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Inside this issue:

New name for new beginnings

The Agricultural Research Council (ARC) established a new business entity, namely, the ARC-Vegetable, Industrial and Medicinal Plants (ARC-VIMP) research campus through an amalgamation of the ARC-Vegetable and Ornamental Plants (ARC-VOP) and the ARC Industrial Crops (ARC-IC) research campuses. The purpose of the new entity is to ensure a more sustainable and viable ARC for the future that will continue to make an impact on the food and agricultural sector through improving productivity of agricultural value chains, that contributes to improved skills for the sector. The new entity will drive research on vegetables, industrial crops and medicinal plants, and continue to serve the agricultural sector with excellent research and development (R&D) and commercialization initiatives. The research mandates of the two campuses have been integrated into a new research strategy, business and management model for the newly-established research campus. The ARC-VIMP will operate as a single entity, with one management and support team from the Roodeplaat campus as the main campus. All other campuses of the entity will continue to function as research facilities for research and development, training and technology transfer and commercialization.

The purpose of the establishment of the new business unit was to create a stronger R&D entity for the ARC with optimal utilization of resources for increased efficiency and the development of a delivery model for high quality research and development outputs. These outputs should ensure a positive impact on the agricultural commodities and value chains it serves in response to global, continental, regional and national challenges and priorities. The ARC Council and Executive Management believe the reorganization of the two campuses will facilitate growth in existing and new areas of research for growth, which will also ensure industrialization of value chains for future profitability of the sector. It was of equal importance to create a research system designed to provide R&D services across a given commodity value chain, thereby enabling a one-stop-shop to stakeholders and clients of the ARC across a commodity value chain.

The following key research focus areas have been identified as commodity value chains, which will each be supported by a multi-disciplinary team:

- Non-food crops research (medicinal plants, industrial crops and ornamental plants);
- Root, tuber and bulbous crops research (potato, sweet potato, cassava, onion, garlic, Amadumbe, etc.);
- Fruits, seeds and leafy vegetables research [e.g. indigenous vegetables (Amaranth, cowpea, Bambara groundnut, etc.), tomatoes, green peppers, lettuce, etc.]; and
- A fourth research team focused on farmer support, training and commercialization has been established.

The ARC-VIMP is looking forward working with current and new stakeholder to service the vegetable, industrial and medicinal plant industries.

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Hemipteran pests of vegetables

Compiled by Dr Diedrich Visser, Crop Protection Division, ARC-VIMP

At least 66 species in the insect order Hemiptera (sucking bugs), attack vegetables in South Africa. Some only damage certain crops, while others prefer to feed on many crops. Below is a short description of the six most common and important hemipteran vegetable pests in South Africa (sorted alphabetically), with visuals on the last page. For a complete list of all vegetable pests, and for more information, see Visser, D. 2009. A Complete Guide to Vegetable Pests in South Africa, ARC-Roodeplaat, Vegetable and Ornamental Plant Institute, Pretoria. Information for this article was extracted from the latter publication.

Aphids. Nearly 40 aphid species are known to attack vegetables in South Africa. Some species are wide-feeders, while others only attack certain crops. Damage: a) the sucking of plant sap may stress plants, b) they may transmit yield reducing virus diseases, c) they produce excessive honeydew that causes the growth of black sooty mold on leaves, and d) the unacceptable presence of aphids on produce. Of these, their ability to act as vectors of plant viruses is the most important factor that make aphids one of the most important pest groups. Plant viruses weaken and stunt plants; the ability of a virus infected plant to produce a normal yield is limited. Only certain aphids are considered as important virus vectors, the most important and wide spread species is the green peach aphid, *Myzus persicae*. Aphids secrete excess liquids in the form of honey dew. It is a clear translucent liquid, usually only noticed when leaves and fruit become sticky. A non-pathogenic fungus grows on leaves and fruit that contain honeydew, and is visible as a brownish or blackish layer covering the affected plant parts. Control: Several insecticides are registered, but they may not work quick enough to prevent aphids from transmitting certain viruses to healthy plants. Other control options include planting in cooler areas where aphid numbers are lower, removing alternative host plants, e.g. weeds, that may sustain viruses and aphid populations, and controlling ants that protect aphid for their honeydew.

Bagrada bug. Scientific name: *Bagrada hilaris*. Crops attacked: Females only lay eggs on Brassicas, but they will move to other nearby crops when their host plant is destroyed. Damage: Nymphs and adults are gregarious and suck sap from foliage, causing yellow or whitish areas on leaves. Entire leaves or plants may die back, especially when large numbers occur on crops. When non-brassica crops are attacked, it is nearly always because the bugs moved from nearby brassica crops. The adults can fly, but they prefer to walk to nearby crops. Control: Several insecticides are registered. Other control options include sanitation (removal of affected plants with the bugs), and monitoring of all crops near a harvested crop that was previously infested.

