Integrated vegetable seed systems development
in ethnic minority communities in Northern Vietnam
for enhanced nutrition and income security

TRAINING MANUAL ON VEGETABLE SEED SYSTEMS

MODULE 3: SEED PRODUCTION, HANDLING AND STORAGE

NWO
CGIAR INITIATIVE ON Nature-Positive Solutions
Alliance Bioversity & CIAT
WAGENINGEN UNIVERSITY & RESEARCH
FAVRI
TANLOCPHAT SEEDS

COLOPHON

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This module was developed within the framework of the project ***"Integrated vegetables seed systems development in ethnic minority communities in Northern Vietnam for enhanced nutrition and income security"*** (2019 – 2022). The project was part of the Netherlands - CGIAR research programme with project number W.08.240.101, funded by the Dutch Research Council (NWO). The project was implemented by a consortium led by the Alliance of Bioversity International and CIAT, in collaboration with Wageningen University & Research, the Fruit and Vegetable Research Institute of Vietnam, and Tan Loc Phat Seeds Company Ltd. The module was also developed with support from the CGIAR Initiative on ***Nature-Positive Solutions for Shifting Agrifood Systems to More Resilient and Sustainable Pathways (NATURE+).***

MANUAL GUIDELINES

Vegetables are a main source of income and nutrition for ethnic minority farmers in Vietnam's Northern highlands. While value chains for fresh produce and seed markets offer significant opportunities for development—particularly for women and youth—the current smallholder seed systems suffer from multiple problems. Such problems include inadequate access to quality seeds, lack of guaranteed product quality, poor storage and treatment practices, and limited smallholder participation in seed value chains.

The project ***"Integrated Vegetable Seed Systems Development in Ethnic Minority Communities in Northern Vietnam for Enhanced Nutrition and Income Security"*** (2019-2022) aimed to address the mentioned challenges. It focused on enhancing farmers' access to and use of good quality vegetable seeds, allowing higher vegetable yield and productivity, increased income, increased quantity, and more diverse vegetables in their diets.

The training manual, of which this module is part, is based on the project's experiences and lessons learned, particularly through capacity-building activities for and participatory action research with local partners and ethnic minority farmers in the north-western part of Vietnam.

The training manual is designed to assist facilitators in designing and customizing their own training sessions on seed system related topics. Each module provides facilitators with theoretical knowledge, practical experiences and examples from the field, group discussions and exercises to connect theory and practice, reflection questions, and tips/guidance organizing and delivering sessions. At the time of publishing, the manual is made up of four (4) modules.

Module 1	**Integrated Vegetable Seeds Systems,** introduces formal and informal vegetable seed systems, their differences and complementarities, key activities and actors, the relation between food security, seed security and diversity, and how challenges can be addressed through integrated seed systems.
Module 2	**Nutrition, Vegetables and Seeds,** presents the fundamentals of dietary diversity and balanced diet, food sourcing and processing with a focus on nutritious vegetables.
Module 3	**Seed Production, Handling, and Storage,** introduces the principles of seed production, coupled with the project's lessons learnt in providing technical training for farmers
Module 4	**Seed Value Chain Development,** looks at the organization of seed value chains and provides self-assessment tools and guidance for farmer groups interested in producing and selling seeds as a business

Approach

The curriculum incorporates the following training approaches.

Practical, contextualized learning – Uses meaningful and relevant context so participants can have a more engaging and internally motivating learning experience.

Learner-centered – Aims to acitvely involve the participants in the training process, encouraging them to share their knowledge, past experiences, interests, needs, and ideas.

Difficult-to-easy and complicated-to-easy – Helps participants understand the training content, especially the more theoretical and technical concepts.

Learning-by-doing – Provides a space to learn through demonstration and knowledge-sharing activities.

Using the training manual

The manual content largely draws from knowledge relevant to the project sites; however, it caters to a broader audience. It is applicable to other locations in Vietnam and other countries worldwide where information on vegetable seed systems and its relevance to nutrition and income generation are needed.

The manual is intended for agriculture extension officials, local governmental officials, researchers, and development workers involved in strengthening the seed and vegetable sectors. Each module of the manual provides key concepts, practical examples, discussions, and exercises to bridge theory and practice. It serves as a guide for designing and delivering training on seed system-related topics. While not fully comprehensive, the modules focus on essential concepts and provide references for further learning.

Throughout the curriculum, icons are used to indicate the function of each part.

Section learning objectives

Enumerates what participants are expected to learn in each session.

Facilitator notes

Emphasizes the main content which facilitators can use during training delivery.

Link to reality

Provides practical approaches that the facilitator can use to stimulate learning and convey the theoretical content.

Reflections

Highlights questions that can be used to encourage participants to reflect on the key content covered in the section.

Stories from the field

Presents real-life examples from the project on ***"Integrated Vegetable Seed Systems Development in Ethnic Minority Communities in Northern Vietnam for Enhanced Nutrition and Income Security".***

Learn more

Provides information on additional readings and links which facilitators can access to better understand or present the concepts in each module.

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INTRODUCTION

Quality seed is an essential initial input for healthy vegetable crops and good yields; however, smallholder farmers often face multiple challenges in seed production such as insufficient seed availability and quantities, poor post-harvest handling practices, lack of facilities or equipment, poor access to agricultural inputs (e.g., fertilizers), and lack of skills and knowledge related to crop and seed management [1]. The ability to produce seeds for future growing seasons and possibly for sales could therefore provide them with an opportunity to secure their local seed resources, reduce input cost, and to increase their incomes.

Seed quality encompasses four key dimensions: genetic, physical, physiological and health quality. To produce formally certified seeds that satisfy all these attributes, producers must strictly adhere to the technical procedures of their selected seed crops and regulatory requirements. Our focus for this module, however, is to equip small-scale farmers with knowledge of fundamental principles and skills in key practices of vegetable seed production so that they can produce quality seeds that meet expectations. As such, this module provides practical guidelines for the complete cycle of seed production, harvest, seed treatment, and storage with a focus on H'mong mustard, French bean, and pumpkin.

The module draws on the project's experience in conducting seed production training and joint experiments with ethnic minority farmers in Northern Vietnam. Facilitators can make use of the information from this manual to design their own training sessions and use the exercises as inspiration to engage participants and build on their personal experience and insights.

The module consists of six (6) sections as listed below.

Section 1: Seed type, quality, and influencing factors

Section 2: Preparation before planting

Section 3: Seed sowing and seedling management

Section 4: Management of crops for seed production

Section 5: Seed harvesting and storage

Section 6: Seed production for commercial purposes

GENERAL LEARNING OBJECTIVES

At the end of Module 3, the participants will be able to:

- Describe and interpret key attributes of seed quality.
- Understand the differences between vegetative and generative starting materials, and between cross-pollinating and self-pollinating crops.
- Understand and describe the different steps and guidelines to ensure quality seed production;
- Apply guidelines for quality seed production during preparation, planting, seed crop management, harvesting and storage, based on the local context and conditions.
- Describe important requirements of quality seeds and opportunities for income generation from producing seeds and seedlings.

SECTION 1: SEED TYPE, QUALITY, AND INFLUENCING FACTORS

Starting materials are parts of a plant that can grow and develop into a complete, independent plant after being separated from the parent plant. Vegetables are diverse in terms of genotypes, varieties, cultivars, and species, so the starting materials are also diverse (i.e., seeds, tubers, roots, bulbs, cuttings, etc.). Each group of seed materials has its own advantages and disadvantages. Identifying the plant organs used for seed production is crucial in developing and refining effective seed production and management techniques. This ensures seed quality for production and meets commercialization standards.

This section introduces methods to distinguish different groups of starting materials, assess seed quality, and identify factors affecting it. It also proposes solutions to enhance the quality of true seeds.

Section learning objectives

By the end of the section, the participants will be able to:

- Distinguish the difference between vegetative and generative starting materials.
- Describe key attributes of seed quality and select the methods to assess them.
- Distinguish self-pollinated from cross-pollinated vegetable crops.
- Identify the considerations along different stages of the vegetable crop growing cycle to ensure seed quality.

1.1. Seed types and their characteristics

Seeds (i.e., starting materials) are classified into two groups based on how they are commonly reproduced in practice: vegetatively and generatively:

- **Vegetative reproduction** involves utilizing vegetative organs to cultivate a new plant. This method is common in crops such as sweet potatoes, potatoes, cassava, sugarcane, water spinach, sauropus, strawberries, and taro. Propagating from vegetative organs is relatively simple and maintains the genetic purity of the strain, but it often has a low multiplication ratio. It is susceptible to infections and the spread of various fungi and diseases (e.g., Navarette et al., 2022) [2]. Additionally, it presents challenges in handling, packaging, transportation, and post-harvest preservation.
- **Generative reproduction** involves using true seeds resulting from pollination and fertilization between male and female reproductive parts. Generatively propagated crops include cabbage, green mustards, lettuce, kohlrabi, wax gourd, pumpkin, cucumber, chili, cauliflower, broccoli, bitter gourd, legumes, etc., where true seeds are produced and used as starting materials. This method typically results in a higher multiplication ratio but demands careful plant management, particularly during flowering and pollination stages, to maintain strain purity. Pollination can be either self or cross-pollination, with the development of fruits and seeds being crucial. Cross-pollinated crops are at risk of genetic impurities, influenced by external factors like pollinators (insects, wind), humidity, and environmental temperature. Moreover, accurate timing of fruit/seed harvest is essential to ensure physiological maturity. The process of handling fruits, seed separation, drying and preservation significantly influences seed quality, prolongs preservation, germination rate, and seedling formation in the following crop season.

