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BSF FOR BIO CIRCULAR ECONOMY AND ENVIRONMENTAL SUSTAINABILITY

World Vegetable Center

A PRACTICAL TRAINING GUIDE FOR VEGETABLE PRODUCTION

LED BY WORLDVEG UNDER THE FRAMEWORK OF THE BLACK SOLDIER FLY FOR BIO CIRCULAR ECONOMY AND ENVIRONMENTAL SUSTAINABILITY (BBEST PROJECT)

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EXECUTIVE SUMMARY

This training guide is designed to empower vegetable farmers with practical knowledge on the utilization of Black Soldier Fly (BSF) frass fertilizer, emphasizing its role in the bio-circular economy and environmental sustainability. WorldVeg is a partner on the "BSF for Bio-Circular Economy and Environmental Sustainability" Project and this serves as the foundation for this training guide. The project emphasizes the potential of BSF frass as a natural and nutrient-rich fertilizer. This initiative aligns with broader goals of promoting circular economies by recycling organic waste into valuable agricultural inputs, reducing environmental impact, and fostering sustainable farming practices. The manual is divided into five key modules. The introductory module provides participants with a comprehensive understanding of the BSFand its life cycle, emphasizing the significance of BSF frass in sustainable agriculture. Farmers gain insights into the environmental benefits and the overall impact on crop health and yield. Module two guides farmers through the establishment and management of nurseries using BSF frass. It covers essential aspects such as seed selection, germination techniques, and optimal conditions for seedling growth, showcasing the role of BSF frass in nurturing robust and healthy seedlings. Module three focuses on field application of BSF frass. This module addresses land preparation techniques and transplanting practices enhanced by the integration of BSF frass. Farmers learn how to optimize soil structure, moisture retention, and nutrient availability, leading to improved crop establishment and growth. Module four highlights holistic farming approaches. This module explores integrated management practices that incorporate BSF frass. Farmers gain insights into pest and disease management, as well as the reduction of synthetic inputs, fostering a balanced and sustainable ecosystem within the agricultural setting. Module five, emphasizing the importance of documentation and safety, this module educates farmers on maintaining accurate records of BSF frass application. Additionally, it addresses safety precautions for both farmers and the environment, ensuring responsible and secure utilization of this natural fertilizer. By combining environmental responsibility with enhanced crop productivity, the guide contributes to the broader mission of creating sustainable and resilient agricultural systems.

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ACCRONYMS AND ABBREVIATIONS

BSF	Black Soldier Fly
BSFL	Black Soldier Fly Larvea
BSFFF	Black Soldier Fly Frass Fertilizer
IPDM	Integrated Pest and Disease Management
IPM	Integrated Pest Management
NORAD	Norwegian Agency for International Development
WorldVeg	World Vegetable Center
NPK	Nitrogen, Phosphorus, Potassium
ZECC	Zero Energy Cooling Chamber
IITA	International Institute for Tropical Agriculture

BACKGROUND

Vegetable production is a fundamental component of agriculture, providing nutritious food for human consumption. To meet the growing demand for vegetables, farmers face numerous challenges, including maintaining soil fertility, managing pests and diseases, and adopting sustainable farming practices. Traditional methods of soil fertility improvement in commercial vegetable farming often rely on synthetic fertilizers, which can have adverse environmental impacts and may not be sustainable.

In recent years, there has been a growing interest in more sustainable and eco-friendly approaches to vegetable production. One promising solution is the use of Black Soldier Fly (BSF) frass fertilizer, a nutrient-rich organic amendment produced through the composting of organic waste by BSF larvae. BSF frass offers a natural and sustainable source of essential nutrients and beneficial microorganisms that can enhance soil fertility and improve the overall health of vegetable crops.

Conventional synthetic fertilizers can lead to soil degradation, nutrient imbalances, and environmental pollution. Vegetable crops often require specific nutrient profiles for optimal growth and yield. Meeting these nutrient requirements while maintaining the long-term health of the soil is a significant challenge. BSF frass fertilizer offers a viable solution to address the challenges of soil fertility in vegetable production. BSF frass is not only rich in essential nutrients such as nitrogen, phosphorus, and potassium but also contains a diversity of beneficial microorganisms that promote soil health. When integrated into vegetable farming practices, BSF frass can improve nutrient availability, enhance soil structure, and suppress soil-borne diseases, ultimately leading to higher crop yields and improved crop quality.

The goal of this training guide is to equip vegetable growers and agricultural practitioners with the knowledge and practical skills required to effectively utilize BSF frass fertilizer in vegetable production. This manual serves as a comprehensive resource to understand the benefits of using BSF frass and provides step-by-step guidance on its application.

How the Manual is Organized ?

The manual is organized into five modules, each module addressing critical aspects of using BSF frass fertilizer in vegetable production. These sections include:

MODULE 1 : Introduction
MODULE 2 : Nursery Establishment
MODULE 3 : Land Preparation/Transplanting
MODULE 4 : Integrated Managmenent Practices
MODULE 5 : Record Keeping and Safety Precaustions

How to Use the Manual

This training guide is designed to be used as a practical resource for vegetable growers and agricultural practitioners. To make the most of the manual, start with an understanding of the basics and gradually progress to more advanced topics. As you apply the knowledge and techniques learned from this manual, adapt them to your specific vegetable farming context to achieve the best results. By following the guidelines and best practices outlined in this guide, you can enhance your vegetable production methods, improve soil fertility, reduce reliance on synthetic fertilizers, and contribute to more sustainable and environmentally friendly agriculture through the use of BSF frass fertilizer.

Estimated Duration :

This training manual is a comprehensive guide covering a broader range of topics, including hands on practical activities in the field. It is a medium-length Training manual with an estimation of 1-2 days of training.

MODULE 1 : 2 hrs
MODULE 2 : 2 hrs
MODULE 3 : 3 hrs
MODULE 4 : 2 hrs
MODULE 5 : 1 hr

MODULE 1: INTRODUCTION

GOAL :

To comprehensively educate participants about the multifaceted role of Black Soldier Fly (BSF) in sustainable agriculture

Learning Objectives :

- To understand the BSF and its roles
- To educate farmers on the benefits of BSF frass compost

The Black Soldier Fly and its suitability in sustainable agriculture

The Black Soldier Fly (BSF) is a key player in sustainable agriculture, well-known for its efficient organic waste management abilities. Its life cycle involves distinct stages: egg, larva, pupa, and adult, with the larval stage being key for organic waste decomposition. BSF larvae consume vast amounts of organic matter, quickly converting it into nutrient-rich frass, an organic fertilizer teeming with beneficial microbes and essential nutrients. This frass contributes to enhanced soil fertility, improved structure, and increased crop yields. The adaptability of BSF frass across various agricultural settings further solidifies its suitability in boosting sustainable farming endeavors.

Interactive Discussions

Step one : Ask farmers if they have heard about the BSF. How and when did they hear about it ?

Step two : Ask them if they are aware of the possibility of using the BSF for producing fertilizer ?

Step three : Open up a discussion on the benefits of the BSF frass fertilizer

Step four : Open a discussion on different groups of vegetables that can be fertilized using BSF fertilizer.

Key messages

- The BSF (Hermetia illucens) is a common and widespread fly species. Unlike many other fly species, BSF are not considered pests and do not pose health risks to humans and livestock
- The description of the BSF which includes its taxonomy and appearance is shown in the figure below:

Taxonomy

Kingdom Animalia

Phylum: Arthropoda

Class: Insexta

Order: Diptera

Family: Stratiomyidae

Genus: Hermatia

Species: Illucens

Description

Color: black to blue, medium white strips

Adult: Wasp like appearance

Adult: Small/narrow

Broadly seperated eyes, dark brown/blue antena

Wide black hairy basal segments

Adults: 2cm in length, longer head capsule

Larvae: well developed labrum and mandibular

Larvae: Earth brown/golden yellow hairs and satae

Life Cycle

- **BSF** undergoes four distinct stages in its life cycle, which lasts for about 45 days
- **Egg stage :** Lasts for four days, during which the eggs hatch and the larvae emerge
- **Larval stage :** Lasts for two weeks, during which the larvae feed on organic material, such as decomposing waste. The larvae shed their exoskeleton five times during this stage.
- **Pupal stage :** Lasts up to two weeks, during which the larvae stop feeding and form a pupa, which is a protective casing that they use to complete their metamorphosis.
- **Adult stage :** Lasts for about 5 to 8 days, during which the adult BSF will mate, lay eggs, and then die.

