS

- Small plastic funnels (you can make them from soft drink bottles)
- Liquid soap (dishwashing detergent)
- Clean water
- Cloth with a loose weave (like muslin)
- Small bottles
- A dark box in which to place the bottles.

A FARMER LOOKS AT NEMATODES UNDER THE MICROSCOPE. TIRAQUE FAIR.

◊ PROCEDURE

- Collect three soil samples from different kinds of land, for example, forest, field, fallow, a corral.
- Stir the sample and take a sub-sample (a handful, a small cup or about 100 g).
- Wrap the sub-sample in a single layer of muslin and place it in the funnel.
- Place the funnel over a small glass jar containing clean water and a drop or two of liquid soap.
- Give it a label, with date, names of the people who will be in charge of looking after the bottle.
- Expose the upper part of the funnel to direct light, but try to protect the bottom part from the light, so that the mouth of the funnel and the jar are cooler and darker (see the drawing on the next page).
- Leave it for 24 to 48 hours.
- Remove the funnel and collect the contents of the glass jars.

◊ OBSERVATIONS

The farmers will want to compare cultivated soil with soil from a long fallow. Once the objective of the exercise is explained to them, encourage the farmers to select the treatments (types of soil to examine). For example, they may want to see the difference that a 10-year fallow makes in soil organisms.

Compare the contents of each of the 3 bottles. Notice the quantity and diversity of organisms in soil from the forest, fields and in seasoned manure, using a magnifying glass (or a stereoscope).

◊ DISCUSSION

Does the magnifying glass allow you to see all living creatures (including nematodes) in the soil?

Which soil has the most diverse organisms? Why?

Why do some soils have more micro-organisms than others?

What kinds of interactions do you think exist between the different micro-organisms in the soil? In other words, do you think there are natural enemies and pests, just like in the rest of the agro-ecosystem?

What can we do to improve impoverished soils?

Potato 2

NEMATODES VS. RHIZOBIUM

Objectives: Learn more about nematode damage, and about their basic ecology. See the difference between nematode root knots and rhizobia on legumes.

You need to know of a nematode-infested field to do this exercise. There is little point to this exercise unless the field is infested with nematodes. Nematode root knots are common in fields that have been planted with solanaceous crops. (Before doing the exercise, the facilitator must look at the roots of some diseased plants to see if they have root knots). The exercise can be done quite well in fairs and markets, as well as in farm communities.

◊ MATERIALS

- A field infested with nematodes (see above)
- Leguminous plants
- Trowel or other tool to uproot plants
- Plastic bags
- Measuring tape. (It can be a carpenter's tape)
- Some buckets of water

◊ PROCEDURE

- Talk with some farmers to identify a field with problems. Many farmers know of fields with soil problems.
- As a group, observe the field and talk about the variation in height and health of the plants.
- Ask the group to select a sample of healthy and diseased plants to uproot. Measure the plant if possible (from the soil surface to the highest leaf) and describe the health of the plant. Use local names for symptoms so that the people feel more comfortable discussing the plant.
- Pull up some leguminous plants also. They may be crops (for example, broad beans or lupines), or weeds (for example, garrotilla—*Medicago hispida*).
- If there are tomato seedbeds, uproot a few plantlets and look for root knots.
- Pull up some weeds which are hosts of nematodes (like Spergula).

Try to pull up at least 3 plants of each category (healthy potatoes, diseased potatoes, legumes and weeds which are nematode hosts). Sometimes farmers do not like to pull up healthy plants. But try to obtain at least one cultivated plant to compare with the others.

SHOWING THE DIFFERENCE BETWEEN RHIZOBIUM NODULES AND ROOT-KNOTS CAUSED BY NEMATODES.

A FARMER COMPARES ROOTKNOT NEMATODE DAMAGE (RIGHT) WITH RHIZOBIUM NODULES ON BEANS (LEFT)

- Take the samples to a house or some other place where you can work comfortably.
- Wash the soil from the roots, swishing the plants softly in the buckets of water.

◊ OBSERVATIONS

- The group observes the roots.
- Notice their size and shape.
- Compare the healthy roots and the stunted ones.
- Try to determine how severe the symptoms are.
- Are there root knots on the diseased potato plants?
- Are there root knots on the healthy potato plants?

- Are there root knots on the weeds?
- Are there knots on the roots of the leguminous plants?

◊ DISCUSSION

Is the crop healthy or are there spots of diseased plants?

Examine the size of the roots. (Do the small plants have many or few roots?)

Which plants have the most severe symptoms of root knots? Why?

What is the difference between nematode root knots and the rhizobia of leguminous plants? (Use the plants you have pulled up to stimulate the discussion).

The discussion can help people to understand some basic concepts:

- The more root knots there are, the less the field produces. Explain why.
- There are nematode root knots on certain kinds of weeds. Explain the difference between root knots on weeds and on potatoes.
- The difference between nematode root knots and rhizobia on legumes. Explain that the rhizobia are good for the field.
- Nematode damage is usually uneven, in spots scattered about the field. What does that mean? How did the nematodes get to the field? (Did they arrive in seed? Are the nematodes distributed unevenly on the field? Do nematodes move very far?)
- Nematodes damage roots, and make them smaller, so the plants become smaller.
- The healthy and the stunted plants can have root knots, so it is important to explain that the time of infection is important. The infections in the first vegetative stages do the most damage.
- Sometimes farmers know the history of the weak plants, which can help explain the importance of using healthy seed, and of planting in healthy soil to produce a healthy crop.

