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General enquiries

ARC-Vegetable and Ornamental Plants
Private Bag X293
Pretoria
0001
South Africa

e-mail: vopiinfo@arc.agric.za
website: http://www.arc.agric.za

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ARC-Vegetable and Ornamental Plants and ARC-Industrial Crops Newsletter

Newsletter of Vegetable and Ornamental Plants and Industrial Crops, campuses in the Crop Sciences Programme of the Agricultural Research Council (ARC)

The Organisation for Economic Co-operation and Development (OECD) Biosafety Working Groups

Compiled by Dr Dean Oelofse, Crop Protection Division, ARC-VOP

The OECD provides a forum in which governments work together, sharing experiences and seeking solutions to common problems. The 37 OECD member countries (Table 1) turn to one another to identify problems, discuss and analyse them, and promote policies to solve them. Key partners (non-member countries) contribute to the OECD's work in a sustained and comprehensive manner, and these include: Brazil, China, India, Indonesia and **South Africa**.

OECD countries recognise the value of working together to harmonise approaches and share information used in the safety assessments of genetically modified (GM) products, increasing the efficiency of the risk/safety assessment process, and reducing duplicative efforts. Thus, two OECD Biosafety Working Groups have been established:

- The Working Group on Harmonisation of Regulatory Oversight in Biotechnology (WG HROB): addresses aspects of the environmental risk/safety assessments of GM plants, fish and micro-organisms.
- The Working Group for the Safety of Novel Foods and Feeds (WG SNFF): addresses aspects of the safety assessments of foods and feeds derived from GM crops.

The OECD work on biosafety and food/feed safety assessments is aimed at assisting countries in the evaluation of the potential risks of transgenic products, to ensure that high safety standards are maintained, and to foster a mutual understanding of relevant regulations.

The main objective is to ensure that the types of information and data used in the risk/safety assessments, and the methods used, are as similar as possible amongst countries. Both programs identify a common base of scientific information that can be useful in assessing the safety of specific products regarding human food, animal feed and the environment.

The main outputs are the 'Consensus Documents'. These documents are practical and science-based tools containing key information on major crops, agreed upon by consensus, which countries believe to be relevant in the risk/safety assessments of new, genetically engineered products, compared to the conventional ones.

WG HROB: This Working Group develops Consensus Documents on aspects of the biology of major crop species and trees, introduced traits, as well as micro-organisms that are of relevance to the risk/safety assessment. These documents address the biology of the crop and include a short natural history of the plant, its major uses, agronomic practices, and if relevant, the potential for out-crossing within crop species and among related species. There are also documents addressing traits inserted in plants derived using modern biotechnology.

WG SNFF: This Working Group develops Consensus Documents to address food and feed safety assessments. They contain information on the major components of specific crop plants, such as key nutrients, toxicants, anti-nutrients and allergens at the time of harvest (fresh), as well as after processing for use as food and feed. This information is of value in the safety assessments of new GM varieties for the comparison of these components of the new variety to those of the traditional varieties.

In 2012, the ARC was requested to send a representative to attend the OECD Biosafety and Food Safety meetings and events, and to represent South Africa. Subsequently, Dr Oelofse has been attending the meetings and events held in Paris, France, annually.

Table 1: List of the Organisation for Economic Co-operation and Development (OECD) member countries

Australia	France	Latvia	Slovenia
Austria	Germany	Lithuania	Spain
Belgium	Greece	Luxembourg	Sweden
Canada	Hungary	Mexico	Switzerland
Chile	Iceland	Netherlands	Turkey
Columbia	Ireland	New Zealand	United Kingdom
Czech Republic	Israel	Norway	United States
Denmark	Italy	Poland	
Estonia	Japan	Portugal	
Finland	Korea	Slovak Republic	

Dr Oelofse is a committee member of the OECD WG HROB, and a Bureau member (vice-chair) of the WG SNFF (the first non-member country member to hold this position within this Working Group).

The presence of an actively participating representative from South Africa is highly appreciated by all of the OECD member countries, and serves to strengthen future collaboration between South Africa and OECD countries regarding issues around the safety assessments of products derived from biotechnology, and the harmonisation of approaches and sharing of information used in safety assessments of GM products.

The presence of multiple differences between the GM crop and the untransformed counterpart requires rigorous safety assessments to determine the impact of these unintended and unexpected alterations of the intended enhancement of the GM crop. Thus, it is very important that the ARC and South Africa ensures that the types of information and data used in the risk/safety assessments, as well as methods used, are as similar as possible amongst countries, as indicated in the developed Consensus Documents. This will ensure that we comply to the required international legislation requirements, and that we note possible changes in legislation as it can/will affect trade/export.

South Africa's participation in the development of Consensus Documents

1. Consensus Document on the Biology of Sorghum (*Sorghum bicolor* (L.) Moench). South Africa and the USA were co-leads. Declassified June 2016.
2. Cowpea Composition Consensus Document: South Africa (the ARC) assisted. Declassified December 2018.
3. Revision of the OECD Potato Composition Consensus Document: South Africa (the ARC) co-lead with the Netherlands. In progress and almost ready for submission to be declassified.

Dr Oelofse also reviews and edits all of the draft versions of the Consensus Documents being drafted by both of the Biosafety Working Groups. These documents are extremely important and recognised world-wide as high quality documents, and are only declassified by the OECD after intensive review. The ARC (and South Africa) is thus making an important contribution to highly regarded documents world-wide.

Update of the OECD BioTrack Database

The OECD Product Database is publicly available on BioTrack at http://www2.oecd.org/biotech/. The database allows regulatory authorities and a wider range of stakeholders to easily share basic information on transgenic products that have been officially approved for commercial application in at least one country, for either release to the environment (crops) and/or for use in foods or feeds. Products with their respective unique identifier are described, with a corresponding list of country approvals. The database is updated using information provided on a voluntary basis by authorities in OECD member and non-member countries that have approved these products. Dr Oelofse, with the assistance from the then Department of Agriculture, Forestry and Fisheries (DAFF) (now the Department of Agriculture, Land Reform and Rural Development (DALRRD)), provided the OECD Secretariat with all of the relevant information needed in order to enter all of the approved GMO events in South Africa into the OECD BioTrack Database, dating back to 1997. It is the first time that the South African information has been entered into the OECD BioTrack Database. There are 21 general release entries and 75 commodity clearance entries. Dr Oelofse will ensure that the approved GMO events in South Africa will be entered into the OECD BioTrack Database on a regular basis. The entries can be viewed at: http://www2.oecd.org/biotech/default.aspx

South Africa's participation in OECD Biosafety Working Group surveys

Dr Oelofse actively participates in the surveys conducted by the OECD Biosafety Working Groups. These surveys are conducted in the form of questionnaires developed by the OECD Secretariat in collaboration with the OECD Biosafety Working Groups. These surveys cover a variety of topics of relevance to the Program of Work of these two Working Groups. They also address new technological developments in the field of biotechnology (genetic engineering) that the Working Groups should take note of, as these could impact on the Program of Work of these two Working Groups, with the identification and development of new project proposals for future work to be undertaken to ensure that emerging needs are addressed. Once the questionnaires have been finalised by the OECD Secretariat, each of the country delegates are expected to conduct the surveys in their respective countries, by seeking inputs from all of the relevant role players. Thus, once these questionnaires are finalised, Dr Oelofse seeks the inputs from the role players in South Africa, and forwards the consolidated inputs for South Africa to the OECD Secretariat. In this way, Dr Oelofse ensures that the South African information is noted by the delegates attending the meetings in Paris, which adds value to the discussions held on the outcomes of these surveys at these meetings. These activities all aim at information sharing between the various countries, thus by participating in the surveys, Dr Oelofse ensures that South Africa participates in knowledge sharing, one of the very important objectives of the Working Groups.

