BAG SYSTEM FOR RURAL SETTING DEMONSTRATION AT GIYANI COMMUNITIES AS PART OF THE GIYANI LOCAL SCALE CLIMATE RESISTANCE PROGRAMME

Hintsa Araya, Hunadi Chaba, Nadia Araya and Mariette Truter

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Bag System for Rural Setting Demonstration at Giyani communities as part of the Giyani Local Scale Climate Resistance Programme

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Water Research Commission of South Africa

Edited by

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EXECUTIVE SUMMARY

Malnutrition is widespread in South Africa, and the country faces both under- and over-nutrition. Undernutrition is prevalent in particularly rural areas and disadvantaged communities, such as those living in informal settlements. Over-nutrition is highly prevalent in adults, some adolescents, and urban community members. Malnutrition, particularly a deficiency in vitamins and micronutrients (especially Fe and Zn), is a common problem in children and women. According to the World Health Organization (WHO, 2020), vitamin A and micronutrient deficiency remain a widespread problem and cause of cardiovascular disease, cancer, chronic respiratory diseases, and diabetes (which together are responsible for 60% of all deaths) and increasing globally. In South Africa, vitamin A deficiency is a severe health problem, particularly in women and children. Vegetables can play an essential role in combating the challenges faced by communities in the country.

The Water Research Commission (WRC) funded this project (project no. C2022/2023-01497), which was undertaken by the Agricultural Research Council (ARC). The project focused on demonstrating the bag system for rural areas in communities in Giyani as part of the Giyani Local Scale Climate Resistance Programme (LSCRP). A bag system is a simple hydroponic system for vertically growing vegetables in polypropylene bags filled with sawdust (wood dust) for vegetable production in resource-limited areas. Implementing a bag system can increase vegetable productivity per unit of land area, resulting in more efficient utilization of crop water, reducing the amount of irrigation water required per unit area of produce, and enhancing food and nutrition security in communities.

The proposed invention was implemented within selected co-operatives, households, and schools in the Giyani municipality, Mopani District, Limpopo Province, with affordable and more environmentally friendly vegetable production practices. The project focused on how to grow vegetables using the system, and the project inception workshop was held in Giyani, Limpopo Province. The inception workshop ensured that the broadest range of stakeholders (including community members, beneficiaries of the project, and farmers) and young researchers were involved in the project from the beginning.

The objectives were to introduce cost-effective and ecologically sustainable methods for vegetable production. Several Giyani community projects, including co-operatives, households, and schools, were involved in Loloka, Mbedhle, Mzilela, Mayephu, Matsotsosela, Daniel Ravalele, and Ndhambi villages. The bag system installation was successfully executed, and to facilitate the planting and upkeep of the site, the project

appointed community members to assist. The team continuously transferred skills and trained the community members.

The training provided insight into alternative vegetable production systems to smallholder farmers around the sites through stakeholder engagement and training provided on vegetable production. The training included basic cultivation practices (planting, fertilization, watering, harvesting, storage, and nutritional values of vegetables, pest and disease management). The training based on the practical activities created essential in enhancing participants' adoption of simple technologies to produce vegetables, the basic understanding of the beneficiaries of vegetables, and crop management and planning concepts to ensure sustainable production.

In conclusion, the project has successfully introduced an alternative vegetable production system that requires minimum input and space. Continuous stakeholder engagement positively impacts the adoption of the production system and assists farmers in understanding the benefits of the system. Through participatory research approaches, the intervention has highlighted innovative disinfecting vegetable production and pest and disease control measures such as home remedies. Future research should focus on the following:

- Environmental impact of the bag system, including assessing the carbon footprint of bag systems compared to open-field and greenhouse vegetable production, investigating the potential for urban greening and carbon sequestration with vegetable bag systems and studying the impact of microclimates on crop performance in urban settings.
- Economic feasibility of the bag system, including analysing the cost-effectiveness of vegetable bag systems for smallholder farmers and urban gardeners. Comparing profitability with other small-scale farming methods. Exploring market opportunities for bag-grown produce as a niche product.
- Community and educational impacts of the system in evaluating the role of bag gardening in food security for urban and peri-urban communities, using bag systems as educational tools in schools and community programmes in other areas of the country and studying the social and psychological benefits of engaging in bag gardening.
- Climate resilience of the bag system, including investigating how bag systems perform under extreme weather conditions (e.g., drought, floods, heatwaves), testing crop resilience and adaptability to climate variability in controlled bag environments and exploring the role of bag systems in mitigating urban heat islands.
- Green technology, such as solar-driven irrigation systems, improves the sustainable production of vegetables and the adoption of climate-smart irrigation technologies.

Most smallholder farmers, schools and households also face challenges of irrigation water and support them with infrastructures such as the provision of boreholes, rooftop rainwater harvesting techniques and water storage tanks. The project has been successfully implemented and has shown excellent potential for smallholder farmers, schools and households to adopt climate-smart agriculture and to be rolled out nationwide to improve limited resource utilisation.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALVs	African leafy vegetables
ANOVA	Analysis of variance
ARC-NRE	Agricultural Research Council – Natural Resources and Engineering
ARC-VIMP	Agricultural Research Council – Vegetable, Industrial and Medicinal Plants
CA	Conservation agriculture
CDF	Cumulative distribution functions
CSA	Climate Smart Agriculture
CSIT	Climate Smart Irrigation Technology
DAFF	Department of Agriculture, Forestry and Fisheries
DM	Dry matter
ERWH	Ex-field RWH
FAO	Food and Agriculture Organisation
IFPRI	International Food Policy Research Institute
IRWH	In-field RWH
LAI	Leaf Area Index
LDARD	Limpopo Department of Agriculture and Rural Development
LSD	Least significant difference
M&E	Monitoring and evaluation
OLS	Ordinary least squares
PPE	Personal productive equipment
RSA	Republic of South Africa
RWH	Rain Water Harvesting
SHF	Small Holder Farmer
SIS	Smallholder irrigation schemes
SPSS	Statistical Package for the Social Sciences
SWC	Soil water content
TMI	Traditional methods of irrigation
TUT	Tshwane University of Technology
WRC	Water Research Commission

LIST OF SYMBOLS

B	Boron
Ca	Calcium
Cu	Copper
Fe	Iron
g	Gram
K	Potassium
kg	Kilogram
L	Litre
LAN	Lime Ammonium Nitrate
Mg	Magnesium
mg	Milligram
Mn	Manganese
N	Nitrogen
Na	Sodium
P	Phosphorus
Zn	Zinc

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CHAPTER 1

INTRODUCTION

1.1 Background

Malnutrition is widespread in South Africa, and the country faces both under- and over-nutrition. Undernutrition is mostly prevalent in rural and disadvantaged communities, such as those living in informal settlements. Over-nutrition is highly prevalent in adults, some adolescents, and urban community members. Malnutrition, particularly a deficiency in vitamins and micronutrients (especially Fe and Zn), is a common problem in children and women. According to the World Health Organization (WHO, 2020), vitamin A and micronutrient deficiency remain a widespread problem and cause of cardiovascular disease, cancer, chronic respiratory diseases, and diabetes that cause 60% of all deaths and are increasing globally. In South Africa, vitamin A deficiency is a severe health problem, particularly in women and children. Home vegetable gardens are an innovative tool and strategy that incorporates hands-on activities into community-based food security tools by providing a dynamic environment where participants observe, discover, experiment, nurture, and learn.

Garden programmes should consider local customs and the need for specific socio-economic, climate, and environmental situations (FAO, 2004a). Gardens contribute significantly to increasing the relevance and quality of nutrition in communities, improving society's knowledge of food production techniques and nutritional benefits while motivating home garden development (FAO, 2004b). Home gardens can connect the community and nature, positively influencing the community's health, growth and development, and opportunities over time by preserving a healthy society. Influencing the mindset of communities will impact the community's healthful nutrition habits and produce their food, significantly influencing families. Gardens can play an essential role in the long-term human impact on the natural environment, including protecting soil and water resources by reducing nutrient leaching, proper nutrient and irrigation management, and water shortage due to the over-use of pesticides.

South Africa has experienced increasing urbanisation over the past few years. Reasons for the high population in the urban include the fact that they are home to several large mines, which results in large numbers of people migrating from rural areas to the cities of the provinces looking for better employment opportunities. The influx of people from other African and Asian countries also contributes to the province's large population. Increased population density often puts more significant pressure on the available land and water resources, influencing food availability tremendously. Many of the urban population is poor and food insecure, without reliable access to enough affordable, nutritious food such as leafy green vegetables. Most of the population depends on cash income to access food, and with unemployment increasing, more urban households cannot access food to meet their needs. Therefore, alternative ways to increase agricultural productivity by optimizing land and water resources have become necessary to curb food insecurity in such areas.

Alternative production systems, in which crops grow in veggie tunnels and soilless cultivation using various substrates, can be put up anywhere in a household garden, terraces, verandas, or near the market, reducing transportation distances and conserving the marketable quality of the produce. This is particularly important for leafy green vegetables due to their high perishability. Compared to conventional soil cultivation methods, hydroponic systems are generally more efficient in land, water, and nutrient use. They are often less susceptible to pests and diseases due to lower crop exposure to environmental stress. Besides, hydroponic productions are less labour-intensive since they do not require cultural operations such as ploughing, weeding, and soil fertilization (Nguyen et al., 2017).

1.2 Rationale

There are several types of vegetable production systems, including open field and controlled (such as veggie tunnels and bag systems) vegetable production systems. The combined production systems can optimise the accessibility of vegetable crops within the limited available space. In an open-field production system, vegetables can be planted systematically to help manage soil fertility and avoid or reduce problems with soil-borne pathogens and some soil-dwelling insects, such as rootworms. All pre-plant inputs, such as Kraal manure, can be applied to ensure soil health before direct seeding and seedbed preparation. The vegetable garden can be divided into plots, and each plot can be designated for a crop. Crops can be rotated for the next growing season, which means crops can be moved through the same garden bed over time. The production system can be linked with spraying plant extracts as a measure of disease and pest control, rainwater harvesting, and organic mulching.

The Agricultural Research Council, Vegetable, Industrial and Medicinal Plants has been conducting research on controlled environment and open field systems for over a decade, with research findings and technologies developed being transferred to various beneficiaries, including smallholder farmers, students, and private and public sector bodies (Maboko et al., 2017; Mampholo et al. 2016; Maboko and du Plooy, 2013). Research on closed hydroponic systems with vertical cultivation is significant due to the limited availability of water and land resources for agriculture. Such systems can grow considerably more plants per unit of land, with less irrigation water and nutrient supply than open-field production systems due to minimum/ non-existent water losses through drainage, runoff, and growing media water evaporation.

1.3 Aims and objectives of the study

The project's long-term objectives focus on improving food and nutrition security and income generation of the less privileged community members in Giyani, Limpopo Province of South Africa, by maximising vegetable productivity per unit of land, water and nutrient resources used using the bag system.

Short-term objectives:

1. Engage with communities in the Giyani area and Limpopo Province as key partnerships and networks that could add value to capacity development and new knowledge generation, as well as identify agricultural co-operatives and water community schemes that will benefit from a train-the-trainer programme to participate in the project.
2. Identify and develop appropriate training modules for alternative vegetable production (the bag system) that require fewer inputs to improve community resilience to climate change.
3. Pilot alternative vegetable production (the bag system) training modules across all agricultural and community water schemes as part of a train-the-trainer initiative to finalise a package of learning tools and appropriate approaches that sector partners can implement more broadly.
4. Investigate the role of training in service payment and investment in rural community-based water schemes and integrated agricultural activities.
5. Provide insights and recommendations for key partnerships and networks to adopt, as well as advice on how similar capacity development programmes in other parts of the water sector could benefit such communities in Limpopo and possibly South Africa, as well as the potential for other African partners/contexts.

1.4 Research approach and methods

The project was implemented in communities and small-scale farming areas targeted by the programme. Five (5) agriculture sites: Hlamebeto multipurpose agricultural primary co-operative, Duvadzi Youth Organic Agriculture co-operative, Ahi thireni Mceqkwa co-operative, Matsambo Gamba Project (PTY)LTD and Macena agricultural primary co-operatives limited. In addition, four (4) Community Water Supply areas, including Mbhedle

(Population=1230), Mayephu (Population=1940), Mzilela (Population=1150), and Matsotsosela (Population=2300), were involved.

The project inception workshop was held in Giyani, Limpopo Province. It ensured that the broadest range of stakeholders (including community members, beneficiaries, and farmers) and youth were involved in the project from the beginning. The research questions were refined with stakeholders, and the activities were agreed on.

Throughout the project's lifespan, a comprehensive literature review assessed existing knowledge and understanding of current opportunities, problems/challenges in community enterprise development, climate change resilience, and alternative production systems. As a result, the data was updated to reflect green technologies, highly nutritious crops, their specific effects on human nutrition, and foods tested in communities. A systematic review was conducted to identify relevant research works for the literature review. The review examined the advantages of having a vegetable garden, implementation strategies, challenges, and critical successes in solving all nutrition-related problems in South African schools. Notably, the review provided a framework for implementing low-input production systems in poor communities as a poverty alleviation intervention.

The bag system is a low-input and alternative method of growing vegetables that maximizes yield per unit of area used predominantly in South Africa's arid and semi-arid regions, such as the Giyani area, where good soil and land/space for vegetable production is becoming an issue, particularly in home gardens. The bag system can hold water longer without draining water and nutrients into the soil since the system allows for precise irrigation water applications, resulting in less water lost through drainage and, thus, less nutrient leaching. Furthermore, because plant leaves are not in contact with soil, cleaning the leaves, which saves water for washing before consumption or marketing, requires less effort. The bag system can also be used anywhere in the garden to grow leafy and root vegetables like Swiss chard, beetroot, carrot, amaranth, kale, and so on, eliminating the need for weeding.

The system is a low-cost hydroponic production system consisting of growing vegetables vertically in polypropylene bags or empty maize meal bags filled with sawdust and placed upright on the ground surface under a 30-40% white shade net. During planting using scissors, small holes (3 cm x 3 cm) were perforated uniformly around the bags to allow seedlings to be inserted. On 1.89 m^2, 40 vegetables (10 cm x 12.5 cm spacing per plant) per bag were planted with an expected yield of about 12 kg of leafy vegetables over four harvests. A soluble fertilizer containing all the necessary macro and micronutrients was added to a watering Can at a rate of 5 g per 10 L of water to feed the plants daily (2 to 4 L per bag). An integrated pest and disease management programme was used to control pests and diseases where necessary.

In addition, train community members/beneficiaries in basic gardening practices (planting, fertilization, watering, harvesting, storage, and nutritional values of various crops), business skills, and irrigation management. The training covered climate-smart technologies such as organic and inorganic vegetable production, integrated pest and disease management, and alternative production systems through group discussions, demonstrations, pamphlets, and popular articles. It also covered the income generation of communities. It created an understanding of how climate-resilient low-input technologies, such as the bag system, can improve community livelihood on a market development strategy that assists growing businesses in identifying and developing new opportunities to sell their current products for economic development. The project involved three BSc final-year undergraduate students as part of capacity building.

1.5 Report structure

The approaches used in this project are aligned to answer the project's specific objectives and are presented in this report's Chapters. The first chapter overviews the project's goals, objectives, and rationale. The second chapter is a comprehensive literature review to compile existing knowledge and understand the current problems/challenges of the bag system vegetable production. This chapter elaborates on the methods used to conduct a literature search on the various research topics linked to the advantages and disadvantages of the production system. Further, the chapter narrates the possible vegetables that can be grown in the bag system, how this simple alternative vegetable production system can benefit communities, and the materials needed for a functional bag vegetable production system.