Green vegetable bug. Scientific name: *Nezara viridula*. The adults are green, but turn brown when they overwinter. The immatures are brownish/blackish with white spots. Crops attacked: Most vegetables, but particularly those that bear fruit and pods. Favoured crops include bean and tomato. Damage: The adults and nymphs are sap suckers, using their long rostrums to extract fluids from plant tissue. While feeding, they inject digestive enzymes to enhance sap flow through their thin stylets (needle-like mouth parts). When young shoots are attacked, the distal parts towards the tips may wilt and perish. This is usually due to feeding, but is also due to the enzymes that the bugs secrete (also see feeding behaviour of the tip wilters). Indirect damage may occur when puncture wounds become infected with pathogens or when disease organisms are transmitted mechanically. Control: The choice of insecticides are limited for green vegetable bug control. Contact insecticides that are applied for other pests may suppress their numbers. Planting trap crops, e.g. legumes, near a susceptible crop may be an option. These trap crops are then monitored and sprayed before the bugs develop wings and move to the tomato plants. In small plots, bugs may be removed by hand and destroyed.

Mealybugs. Scientific name: Various species in the family Pseudococcidae. They are common pests of fruit trees, pineapple, grapevine, cassava, garden flowers, sugarcane and proteas. However, they are sometimes found on vegetables, especially in greenhouses. Damage: Mealybugs suck sap from plants and may be serious pests on some crops. On vegetables they are more of a nuisance, making produce unmarketable. Copious amounts of honeydew are produced that make leaves and produce sticky, and on which a brown/black sooty mould grows. Control: Control is only needed when infestation levels are high and when the honeydew they produce are a cause for concern.

Tip wilters. Scientific name: Various species in the family Coreidae. The two most common species are *Anoplocnemis curvipes* (known as the large black tip wilter), and *Elasmopoda valga* (known as the common tip wilter). Damage: Various vegetables may be attacked, but favoured crops include cucurbits, eggplant, legumes, potato, and tomato. Tip wilters have sucking mouthparts with which they extract sap from plant parts. They usually do this near the growth points. While extracting sap, they secrete saliva into the plant tissue, causing wilting of the entire growth point. When young plants are attacked, most growth points of a single plant may be destroyed, resulting in the death of the plant. However, when larger plants are attacked, the damage is usually not that severe. In bean fields, pods may also be attacked, resulting in chlorosis and malformation. Control: Removal by hand is an option, but most tip wilters are very aware of their surroundings and when approached, will hide or fly away. When large numbers occur on plants, i.e. when the gregarious young are present, they can be shaken off branches into a container with soapy water or paraffin. Most species are easily spotted on plants because of their size and colour. Adult tip wilters overwinter under old discarded plants. Sanitation by burning or burying such plant rests is therefore advisable.

Whiteflies. Scientific name: *Bemisia tabaci* is referred to as the sweet potato whitefly, cotton whitefly or the tobacco whitefly, while *Trialeurodes vaporariorum* is known as the greenhouse whitefly. Although adult whiteflies look like very small moths rather than flies, they are neither flies nor moths. Damage: Favoured crops include bean, cabbage, cucurbits, eggplant, lettuce, sweet potato and tomato. Plants in greenhouses are particularly susceptible. Damage: Nymphs and adults suck sap from plant parts, usually on the underside of the uppermost leaves. Some plants may be more sensitive to whitefly feeding, resulting in yellowing, wilting and leaf-drop. Other damage symptoms include white streaking or discolouration of leaves and veins, irregular ripening of fruit (both externally and internally), and silverleaf disorder caused mainly by *Bemisia tabaci*. Whiteflies may cause serious damage by transmitting viral diseases. *Bemisia* is capable of transmitting more than 60 plant viruses, of which Tomato yellow leaf curl virus (TYLCV), and Tomato curly stunt virus (ToCSV) are the most important. ToCSV is thought to be transmitted only by some races of *Bemisia tabaci*, and often results in tomato yield losses of up to 100%. Control: Several insecticides are available for whitefly control. Control with insecticides is difficult, however, and the recommendation is to select an insecticide that will also kill the immature stages. Application of sprays must be directed at the concealed nymphs on the underside of leaves. Removal of weeds around fields or greenhouses will reduce the infection rate in newly planted crops.

Many other hemipteran pests may be found feeding on vegetables. Some may only become damaging when their numbers increase to abnormal levels, which is, as with most vegetable pests, unpredictable. To mention a few: Bean bug (common on bean and cowpeas), False chinch bugs (common on onion, leek, garlic and turnip, Leafhoppers (on most crops), Melon bugs (common on cucurbits), Milkweed bugs (on various vegetables), and Tree hoppers.

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Hemiptera Pests of Vegetables in South Africa


False cabbage aphids


Black bean aphids


Bagrada bug adults


Bagrada bug nymphs are gregarious


Green vegetable bug adult


Green vegetable bug nymphs


Mealy bugs on a potato tuber


Mealy bugs on a sweet potato leaf


Tip wilter, with damage to the right (arrow)


Tip wilter hatchlings


White fly adults


Sooty mould growing on pumpkin leaves

Author: Diedrich Visser, Agricultural Research Council, South Africa. **Notes**: Only a few common hemipteran pests are illustrated above, many more occur on vegetables in South Africa.