OECD Biosafety events

The OECD Secretariat often arranges side-events back-to-back with the two Working Group meetings. Dr Oelofse is always invited to attend these side events. These events are of utmost importance to attend as they address issues of relevance to the day, as well as on new emerging technologies, such as the New Plant Breeding Techniques (NPBTs), which includes genome editing. Of note are the following:

1. The European Food Safety Authority (EFSA)-Austria-Norway Workshop on Allergens and Allergenicity (21 March 2012).
2. The International Life Science Institute (ILSI) Workshop on the Molecular and Genetic Basis of Potential Unintended Effects in Modified Plants (14 April 2015).
3. The OECD Workshop on High-throughput DNA Sequencing in

the Safety Assessment of Genetically Engineered Plants (18 April 2016).

4. The OECD Conference on Genome Editing: Applications in Agriculture – Implications for Health, Environment and Regulation (28-29 June 2018).
5. Joint WG-SNFF/WG-HROB Workshop on "Environmental and Food/Feed Safety Assessments of Biotechnology Products, Four Decades of OECD Work – Experience Gained, Achievements, Looking Forward and Planning for the Future (8 April 2019).

Tour de Table

The '*Tour de Table*' gives the delegations (countries, observer organizations) the opportunity to briefly present their developments relating to their environmental safety activities at the Working Group meetings since the last meeting. This exercise is an informal update, supported by short written statements sent by delegations in advance of the meetings, enabling information sharing. Dr Oelofse prepares, submits and presents the '*Tour de Table*' document for South Africa at the meetings. One of the 'hot topics' to be addressed in the '*Tour de Table'* is "The regulatory implications of new plant breeding technologies in each country".

When Dr Oelofse requested information from some of the stakeholders on research being performed using NPBTs in South Africa, they all expressed their interest in receiving the information on NPBTs contained in the OECD '*Tour de Table'*. This includes research institutions, universities, Biosafety South Africa, the then DAFF (now the DALRRD), the Department of Science and Innovation (DSI), and the Technology and Innovation Agency (TIA). Biosafety South Africa and the DSI/TIA unit for promoting biosafety in South Africa are intimately involved in advancing regulations in genome editing and other NPBTs. The DSI indicated that the information would be most useful to the regulators in South Africa, in particular the Advisory Committee (AC) and the Executive Council (EC).

Biosafety South Africa has expressed an interest in developing a South African database on people who are working on genome editing, together with Dr D Oelofse, as this information is not that easy to obtain, because the plant genome editing community in South Africa is still small. This will assist in the gathering and sharing of information on genome editing research being performed in South Africa at the OECD WG HROB and the OECD WG SNFF meetings. This is important because it was previously agreed that delegations will continue with information sharing on NPBTs and other new technologies at these meetings, and that delegations will include in the written *T'our de Table'* their experiences with NPBTs and other new technologies.

It is very important to note that the OECD document containing the consolidation of the written summaries on NPBTs submitted by each country is the only document in the world that contains this information. Thus, it is an extremely valuable document that is available to all delegates attending the meetings in Paris, thus as well as to the ARC and South Africa.

Contact: Dr Dean Oelofse at doelofse@arc.agric.za

Common viral diseases of cucurbits: Symptoms identification and management

Compiled by Dr Julia Mulabisana, Crop Protection Division, ARC-VOP

Cucurbitaceae is a plant family consisting of many species and genera, and those important for human consumption are squash, zucchini, cucumbers, pumpkins, watermelons, muskmelons, etc. Some of the plants play an important role as vegetable relishes for smallholder farmers in rural and peri-urban areas of South Africa. Crops such as pumpkins, butternuts, patty pans, baby marrows, melons, zucchini, etc., are grown by commercial and emerging farmers for export and income generation. Biotic factors such as virus infections disrupt the plant's growth and development, thereby affecting production. This leads to losses in production and quality. Most plant viruses are transmitted from infected to healthy plants by living organisms or by insect vectors such as aphids. All aphids are characterized by a stylus (a kind of syringe needle) that is used to pierce and suck the sap from the plant. But the most harmful consequence for the crop is the transmission of viruses. Aphids can transmit dozens of viruses from a diseased plant to healthy plants in a few seconds. Virus infected leaves often have a mottling or mosaic pattern in shades of green and yellow. It is, therefore, crucial for all producers to familiarize themselves with common viruses of vegetables, including cucurbits.

CUCUMBER MOSAIC VIRUS

Cucumber mosaic virus (CMV) is the most widely distributed and important virus of cucurbits. It is transmitted by aphid species. Weed species harbor the virus when crops are not in season and aphids will acquire the virus and transmit it to new crops.

Recognising the symptoms: Leaves of infected plants will show mottling with yellow, light and dark green spots or patches, which appear to be prominent (Fig. 1A). A well-developed mosaic with a star shaped yellow mosaic, and in some cases, deformation on the edges of the leaves (Fig. 1B) can be observed. Severely infected plants are stunted and often exhibit a "shoe-string appearance", which is an indication that the edges of the leaves have failed to develop.

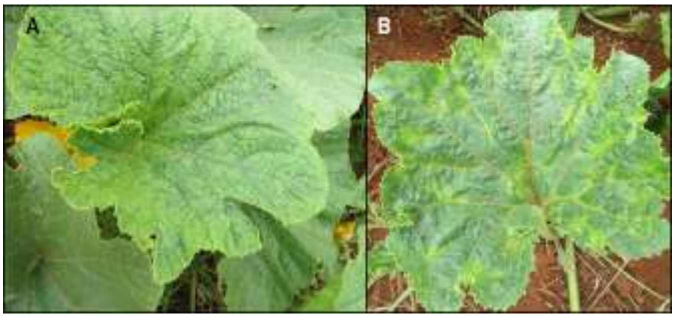

Figure 1: Symptoms of the Cucumber mosaic virus (CMV) includes (A) mottling with yellow, light and dark green patches, and (B) star shaped yellow mosaic appearance.

ZUCCHINI YELLOW MOSAIC VIRUS (ZYMV)

Zucchini yellow mosaic virus (ZYMV) is regarded as a major pathogen of cucurbits in most regions of the world, including South Africa. It is also transmitted to uninfected cucurbit crops by aphid species while feeding.

Recognising the symptoms: ZYMV is characterized by severe yellow mosaic symptoms. Symptom characteristics may be similar to that of the Watermelon mosaic virus (WMV). Foliar symptoms consist of a prominent yellow mosaic patterning, necrosis, distortion, and stunting (Fig. 2A and B). Severe mosaic symptoms will also develop a shoe-stringing appearance (Fig. 2C). Fruits may remain small, bumpy and deformed, with some green mottling (Fig. 2D), which makes them unmarketable.

Figure 2: Symptoms of the Zucchini yellow mosaic virus (ZYMV) includes (A) and (B) yellow mosaic pattern characterized by light and dark green patches, (C) shoe-stringing appearance, and (D) small, bumpy and deformed fruits.

WATERMELON MOSAIC VIRUS 2

Watermelon mosaic virus (WMV-2) is also one of the important viruses of cucurbits. Another water melon virus is Watermelon mosaic virus-1 (WMV-1), which is also known as Papaya ringspot virus (PRSV). Water melon mosaic virus is also transmitted to uninfected cucurbits by aphid species.