This module focuses specifically on the production of true seed, which is the result of successful pollination and fertilization through mating between male and female flowers. Thereby, the term 'seed' used hereafter will refer exclusively to true seeds.

H'mong mustard seeds are formed through the natural pollination process, inheriting genetic characteristics from both parent plants

Link to reality

Group exercise: Vegetable sorting based on practical reproduction means

This exercise aims to facilitate learning among participants on classifying vegetables based on their practical propagation methods.

Instructions

1. Divide the participants into groups of 3-5 people.
2. Distribute picture cards of various vegetables to each group.
3. Ask groups to classify the vegetables based on their propagation method.
4. After 10 minutes of group discussion, bring everyone back together and ask each group to present their classification and reasoning.
5. As a follow-up, ask the participants which of the vegetables they plant are vegetatively propagated or generatively propagated.

1.2. Seed Quality

Seed quality is a determining factor in the success of crop production. This is formally considered and evaluated based on four main attributes: genetic, physical, physiological and seed health [3].

- **Genetic quality** refers to the degree of genetic purity, stability, and uniformity of a particular plant variety or crop. It is the ability of the seed maintain its typical traits of a variety such as appearance, taste, nutrition content, and others. This includes high yield, pest and disease resistance, or drought tolerance when the seed is multiplied. Maintaining genetic quality in crop production ensures consistency in crop performance and preserves the desired traits of the crop, leading to improved food security and sustainability.
- **Physical quality** refers to the physical attributes of seeds, which can affect seed germination and overall plant performance.
- **Physiological quality** is an essential factor that can significantly influence seed germination, seedling emergence, and crop performance. It refers to the inherent physiological characteristics of seeds, such as their viability, vigour, and longevity.
- **Seed health** refers to the presence or absence of diseases in or on the seed. Seed-borne pathogens include fungi, bacteria, viruses, and pests such as nematodes and insects.

To align with these quality attributes, the project provided guidance and support to some households on crop production and on-farm management, focusing on crop-specific isolation methods, and selection techniques during harvesting. Key recommendations included avoiding harvesting fruits at the top for H'mong mustard, cabbages, selecting middle pods for beans, and choosing large and uniform fruits for pumpkin to obtain uniform and quality seeds. After two years, the households expressed satisfied with the quality of the seed they grow. However, they are concerned about about the need to discard a significant quantity of seeds, which they viewed as wasteful, the labor-intensive nature of seed production.

It's important to recognize that farmers may not consider all four quality indicators when evaluating seed quality. This varies depending on the seed material, production purpose, crop importance in livelihoods, and ecological conditions. For example, the quality requirements for seedlings might differ from seeds for crops like cabbage, lettuce, broccoli, kohlrabi, or the quality of sweet potato vine cuttings compared to tubers, and the quality standards for onion and garlic bulbs might differ from those for potato tubers. When growing vegetables for family consumption, the requirement for genetic purity is usually not as important as the germination rate and the ability to form seedlings, but it becomes essential when growing for sale.

For projects that aim to support farmers' seed production, understanding their own perspectives on seed quality is as important as helping them meet the established quality requirements of seed production. This insight is key to evaluating and refining the essential technical aspects of on-farm seed production, ensuring alignment with the specific needs and circumstances of the farmers.

Table 1: Key attributes of seed quality and assessment methods

Key attributes	Assessment method
Genetic quality	Features (colour, taste) and their stability from generation to generation
Physical quality	Shiny, big, and firm seed; uniform size, weight and colour; free from stones, dust, debris, weeds, and absence of damaged or empty seeds
Physiological quality	High germination rate, long storage (seed longevity)
Health quality	Free from seed-borne diseases and insects

Stories from the field

Challenges in ensuring quality seed attributes among ethnic minority farmer in Northern Vietnam

Ethnic minority farmers in Sa Pa township (Lao Cai province) and Mai Son district (Son La province) of Vietnam face challenges in ensuring quality seed. These challenges arise in both their own seed production and when purchasing seeds from external sources.

In on-farm seed production, particularly with cross-pollinated crops like cabbage and H'mong mustard, maintaining genetic purity is a major challenge. Farmers often use the same plants for both consumption and seed production without proper isolation or removal of different varieties. This leads to genetic impurities, affecting the subsequent generation's genetic purity. The H'mong ethnic group, primarily focused on home consumption, may be aware of mixed varieties but do not prioritize purity or uniformity (i.e., trait similarities) among plants in a land plot. On the other hand, the Dao (Sa Pa) and Thai (Mai Son) communities have concerns and restrictions regarding impurities (i.e., trait dissimilarities) among plants in a land plot, particularly when growing vegetables for sale. However, if crops are solely for home consumption, they allow natural pollination and do not emphasize variety separation and/or removing undesired plants.

Another challenge is ensuring seed cleanliness and uniformity, particularly for crops with small or numerous seeds such as mustard, lettuce, kohlrabi, and cabbage. Cleaning seeds is labor-intensive, often leading to quick sieving practices where thorough cleaning is often not implemented. For example, the H'mong group often separates seeds from dried fruits without further processing. Similarly, when purchasing seeds, ethnic minority farmers also face difficulties in distinguishing and selecting quality seeds.

Hmong farmers discussing attributes of seed quality

Link to reality

Group exercise: Seed quality comparison

This exercise is designed to helps participants distinguish between good and poor quality seeds, and to understand the characteristics that define seed quality.

Instructions

1. Divide the participants into groups.
2. Ask each group the following:
   - What do you consider quality seeds?
   - How would you produce seeds that meet your needs?
3. As the facilitator, prepare two packages of the same type of vegetable seed for each group: one package containing seeds of good quality and the other containing seeds of bad quality.
4. Ask the participants to distinguish between the good and bad quality seeds by having them list the different characteristics (i.e., differences can be based on seed traits such as seed size, colour, shape, and uniformity).
5. Gather the groups and have them compare each other's work and discuss the choices made.
6. Debrief the activity by summarising the key points and highlighting the importance of seed quality in crop production. Use **Table 2** below to remind participants of the criteria for distinguishing good and poor quality seeds.

Table 2: Characteristics of good and poor quality seeds

Characteristics of good quality seeds	Characteristics of poor quality seeds
Big and firm	Small and soft
Shiny	Dull
Uniform	Contain impurities
Full maturity	Too immature
	Too mature or over-ripened
	

1.3. Varietal purity of seeds

As mentioned in the previous section, genetic purity is one of the key attributes of quality seeds. It refers to the uniformity in characteristic traits of a variety and is strictly required for certified and commercialized varieties. For example, according to the Vietnamese Standards (detailed in TCVN 8550:2011, TCVN 8548:2011, TCVN 8557:2011) for crop varieties and seeds, the varietal purity for certified seeds of certain crop types is as follows: mung beans (≥ 99.0%), turnips (≥ 95.0%), kale and sweet potatoes (≥ 98.0%), various beans (≥ 99.0%), pumpkins (≥ 98.0%), and spinach (≥ 95.0%).

Ensuring varietal purity in seed production requires accurate determination of a plant species' pollination and fertilization characteristics. This is crucial due to the risk of cross-pollination among different varieties during pollination and fruit set, which can be effectively mitigated through crop isolation.

Identifying whether a crop is cross-pollinating or self-pollinating is important for seed production. This determination guides the required isolation distance between the seed field and other fields of the same crop to prevent contamination from unwanted external pollens. This contamination can result in a mixture of seeds which carry diverse genetic information and crop traits.

Self-pollinating vegetable crops. Many species of vegetables reproduce by self-pollination. These species are self-fertile, so two reproductive parts (stamens producing pollen and pistils producing ovules, thereby allowing self-mating) are present on the same flower or separate flowers on the same plant. Nevertheless, cross-pollination can still occur to some extent in self-pollinating crop species to some extent, varying among crops and locations from very low (0.2%) to relatively high (e.g., 17.6%) given high seed quantities [4, 5]. The degree of cross-pollination in self-pollinating species is influenced by many factors, including crop species, environmental conditions such as wind, geographical location, the presence of pollinators (e.g, bees, butterflies), flowering time, and the physical distance between plants. Typical self-pollinating vegetable crops include tomato, lettuce, string bean, French bean, peas, chilli, eggplant, okra, hot pepper and sweet pepper. Seed producers are recommended to maintain a short isolation distance (a minimum of 5-10 m between two adjacent fields of two different varieties of the same crop) to produce seeds of these self-pollinating crops to avoid outcrossing (see Section 2.3 below).