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Garlic virus diagnostics and elimination to improve the productivity

Compiled by Dr Inge Gazendam, Mr Flip Steyn, Dr Willem S Jansen van Rensburg and Ms Roelene Marx, Plant Breeding Division, ARC-VIMP

Garlic (*Allium sativum*) is a well-known herb and can also be used for medicinal purposes. Garlic is a high value commodity, and is suitable for increased market returns under conditions of limited agricultural resources. The gross value of garlic production was over R10 million in 2018 according to the Department of Agriculture, Land Reform and Rural Development. Garlic and onion (*Allium cepa*), both members of the *Allium* genus, are prone to viral infections. Symptoms include yellow mottling (mosaic) or stripes on the leaves (Fig. 1) and reduction in yield and quality. Consecutive planting of virus infected planting material can lead to yield losses of up to 50% (Lunello et al., 2007).

Figure 1. Characteristic symptoms caused by viruses on garlic leaves submitted to ARC-VIMP by a garlic farmer.

The five major viruses affecting garlic in South Africa include the *Onion yellow dwarf virus* (OYDV) and *Leek yellow stripe virus* (LYSV), both part of the Potyvirus genus, the *Shallot latent virus* (SLV) in the Carlavirus genus and the *Garlic common latent virus* (GarCLV) in the Allexivirus genus. They normally occur in mixed infections. The most common viruses detected on garlic worldwide are potyviruses and carlaviruses. Electron micrographs depict all these viruses as non-enveloped, flexuous and filamentous helical particles, 12 nm in diameter and of nearly the same length (between 500 and 1000 nm) (Viralzone, Swiss institute of bioinformatics) (Fig. 2).

OYDV is one of the most damaging viral pathogens of onion and garlic in South Africa (Stork et al., 2004). Symptoms on garlic include yellowing and drying of leaves, curling and stunting of garlic leaves and distortion of onion flower stems. LYSV are frequently found in mixed infections with OYDV, and causes distinct yellow or chlorotic striping of leaves. Carlaviruses have a wide host range in the genus *Allium*. They cause latent infections that do not result in crop losses. But when these are co-infected with potyviruses, it can cause significant yield losses due to synergistic effects. Both poty- and carlaviruses are aphid transmitted in a non-persistent manner, which means the aphids become viruliferous quickly but remain so only for short period (EPPO standards PP 2/4 (2), 2000). Controlling aphids by chemical spraying is therefore not a successful control strategy. Allexiviruses are a complex group of different viruses with related sequences which are mostly mite-transmitted and causes yellowing and deformation of garlic leaves, causing bulb yield reduction.

Garlic viruses does not seem to be seed-borne, but spreads through vegetative transmission. Management should therefore include virus-free bulbs for planting and control of aphids and insect vectors. A 2-3 month host-free period should be included in the cropping schedule. The principal causes of infection (infected seedlings in the field, infected weeds, volunteers, biennials and perennial crops) should be eliminated to minimise virus spread. Nurseries should be inspected at regular intervals, possible virus-infected plants should be rogued immediately, and onion seeds should be produced in plots isolated from other crops of *Allium* spp.

Virus-free assurance system

Due to the quality of garlic material available in South Africa, the ARC started with the set-up of a garlic virus-free assurance system, which is imperative to improve production quality by South African farmers. This will ensure that nuclear stock plants are maintained under virus-free conditions and tested at regular intervals. Such a system does not exist currently in South Africa, and garlic producers have expressed an interest in obtaining virus-free material. Researchers at the ARC-VIMP have the expertise to develop and implement such an assurance system through research expertise and diagnostic services. Up to now, material was scrutinised with an electron microscope for virus particles. This is not only very expensive, but it is unreliable.

Due to difficulties experienced with serological detection methods, such as Enzyme Linked Immunosorbent Assay (ELISA), sequence-specific molecular detection methods are recommended to detect viruses in garlic plants. A diagnostic method that is fast and sensitive was therefore developed by the ARC-VIMP. The method is based on the reverse transcriptase polymerase chain reaction (RT–PCR), which is 10–100 times more sensitive than ELISA (Dovas et al., 2001).

The isolation of RNA from virus-infected garlic leaf or bulb material was optimized at the ARC-VIMP. Primers from the five major viruses were combined into a multiplex RT-PCR, and conditions optimised on ordinary and red garlic grown at ARC-VIMP to detect a mixture of viruses present in the samples. Amplified virus fragments were then separated by gel electrophoresis under optimised conditions. The diagnostic test was successful to detect all 5 major garlic viruses in a single step, and was subsequently applied to more symptomatic garlic samples received from farmers. Both leaf and garlic bulb samples were suc-