Recognising the symptoms: Infected plants with WMV-2 will first develop some yellowing between the veins (Fig. 3A and B). Leaf distortion may occur and fruits may also appear blistered. Mottling and vein banding symptoms, with some being light/dark green and silver in appearance, are characteristic of WMV-1. WMV infection is severe during warm, rainy seasons. Mixed infections of WMV and CMV is common by the end of the season and symptoms may appear severe.

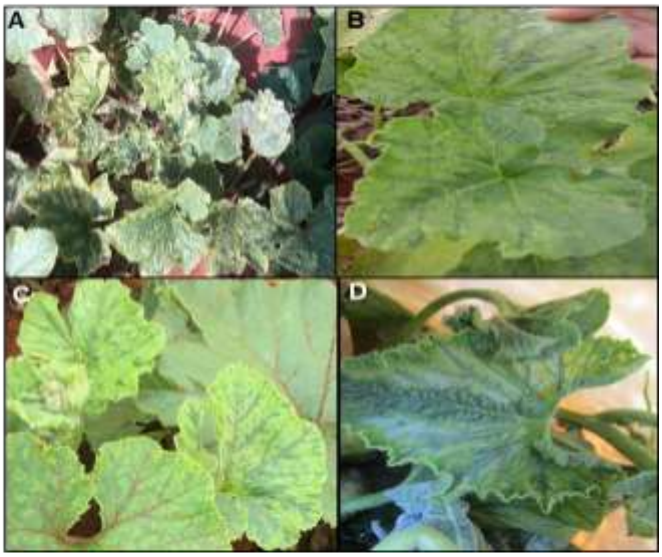

Figure 3: (A) and (B) Severe yellowing between veins (WMV-2). (C) and (D) Mottling and vein banding symptoms with some being light/dark green and silver in appearance (WMV-1).

Disease management

- The use of virus-free seeds to plant new crops.
- Avoid planting near old crops or crops planted in the previous seasons.
- A good sanitation program, which includes controlling of weeds, the use of disinfectants to wash implements and pruning equipment, and the elimination of plant debris around the crop fields is crucial to minimize infections and the spread of viruses.
- Infected plants should be removed and discarded away from the planting areas.
- The use of registered insecticides to control aphids, whiteflies, mites, etc., is recommended. This will not kill the virus, but will minimize infection and the spread from infected to uninfected crops.
- Some cultivars may have some form of resistance (natural immunity against some viruses). It is therefore important for farmers/producers to enquire from the seed/seedling distributors if a cultivar of interest has immunity against viruses. This may serve as a form of prevention and control.

Important to note: virus symptoms also differ, depending on the cultivar and the age of the plant when infection took place. Plants may be infected with one or two of the viruses described above, and in such cases, symptoms may be severe or difficult to diagnose from photographs. The best way to accurately identify virus diseases is through consultations with experts and to send samples for viral analysis in a laboratory. The ARC-VOP offers such services through the Diagnostic Centre. For more information on how to send samples, contact Dr René Sutherland at SutherlandR@arc.agric.za or on 012 808 8000. Alternatively, send a WhatsApp message to 073 3516930.

For more information, please refer to the references below:

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Contact: Dr Julia Mulabisana at MJMulabisana@arc.agric.za

The ARC-Vegetable and Ornamental Plant (VOP) Diagnostic Centre: assisting in identifying and controlling plant diseases

Compiled by Drs Julia Mulabisana and Rene Sutherland, Crop Protection Division, ARC-VOP

The Diagnostic Centre is situated on the ARC-VOP campus at Roodeplaat, 11 km North of Pretoria on the R573, Moloto Road (See map). It serves the research needs of vegetable, medicinal and ornamental plant growers in South Africa.

The Diagnostic Centre has different laboratories that address different diseases. Different diseases include those that are caused by fungal, bacterial and viral pathogens. It is therefore crucial for small-holder and commercial farmers, vine growers, nurseries, etc., to bring sick plants to the Diagnostic Center for correct identification of the infecting pathogens and recommendations on control measures. Scientifically verified nucleic acid based methods (RT-PCR, PCR or DNA sequence analyses) are used to accurately identify different disease causing pathogens. Several fungal pathogens can also be identified based on morphological characteristics. Depending on the disease and methods used for identification, results are provided within 10 - 14 days from when samples are received. Tomatoes, potato, sweet potato, onions, garlic, celery, Swiss chard, peppers, cucurbits, chrysanthemums, etc., are some of the samples that are regularly submitted to the ARC-VOP Diagnostic Centre for disease identification.

Location of the ARC-VOP, north of Pretoria. Entrance to campus at blue pin circled in red (S 25°36'54.0" E28°21'15.0").

Brown necrotic lesions on potato leaves, characteristic of late blight, caused by *Phytophthora infestans*.

Concentric blotches on pepper caused by the Tomato spotted wilt virus.

A sample that is not properly collected and shipped will arrive in poor condition, making it very difficult to diagnose the disease correctly. For more information on how to send samples, contact Dr René Sutherland at SutherlandR@arc.agric.za or 012 808 8000. Alternatively, send a WhatsApp message to 073 3516930. The sooner the sample is submitted to the Diagnostic Centre, the more accurate the diagnosis will be, and the sooner you will be able to control plant diseases.

Plant pathologists to contact for enquiries on different diseases:

Fungal diseases
Dr Elsie Cruywagen
012 808 8000
CruywagenEM@arc.agric.za

Bacterial diseases
Dr René Sutherland
012 808 8000
SutherlandR@arc.agric.za

Viral diseases
Dr Julia Mulabisana
012 808 8000
mjmulabisana@arc.agric.za

Black rot of cabbage, caused by the bacterium *Xanthomonas campestris* pv. *campestris.* Characteristic, brown V-shaped areas with yellow borders develop on the edges of the outer leaves.

Coleoptera pests of vegetables in South Africa

Compiled by Dr Diedrich Visser, Crop Protection Division, ARC-VOP and Ms Elizabeth Grobbelaar, Biosystematics Division, ARC-PHP

At least 82 beetle species (order Coleoptera) are known to attack vegetables in South Africa. However, most of these are minor pests that seldom inflict damage of economic importance to crops. A short description of eight of the most common and important beetle vegetable pest complexes/groups in South Africa follows, alphabetically sorted and complemented by colour photographs. For more information on the different beetle species and their names, as well as a complete list of all the insect vegetable pests, consult the book "Visser, D. 2009. A Complete Guide to Vegetable Pests in South Africa. ARC Roodeplaat Vegetable and Ornamental Plants Institute, Pretoria, South Africa. Pp. 316.", available from the ARC-VOP.

Blister beetles

Blister beetles are commonly found in gardens and vegetable plots. At least five species are known to attack vegetables in South Africa. Spotted and lunate blister beetles are known to damage pea and bean plants, whereas small grey blister beetles occasionally damage potato and spinach foliage. Felt blister beetles damage a variety vegetables, but beans in particular. The CMR beetle, like most blister beetles, preferably feeds on flowers, but may feed on bean foliage and pods when flowers are not available. Blister beetles can easily be removed by hand as a control strategy, thus preventing crop damage. However, they are known to release a blistering agent when disturbed, so wearing gloves is therefore recommended if one handles these beetles.