Cross-pollinating vegetable crops. Cross-pollinating vegetable crops are those that require a fertilization of pollen from one flower of one plant to the ovule on the pistils of a flower on another plant. Cross-pollination can happen between plants of the same variety and the offspring is rather similar to their parents (in open-pollinating crops) or of different varieties creating the heterogeneous offspring (i.e., hybridization). This type of pollination is typically achieved through various means such as wind and pollinators (e.g., insects, birds, bats, butterflies, bees, etc). Examples of cross-pollinating vegetable crops are cabbage, cauliflower, broccoli, kohlrabi, Chinese cabbage, carrot, radish, mustard, etc. To ensure clean and pure seed production, it is essential to protect seed-producing plants from contamination of external, unwanted pollen carried by pollinators, or wind by applying isolation measures (see Section 2.3 below). It is therefore advised to apply appropriate isolation means for quality seed in case of cross-pollinating vegetable crops.

H'Mong mustard is a cross-pollinated vegetable

Link to reality
Group discussion

This activity is designed to help participants distinguish between self-pollinating and cross-pollinating crops and to understand the importance of pollination in seed production.

Instructions

1. Divide participants into groups.
2. Ask each group to list the crops they have been growing or know. The maximum number of crops listed depends on time availability and is decided by the facilitator.
3. Ask each group to classify the crops based on whether they are self-pollinating or cross-pollinating.
4. Facilitate a discussion on how the types of crops (self-pollinating and cross-pollinating) impact seed production.

1.4. Factors that influence crop growth and seed development

Crop growth and seed development are influenced by a combination of internal and external factors. Internal factors include the genetic makeup and physiological characteristics of the plant, which determine its growth patterns (e.g., short- or long-day plants) and reproductive capabilities. External factors, on the other hand, encompass environmental elements like soil quality, weather conditions, water availability, presence of pests and diseases, and management practices.

Managing and adjusting external factors (excluding temperature for outdoor production) is often more feasible than manipulating internal factors. Therefore, the focus is often on the effective management of external factors so that the seeds produced are of the highest quality. By doing so, farmers can ensure that their crops are healthy, resilient to pests and diseases, and capable of producing high-quality seeds.

The growing cycle of vegetables begins with starting materials (e.g., true seed, tuber, bulb, stems, roots, etc.). For true seed crops, growth triggers are external elements like water trickling through a tiny hole on the seed's surface, and the air or soil temperature reaching a certain temperature for the seed to emerge from dormancy. Table 3 describes the key growth and developmental stages of seed-producing plants and the considerations for seed quality maintenance.

French bean garden in the northern mountainous region of Vietnam

Table 3: Vegetable seed producing cycle and factors influencing crop growth and seed development.

Key stages of vegetable seed growing cycle	Key points for consideration at each stage
Seed germination and seedling formation is the process in which the seedling emerges from the seed hull. The roots continue to develop, uptaking water and nutrient minerals from the soil via root hairs. The leaves start absorbing energy from light to generate foods for plants to grow	Proper moisture of soil/substrate and suitable air humidity Enough light when true leaves are formed Moderate temperature Adequate water supply
Leaf and canopy formation and growth begin when the seedling grows its first sets of true leaves	Soil nutrition and moisture Pests and disease management practices Sufficient water supply Weeding
Flowering marks the end of the vegetatively developmental stage of and a transition to reproductive development to form fruits and seeds. Ư	Isolation needs to be applied properly to avoid hybridization or impurity In case pollination by wind or insect pollinators is difficult due to lack of wind and insects; hand pollination is a practical yet time-consuming alternative
Fruiting. Flowering and pollination pave the way for the vegetable plant to fruit. As a plant nurtures fruits, more energy is expended than other stages during the plant's lifespan. Sufficient water and nutrients are needed for fruits to reach optimal weight and physiological maturity.	Soil nutrition and moisture Avoid high air humidity and prolonged, heavy rains Moderate watering The degree of fruit and seed maturity is important as it determines seed vigour and longevity. Aged seeds would reduce their viability and deteriorate quickly. Harvesting unripe fruits usually result in smaller, immature, or underdeveloped seeds
Note: Pest and disease management needs to be considered and implemented throughout the vegetable seed production cycle, and during seed processing and storage stages.	

Hmong mustard plants in the flowering stage

Link to reality

Group discussion

The aim of this group discussion is to encourage the participants to share their own experience in what needs to be considered as seed producers along the vegetable seed production cycle.

Instructions

1. Training participants list common vegetables typically grown and saved for seeds. They should choose 3 to 4 main locally grown vegetables to discuss.
2. Choose between two options. The choice depends on the facilitator and members to determine the most effective approach.
   - a) Discuss each vegetable/vegetable group as a whole class; or
   - b) Divide into small groups to discuss individual plants.
3. Assign each group a stage of the seed growing cycle: (i) Seeding and germination, (ii) Leaf growth, (iii) Flowering, and (iv) Fruiting, and ask each group to identify and discuss:
   - Challenges and barriers associated with the assigned stage
   - Key external factors that need to be considered in this stage
   - If applicable, provide the best practices to minimize/ overcome challenges and barriers if any in this stage
4. Each group will present their results for feedback.

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- What are the key attributes of quality seeds?
- What are differences between self-pollinating and cross-pollinating vegetable crops, and provide examples for each group?
- Is it important to distinguish between cross-pollinating or self-pollinating vegetable crops in seed production? and why?
- What are some key considerations for seed producers throughout the life cycle of a seed crop, from seed sowing to seed harvest?

SECTION 2: PREPARATION BEFORE PLANTING

As highlighted in the previous section, seed quality is crucial for the success of vegetable and seed production. Therefore, selecting high-quality seeds for planting is essential. Poor germination, uneven seedling growth, or vulnerability to pests and diseases can lead to reduced productivity or even crop failure. The seed production process involves multiple stages (section 1), and each stage requires specific appropriate techniques.

During seed sowing, factors such as germination rate, germination time, and seedling quality are of utmost concern. These factors help farmers estimate the amount of seeds needed for sowing and avoiding seed excess or shortage. This also ensures timely planting and effective pest and disease management during the seedling stage. The seedlings are highly sensitive to external conditions and diseases transmitted through seeds or soil, such as root rot, damping-off, and leaf blight that cause serious losses of multiple vegetables like eggplants, cucumber, watermelon, tomato, squash, etc. [6, 7]

This section focuses on pre-seeding seed treatment, sowing time, land preparation and isolation, and pre-planting fertilization to minimize these risks.

Section learning objectives

By the end of this section, the participants will be able to:

- Describe the importance of seed selection and quality on seed germination, seedling emergence, plant growth, and yield.
- Apply their knowledge of seed selection criteria to select high-quality seeds for vegetable planting and seed production.
- Select a suitable land site and appropriately prepare land for vegetable seed production.

2.1. Seed selection and treatment

Seed selection is a crucial step for successful vegetable and seed production. Quality seeds are essential for high seed germination, healthy seedling development, increased yield, and cost savings.

To ensure the use of quality seeds, it is recommended to obtain them from certified or quality declared seed suppliers. Additionally, the following criteria can be applied to identify quality seeds:

- Not mixed, broken or insect damaged
- Big and firm
- Uniformity in size and colour
- Natural in colour and normal shape
- High germination rate (≥ 80%)

Seed treatments before sowing

Proper seed treatment can help to improve seed germination and reduce the risk of seed-borne diseases spreading to crops and accumulation in fields. There are several simple methods that can be used for seed treatment. The following methods are recommended:

- **Warm water soaking:** This method eliminates damaged and floating seeds and minimizes pathogens as much as possible without affecting seed germination. It is suitable for seeds such as pepper, eggplant, tomato, cucumber, carrot, spinach, celery, cabbage, turnip, radish, and various cruciferous vegetables. Soaking seeds in warm water (3 hot water cups mixed with 2 room temperature water cups) for about 30 to 60 minutes before sowing can also be effective in seed treatment. The duration of soaking depends on the thickness of the seed skin. Seeds with pen-point and smaller size, for example, seeds of tomato, gourd, chili, eggplant, celery, carrot, cabbage, only need 20-30 minutes

[8]. After treatment, rinse the seeds and sow them once white roots appear.

- Chemical seed treatment: This method involves using fungicides like Ridomil Gold 68 WG, Daconil 75 WP to soak or spray the seeds at the recommended dose specified on the label. This helps to kill harmful fungi and other pathogens that may be present on the seed coat surface.

Take note that, for small seeds with thin coats such as lettuce, amaranth, and green mustards, soaking may not be necessary. When harvesting seeds from the field that shows signs of fungal infestation, pre-treatment before the subsequent planting season is crucial. Additionally, implementing other measures to reduce harm, accumulation, and spread of diseases through crop rotation with different plant species (e.g., planting rice or corn in fields after growing vegetables, or planting beans and lentils in fields after cultivating cabbage, broccoli, tomatoes, etc.) is advisable.

H'Mong mustard seed

Learn more

Watch videos to learn about the step-by-step instructions for H'Mong mustard and French bean seed production.