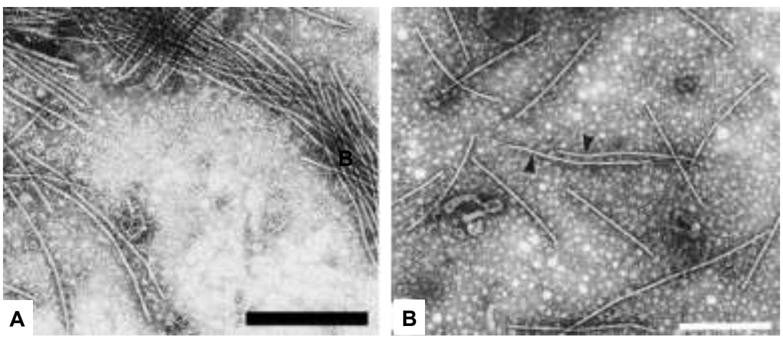

Figure 2. Electron micrograph of particles of LYSV from leek (A) and SLV together with some slightly longer particles of OYDV (black arrows) in crude sap from shallot (B) (After Bos et al., 1978). (Bar = 500nm).

cessfully screened. It was evident that all tested samples were infected by at least 3 viruses, and none were found to be free from any of the five major viruses screened (Figure 3).

Preliminary results showed that subsequent to establishment of meristems *in vitro,* a decrease were detected in the number of viruses infecting the plant material. The lowest infection numbers were found in white and red garlic clones maintained *in vitro*, all of which had OYDV which was in some cases in co-infection with Allexivirus. The next step in the garlic assurance system is to clean material from virus and other diseases, and then to multiply it for use by our farmers. Different treatments can be performed on garlic plants in tissue culture to eliminate viruses, but the success depends on the virus involved, as well as genotype since these vary with regards to response to tissue culture conditions.

Future efforts endeavour to apply the diagnostic test to samples that have been subjected to virus elimination, to confirm the absence of virus. More experiments of virus elimination and diagnostic screening need to be performed to collect more accurate data and to generate virus-free clones for multiplication and distribution. Also in the pipeline is the next generation sequencing of the infecting virus genomes from a pool of garlic samples infected with viruses.

The assurance system the ARC is developing will add value to farmer's planting material through an easily identifiable assurance mark that will attest to the quality of the material . This development is set to improve the garlic industry to a new level in South Africa.

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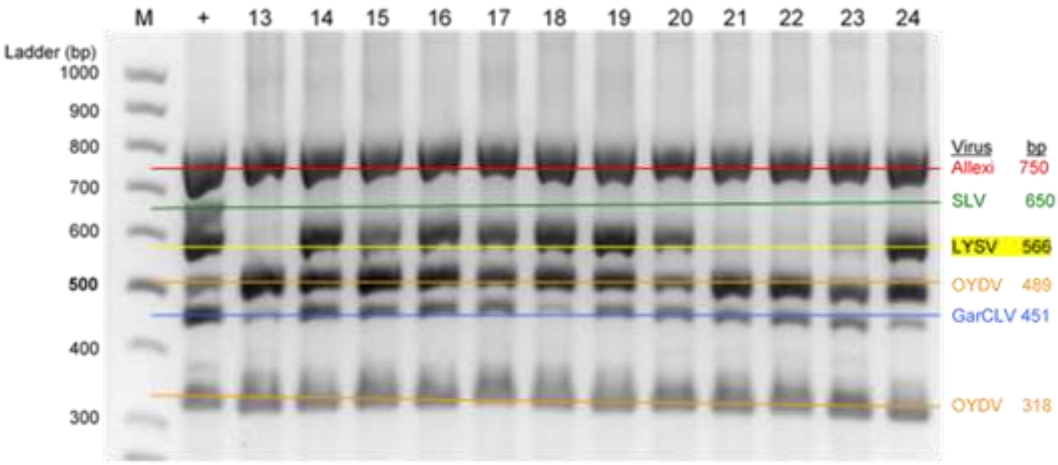

Figure 3. Diagnostic screening of garlic material for the major viruses infecting garlic using selected virus diagnostic primers combined into a multiplex RT-PCR. M: 50 bp ladder (GeneRuler, Thermo Scientific). +: Positive control multiplex RT-PCR reaction of garlic cDNA containing all five viruses. Sample numbers 13 to 24. The detected viruses, and fragment size expected according to the literature, are indicated on the right.

Characterisation of the *Fusarium oxysporum* species complex associated with sweet potato in South Africa

Compiled by Ms Brightness Z. Nkosi , Drs Michele Cloete , Sonja Venter and Mariette Truter, Crop Protection Division, ARC-VIMP, and Dr Adriaana Jacobs, Biosystematics Division, ARC-PHP

Sweet potato can be infected by many fungal diseases including *Fusarium* wilt (FW), one of the economically important fungal diseases worldwide (Clark 2013). Symptoms on sweet potato plants include leaf yellowing (Fig. 1), wilting (Fig. 2) and browning of vascular tissues in the lower stems (Fig. 3). Preliminary molecular identification of South African isolates indicated that there were other *Fusarium oxysporum formae speciales* (*f. sp.*) associated with FW of sweet potato, besides *F. oxysporum f. sp. batatas* (Thompson *et al.* 2011).