Do you know of potato varieties that are resistant to nematodes?

Potato 3

ROOT KNOT NEMATODES IN TUBERS

Objective: Show that root knot nematodes exist, and that they live below the skin of potato tubers.

Root knot nematodes can be found below the surface of the potato skin, as deep as 3 mm inside the tuber.

◊ MATERIALS

- Tubers with toot knot nematodes, preferably with blisters (advanced symptoms, for example in potatoes from the low valleys)
- Knife
- Magnifying glass or a stereoscope
- Tincture of iodine

◊ PROCEDURE

- Select some tubers with root knot nematode blisters.
- Cut off a little of the potato skin.
- Dye the cut in the potato with tincture of iodine.
- Observe the nematodes. The potato starch turns purple, while the nematodes remain white.

◊ OBSERVATIONS

The group observes the nematodes, using a magnifying glass or a stereoscope.

◊ DISCUSSION

What do you see below the skin of these potatoes?

What are these nematodes? (Small animals, which are potato pests.)

Can these nematodes damage our field, even though we do not see them?

SWELLINGS OR GALLS ON POTATO TUBER CAUSED BY THE ROOT-KNOT NEMATODE, *MELOIDOGYNE*.

Potato 4

NEMATODES IN THE ROOTS

OBSERVATION OF ROSARY BEAD NEMATODES WITH A MICROSCOPE

Objective: Show that rosary bead nematodes are living creatures, and that they live in the roots of plants.

*Rosary bead nematodes (*Nacobbus*) can be found in the roots of potato plants. (They also live in the tubers).*

◊ MATERIALS

- Roots with rosary bead nematodes
- Knife
- Stereoscope
- Potato tubers
- Clean water
- Porcelain mortar or a grinding stone
- Samples of roots with nematodes in tightly sealed jars

◊ PROCEDURE

- Using a mortar or a grinding stone, liquefy the roots of potato plants with rosary bead galls. Use the roots of 3 plants, and a cup of clean water.
- Use muslin or silk or some other cloth to strain the water. Put the mixture of roots and water in the cloth; tie a knot and press out water, without roots. The water will contain nematodes.
- Keep the water with nematodes in a jar.
- Place a few drops of water under a stereoscope or a microscope.

THE SMALL SWELLINGS ON THE ROOT ARE KNOWN AS *ROSARIO* IN BOLIVIA BECAUSE OF THEIR SIMILARITY TO ROSARY BEADS

◊ OBSERVATIONS

The group observes the nematodes, using a microscope or a stereoscope. After every person has had a look, ask them to draw what they have seen.

◊ DISCUSSION

Do the roots have nematodes?

Is the soil healthy?

Is this potato good to plant in order to grow seed potato?

What happens if we plant certified seed in soil that is contaminated with nematodes?

Potato 5

THE GLASS AND THE PAPER

IDENTIFYING POTATO CYST NEMATODES

Objective: Show that potato cyst nematodes exist, and that they live in the soil. Explain the difference between nematode cysts and the seeds of the weed *Spergula arvensis*.

*Potato cyst nematodes (*Globodera*) live in the soil, where one can see their cysts. Explain to the people that the cysts are dead females, and that they contain the eggs of the next generation of cyst nematodes. Tell the farmers that it is a little like chilli. The chilli fruit is like a nematode female, it has seeds inside its body. Even though the chilli fruit dries up, its seeds are still good.*

◊ MATERIALS

- Soil with potato cyst nematodes
- Drinking glasses (2)
- Clean water
- Newspaper
- A small stick or a spoon
- Pencil, hen's feather or some other thing to point to the cysts and the seeds

◊ PROCEDURE

- Select a field with potato cyst nematodes.
- Collect 4 to 6 spoonfuls of earth in a bucket or other receptacle.
- Place the piece of newspaper like a cylinder inside the drinking glass. Place the soil inside the glass with the paper (see photo).
- Add a quarter glass of water and stir the earth with a stick or a spoon.
- Add more water until the glass is almost full, and continue stirring.
- Wait a minute.
- Remove the paper and examine it.
- The farmers may bring soil from their fields to test. When we have done this exercise at fairs, sometimes farmers bring a little soil from a large potato bag, to see if the potatoes come from soil that is free of potato cyst nematodes.

A FARMER PLACES SOIL FOR TESTING INSIDE THE PAPER PLACED IN THE GLASS

THE PAPER IS REMOVED FROM THE GLASS AND JUAN (LEFT) DISCUSSES THE DIFFERENCES BETWEEN POTATO CYSTS AND SEEDS OF *SPERGULA ARVENSIS*

◊ OBSERVATIONS

The group observes the nematode cysts, which are the size of a pin head and visible to the naked eye.

In Quechua, people call the potato cysts *ch'iya* (nits).