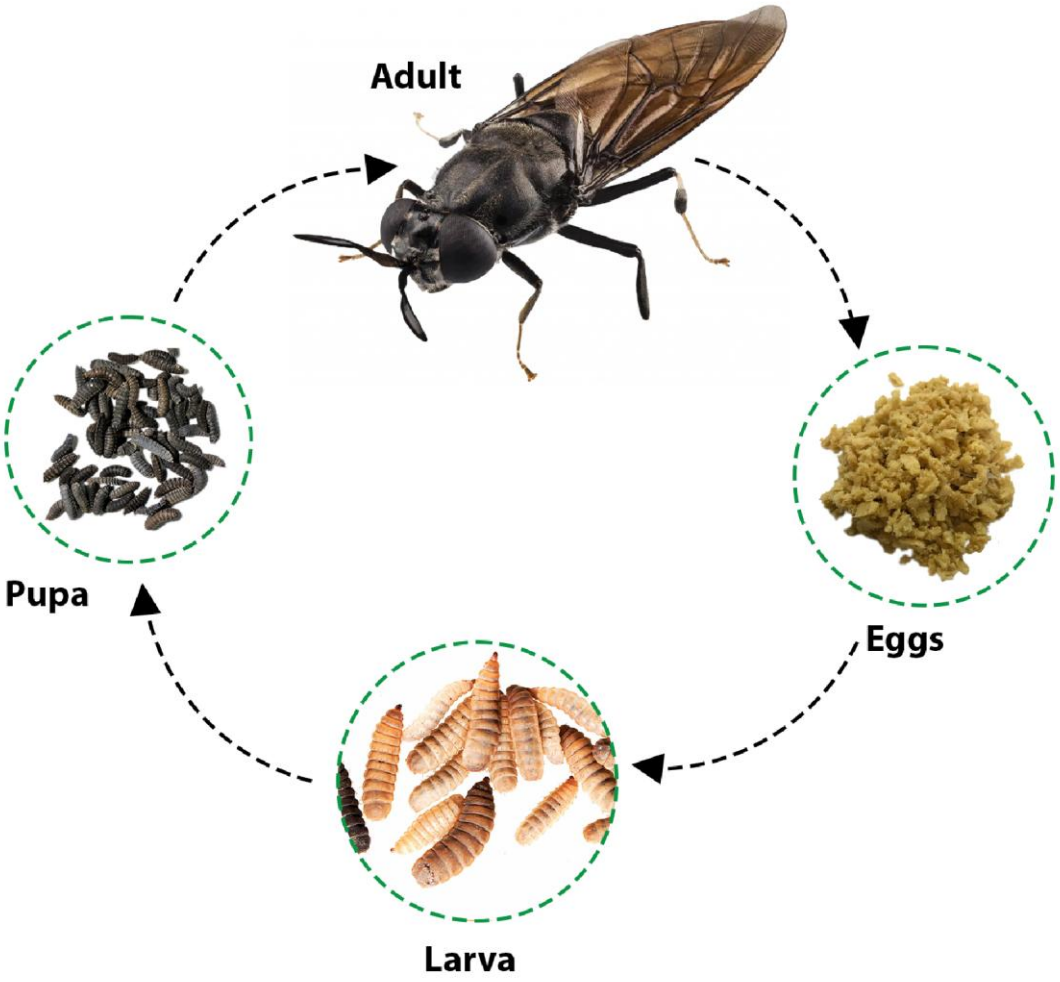


Figure 1: *Life cycle of the BSF fly*

Feeding Habits

- BSF larvae are generally detritivores and scavengers meaning, they feed on dead organic material
- Consume a wide range of decaying organic waste e.g. kitchen waste, manure, crop residues, slaughterhouse waste etc.

Ecological role and agicultural applications

- Waste management: larvae are highly efficient at converting organic waste into valuable resources, such as compost.
- Reducing greenhouse gas emissions: Reduce the amount of waste that ends up in landfills, where it would produce methane.
- Creating compost: Produce BSF Frass compost
- Producing animal feed: larvae of the BSF are very nutritious feed source for animals (poultry, fish, swine)
- Sustainable circular farming: larvae can be farmed sustainably, using organic waste as a food source and producing minimal waste in the process, making them an excellent candidate for sustainable agriculture and aquaculture.

BSF Frass Fertilizer

- BSF Fertilizer is produced by feeding organic waste to black soldier fly larvae, which digest the waste and convert it into fertilizer through their excrement.
- Frass: Mixture of primarily Black Soldier Fly Larvae (BSFL) faeces, substrate residues, and shed BSFL exoskeletons.
- BSFL frass harvested after 9–23 days of BSFL composting, depending on the type of waste used
- One thousand kilograms of food and vegetable substrate in the BSFL treatment process can yield 25% (250 kg) BSFL frass .
- Dry BSFL frass is produced mainly as dark brown frass with granular texture and has lower water content whereas wet BSFL frass is dense, grey in colour and has high moisture content.
- The rapid composting of organic waste by BSFL produces compacted BSFL frass with high organic matter, macronutrients (NPK), micronutrients, and organic matter contents that are readily available for agricultural use.
- BSF frass can be classified as compound NPK fertilizer with 3.4 % N, 2.9 % P2O5, and 3.5 % K2O on average
- BSFL frass contains rich beneficial microbes, such as nitrifying and nitrogen-fixing bacteria that make nitrogen available for plant uptake
- The presence of chitin in BSFL frass helps promote plant development and trigger plant defenses against pests and diseases

Egg stage

Bio-convertion process

Frass compost

Figure 2 : *BSF Frass compost production process*

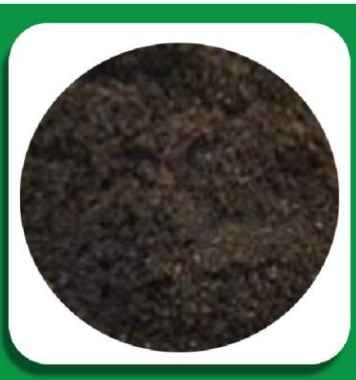
Benefits of BSF frass fertilizer

Nutrient Availability

- Macronutrients: Nitrogen, Phosphorus, Potassium
- Micronutrients: Zinc and Copper
- Rich Beneficial Microbe: Nitrifying and Nitrogen Fixing

Potential of pest and Disease control

- **Chitin:** Exhibit disease suppressive functions in the soil such as plant-parasitic fungi and nematodes
- Ability to suppress plant diseases due to presence of bioactive compounds, certain microorganisms and chitin-rich compounds
- **Chitin :** Makes mineral nutrients inaccessible to pathogens
- **BSFL frass :** Prevents Rhizoctonia, Fusarium, and Pythium from attacking the crops



Yield potential

- Boost yields, crop productivity and farm revenues
- Yields increase due to improved soils, nutrient enrichment, improved soil fertility, enhanced plant growth/development,

Range of vegetables fertilized with BSF Frass

- BSF frass serves as an excellent organic fertilizer for a diverse range of vegetable crops :
- Leafy vegetables such as amaranth, roselle, jute mallow, leafy pumpkin
- Root vegetables like carrots, beets and radishes, etc.
- Fruit-bearing vegetables such as tomatoes, pepper, okra, eggplant, among others

METHODS

Methods

- Workshops and seminars
- Field demonstrations
- Practical sessions
- Questions and Answers
- Online resources

Materials Required

- Writing materials
- Visual aids
- Sample BSF
- Sample BSF compost material
- Demonstration videos
- Educational handouts

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MODULE 2: NURSERY ESTABLISHMENT

Learning Objectives :

- Participants will understand BSF fertilizer application as a nutrient rich medium for seedling establishment
- Participants will learn effective nursery management techniques

Growing Media

The application of BSF frass as a growth medium enhances seedling vigor, root development, and overall plant health, leading to stronger and more resilient seedlings. The BSF frass is a suitable growing media to promote soilless agriculture because it can replace the commercial peat used in potted plants. Using 80% commercial peat and 20% BSF frass as growing media improve plant growth. For instance, for crops such as baby leaf lettuce, basil, and tomato, it increased survival of potted plants by up to 20% as compared to potted plant production by using commercial peat.