The third chapter addresses the production of seedlings, what quality seedling means, which growing media to use, seedling trays to use, what steps one must follow before planning seedlings and material needed for the bag system, and possible suppliers. The chapter provides guidelines on leafy vegetable production in a bag system, including day-to-day activities, symptoms of nutrient deficiencies, common diseases and pests, and basic biological controlling methods, including possible home remedies. This Chapter addressed objectives 2 and 3 of the project.

Chapters four and five focus on implementing a bag system for vegetable production that demonstrates the hands-on involvement of co-operatives, schools, and households in the Giyani communities. Giyani communities, establishing the bag system, including sourcing materials needed from local supplies, planning, building tank stands, installing an irrigation system, and building shade net structures. Community members participated during the establishment of the bag system and practical training was provided. This Chapter addressed objectives 1, 2, 3 and 4.

Following this, chapter seven discusses stakeholder engagement, information dissemination and training provided on the bag system vegetable production. This chapter has demonstrated several activities that smallholder farmers were trained on using the on-farm practical approach, which creates opportunities for beneficiaries. The training based on the on-farm practical activities is essential in enhancing smallholder farmers' adoption of the bag system. The chapter further discusses the basic understanding of the beneficiaries of vegetables and a crop management and planning concept to ensure sustainable growth of the crops. Chapter eight provides a general discussion, conclusion and recommendation on future research works.

CHAPTER 2

BAG SYSTEM VEGETABLE PRODUCTION

2.1 Introduction

Good soil and land/space availability for household vegetable production are becoming a significant concern (Figures 2.1 and 2.2). However, there is an alternative way of growing vegetables and optimizing yield per unit area for household production. Plants grown in bag systems are growing vertically upwards, which results in inefficient use of space/land. Bag systems can be used in places that have not been previously thought of as appropriate for food gardens, such as paved land and balconies. The bag can hold water longer without water and nutrients draining into the soil. Plant leaves are not in contact with the soil, resulting in less effort to clean the leaves before consumption or marketing. It can be produced organically. When fully planted with Swiss chard/spinach, this small bag system can feed a family of four with a bunch of spinach every week.

Figure 2-1: Growing vegetables using a bag system.

Many people in South Africa are challenged with food access and nutritious food that meets their dietary needs for an active and healthy life. Lack of accessibility to healthy food is an essential aspect of food insecurity. Good nutrition is essential for individuals' optimal growth, development, health, and well-being in all stages of life. Malnutrition, including undernutrition, vitamin A, iron, and zinc deficiency, is among the leading causes of disease burden and mortality in communities. Nutritional deficiencies are similarly a significant health problem in South Africa. Some findings on the severity of micronutrient deficiency in South Africa indicated that about 50% of children between 1 and 9 years old required energy, vitamin C, riboflavin, niacin, vitamin B6, folic acid, iron, and zinc.

Malnutrition, either over or undernutrition, is becoming a significant problem in South Africa, especially in young women and children. Although many households have shown knowledge about nutrition and healthy food, their knowledge did not influence their daily healthy food choices. Community gardens can play a more significant role in making nutrition education and participatory exercise where the community can not only learn about the healthy parts of the food, how to grow them, how to choose the crops according to their environment and how to ensure a sustainable supply of a healthy variety of foods to their household members.

Many children and adults in South Africa suffer from inadequate vitamin A intake, a public health problem. The consequences of vitamin A deficiency are higher maternal death risks, increased risk of death from measles and diarrhoea in children, reduced resistance to infections, delayed recovery from illness, and eye damage. To address this chronic problem, ARC-VIMP applies alternative production systems such as the bag system. This approach is based on producing nutritious vegetables on non-arable land using bags to increase the availability, access, and consumption of nutrient-rich vegetables. The system is ideal for vertically growing green leafy vegetables such as Swiss chard, kale, amaranth, spinach, and lettuce and root crops such as carrots, beetroots, sweet potatoes, onions, and so on top of the bag. The system will allow households to consume nutritious vegetables that contain protein, ascorbic acid, beta-carotene, micro and macronutrients.

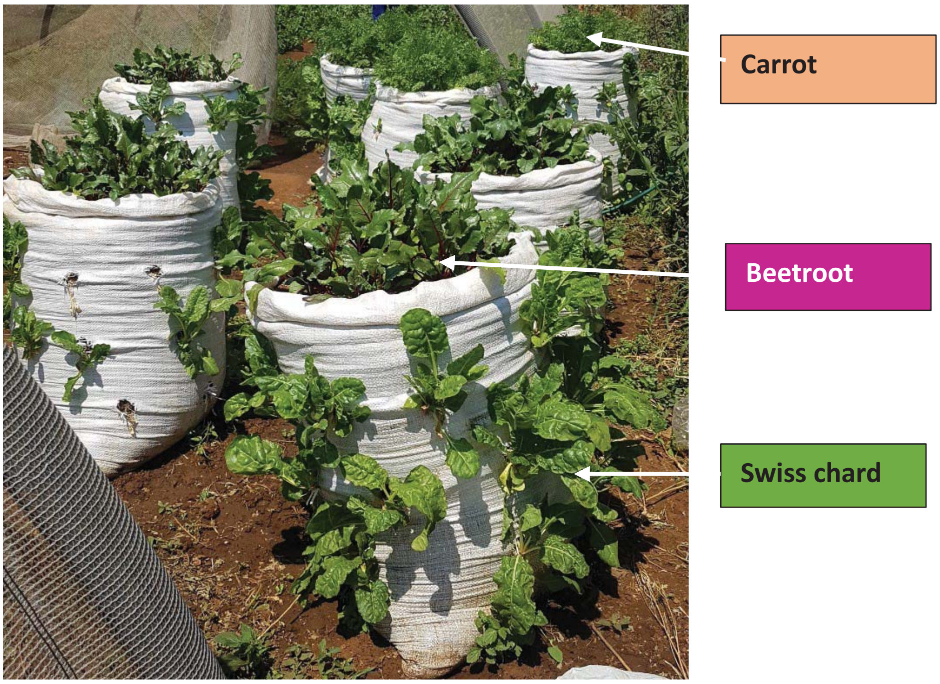


Figure 2-2: Growing green leafy and root vegetable crops in a bag system.

Advantages of the bag system	*Disadvantages of the bag system*
• It conserves water since there is a small amount of water draining out of the bag	• Poor drainage medium can have a negative effect on moisture distribution and root aeration
• It suppresses weeds; no weed control is needed	• Bags need to be supported and kept upright for uniform distribution of water
• Plant leaves are free from soil particles since plants leave faced upwards	• The maize-meal bag cannot be reused; with time, it can be torn apart and disintegrate, depending on the bag's durability
• There is a high yield per unit area compared to growing on a flat area	
• Requires less area to produce food (56 plants/m^2)	

2.2 Crops to be produced in a bag system

To ensure that communities' eating habits improve through healthy foods, a substantial portion of each type of vegetable should be available. A balanced diet to keep the human body healthy and ensure proper growth and mental development can only be attained if various foods are consumed daily. A balanced diet comprises proteins, vegetables, and carbohydrates (Figure 2.3). This includes consuming animal foods such as fish, chicken, eggs, milk, etc., as often as they are available. However, animal foods are not always available and are usually expensive. Animal products can, however, partly be replaced by leguminous vegetable products, as included in Figure 2.3.

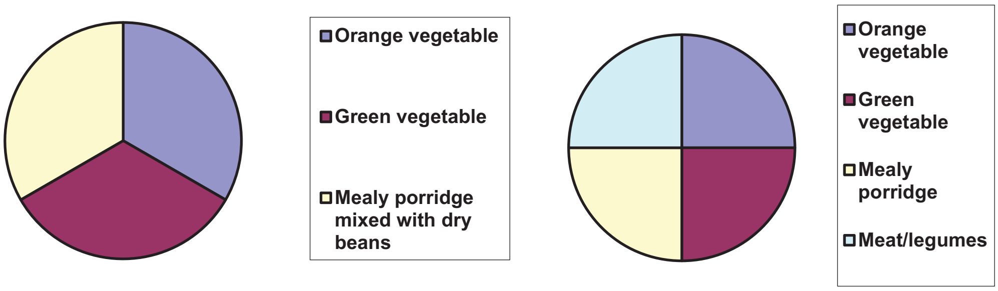


Figure 2-3: Examples of proportions of types of food needed daily.

Although vegetables and fruits are usually eaten as sources of vitamins, minerals, and fibre, many of these crops also provide large amounts of digestible carbohydrates, e.g., potatoes and sweet potatoes, and ample proteins in leguminous vegetable crops such as cowpeas, Bambara and green beans. Orange-fleshed sweet potato is an excellent carbohydrate source, containing high levels of provitamin A and adequate quantities of vitamin C, pyridoxine (vitamin B_6), and minerals such as copper and magnesium.

The production plan and layout of the bag system vegetable garden should be structured in such a way as to address the provision of crops for a balanced diet (Table 2.1). Different crops must be available for at least ten months to supply the necessary provisions for feeding nutritious vegetables to the community or households. The garden's size must also be considered and large enough to feed the number of households. In the case of school gardens, enough to feed the number of learners.

Growing crops should be intensive, and a continuous planting programme should be followed to ensure sustainability. However, it is advised to start small and gradually increase as the capacity and know-how improves.

Table 2-1: Sowing and planting chart for Feb/Mar/Apr.

CROP	Months for planting/sowing	Months for Transplanting	Months for harvesting
Bean (bush)	Feb-Mar	-	May-Jun
Beetroot	Jan-Mar	Feb-Apr	Apr-Jun
Cabbage	Feb-Mar	Apr-May	Jun-Jul
Carrot	Feb-Mar	-	May-Jul
Cauliflower	Feb-Mar	Apr-May	Jun-Sep
Onion	Feb-Apr	Mar-May	Aug-Nov
Pepper (frost-free areas)	Jan-Feb	Feb-Mar	Apr-May
Potatoes	Jan-Feb	-	May-Jun
Spinach	Feb-Apr	Mar-May	Apr-Jun

Table 2-2: Sowing and planting chart for Aug/Sep/Oct.

CROP	Months for planting/sowing	Months for Transplanting	Months for harvesting
Beetroot	Jul-Sept	-	Nov-Jan
Green beans	Aug-Oct	-	Nov-Feb
Carrots	Jul-Sept	-	Oct-Dec
Cabbage	Aug-Sept	Oct/Nov	Dec-Jan
Sweet potatoes		Oct	Feb-Mar
Potatoes		Sept	Dec
Pumpkins	Aug-Sept	-	Dec-Feb
Squashes	Aug-Oct	-	Nov-Feb
Tomatoes	Aug/Sept	Oct	Jan-Mar

Table 2-3: Vegetable seed germination requirements.

Name of Vegetables	Planting depth (mm)			Germination of seed		Propagated by
	Minimum	Optimum	Maximum	Optimum Temperature	Time (days)	
Amaranthus (Marog)	10	15	20	25	7	Seed/Seedlings
Bambara nuts	3	5	8	22	10	Seed
Beans (Bush)	12	25	40	27	7	Seed
Beans (Climbing)	12	25	40	27	7	Seed
Beet	15	25 – 30	40	22	7	Seed
Broccoli	6	9 – 15	20	22	7	Seed/Seedlings
Brussels sprouts	6	9 – 15	20	22	8	Seed
Cabbage	6	9 – 15	20	22	7	Seed/Seedlings
Carrots	3	12 – 15	25	25	6	
Cauliflower	6	9 – 15	20	22	7	Seed/Seedlings
Celery	6	9 – 15	20	20	7	Seed/Seedlings
Cleome	1	2	3	23	7	Seed/Seedlings
Cowpeas	30	40	50	22	8	Seed
Cucumber	6	12 – 15	30	25	4	Seed/Seedlings
Eggplant	6	12	25	29	10	Seed/Seedlings
Garlic	15	30	50	20	14	Cloves
Leek	6	12 – 15	25	20	7	Seed/seedlings
Lettuce	3	9	15	20	4	Seed/Seedlings
Melon	12	19	40	22	7	Seed/Seedlings
Onion	6	12 – 15	25	20	7	Seed/Seedlings/Sets
Parsley	6	9 – 15	20	24	14	Seed/Seedlings
Parsnip	5	10 – 15	25	20	14	Seed
Peas	15	20 – 30	50	23	8	Seed
Peppers	6	12	25	29	10	Seed/Seedlings
Pigeon Peas	25	40	50	29	10	Seed

Name of Vegetables	Planting depth (mm)			Germination of seed		Propagated by
	Minimum	Optimum	Maximum	Optimum Temperature	Time (days)	
Potato	75	100	200	22	21	Tubers
Pumpkin (butternut)	15	25	40	22	7	Seed
Pumpkin (boer)	19	37	50	30	10	Seed
Radish	10	15 – 20	30	20	6	Seed
Spinach	3	6	12	20	7	Seed/Seedlings
Squash (Gem)	15	25	40	22	7	Seed
Sweet potato		2/3 of vine underground		28		Vines
Tomato	6	12	25	29	10	Seed/Seedlings
Turnip	10	15 – 20	30	20	6	Seed
Watermelon	19	37	50	22	5	Seed/Seedlings

2.3 Selection of vegetables: drought and heat-tolerant

Before planting the bags system, consider drought-tolerant vegetables bred explicitly for drought resistance and those that thrive in hot, arid climates. Popular choices include:

- Cowpeas, black-eyed peas, and field peas
- Indigenous/indigenized leafy vegetables: amaranth, cleome, kale,
- Mustard greens
- Swiss chard
- Summer squashes
- Most herbs

Drought-tolerant vegetables develop deeper root systems to compensate for heat and low water levels. Many increase, which also reduces their long-term water requirements. Drought-tolerant strains of some vegetables with high water usage requirements are available, such as the Black Diamond watermelon and Heatwave II tomatoes. When shopping for seeds and plants with increased drought resistance, look for labels indicating that plants can grow at higher temperatures and have low to moderate water needs. If you are in the middle of or anticipating a drought year, buy young plants to establish your garden rather than plant seeds.

Visit a local nursery and choose from the vast array of drought-tolerant vegetable seedlings. Buying young plants on the verge of flowering can save a month or two of watering at home.

If you choose a vegetable known for its quick maturity, like zucchini (which typically takes 60 days from seed to fruit), you will have a bountiful harvest within a month of transplanting it into your garden. If you must plant from seeds, choose vegetables that go from seed to harvest in a short period, like spring radishes, which can be harvested in less than 30 days after planting.

Different vegetables have different water requirements for optimal production. If you establish your garden without considering individual plant species' water needs, you could water some plants more than what they need and others less than what they need. Instead, focus on giving plants the optimal amount of moisture – while conserving water – by grouping vegetables in your garden according to their drought tolerance and watering requirements see Figure 2.4.

Figure 2-4: Different groupings of vegetables according to their water needs. High water needs: Pumpkins, onions, peppers, cabbage, cauliflower, broccoli, cucumbers, eggplant, and potatoes; Moderate water needs: Beans, asparagus, and cowpeas; and Low water needs: Herbs, mustard greens, spinach, turnip, watermelon, lettuce, and radishes.

2.4 Why can the bag system work in communities?

Good soil and land availability for household vegetable production are becoming a significant concern, especially in urban and informal settlements. The bag system is an easy way of growing vegetables in limited space to optimize yield per unit area.

Plants grown in the bag system are growing vertically upwards, which results in inefficient use of space/land. The bag can hold water longer without water and nutrients draining into the soil.