The group observes other things that have come from the earth, including seeds of weeds like *Spergula arvensis* (common names include *mach'a qhora, comino qhora, yuraj t'ika, asnan qhora, wila qhora*).

You can use a magnifying glass to see them better.

◊ DISCUSSION

What is the difference between *Globodera* cysts and *Spergula* seeds? (The cysts are a little smaller than the *Spergula* seed. Besides, the cysts are white, yellow or a brilliant brown, while the seeds are black. The cysts are round, but the *Spergula* seeds are oval).

What are these cysts? (The bodies of female *Globodera*, which contain the eggs from which their offspring will hatch).

Can these nematodes damage our field, even though we do not see them?

What happens when there are weed seeds in our field?

What happens when there are nematode eggs in our field?

GLOBODERA (POTATO CYST NEMATODE) CYSTS ON POTATO ROOTS

Potato 6

BIOASSAY IN A PLASTIC BAG

Objective: See if a field has clean soil, or if it has root galling nematodes.

*Rosary bead nematodes or false root knot nematodes (*Nacobbus*) and root knot nematodes (*Meloidogyne*) live in the soil and cause root galling, and can move from the soil to clean potato seed. It is important to know if a field is free of these nematode galls, especially if one intends to grow seed potatoes there. Farmers ask, what should I do if my soil is healthy and my seed is diseased? Or the opposite, what should I do if my seed is healthy, but my soil is contaminated? This exercise allows us to diagnose soil and seed that is contaminated with root galling nematodes.*

◊ MATERIALS

- Field where a farmer wants to plant potato for seed
- Shovel, hoe or other tool to dig earth
- Bucket
- Plastic bag
- Clean water
- A healthy potato tuber, which we know to be free of nematodes. It can be certified seed.
- Option. Instead of using a tuber, one can use potato sprouts, since there is no rosary bead nematodes in sprouts, but there is in tubers

◊ PROCEDURE

- Collect soil from at least 6 different places in the field. From each place, take a little soil, to a depth of 10 cm deep.
- Mix the earth in a bucket.
- Take out some of the soil, until half a kilo is left in the bucket.
- Add water to the soil, until it is moist enough to plant potatoes.
- The soil should be neither too moist nor too wet, but just right for planting potatoes.
- Put the moist soil in a plastic bag.
- Put a healthy and well-sprouted potato into the bag.
- Close the bag.
- Keep the bag in the house beneath the bed or in the kitchen for a month.
- Remove the potato and look at the roots.

◊ OBSERVATIONS

The group observes the potato roots.

AFTER ONE MONTH OPEN THE PLASTIC BAG AND SEE THE SWELLINGS ON THE ROOTS PRODUCED BY THE NEMATODES

◊ DISCUSSION

Do the roots have nematode root galls or not?

Is the soil in this field healthy or infested?

Is it good for growing seed potato?

What happens when there are nematode galls on the roots of the plants in our field?

◊ OPTION

You can do this exercise with sterilized soil and with tubers that are possibly infested, to see if they are healthy or not.

Use infested seed, and virgin soil, or toast some soil on a grill to kill the nematodes.

Plant 4 infested seeds in 4 bags, with healthy soil. (The 4 repetitions make it more likely to obtain positive results, if the seed is infested).

If there are nematode root knots after a month, it means that the seed is infested with nematodes.

Potato 7

CROP ROTATION

(FOR THE CONTROL OF NEMATODES)

Objective: Explain that crop rotation and fallowing help to control nematodes.

Nematodes live in the soil and in the tubers of potatoes.

◊ MATERIALS

- A field that was planted the previous year with:
- potato
- barley or another cereal (maize, wheat oats)
- legume crops (broad beans, lupines, peas, beans)
- A field that has been in fallow for many years
- Diagnostic materials (see previous exercises)

◊ PROCEDURE

- Select 4 fields based on conversations with farmers.
- Do the diagnostic tests for nematodes in these fields (Potato 6. Bioassay in plastic bag; Potato 5. Glass and paper).

◊ OBSERVATIONS

The group observes which of the plots has the most nematodes in the soil.

This exercise works in field schools, CIALs or in community meetings. It does not work well in fairs, because it is more difficult to collect soil from 4 specific kinds of fields. In a community, people know their fields, but in a fair if the extensionist brings soil from elsewhere, and the exercise will not be as convincing.

◊ DISCUSSION

Which fields have the most nematodes?

Which fields are free of nematodes?

Why?

How can we rotate crops to control nematodes?

Potato 8

'CIGARETTE SMOKE'

IDENTIFYING BACTERIAL WILT

Objective: Identify bacterial wilt in potatoes and study the symptoms.

This is a simple and definitive method for identifying bacterial wilt. If there is no cloudy fluid flowing from the piece of stalk, the wilt is probably not caused by bacteria.

◊ MATERIALS

- A field with potato plants that are wilting
- 2 clear, transparent drinking glasses
- Clean water
- A small stick, about 10 cm long, and a piece of wire or a paper clip

SUSPEND A PIECE OF STEM IN CLEAR WATER TO OBSERVE THE 'CIGARETTE SMOKE' WHICH EMERGES FROM THE CUT SURFACE. THIS INDICATES THE PRESENCE OF BACTERIA.