Scan QR codes to access the videos

H'Mong mustad video

French bean video

Link to reality

Group discussion

In this group discussion, participants are encouraged to share their experiences with seed selection, germination testing, and seed treatment before sowing vegetable seed.

Instructions

1. Form two to three groups
2. Ask the following questions
   - How do you select seed (i.e., criteria of seeds) for vegetable planting and seed production?
   - Are there reasons for differences (if any) between selecting seeds for vegetable production and for seed production?
   - Do you find that testing seed germination rate is necessary? Why or why not?
   - Have you tested seed germination before? How did you conduct the test?
   - Have you ever applied seed treatment, which, and what was the result?

Stories from the field

A quick simple test of seed germination rate

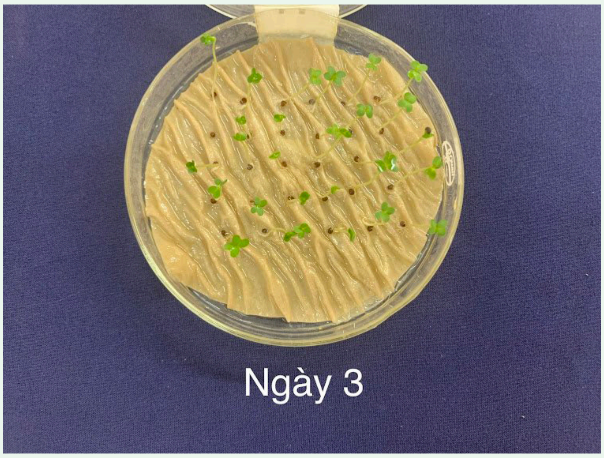
In Sa Pa, H'mong farmers often do not dry and select seeds after separating them from the dried fruits for French bean and H'mong mustard. Consequently, the seeds often get moldy and damaged after storage. The germination rate of the sown seeds is low, resulting in a high number of weak and uneven seedlings. To address this issue, agricultural technicians guided and collaborated with groups of farmers to experiment with a simple method to quickly assess the germination rate of seeds. The method was executed as follows:

1) Prepare the seeds: Place the seeds on a damp paper towel or sponge, spreading them out in individual rows to aid in identification of seed germination afterwards.

2) Cover and keep warm: Cover the seeds after sowing with a clear plastic sheet or cling film to create a warm, humid environment. Keep the seeds in a warm place indoors and check regularly to ensure the towel remains damp.

3) Monitor germination: Germination time varies depending on the vegetable species and variety and surrounding air temperature, but most viable seeds will germinate within two weeks. Check daily for signs of germination and ensure high relative humidity (~ 95%) to maintain growing media, noting the date the roots appear.

4) Determine germination: When no germinated seeds are observed after two to three consecutive days, count how many seeds have germinated (i.e., roots appear). Calculate the germination rate by dividing the number of germinated seeds by the total number of seeds tested. If the germination rate is above 80%, the seedlot has good germination [9]. However, some households accept and feel satisfied with a germination rate of approximately 60% for self-saved seeds due to the abundance of seeds and they have limited land area. Results indicate that some seed samples have a very low germination rate due to damaged or poor-quality seeds. Many households notice the poor germination rates from previous seasons, attributing it to poor soil quality, even when sowing a large quantity of seeds. Swift seed testing helps households prepare a larger seed quantity for the next season and eliminate damaged seeds, resulting in a higher germination rate and more uniform seedlings.



Checking seed germination rate by placing them on a damp paper

2.2. Crop seasonality and timing of seed sowing

Selecting the right time for seed sowing and/or seedling transplanting in vegetable and seed production has a significant impact on the crop yield and quality. Several factors need to be considered, including:

- **Optimal seed sowing and planting window:** This refers to the ideal timeframe for sowing seed and/or seedling planting of a particular crop based on various factors, including the expected maturity date of the crop, the local weather patterns, and the specific needs of the crop.
- **Local weather patterns:** It is crucial to consider the local weather regime and seasonal weather patterns, such as temperature, rainfall, and frost dates/months, to ensure that seed production period falls in a favourable growing season.
- **Availability of resources:** Resources such as water, labour, and equipment should be assessed to ensure adequate support for the seed crop management throughout its growth cycle.

Learn more

H'mong mustard seed production calendars are particularly designed with and for the H'Mong and Dao people in Lao Cai province and Thai people in Son La province, Vietnam

Scan QR codes to access the calendars

H'Mong mustard calendar

French bean calendar

Link to reality

Group discussion

As a facilitator, you can organize a group discussion to encourage participants to share their knowledge and experiences on crop seasonality of their key vegetable seed crops. The crop calendars on H'Mong mustard and French bean seed production that were developed based on inputs from local farmers in the project sites can be used as examples of how the farmers select the time to start their seed crops.

Instructions

1. Gather all participants in one place
2. Ask them the following questions:
   - What factors should be considered when determining the optimal time for sowing seed and/or planting seedlings in seed production? Are the weather patterns importantly considered?
   - What are the potential risks of planting a seed crop too early or too late, and how can these risks be mitigated?
   - How can the availability of resources such as water, labour, land, and equipment impact the selection of planting time for a seed crop, and what strategies can be used to ensure adequate support throughout the growth cycle?

Stories from the field

Optimizing seed production timing: Lessons from project sites in Sa Pa and Mai Son, Vietnam

In Ngu Chi Son commune in Sapa township (Lao Cai province), a seed production group within the project decided to start planting flowering cabbage, flowering kohlrabi, and H'Mong mustard seeds at the end of September or early October. This timing allows for seed harvesting in April of the following year, ensuring good plant establishment before the harsh cold weather in November and December. Planting too early would expose the plants to severe cold when flowering and fruiting, while planting too late would result in plants exposed to heavy rainfall during the fruiting period and potentially affect the rice and corn crops.

On the other hand, farmers from Van Phuc Cooperative in Mai Son district (Son La province) started planting gourd and H'Mong mustard seeds at the end of August or early September. This timing allows for seed harvesting around March and avoids the rainy period from April to August. It also prevents planting during the rainy season and high temperatures, which can lead to premature aging of the plants, nutrient deficiency, and poor seed development.

Similarly, for French bean seed production in Sa Pa, it can be planted for pod consumption from February to April and harvested from August to September. However, the most suitable time for seed production is from late March to early April until July or August. This timing ensures proper flowering and fruiting, although it poses challenges for seed harvesting. Therefore, in the Sa Pa region, proper timing and post-harvest practices, including seed processing and drying, play a crucial role in ensuring seed quality and require careful attention and care.

Farmers in Sapa sowing seeds into trays

2.3. Land selection, land preparation and isolation

The selection and preparation of land for seed production are critical initial steps that significantly contribute to seed germination, as well as successful plant growth and development. They are closely linked with other cultivation and care techniques, such as weeding, fertilization, irrigation, pest and disease control, and the selection or removal of different plant varieties. Land selection involves choosing an appropriate location (plot), assessing soil quality, and considering other related factors like slope, isolation from plots of different varieties, available water sources for irrigation, and the types of crops grown in the previous season.

Selecting a land plot nearby water sources for convenient irrigation

Land selection

Several factors should be considered when selecting land for vegetable seed production, including:

- **Soil quality:** Soils should be well-drained and be free from contaminants, and crop residues of previous crops should be turned down. Soil is ideally fertile, porous (i.e., has good drainage), and good at holding water. In case of acid soils, lime ($CaCO_3$) can be added. For alkaline soils, phosphate fertilizers (e.g., containing $[H_2PO_4]^{-1}$) are a practical option to adjust the soil pH. It is recommended to adjust the soil pH around one to two weeks before sowing seeds. Steep sloping land should be avoided to prevent soil erosion when it rains.

A land plot designated for the production of H'Mong mustard seeds

- **Weather conditions:** Appropriate temperature, rainfall, and sunlight levels are necessary for optimal crop growth (as mentioned in the story from the field above).
- **Water availability:** Having sufficient water resources is crucial, especially because most leafy vegetables need regular irrigation for optimal growth and fruiting. Prioritizing land near irrigation sources like reservoirs, ponds, dwells, or lakes is advisable. In cases where the land is far from water sources, nearby households can collaborate to establish a water distribution system. Additionally, rainwater harvesting can be employed to address irrigation needs during critical stages such as seed sowing, seedling growth, flowering, fruiting, and seed maturation.
- **Pest and disease pressure:** A low level of pest and disease pressure is important to minimize the risk of contamination and damage to the seed crop. Crop rotation, especially with legumes, or ensuring the land plot should not be planted with similar crop varieties in the past two years, or application of soil treatments by water-logging as below prior to seed sowing are recommended practices to mitigate pest and disease risks and enhance soil fertility.

Stories from the field

Adjusting technical guidance on seed production to suit the local context

In the mountainous regions, vegetable seed production faces numerous challenges due to the steep terrain, limited area for cultivation, and low priority given to seed production by farmers.