The system allows for more precise irrigation water applications, which results in little water being lost through drainage, thus minimising the leaching of expensive nutrients. When excess fertilizer is applied, vegetables can take up, and the extra nutrients can be lost to the environment. Unutilised fertilizer can leach downward into groundwater, enter nearby surface waters through runoff, pollute water bodies, or be released into the atmosphere as a greenhouse gas and contribute to global warming. Besides, plant leaves do not contact the soil in the bag system, resulting in less effort to clean the leaves before consumption or marketing, and crops can be produced organically. The bag system can also be implemented anywhere in the garden and does not require weeding (Figure 2.5A&B).

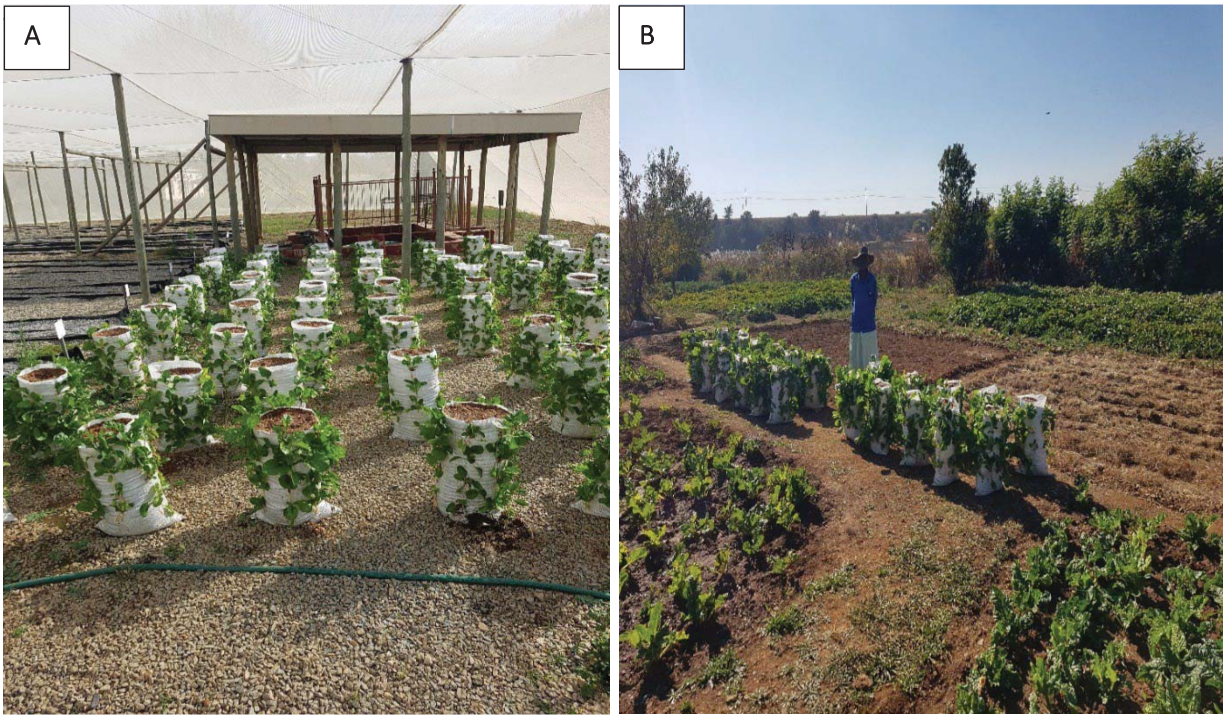


Figure 2-5: Bag system vegetable gardens on (A) gravel ground surface (B) soil surface.

2.5 Methodology and infrastructure needed for bag system vegetable production.

The system is a low-input, cost-modified hydroponic production system. It comprises the use of polypropylene bags or simply empty maize meal bags about 100 cm high x 70 cm wide, filled with sawdust and placed upright on the ground surface to grow leafy green vegetables vertically in the open field or under a 30% white shade net (like the Intensive vegetable tunnel described above) (Figure 2.6A&B). Small holes (3 cm × 3 cm) are uniformly perforated around the bags following the desired planting density to insert the transplanted seedlings of different crops (Figure 2.6A). With Swiss chard and other leafy vegetables, 40 plants per bag and 52 bags per 100m^2. The system will yield 12 kg per bag of leafy vegetables over four harvests, equal to a 624 kg yield over four harvests within 2-3 months from planting.

Irrigation is done using a regular watering can at 2-4L per bag daily. A soluble inorganic fertilizer containing all the necessary macro and micronutrients is added at 5g per 10L to feed the plants with each irrigation.

Figure 2-6: Transplanting vegetables into the bag system (A) and after one month from transplanting (B).

The material needed to establish a bag system includes the following:

1. Open space: this could be an open space outside either a soil surface, gravel ground surface, concrete paving, or slabs.

2. Woven polypropylene bags or empty maize-meal bags are specialized materials used for packaging and transporting commodities in different sizes, either 80, 50, or 25 kg.

3. Soluble fertilisers can be dissolved in water, added into the growing media, and quickly taken up by the vegetables.


4. A growing medium is a material other than soil in which plants are grown. These include compost, sawdust, perlite, vermiculite, coco peat, and rock wool.

5. Watering-can and seedlings


CHAPTER 3

VEGETABLE SEEDLING PRODUCTION

3.1 Introduction

A young plant, especially one raised from seed and not from a cutting (Figure 3.1A&B). It is a young sporophyte developing out of a plant embryo from a seed. Seedling development starts with a seedling of seed. A typical young seedling consists of three main parts: the radicle, the hypocotyl, and the cotyledons.

Figure 3-1: Seedlings from seeds (A) and rooted cuttings (B).

3.2 What is a quality seedling?

When transplanting seedlings to the bag system, it is essential to transplant quality seedlings. This will ensure vigorous growth and minimize missing vegetable plants in the system. Quality seedlings are seedlings that are:

- Disease and pest-free
- Vigorous
- Uniform
- At the right stage (size)
- The right cultivar
- White roots

Figure 3-2: Good quality seedlings (A) and diseased seedlings.

3.3 Seedling growing medium

The seedling growing medium can be a simple potting mix of compost, coir, perlite, well-drained soils, or a mix of well-drained soils and compost that gives seeds an excellent start in life. The growing medium should provide the following:

- Support to seedling
- Good aeration
- Good drainage
- Water holding capacity
- Nutrients

Figure 3-3: Different seedlings growing medium

3.4 Seedling trays

Trays come in different sizes, e.g., 128, 200, and 300 cavity trays. Plants with small root systems, like onions, Swiss chard, and lettuce, can be sown in 300 cavity trays. The 128 cavity trays can be used for large root system crops like cucumber and sweet melons. Never use small-rooted crops in large cavity trays to save space and growing media.

Figure 3-4: Different sizes of seedling trays.

Seedling trays can be reused; however, they should be sanitized with a registered disinfectant followed by a rinse in clean water and air drying.

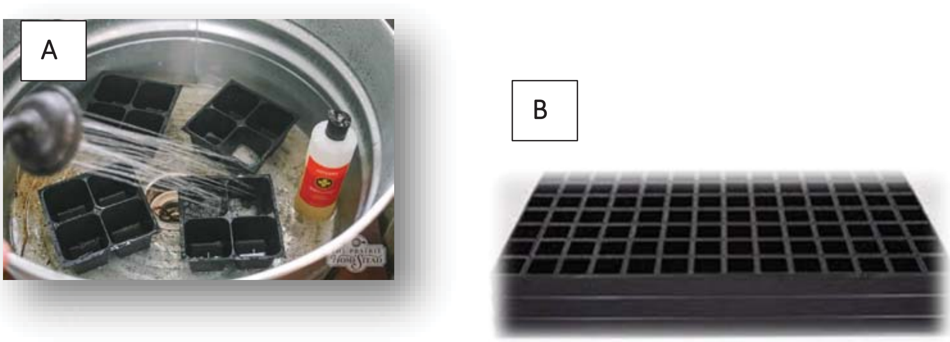


Figure 3-5: Sterilizing and rinsing with clean water (A) and air-drying seedling trays (B).

3.5 Before sowing the seeds

The vegetable seedlings for the bags system could be prepared as follows.

1. Pour seedling growing medium into a container:

2. Moisten the growing medium with water and mix it thoroughly by hand. The growing medium should not be too wet.

3. Pour moist growing medium into trays. Do not over the compact. Make 1 hole per cavity with your forefinger (4 x seed diameter).

4. Cover the seeds with a thin layer of vermiculite. This very light material will hold water and allow the tender seedlings to emerge quickly.

5. Seedling trays should rest above ground on benches of mesh or steel bars for good aeration and water drainage. Do not put trays on the floor/ ground - it will contaminate seedlings.
6. Water seedlings with a watering can or a hose fitted with a nozzle for fine spraying. Do not wash growing medium out of seed trays when irrigating.
7. Water seedlings with a watering can or a hose fitted with a nozzle for fine spraying. Do not wash growing medium out of seed trays when irrigating.

8. Apply soluble fertilizer 8 - 10 days after germination. Apply 1 gram of Multifeed in 1 litre of water once daily until seedlings are ready for transplanting. Apply 1 gram of Multifeed in 1 litre of water once daily until seedlings are ready for transplanting.

9. Protect tender seedlings from too much sunlight, hail, and birds (use shade net, hail net, etc.). Ensure proper sunlight conditions for healthy plants to develop.
10. Monitor the temperature. Too low a temperature causes slow germination/ growth. A temperature that is too high will dry out the growing medium and cause water stress.
11. Irrigate 3 x per day in winter and 4 x in summer. Never let growing medium dry out. Do not overwet. Ensure adequate air ventilation and circulation to keep seedlings dry and reduce the possibility of fungal diseases.
12. Thin out seedlings if necessary using tweezers. Seedlings compete for light, water, and nutrients.
13. Seedlings ready for transplanting:
    - Swiss chard: 4 weeks.
    - Cabbage: 4 - 5 weeks.
    - Lettuce: 4 weeks.
    - Tomato: 5 - 6 weeks.
    - Peppers: 6 - 7 weeks.

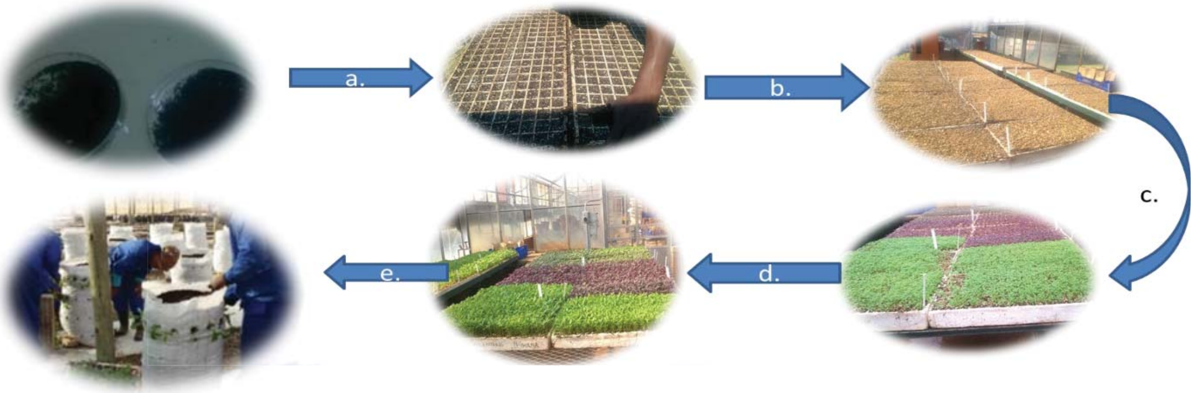


Figure 3-6: The process of vegetable seedling preparation to transplanting to the bag system.

Table 3-1: Material needed for bag system and possible suppliers.

	Items	Supplier	Website for contact
1	Empty maize-meal bag (80, 50, 25, or 12.5 kg bag)	Game stores, Garden Master, Obaro, Build it, Builders warehouse	https://www.builders.co.za/ https://www.obaro.co.za/gardening-diy.html?SID=i9v2mqel4gq3ptpb1mvfo6db45 https://www.buildit.co.za/
2	Water-soluble fertilizer (multi-feed & calcium nitrate)	Hygrotech, Makro, Garden Master, Obaro, Build it, Builders Warehouse	https://www.hygrotech.co/ https://www.gardenmaster.co.za/products/ https://www.makro.co.za/home-garden/lawn-garden/garden-tools/c/DFC
3	Growing medium (compost, sawdust, or soil with excellent drainage)	Timbercity Hardware	
4	Watering-can	Game stores, Garden Master, Obaro, Build it, Builders Warehouse	
5	Seedlings	Makro, local nurseries, Spar stores	
6	Certified vegetable seeds	Game stores, Garden Master, Obaro, Build it, Builders Warehouse	
7	Seedling trays	Hygrotech, Builders Warehouse, Local suppliers	
8	A measuring tape or ruler	Game stores, Garden Master, Obaro, Build it, Builders Warehouse	
9	Scissors or a knife	Game stores, Garden Master, Obaro, Build it,	

	Items	Supplier	Website for contact
		Builders Warehouse	
10	Building bricks or stones to support the bags	Game stores, Garden Master, VKB Stores, Build it, Builders Warehouse	https://www.builders.co.za/ https://www.obaro.co.za/gardening-diy.html?SID=i9v2mqel4gq3ptpb1mvfo6db45 https://www.buildit.co.za/ https://www.hygrotech.co/ https://www.gardenmaster.co.za/products/ https://www.makro.co.za/home-garden/lawn-garden/garden-tools/c/DFC
11	A plastic container for mixing and moistening the growing medium	Game stores, Makro, Garden Master, Build it, Builders warehouse	

CHAPTER 4

PRODUCTION GUIDELINES FOR LEAFY VEGETABLES SUCH AS SPINACH OR SWISS CHARD USING THE BAG SYSTEM

4.1 Introduction

The availability of good soil and land/space for household vegetable production is becoming a major concern. However, there is an alternative way of growing vegetables and optimising yield per unit area for household production. Plants grown in a bag system are growing vertically upwards, resulting in efficient use of space/land. A bag system can be used in places not previously considered appropriate for food gardens, such as paved land and balconies. The bag can hold water longer without water and nutrients draining into the soil. Plant leaves are not in contact with the soil, resulting in less effort to clean the leaves before consumption or marketing. It can be produced organically. It is a climate-smart, land and water-efficient production system, ideal for growing nutritious leafy vegetable crops such as lettuce, Swiss chard, kale, and Chinese cabbage. The growing bag can be made of locally available maize meal sacks. In this relatively low input cost hydroponic production system, plants are grown in bags filled with a soilless substrate such as sawdust and cocopeat, positioned vertically on the ground, thus resulting in efficient use of space/land and limited water supply. This system is suitable for urban farming on paved land and balconies and for small home gardens.

When fully planted with Swiss chard/spinach, a small bag system can feed a family of four with a bunch of spinach every week. In this document, the word " leafy vegetables " refers to “spinach” or “Swiss Chard’’ (Figure 4.1). Swiss chard resembles spinach but produces much broader leaves with thick stems and higher beta-carotene levels (provitamin A). As a result of this, Swiss chard (*Beta vulgaris var. cicla)*, also known as Chard, Silverbeet, and Perpetual Spinach, has become widely cultivated. It belongs to the beetroot family and is grown for its nutritious, luscious leaves.