◊ PROCEDURE

- Uproot a wilting plant.
- Observe the roots to see if there are any abnormalities, like galls (which could be caused not by bacteria, but by nematodes, wounds, insects etc.)
- Cut the stem and the upper root lengthwise to see if the vascular tissue is dark. This is not common, but rather is an advanced symptom of bacterial wilt.
- If there are tubers, cut one to see if pus oozes out of the vascular tissue. (It is often necessary to squeeze the tuber to press out the bacterial pus). It is an advanced symptom.
- Cut the stalk at the top of the root, and again about 5 cm higher.
- Hold the cut section of stalk in a glass of clean water (using sticks, wire etc.) with the bottom of the stalk in the water (one stalk per glass) – *see the photo on the next page*.
- Wait a few minutes.
- Be careful not to disturb the water, and to keep the glass still (if it moves, you will not see the fluid).
- This test usually only convinces people when there is a control, i.e. a healthy plant. If a farmers will allow it, pull up a healthy plant and follow the same steps as above, to compare the results with those from a wilted plant.

◊ OBSERVATIONS

After a few minutes, if you see a milky fluid draining like "cigarette smoke" from the section of stalk, there is bacterial wilt. After observing the flow, cut the stalk lengthwise to look at the vascular tissue.

- Is there dark tissue?
- Have the cut tubers turn dark?
- Does pus ooze from the pieces of cut tuber when one squeezes them?

◊ DISCUSSION

Why does the plant wilt?

Why did the plants wilt if there was no bacterial flow? (Possibly from nematodes, drought etc.)

Potato 9

'WARM BAG'

IDENTIFYING BACTERIAL WILT

Objective: Identify bacterial wilt in potato tubers.

A simple method to identify bacterial wilt in seed potatoes.

◊ MATERIALS

- Several potatoes (one or two pounds)
- Paper bags, or sheets of newspaper
- A knife

◊ PROCEDURE

- Get some potatoes that are suspected of having bacterial wilt.
- The test will be more interesting if you use it to compare 2 or 3 lots of seed, to see which one is healthier.
- Place the potatoes in paper bags, or wrap them in sheets of newspaper. Put just one potato in each bag.
- Close it tightly.
- Leave the tuber in a warm place for a week. It can be in the kitchen or some other warm place.
- Open the bag and cut open the tuber; see if it has pus.

◊ OBSERVATIONS

A potato with bacterial wilt that does not show any symptoms may develop symptoms after being in a warm place for a week.

- Is there dark tissue?
- Have the cut tubers turned dark?
- Does pus ooze from the cut pieces of tuber when you squeeze them?

◊ DISCUSSION

Does the potato have symptoms of bacterial wilt?

Do we want to plant this potato?

This method may take too much time to identify bacterial wilt in potatoes from the market, but we can use it to decide if we want to plant some of our own seed again or not.

Potato 10

TESTING IN THE MARKET

IDENTIFYING BACTERIAL WILT

Objective: Identify bacterial wilt in tubers of common seed, before buying it.

Farmers need a method for diagnosing bacterial wilt in common seed before buying it. Once they have spent their money on seed, farmers have no option but to plant it, so a test performed after purchase is of little use. Farmers can do this simple activity with common seed that they buy at fairs and markets.

◊ MATERIALS

- Some potatoes
- A knife

◊ PROCEDURE

- Buy a little bit of common seed in the market (or at a fair).
- Cut the potato, removing a slice around the stolon (root bud).
- Squeeze the potato to see if it has pus.

◊ OBSERVATIONS

Tell the farmers that potatoes grown low in the Andes, below about 2,500 meters, probably show symptoms if they have bacterial wilt. But potatoes from higher than 2,500 above sea level often have a latent infection of bacterial wilt. That is, they have the infection but not the symptoms. This is called a "latent infection." Potatoes from the high Andes have less bacterial wilt, but when they do have it, it is usually a latent infection, which cannot be seen with the naked eye.

- Is this seed from low country or from the high Andes?
- Have the cut tubers turned dark?
- Does pus ooze from the cut tubers when they are squeezed?

THE WHITE OOZE CONTAINS BACTERIA AND IS A CLEAR SIGN OF INFECTION. THIS POTATO SHOULD NOT BE USED FOR PLANTING NEW CROPS.

◊ DISCUSSION

Does this potato come from the high Andes? (If the answer is "yes," then it is probably free of bacterial wilt).

Is this potato from the low country? (If the answer is "yes," cut it to see if there is pus in the ring of vascular tissue).

Does the potato have pus? (If it does, do not buy it for seed).

Potato 11

POTATOES IN POTS

THE LIFE OF BACTERIAL WILT

Objective: To compare the development of healthy plants with that of diseased plants. To recommend the use of clean soil and healthy seed potato.

A method for observing the development of bacterial wilt.