Fungal strains were retrieved from symptomatic sweet potato stem material collected from various sampling sites in the Eastern Cape, Gauteng, Limpopo, Mpumalanga, Northern Cape and Western Cape provinces of South Africa. DNA sequence data of the *TEF-1α* gene were used to identify the fungal strains to species level via nBLAST[TM] queries on the *Fusarium* MLST and *Fusarium*-ID databases. In addition, phylogenetic analyses using portions of the *TEF-1α* and *RPB2* genes were done based on Maximum Parsimony (MP) and Maximum Likelihood (ML) analyses. Morphological characteristics examined included the shape and size of macroconidia, the shape and the mode of formation of microconidia, the production of chlamydospores and the colony colour. All *Fusarium oxysporum* isolates were confirmed morphologically based on the description in Leslie & Summerell (2006), that include these above mentioned characteristics.

The collected symptomatic sweet potato plant material showed one or more of the following symptoms: wilting of the plants, stunted growth, a dark to reddish brown discoloration of the vascular tissue in the lower stem when cut open longitudinally, and yellowing of leaves with dark brown, marginal or interveinal browning. These symptoms were similar to those of FW infected plants worldwide (Clark 2013) and reported locally (Thompson *et al.* 2011).

In total, 89 *Fusarium* strains, including 55 strains resembling the *F. oxysporum* species complex (FOSC) based on morphology, were obtained from the symptomatic sweet potato plant material. The TEF-1α *Fusarium* MLST database nBLAST™ results revealed that the sweet potato strains in the FOSC, matched reference sequences in the FOSC with a percentage similarity ranging from of 99.52-100%. The phylogenetic analysis of the isolates from diseased sweet potato, based on the TEF-1α gene, resolved the FOSC into four distinct clades as previously described by O'Donnell *et al.* (2004) and Laurence *et al.* (2014), indicating some level of genetic variation among the FOSC isolates in South Africa.

This work highlights the importance of characterisation of other *F. oxysporum formae speciales* associated with sweet potato present in South Africa. This study has revealed that apart from *F. oxysporum f. sp. batatas*, two other *formae speciales* are associated with FW of sweet potato in South Africa. The identification of new *formae speciales* can have an impact on South African agriculture as it should be considered in determining risk evaluation approaches, control measures for farmers and assist breeders.

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Figure 1. Symptomatic sweet potato field showing the yellowing of leaves.

Figure 2. Symptomatic sweet potato plant showing wilting, yellowing of leaves with dark brown dead leaves.

Figure 3. Symptoms of *Fusarium* wilt of sweet potato plant showing browning of vascular tissues in a stem.

Growing vegetables using old maize meal bags to address food security in urban areas of South Africa

Compiled by Mr Silence Chiloane, Dr Nadia Araya, Dr Ian du Plooy, Dr Sunette Laurie (ARC-VIMP), Mr Ignecious Hlerema (Jayden Nashe Enterprises) and Prof Hettie C Schönfeldt (University of Pretoria)

The Agricultural Research Council collaborated with the University of Pretoria in the implementation of Imvelo Food Gardens project through the provision of training and practical demonstrations to the community of Cemetery View informal settlement, Pretoria East on the production of vegetables in an effort to address food security in urban areas of South Africa. Such areas have recorded increased urbanization over the past years, due to increased unemployment rates in rural areas. Increased population density often puts greater pressure on the available land and water resources, which affects food availability tremendously. Figure 1 illustrates a typical example of limited land and water resources availability in some of the urban areas of South Africa.

Figure 1: Small gardens (1m x 2m) available for vegetable production (a) and limited access to water (b, c) for households at Cemetery View informal settlement in Pretoria.

As part of the Imvelo Food Gardens project, five representative community beneficiaries were trained on the basic principles of growing vegetables using old maize meal bags (the so-called "bag system"). This included system's set-up, planting of seedlings, irrigation and fertilizer application. The implementation of resource-efficient hydroponic production systems, such as the bag system for growing vegetables, can be an option to address the challenge of food insecurity in urban areas of South Africa. Vegetables, especially leafy greens such as kale and Swiss chard, are nutrient rich foods, containing several vitamins and minerals, with great potential to meet human nutrient requirements, thus contributing to the alleviation of hidden hunger, particularly amongst the most vulnerable communities. Prior to planting, the bags were filled with sawdust organic growing medium, which was subsequently soaked with water before making planting holes (Fig. 2). Good quality compost can also be used as an alternative growing substrate if available. Vegetable seedlings for growing in the bag system are raised in a seedling nursery using seedling trays filled with seedling mix as the growing substrate for seedlings, which enables them to be transplanted with ease into the bags.

The spacing of holes around the bag should be done according to the recommended spacing of the crop to be planted, based on previous research done by the ARC. A specific plant arrangement should also be considered to maximize sunlight penetration through the crop canopy. In general, for leafy crops such as Swiss chard and kale, a plant spacing of 10cm x 15cm can be adopted (Fig. 3).

Figure 2. Soaking of the sawdust growing medium with water before making the planting holes.

Figure 3. Transplanting of seedlings into the bag system.