Both leaf and stem (petiole) are edible and can be cooked separately. Besides vitamins, it also contains considerable amounts of readily available minerals, of which iron is the most important. The uptake of iron by humans is enhanced by adding tomato (vitamin C) during cooking. The crop is relatively easy to cultivate and can be harvested regularly. Average yields range between 8-10t/ha with a maximum of 15t/ha.

Figure 4-7: Swiss chard (A) and Spinach (B).

Leafy greens such as spinach, Swiss chard, kale, lettuce, rape, beetroot, and spring onion perform well in this type of system. The first harvest is expected after 6 to 8 weeks from transplanting. Harvesting of leafy crops is done by manually picking only the matured leaves, leaving about 2-3 young/small developing leaves for re-growth. For instance, spinach can be used for:

- Cooking with other vegetables such as potatoes, onions, and tomatoes
- Cooking with mincemeat (green meat)
- It can be used in stir-fry recipes
- It can be sun-dried and be stored for later use.

Swiss chard – far more common in this country than “true” spinach – is easy to grow and packed with nutrients. When we refer to “spinach” in this article, we mean Swiss chard, which looks very similar to “true” spinach but has much broader leaves, thick stems, and contains more vitamin A. True spinach is richer in calcium (Ca) than Swiss chard. Still, it is in an oxalate form and is not healthy for children. Thus, due to spinach’s low yield, Swiss chard has become widely cultivated in South Africa. It belongs to the beetroot family and is grown annually for its nutritious, luscious leaves. Both leaf and stem (petiole) are edible and can be cooked separately. In addition to vitamins, Swiss chard also contains considerable quantities of readily available minerals, of which iron is the most important. The crop is relatively easy to cultivate and can be harvested regularly. Average yields range from eight to 10t/ha to a maximum of 15t/ha.

The following steps are used in the preparation of a bag system: (1) moisten the growing media (preferably sawdust) with water; (2) fill the empty bag with growing medium and compact lightly; (3) use a measuring tape and marker to position planting holes. Use a sharp blade to cut openings in the bag for planting holes (usually 5 cm in diameter); (4) prior to planting, support the bag upright to allow uniform water distribution when watering; (5) moisten the growing medium within the bag just before planting to prevent water stress or transplanting shock to the seedlings; (6) transplant the seedlings. Push the seedling root plug into the hole in the maize-meal bag; (9) water the plants every second day, twice per day, 10L of water per bag each time.

Inputs required to plant vegetables in a bag system:

- Empty maize-meal bag (80, 50, 25, or 12.5 kg bag)
- Water-soluble fertiliser (multifeed & calcium nitrate)
- Growing medium (compost, sawdust, or soil with very good drainage)
- Watering-can
- Seedlings

Steps to follow when preparing the bag system:

- Moisten the growing medium (like sawdust, compost, topsoil mixed kraal or chicken manure) with water to allow good distribution of water during irrigation
- Fill the maize-meal bag with the moistened growing medium
- 80 kg maize meal bag can plant on average, up to 56 plants
- Use a sharp blade to cut openings in the bag at a distance of 20 cm x 10 cm for planting holes. Leafy vegetables such as kale, rape, mustard spinach, Swiss chard, spinach, beetroot and lettuce can be planted successfully in the bag system
- Push the seedling root plug into the planting hole in the maize-meal bag
- Make sure that the bag is upright to allow uniform distribution of water
- Make sure that the growing medium doesn't dry out, and water the plants from the top of the bag so that the water will drain downwards to benefit the lower plants
- A complete nutrient solution can be applied weekly to supply plants with nutrients. Fertilizer formulation:
    - Dissolve 1 g/litre of water of each of the following fertilisers: Multifeed and Calcium Nitrate.
    - Organic fertilizers like kraal or chicken manure can also be used in the system.
- Plants can be watered every second day (e.g., an 80 kg planted bag requires about 60-90 litres of water per week).
- Plants should be exposed to sunlight for photosynthesis to take place; therefore, it will be advantageous if the bag is rotated weekly.

4.2 Day-to-day maintenance

Fertilization of plants (crops) replenishes the growing medium with nutrients that have been removed during plant growth and optimally maintains the plant's physiological health. They are applied to the growing medium, directly on the plant (foliage), or to aqueous solutions. These fertilizers contain different N- Nitrogen, P – Phosphorus, and K – Potassium elements. These are the essential elements which plants need to grow well. A complete nutrient solution can be applied to the bag three times per week to supply plants with nutrients. The table below shows all the essential mineral nutrients needed for healthy plant growth (Table 4.1). Plants need a balanced and adequate supply of all essential major, minor, and micro-nutrients to optimize performance. Many pests and diseases are caused by low-quality fertilizers that might be cheap but do not satisfy the plant's full requirements or leach out very easily with watering or rain. The nutrients are only available for plant uptake while they pass the root zone. So frequent re-applications of fertilizers are necessary to feed the plant, or nutritional stress develops. Low nutrient levels or too high and fast supply of Nitrogen can also bait in pests and cause disease.

Table 4-1: Essential elements for plant growth.

Essential Elements for Plant Growth	
Macronutrients	**Micronutrients**
Carbon (C)	Iron (Fe)
Hydrogen (H)	Manganese (Mn)
Oxygen (O)	Boron (B)
Nitrogen (N)	Molybdenum (Mo)
Phosphorus (P)	Copper (Cu)
Potassium (K)	Zinc (Zn)
Calcium (Ca)	Chlorine (Cl)
Magnesium (Mg)	Nickel (Ni)
Sulphur (S)	Cobalt (Co)
	Sodium (S)
	Silicon (Si)

Chemical fertilizer mixtures are very convenient to use because they contain all three essential nutrients (N, P, K). The only way to make an accurate fertilizer recommendation is to analyse your soil or substrate. In this way, you can only add what is needed and will save money. If no soil analysis is available, a fertilizer mixture can be used. The fertilizer mixture, such as 2:3:2, is probably the best choice when this will be the only fertilizer you will apply to the garden.

Plants deficient in nutrients have soft growth, like drooping leaves and stems. Leaves that yellow show mottled spots, interveinal patterns, or scorched tips with reduced or no blooms and fruit. Cultivated soils in home gardens are often depleted from K, and P. Roles of N, P, and K mineral elements and their deficiencies are included below (Figures 4.1 to 4.3):

- Nitrogen (N) increases leaf and stem growth, plant cells, and chlorophyll.

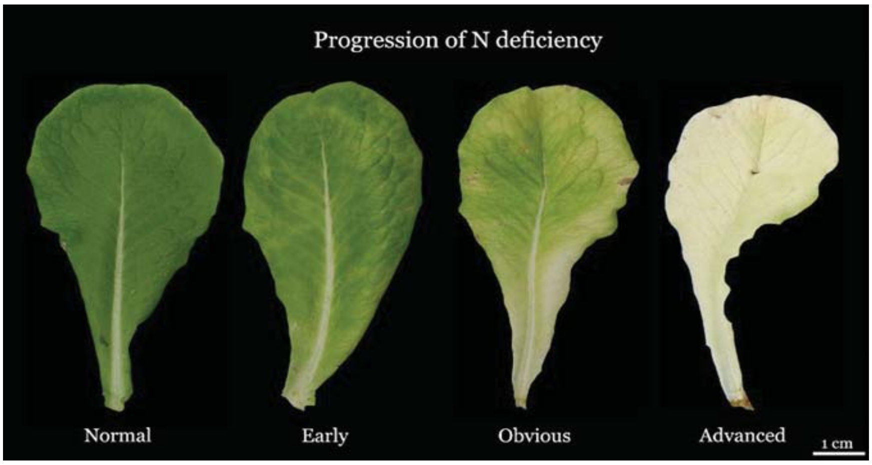


Figure 4-8: Progression of N deficiency (Wilhelm Haug GmbH & Co. KG, 2023).

- Phosphorus (P) is important for the development of flowers and the ripening of fruits and seeds

Figure 4-9: Phosphorus (P) deficiency symptoms in kale (Trifecta Natural Solutions, 2023).

- **Potassium (K) is important for disease resistance and strong growth of leaves and fruit.**

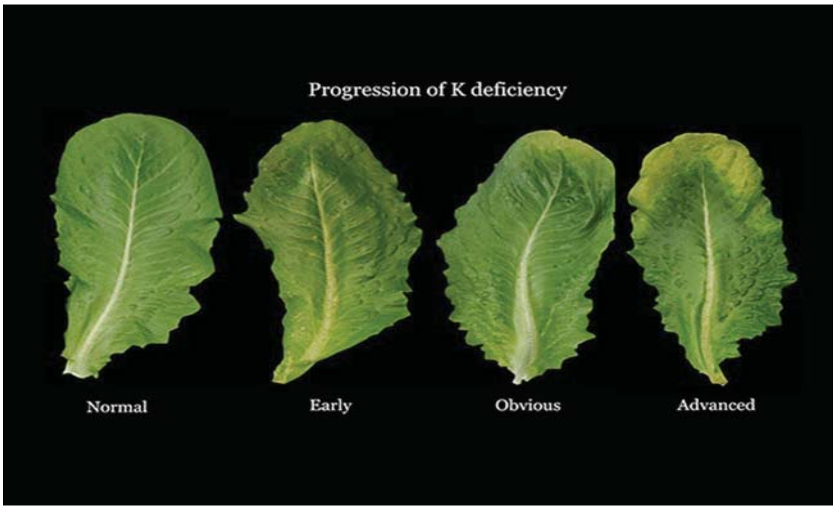


Figure 4-10: Progression of K deficiency (Wilhelm Haug GmbH & Co. KG, 2023).

Fertigation

Dissolve a multi-compound soluble fertilizer such as Multifeed or Hygroponics with Calcium Nitrate in water using 1 g per litre during the watering cycles.

- On a hot, sunny day, add one Coca-Cola lid full of Multifeed soluble fertilizer to an empty 10 L watering can and fill it with water from a borehole, river, dam, or tap. Water each bag with the nutrient solution mixed in the watering can twice a day—half of the watering can in the morning around 11:00 a.m. and the other half in the afternoon around 3:00 p.m.
- On a cold, cloudy day, water each bag only once at midday with a half-watering can.

Light incidence and distribution

- Position the bags on a flat surface supported by bricks, at about 0.6 to 0.8 m apart from each other to avoid shading effects
- Rotate each bag once per week to improve light distribution

Growing media reuse

- Cocopeat growing media can be reused at least three consecutive times, while sawdust at least twice. Sun-dry the media during the off-season when the bag is not being used for production. This can be done by spreading the material on a plastic sheet laid on the ground surface during unexpected rainfall. Once the media is fully dry, collect it in maize meal bags and keep it in a dry, well-ventilated storage room.

4.3. Common pests

- **Cutworms**: Cutworms usually hide under the ground during the day and come out at night to feed on small seedlings by cutting them off at ground level (Figure 4.5). **Control:** Scout regularly. Use cutworm bait.

Figure 4-11: Cutworm damage on leaves.

- **Red Spider Mite:** An early sign of an infestation is stippled areas on leaves (Figure 4.6). Leaves become chlorotic, and webs are produced on leaves and stems in severe cases. **Control:** Regular scouting for spider mites is essential. Use registered miticides to control mites.

Figure 4-12: Red spider mite damage on leaves.

- **Hawaiian beet webworm:** The light greenish larvae of a small brown and white moth feed on the undersides of leaves (Figure 4.7). They spin loose webbing on the underside of leaves under which they hide and where excreta accumulate.

Figure 4-13: Hawaiian beet webworm damage on leaves.

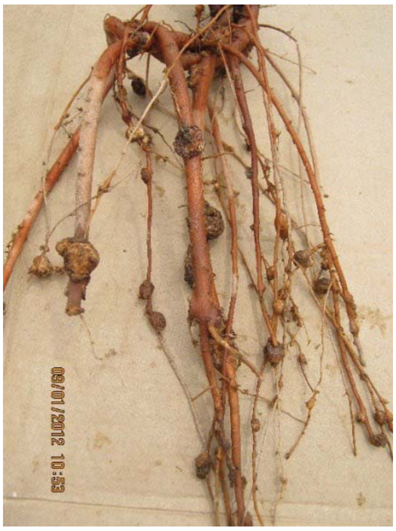
- **Lesser armyworm:** Also known as the beet armyworm (Figure 4.8). They are usually green but maybe brown or blackish, with lengths of approximately 25 mm. The larvae hide during the day lower down on the plant between stems or between clods on the ground and emerge at night to feed on the foliage.

Figure 4-14: Lesser armyworm damage on leaves.

- **Potato lady beetle:** Yellow and black lady beetles resemble the good predatory lady beetles but have fewer shining wing covers (Figure 4.9). The spiny yellow larvae and adults eat narrow bands on leaves, giving it a characteristic appearance. When present in large numbers, they may completely defoliate plants.

Figure 4-15: Potato lady beetle damage on leaves.

- **Nematodes:** Infestation by nematodes causes swellings on the roots (Figure 4.10).



<u>Control:</u> Crop rotation, intercropping with marigold, mustard, or rapeseed, fallowing, soil solarization (cover tilled, slightly moist soil with plastic for 6-8 weeks in sunny areas) and Spray with registered pesticides.

Figure 4-16: Nematode damage on roots.

4.4. Common diseases: understanding the signs and symptoms of stressed plants

The most likely causes of pests and diseases on plants are the following:

- Incorrect watering – too much or too little, not adjusting for season and climate.
- Poor feeding practice – applying excess, too little, or not using the correct fertilizer balance for the plant's requirements.
- Soil structure and Aeration – sandy soil leaches water and fertilizer too quickly, and heavy clay soils cause poor drainage and waterlogging.
- The pH of the soil – too low causes acidic soils, and too high causes alkaline conditions. Both extremes can inhibit the uptake of nutrients.
- Climatic conditions and incorrect seasons – plants are part of the natural ecosystem and depend on correct conditions for healthy growth and production.

Common diseases include:

- **Cercospora leaf spot:** It is caused by a fungus that attacks the leaves and causes small, round, black spots with a dark brown border (Figure 4.11). As the spots age, the tissue in the centre falls out, leaving holes in the leaf. The disease can be severe during wet weather**. <u>Control:</u>** Practice crop rotation and treat the seed with a registered chemical.

Figure 4-17: Cercospora leaf spot damage on leaves.

- **Pythium Root Rot:** Germination is lacking; the young seedlings grow poorly, turn yellow, wilt, topple over and die. The roots are rotten and turn black (Figure 4.12). The disease can be severe on compacted soils. **Control:** Avoid over-irrigation. Plant in well-drained soils. Treat the seed with thiram. Practice crop rotation. Make sure that the crop does not lack sufficient boron. Plant at the right time and not too deep.

Figure 4-18: Pythium Root Rot damage on seedlings.

General disease control measures:

- Practice crop rotation with non-host crops.
- Remove infected plants from the field and burn or bury them.
- Remove all plant residues from the field after harvesting
- Fertilize plants well.
  - Excess or imbalanced fertilizers with high Nitrogen levels result in fast and soft growth of leaves and stems that attract sucking pests such as Aphids and Whitefly. Excess phosphate can block the uptake of micro-nutrients essential for plant functions or disturb the soil chemistry, resulting in slow growth.