Firstly, steep terrain can have a significant impact on water availability and distribution for vegetable production. Due to gravity, rainwater runs downhill rapidly, resulting in water runoff and soil erosion, leading to the loss of valuable topsoil and soil nutrients. Steep slopes can also cause water to accumulate in certain areas, leading to waterlogged soil that is unsuitable for vegetable cultivation.

Because of limited area available for vegetable cultivation, farmers also often grow diverse types of crops in a single area, making it challenging to isolate plants for seed production. Moreover, when farmers do not prioritize vegetable seed production, seeds are used to be collected from leftover plants after consuming the leaves or fruits, thereby entailing low-quality seeds.

To address these challenges, several practical and effective solutions have been tested and recommended in practices.

- Dedicating a small plot of land in the garden or field for seed production, if the number of seeds used is not large.
- Applying isolation methods such as physical isolation using nets, time isolation to ensure that vegetable plants flower at different times, and spatial isolation by planting on different plots that are far enough from each other to limit mixed or impure seeds.
- Adding more manure to improve soil nutrients by guiding farmers how to make compost.
- Using soil cover films to stabilize soil temperature (for cold sites) and prevent soil erosion (for sloping land).

The project experience highlights the importance of adapting technical guidance to local conditions and implementing practical solutions to help farmers overcome challenges in seed production in remote areas.

In addition, soil-born diseases can be problematic when the seed crop and the previous crop on the same land plot are the same species (e.g., a mustard season follows a cabbage season). For example, in 2021-2022 seed season for H'mong mustard in one of the project sites, two farmers faced the root fungal disease and lost all their plants due to roots being swollen from the fungus named Plasmodiophora brassicae. The plant roots get swollen when they are big (not at seedling stage) and prior to flowering stage. Crop rotation with paddy rice after a season of growing cabbage or H'mong mustard would be helpful in substantially mitigating this pathogen.

A farmer covering vegetable plants for seed production with a net to ensure isolation

Land preparation

To prepare the soil for planting crops, it is important to plough the soil, remove weeds, and break up large clumps. After this, the soil should be raised into beds that are suitable for the type of seed crop and convenient for irrigation. To improve the soil's resistance to harmful fungi and microorganisms, biological control agents like Trichoderma spp. -based products against multiple fungal and bacterial pathogens [10] can be used or exposing soil to solar heat or water-logging treatment for several (5-7 days) can be used to disinfect the soil if necessary. Several researchers reported that seed treatment had been a successful technique in ensuring the colonization Trichoderma spp. on the root to provide plant benefits [10].

Farmers making raised beds for the cultivation of mustard seed crops

Finally, if possible, the beds can be covered with materials like rice straw or mulch film before planting to preserve soil moisture and warmth during cold months and prevent weed growth.

Soaking soil entirely in water is a simple technical measure of shallow-water crop rotation, creating an unfavourable environment for and thus preventing pests and diseases from arising and causing harm to the following crop. For example, according to the report of Dong Anh Plant Protection Station (Hanoi, Vietnam) in 2014, a field experiment of soil waterlogging showed that, for the water-soaked treatments, the number of pesticide sprays was reduced by 50% compared to the control treatment without soaking. At the same time, natural enemies and other pests and diseases did not differ significantly between the treatments. It is recommended to apply soaking the field before sowing seeds with a soaking time of about 10-15 days for high effectiveness. This will help limit pests and diseases, ensure better yields and promote the production of safe vegetables.

Isolating plants for seed production

Isolation is crucial to maintaining the varietal purity of seed crops. There are three main isolation methods to consider, and it is important to understand the pros and cons of each one to select the most appropriate method.

Temporal or time isolation. This method involves planting different varieties of the same crop at different times to prevent overlap in flowering and prevent cross-pollination. Time isolation is relatively simple and cost-effective, but it may require multiple plantings of the same crop, which can increase production costs and reduce economic efficiency and yield. It is also important to ensure that different varieties of the same crop are not planted in the neighbouring fields.

Spatial or distance isolation. This method involves separating different varieties of the same crop by a certain distance to prevent cross-pollination. The distance required depends on the crop and pollination method. In general, highly cross-pollinating vegetable plants (by insects) such as onion, turnip, kohlrabi, cabbages and broccoli need an isolation space of 800 – 1,000 m, whereas the crops pollinated by wind

Netting is used to cover seed-producing H'Mong mustard plants to prevent cross-pollination like radish needs 2,000 m far. Distance isolation is a relatively simple and cost-effective method that can be used for both self-pollinating and cross-pollinating crops. This method is easy to implement, but it requires land plots distant enough to be effective. Taking care of crops that are grown too far from home could also be challenging and time-consuming.

Physical barriers. This method involves using physical barriers such as cages, nets, or bags to prevent pollinators from accessing the flowers of different varieties of the same crop. Physical barriers can be an effective method for both self-pollinating and cross-pollinating crops. This method can be used in a variety of growing conditions, including field and greenhouse environments. However, it can be labour-intensive which may require frequent maintenance and height adjustment to ensure effectiveness. The net used for crop isolation must be wide enough and not touching the flowers to prevent flower/fruit rotting or drop. The net should be removed once the fruits have formed.

Link to reality

Group discussion

This exercise is meant to tackle participant insights on land selection, particularly on (i) land preparation, and (ii) isolation for vegetable seed production.

Instructions

1. Ask participants form three groups.
2. Encourage each group to share their experiences using the following guide questions.

(i) Site and soil selection:

- What factors do you consider when selecting a land plot for vegetable seed production?
- Have you encountered any challenges related to soil characteristics in the past? If so, how did you address them?
- What improvements can be made in land selection (e.g., location of land plots and soil characteristics) to ensure better plant growth in the next crop?

(ii) Soil preparation and treatment:

- What methods have you used for soil preparation and treatment in the past?
- Have you noticed any changes in plant growth or seed production because of these methods?
- What can be improved in soil preparation and treatment to remove soil-borne pathogens and ensure better plant growth in the next crop?

(iii) Isolation for vegetable seed production:

- What isolation methods have you used in the past for seed production?
- Have you encountered any challenges or limitations in implementing these methods? If so, how did you address them?

2.4. Pre-planting fertilization

Pre-planting or basal fertilization is crucial for providing the necessary nutrients to seeds after germination for the establishment of strong root systems and early growth, while also enhancing soil fertility and promoting pest and disease resistance in plants.

Farmers can choose between organic or chemical fertilizers. Lime can be added in small amounts to reduce soil acidity if needed. Organic fertilizers, such as compost, green manure, and crop residues, are a sustainable and environmentally friendly source of nutrients that can improve soil structure and fertility in the long term. However, making organic compost from animal wastes can be time-consuming and labour-intensive. Organic compost may contain weed seeds or pathogens that can harm crops if not properly composted or sterilized. it is therefore recommended to ensure that compost is well treated (e.g., decomposition of fresh manures at high temperatures) to be safe for crops.

Inorganic fertilizers, such as nitrogen, phosphorus, and potassium, provide a source of nutrients that plants can absorb directly. These fertilizers are easy to apply and can be split into small amounts and application times to specific crop needs. However, excessive use of chemical fertilizers can result in environmental pollution, soil degradation, and decreased soil fertility over time.

The timing and method of pre-planting fertilizer application are crucial to achieving optimum results. The application should be done a few weeks before planting, depending on the type of fertilizers. Fertilizers can be applied using the broadcast or row application method. Broadcast application involves spreading the fertilizer uniformly over the entire field, while row application involves placing the fertilizer in a concentrated band on or near the seed row. Table 4 shows the amount of compost and chemical fertilizers per hectare of French bean seed crop according to the recommendation of Fruit and Vegetable Research Institute (Vietnam).

A training session on how to make compost

Table 4: Recommended amount of compost and chemical fertilizers in seed production of French bean

Pre-planting fertilization		Amount/dose per ha of farm/plantation
Composts		20 ton/ha (720 kg/sao)
Chemical fertilizers	Nitrogen	30kg/ha (1 kg/sao)
	Phosphorus	80kg/ha (3 kg/sao)
	Potassium	30kg/ha (1 kg/sao)

Note: 1 sao = 360 m^2
Source: Fruit and Vegetable Research Institute, Vietnam

Stories from the field

Promoting safe manure management through composting

The practice of using organic manure or compost is still common among the Dao and H'mong farmer groups participating in the project in Sa Pa - Lao Cai. However, decreasing livestock rearing and the need to purchase fresh manure resulted in the direct application of untreated manure. This practice carried risks of bacterial pathogenic contamination (e.g., E. coli, Listeria and Cryptosporidium present in cattles, sheep and deer feces), which could potentially harm consumers and cause the burning of young seedlings due to high nutrient levels.

The project provided local farmers composting techniques and added Effective Microorganisms (EM) to accelerate decomposition process. These beneficial microorganisms, including photosynthetic bacteria, lactic acid bacteria, yeast, and actinomycetes, were incorporated into the composting process aiming at acceleration of organic matter decomposition. This product can be obtained from local agro-input dealers. In practice, EM products are not obligatory but recommended to significantly shorten the composting time. After 2-3 months of composting, the manures transformed into humus-like compost suitable for farming applications.