Chafer beetles

The term "chafer beetle" is generally used to describe several beetle species from the family Scarabaeidae. Chafer beetle ecology is very variable and some may even be predatory in the adult stage. However, at least 14 species are known to damage vegetables, feeding on the fruits, roots and foliage of certain vegetables. Six chafers in the subfamily Cetoniinae have been recorded feeding on overripe tomato fruit, while one species is known to feed on the "shoulders" of carrots. These beetles seldom inflict serious damage and are usually categorized as minor or "nuisance" pests. Leaf chafers may, however, become serious pests, particularly on leafy vegetables. Seven species regularly damage crops by eating irregular holes into leaves, or gnawing on the stems of crops, like eggplant. Some species are only active after sunset and are therefore seldom seen. They usually return to the same plants on successive evenings, and collecting the beetles by hand is a recognized control strategy. The larvae of most chafer beetles live in the soil where they feed on organic matter. Some are known to feed on roots and tubers – in such cases they may be regarded as pests and are referred to as white grubs.

Cucurbit leaf beetles

Three cucurbit leaf beetles species are known to damage the foliage of pumpkins and related crops, but sometimes they also feed on the flowers of these plants. Although these beetle species belong to different genera, they all have distinct black and orange/red colouration. They occur sporadically on cucurbits and may cause damage when their numbers increase, but control is usually unwarranted.

Flea beetles

The name 'flea beetle' is due to their ability to "jump" like fleas when disturbed. They are often small (< 4 mm) beetles, frequently blackish in colour, and have strongly developed hind femora. Although many different crops may be damaged, they are particularly abundant on brassicas, and then usually on young developing plants. Because they are mostly gregarious (occurring in groups), their damage is easily noticeable as numerous small, shallow pits, that may later form minute holes in leaves. Destroying brassica weeds in the near vicinity, four weeks prior to planting, may reduce damage to newly planted crops.

Plant-eating ladybirds

Most ladybirds are beneficial, feeding on small pestiferous insects like aphids and thrips, as well as the eggs of moths. However, at least six species are known to damage vegetables, especially potatoes, cucurbits, and Swiss chard. The beetles, and their spiny porcupine-like larvae, chew a distinct, narrow, zig-zag band-like pattern into leaves, leaving one of the two leaf surfaces intact. When beetle numbers are high, entire plants may be skeletonised and killed. Because the beetles and their larvae are sluggish, they can be removed by hand to prevent serious crop damage.

Tortoise beetles

At least eleven tortoise beetle species are known to damage vegetables, particularly sweet potato, but they only feed externally on the leaves. One of these species, *Aspidimorpha angolensis* (sweet potato tortoise beetle), was recently reported to defoliate sweet potato plantings in the Limpopo Province. Control of tortoise beetles is usually not necessary.

Weevils

More than a dozen weevil (snout beetle) species are known to damage vegetables. However, it is the sweet potato and potato weevils that are most often responsible for causing economic damage. Larvae of the potato weevil, white-fringed weevil, and the rough sweet potato weevil make shallow holes and grooves in tubers and storage roots, while larvae of the slender sweet potato weevil create deep tunnels in the storage roots. Larvae of the vegetable weevils are legless, like all weevil larvae, but they still manage to crawl up plants to feed on the foliage. Spinach/amaranth weevil larvae may tunnel in the stems of amaranth plants. Adult weevils that attack vegetables usually chew externally on the foliage, but when their larvae attack the subterranean plant parts, e.g. roots and tubers, or main stems as in amaranth, damage may be severe. Weevils are very sensitive to movement, and either hide or drop off plants and pretend to be dead if one comes too close to them. Control of weevils is difficult - the alternative options to chemical control include: sanitation, crop rotation, and in the case of sweet potatoes, the use of clean propagation material.

White grubs

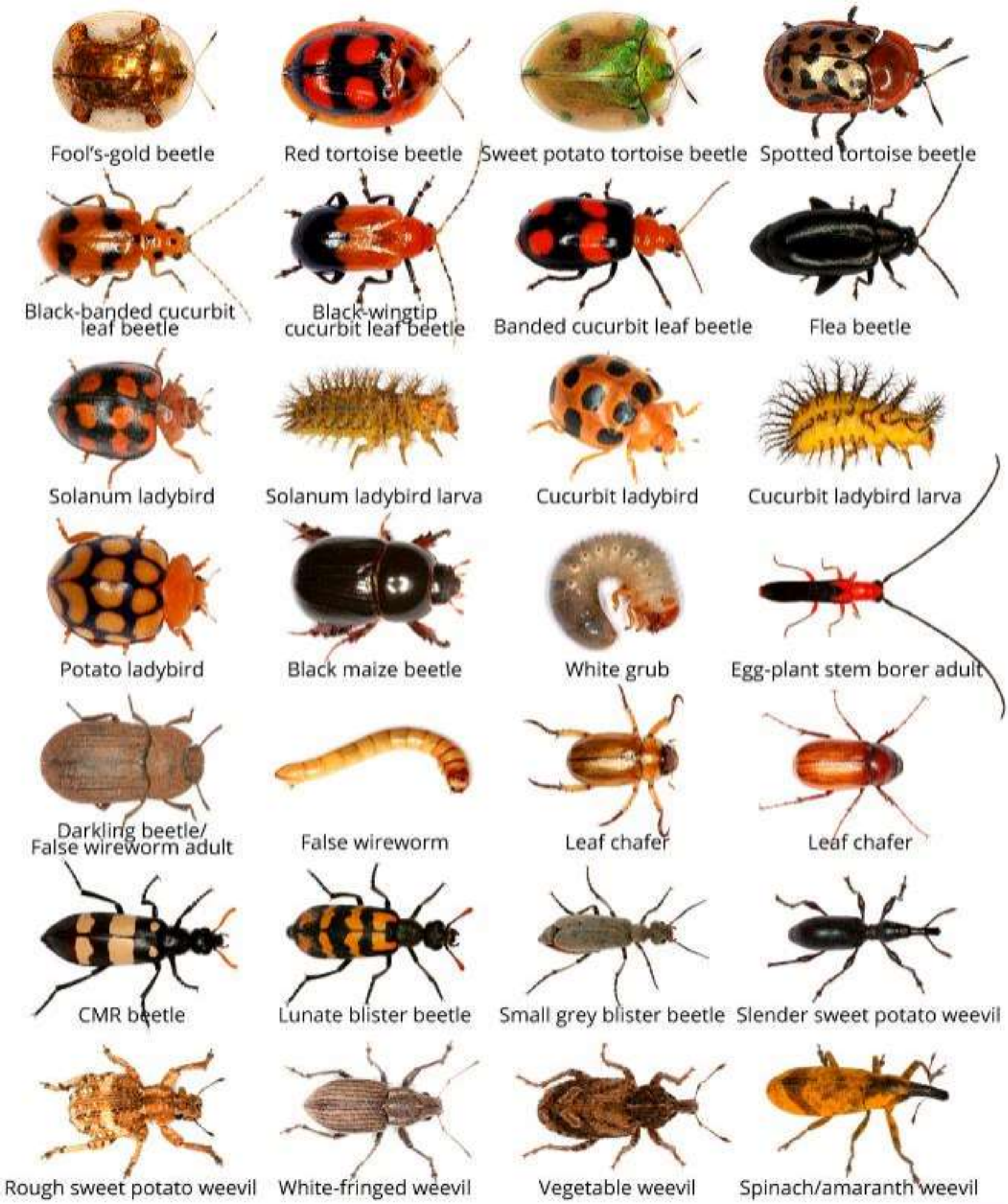
The term "white grub" is generally used to describe the larvae of several beetle species in the family Scarabaeidae. They are usually a pale whitish colour, except for the darker posterior part of the body, and always found in soil where they attack the roots and tubers of crops. Potato and sweet potato are crops that are particularly vulnerable to their attack. These beetles do not select a vegetable crop on which to lay their eggs – they are mostly deposited in soils rich in organic matter, or where grasses are growing. Young white grubs feed on organic material, but older white grubs prefer the roots of plants – mostly those belonging to grasses. If a potato or sweet potato crop is planted in soils where the grubs are already present, the tubers and storage roots of the planted crop will also be attacked. Older white grubs may chew large irregular holes into tubers and storage roots, sometimes causing severe yield losses. The only alternative control strategy to chemical control is planting in soils that were kept clean from grasses or other weeds for a minimum of four weeks, but preferably longer.