    - Select fertilizers which contain the full spectrum of plant nutrients best suited for growth phases like planting with VITA Grow 2:3:2(16) for firm root and plant or VITA Green 5:1:5(16) for leaf growth or VITA Fruit & Flower 3:1:5(18) to promote flowering and fruiting. Compost or manure alone is seldom nutritious enough to ensure healthy and productive plants.
- Avoid over-watering.
    - Symptoms of over-watering conditions include fungal diseases like downy mildew, black spots, rust, root rots, damping-off disease, powdery mildew, insect attacks like mealybug, Australian bug, scale, and red spider mite. Wilting leaves and stems, eventual death. Plants are made mostly of water and depend on regular and enough water for hydration processes, carrying nutrients to all parts of the plant, and transpiration to regulate plant temperature.
- Water plants early in the day so that leaves can dry before nightfall.
    - Water more often and extend periods to ensure water reservoirs to prevent plant stress. Add compost. Reduce watering in rainy periods or cooler months when less water is lost through transpiration through leaves. Ensure adequate drainage in beds and growing bags. Add compost or grow green manure and water-holding products to absorb and hold excess water.

4.5 Biological control basics

The wide variety of available natural products is enough to confuse any farmer. The increased demand for biological control products can mainly be ascribed to problems developed from chemical pesticides. These problems include pest resurgence, resistance, environmental pollution, and risks to human health. The biological control of plant pests and pathogens continues to inspire research, and there have been developments in many fields. Biological control reduces plant pathogens and limits pests such as insects, parasitic nematodes, and weeds. In the narrowest sense, biocontrol involves suppressing pest organisms by other organisms. However, the interrelationships of many environmental variables can result in multiple interactions among organisms and their environment, several of which might contribute to effective biological control.

The rate at which biological control products or inoculants are introduced into South Africa has increased rapidly since the early 1990s. Products may be single ingredients or blends of several materials. The scientific and farming communities recognize that some ingredients improve crop yields and/or quality. The value of others is often unknown and should first be evaluated for their ability to deliver upon the manufacturer's claims. More often than not, farmers find themselves in a situation where they need to make decisions about purchasing such products. The following guidelines can help farmers make informed decisions:

- Be aware of the specific disease problems you experience on your farm. Biological products can be particularly useful in disease control.
- Find out if the proposed product has been registered in terms of Act 36 of 1947.
- Look for a label on the packaging containing specific product information, such as shelf life, application rate, active organisms, and compatibility with other biological control products.
- Find out at what pH and temperature range the biological agent is active. This information is beneficial for the effective storing and application of these products.
- Find out if the biological control product is compatible with the chemicals you apply during a growing season.
- Biological products contain living organisms that can be deactivated or killed by agrochemicals.
- Can the company sell the product and provide you with a professional consulting service to set up an Integrated Pest Management control programme before selling the biological control products?
- This should include thoroughly investigating your farm's disease problem situation and the current crop management practices.
- Does the company provide detailed instructions on handling and applying biological control products?
- Is there any measure of the quality and purity of the biological control product you received? For example:
- Does the company tell you exactly which organisms are in the product and who determines the species?
- This should have been done by a recognized taxonomic expert, not necessarily someone at the company.
- The company offers reasonable solutions for any difficulties you may encounter, and does it follow up to determine your programme's success or failure of your programme?
- Instead of jumping right into using the product on your farm, test it to see whether it yields results in your production environment.

4.5.1 Staggered planting

A continuous supply of vegetables can be achieved by staggering planting: making smaller but regular plantings at regular intervals (for example, every four weeks) during the planting season to ensure a continuous crop supply. Maturity can be predicted partly by using days from planting to harvest for each crop. Continuity can also be achieved from single plantings of crops that don't require a particular stage of maturity to be ready for harvesting, such as sweet potatoes, which can be harvested when the size is adequate for marketing.

4.5.2 Companion planting

Companion planting also has value in protecting plants from pests. It's based on the theory that companion plants – for example, flowers growing next to a food crop – disrupt pests' search pattern looking for host plants. They detect the host plants but become confused by the more diverse planting style. Separating rows of cabbages, broccoli, or other brassicas with rows of onions is a popular combination and possibly works because the onion's strong smell disrupts cabbage pests. Tomato plants grow well next to cabbages, which seem to deter caterpillars. Growing leeks near carrots seem to repel carrot flies. Planting marigolds or calendula between vegetables may reduce unwanted nematodes in the soil. Nematodes occur naturally in the soil, but monoculture can result in a build-up of species that could be harmful to specific crops. These nematodes might feed on the root system of host plants and can cause considerable damage. Various herbal plants planted amongst the vegetables or around the vegetable patch may have beneficial effects. Basil planted with tomatoes and lettuce may deter insects. Oregano planted with broccoli may repel cabbage flies.

4.6 Home remedies for pest control on different vegetable crops

Farmers can prepare pest control remedies as included below:

MANAGEMENT OF INSECT PESTS

- Crop rotation is an important strategy to help combat pests
- Keep the field clean from weeds
- Practice weed control effectively as many weeds can host pests (e.g. aphids).
- Keep fields free from weedy amaranth.
- There is a possibility of biological control by wasps and flies that attack caterpillars on amaranth

Garlic Spray Insecticide

For aphids, whiteflies, and spider mites

- 1 whole garlic bulb
- 2 cups of water
- 4,5 liter of water

Combine in blender the entire garlic bulb and two cups water, and blend on high speed until garlic is finely pureed. Put in storage container and set aside for a day. Strain out pulp, and then mix liquid with 4,5 liter water in sprayer. Spray tops and bottoms of leaves thoroughly. Apply about once a week, and after a rain.

Garlic and pepper spray

Gets rid of Diamond back moths, caterpillars, hornworms, aphids, flea beetles, and other insects

- 6 cloves of garlic
- 1 table spoon dried hot pepper
- 1 minced onion
- 1 tsp liquid soap
- 4,5 liter of hot water

Blend all ingredients and let sit for one to two days. Strain and use as spray.

Ground cayenne or red hot pepper can also be sprinkled on the leaves of plants (apply when leaves are slightly damp) to repel chewing insects or added to the planting hole with bone meal or fertilizer to keep squirrels, chipmunks, dogs and other mammals away from your gardens. Be sure to reapply after rain.

Milk spray

Treats powdery mildew and other fungus

- 1 cup of milk
- 1 cup of water

Mix milk and water in a sprayer and treat infected plants. Three separate treatments a week apart should control the disease.

Baking soda spray

Treats powdery mildew and other fungus

- 4,5 liter of water
- 3 tablespoons of baking soda
- 1 teaspoon of dishwashing liquid soap

Mix all the ingredients in a sprayer and apply to leaves of affected. It is best to remove leaves that are seriously infested if possible. Treat every one or two weeks.

Natural insect repellant

Ground cayenne or red hot pepper can also be sprinkled on the leaves of plants (apply when leaves are slightly damp) to repel chewing insects or added to the planting hole with bone meal or fertilizer to keep squirrels, chipmunks, dogs and other mammals away from your gardens. Be sure to reapply after rain.

Sticky Traps

For whiteflies

- 1-2 Tablespoons Vaseline
- 10 x 20 cm plastic cards or cardboard
- Waterproof yellow paint

Apply paint onto both sides of the card and let it dry. Once the paint is dry, apply non-petroleum jelly/vaseline liberally over both sides of the card. Place the card just above the plant canopy.

Ant Traps

For unwanted ants in the vegetable garden

- 1/4 cup of sugar
- 1/4 cup of borax

Mix the sugar and borax, then sprinkle around any hills and travel paths. The ant will think it is all sugar and take the borax back to the nest. The borax is poisonous to ants.

CHAPTER 5

BAG SYSTEM VEGETABLE PRODUCTION IN THE GIYANI COMMUNITIES

5.1 Introduction

Insufficient intake of vegetables and fruits leads to the death of 2.7 million individuals globally annually and ranks among the top 10 risk factors for mortality (Ruel et al., 2005). According to the International Food Policy Research Institute (IFPRI), there is a projected 18% rise in the prevalence of undernourished children in Sub-Saharan Africa from 2001 to 2020 (IFPRI, 2001). Vitamin A and micronutrient inadequacy, as stated by the World Health Organization (WHO, 2020), continue to be a prevalent issue that contributes to cardiovascular disease, cancer, chronic respiratory illnesses, and diabetes. These conditions collectively account for 60% of global mortality. Vitamin A deficiency is a significant health issue in the rural South African Development Community, with a particular impact on women and children. In South Africa, the prevalence of vitamin A deficiency among preschool children is 63.8%. Additionally, one-third of children under the age of six are deficient in vitamin A, while half of children aged 1-9 have less than 50% of the recommended intake of energy, vitamins A and C, iron (Fe), and zinc (Zn) (Mchiza et al., 2020; Bain et al., 2013; Smuts et al., 2005).

A considerable proportion of the population residing in urban and peri-urban areas experiences poverty and lacks food security, as they do not have reliable access to an adequate amount of high-quality, inexpensive, nutritious food, including leafy green vegetables. Most individuals depend on monetary earnings to purchase meals. The rise in unemployment in Southern Africa resulted in many communities and households struggling to fulfil their fundamental requirements. Additionally, individuals have been migrating from the middle-income levels to the lower-income brackets. In addition, the South African case demonstrates that conventional household gardens are frequently unsustainable due to inadequate upkeep and weed management. South Africa experiences water scarcity due to inadequate precipitation, resulting in a lack of water resources. The cost of municipal water for food gardens might be too high. Most community settlement houses in the country lack the necessary knowledge, adequate space, sufficient water, and suitable soil for profitable vegetable cultivation. Home gardeners face the challenge of controlling pests and illnesses, compounded by the difficulty and expense of acquiring chemicals. It has become vital to explore alternative methods to improve agricultural productivity in rural, communal, and homestead areas by optimizing land and water resources. This is crucial in addressing the issue of food insecurity in these regions.

Community food garden initiatives have been established in many regions of South Africa (Mongwa, 2005; Tundzi, 2008; Laurie et al., 2013). The vegetable gardens in the majority of these projects were created using open-field production systems, which require additional crop management techniques such as weed control, soil fertility management, and mitigation of yield and quality losses caused by soil-borne diseases and certain soil-dwelling insects like rootworms. Nevertheless, it was crucial to have an innovation that enhanced community health and promoted knowledge regarding food production practices that saved natural resources and the environment. The ARC-VIMP carried out a project (K5/2784/4) in the Gauteng Province, focusing on technology transfer and mobilization of local organizations. This project, supported by the WRC, followed a food-based approach. The project implemented a novel vegetable-producing technology known as the bag system. The bag system is a straightforward hydroponic system in which vegetables are cultivated in polypropylene bags filled with sawdust. These bags are positioned vertically on the ground surface, allowing for the vertical growth of leafy green vegetables. This system can be implemented in an open field or under a 30% white shade net. The project evaluation revealed that schools and households participating in the programme exhibited enhanced nutritional knowledge and consumed more vegetables high in β-carotene than households that did not participate.

Vegetables are specific herbaceous plants' fresh, edible parts, including roots, stems, leaves, flowers, fruit, or seeds. These plant components are consumed in their raw form or prepared through several methods, typically as a flavourful rather than saccharine dish. Throughout history, "vegetable" has been employed to encompass various consumable botanical components, such as flowers, fruits, stalks, leaves, roots, and seeds. In the realm of culinary and cultural traditions, an alternative definition that is somewhat arbitrary is employed. According to Harris and Bianchini (2003) and Melissa Petruzzello (2018), the assortment of ingredients encompasses savoury fruits and vegetables like tomatoes and courgettes, flowers such as broccoli, and seeds such as pulses.

Vegetables are cultivated worldwide, and their adaptability varies based on the global climate. Due to global agricultural trade, it is now feasible to purchase vegetables cultivated across vast distances, from small-scale farmers meeting their family's food requirements to large-scale agribusinesses cultivating single-product crops. The subsequent stages following crop harvesting encompass grading, storage, processing, and marketing. Raw veggies hold significant nutritional value for individuals due to their elevated levels of vitamins, minerals, and dietary fibre, along with their relatively low content of fat and carbohydrates. Numerous nutrition experts recommend consuming at least five servings of fruits and vegetables daily. Nevertheless, many agricultural commodities exhibit susceptibility to the ramifications of climate change, including but not limited to drought, heatwaves, hail, pests, and diseases. The implementation of climate-smart technology has the potential to mitigate these impacts during the cultivation process.

South Africa is highly susceptible to severe water scarcity due to ineffective water management systems (Mjoli, 2010). Water disputes between residential, agricultural, and industrial needs are highly likely to occur (Mjoli, 2010). Due to the scarcity of freshwater, increasing input expenses, and population growth, there is a need to enhance water use efficiency (WUE) in agriculture. Rural populations in South Africa have persistent effects from heightened regulations about water consumption and severe droughts. South Africa is classified as one of the top 30 driest countries globally, characterized by its arid climate. South Africans have a daily water consumption of 237 litres, above the global average of 173 litres.

Food and nutrition security is a significant concern in South Africa. In addition, severe meteorological phenomena such as El Nino and El Nina, along with increasing temperatures, low soil fertility, and unpredictable rainfall, will worsen the issue of food and nutrition security, impacting households with limited resources. The quality of fresh water in South Africa is declining due to heightened pollution and the destruction of river catchments resulting from urbanization, deforestation, river damming, wetlands destruction, industry, mining, agriculture, energy consumption, and accidental water contamination. The human population's growth is leading to a rise in pollution and degradation of catchment areas.

The application of a universal formula to all situations is not feasible. The transition to climate-smart vegetable production systems will involve implementing various strategies, including mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing, and improved water management. Additionally, innovative practices such as enhanced weather forecasting, the cultivation of more resilient food crops, and the adoption of risk insurance will also contribute to this transition. These systems must be adaptable to local, regional, and global circumstances, and their implementation may differ significantly among farmers.

The issue of adequate soil quality and land availability for domestic vegetable cultivation is progressively emerging as a significant area of apprehension. Nevertheless, proposing an alternate approach to cultivating vegetables and enhancing the productivity per unit area for domestic consumption is noteworthy. Plants cultivated in a bag system exhibit vertical growth, enabling optimal utilization of the available space or area due to vertical expansion. The bag system can be implemented in areas previously deemed inappropriate for food gardens, such as paved land and balconies, resulting in cost savings. The bag has the capacity to retain water for an extended duration, hence mitigating the loss of water and nutrients through erosion into the soil. Due to the absence of direct touch between the plant's leaves and the soil, a reduced amount of work is necessary for leaf cleaning before eating or selling. Organic production is a feasible endeavour. This vegetable cultivation method is an alternative to conventional methods to optimize yield per unit area for domestic production. The vertical growth of plants in a bag system leads to more plants and yield per unit space than plants grown in a conventional system. This technique is ideal for small-scale residential gardens with restricted availability of high-quality soil.

The Swiss chard/spinach in this small bag system, when fully planted, can provide a family of four with a bunch of spinach once a week for a month (Figure 5.1).

Figure 5-1: Bag system just after transplanting.

Research indicates that there has been a certain degree of advancement in tackling food security through enhancing agricultural yield. Nevertheless, it is important to note that these improvements are not directly associated with ensuring nutritional security. There is a lack of connection between enhancing agriculture productivity, selecting crops, and treating deficiencies in nutrition. Consequently, the majority of impoverished rural households continue to experience significant levels of food insecurity and malnutrition. This is partly linked to a persistent deficiency in dietary variety and limited availability of nutrient-rich foods. Unchecked, the escalating hunger might perpetuate a detrimental cycle of poverty within impoverished rural areas. Prior WRC research has established the necessity for a fundamental change in designing and implementing agricultural interventions. This entails establishing stronger connections between the interventions and the water, nutrition, and human health results. Hence, this project aims to bring about innovation to the communities residing in Giyani Mopani District, located in the Limpopo Province. The research findings have demonstrated the favourable efficacy of the bag system in enhancing the productivity and quality of various vegetables, hence providing advantages to the communities. Implementing a bag system for vegetable production will greatly enhance food and nutrition security while minimizing resource requirements and lowering the likelihood of garden crop failures. Additionally, this system offers the opportunity to produce cash by selling vegetables.