While some farmers initially found composting labor-intensive due to the preparation and maintenance of compost piles, as well as the waiting period, many households embraced the practice the following year and started composting at home. They recognized the advantages of composting, including increased safety for young seedlings, enhanced soil fertility, and improved plant growth. Composting also provided a more secure environment for vegetable cultivation, reducing the risk of bacterial contamination and ensuring safer vegetable production.

Dao farmers in Can Ho B village, Ngu Chi Son commune, Sa Pa town making compost from manure for seed production

Link to reality

Group discussion

As a facilitator, you can encourage training participants to reflect on their pre-planting fertilization practices and compare with what they learn during the training.

Instruction

Ask participants the following guide questions.

1. Have you applied pre-planting? Why and why not?
2. Have you noticed any differences in crop growth or yield when using organic versus chemical fertilizers as basal fertilizer?
3. How do you determine the amount of basal fertilizers to apply based on the crop and soil conditions?
4. How do you typically apply basal fertilizer (broadcast, row application, etc.) and why do you prefer this method?

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- What factors do you consider in selecting land and soil quality for vegetable and seed production?
- Whether and how do you treat seed before sowing?
- Is the pre-planting fertilization important in vegetable/seed production? How do you apply it in practice?

SECTION 3: SEED SOWING AND SEEDLING MANAGEMENT

Vegetable seeds can either be directly sown in the fields or in a nursery, or on seedbeds covered with transparent nylon. The latter measure protects seedlings from extreme weather conditions. Seed germination and early seedling stages are highly susceptible to abrupt temperature changes and environmental stressors mentioned above.

This practice is particularly recommended for crops that have a longer duration for seedling establishment and/or come with high seed costs, such as cabbage, kohlrabi, Chinese cabbage, cauliflower, broccoli, cucumber, and certain varieties of pumpkins and gourds. Starting seed germination in a nursery or a protected shelter can also provide an optimal environment for seedling emergence.

External factors, such as inadequate or excess water, extremely low or high air and soil humidity, imbalanced nutrition around the root zone, wind, and extreme temperatures can slow down leaf and plant growth. Protecting seedlings indoors or in a shelter, therefore, helps maintain better control, ensure adequate soil and air moisture, and effectively monitor and manage potential plant diseases and pests during the seedling stage.

This section covers direct seed sowing and nursery management, as well as transplanting, to provide valuable insights on effective seedling establishment.

Section learning objectives

By the end of this section, participants will be able to:

- Understand the benefits and drawbacks of direct seed sowing and nursery management of seedlings for different vegetables.
- Apply their knowledge of crop planting to select the appropriate method (direct seed sowing or nursery raising) and carry out successful nursery and transplanting practices.
- Identify areas for improvement in crop planting, nursery raising, and transplanting based on current practices.

3.1. Direct seed sowing

Direct seed sowing involves planting seeds directly in the field where the crop will be grown. This method is commonly used for crops that have large seeds, such as corn, pumpkin, and legumes (beans, and peas). Direct seed sowing is a simple and labour-, cost-effective method. While it eliminates the need for a nursery and transplanting, it requires careful soil preparation and timing to ensure optimal seed germination and plant growth. Below are some tips for direct sowing.

- Sow seeds in rows with moderate spacing, providing enough light for optimal growth of seedlings.
- Mix seeds with powdered soil before sowing and gently rub the soil surface after sowing to ensure the seeds are adequately covered with soil.
- Cover the sown area with dry rice straw, banana leaves, or dry tree leaves to maintain humidity and protect the seeds from direct sunlight and wind.
- Water lightly after sowing 1-2 times per day for the first three days. Once the seeds germinate and sprout, reduce watering to 1 time every 2-3 days to avoid over-watering

3.2. Nursery raising of seedlings

Nursery raising involves sowing seeds in a separate location, such as a greenhouse or a seedbed, and later transplanting the seedlings to the field where the crop will be grown. This method is commonly used for crops that have small seeds or takes time to seedling emergence, such as tomatoes, peppers, kohlrabi, cauliflower, broccoli, and mustards. Growing seedlings in a nursery allows for greater control over growing conditions which can aid in seed germination and seedling growth. However, it necessitates more labour and resources, such as seedbed preparation or sowing substrates, watering, fertilizing, and transplanting.

Sowing seeds in trays to avoid harsh weather and undesirably external conditions and physical damages

Growing seedlings in nursery

There are two methods of seedling production:

- **Direct seed sowing on soil beds** (sowing method can be referred to the direct seeding as mentioned above). This method is applicable to mustards, cabbages, kohlrabi, cauliflower broccoli.
- **Seed sowing on foam/plastic trays with growing media or in nylon bags.** This method is applicable to all crops. This method offers advantages such as decreased seed quantities used and increased seedling uniformity. Growing media for trays or nursery growing bags should be good at drainage and water holding capacity, and contain some nutrients for assuring early growth of seedlings after emegernce. For example, a combination of 40% soil, 30% treated humus (or cocopeat), and 30% compost is recommended. The combination ratio of organic materials can be adjusted based on the material availability at the localities. For example, treated humus or cocopeat can be replaced by smoked rice husk, or rice straw. Compost can be omitted without serious influence on seedling growth but it is necessary to transplant seedlings (with 3-4 full true leaves) early to get sufficient nutrients. After sowing, trays should be placed on a high shelf at least 50 cm above the ground or on a raised bed, and covered with a light transparent material (such as nylon or white plastic sheeting)

Watering during nursery stage

During the nursery stage, keeping the substrates or seedbeds moist is crucial for promoting optimal seed germination and seedling growth. Several factors need to be considered, including:

- **Soil or substrate moisture level:** Before watering, check the soil moisture level by using a soil moisture meter if available, or by manually inserting a finger into the soil or holding the soil firmly in the hands to feel if soil is too sticky (too wet) or fragile (too dry). If the soil is dry to the touch, it is time to water.
- **Water quality:** Seedlings are sensitive to the quality of water they receive. Water should be clean and free from contaminants such as salts, minerals, or other impurities that can affect seedling growth and development.

Watering young H'Mong mustard seedlings

- **Watering method:** Over watering can lead to waterlogging and root rot. Light watering or drip watering is recommended to avoid seedling damage.
- **Timing of watering:** Watering in the early morning or late afternoon is generally recommended as these times tend to be cooler and retaining moist longer, which reduces the risk of water loss due to air drying.
- **Watering frequency:** Seedlings require regular watering to maintain adequate moisture levels in the soil or substrate, especially in the initial stage when the seeds have just been sown and seedling stage. The frequency and amount of watering will depend on several factors, such as the type of crop, the size and age of the seedlings, and the environmental conditions of the nursery.

Pest and disease management during nursery stage

Seedlings are susceptible to a range of pests and diseases that can negatively impact growth and development seedlings and plants after transplanting. Root-related diseases are particularly common during the nursery stage, which can be caused by too much moisture in the soil, seeds sown too deep, or contaminated soil and growing media that contain fungal pathogens. To prevent these issues, consider the following measures.

- Ensure that the soil and growing media are properly treated before sowing (see land preparation for practical measures). In some cases, mixing seeds with Trichoderma spp. -based products or with fungicides can also be effective when direct seeding is applied in the nursery soil.
- Maintain soil moisture levels between 70-80% to avoid over-watering (too wet) or under-watering (too dry).
- Use clean water for watering seedlings to prevent contamination from harmful heavy metals (e.g., lead, Arsenic, mercury) or substances (e.g., nitrate, pesticide residues).

H'Mong mustard plant in nursery stage

Link to reality

Group discussion

This exercise is created to encourage participants to share their experience in direct seed sowing and nursery raising.

Instructions

1. Divide the participants into groups
2. For each group, have them discuss the following guide questions:
    - What is the purpose of seed sowing and seedling raising in nursery?
    - Why is nursery raising important?
    - Why is the seed sowing and seedling formation stage critical to the success of seed crop production?
    - What factors are considered to ensure the healthy development of seedlings during the nursery stage?
    - What are some traditional practices of nursery raising that you know? Compare them with what you have learned during the training.

Stories from the field

Enhancing seedling establishment through protected seedbeds in Sa Pa

The weather in Sa Pa during late summer and autumn is characterized by rain, strong winds, significant temperature fluctuations between day and night times, cold nights, and salt mist. Storms with heavy rain and strong winds have become increasingly frequent in recent years. Additionally the Dao farmers also experienced risks associated with direct seed sowing on-farm for various crops, including H'mong mustard, cabbage, Chinese cabbage, kohlrabi, and broccoli. Challenges include root damage from fresh manure usage, poor growth due to soil fertility issues, and heavy damage caused by striped flea beetles.

Guided by the project, the Dao farmers have adopted a method of sowing and caring for seedlings in simple seedbeds covered with nylon film. Plastic trays were used to sow the seeds, and these trays were placed on the raised soil beds. To protect the seedlings, a light, transparent nylon cover was placed above and around 1-1.5 m over the tray surface. Proper air ventilation was ensured by adjusting the nylon cover, opening it on non-rainy days and closing it during strong sunlight, heavy rains, or cold days to maintain optimal temperature and moisture levels inside.