Other beetles

Many other beetles may be found feeding on vegetables. Some may only become damaging when their numbers increase to abnormal levels, which is unpredictable. To mention a few: black maize beetle – sometimes damaging potato tubers in fields planted close to maize fields; eggplant stem borer – larvae bore into eggplant stems; and wireworms and false wireworms - may consume plant parts beneath, or close to soil level. All these pests, as well as the ones described above, are illustrated on the accompanying poster.

Contact: Dr Diedrich Visser at DVisser@arc.agric.za

Coleoptera Pests of Vegetables in South Africa



Authors: Diedrich Visser & Elizabeth Grobbelaar, Agricultural Research Council, South Africa. **Notes**: The images are not scaled to indicate sizes, the lengths of beetles vary between 3 mm (flea beetle) and 30 mm (CMR beetle). Many more coleopteran pests occur on vegetables in South Africa, these are just selected ones.

ARC • LNR

Can the roll planter fibre technology be relevant for vegetable production?

Compiled by B. Mndzebele, S. Chiloane, T. Mononyane, S. Mokgehle, M. Nyathi, K. Seetseng, H. Araya, D. Mogotlane, Crop Science Division, ARC-VOP

A company known as G-Tech (South Africa) developed the roll planter fibre technology (Fig. 1) to assist smallholder farmers in having an alternative to growing vegetables if they have marginal lands or are in mine tailings. The roll planter is made of polylactic acid (PLA) fibre that is knitted into a tube shape that can be filled with growing media. When using the roll planter, farmers can add any growth medium (i.e. sawdust, compost, or biochar) and plant leafy vegetables. The ARC-VOP conducted a study to ascertain the usability of the roll planter for vegetable production, against some claims that:

- It can be used for growing vegetables on any surface;
- It has a long lifespan (of about 10 years), and is therefore durable;
- Allows for uniform distribution of nutrients and has a high water retention capacity; and
- It is light, flexible and easy to transport.

Figure 1: Growing *Beta vulgaris* using the G-Tech roll planter technology.

The study was conducted at Roodeplaat (located at 25°35” 992’ S, 28°21” 544’ E, at an altitude of 1165 m.a.s.l), under a shade net structure (40%) and in an open field. The experiment under the shade net was laid out as a split-plot design with two crops (Swiss chard and amaranth) as the main factors and different growing media (sawdust, compost, sawdust/compost and compost/biochar) as subplots. Similarly, the open field experiment was laid out as a split-plot design with two crops (Swiss chard and amaranth) as the main factors and using six different soil surfaces as subplots. The different soil surfaces for the roll planter technology included planting on the soil surface as a control, planting in a buried roll planter, planting in buried compost, broadcasting compost on the soil surface, a roll planter on a plastic surface and a roll planter on the soil surface.

The shade net and open field experiments were managed through the following steps:

1. Irrigation installation
2. Amaranth and Swiss chard seedling preparation
3. Preparation of the roll planters in the shade net and open field experiments
4. Filling of the roll planters with growing media
5. Transplanting of amaranth and Swiss chard
6. Trial management (weeding and pest management)
7. Data collection
8. Harvesting
9. Preparation of samples for analyses

Figure 2: A roll planter at the commencement of the experiment (A) and at the end of the season (B).

The findings of the study revealed that the roll planter degraded at the end of the growing season when used in the open field (Fig. 2). However, the lifespan of the roll planter could be lengthened if used under a controlled environment, or on concrete or tile floors where degradation is minimal.

Seasonal fresh biomass of amaranth (Fig. 3A) and Swiss chard (Fig. 3B) grown in the different growth media in the roll planter under different placements in an open field were significantly different at $p \leq 0.05$ in the 2018/19 season. The roll planter resulted in lower biomass production (40% less yield), as compared to the conventional production system. However, the roll planter comes with additional costs. The estimated cost of the roll planter is R2 000 per 1 800 metres. There is also an additional cost for growing media and labour to prepare the roll planters. In principle, the roll planter is costly under open field conditions, especially if the soil is favourable for vegetable production, since the roll planter did not contribute to additional yield in our study. Placing the roll planters on black plastic (RP) did not improve the yield of amaranth or Swiss chard. This could be related to the build-up of surface heat between the plastic and soil that exceeded 45°C during sunny days. This resulted in injury to or withering of the leaves, which resulted in yield losses.

On the other hand, weed management and irrigation frequency were minimal with the use of roll platers, as compared to the conventional plots. When arable land is not available, the technology can support plant growth and contribute towards combating food and nutrition insecurity and broaden the food basket in communities.

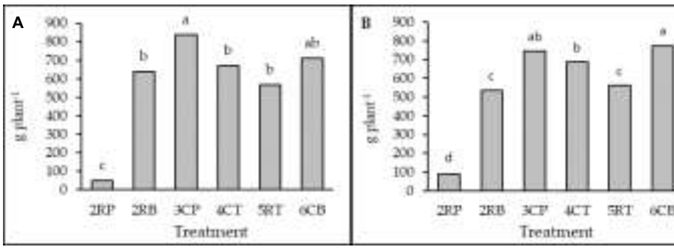


Figure 3: Seasonal above ground fresh biomass of Amaranth (A) and Swiss chard (B), using different growth media inside the roll planter. *Note: roll planter on plastic (RP), roll planter buried (RB), conventional planting (CP), compost on top of the soil (CT), roll planter on top of the soil (RT) and compost buried (CB). Bars with the same letters do not differ significantly.*

Key findings revealed that the roll planter could support vegetable production under specific conditions. For urban farmers and households, who have limited space, the roll planter can be cost effective, even though it can result in lower yields.

Contact: Buhlebelive Mndzebele at MndzebeleB@arc.agric.za

Screening tobacco seedlings at commercial nurseries for diseases

Compiled by Mr Phillip Mphuthi, Crop Protection Division, ARC-IC and Dr Mariette Truter, Crop Protection Division, ARC-VOP

A very small fraction of tobacco farmers in South Africa produce their own seedlings, as they are mostly produced in greenhouses by commercial seedling nurseries. These private nurseries sell the seedlings to tobacco farmers when the plants are ready to be planted in the field. Planting of healthy good quality seedlings is the basis for successful production of a good tobacco crop. Profitability remains a concern to both the farmers and nurseries, as a result of rapidly increasing production costs. Therefore, the seedling growers' main goal is to minimize production costs, while ensuring production of high quality seedlings. Although no single characteristic determines seedling quality, diseases occurring at the seedling stage remain a major issue for tobacco farmers. Improper management of major diseases in the greenhouse will result in higher disease pressure in the field and often leads to reduced yield. For the effective management of diseases and the production of a healthy crop, the detection and accurate diagnosis of these diseases is crucial. Some growers confuse certain diseases such as black shank, sore-shin, Fusarium wilt and Granville wilt. This could be a costly error, since varieties may be high in tolerance to one disease and low to another.