5.2 Project inception and establishment of the bag system

A significant portion of the population in South Africa lacks access to sophisticated technologies that can enable them to produce an adequate amount of food, namely green vegetables, to enhance food security. This can be achieved by implementing more advanced bag systems. Rural communities are urged to adopt growing bags as they provide a practical and efficient method for producing abundant harvests of fresh vegetables. These bags offer a convenient alternative for cultivating a variety of crops, suitable for both experienced gardeners and beginners. Exploring the advantages of using grow bags, these versatile and space-saving containers promote the growth of various plants, ranging from root vegetables to leafy greens. Plant roots thrive in growing bags crafted from permeable fabric that facilitates optimal drainage and moisture retention. The use of grow bags in Giyani communities facilitates air circulation, mitigating the negative consequences of excessive moisture and helping to prevent overwatering and root rot. This diminishes the probability of weed proliferation, offering a more pristine gardening encounter. Furthermore, grow bags have the advantageous qualities of being easily transportable and low weight, rendering them ideal for interior environments. Alleviating poverty involves providing education to economically disadvantaged areas to enable them to utilize modern technologies that can help increase food production in response to the challenges posed by climate change, particularly water scarcity.

The Agricultural Research Council – VIMP team travelled to Giyani to meet with the Water Research Commission (WRC) and the enterprise development team (Figure 5.2). The project milestones were discussed during the meeting, and it was agreed on how both teams will work together to achieve them. Further, the number of beneficiaries involved in the project was also discussed. The team then travelled to meet various Giyani community projects (Loloka, Mbedhle, Mzilela, Mayephu, Matsotsosela, Daniel Ravalele and Ndhambi), including co-operatives, households and schools. The team visited six co-operatives and eight households and introduced the project on how it will help improve their livelihood, food and nutrition security, and sustainable and environmentally friendly way of producing vegetables (Figure 5.3 to 5.5).

Figure 5-2: Meeting held at Giyani with the WRC Enterprise Development Manager (Giyani).

Figure 5-3: Visiting Loloka (Duvhadze co-operatives) and Mbhedle (Seda co-operatives) examining where the bag system will be placed.

Figure 5-4: Visted Daniel Ravalele co-operatives and Muyexe co-operatives.

Figure 5-5: Visits made at Mayephu (Mvhuleni co-operatives), Ndhambi (Mangamba co-operatives) and various households of Giyani at the traditional chief.

The bag systems were established at Mayephu (Mvhuleni co-operatives). The project procured a water storage tank (Figure 5.6) and established a tank stand (Figure 5.7). The project appointed five community members (women and youth) (Appendices B). The ARC team shared knowledge, including the steps to prepare the bag system, such as using polypropylene bags or emptying maize meal bags filled with sawdust mixed with compost and placed upright on the ground surface to grow leafy green vegetables. Small holes (3 cm × 3 cm) are uniformly perforated around the bags, allowing the desired planting density into which the transplanted seedlings of different crops are inserted (Figure 5.8) with beetroot and other leafy vegetables. The system will yield leafy vegetables of 12 kg per bag over four harvests, which is equal to a yield of 624 kg over four harvests within 2-3 months from planting. Irrigation is done using a regular watering can at 2-4 L per bag daily. A soluble inorganic fertilizer containing all the necessary macro and micronutrients is added at 5 g per 10 L to feed the plants with each irrigation.

Figure 5-6: A 5000-litre Jojo tank for water storage at Mvhuleni co-operative for bag system vegetable production.

Figure 5-7: Building a Jojo tank stand at Mvhuleni co-operative with the bricks and cement acquired from the local enterprises in Giyani.

Figure 5-8: Appointed community members planting the bag system vegetable production at Mvhuleni co-operative in Giyani.

The bag systems yielded leafy vegetables of 12 kg per bag over four harvests from planting. The first Swiss chard harvest was done in the middle of March 2024; subsequent harvests were done weekly (Figure 5.9). Irrigation was done using a spaghetti tube connected to mainline dripper emitters. A soluble inorganic fertilizer containing all the necessary macro and micronutrients was added at 5 g per 10 L to feed the plants with each irrigation.

Figure 5-9: A 5000-litre Jojo tank for water storage with spaghetti tube irrigation system at Mvhuleni co-operative for bag system vegetable production.

The project continued with establishing the bag system at Muyexe Co-operative Project. Twelve co-operative members were appointed and supported with protective clothing. The activities started with collecting sawdust from the Modderspruit Plantations and Projects (Figure 5.10). This was followed by filling the bags, purchasing vegetable seedlings (Figure 5.11), renovating the nursery (Figure 5.12), installing irrigation, and planting 120 bags that consist of Swiss chard, tomato, onion, and green pepper (Figure 5.13).

Figure 5-10: Vegetable seedlings purchased from Khosouthopa Seedlings Nursery to establish bag system at Muyexe Co-operative Project.

Figure 5-11: Renovated nursery at Muyexe Co-operative Project.

Figure 5-12: Appointed community members planting the bag system vegetable production at Muyexe Co-operative Project.

The team continued to establish the bag system as a co-operative at Mbhedle. The activity started by engaging with the co-operative and introducing the project (Figure 5.13). A site for establishing the project was then identified, followed by delivering sawdust and compost, mixing the growing media, and filling the bags (Figure 5.14). Water storage tanks for the co-operatives and schools (5000 litres) and households (1000 Liters) were procured and delivered at the ARC-VIMP (Figure 5.15).

Figure 5-13: Introducing the bag system to a co-operative at the Mbhedle project.

Figure 5-14: Establishment of the bag system at the Mbhedle project.

Figure 5-15: Water storage tanks procured for the project's beneficiaries.

5.3 Stakeholder engagement

One of the project's milestones is to introduce the project to different local partners about the project. The initiative started by identifying local enterprises around Giyani that can provide the materials needed for the bag system, such as sourcing vegetable seedlings, sawdust, and construction materials. The team identified Khosouthopa seedlings nursery, where vegetable seedlings can be sourced (Figure 5.14). Khosouthopa Seedlings is located at Jamela Village, Duiwelskloof, Limpopo, and provides agricultural services to local farmers around the Giyani area. The team further identified a sawmilling company to source sawdust. Sawdust is the substrate that will be used to grow vegetables.

Figure 5-14: Khosouthopa seedlings nursery at Jamela Village, Duiwelskloof, Limpopo.

The project continued to work with different local partners. The initiative started by identifying local enterprises around Giyani that can provide the materials needed for the bag system, such as sawdust (Figure 5.15) and wooden poles (Figure 5.16) for the shed net construction materials. The team identified a sawmilling company around Giyani to source sawdust. Sawdust is the substrate that was used to grow the vegetables. Moddersspruit Plantations and Projects owned by Mr Daniel Rasebopela, located at Duiwelskloof, Limpopo, and willing to supported the project with sawdust (Figure 5.15). In addition, wooden poles were sourced from local businesses to construct shade net structures at the co-operatives and schools (Figure 5.16).

Figure 5-15: The sawdust collection from the Moddersspruit Plantations and Projects was used as a growing medium for the vegetables in the bag system.

Figure 5-16: Wooden poles were sourced from local businesses to construct shade net structures at the co-operatives and schools.

CHAPTER 6

HOW TO UTILISE THE PRODUCE: HOUSEHOLD SUPPLEMENTATION OF FEEDING PROGRAMME/INCOME GENERATION

6.1 Introduction

An important consideration during bag system vegetable garden management is deciding which days crops must be harvested to supply provisions for household meals and how much of each crop is needed. The daily household menu can be adapted according to the crops' seasonal availability from the bag system vegetable garden.

Another important aspect is ensuring enough funds are available for the garden to be sustainable. Thus, cultivating the different crops in the garden should occur continuously for at least ten months of the year, and enough of each crop should be planted to enable weekly harvesting. The household should cook from a few times a week to daily with the supply from the garden. Thus, the garden's bags and size should be sufficient to supply according to the household members' quantities and the available space for the bags to sit.

Besides, surplus vegetables can be sold, and the vegetables/fruits can be a good source of income to sustain the garden. However, in the case of a school garden, it should be strongly emphasized that the garden is there to support the feeding scheme and not generate income. If there are surplus crops, this can be sold. The pricing should be realistic, cover the expenses incurred, and ensure a reasonable demand. Thus, record-keeping is essential and must be accurate to determine the prices of the products.

6.2 Marketing tips for the excess produce

Some advice is now provided in the case of marketing of the excess produce, including:

- Make sure the crops are sold at market-related prices. Observe what is happening in the commercial or fresh produce markets – this information is open to anyone.
- Harvesting is a good marketing strategy when the customers are with you.
- Make market-related bundles of spinach, beetroot, and carrots. The size of the bundles is significant – generally around 1 kg.
- Make sure to produce crops for which there is a demand.
- A proper planting programme is required to ensure customers have a continuous supply.
- The size of the crops, e.g., cabbage, and the size of bundles, e.g., spinach, will convince the clients to buy from your garden. If they prefer large cabbages, do not plant a cultivar that produces small heads.

- The demand for a crop will determine the prize. For instance, the prize will rise if the produce is unavailable from many gardens. The prize will drop if a type of vegetable is available in all surrounding gardens.
- Everybody is prepared to pay for good quality, so if the crops from your garden are of good quality, customers will pay what you charge.
- Make sure you know what the demand for package size is. Do not pack in large bags if people can only afford small packets.
- Do not try to cater to a faraway market since high transport costs can take up all your profit.
- If a market demands a particular product, try to deliver the product at the right time and place.
- Labelling is important. Labels are a useful marketing tool. Add the name on the label if the garden has a brand name or is registered as a closed corporation or company.
- Advertise professionally - put your advert in colour next to the road, not on the back of a castle lager box by hand.
- Be clear about the price in your advertisement. Do not let people come a long way to buy your produce; the price is so high that no one can afford it.
- Be consequent on your price, not one day high and the next day low. Buyers will lose confidence in the quality of your produce.
- Transport is essential if the market needs a crop at a particular time. Specifying a specific time for delivery is for a reason. Try to arrange transport before the time to ensure timely delivery. Also, settle beforehand on a price for the transport. The price must be realistic. If the price is unrealistic and not determined beforehand, the cost can take up all your profit.

6.3 Preservation: drying vegetables

There are two reasons for drying vegetables: First, drying vegetables is a way to have your favourite vegetable available throughout the year, and second, dried vegetables take little storage space and can be stored without electricity. Dried vegetables can be stored for up to six months. The vegetables can be utilized at any time during storage by soaking them in cold water until they are soft (half an hour to two hours) and then used in soups, stews, or sheba. The dried vegetables will lose some taste and nutrients during drying and should not replace fresh vegetables if available.

Dried vegetables can also be sold to various users. If sold to households, they should be packed in small containers, but bigger containers can be used if sold to schools or hospital kitchens. It is vital to ensure that the containers are free of insects and that the vegetable pieces are not damp or show any form of decay. It is also essential to store the containers away from direct sunlight and not at high temperatures.

Method of drying vegetables

There are seven basic steps to be followed to dry vegetables:

Step 1: Decide which vegetable

It must be a popular vegetable that is expensive or unavailable during certain times of the year.

Step 2: Select vegetables

Use fresh vegetables at the right ripeness stage and not rotten or damaged. It is best to pick a vegetable very early in the morning.

Step 3: Peel and trim

If there are small rotten or damaged pieces, these should be removed using small, sharp, stainless steel knives. It is vital to ensure that vegetables are always handled hygienically and that people are trained to do this.

Step 4: Blanch vegetables

Enough clean tap water is needed to wash the vegetables, and after that, scald/blanch and cool the vegetables. Untreated water from rivers or dams should never be used, as this water can contain bacteria and infectious diseases that can make people sick. A large pot is needed for blanching. During blanching, the vegetables are placed in a muslin cloth in boiling water for about 5 minutes and then removed. Blanching fixes the colour and helps to dry vegetables faster. Not all vegetables need to be blanched.

Step 5: Cool blanched vegetables

Hot vegetables are cooled quickly by holding the muslin bag containing the blanched vegetable under running tap water or dipping it in cool water for about 1 minute.

Step 6: Dry Vegetables

Drying preserves the vegetables. Drying can be done using dryers (cabinets with trays and heated fans that blow hot air over the vegetables), the sun, or the oven. Sun-drying is the cheapest way to dry vegetables because dryers and ovens use lots of electricity. Ovens should only be used in case of emergency, for example, when it starts to rain. Dryers can dry vegetables in a short time, but they are expensive to buy. Sun drying is done by spreading the vegetables in a single layer on dry trays and drying them until they are hard and brittle. It is important to remember that dry trays should be brought inside at night and when it rains to prevent vegetables from getting wet again. Drying vegetables should also be protected from flies and animals.

Drying trays are flat frames with a bottom made of insect netting, shade netting, or bird wire. Before using, the netting should be appropriately cleaned, and rusted wire should not be used. It is also essential to be able to stack the trays when not in use.

Step 7: Store dry vegetables

Dry vegetables can be stored for up to 6 months. Dried vegetables should be stored in a room or under a roof in the shade where they cannot get wet and where rats, mice, and insects cannot damage the vegetables. Containers used should be water and airtight. Plastic cold drinks or water bottles are ideal because they are transparent, making it possible to inspect the vegetables without opening the bottle. Before using, these bottles should be rinsed in clean water and left to dry completely.

For example, when drying spinach

- **Step 1: Choosing**

It is easy to dry spinach. The leaves are not blanched, and they dry quickly in the sun because they are thin. Spinach is available most of the year but is most abundant in summer.

- **Step 2: Picking**

After picking the leaves, the rotten or badly damaged ones are removed and thrown in the scrap bin. Handle spinach leaves carefully, as they become damaged very easily.

- **Step 3: Preparing**

Wash the vegetables properly to remove ALL dust, bird droppings, and dry leaves. Rinse the leaves in clean tap water and place them on a rack so the excess water drips into a bucket or the sink. Washing the leaves more than two times may be necessary to remove all the dirt. Inspect the leaves once more and throw away the bad ones. Trim spinach by cutting away the stem and veins. Cut the leaves into wide strips. The leaves are now ready for drying, as they do not have to be blanched.

- **Step 4: Drying**

The leaves should be spread out on the drying tray in one layer and placed in the sun as soon as possible. Cover the drying spinach with a muslin cloth to keep insects and birds off. Watch the weather. Bring the trays with drying vegetables indoors before it starts to rain. Sun drying of spinach takes 1 -2 days. The spinach leaves are dry when they become brittle and crumble easily.

- **Step 5: Storing**

Dry spinach is stored in air and watertight containers. Crumble dry leaves into smaller pieces to make them easy to handle. Store the containers in a dry, cool place out of the sun. You must keep insects and rats out of the storage room using cloth or plastic bags. Check the containers of dry leaves now and then to see if they are still in good condition. If you used clear plastic or glass bottles with lids that screw on lightly, you would be able to check the condition without opening the container. The screw caps also keep rats and insects away. Plastic bags can be used, but insects and rats can eat holes in plastic bags.