Interactive Discussions

Step one : Open up a discussion on what nurseries are
Step two : Discuss the importance of raising nurseries
Step three : Allow participants to give feedback on some problems encountered at nurseries
Step four : Discuss the various types of nursery establishment methods
Step Five : DDiscuss with participants how to prepare medium with BSF fertilizer for nurseries

Key messages

- Vegetable nursery is a place for raising or handling of young vegetable seedlings until they are ready for more permanent planting.
- Raising healthy seedlings under good nursery management is an important part of successful vegetable production
- Poor nursery establishment will reduce the number of seedlings because of dead seedlings and a lot of diseases will be carried from seedling establishment to the field

Importance of Nursery Establishment

- Eliminates the problem of soil compaction which affects seedlings
- Easy weed control
- Easy to protect seedlings from pests and diseases
- Production of healthy and disease-free seedlings
- It is very convenient in sorting out weak seedlings
- More optimal use of seeds
- Higher yields

Note to trainer : Trainer should emphasize the following points

- Key factors like seed quality, location of nursery, accessibility to water and nature of growing medium should be considered when raising seedlings.
- Nursery should be easily accessible, well exposed to the sun but protected against severe heat and animal damage.
- Select varieties of seeds that are high yielding, heat tolerant, disease resistant and with good postharvest quality.
- Certified seeds should be acquired from certified seed dealers.

Problems observed in traditional nurseries

- Higher pest and disease incidence (such as damping off)
- Poor germination due to improper management of moisture in beds
- Lack of awareness of improved nursery practices such as raised beds, seed treatment, protection against environment, etc.
- Over-fertilization of seedlings.
- Oversized seedlings at transplanting

Methods of seed bed establishment

Seedling Trays

- Seedlings are raised in pots, containers, seed trays etc
- 100 % establishment rate
- Prevents root injury and transplanting shock to seedlings

Seedbox

- Seedlings raised in seed boxes
- Convenient for transporting seedlings to distant fields
- Use 10-12 cm deep and locally available wooden seed boxes with drainage holes

Seed Bed

- Seedlings raised in beds when large quantities of seedlings are needed
- Widly practiced among smallholder farmers in rural communities

Soil Sterilization/Solarization

Method One (Heating of seedbed)

- Moisten the soil to about 60% moisture content
- Spread dry mulch evenly on the bed and pure boiled water on top of the mulch.
- Allow the soil to cool for about 5-7 days before sowing.

Method two (Soil Solarization)

- Apply water to moisten seedbed soil
- Cover the soil with transparent plastic sheets for 3-4 weeks
- After 3-4 weeks, remove the plastic sheets and plough the soil
- About 2-3 days later, level the soil and sow the seeds

Medium Preparation and sowing

- Growing media could comprise BSF frass and a mixture of locally available materials such as soil and sand
- Incorporate well-decomposed and sieved BSF frass fertilizer at a rate of 2 kg/m2 into beds
- Make drills on the seedbed at a spacing of 5cm apart and 0.5cm deep at a rate of 250-300g.
- Thinly sow the seeds in the drills and cover lightly with soil. Water the nursery regularly.
- Cover the seeds in the rows lightly using either soil from the bed or finely sieved BSF frass fertilizer.
- Cover the seed bed with locally available shading mats until seedlings emerge

Seedling Management

Watering : Water seedbed daily during the hot and dry season by using a fine sprinkler. In the cool season, watering can be carried out once every two days. Avoid excessive watering.

Monitor : Monitor for disease and pests regularly and react accordingly. Seedling death (damping-off) or poor growth can be due to fungal infection. Young seedlings may develop a sunken, brown, necrotic lesion near the soil line due to fungal infection.

Fungicides : Seed can be treated with broad-spectrum fungicides to reduce losses from damping-off.

Pest : Insects, such as whiteflies, thrips, and aphids, can transmit viruses to young seedlings. If whiteflies are a problem in the nursery, seedlings can be covered with a net, 60-mesh or finer, to prevent insect infestation.

Thin out : The excess plants. This is usually done within 2-3 days after the first true leaf has appeared (about 5-7 days after sowing). Excess seedlings can be transplanted to trays or individual containers for transplanting to the field later, especially when expensive seeds such as hybrid varieties are used.

Practical Session

Methods	Materials
✓ Participants apply BSF fertilizer to seedlings, learning the proper techniques for incorporating the fertilizer into the growing medium. ✓ Participants collectively establish a model nursery	✓ Seedlings, ✓ BSF fertilizer ✓ Planting trays or pots ✓ Soil ✓ Shade cloth
✓ Divide participants into groups to discuss and share observations. ✓ Facilitate a discussion on the benefits and challenges of using BSF fertilizer for seedlings	✓ Flip charts ✓ Markers
✓ Demonstrations on proper transplanting techniques.	✓ Water ✓ Transplanting tools ✓ Planting medium. ✓ Seedlings
✓ Conclude with Q&A session where participants can ask questions and discuss challenges they may face in nursery management. ✓ Facilitate a group troubleshooting exercise.	✓ Whiteboard ✓ Markers

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MODULE 3: LAND PREPARATION AND SEEDLING TRANSPLANTING

Learning Objectives:

- Participants will gain knowledge on land preparation
- Participants will gain practical knowledge on seedling transplanting

Interactive Discussions

Step one : How do farmers prepare lands for vegetable production ?
Step two : Open up a discussion on how seedlings are transplanted
Step three : Ask farmeres to mention the various challenges faced during transplanting and how these challenges are managed
Step four : Take participants through practical session on seedling transplanting

Key messages : Land Preparation

- Prepare ridges or bed across the contours on which seedlings may be transplanted.
- Incorporating frass fertilizer into pre-planting soil preparation improves soil quality and provides nutrients for plants.
- The incorporation of compost must be done according to the following steps:
  - Plough the soil to a depth of about 30 centimetres
  - Lay out the planting pattern according to the spacing of your crops
  - Incorporate a range of 7 - 10t/ha of BSF frass

Key messages : Transplanting

Hardening off

- Harden seedlings before transplanting for one week
- Slightly reduce watering, reduce shade and expose the seedlings to strong sunlight
- Thoroughly water the seedlings 12-14 hours before transplanting hem to the field.