A typical tobacco seedling nursery

In an effort to address these challenges for the tobacco industry, the ARC-Industrial Crops has conducted screening of tobacco seedlings at commercial nurseries and for farmers who produce their own seedlings for several years. Screening is done for major diseases prior to the dispatch of seedlings to farmers for transplanting in the fields. During a survey over two production seasons (2018/2019 and 2019/2020), several pathogens were isolated from symptomatic tobacco seedlings (Table 1). Important diseases that were detected in the past on tobacco seedlings are also discussed.

Table 1: Incidence of pathogens recovered from tobacco seedlings during the 2018/2019 and 2019/2020 seasons

Pathogen	Recovery of pathogens (%)	
	2018/19 (153 samples)	2019/20 (232 samples)
Alternaria sp.	17.0	38.4
Colletotrichum sp.	19.0	4.7
Fusarium sp.	88.0	50.0
Phytophthora sp.	0.0	2.2
Pythium sp.	3.0	23.7
Rhizoctonia sp.	30.0	7.3
Thielaviopsis sp.	0.0	0.0

Alternaria alternata - Causal agent of brown spot of tobacco. The first indication of infection is small, water soaked circular spots, which rapidly enlarge to brown lesions with distinct concentric rings usually surrounded by a yellow border. Infected leaves are unsuitable as natural cigar wrappers and have little value. In South Africa, this disease is mostly regarded as a minor disease on tobacco, with losses averaging to 0.5%. However, when conditions are favourable (susceptible cultivars, frequent rains, excessive nitrogen fertilization and plants remaining for longer than normal in the field) considerable reduction in the quantity and quality of the tobacco crop is possible. Common practices in managing the disease in the greenhouse include the use of sterile growth media and chemical control. In the field, several cultural practices, such as the use of tolerant cultivars, avoiding excessive nitrogen fertilization, and destruction of stalks aid in managing this disease.

Typical symptoms of brown spot of tobacco, caused by *Alternaria alternata*, on mature leaves in the field.

Colletotrichum nicotianae - Causes anthracnose on tobacco leaves. Leaf lesions are small, dark in colour, water-soaked and depressed. These small pinpoint spots soon enlarge to form circular areas, which often appear oily or greasy, especially on the underside of the leaf. Continuous high humidity, cool weather and low light intensity are conditions favourable for the development of this disease. Under these favourable conditions, this disease can cause severe damage, especially in unprotected seedling beds. The pathogen survives as a saprophyte in the soil (growth medium) on plant debris. Primary infection therefore starts from plant debris left in the soil from the previous season. The use of sterile growth medium and seedling trays helps to reduce the initial infection. Rogueing of diseased greenhouse seedlings, especially with necrotic lesions on the stems, is also a recommended practice. This pathogen is very sensitive to fungicides, therefore the use of registered fungicides on tobacco seedlings is recommended.

Anthracnose of tobacco seedlings, caused by *Colletotrichum nicotianae.*

***Pythium* species** - Causes damping-off of tobacco seedlings. Usually this occurs in two stages, namely, pre-emergence and post-emergence damping-off. In the pre-emergence phase, the seedlings are killed just before they emerge from the soil surface and usually there is complete rotting of most of the seedlings in the seedling tray. Post-emergence damping-off is usually characterised by the infection of young, juvenile tissues of the seedlings near the soil line. A brown, watery, soft rot develops and seedlings topple over. Frequently, diseased areas are more or less circular and all seedlings are killed within the patch. The circle or diseased seedlings will enlarge over time. The pathogen survives in soil and primary infection occurs by contaminated soil. High humidity, high soil moisture, cloudiness and temperatures below 24°C for a few days are ideal for infection and development of the disease in the greenhouse or seed beds. In the greenhouse this disease can be managed by regulating and monitoring the abovementioned favourable conditions, as well as using recommended registered chemicals.

Post-emergence damping-off of tobacco seedlings, caused by *Pythium* species.

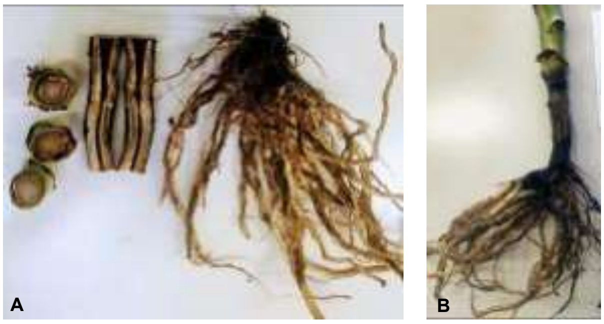
Phytophthora nicotiannae - Causes black shank disease of tobacco. If not properly managed, losses of up to 100% on susceptible cultivars can be experienced in the field. The characteristic symptom is a dark lesion at the base of the stem and wilting of leaves. Seedlings in the nursery show black discolouration of the stem near the soil level and blackening of root tips. When the affected stem of larger plants is split open, the pith region is found to be dried up in disc-like plates showing black discolouration. The pathogen is saprophytic and survives in the soil on plant debris and soil. High soil moisture and high populations of root-knot nematodes, *Meloidogyne incognita,* favours the development of black shank disease. The disease is managed by using sterile growth media for seedling production, avoiding excessive soil moisture and ensuring proper nematode control. Current chemical control is ineffective, however, various new fungicides are being evaluated for the management of this disease. The ARC has developed air-cured and flue-cured tobacco cultivars with high tolerance to this disease and these are recommended for tobacco producers in the country.

Black shank symptoms on mature tobacco stems. When the lower part of the stem is cut open, the pith region is dried up in disc-like plates showing black discolouration.

Rhizoctonia solani - Causes damping-off and sore-shin (brown lesions or girdling) on the stem and target spots on tobacco leaves. On tobacco seedlings exhibiting sore-shin symptoms on the stem, the roots usually remain healthy. Target spot symptoms are easily mistaken with those of brown spot disease (caused by *Alternaria alternata*), since the same concentric rings and yellow discolouration around the lesion are present. The centres of the target spot lesions are, however, necrotic, brown and papery thin. The necrotic part of the lesions sometimes falls out and results in a shattered appearance of the leaves. High humidity and high temperatures favours the development of diseases. The primary sources of inoculum for diseases caused by *R. solani* are infested trays and growth medium. The pathogen's resting structures (sclerotia) are formed in trays where the disease was present during the previous season. The use of sterile growth medium and seedling trays is highly recommended in seedling production facilities. There are currently no registered fungicides for controlling *R. solani* on tobacco in South Africa. The tobacco industry is, however, running a series of trials testing the efficacy of various fungicides for potential management of this pathogen on tobacco.

Diseases caused by *Rhizoctonia solani* on tobacco: (from left to right) target spot on the leaves, damping-off of seedlings and sore-skin of a seedling.

Fusarium oxysporum – Causes Fusarium wilt of tobacco. The fungus is soil-borne and primary infection occurs through inoculum present in the soil or growth medium. The most characteristic symptoms are a light to dark brown discolouration in the vascular tissue in stems, as well as wilting and chlorosis of the leaves, usually on the one side of the stem. The pith of the stem usually remains white. Roots are also affected and start to rot on one side of the plant first. On older seedlings, a purple discolouration of rotten roots can usually be seen. Relatively high soil moisture and soil temperature are favourable for infection by this fungus. The most effective and highly recommended method for control of this disease is the use of tolerant varieties. Nematode damage of the roots, however, reduces the effectiveness of resistant varieties, therefore control of root-knot or cyst nematodes is recommended as part of Fusarium wilt management.