◊ MATERIALS

- 8 healthy tubers, ready to plant
- 8 tubers infested with bacterial wilt, ready to plant
- 16 large pots
- Clean soil
- Contaminated soil, from a field infested with bacterial wilt
- Organic fertilizer, well decomposed
- Paper and marker

◊ PROCEDURE

- Mix the fertilizer (manure) into the soil.
- In 4 pots plant healthy seed in clean soil.
- In 4 pots plant healthy seed in contaminated soil.
- In 4 pots plant diseased seed in healthy soil.
- In 4 pots plant diseased seed in contaminated soil.
- Make small labels or in some way mark the pots so you know which one is which.
- Water the pots with clean water, and keep them free of weeds and do the other normal tasks that are necessary for growing potato plants.
- Observe the plants every week or two.
- When they are ripe, harvest the tubers.
- ***Alternative***: Take 2 healthy plants and 2 diseased ones in pots to the fair to show to the public.
- ***Alternative***: Farmers may suggest other treatments to try. One community in Chuquisaca, Bolivia decided to fertilize some potatoes with chicken manure, and not others (they did this in contaminated soil, but with healthy seed), to see if the chicken manure could improve contaminated soil. This treatment stemmed from the community's concern with how to disinfect their soil (they have access to clean seed). Every place has its own conditions and worries.

◊ OBSERVATIONS

Every week:

Which plants wilted?

Which plants are big and healthy?

At harvest, do the warm bag test. Cut a tuber and see if it has pus.

Which plants yielded more, the healthy ones or the diseased ones?

Which potatoes had pus?

◊ DISCUSSION

What are the differences between potato plants that come from healthy seed and those that come from diseased seed?

When a plant has bacterial wilt, are all the tubers from that potato plant diseased, or just some of them?

What are the differences between plants reared in healthy soil and those grown in contaminated soil?

What happens if we plant diseased seed in our fields?

Potato 12

'COFFEE AND WATER'

AN ANALOGY OF THE SPREAD OF DISEASE BY INSECT VECTORS

Objective: Demonstrate (symbolically) the spread of pathogens by insects.

◊ MATERIALS

- A syringe or a drinking straw
- 5 transparent drinking glasses
- Strong coffee
- Clean water

Optional: samples of healthy and diseased plants. Samples or photos of sucking insects.

◊ PROCEDURE

- Fill a glass with coffee and the others with clean water. The syringe or straw represents a sucking insect. The glass with coffee represents a diseased plant with a virus. The glasses of water represent healthy plants. Suck a bit of coffee into the syringe and go to the first healthy plant (glass of water). Dip the syringe into it, squirting ("spitting") a bit of coffee before sucking from the plant (the glass). Observe the colour of the water.
- The healthy plant (the glass of water) gets a dose of virus (coffee). Go from glass to glass, squirting a bit of coffee into each one, "infecting" them. "Suck" a little water from each glass ("feeding"). Observe the colour of the water in the glasses, and that there is less inoculum in the syringe, because it has been diluted by the "healthy plants".

THE CUP ON THE LEFT CONTAINS COFFEE AND REPRESENTS THE DISEASED PLANT. AS THE FLUID IS 'TRANSMITTED' SO THE CLEAR WATER BECOMES 'INFECTED', REPRESENTING THE EFFECTS OF INSECT VECTORS. (ENFERMA – DISEASED; SANA – HEALTHY)

◊ DISCUSSION

Which diseases are transmitted by sucking insects?

Which diseases are transmitted by water splash, by infested soil?

Which sucking insects do you know?

How can we avoid spreading diseases from one plant to another? (Emphasize deterring vectors through cultural practices. If infection is low, rouging of diseased plants may be considered only when there is no further infection expected from outside the field). Caution farmers against making unnecessary applications of insecticides).

3 *Exercises* • peach

1. Aphids versus peach leaf curl
2. The Natural Enemies of Aphids
3. Development of peach leaf curl
4. *Ring of Wool*: controlling aphids and ants
5. *Green Pruning*: control of peach leaf curl
6. Peach Yellows (and the death of trees)

FROM LEFT TO RIGHT: APHID DAMAGE, PEACH YELLOWS, MITE DAMAGE (SEEN MORE CLEARLY ON THE RIGHT)

BROWN ROT OF PEACH (FRUIT) IS CAUSED BY THE FUNGUS *MONILIA*. THE EARLY STAGES OF INFECTION CAUSE A SHOOT BLIGHT.

MITE DAMAGE IN THE CROWN.

Peach is attacked by a number of pests in Bolivia and not all are included in these exercises (or datasheets). In wetter regions brown rot is a reported to be serious while mite damage is commonly observed in all areas.

Peach 1

APHIDS VERSUS PEACH LEAF CURL

Objective: Learn the difference between aphids and peach leaf curl.

People in Bolivia often call both aphids and leaf curl "musuru." But aphids are insects and leaf curl is caused by the fungus Taphrina deformans.

◊ MATERIALS

- Peach trees with abundant aphids and leaf curl (not necessarily on the same tree)
- If you are going to use this exercise in a public place (like a fair) take branches with aphids and leaf curl
- Magnifying glass

◊ PROCEDURE

- Observe the aphids and the leaf curl on the peach trees. Discuss the difference between aphids and peach leaf curl.