Note to trainer

Good seedlings should be :

- Vigorous and stocky
- Healthy
- No pest & disease symptoms
- No flower buds or flowers

Transplanting Process

- Transplant seedlings late in the afternoon when temperatures are low or it is cooler, to avoid excess transpiration.
- Ensure soil is moist before transplanting and apply water to the field soon after transplanting
- Make a hole just big enough to hold the seedlings root ball
- Use appropriate planting distances per each crop
- Place one seedling in each planting hole within plots.
- Bury plant roots firmly into the soil, but not more than half the height of the seedling.
- Pull soil around it and press it lightly to hold plant upright and firmly in position

Table 1: *Transplanting distances for selected vegetable crops*

CROP	SEED QUANTITY (G/HA)	BETWEEN ROWS (CM)	WITHIN SEEDLINGS (CM)	DAYS TO GERMINATION (DAYS)	DAYS TO TRANSPLANTING
TOMATO	100 - 150	60	40	3 - 5	28-35DAYS (4-5WEEKS)
PEPPER	100 - 150	60	45	8 - 12	28-35DAYS (4-5WEEKS)
CABBAGE	200 - 250g	60	45	3 - 5	30-30 DAYS (4-5WEEKS)
ONION	5 - 7kg	20	10	7 - 10	42-56DAYS (6-8WEEKS)

Practical Session

METHODS	MATERIALS
☑ Participants visit a field where land preparation has been done effectively. ☑ Discuss the physical characteristics of the soil, layout, and considerations for different crops.	☑ Transportation to nearby field ☑ Land and Soil
☑ Train participants on the proper incorporation of organic materials, such as BSF compost, into the soil.	☑ BSF fertilizer ☑ Measuring tools ☑ Shovel
☑ Demonstrations on proper transplanting techniques,	☑ Water ☑ Transplanting tools ☑ Planting medium. ☑ Seedlings
☑ Conclude with a Q&A session where participants can ask questions and seek clarifications on land preparation	☑ Open forum

MODULE 4: INTEGRATED MANAGEMENT PRACTICES

Learning Objectives

- Participants will learn the various integrated management practices for vegetable production.
- The will know the role of BSF frass fertilizer in an integrated magement system of vegetables

Integrated agriculture management strategies

Integrated management practices for vegetable crops involve a holistic approach that incorporates various strategies to optimize crop health and yield. This comprehensive method integrates pest and disease management, nutrient management, efficient irrigation practices, the use of appropriate fertilizers, and effective postharvest handling. A notable addition to these practices is the utilization of BSF frass fertilizer. When integrated within these comprehensive agricultural management practices, BSF frass fertilizer plays a vital role in supporting the overall health and productivity of vegetable crops while promoting environmentally conscious and sustainable farming.

Content

This module is divided into four topics :

- Ecological fertilization of vegetables using BSF frass
- Integrated pest and disease management
- Vegetable irrigation
- Vegetable harvest and postharvest management

Topic 4.1 : Ecological fertilization using BSF Frass Fertilizer

The WorldVeg conducted field experiments in Ghana and Benin to understand the fertilization ability of BSF compost for vegetables such as tomato (in Ghana), okra and African eggplant (in Benin). The research findings indicate that a combination of BSF frass (5t/ha) and farmers practice at a rate of 100kg/ha of NPK, and sole BSF frass (10t/ha) were the best performing treatments which had a significant impact on the agronomic performance, yield, fruit quality of tomato and soil properties in Ghana. Results from Benin indicates that, BSF frass holds great potential as an organic fertilizer for okra and African eggplant especially when applied at the rate of 10t/ha. The two best performing treatments for most parameters investigated were 10t/ha of BSF frass + 100kg/ha NPK + 50kg/ha urea + 50kg/ha K2SO4 and BSF frass at 10t/ha for okra. While for African eggplant, the top two performing treatments were BSF frass at 10t/ha and Research recommended rate as Positive control (10t/ha of Chicken manure + 100kg/ha NPK + 50kg/ha Urea + 50kg/ha K2SO4). Literature indicates that, the combined application of BSF frass and NPK at a rate of 2t/ha resulted in substantial increase in vegetable yields, with tomatoes, kales, and French beans showing 4.5, 2.4, and 5.4-fold higher yields compared to the control treatment.

Learning objectives

- Participants will learn application rates and methods of BSF fertilizer vegetables
- The will understand the application timing and frequencies of BSF fertilizers

Interactive Discussions

- **Step one :** Ask participants to mention the types of fertilizers used on their vegetable fields
- **Step two:** Let them discuss among themselves the traditional methods of fertilizer applications
- **Step three :** Open up a discussion on the methods and rates of application of the BSF fertilizer

Key messages : Application Rates

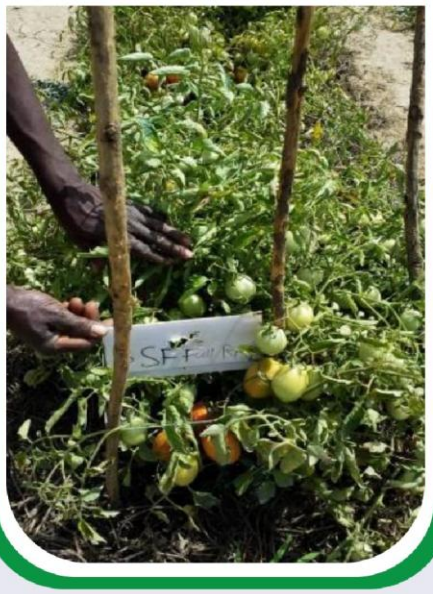
Tomato :

- For good management in low nutrient soils and for best results in tomato production, apply BSF frass (5t/ha) and NPK at 100kg/ha.
- Farmers can also apply sole BSF fertilizer at 10t/ha during tomato production
- For micro-dosing application, Apply 50g of BSF frass with 3g of NPK on each tomato plant; For the option of sole BSF fertilizer, farmers can apply 100g of BSF fertilizer per plant
- Fertilizer can be applied as basal application one week after transplanting.
- Top dressing can be done at four and six weeks after basal application

BSF frass (5t/ha) and farmers practice at a rate of 100kg/ha of NPK

Conventional compost (5t/ha) and BSF frass compost (5t/ha)

Sole BSF frass (10t/ha)



Conventional compost at the rate of 10t/ha

Farmers practice (100kg/ha NPK) and CC at 5t/ha

Farmers practice (NPK/SO4) at 200kg/ha

Figure 3: *Tomato grown with BSF compost*

Key messages : Application Rates

Okra

- For best results in okra production, apply 10t/ha of BSF frass compost + 100kg/ha NPK + 50kg/ha urea + 50kg/ha K2SO4

- Farmers can also apply BSF frass compost at 10t/ha for okra.

- Apply fertilizers in splits to supply nutrient to the plants at different stages of growth

- For okra, apply the first application of fertilizer at the growing stage while the second and third application are made at the fruiting stages.