Symptoms of Fusarium wilt of tobacco, caused by *Fusarium oxysporum*. Symptoms include light to dark brown discolouration of the vascular tissue (A), necrotic root tissue (A and B), or affected roots starting to rot on one side of the plant first (B), before spreading to the whole root system.

Thielaviopsis basicola – causes black root rot of tobacco. The pathogen is soil-borne and persists in soils almost indefinitely. It thrives at relatively low temperatures and high populations of the organism can build up in the soil over time, causing severe losses in cool seasons. Soil pH has also been found to influence the incidence of black root rot, where plants in soils that have a low pH (pH of 5.6 or lower) have fewer symptoms, however, the tobacco crop does not grow well at these conditions. If not properly managed the pathogen can cause losses of up to 100% on tobacco. Infected tobacco plants may exhibit several characteristic symptoms limited largely to the roots, such as stunted growth and chlorotic leaves. Infected roots appear dark brown or black due to the presence of large numbers of black spores produced by the proliferating fungus. The rotting of root tissue also greatly reduces the number of roots, as may be seen when infected plants are pulled from the seedling tray or the ground. These symptoms, however, do not provide positive identification and only microscopic inspection will result in a definite identification of the disease. The best control of black root rot is prevention. If the disease has not invaded an area yet, care should be taken to ensure that no soil, plant material or implements containing the black root rot organism is brought into a non-infected field or into seedling production facilities. Maintaining a soil pH of about 6.0-6.4 and avoiding excess liming may enhance the management of this fungus. The use of resistant cultivars is also recommended.

Tobacco mosaic virus (TMV) on tobacco is characterised by blotching of the leaves with light and dark areas. The TMV is transmitted by mechanical means therefore to avoid infection, hygiene in the greenhouse should be a top priority.

Black root rot of tobacco, caused by *Thielaviopsis basicola.*

Tobacco mosaic virus of tobacco showing mottling and blotches of light and dark green colours of a tobacco leaf.

Contact Mr Phillip Mphuthi at MphutiL@arc.agric.za

IBSA fund-supported project in the Union of the Comoros: Creating leader farmers in the community

Compiled by Dr George Chirima, ARC-SCW and Ms Erika van den Heever, ARC-VOP

The India, Brazil and South Africa Facility for Poverty and Hunger Alleviation (IBSA) fund pilot project in the Union of the Comoros, is a $1.8 million initiative that aims to improve local livelihoods and food security through enhanced agricultural practices. This project is being implemented by a national institution of South Africa, the Agricultural Research Council (ARC) in collaboration with the Ministry of Fishing, Environment, Livestock, Industry and Agriculture of the Union of Comoros and the United Nations Development Programme (UNDP) of Comoros. The broad aim of the project is to establish an agricultural school for the Union, which can be supported over time, instead of providing a once-off project deliverable. This project aims to enhance and improve the production conditions and commercialisation of agricultural products on the island of Mohéli. It consists of three phases: (a) topographic, soil and water surveys; (b) irrigation infrastructure and training; and (c) vegetable production. Refer to the ARC-VOP Newsletter 2, pages 2-3 for more information on the background of the project.

A pilot farm school established on Mohéli will serve as a teaching centre for demonstrating commercial farming practices to local farmers. Through this farm school, the project aims to partner with 1 140 farmers from eight villages on Mohéli, of whom 50% are women and 10% are youth. Training and demonstrations will also take place on the islands of Ngazidja and Anjouan. Moreover, this project will promote South-South knowledge-sharing on agricultural extension services between the South African ARC and the Government of the Union of the Comoros.

The farm school has provided opportunities for the development of farmers as leader farmers, of which Abdoulkarim Hamidi is an exemplary young person who represents part of the success of this project. He is 26 years old, married and lives in Siri Ziroudani on the island of Mohéli, Comoros. As many other young Comorians, Abdoulkarim decided to drop out of school at a very young age to become a farmer to be able to provide for his family. “Being a farmer in Moheli is not easy and we lack a lot of things, we need hand tools and anti-slug compounds, rivers are drying, and water is an issue for farmers” he says. Abdoulkarim did not hesitate to show his interest in participating in the activities of the Rural Centre for Economic Development (CRDE), a centre that conducts awareness campaigns on irrigation infrastructure. "We have always lived around the centre (CRDE), but we did not know that such projects could be implemented here next to where we live to teach us new agricultural practices ".

Abdoulkarim Hamidi, tractor operator in Moheli and one of the leader farmers in training as part of the IBSA funded project.

His interest in the IBSA funded project and his desire to learn led him to fully commit to the project until he became a leader farmer in his community. The project was able to provide the tools and new knowledge required to improve his lifestyle as a farmer. Young and ambitious, Abdoulkarim met the selection criteria and benefited from the mechanization training provided by experts from the ARC. He is now the main tractor operator for the project and the CRDE, but is also the only tractor driver operating throughout the Djando region.

Abdoulkarim speaks about the positive impact that the project has had on his life: “Before I was involved in this project, it was very hard to plan my future. Today, thanks to the IBSA project, I have a steady income, have acquired technical knowledge and even a diploma. Above all, I regained my pride that I will be able to share with my child very soon. At the end of the project, I will have the opportunity to put into practice new knowledge in agriculture and the experience acquired as a tractor driver throughout the project will allow me to lead a peaceful life and take care of my family” he says.

Abdoulkarim Hamidi at the farm supported by the IBSA Fund.

A young leader farmer teaches other farmers to grow organic carrots.

The IBSA Fund is a pioneering initiative to implement South-South cooperation for the benefit of other Southern countries in partnership with the United Nations. Its purpose is to identify replicable and scalable projects that can be disseminated to interested developing countries as examples of best practices in the fight against poverty and hunger. The United Nations Office for South-South Cooperation is the Fund Manager for this initiative.

Contact: Ms Erika van den Heever at EvdHeever@arc.agric.za

Screening method against late blight of potatoes

Compiled by Ms Mary Makapela and Dr Rene Sutherland, Crop Protection Division, ARC-VOP

Potato production in Africa has quadrupled during the last 30 years due to the availability of adaptable varieties, however, production has been hampered by different diseases. One of the most important potato diseases is late blight, caused by *Phytophthora infestans*. Yield losses due to late blight range from 40 to 95% in unsprayed potato crops. Furthermore, there is an increase in the reported virulence of *P. infestans* worldwide.

Tolerance to late blight is very important in a potato breeding strategy. The objective of this study was to evaluate a quick screening technique for tolerance of different potato varieties against late blight. As field trials are costly and time-consuming to screen for tolerance, a screening technique that is rapid and reliable is required. This will allow breeding programs to identify tolerant breeding lines quicker, which will result in savings of cost and time.

Four potato cultivars (Up-To-Date (UTD), Innovator, Sifra and Mondial) were screened for tolerance to *P. infestans* using a plant assay of *in vitro* plantlets (Fig. 1). Forty *in vitro* plantlets per cultivar were sprayed with 5 ml of the inoculum suspension of *P. infestans.* Only water was used as the control. Plants were incubated at 25˚C, and scored over 6 days for lesion formation and necrosis.

On the inoculated treatments, lesion formation started after day 2, and 100% of the plants of UTD, Innovator and Sifra showed necrotic lesions on the plantlets after day 4 (Fig. 2). In the case of Mondial, 71% of the plantlets had lesions. On day 6, more *in vitro* plantlets of UTD, Innovator and Sifra died compared to Mondial after *P. infestans* infection.