CHAPTER 7

DISSEMINATING BAG SYSTEM VEGETABLE PRODUCTION TO THE GIYANI COMMUNITIES

7.1 Introduction

Inadequate vegetable and fruit consumption kills 2.7 million people worldwide each year and is one of the top 10 risk factors for death (Ruel et al., 2005). The International Food Policy Research Institute (IFPRI) predicts an 18% increase in the number of malnourished children in Sub-Saharan Africa between 2001 and 2020 (IFPRI, 2001). According to the World Health Organization (WHO, 2020), vitamin A and micronutrient deficiency remain a widespread problem and a cause of cardiovascular disease, cancer, chronic respiratory diseases, and diabetes, which account for 60% of all deaths globally. In the rural South African Development Community, vitamin A deficiency is a serious health problem, particularly among women and children. In South Africa, for example, 63.8% of preschool children were vitamin A deficient, one in every three children under the age of six is vitamin A deficient, and one out of every two children (1-9 years old) had less than 50% of the recommended intake of energy, vitamins A and C, iron (Fe), and zinc (Zn) (Mchiza et al., 2020; Bain et al., 2013; Smuts et al., 2005).

A significant portion of the urban and peri-urban population is poor and food insecure, with no consistent access to a sufficient quantity and quality of affordable, nutritious food, such as leafy green vegetables. The vast majority of people rely on cash income to buy food. With the COVID-19 coronavirus pandemic, unemployment is increasing in Southern Africa, with more communities and households unable to meet their basic needs. More people have also moved from the middle to the lower income brackets. Furthermore, the South African experience shows that typical home gardens are not always sustainable (often because of insufficient maintenance and weed control). Due to low or infrequent rainfall, South Africa lacks sufficient water, and municipal water can be prohibitively expensive for food gardens. Most of the country's communal settlement households lack knowledge, space, water, and suitable soil for viable vegetable production. Controlling pests and diseases is another challenge for home gardeners due to the difficulty and cost of obtaining chemicals. Alternative approaches to increasing rural, communal, and homestead agricultural productivity through better land and water resource optimization have become necessary to combat food insecurity in such areas.

Community food garden projects have been implemented in several South African provinces (Mongwa, 2005; Tundzi, 2008; Laurie et al., 2013). The vegetable gardens in most of these projects were established in open-field production systems, which necessitate more crop management practices such as weeding, managing soil fertility, and reducing yield and quality due to soil-borne pathogens and some soil-dwelling insects such as rootworms. However, an innovation that improves community health and raises awareness about food production methods that protect natural resources, and the environment was essential. The Agricultural Research Council-Vegetable, Industrial, and Medicinal Plants (ARC-VIMP) implemented a food-based approach project (K5/2784/4) in the Gauteng Province, with a focus on technology transfer and mobilization of local organizations, with the support of the Water Research Commission (WRC). The project introduced an alternative vegetable production system called the bag system. The bag system is a simple vertical hydroponic system where vegetables are grown in polypropylene bags filled with sawdust and placed upright on the ground surface to grow leafy green vegetables vertically in an open field or under a 30% white shade net. The project evaluation also found that participating schools and households had better nutritional knowledge and consumed more β-carotene-rich vegetables than non-participating households.

Studies show that there has been some progress in addressing food security driven by increased crop productivity; these gains, however, are not linked to nutrition security. There is a disjoint between improving crop productivity, the choice of crops and addressing gaps in nutrition. As a result, most poor rural households still suffer high levels of nutrition insecurity and malnutrition. This is associated with, in part, a chronic lack of dietary diversity and access to nutrient-dense foods. If left unchecked, such increasing malnutrition could reinforce a vicious cycle of poverty among poor rural communities. Previous WRC research confirmed that there was a need for a paradigm shift in how agriculture interventions were designed and implemented, such that the interventions were more closely linked to water, nutrition and human health outcomes. Therefore, this project aims to introduce innovation to communities in Giyani Mopani District, Limpopo Province. The research findings have shown the promising performance of the bag system for improved yield and quality of several vegetables, which will benefit the communities. Producing vegetables using a bag system would significantly improve food and nutrition security while requiring less input, with a reduced risk of crop failure in the gardens and the ability to generate income from vegetable sales.

7.2 Information dissemination

The Agricultural Research Council – VIMP team participated in a Water Research Commission (WRC) launch of climate-smart technologies at Ndambi village in Dzumeri, Great Giyani municipality. South Africa. The launch's objective was to assist farmers in coping with severe climatic change by providing them with alternate sources of energy and water. Rural areas frequently lack access to appropriate water supplies. Giyani is most likely vulnerable to drought and climate change, leading to water scarcity. Many Giyani households lack access to water through standpipes on the street or faucets inside their homes. Those who do have taps reported that they are unreliable and that they frequently must purchase water. Some claim to depend on rainwater harvesting. Ahitireni, Tubatse, and Mangena are just a few examples of small-scale and developing farmers that WRC has helped.

The launch included a knowledge-sharing session on the bag system. The knowledge-sharing included the steps when preparing the bag system, such as using polypropylene bags or emptying maize meal bags filled with sawdust mixed with compost and placed upright on the ground surface to grow leafy green vegetables (Figure 7.1A&B). Small holes (3 cm × 3 cm) are uniformly perforated around the bags, allowing the desired planting density into which the transplanted seedlings of different crops are inserted (Figure 7.1C) with beetroot and other leafy vegetables. The system will yield leafy vegetables of 12 kg per bag over four harvests, which is equal to a yield of 624 kg over four harvests within 2-3 months from planting. Irrigation is done using a regular watering can at 2-4 L per bag daily. A soluble inorganic fertilizer containing all the necessary macro and micronutrients is added at 5 g per 10 L to feed the plants with each irrigation.

Figure 7-1: Preparation of bag system.

The efficient use of space and land is achieved by plants grown in the bag system, which are growing vertically upward and out from the sides of the bag. The bag has a longer retention time for water. The method enables more precise irrigation applications, reducing the amount of water lost through drainage and lessening the amount of essential nutrients leached from the growing medium. Plant leaves are not in contact with the soil in the bag system, resulting in less effort to clean the leaves before eating or marketing, and crops can also be grown organically. The system vegetable production method can also be used anywhere and eliminates the need for weeding.

The goal of the bag system was to encourage the farmers in Giyani that despite a lack of water, they could still plant their vegetables using less water and recycle a maize meal bag. They were very excited when they saw that one could reuse a bag to plant the vegetables. Figure 7.2 A&B shows farmers participating and asking questions during the session. The information on the bag system was shared through the local Giyani community radio (Figure 7.2C) in the Tsonga language.

Figure 7-2: Demonstration of bag system

Farmers were allowed to put what they had learned the previous days into practice at Ahitireni Farm. During the practical, the farmers divided themselves into groups and created their bag system, as shown in Figures 7.3A & B, and it was a success. The last day of the launch was a market day, and farmers were allowed to sell their products (Figures 7.3C, D & E). The farmers were excited about the technologies and showed a willingness to adopt them.

Figure 7.3: Group of farmers with the bag system they prepared and Market day.

7.3 Capacity building and skill transfer

The ARC team continuously shares information on how to establish the bag system, where to get the inputs needed for the project's sustainability and share the contact information of the local partners with the co-operatives. The team always encouraged the community members to participate in mixing the growing medium, filling the bags, planting, installing an irrigation system, applying soluble fertilizer etc (Figure 7.4).

Figure 7.3: Community training in establishing the bag system.

Other information shared with the community members are included below.

7.3.1 Watering Techniques

From the time of planting until harvest, food crops require a consistent supply of water. If you give your plants too little water, they will begin to wilt and, if the situation is not corrected, they will die eventually. Giving plants too much water may cause the roots to drown, resulting in the plants ceasing to grow or die. Proper (correct) watering is something of an art – the best way to learn how often and how much to water your crops is through trial and error in the field.

The frequency with which you water your crops is determined by the types of crops you are growing, the age and size of the plants, the type of soil, and the weather. To keep their root zones moist, young seedlings with small shallow roots located in the top layer of the soil will require frequent watering – sometimes as frequently as twice or three times per day. Crops with deep roots in the soil (such as pigeon pea) may only require watering once a week or once every two weeks.

Watering frequency is determined by the amount of clay, sand, silt, and organic matter present in the soil. Clay is the most common type of soil. Clay soils retain a large amount of water and release it slowly, whereas sandy soils retain a small amount of water and release it quickly.

The weather also has an impact on how frequently the crop needs to be watered. Cool, cloudy weather allows any soil to retain moisture for a longer period than it would in hot, dry weather. In a few places, rainfall during the growing season is sufficient to meet all water requirements.

Water must reach the root zone of the plants in sufficient quantities. The soil type determines the depth to which a given amount of water will penetrate. Water applied to a square metre of land at a rate of 25 litres per square metre will wet sandy soil to a depth of 30 cm, while clay soil will be wet to a depth of 10-15 cm.

7.3.2 Water requirements of vegetable crops

Vegetables require a consistent supply of water from the time they are planted until harvested, and they cannot be grown successfully in rain-fed conditions. The following are only general guidelines that should be tailored to your specific plot or garden based on the season and local conditions:

- Seedlings: The critical time is between sowing and the emergence of the seedling. At all times, the soil in contact with the seed must be moist.
- Transplants: Watering before and after transplanting is essential, particularly in hot weather
- Leafy crops: Leafy crops such as Brassicas (e.g. Swiss chard, Cabbage) generally need about 25 litres per square meter of soil a week and should be actively growing from the time they are sown or transplanted. Any lack in the water supply can affect yield and quality, and during summer, it may be necessary to irrigate twice a week.
- Root crops: (e.g., Potatoes, carrots, sweet potatoes) The average weekly water requirement is between 10 and 15 litres per square meter during the first month after planting. From one month after planting until plants approach maturity, 30 litres per

square meter will be adequate. Regular watering must be maintained in the absence of rain, and it is important to ensure that water penetrates deeply into the soil. Shallow watering discourages good root development. Potatoes need additional water when tubers start forming.

- Other crops: (e.g., green beans and other legumes, cucurbits, and Solanaceae (e.g., tomato). The average weekly water requirement is 25 litres per square meter, but it varies according to the stage of development.

Water-efficient vegetables (e.g., cowpeas, amaranth, pigeon peas and Bambara). These crops are tolerant to drought and can be grown under rainfed conditions if the rain is well distributed.

7.3.3 Water-saving techniques

Watering slowly, deeply, and infrequently is the key to success. Frequent shallow watering encourages plants with shallow root systems to grow.

- Use drip or trickle irrigation. This method wets the soil slowly, allowing for slow, deep penetration. Up to 60% of the irrigation water can be saved using drip vs conventional sprinkler irrigation. A perforated hose placed upside down (with holes facing down) makes a very good temporary drip irrigation system.
- Water at low application rates. If water runs off the soil surface or forms puddles, the water application rate is too high and wasted.
- Irrigate at night or in the early morning when the temperatures are cooler and the humidity is higher. This will reduce evaporation.
- Plant vegetable plants at optimal spacing. Using this method decreases the amount of water needed per unit area and reduces evaporation from the soil surface.
- Use drought-tolerant (water-conserving) plants or varieties. Separate water-conserving plants from water-demanding plants. Group plants with similar water needs together.

Other methods that can be used to supplement water in the garden will be discussed.

7.3.4 Use of rooftop rainwater harvesting and greywater

The system can be linked to rooftop rainwater harvesting. In addition, it can be linked to wastewater recycling systems, usually referring to greywater (wastewater produced in the average household, including the water from bathtubs, showers, sinks, washing machines, and dishwashers). The team has procured a greywater recycling system to demonstrate this activity, and the outcome will be included in the next deliverable.

CHAPTER 8
GENERAL SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The bag system refers to a crop production system and technology that has been specifically developed to optimise yield while simultaneously reducing land and water consumption in areas characterised by restricted resources. The use of the bag system is a highly effective strategy that complements and strengthens food fortification initiatives, effectively addressing the challenges associated with concealed hunger and food insecurity. The project seeks to broaden the scope of this research by demonstrating the effectiveness of this method in underprivileged Giyani villages or farms as part of the Giyani LSCRP. The bag system has been implemented in co-operatives, schools, and households. The project appointed five community members at Mvhuleni and 12 co-operative members at Muyexe co-operative to assist in the planting and maintenance of the site.

Implementing a bag-system vegetable garden in communities has proven to be a sustainable and effective solution to address food security, enhance nutrition, and promote community self-reliance. This system involves growing vegetables in soil-filled bags, which are compact, water-efficient, and suitable for areas with limited space or poor soil quality. The project was successfully carried out by engaging the community in training sessions on gardening techniques, the importance of crop rotation, pest management, and organic composting.

The initiative provided a cost-effective way for households to produce their food, reduce grocery expenses, and generate income by selling surplus produce. Additionally, it fostered community collaboration and encouraged environmentally friendly practices. The project demonstrated that minimal resources, practical training, and community participation can significantly enhance livelihoods, including:

- **Improved food security**: The bag system vegetable garden effectively provided communities with a steady supply of fresh vegetables, improving nutrition and reducing dependence on external food sources.
- **Cost-effectiveness**: The low initial setup costs made the system accessible and sustainable, even for low-income households.
- **Environmental benefits**: The project promoted sustainable agricultural practices by utilizing organic waste for compost and conserving water through efficient irrigation methods.
- **Community empowerment**: Training and collaboration fostered a sense of ownership, self-reliance, and resilience within the community.

- Scalability: The bag gardening system's simplicity makes it replicable in other communities, especially in urban and semi-urban areas with space constraints.

The project recommends that the bag system is a crop production system and technology designed to enhance yield while minimising land and water usage in locations with limited resources. The bag system is a highly efficient approach that supplements and enhances food fortification programmes, effectively tackling the issues of hidden hunger and food insecurity.

- **Expand training and awareness programmes**: Conduct regular workshops to educate communities on advanced gardening techniques, pest management, and crop diversification to ensure long-term success.
- **Provide access to resources**: Establish partnerships with local governments, NGOs, or businesses to supply affordable seeds, soil, and tools to sustain the project.
- **Incorporate monitoring and support**: Implement a system to monitor garden progress and offer expert guidance to address challenges such as pest infestations or crop diseases.
- **Encourage community networking**: Create forums or co-operatives where participants can share experiences, knowledge, and resources and collectively market their produce.
- **Promote policy support**: Advocate for local government policies that support urban agriculture and allocate spaces for community gardening projects.
- **Integrate additional livelihood opportunities**: Explore ways to add value, such as teaching participants to process vegetables into marketable products like sauces, dried herbs, or pickles.

Day-to-day maintenance of the bag system includes:

Fertigation:

- On a hot, sunny day, add one Coca-Cola lid full of Multifeed soluble fertilizer to an empty 10-L watering can and fill it with water from a borehole, river, dam, or tap. Water each bag with the nutrient solution mixed in the watering can twice a day—half of the watering can in the morning around 11:00 a.m. and the other half in the afternoon around 3:00 p.m.
- On a cold, cloudy day, water each bag only once at midday with a half-watering can.

Light incidence and distribution

- Position the bags on a flat surface supported by bricks, about 0.6 to 0.8 m apart, to avoid shading effects.
- Rotate each bag once per week to improve light distribution.

Growing media reuse

- Cocopeat growing media can be reused at least three consecutive times, while sawdust at least twice. Sun-dry the media during the off-season when the bag is not being used for production. This can be done by spreading the material on a plastic sheet laid on the ground surface during unexpected rainfall. Once the media is fully dry, collect it in maize meal bags and keep it in a dry, well-ventilated storage room.

A successfully implemented bag-system vegetable garden project can be transferred to communities in other areas of the country to promote food security, economic resilience, and environmental sustainability. Scaling this model across regions can have a significant positive impact on the country's livelihoods and ecosystems.