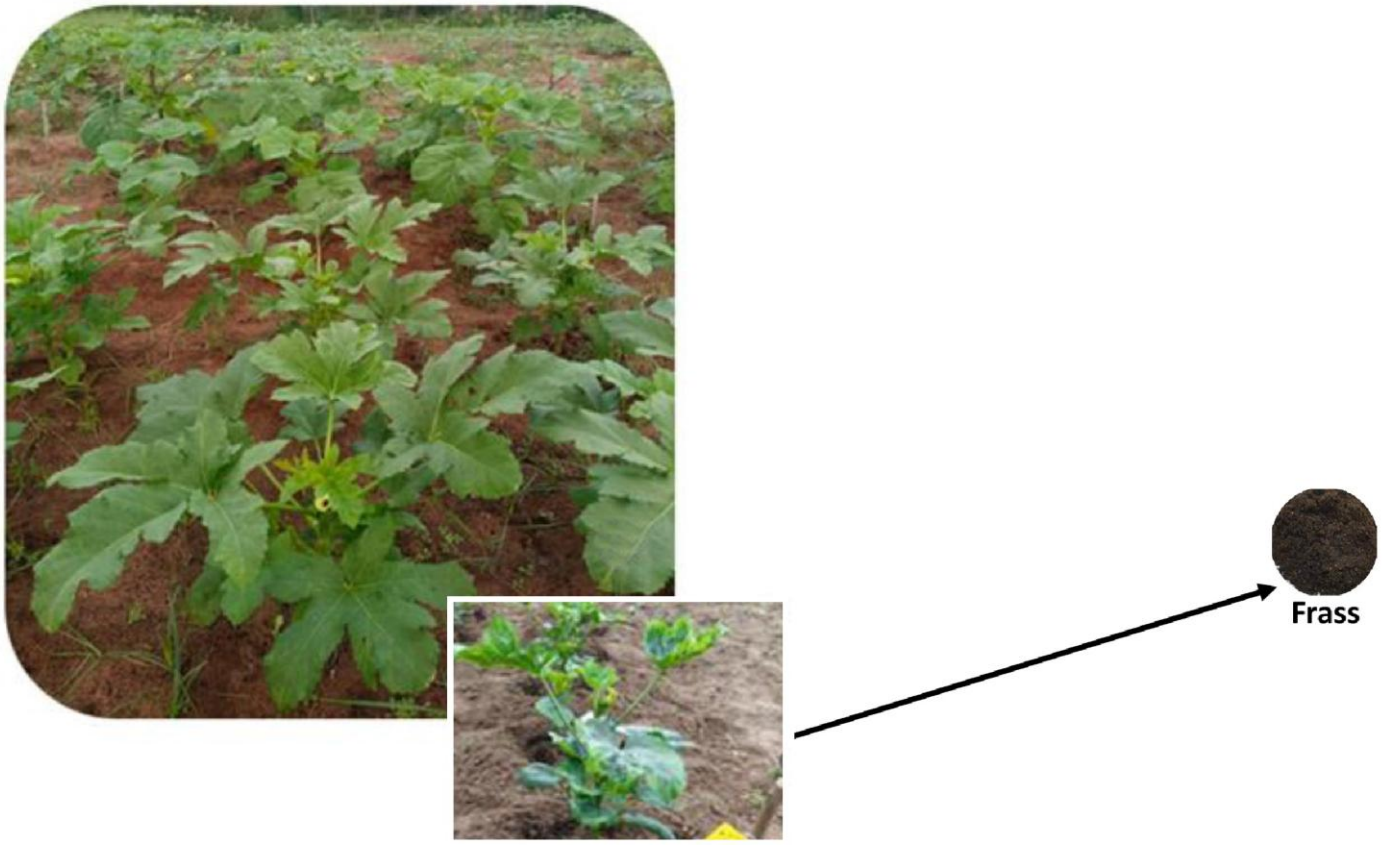


Figure 4: *Okra grown with BSF fertilizer*

Key messages : Application Rates

Eggplant

- For best results in eggplant production, apply BSF frass compost at 10t/ha and Research recommended rate as Positive control (10t/ha of Chicken manure + 100kg/ha NPK + 50kg/ha Urea + 50kg/ha K2SO4).

- Basal application is done 2 weeks after transplanting/sowing

- Top dressing is done 4 and 6 weeks after transplanting which is the second and third application

Figure 5 : *African eggplant grown with BSF frass fertilizer*

Key messages : Application Rates

Root Crops

- For root crops like sugar beets and cress, use a BSF concentration of 7.5 and 15g/kg of soil
- This demonstrates effectiveness as soil applications, promotes robust plant emergence and growth for both sugar beet and cress crops.
- The highest concentration of BSF frass (15 g/kg of soil) exhibits significant fertilizing effects.

Key messages : Application methods

Seed Coating

Description

Coat seeds with a thin layer of BSF frass before planting

Application

This method is particularly useful for promoting early plant growth. The nutrients from the frass provide a nutrient boost to the germinating seed and emerging seedling

Incorporation into soil

Description

Mix BSF frass into the soil before planting or during soil preapartion

Application

This method is effective for providing a more even distribution of nutrients throughout the root zone. It is often done during land preparation or before planting

Organic Matter Addition

Description

Mix BSF frass with other organic materials (such as compost or well-rotted manure) to create a nutrient-rich blend.

Application

Incorporate this blend into the soil or use it as a topdressing for established plants

PRACTICAL SESSION

METHODS	MATERIALS
☑ Guide them through the different application methods ☑ Engage participants in hands-on exercises where they calculate fertilizer application rates for given crop and soil scenarios. ☑ Review and discuss the results as a group	☑ BSF fertilizers ☑ Shovels ☑ Sample scenario

Reference

Anyega A. O., Korir N. K., Beesigamukama D. et al. (2021). Black soldier fly-composted organic fertilizer enhances growth, yield, and nutrient quality of three key vegetable crops in Sub-Saharan Africa. Frontiers in Plant Science. https://www.frontiersin.org/articles/10.3389/fpls.2021.680312

Topic 4.2: Integrated Pest and Disease Management

Pesticide usage in Africa experienced a substantial surge of nearly 64% from 1990 to 2019, with West Africa notably witnessing a staggering 10-fold increase in pesticide consumption. This practice often results in the inappropriate application of doses and frequencies of pesticides, with some instances involving up to 30 applications over a 3-month cropping season for crops like cabbage, pepper, and African eggplant. in Kenya, the per-hectare application of pesticides in vegetable crops rose by 47% per season between 2005 and 2008. In Benin, farmers spray a maximum of eight to sixteen times synthetic pesticides during each season of tomato production, while for pepper, they spray up to forty-eight times during six months production of pepper. In Burkina Faso, farmers sprayed insecticides up to 35 to 95 times for onions, tomato, pepper and eggplant. WorldVeg has developed integrated pest and disease management packages for some of the most serious pests and diseases of vegetable production. WorldVeg promotes IPM strategies which involves better field sanitation, prompt removal and destruction of infested plant shoots and fruits throughout the season, the use of sex pheromone traps to attract and kill adult insects. By following the IPM strategy, farmers will be able to reduce pesticide use by 65-75%. Studies also showed that, insect frass in combination with inorganic fertilizers produced the best results on crop and pathogen/disease resistance with a typical effective dosage of 10-40 percent of the total fertilizer volume administered.

Learning Objectives

- Enhance Participants' Understanding of Integrated Pest and Disease Management (IPDM)
- 2. Build Practical Skills in Pest and Disease Identification and Monitoring

Interactive Discussion

- **Step one :** Ask farmers to mention some of the pest and diseases observed on their field
- **Step two :** Take participants through the identification process of pest and diseases
- **Step three :** Discuss with participants the various management practices for pest and diseases

Key Messages

Note to Trainer

- Vegetables such as tomato, okra, carrots and egg plant are susceptible to a wide range of pests and diseases
- Pests and diseases can have significant impacts on vegetable crops leading to various forms of damage
- Here are five general damage impacts:

General Damage Inpacts

Reduced Yield

- Pests and diseases often directly target the reproductive structures of plants, such as flowers, fruits, and seeds.
- The damage inflicted on these structures can result in a substantial reduction in crop yield.

Quality Degradation

- Pest feeding and disease infections can negatively impact the quality of harvested vegetables.
- For example, chewing insects may cause cosmetic damage, while diseases can lead to discoloration, rotting, or other undesirable changes.
- Quality degradation can affect marketability and consumer acceptance.

Stunted Growth and Vigor

- Continuous feeding by pests or the presence of diseases can lead to stunted growth and reduced plant vigor.
- Infected plants often exhibit symptoms such as yellowing, wilting, or distortion.

Transmission of Pathogens

- Some pests act as vectors, transmitting pathogens that cause diseases.
- For instance, insects like aphids and whiteflies can carry and spread viruses among plants.

Key Message : Key Pest and Diseases of okra, tomato and eggplant

Phthorimaea absoluta

Impact

Creates Mines on leaves
Larvae creates holes on fruits

Helicoverpa armigera

Impact

Leaf defoliation, bore holes in fruits, reduced market suitability

White flies

Impact

Reduced plant vigor, transmission of diseases, and the secretion of honeydew, leading to sooty mold development

Fruit worm

Impact

fruit damage, reduced marketability

Jassids

Impact

Yellowing of leafs, leaf curling, transmit pathogens, reduced vigor

TYLC disease

Impact

Curling of leaves, yellowing of leaves, stunting

Okra yellow vein virus

Impact

Yellowing of veins, leaf distortion, and reduced plant vigor.

Anthracnose

Impact

Fruit rot, dark sunken lesions, post-harvest losses

Bacterial wilt

Impact

exhibit brown or black streaks in their vascular tissues, Wilting of plant, reduced yield

Phomopsis Blight

Impact

Premature defoliation, reduced fruit quality, and yield loss.