The implementation of protected seedbeds proved to be successful in seedling establishment for the Dao farmer group. Initially applied to H'mong mustard, the method was later extended to other crops such as cabbage, Chinese cabbage, kohlrabi and broccoli.

Dao farmers protecting vegetable seedlings with a nylon cover

3.3. Transplanting

As the seedlings grow to 3-4 true leaves, they are ready to be transplanted into the fields. It is important to choose healthy, well rooted, disease-free seedlings. Watering and nutrient care should be limited between 3 and 5 days before transplanting. About 4 to 5 hours before transplanting, the seedling trays should be wet to avoid breaking the pot when pulling out the seedlings.

Ideally, transplanting should be done in the cool or late afternoon to allow the plants to adjust to the outdoor environment before direct exposure to the sun, especially in hot weather. When transplanting, handle the seedlings with care to avoid damage to the roots, which can lead to drying out and disease entry through wounded root parts.

The spacing between plants and rows in the field is crucial for crop growth, fruit formation, seed filling, and ultimately seed quality. Dense planting causes competion for light and nutrients among individual plants, leading to weaker growth and smaller fruits, seeds and yield. Additionally, diseases are more likely and easier to spread in densely placed plants. Therefore, it is important to leave enough space and even light interception for the seedlings to receive sunlight and grow properly. Spacing depends on the crop, variety, season, and soil nutrition. For example, for a H'Mong mustard variety with a plant height of 70-80 cm at full plant canopy, it is advised to maintain a row spacing of 45-50 cm and a plant distance of 40 cm. For climbing French beans, common spacing is 60 cm between rows and 40 cm between plants in a row.

Farmers transplanting Hmong mustard seedlings from trays into the field

Link to reality

Group discussion

This exercise is developed to encourage participants to share their experience in seedling transplanting.

Instructions

1. Gather all participants
2. Ask the following questions to guide the discussion
   - How can you distinguish or consider the criteria of good seedlings for transplanting?
   - What are some best practices for handling seedlings during the transplanting process to avoid root damage?
   - How does plant spacing (or plant density) affect crop growth after planting, fruit set, and seed formation? What factors should be considered when determining the appropriate spacing between plants and rows?

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- In what situations would you choose direct seed sowing over nursery raising, and vice versa?
- What measures or management strategies can you take to prevent pest and disease problems in your seedlings during the nursery stage?
- How do you determine the spacing between plants and rows when transplanting seedlings, and what factors influence your decision?

SECTION 4: MANAGEMENT OF CROPS FOR SEED PRODUCTION

After transplanting into fields or beds, plants begin independent growth, and crop management techniques and external conditions greatly influence their development. Leafy vegetables particularly need ample water. Fertilization is also key, providing essential nutrients for healthy growth and development. These nutrients include macronutrients like nitrogen (N), phosphorus (P), and potassium (K); intermediate elements such as calcium (Ca), magnesium (Mg), manganese (Mn), and sulfur (S); and micronutrients including boron (Bo), zinc (Zn), and iron (Fe).

For leafy vegetables, pests like stem borers, leaf-eating insects, hoppers, fruit borers, caterpillars, red mites, striped flea beetles and weevils are common. Some diseases such as root rot, damping-off, leaf blight, root crown, powdery mildew, and downy mildew are also just as common, especially in hot, humid climates. Cooler climates often experience less severe infestations.

Controlling pests and diseases during production can prevent their spread to other plants and to the next growing season. Rouging is a crucial technique, especially for cross-pollinating plants, to avoid contamination.

This section focuses on fundamental crop management practices, including watering, fertilizing, managing pests and diseases, and removing unwanted plants, creating optimal conditions for growth, flowering, fruiting, and seed development.

Section learning objectives

By the end of the section, the participants will be able to:

- Identify and apply the appropriate practices in the practical guidelines for quality seed production, including watering, top-dressing fertilization, pest and disease management, and rouging.
- Analyse the key factors to consider when taking care of seed crops, such as crop type, growth stage, soil nutrient levels, and environmental conditions.
- Evaluate the pros and cons of different crop management practices, such as chemical vs. biological pest control methods, and make informed decisions about their own practices.
- Design and implement their own seed crop management plan, incorporating the knowledge and skills gained during the training.

4.1. Watering

After transplanting, it is important to water the plants every morning or late afternoon to ensure that they receive enough water for root establishment and recovery. Once the roots are established, watering frequency can be reduced to once every two to three days. The amount of water and frequency of watering are decided based on soil moisture, weather conditions and the crop growth stages. During the leaf development, plants need much water. When plants flower, and form fruits and seeds, watering frequency should be reduced to avoid failure of fruit set, and early fruit drop. It is recommended that watering should not be done at noon when the sun is shining and too late in the afternoon to avoid leaf burning and disease infection for the plants. Use clean water sources and avoid water from polluted sources, such as wastewater from industrial processes, hospitals, residential areas, animal raising farms, animal slaughterhouses, stagnant ponds which could carry diseases (plant pathogens), bacteria or heavy metals that are toxic to humans.

Watering French been plants for seed production

Link to reality

Group exercise: Developing watering schedules

This exercise will allow participants to apply their knowledge of watering practices to specific scenarios and engage in discussion with their peers. It will also reinforce the importance of adapting watering practices to the unique needs of each crop and the environment it is grown in.

Instructions

1. Divide participants into groups.
2. Assign each group a specific type of seed crop (e.g., tomato, chili pepper, cucumber).
3. Provide each group with a scenario that describes the current weather conditions, soil moisture levels, and growth stage of their assigned crop.
4. Ask each group to discuss and come up with a watering schedule for their crop based on the scenario provided.
5. Each group will present their watering schedule to the class and explain the factors they considered in determining their schedule (e.g., crop growth stage, weather conditions, soil moisture levels).
6. After all groups have presented, lead a discussion on the different factors considered and the importance of adapting watering practices based on these factors.

4.2. Top-dressing fertilization

Top-dressing is a process of adding nutrients to the soil after the crop has been planted to supplement the available nutrients for crop growth and improving seed yield and quality. Top-dressing fertilization is particularly important in areas with poor soil fertility or where the soil has been depleted of nutrients due to intensive cropping. The practice helps to ensure that the seed-producing plants have the necessary and sufficient nutrients for optimal growth, flowering, fruiting and seed filling, and ultimately good quality seeds.

To ensure proper application of fertilizers, consider the crop type, growth stage, expected yield potential, soil nutrient levels, environmental conditions, fertilizer type and application methods. For example, a crop in its vegetative growth stage may require more nitrogen for leaf and stem growth, while a crop in its reproductive growth stage may require more phosphorus for flower and fruit development. In general, top-dressing fertilization should be done from 2-3 times during the growing season to ensure that the plants have a sufficient, steady supply of nutrients throughout their growth cycle. Usually, the first time is when the plants recover and establish leaves well after transplanting (1-1.5 months after planting), the second time before flowering (2-2.5 months after planting), and the third time when fruits are growing fast.

It is also essential to regularly monitor the crop's nutrient status and adjust fertilizer application as needed to ensure that the crop's nutrient requirements are met. A simple method is to visually inspect the crop for signs of nutrient deficiencies or excesses. For example, uniform yellowing of older leaves may indicate a nitrogen deficiency, while plants with phosphorus deficiency will have stunted growth and their leaves will appear dark green or bluish-green.

For French bean seed, it is recommended to split fertilizer application into three during the crop's growing cycle. The fertilizer should be applied along the furrow between two rows or between two holes, at a depth of 7-10cm, and then covered with soil to prevent nutrient loss.

Below (Table 5) are recommendations provided by the Fruit and Vegetable Research Institute in Vietnam on the amount and types of fertilizer, as well as the time of application for French bean seed crop. It is important to consider the amount and time of application as they can be adjusted based on the exact growth, developmental status of plants on the fields, and soil fertility.

A farmer applying top-dressing fertilization to her French bean seed crop

Table 5: Recommended amount and time of top-dressing fertilization for French bean seed crop

Fertilizers	Top-dressing fertilization		
	1st application	2nd application	3rd application
Time of application	10-15 days after sowing	25-30 days sowing	40-50 days after sowing
Nitrogen (N)	20 kg/ha	30 kg/ha	20 kg/ha
Potassium (K_2O)	30 kg/ha	30 kg/ha	10 kg/ha

Source: Fruit and Vegetable Research Institute, Vietnam

Link to reality

Group exercise: Fertilization and nutrient management practices

This group discussion will focus on nutrient management of vegetable seed production. The discussion can be in a whole group or in smaller groups of 4-5 participants which is decided by the facilitator.

Instructions

1. List vegetables that farmers are used to save seeds
2. Per vegetable crop, the questions below are discussed:
   - What types of fertilizers do you apply?
   - Why and when do apply these fertilizers?
   - What are your experiences in terms of effect of these fertilizers on crop growth?