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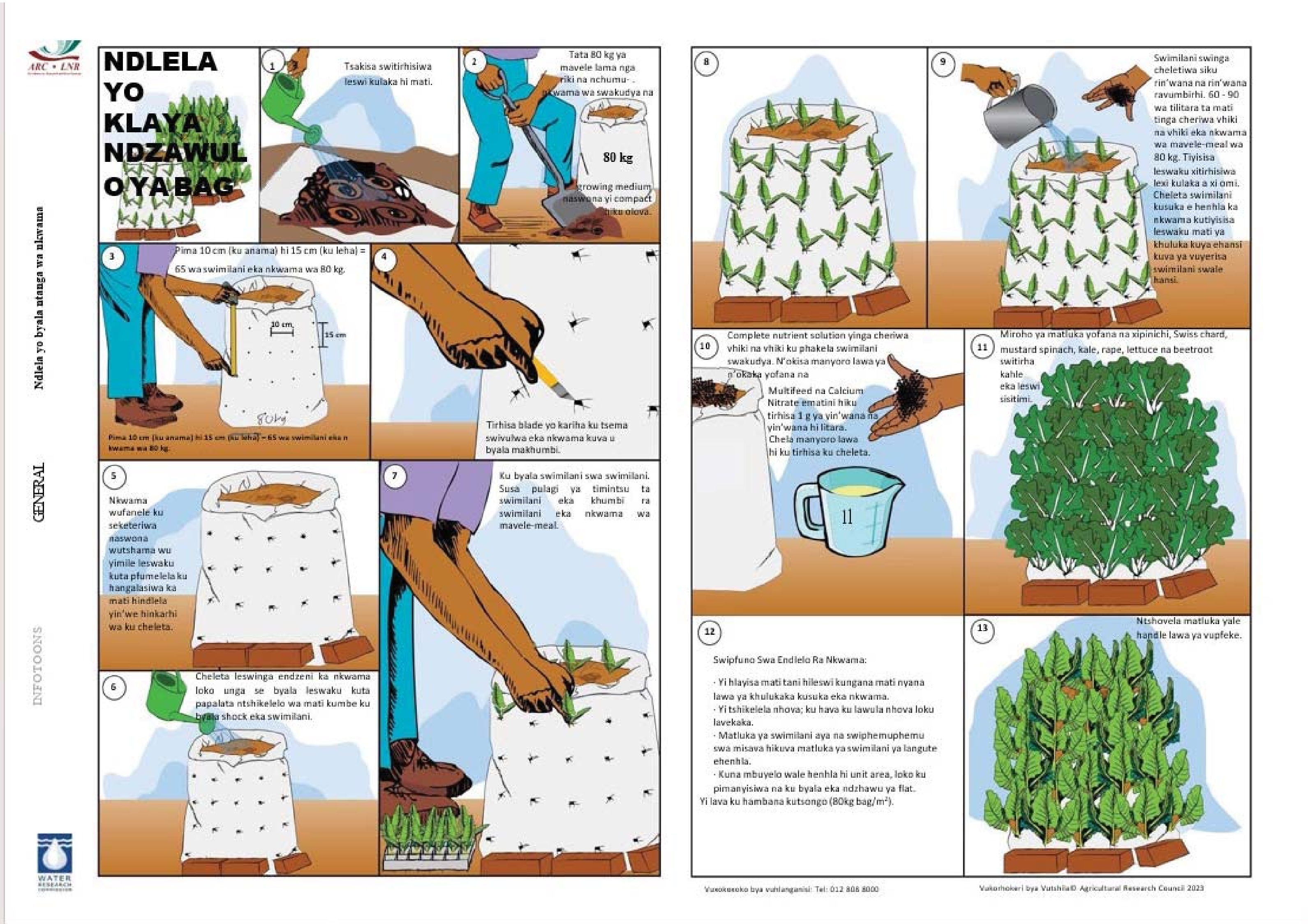
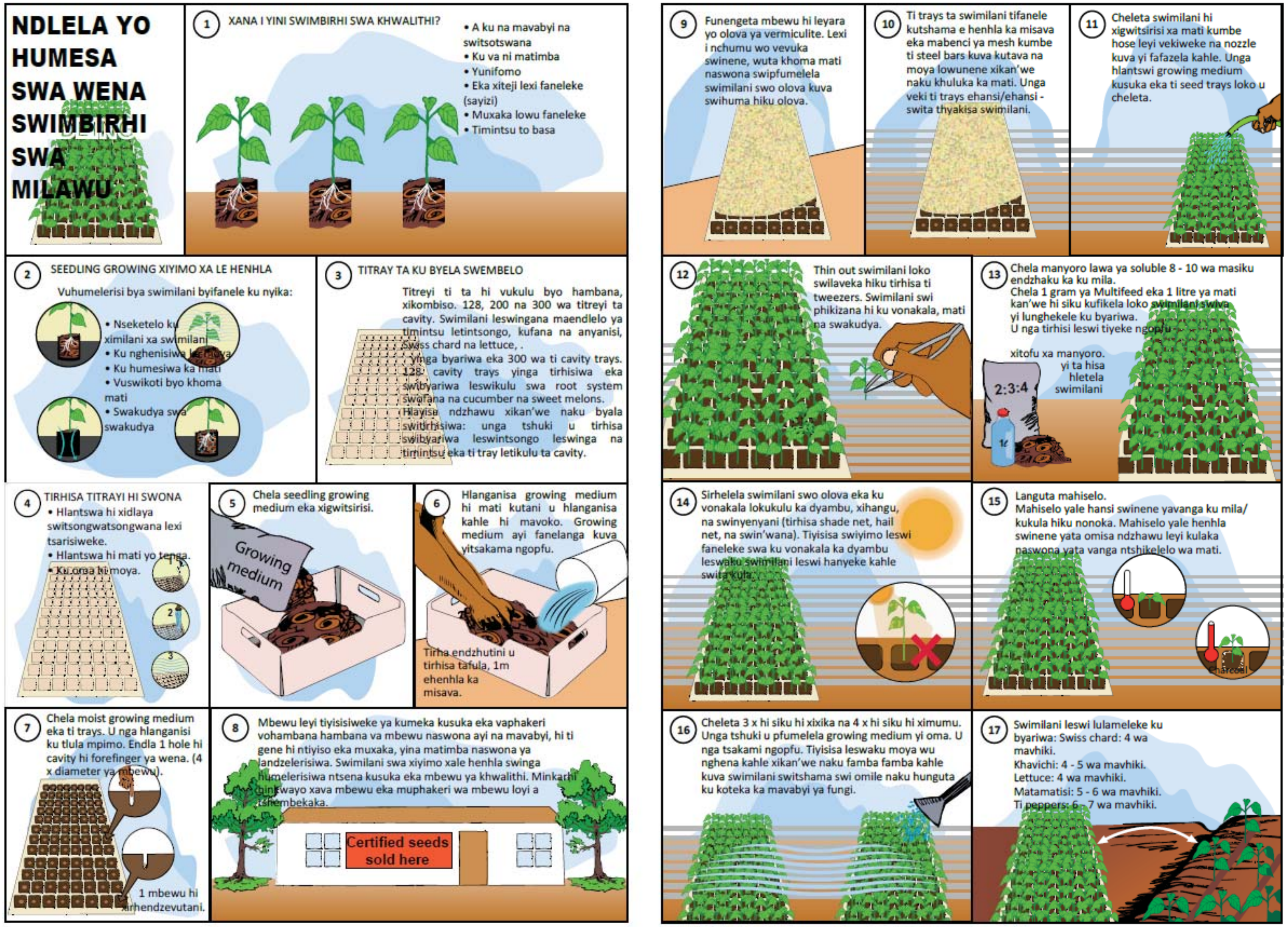
APPENDIX I: REPORT ON RESEARCH DISSEMINATION MATERIALS





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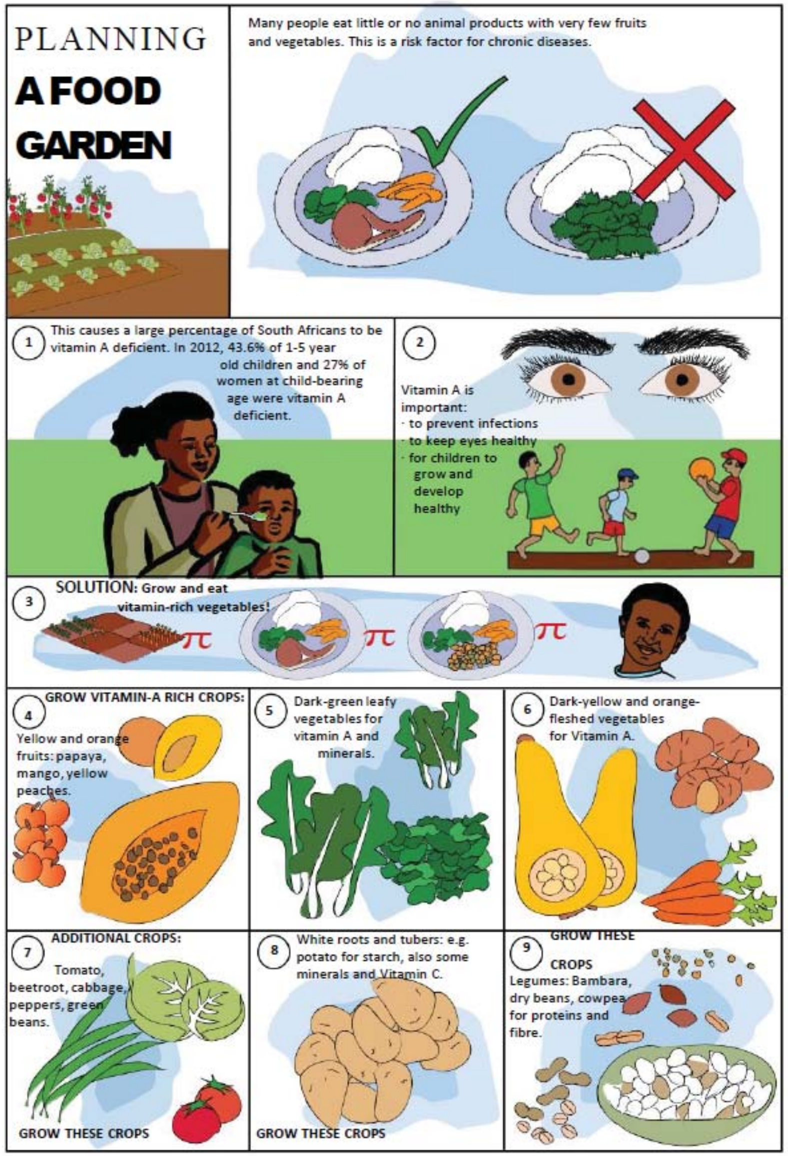
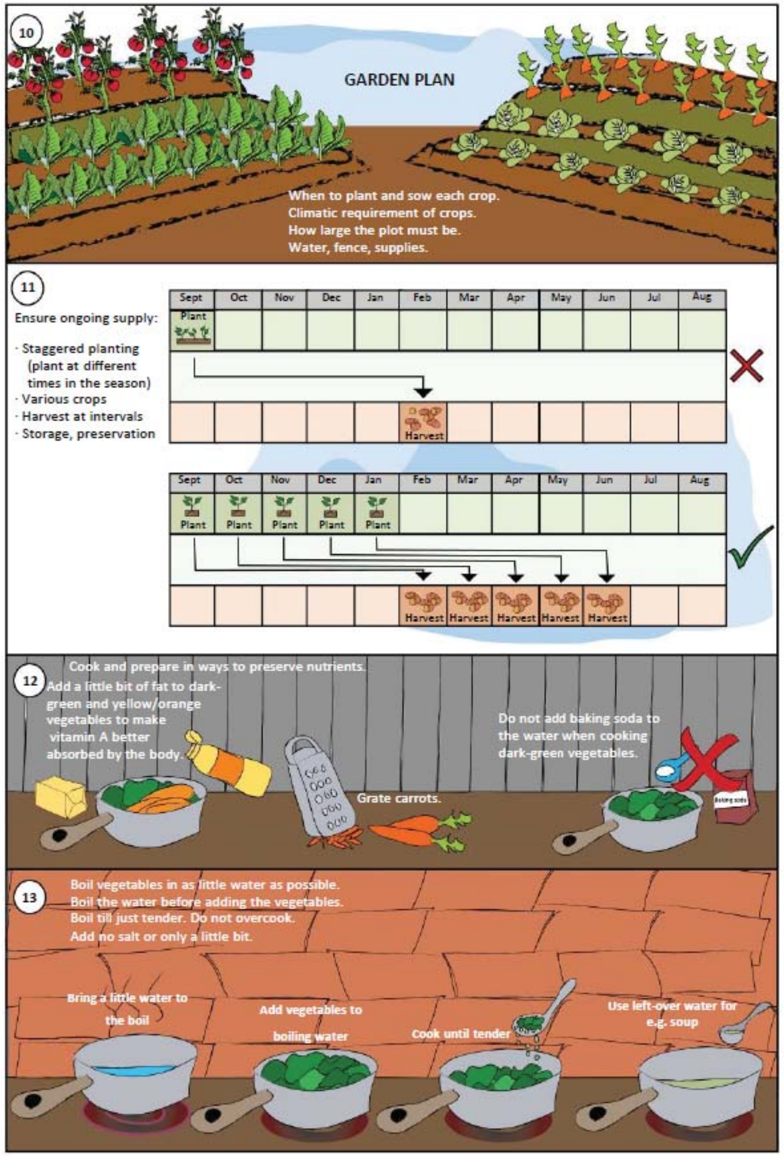

PLANNING
A FOOD
GARDEN
Many people eat little or no animal products with very few fruits and vegetables. This is a risk factor for chronic diseases.
1
This causes a large percentage of South Africans to be vitamin A deficient. In 2012, 43.6% of 1-5 year old children and 27% of women at child-bearing age were vitamin A deficient.
2
Vitamin A is important:
· to prevent infections
· to keep eyes healthy
· for children to grow and develop healthy
3
SOLUTION: Grow and eat vitamin-rich vegetables!
4
GROW VITAMIN-A RICH CROPS:
Yellow and orange fruits: papaya, mango, yellow peaches.
5
Dark-green leafy vegetables for vitamin A and minerals.
6
Dark-yellow and orange-fleshed vegetables for Vitamin A.
7
ADDITIONAL CROPS:
Tomato, beetroot, cabbage, peppers, green beans.
GROW THESE CROPS
8
White roots and tubers: e.g. potato for starch, also some minerals and Vitamin C.
GROW THESE CROPS
9
GROW THESE CROPS
Legumes: Bambara, dry beans, cowpea for proteins and fibre.


10
GARDEN PLAN
When to plant and sow each crop.
Climatic requirement of crops.
How large the plot must be.
Water, fence, supplies.
11
Ensure ongoing supply:
· Staggered planting (plant at different times in the season)
· Various crops
· Harvest at intervals
· Storage, preservation
Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Plant
Harvest
Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Plant Plant Plant Plant Plant
Harvest Harvest Harvest Harvest Harvest
12
Cook and prepare in ways to preserve nutrients.
Add a little bit of fat to dark-green and yellow/orange vegetables to make vitamin A better absorbed by the body.
Grate carrots.
Do not add baking soda to the water when cooking dark-green vegetables.
13
Boil vegetables in as little water as possible.
Boil the water before adding the vegetables.
Boil till just tender. Do not overcook.
Add no salt or only a little bit.
Bring a little water to the boil
Add vegetables to boiling water
Cook until tender
Use left-over water for e.g. soup