Powdery mildew

Impact

Reduced photosynthesis, stunted growth, and decreased fruit quality.

Fusarium Wilt

Impact

Severe wilting, yellowing, and reduction in yield.

Root Knot

Impact

Formation of small, swollen root structures known as galls, stunted plants

Okra leaf curl virus

Impact

Reduced yield and quality of okra fruits, stunted plant growth.

Early Blight

Impact

Reduced photosynthesis, lower fruit quality, and yield loss.

Key Messages : Basic component of IPDM strategy

Preventive Cultural Practices

- Planting resistant varieties suited to local growing conditions, maintaining healthy crops, and removing infested plants.
- Cleaning of growing material,
- Avoiding excess water in the soil and foliage,
- Watering in the morning,
- Eliminating weeds
- Eliminate the first diseased plants/ affected organs (rogueing),
- Mulching

Monitoring

- Visual inspection, traps, and other surveillance methods and monitoring tools are used to identify pests and track infestation levels.

Mechanical Control

- Simple hand-picking, erecting insect barriers and tillage to disrupt breeding

Biological Control

- Be aware of beneficial organisms such as predator and parasitoid insects that eat and develop on target pests and biological pesticides derived from microorganisms
- This provides control with minimal or no environmental impact.
- Use of plant extracts (neem, hyptis, eucalyptus); copper products, sulfur, biopesticides from micro-organisms

Utilisation responsable des pesticides

- Selective and systemic chemical pesticides are carefully targeted (to enable preservation of beneficial organisms) to specific stages in the pest life cycle and used only if necessary to protect or save a crop.

Responsible Pesticide Use

- Selective and systemic chemical pesticides are carefully targeted (to enable preservation of beneficial organisms) to specific stages in the pest life cycle and used only if necessary to protect or save a crop.

Cropping System

- The adoption of a crop rotation to avoid continuous cultivation of species from the same family and build-up of soil-borne diseases (for instance plant leafy vegetable before tomato production and follow it by grain legumes which can improve organic matter in soil)
- Staking of tomato to avoid diseases

Table 2: *List of main diseases and pest of various vegetables and their management methods:*

	Bacteria	Viruses	Fungi	Aphids	Caterpillars	Flies	Thrips	Mites	Nematode
Chemical control									
Use of direct-acting synthetic products	+	+	+	+	+	+	+	+	+
varietal control									
Use resistance varieties	+	+	+						
Biologic control									
Copper and sulfur-based products	+				+	+			
Biopesticides from plant extracts	+	+	+	+		+	+		
Physical control									
Plant mulching	+	+	+						
Use of anti-insect nets				+		+	+	+	
Prophylaxis measure									
Cleaning and disinfection of cultivation equipment	+	+	+		+				+
Avoid excess water in the soil		+	+						
Avoid irrigating foliage		+	+		+				
Eliminate weeds and host plants	+	+	+						
Avoid proximity to already affected or susceptible crops	+								
Remove plant debris during and at the end of cultivation	+	+	+						
Cropping systems									
adopt crop rotations				+		+	+	+	+
Prefer organic amendments	+	+	+						
Trap plants				+		+	+	+	+
Respect crop densities	+	+	+	+	+	+	+	+	

PRACTICAL SESSION

Methods	Materials
✓ Conduct a hands-on session where participants learn to identify common pests and diseases. ✓ Emphasize the importance of accurate identification for effective management ✓ Train participants on systematic scouting and monitoring methods. ✓ Discuss how to establish monitoring zones, record observations, and use thresholds for intervention	✓ Samples of common pest and diseases ✓ Field note book ✓ Pest and disease guide ✓ Magnifying glass
✓ Introduce participants to crop varieties that are resistant to specific pests or diseases. ✓ Discuss the advantages of incorporating resistant varieties into farming practices ✓ Discuss and demonstrate cultural practices that can help prevent pest and disease issues. ✓ This may include proper spacing, crop rotation, and companion planting	✓ Charts/diagrams on cultural control ✓ Disease resistant varieties
✓ Engage participants in a group activity where they develop pest and disease management plans for specific crops. ✓ Encourage discussion on the integration of multiple methods	✓ Flip charts ✓ markers
✓ Create a simulated field scenario with potted plants infested with mock pests and diseases. ✓ Participants work in teams to assess the situation and implement an integrated management strategy	✓ Potted plants ✓ Mocked pest and diseases
✓ Conclude the training with a Q&A session where participants can ask questions and discuss real-world challenges they may face in pest and disease management ✓ Facilitate a group troubleshooting exercise	✓ Open forum

Reference

Srinivasan, R., Tamò, M. and Subramanian, S. (2022). The case for integrated pest management in Africa: transition from a pesticide-based approach. Current Opinion in Insect Science, 54:100970. https://doi.org/10.1016/j.cois.2022.100970

Elissen, H. J. H., R. van der Weide and L. Gollenbeek, 2023. Effects of black soldier fly frass on plant and soil characteristics – a literature overview. Wageningen Research, Report WPR- 996.

Food and Agriculture Organization (FAO): FAOSTAT Production – Crops and Livestock products. (Accessed 2nd December, 2023) https://www.fao.org/faostat/en/#data/RP

Topic 4.3: Irrigation

The irrigation method used depends on the structure (furrow or drip) available. As a general rule, apply water two to three times a week and water deeply each time as opposed to a brief, shallow watering every day. Watering early in the morning gives crops time to absorb the moisture before it evaporates in the heat of the day. Fruit vegetable irrigation requires careful consideration of the species water needs. The crops need of water vary across species, growth stage, soil type, and weather conditions. Developing an irrigation plan is important for farm resilience

Learning Objectives

- To educate participants on various methods and mechanisms of irrigation
- Participants will learn vegetable irrigation procedures

KEY MESSAGES

Choosing Right Irrigation System

- Three types of irrigation systems are commonly used for fruit vegetable production including sprinklers, drip irrigation and flooding
- Drip irrigation is the most efficient water application method in fruit vegetable production as it conserves water by directing water to the root zone of plants where it is needed.
- Small holder farmers are mostly familiar with the system of flooding due to lack of adequate irrigation resources

Root Vegetable Irrigation

- Root vegetables, such as carrots, sweet potatoes, and onions, require frequent irrigations for optimal quality.
- Root vegetables are shallow-rooted crops and benefit from frequent irrigation throughout the growing season
- Sprinklers and drip irrigation can be used to grow root vegetables.
- However, the drip irrigation is the most efficient water application method for root vegetables
- It is well suited to many roots vegetable and can help reduce weeds, fungi, and diseases.