◊ OBSERVATIONS

Observe the aphids. Notice if they have ants with them or not. Observe the peach leaves with leaf curl. Notice the differences between aphids and leaf curl. Use a magnifying glass to observe them better.

Frequently, Bolivian farmers say that peach leaves have become a ***k'urpa*** (dirt clod) where there are aphids. There is a small black ant among the aphids. On the other hand, the peach leaf curl may take the form of yellow dots, or a red swelling, or of a black smut (***musuru***) (see exercise Peach 3 for a more complete description of the stages of peach leaf curl.

The aphids make a "dirt clod" from the leaves, i.e. a ball of leaves, and inside the ball the leaves are twisted. But leaf curl makes the leaves swell, like maize smut. There are ants with aphids, but not with peach leaf curl.

In its most mature or advanced form, the ball of leaves where the aphids live dries, and becomes brittle; it has a dark colour. Leaves with leaf curl become covered in a soft powder (like charcoal) of a vivid black colour. The texture of the leaf is soft and not brittle.

◊ DISCUSSION

What do aphids eat?

Were there other insects with the aphids?

What do the ants do? (They do not eat the aphids, they take care of them).

Do the ants protect the aphids or attack them?

Were there ants on the peach leaf curl lesions?

What colour where the leaves with aphids?

What colour were the leaves with leaf curl?

Were the leaves with leaf curl swollen?

What shape were the leaves with aphids?

Which causes more damage here in this area, aphids or peach leaf curl?

PEACH SAMPLES ARE USED TO DEMONSTRATE THE DIFFERENCE BETWEEN APHID DAMAGE AND OTHER PEST ATTACK IN LA PLAZA DE TARABUCO. BOLIVIA

When are aphids the most problamatic? When is leaf curl the most problematic?

Are there any varieties that have no problems with leaf curl?

Peach 2

THE NATURAL ENEMIES OF APHIDS

Objective: To see the natural enemies of aphids, especially hover flies and ladybird beetles.

Not all insects are pests. Some are the enemies of the pests, and the friends of the farmers.

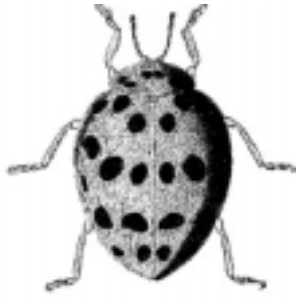
◊ MATERIALS

- Peach trees where insecticides have not been applied, with aphids

◊ PROCEDURE

- Explain about the natural enemies of aphids. The most abundant ones are hover flies, ladybird beetles and wasp parasitoids.
- Teach farmers about the life cycle of the different insects. Photographs may be useful.
- Visit the grove. Each person in the group should go to a peach branch where there are aphids. Each person should observe the aphids and other insects for 15 minutes. Then the group should get back together for discussion. If that is not possible, at least visit the grove and see as many beneficial insects as you can. In a public place, like a fair, show photos, and ask the people if they know the beneficial insects. Explain that they are good insects, because they eat and kill pests.
- Visit another grove where insecticides have been applied, or a field of annual crops where insecticides have been applied. See which beneficial insects you find there. Usually there are far fewer beneficial insects in places where insecticides have been applied.

SYRFID LARVA



LADYBIRDS

◊ OBSERVATIONS

Notes on some natural enemies and their life cycles:

Hover flies: these are a kind of fly (syrphids); they have black and yellow stripes, like bees. They are common in field crops. Their larvae (maggots) are white, with no legs and hardly any head. They live among aphids and eat them.

Ladybird beetles: are small red beetles with black spots. They are also called ladybugs. They are more or less the size of leaf beetles (*Diabrotica* spp.), but leaf beetles are green and yellow. Leaf beetles eat crops, but ladybird beetles eat other insects. Their larvae (juveniles) are orange and black, and they have legs: they look a bit like little crocodiles and they walk around a lot. They are common insects.

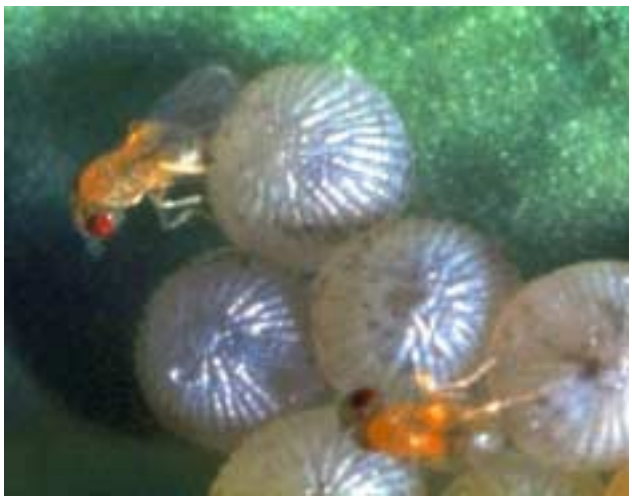
THE DEAD APHID WAS KILLED BY A PARASITIC WASP

Wasps: there are large social wasps, or paper wasps, that build nests and hunt other insects, to take them back to their nests to feed them to their young. Besides these, there are small wasps called parasitoids, which lay their eggs inside or on other insects. The grubs of the parasitic wasps hatch inside the other insect, which they eat and kill. Some of these small parasitic wasps lay their eggs in aphids. The grub of the wasp eats the aphid, leaving it an empty shell, like a straw-coloured balloon.