The results of the whole plant assay is in accordance with previous field trial results. Therefore, the whole plant assay using *in vitro* plantlets is an effective and rapid technique for screening potato cultivars for late blight tolerance. The whole plant assay is a quick method that allows multiple cycles of screening in a short period of time while minimizing the costs, as compared to field assays which can only be carried out once in a year. This method also offers the evaluation of genotypes in a uniform environment with the use of less quantities of inoculum while screening a large number of samples.

Figure 1. Potato *in vitro* plantlets used for the screening.

Contact: Dr Rene Sutherland at SutherlandR@arc.agric.za

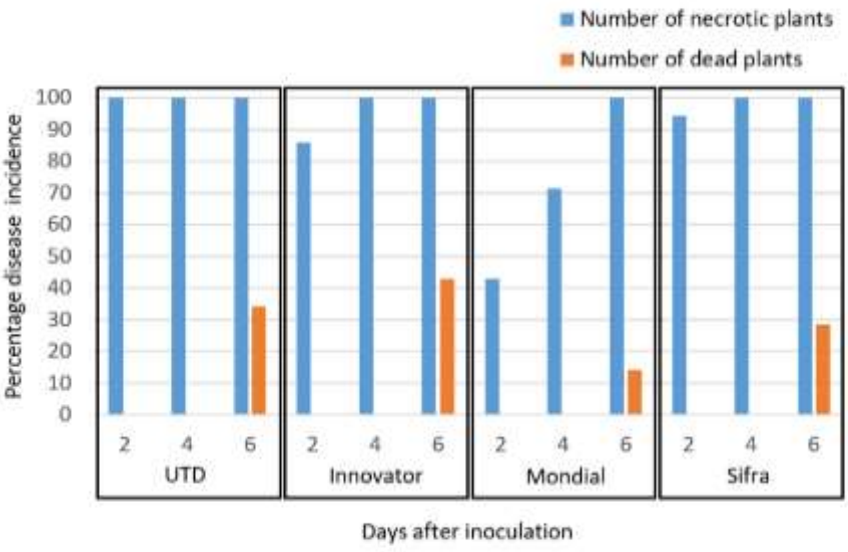


Figure 2. The percentage of necrotic and dead plants after inoculation of *in vitro* potato plantlets with *Phytophthora infestans*.

Growth and mineral nutrition of cassava (*Manihot esculenta* Crantz) grown as an industrial crop in South Africa

Compiled by ZSI Thabethe and LG Owoeye, ARC-IC and IC Madakadze, University of Pretoria

Cassava (*Manihot esculenta* Crantz) is a substantial contributor to the food and industrial crops sectors in most African, Asian and Latin American countries. However, cassava production in Africa has been threatened by the shortage of improved cultivars and a decrease in soil fertility, linked with continuous cultivation, often with inadequate levels of available macronutrients such as nitrogen (N), phosphorus (P) and potassium (K).

In the current study, cultivar adaptability, optimization of NPK application and leaf N assessments were investigated in a field experiment in Mbombela, Mpumalanga, South Africa. The aim was to assess growth and yield parameters of landrace MSAF-1 and the improved P4/10 cultivar of cassava. The growth and yield parameters for these two cultivars were found to be significantly different from each other under the same treatments. The MSAF-1 achieved an averaged higher height (206.5 cm) and larger stem diameter (59.0 mm) compared to P4/10. The MSAF-1 also had a higher number of branches (39.5); Leaf Area Index (LAI) (4.0); Leaf Area Duration (LAD) (893.44 days); total fresh biomass (15.55 kg ha^{-1}); aboveground biomass dry matter yield (3.97 kg ha^{-1}); storage root dry matter yield (5.66 kg ha^{-1}); number of storage roots (13.6); as well as harvest index (HI) (0.621) compared to P4/10. Differences between the parameters of the two cultivars could be attributed to genotypic variations of the cultivars, since they were grown under the same conditions. Both MSAF-1 and P4/10 had a fairly effective redistribution of chlorophyll and conversion of assimilates from leaves and stems into the storage roots in recognition of the hypothesis that the environmental conditions in Mbombela will enhance growth and improve the yield of cassava.

In a bid to optimize NPK application rates for the growth and yield of cassava, 64 NPK treatment combinations were evaluated in a greenhouse. The underlining premise was that the combination of NPK would improve cassava growth and yield more than the individual elements alone. All the growth and yield parameters that were assessed for the objective of this experiment were found to be significant. Generally, cassava growth and yield increased with time and increasing application rates of NPK. Combinations with low or zero N and K negatively affected cassava growth and yield. In addition, combinations that supplied either too much of one element compared to the other elements negatively affected the growth and yield of cassava. The different growth parameters were promoted by different NPK application rate combinations. The best NPK combinations for cassava production was 200 kg ha^{-1} N, 30 kg ha^{-1} P and 150 kg ha^{-1} K. Following regression analysis, strong

Collection of growth parameter data during the glasshouse experiment.

Harvested cassava roots from the glasshouse experiment.

positive relationships were observed between: number of branches and number of leaves (r^2 = 0.76), aboveground biomass and number of branches (r^2 = 0.61), and aboveground biomass and number of leaves (r^2 = 0.82). Meanwhile, weak positive correlations were observed between the number of storage roots and stem diameters (r = 0.40), number of branches (r = 0.45) and number of leaves (r = 0.52). Conversely, NPK fertilization enhanced aboveground growth at the expense of storage root yields.

In a concurrent trial, an experiment was conducted to evaluate leaf chlorophyll content as an indication of the leaf N concentration using a soil-plant analyses development (SPAD)-meter. SPAD readings increased with time, as well as with increasing N application rates. The readings for leaf numbers (Lf_N) Lf_3, Lf_4 and Lf_5 (45.2, 48.1 and 44.6, respectively) were significantly higher ($p < 0.05$) than values of Lf_1 and Lf_2 (32.5 and 38.4, respectively) at 98 days after treatment (DAT). At 98 DAT, the lower leaves (Lf_4 and Lf_5) and Lf_3 readings were also positively correlated with the N application rates and leaf N concentration levels, but the uppermost leaves (Lf_1 and Lf_2) were negatively correlated. This indicates that there was preferential distribution of N to lower leaves, thus optimization of N allocation allowed higher photosynthetic rates in the lower leaves compared to the upper leaves. Generally, there were no significant differences between the readings for Lf_4 and Lf_5, but Lf_3 readings were lower across all of the N application rates over time and therefore the average of Lf_4 and Lf_5 was used for calculating the nitrogen sufficiency index (NSI) values. The N_{200} treatments had the highest average NSI value (1.04) compared to N_{100} (NSI = 0.99) and N_0 (NSI = 0.88). This indicates that N deficiency was immediately reflected in a low chlorophyll content, which was adequately registered by the SPAD meter.

Based on the results presented, the following recommendations were made. Firstly, the landrace MSAF-1 is recommended for production at Mbombela as it maintained a greener canopy than P4/10. Secondly, the P4/10 cultivar can be suitable for various intercropping systems, since it produced low numbers of branches compared to MSAF-1 that could be better utilized for leaf and storage root consumption purposes. Thirdly, the application of 200 kg ha^{-1} N, 30 kg ha^{-1} P and 150 kg ha^{-1} K produced a higher yield than the other NPK rates suitable for cassava production. Lastly, regression analysis shows that cassava biomass was positively correlated with increasing N input.

Contact: Dr Lawrence Owoeye at OwoeyeL@arc.agric.za

Technology Transfer: April to June 2020

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Training courses:

The Agricultural Research Council – Vegetable and Ornamental Plants, Roodeplaat is offering an accredited hydroponic vegetable production training course. For more information, contact Ms Lulama Vitshima: (012) 808 8000 or LMkula@arc.agric.za