Once planting was done, the crop was fertigated using a nutrient solution containing all the required macro and micronutrients for adequate growth. Figure 4 shows the project beneficiaries receiving training on the mixing and application of the fertilizer to the bags through fertigation. For this purpose, a nutrient solution was prepared by mixing 1g of Multifeed (a water-soluble fertilizer) with 1L of water. Once prepared, the nutrient solution mix was applied to the top of the bags manually (10L per bag each time) using a watering can. This was done every day, three times per day.

The beneficiaries started harvesting kale after approximately two months. Harvesting of leafy crops is done by manually picking only the matured leaves, leaving about 2-3 young/small developing leaves for re-growth (Fig. 5). Root crops, like beetroot, take about three months for the bulbs to reach maturity.

There are several benefits associated with the implementation of the bag system. These include water conservation since there is only a small amount of water lost through draining out of the bag; suppression of weeds (no weed control is needed) and improvement of the harvested quality produce, since plant leaves are free from the growing substrate particles, as they

Figure 4. Fertigation of the seedlings using a nutrient solution mix of water and Multifeed with a watering can.

Figure 5. Mature plants ready to be harvested for household consumption.

grow facing upwards, which limits them from getting in contact with the growing medium. In addition, there is high yield per unit area as compared to growing in the open field or on a flat area, due to its vertical growth pattern. Moreover, the bag requires less space to produce vegetables/food and the system can be put up anywhere where there is space available, even on non-arable land and verandas. Despite the numerous advantages, the system also has few drawbacks. Depending on the growing medium used, poor drainage can have a negative effect on moisture distribution and air circulation around the plant roots. Also, the bags need to be supported and kept upright for uniform distribution of irrigation water, and once in a while they need to be rotated to improve sunlight penetration through the plant canopies. In addition, with time the maize-meal bag disintegrates and is torn apart due to heat, particularly if the bag system is implemented under field conditions.

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Climate-smart agricultural interventions by the ARC-VIMP

Compiled by Araya NA, Araya HT, Amoo SO, and Du Plooy CP, Crop Sciences Division, ARC-VIMP

Climate-smart agricultural interventions include those that increase crop productivity through adjusted farming systems, based on perceived or future projected climate change impacts. These interventions are needed in many parts of the world, including South Africa, to tackle the current climate change and food security challenges successfully. Global warming and climate change are becoming more and more of a reality in South Africa. Temperatures have risen significantly over the last 60 years, and are predicted to continue this trend, with a rise in temperature of 1-2 °C expected in coastal regions, and 3-4 °C expected in interior regions by 2050. Seasonal rainfall patterns are also shifting, with unpredictable fluctuations of wetter and drier years, particularly in dry arid to semi-arid areas, which represents the majority of South Africa. As a result, there is a need for researchers to assist in evidence-based technology development and transfer to farmers and most vulnerable communities.

It is in this context that the Agricultural Research Council–Vegetables, Industrial and Medicinal Plants (ARC-VIMP) has, and continues to, work in partnership with several stakeholders, in different research projects, to develop climate-smart technologies as mitigation and adaptation strategies to the effects of climate change on crop production. The Department of Agriculture, Land Reform and Rural Development (DALRRD) is amongst the stakeholders, who contributed to the promotion of low-cost climate-smart agricultural practices such as rainwater harvesting and conservation (rooftop, in-situ and in-field) for improved dryland farming or household use, as well as simple hydroponic systems for vertical cultivation of vegetables for increased crop productivity with limited land and water utilisation. Funding provided by the DALRRD was further extended to investigate optimum intercropping strategies between leafy and legume vegetables for improved fertility of nutrient-poor soils through symbiotic nitrogen fixation. The Water Research Commission (WRC) has also played a significant role in providing funds for the development of strategies for efficient irrigation water use, and technology transfer to beneficiaries in need. These strategies included the development of crop coefficients in determining crop water requirements under a range of climatic conditions, and deficit irrigation methods which provide a means of reducing crop water consumption while minimizing adverse effects on yield, both contributing to increased water use efficiency and nutritional water productivity.

The ARC has also collaborated with DALRRD, Department of Science and Innovation (DSI) and the National Research Foundation (NRF) in the development of nutrient-dense varieties of vegetables, which are simultaneously drought-tolerant, through selective breeding to broadening the food base in South Africa. The development and transfer of the technologies mentioned above have improved farmers crop productivity, decreased use of water, fertilizer and pesticides in farming operations, which in turn increased farmers' profitability and improved the well-being of communities at large.

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Field rainwater harvesting and conservation strategies for improved production of leafy vegetables under dryland conditions at the ARC-VIMP research station at Roodeplaat.

Establishment of school-based vegetable gardens with community involvement at two primary schools in Mamelodi East, Pretoria, South Africa

Compiled by Araya HT, Araya NA, Makgato MJ, Abigail HA, Maleka SK, Mofokeng MM, Du Plooy CP, and Amoo SO, Crop Sciences Division, ARC-VIMP

School-based vegetable gardens are recognized as a promising approach that complements School Feeding Schemes and well-being of children at lower primary levels. In South Africa, the school garden projects are in line with the strategic plan on the Nutrition for Rural Education and Development (Tech4RED) projects of the government, which started in 2013. The school nutrition gardens are a long-term strategy that complements supplementation and food fortification programmes. Running a school garden requires not only horticultural knowledge but also common sense, enthusiasm, organizational capacity as well as the ability to mobilize parents and people in the area.