Chrysopa: also called "green lace wings" because their wings are thin and almost transparent. The *Chrysopa* is green, active at night, and it flies. They are abundant, but difficult to see. *Chrysopa* eggs are white. The *Chrysopa* lays them on the tip of an erect white filament, so they look somewhat like small lollypops. *Chrysopa* eggs are found on the leaves of peaches, oranges and other trees.

NOTE. All these useful insects live not just in trees, but in annual crops too.

Observe beneficial insects in crops where insecticides have been applied, and in fields or groves where they have not been applied. Compare them, to see if there are more useful insects where insecticides have been used or where they have not been used.



PARASITIC WASPS PUT THEIR EGGS IN MOTH EGGS

◊ DISCUSSION

Which other insects did you observe with the aphids?

What where those other insects doing?

When we apply insecticides, do we kill the useful insects along with the pests?

Which insects did you observe in the plot where insecticides had been applied?

Which insects did you observe in the plot where insecticides had NOT been applied?

Which grove had the most insect pests?

Which grove had the most beneficial insects, that is, the most natural enemies of the pests?

Were there more pests before we started using insecticides, or afterwards? Why?

What can we do to encourage the presence of these natural enemies?

Explain to the group that beneficial insects are insects too, and that insecticides kill them. Beneficial insects are more susceptible to insecticide than are the insect pests. The pests become increasingly resistant to insecticides, but the natural enemies generally do not.

Peach 3

DEVELOPMENT OF PEACH LEAF CURL

Objective: Learn how the symptoms of peach leaf curl develop.

◊ MATERIALS

- Peach trees with leaf curl
- Paper for labels
- Magnifying glass

◊ PROCEDURE

- Choose a grove, which has not been sprayed with fungicides, which does have symptoms of peach leaf curl (*Taphrina*). Sometimes you can find all the stages of leaf curl on a single tree. Show the group the different stages of leaf curl, and explain them.
- To do this activity in a fair or another public place, take samples of branches, with different stages of leaf curl damage.
- If you cannot find all of the symptoms at once, put labels on the trees and branches that you want to monitor. Observe them once every week or two. Make sure that fungicides are not applied on the grove. See how the lesions change over time.
- In Bolivia, leaf curl is more common in the higher, more humid areas, and after December and January. In dry years it is harder to find.

◊ OBSERVATIONS

Use a magnifying glass to see if there is mould or spores on the leaves. Pay attention to the weather (sunny, cloudy, rainy).

Leaf curl appears on fresh new leaves, not on old ones. The stages of the disease's development are:

Yellow spots appear on the leaves.

The yellow dots swell.

The dots, or swollen areas change from yellow to red, and extend over the surface of the leaf. Once the symptoms are advanced, the swelling covers the leaf, or much of it.

In the end, the lesion changes from red to black and the spores are like a soft, black powder, like charcoal. The leaf curls up and people call it *musuru*, because it looks like maize smut. The texture is soft, and the colour is a bright black.

◊ DISCUSSION

What happened to the branches and leaves over time (colour, shape, structure)?

How can one recognize the start of the development of leaf curl?

What is the difference between the symptoms caused by peach leaf curl, and those caused by aphids?

What effect does the weather have on the development of the symptoms?

Peach 4

'RING OF WOOL'

CONTROLLING APHIDS AND ANTS

Objective: Learn to manage aphids, placing a wool ring around the peach trunks.

◊ MATERIALS

- Peach trees with aphids
- Long, fluffy strands of raw sheep's wool
- A powdered insecticide, of low mammalian toxicity, preferably specific to ants

TIEING THE COTTON WOOL AROUND THE TRUNK OF THE PEACH TREE.

◊ PROCEDURE

- Find peach trees with aphids. It may be a grove or peaches on the edges of a field.
- Do the exercise at the beginning of the growing season, when the young leaves are just coming on.
- Tie a piece of wool around the trunk, just below the main branches. If you place the ring much lower, dogs and other animals may disturb it. Dust the wool with insecticide.
- Put wool rings with insecticide on many trees (for example, half of a grove), not just on two or three trees. That way the exercise will be more convincing.
- Leave a few trees as a control group, with no wool ring and no insecticide.

APPLYING AN APPROVED INSECTICIDE TO THE RING OF WOOL

◊ OBSERVATIONS

Remind the people that aphids have enemies, like hover flies, ladybird beetles, wasps and *Chrysopa*. The ants protect the aphids from their natural enemies.

Watch for a while, after tying the wool, to see if the ants still climb the trunk.

Watch the behaviour of the ants. (They enter the wool, get tangled up; go crazy trying to get through it).

Look for ant nests on the ground below the tree. What colour are the ants?

Go back a week later to see if there are aphids in the trees where wool rings have been placed. See if the tree starts to sprout new, healthy leaves from the places damaged by aphids.