Figure 6: *Flooding / farrow irrigation*

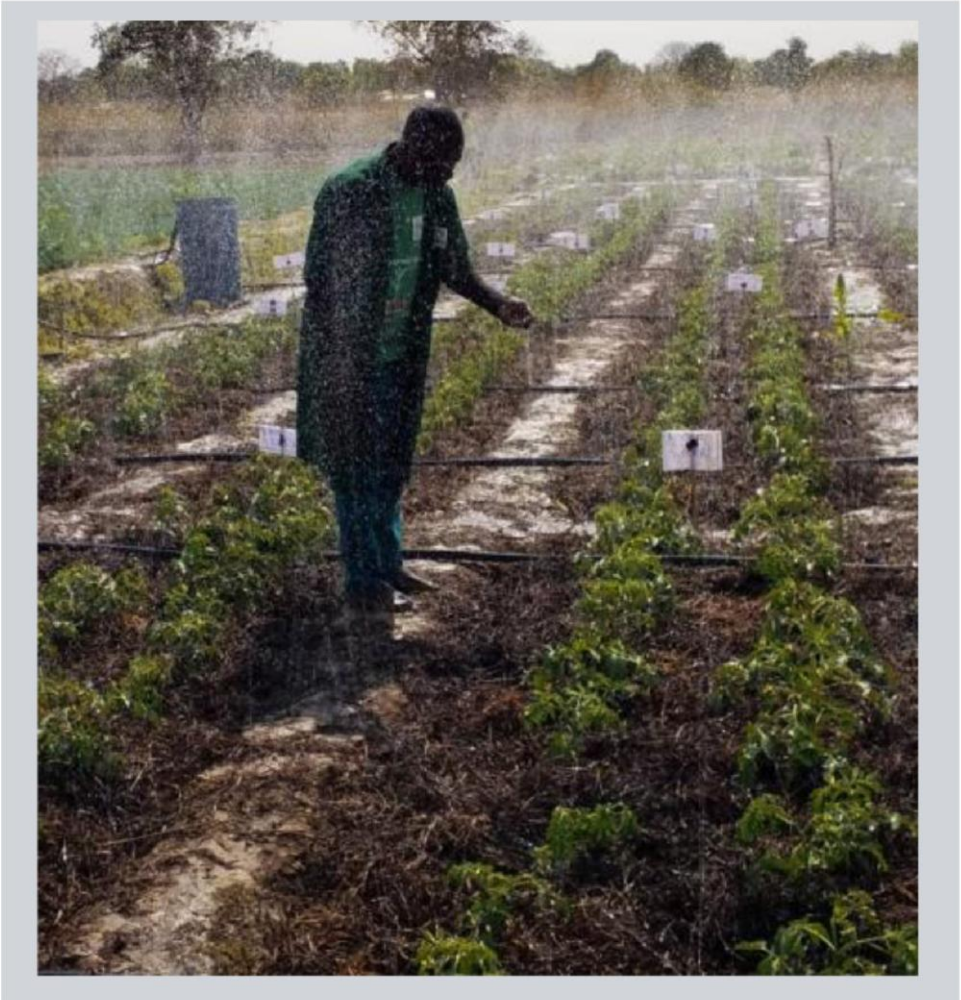


Figure 7: *sprinkler irrigation system*

Topic 4.4: Vegetable Harvest and Postharvest Management

WorldVeg conducted field trials in Ghana and Benin to know the potential of BSF frass compost in improving the yields of tomato, okra and eggplant. The findings indicated that:
- BSF frass (5t/ha) + NPK fertilizer (100kg/ha) resulted in fruit yield of 16.87 t/ha as compared to 200kg/ha with conventional fertilizer
- Sole BSF frass (10t/ha) resulted in 14.9t/ha as compared to 16.05 Conventional fertilizer (NPK)
-BSF frass at 10t/ha resulted in 5.53t/ha yield of leafy African eggplant as compared t0 3.48t/ha of conventional fertilizer
-BSF frass at 5t/ha resulted in 12t/ha of okra fruit yield as compared to conventional fertilizer

Learning Objectives :

- Participants will learn different harvesting periods and methods for vegetables.
- Participants will understand various postharvest handling for vegeatable crops.

Interactive Discussions

Step one : Ask farmers to share on how they harvest their vegetables
Step two : Discuss various harvesting methods with participants
Step three : Let them share on the various postharvest challenges they are facing.
Step four : Share with them effective postharvest techniques.

Note to trainer

- Harvesting must be done properly and carefully to minimize damage to the produce.
- Harvesting should be done at the right time and with the right tool.
- Harvesting should be done when the temperature is low as higher temperature leads to faster respiration and deterioration in the vegetables.
- Vegetables harvested early morning are fully fresh and turgid due to dew drop at that time whereas.
- Harvesting in the evening is preferred for distant market due to higher accumulation of reserved carbohydrates and less amount of moisture.
- Vegetables must be harvested at right stage of maturity. Vegetables harvested immaturely or over mature usually are of low quality.

Key messages : Harvesting

Tomato

- Can be harvested at different stages, depending upon the time needed to market the fruit.
- For long distance transport, harvest fruits at breaker stage (not more than 10% of the surface is tannish-yellow, pink, or red).
- For local market, harvest fruits at later ripening stages.
- Poor care of fruit after harvest will lead to poor fruit quality.
- Avoid fruit injury and do not mix damaged and undamaged fruit.
- Harvest during cool periods, such as late afternoon or early morning.
- Tomatoes are normally packed in wooden & plastic crates but plastic crates are preferable.

Table 3 : *Various stages of tomato fruit ripening*

Class	Description	
Green	Entirely light to dark green, but mature	
Breaker	First appearance of external pink, red or tannish yellow color; not more than 10%	
Turning	Over 10% but not more than 30% red, pink or tannish yellow	
Pink	Over 30% but not more than 60% pinkish or red	
Light red	Over 60% but not more than 90% red	
Red	Over 90% red; desirable table ripeness	

African Eggplant

- Most communities consume unripe fruits, which are light green, yellowish or green.
- Harvesting is done repeatedly at about two-week intervals and lasts for 2-3 months
- To extract seed for use in subsequent trials or breeding nurseries, harvest when the fruit has turned red

Peppers

- Peppers can be harvested when the fruits become green, red or yellow for both sweet and hot (chili) peppers.
- Under commercial production, hot pepper stays in the field until late maturity for drying and grinding into powder for use in making different types of sauces.
- Harvesting is usually done every 1-2 weeks once harvesting has begun, and can last for 2-3 months.

Okra

- The crop comes to harvest 45 – 55days days after sowing.
- Since the pods get matured very quickly, the selection of pods with maximum size but still tender is the point to be considered.
- A total number of 15-18 harvests can be made
- 10-15 tonnes/ha.

Traditional African Leafy Vegetables

- Harvesting should start four weeks after sowing or three weeks after transplanting
- Continues biweekly for continuous harvesting.
- A single harvest by uprooting is also possible.

Onions

- Ready for harvest three to four months after transplanting.
- Neck fall is the indication of maturity.
- The best time to harvest onion is when 60 to 70% of tops have fallen over.

What is ZECC ?

A Zero Energy Cooling Chamber (ZECC), originally developed in India, is a small chamber made out of bricks and sand where farmers can store freshly harvested produce before it is transported to market. The ZECC works on evaporative cooling principles that can be used to provide a cool environment.

The shelf-life of vegetables as well as their quality can be increased by keeping them in a cool environment. This reduces the rate of deterioration, allows more time for marketing the crop, and allows higher quality produce to reach consumers

Key Messages : Post Harvest Management

Precooling

- Immediate cooling after harvest is important to keep the quality of the produce as deterioration doubles at every 10ºC rise in temperature.
- Precooling removes the field heat from the produce.
- **Methods of precooling :** Room Cooling, Hydro-Cooling (Use of water) and Evaporative cooling
- A ZECC can reduce the temperature by 10-15°C but it keeps humidity high. These are perfect conditions to store produce. Traders can also use ZECCs to store produce at markets so that the produce doesn't waste away under the sun all day.

Vegetable	Weight Loss (%)		Shelf life (days)	
	ZECC	Ambient	ZECC	Ambient
Green Pepper	2 - 3	14 - 18	7	3
African Nightshade	1 - 4	4 - 12	3	1
Tomato	1 - 7	5 - 23	12 - 15	7 - 9
Eggplant	1	6	4	2
Cucumber	3	10	4	2
Cauliflower	18	44	9	7

Tableau 4 : *Weight loss and shelf life of vegetables stored in ZECC*

Figure 8 : *technologie de Zero Energy cool chambré (ZECC)*

Washing and Cleaning

- Involves removal of soil dust, adhering debris, insects and chemical residues to make it appealing and also to keep the quality.
- Chlorine is usually added to fresh water to serve as disinfectant during washing of produce.
- For some cleaning of fruit type vegetables, a clean damp cloth is most
- often used.
- There is the need to trim, cut or remove leaves and other vegetative parts of the vegetables after harvest.

Sorting and Cleaning

- Sorting is done by hand to remove fruits which are unsuitable for market or storage due to damage by insects, diseases or mechanical injuries.
- The sorted produce can then be graded according to size, colour and shape.