Malnutrition is still rife in South Africa, where the country faces both under- and over nutrition. The prevalence of under-nutrition is mostly in children, especially in rural areas and disadvantaged communities, such as those living in informal settlements, both in the rural and urban communities. The Water Research Commission (WRC) funded the Agricultural Research Council (ARC) to establish a school garden project. The project's intervention addresses critical areas in improving the nutritional status of the learners. These areas include developing functional school gardens that would supply the school with vegetables and legumes for feeding the learners, and creating nutrition awareness through nutrition education to learners, teachers and caregivers.

The ARC and WRC, together with community participation, have implemented school-based vegetable gardens at two primary schools in Pretoria, Gauteng province of South Africa. Vegetable school gardens were established at Bula-Dikgoro and Mahlasedi-Masana public primary schools as a pilot study. Accredited training (AgriSETA module: Plant the crop under supervision 116200) on basic crop production, seedbed preparation and irrigation maintenance was provided for selected school gardening members from each school. The irrigation system was installed and selected winter and summer vegetable crops were planted. These included commercial vegetables (cabbage, Swiss chard, beetroot, carrot and green pea) and African leafy vegetables (kale, mustard spinach and rape). Moringa trees were planted around the garden to act as a living fence while providing the schools with leaves and pods for inclusion in daily meals. Climate-smart vegetable production systems such as the open field tunnel and the bag system were also introduced to the schools as a way to maximize crop productivity with minimum use of land and water resources. The bag system when plated with 40 Swiss chard and other leafy vegetables per bag and 52 bags per 100 m^2, will yield 12 kg per bag of leafy vegetables over four harvests which will give a total yield of 624 kg within 2-3 months from planting. This project has, therefore, tremendous potential to improve food security and nutrition through increased access to vegetable consumption in school children and can be rolled to household gardens as well.

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JOJO tank and vegetable tunnel installed at a school garden.

Vegetable production by community members using different production systems at the schools.

Supply of harvested vegetable produces to the kitchen for improved nutrition of school feeding meals.

Field rainwater harvesting for vegetable production in South Africa

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South Africa is predominantly an arid to semi-arid country (Fig.1), characterized by low and erratic rainfall (less than 500 mm on average annually), high atmospheric evaporative demand and poor soil fertility. As a result, crop production is constrained particularly under rain-fed conditions. The implementation of improved management practices would considerably increase crop productivity under rain-fed conditions. These include practices that maximize crop water availability through minimization of wasteful water losses. This can be achieved through the implementation of field rainwater harvesting and conservation techniques.

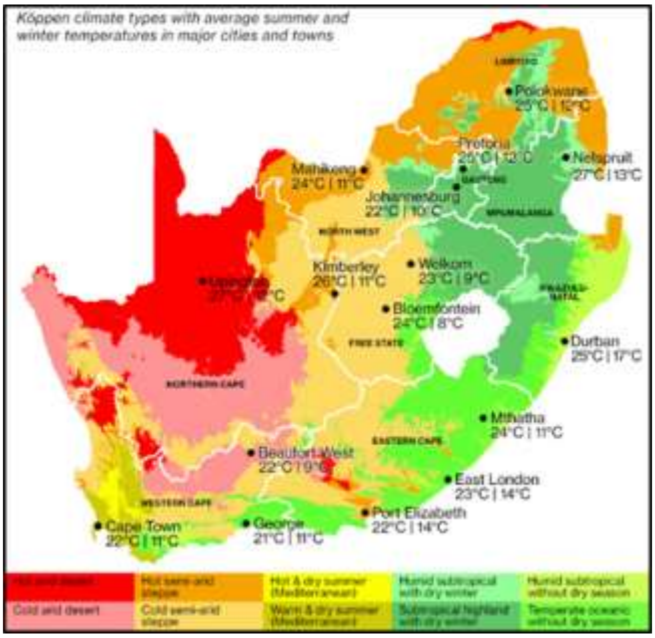

Figure 1. South Africa's climate.

Thus, the Agricultural Research Council has worked in collaboration with the Department of Rural Development and Land Reform in the development, promotion and adoption of small-scale field rainwater harvesting and conservation technologies for improved crop production in dry areas of South Africa. Field rainwater harvesting and conservation is recognized as a method for inducing, collecting, storing and conserving local surface runoff in arid and semi-arid regions, in order to mitigate the effects of temporal shortages of rain. These technologies are grouped in two major categories. The first group is termed *in-situ* rainwater harvesting, which involves the use of methods that increase the amount of water stored in the soil profile by trapping or holding the rain where it falls. In this application, there is no separation between the runoff collection area and its storage area; the water is collected and stored where it is going to be utilized for crop production (Fig. 2). The second group is termed in-field rainwater harvesting, which consists of collecting runoff from a runoff producing area over a flow distance of less than 30 m and storing it for consumptive use in the root zone of an adjacent cropping area (Fig. 3).