◊ DISCUSSION

Which insects kill aphids? (Hover flies, ladybird beetles, wasps and *Chrysop*a).

What do ants do to aphids? (Protect them).

What will happen to the aphids if the ants cannot protect them? (Other insects, the enemies of the aphids, like hover flies and ladybird beetles, will kill them).

What will happen to the aphids' enemies if we spray insecticide? (They die, and cannot kill the aphids).

What happens to the ants when they get to the wool? Do they get through or not?

Do you know of any other ways to control the ants?

Would the ring of wool work without the insecticide?

Peach 5

'GREEN PRUNING'

CONTROL OF PEACH LEAF CURL

Objective: Test this management technique for peach leaf curl.

◊ MATERIALS

- Peach trees with leaf curl
- Pruning shears

◊ PROCEDURE

- Find peach trees with leaf curl. They can be in a grove or on a field edge.
- Find leaves with leaf curl. Cut them off with the sheers or with your bare hand.

◊ OBSERVATIONS

The symptoms of leaf curl appear only on new leaves and branches. The fruit grows on last year's branches. Removing diseased leaves and branches forces the tree to replace them with healthy branches, where fruit will grow the following year. When there is leaf curl, new branches cannot grow, and no fruit will be produced there the next year.

In very large trees it is more difficult to do this practice.

For several weeks, observe the branches where you have pruned the diseased leaves and twigs, to make sure that the pruning has controlled the leaf curl.

See if the trees sprout new leaves and twigs. Are they soft and healthy?

To compare your observations with other trees, you can prune some and not others. The unpruned trees are the control group.

Observe some trees that were properly pruned during dormancy, and compare disease incidence on pruned and unpruned peach trees.

◊ DISCUSSION

Is there more or less leaf curl in the trees that were pruned in winter (in dormancy)?

Does pruning help to manage leaf curl?

Where is there more leaf curl, on new leaf growth, or on old branches near the trunks?

PRUNING LEAFS WITH LEAF CURL

PRUNED LEAVES

Peach 6

PEACH YELLOWS

(AND THE DEATH OF TREES)

Objective: compare the symptoms of peach yellows with other kinds of damage and find out what the farmers know about this disease.

We have observed yellowing in the crowns of peaches in the Camargo and Sucre areas of Chuquisaca, Bolivia. These trees often die. The symptoms are different from those of aphids or mite, but we do not know the cause of this serious disease.

◊ MATERIALS

- Branches and leaves with peach yellows
- Branches and leaves from peach trees with mite damage (or aphid damage, if there are no mites)
- Healthy peach branches and leaves
- Magnifying glass

◊ PROCEDURE

- Show the three kinds of branches and discuss the differences in their appearance. This can be done in the field or in a public place (like a fair).
- Examine the specimens with a magnifying glass to look for insects, remains of mites or other signs of pests.
- Look for trees with different stages of development of damage to the crown. Compare them with mite and aphid damage. Discuss the development of symptoms and the dieback of branches and of trees.

PEACH YELLOWS,SUCRE. DISEASED ON LEFT, HEALTHY FOLIAGE RIGHT.

◊ OBSERVATIONS

We know little about the cause of this problem, but the symptoms are the same as a well-known phytoplasma disease. Therefore, it is important to observe and to try to diagnose this problem.

Sometimes branches with yellows die, and in time even whole trees can die. Leaves with yellows are smaller, more narrow and yellower than leaves with mite damage. The internodes are shorter and the leaf stalks are denser than those of a healthy tree. Some diseased trees produce leaves directly from the trunk.

The tree has more foliage when it is healthy or when it has mites; when it has yellows it loses leaves, and some branches lose all their leaves and die. The yellows are of a bright colour, while mite damage is of a paler yellow. Mites appear on the central vein of the leaf, while yellowing occurs on the whole leaf.

During the early stages of the disease, some parts of the crown stay healthy and make a sharp contrast with the yellow parts of the crown. We have not observed aphid damage in the yellowed trees, but there may be other pests present.

Find out if people have seen the disease. It is possible that they have seen it, but they may have confused it with mites or some other health problem.

◊ DISCUSSION

Have you seen the disease in your home communities? What do you call it?

Is yellowing related at all to different peach varieties? Are the native or the introduced trees more resistant?

How is the disease spread and how can it be controlled?

Control. Although we do not know how to control this disease, there is no point in applying a chemical to it.

Take care to only plant healthy seedlings. Do not plant diseased material.

Do not graft branches from diseased trees onto other trees.

Do not plant seed from diseased trees.

Discovery through Diagnosis

Effective pest management in agriculture begins with the correct identification of the pest responsible for damage. Using examples taken from potato and peach trees grown in Bolivia, this manual describes participatory exercises which show how to diagnose common problems and therefore what control methods could be used. The aim of the exercisese is to promote discovery learning so that farmers and extension workers can use and develop similar approaches for other crops and pests. The exercises are accompanied by datasheets prepared from the CABI Crop Protection Compendium. These provide up to date information that will help local extension workers – for example those working for CIAT Santa Cruz and PROINPA – deliver a better service to local farmers.

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