PRACTICAL SESSION

Methods	Materials
✓ Demonstrate proper harvesting techniques, emphasizing the importance of timing and minimizing damage to the plants. ✓ Train participants on identifying maturity indicators for different vegetables	✓ Harvesting tools ✓ Sample vegetables
✓ Train participants on gentle handling practices to prevent bruising and damage during harvesting. ✓ Discuss the use of suitable containers and methods for transporting vegetables from the field to the packing area	✓ Baskets ✓ Crates ✓ Handling equipment's
✓ Demonstrate sorting and grading techniques for different vegetables. ✓ Discuss the criteria for classifying vegetables based on size, color, and quality. Engage participants in hands-on sorting and grading exercises	✓ Sorting tables ✓ Grading scales
✓ Discuss suitable packaging materials for different vegetables and packing methods that maintain product quality. Demonstrate effective packaging techniques and sealing methods	✓ Packaging materials (bags, crates, boxes) ✓ sealing equipment
✓ Train participants on conducting quality control checks for vegetables. ✓ Discuss common defects and how to identify them. ✓ Conduct a practical session where participants assess the quality of harvested vegetables	✓ Quality control checklists, magnifying glasses
✓ Conclude the training with a Q&A session, allowing participants to share their experiences and ask questions about vegetable harvest and postharvest management. ✓ Encourage knowledge sharing among participants	✓ Open forum

MODULE 5: RECORD KEEPING AND SAFETY PRECAUTIONS

Learning Objectives

- Participants should be able to establish and maintain systematic record-keeping practices for agricultural activities.
- Ensure participants are well-versed in safety protocols and precautions associated with handling BSF fertilizers.

Interactive Discussions

Step one : Ask farmers if they keep farm records.
Step two : Let them explain how they do it.
Step three : Discuss the safe measures to employ when using BSF frass.

Key Message : Record Keeping

Objective : Record and track all inputs used in vegetable production, including seeds, fertilizers, pesticides, and growth regulators.

Details to Record

Date of Application : Document the dates when seeds are planted, fertilizers are applied, and pesticides are sprayed.
Type an quantity of inputs : Specify the type, brand, and quantity of seeds, fertilizers, and pesticides used for each crop.
Application Rates : Record the rates at which fertilizers and pesticides are applied per unit area.

Planting and Harvest Records

Objective : Document planting and harvest activities to track crop development and yield.

Details to Record

Planting date : Note the dates when seeds or seedlings are planted.
Harvest dates : Record the dates of each harvest for different crops.
Yield per harvest : Document the quantity of vegetables harvested during each harvest.

Pest and Disease Monitoring Records :

Objective : Keep detailed records of pest and disease observations to facilitate early detection and intervention.

Details to Record :

Types of pests and diseases : Identify and record the specific pests and diseases affecting crops.
Severity and location : Note the severity of infestations and their locations within the field.
Control measures : Document the measures taken to address pest and disease issues, including the type and timing of interventions.

BSF Frass Fertilizer Safety Precautions

PROTECTIVE GEAR
Wear appropriate protective gear such as gloves, long sleeves, and a mask to prevent direct contact with the frass.

HYGIENE
Wash hands thoroughly after handling BSF frass to minimize the risk of any potential contamination.

DUST CONTROL
BSF frass can generate dust during handling.
Use measures such as dampening the compost or wearing a mask to minimize inhalation of dust particles.

STORAGE
Store BSF frass in a dry and well-ventilated area to prevent mold growth.
Keep it in sealed containers to avoid spills and contamination.

AVOID CONTAMINATION
Prevent cross-contamination by using dedicated equipment for handling and applying BSF frass.
Clean tools thoroughly after use.

REGULATORY COMPLIANCE
Be aware of any local regulations regarding the use of BSF frass as a fertilizer.
Some regions may have guidelines on the application of organic materials.

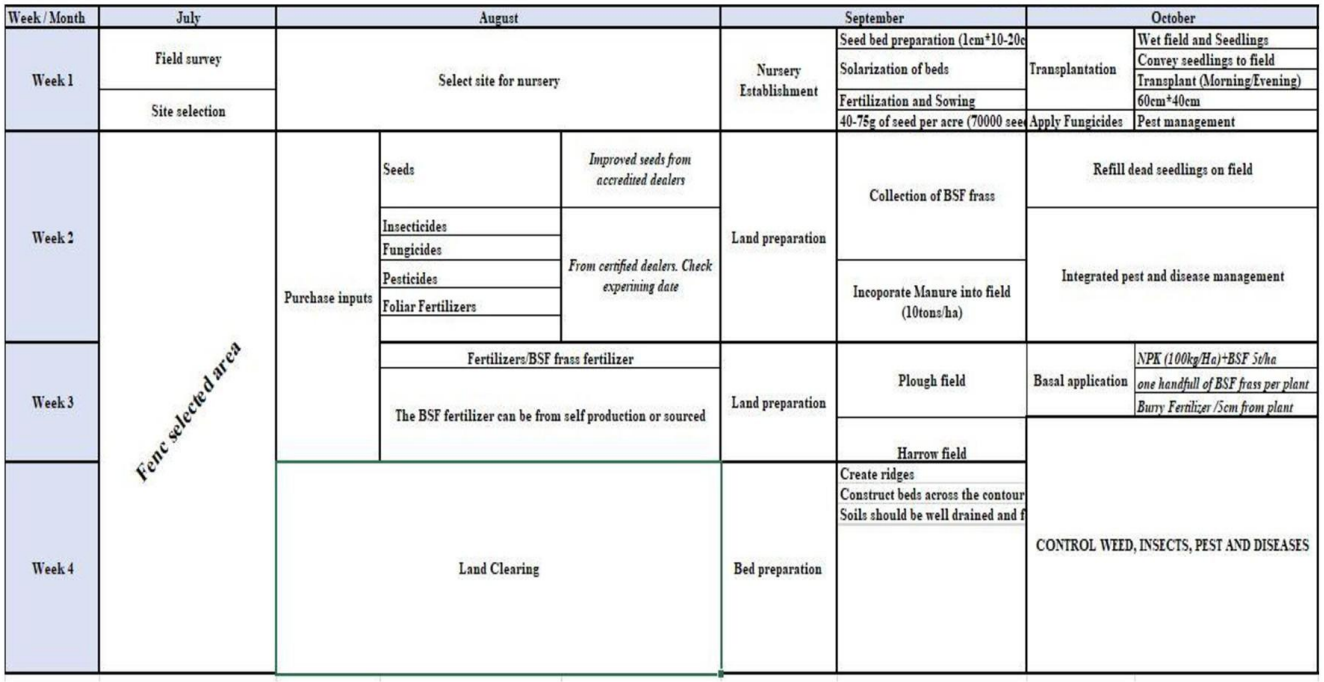


Figure 9 : *Planning calendar for solanacious crops*

Dec		Jan/Feb	
Top Dressing	Apply Urea	1st Harvest	75-85 days after transplanting
	10t/ha BSF fertilizer		harvest at breaker stage (for long distance)
			Harvest at complete ripe stage for local market
Earting-Up	Earth-Up to support crop	Sorting and Grading	Sort into sizes
	Re-shape bed to incorporate fertilizer		Separate quality from non quality
		2nd Harvest	harvest at breaker stage (for long distance)
			Harvest at complete ripe stage for local market
			Yield range from 15-40ton/Ha
		Sorting and Grading	Sort into sizes
			Separate quality from non quality
Staking of plants	Use sticks to support plants	3rd Harvest	harvest at breaker stage (for long distance)
	It prevents fruits from touching grou		Harvest at complete ripe stage for local market
	It prevents end rot, Scalding and inse		Yield range from 15-49Ton/Ha
	Promotes healthy and quality fruits		
		Post Harvest Handling	Avoid fruit injury/do not mix with damaged fruits
			Harvest during cool periods
			Harvest late afternoon or early morning
			Pack tomatoes in wooden or plastic crates

Figure 10 : *Crop planning calendar for solanacious vegetables*