In the in-field rainwater harvesting technique, the runoff producing area can be covered with plastic, as shown in Fig. 3, to maximize runoff collection and delivery to the cropping area.

Figure 2. Cultivation of amaranth using the *in-situ* rainwater harvesting and conservation technique at Roodeplaat, ARC-VIMP.

Figure 3. Cultivation of amaranth using the in-field rainwater harvesting and conservation technique, with a plastic covered runoff area.

Alternatively, it can be kept bare and well compacted in order to reduce implementation costs, as illustrated in Fig. 4. This area should be weeded by hand regularly in order to reduce infiltration of water into the soil, and ensure runoff collection into the planting area. Regular manual weeding should also be performed in the cropping areas, to avoid unwanted plants competing with the crop for space, water, solar radiation and nutrients, while minimizing disturbance of mulching cover on the cropping area. This is particularly important in the early stages of crop growth, since crop roots and canopy are still small to compete against weeds. Besides contributing to a healthier crop, weeding has some other advantages. It helps alter the microclimate below the plants. Sun and wind can penetrate deeper in a weeded crop and reduce the surrounding humidity. This can have a positive

Figure 4. Cultivation of amaranth using the in-field rainwater harvesting and conservation technique, with a bare runoff area.

impact on pest and diseases control.

There are several advantages associated with the implementation of field rainwater harvesting and conservation technologies. These include reduced risk of crop failure, low input requirements for easy implementation by the farmer, increased soil water availability during prolonged dry spells, prevention of soil erosion and leaching of nutrients, and most importantly, increased crop productivity. Cultivation of selected leafy vegetables (amaranth and Swiss chard), using field rainwater harvesting and conservation techniques at ARC – VOP research station, resulted in significant increase of profile soil water content and crop yields. Profile soil water content increased from 162 mm m-1 under conventional flat cultivation practice to 193 mm m-1 under in-field rainwater harvesting, while fresh harvestable yield almost doubled, from 17.0 to 30.0 kg ha-1 for Swiss chard, and from 6.0 to 11.0 kg ha-1 for amaranth. Despite the evident benefits of these technologies, there are also drawbacks associated with their implementation. Labor requirement is the major constraint. As the technologies are manually, earthen made, it may require approximately three months to construct the systems on 1.0-hectare land, with five people. This involves soil preparation using hand tools, fertilization with organic manure, construction of planting pits and compaction of runoff collection area (Figs 5 to 7). Nevertheless, such technologies have been increasingly implemented by smallholder farmers and household gardeners, for increased crop productivity under the noticeable effects of climate change, thus contributing to improved food security, poverty alleviation and overall livelihood sustainability of the most vulnerable communities in South Africa.

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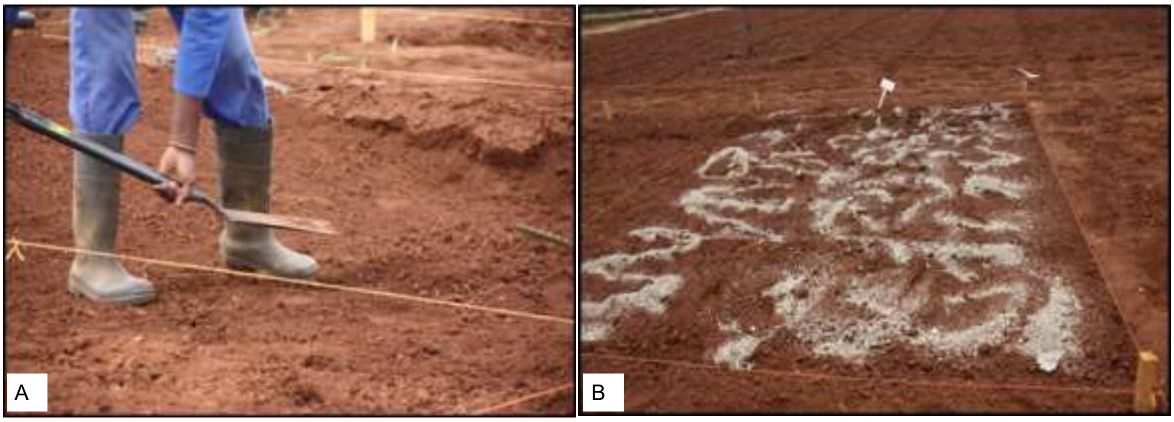

Figure 5. Soil preparation (A) and fertilization (B) before setting-up rainwater harvesting and conservation systems at Roodeplaat, ARC-VIMP.

Figure 6. Construction of the in-situ rainwater harvesting and conservation planting pits at Roodeplaat, ARC-VIMP.

Figure 7. Compaction of the runoff collection areas of the in-field rainwater harvesting and conservation technique at Roodeplaat, ARC-VIMP.

Technology Transfer - July to November 2020

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