4.3. Pest and disease management

Vegetables in general are vulnerable to a wide range of pests and diseases, which can lead to significant yield losses and seed quality degradation. Aphids, thrips, whiteflies, and leaf miners are common pests that can harm vegetable seed-producing plants. Powdery mildew, downy mildew, and bacterial diseases like bacterial blight and bacterial wilt can all be detrimental to vegetable seed crops.

Regular plant monitoring and scouting are essential for early detection and intervention, lowering the risk of severe pest and disease damage to vegetable seed crops. To prevent pest and disease outbreaks in vegetable seed crops, it is recommended to use integrated pest management (IPM) practices that emphasize the use of cultural and mechanical, biological, and as last resort chemical controls.

- **Cultural and mechanical measures** include pest and disease management practices such as crop rotation, sanitation, removing disease-infected residues, and the use of insect traps. Crop rotation is the practice of growing different crop species in the same field to reduce pest, disease accumulation and pressure. Pest and disease populations can be reduced by sanitation practices such as removing crop debris and weeds. Trap crops are pest-attractive plants that can be used to divert pests away from the main crop. These measures reduce the use of synthetic pesticides while encouraging the use of preventive measures.
- **Biological controls,** such as beneficial insects, microbial agents, and biopesticides, are used to manage pests and diseases. These measures are environmentally friendly and promote sustainable agricultural practices. To control pest populations, beneficial insects such as ladybugs and lacewings can be introduced into the seed crop field. Plant diseases can be controlled using microbial agents such as bacteria and fungi, such as Trichoderma spp. biopesticides refer to products containing biocontrol agents – i.e., natural organisms or extracted substances derived from natural materials (such as animals, plants, bacteria, or certain minerals) for controlling pests [11]. Biopesticides are considered as an environmentally friendly and safer measures for users and advised to use if available.
- **Chemical measures** entail the application of synthetic pesticides and fungicides to control pest and disease outbreaks. These measures are fast effective, but they can be harmful to the environment around and human health. When all other methods have failed to control pests and diseases under an acceptable level, chemical measures should be used as a last resort. When using synthetic pesticides and fungicides, it is recommended to allow at least two weeks between the last spraying of chemical pesticides and harvesting time.

Circular 19/2021/TT-BNNPTNT by the Vietnam's Ministry of Agriculture and Rural Development provides information on the pesticides and herbicides that are and are not permitted for use in Vietnam. The circular is updated regularly, so staying up to date on the most recent list of pesticides approved for use is critical. Farmers should consult with extension workers for the most up-to-date information.

LEARN MORE

Circular No. 19/2021/TT-BNNPTNT provides the list of pesticides permitted for use in Vietnam.

Scan QR code to access the Circular

Link to reality

Group exercise: Developing pest and disease management plans

This exercise aims to facilitate discussions among training participants about the common types of pests and diseases encountered in local vegetable/vegetable seed production. It focuses on the preventive and control measures applied. Additionally, it helps learners compare the theory they have learned with the techniques applied in practice, and encourages them to share techniques and experiences with each other.

Instructions

1. Divide participants into groups.
2. For each group, identify three to four most important vegetables grown that will be the focus in the discussion.
3. Based on their assigned crops, ask the participants to list the major/most encountered pests and diseases with the typical symptoms, time of serious infection, and controlling measures if applicable.
4. Each group should then present and discuss their management plan with the larger group, highlighting the specific pest and disease challenges they identified for their crop, and the strategies they developed to address those challenges.

Facilitator notes

Summarize the key takeaways from the activity, emphasizing the imporance of proactive pest and disease management in seed production, and the need to tailor management strategies to the specific needs and challenges of each crop.

4.4. Rouging

Rouging is an important technique in seed production that involves removing plants that do not meet the desired characteristics of the crop. The purpose of rouging is to maintain seed purity, ensuring that only quality seed is produced. Rouging is important for vegetable crops that are grown from hybrid seed and for vegetables that are prone to cross-pollination (e.g., with out-crossing with other varieties).

When performing rouging, it is essential to also remove plants that do not meet the desired characteristics of the crop, such as those that are diseased or have poor growth (i.e., bad-looking plants). This includes removing plants that show signs of cross-pollination or that are different from the parent plants based on characters such as plant height, time of flowering, leaf and stem colour, leaf shape, flower colour.

Rouging should be carried out during the full seed production process. However, there are two stages of it which are of specific importance as they remove as many of the unwanted plants as possible:

- **Before flowering:** The removal of unwanted plants at this stage are often conducted based on characteristics of stem and leaf colour, leaf shape, leaf angle, plant height.
- **During flowering:** Characteristics such as branching ability, flower colour, time of flowering, flower shape and size should be considered when rouging is performed at this stage.

In addition, at post flowering, rouging is still recommended to optimize varietal purity, and should be done based on the fruit-related characteristics such as fruit shape, size, colour.

It is highly important to do rouging before flowering when there has not been cross-pollinating between male and female flowers (especially in cross-pollinating crop species) to ensure the genetic purity quality of seed. This prevents the formation of undesired fruits and seeds, which can be difficult and costly to remove later in the crop cycle. Otherwise, farmers must wait until the next season when they sow the seeds and grow new plants to see if the plants are uniform or not.

Rouging is also recommended before using an isolation net (if distance isolation is not possible) to ensure plant uniformity and to prevent the spread of pests and diseases.

Stories from the field

Rouging practices in seed production: Insights from Dao and H'mong farmers

Rouging is the process of removing undesirable or off-type plants from a crop field to maintain varietal purity and enhance seed quality. For the three farmer groups that the project worked with, rouging is primarily focused on seed production for sale, while vegetable crops consumed at home this practice is rarely done.The Dao farmers expressed a lack of interest in rouging as they consider the leaves of their crops as edible regardless of varieties, making varietal purity less important. The diverse morphological characteristics of the H'mong mustard variety in their region, including variations in leaf shapes and colors, can be attributed to the limited or non- rouging practices.

After receiving guidance on rouging practices, the farmers actively implemented rouging specifically for seed production plots. They also strictly employed the rouging practice and spatial isolation to ensure varietal purity for H'mong mustard vegetable, which is sold in local markets and for tourist-oriented restaurants in the Sa Pa town.

By the second year of the experiment, the farmers had gained confidence and actively implemented rouging practices for these H'mong mustard varieties. Importantly, the knowledge and skills acquired through the project were shared with other households that did not participate in the experiment and training, expanding the adoption of rouging practices within the community.

A hand-on training session on rouging techniques

Link to reality

Rouging practice exercise

This activity aims to help participants comprehend the significance of rouging in seed production, and to provide an opportunity to practice recognizing and eliminating plants that do not meet the crop's desired characteristics. Conducting this exercise in the field can offer farmers a more practical and realistic experience, allowing them to apply the knowledge they gained during the training to actual situations. If fieldwork is not feasible, picture cards of plants can be prepared instead.

Instructions

1. Divide participants into pairs or small groups.
2. Provide each group with a set of potted plants or pictures of plants, some of which meet the desired characteristics of the crop and some of which do not.
3. Instruct the groups to visually inspect each plant and identify which ones should be removed based on the characteristics discussed in the training (such as plant height, leaf shape, leaf colour, flower colour, etc.).
4. Each group should then remove the plants they identified as undesired and explain to the larger group why they chose those plants.
5. After all groups have finished, have a group discussion on the importance of rouging in seed production, and the criteria to consider when selecting plants to remove.

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- What factors do you consider when watering plants in vegetable seed production?
- What types of the nutrients are important for vegetable seed production?
- What are common pests and diseases and their typical symptoms that participants encounter in vegetable seed production?
- What are measures applied in preventing and/or controlling the identified pests and diseases?
- Is it important to do rouging in vegetable seed production? And why?

SECTION 5: SEED HARVESTING AND STORAGE

The biggest threats to seeds during storage are moisture, heat, pests and diseases. Harvesting, seed handling and processing, and storage are critical components of the seed management pipeline, spanning from seed sowing in the current season to providing starting material for the next.

Sun-drying, either natural drying under the sun or hanging over the stove, is the most common method among rural and remote ethnic minority farmers. Challenges in post-harvest management often include high humidity, lack of sunshine, and prolonged rainfall. Additionally, the absence of facilities such as dryers, fridges, and freezers poses significant constraints for these farmers.

Improper practices during post-harvest can lead to insufficient seed or full loss for the next season. Therefore, to ensure high-quality seeds for the next planting cycle, it is important to have precise harvest timing, proper seed processing, and effective storage. These aspects hold immense importance, equivalent to the processes involved in seed production in the fields, especially when seeds need to be transported over long distances or enter the commercial market. In this section, we will explore selecting the appropriate harvesting time, seed handling techniques, and storage practices to ensure optimal seed quality.

Section learning objectives

By the end of this section, the participants will be able to:

- Analyse and select the appropriate practices in the practical guidelines for seed harvesting and post-harvest practices.
- Describe the key factors to consider when harvesting, processing and storing seeds.
- Evaluate the pros and cons of different seed harvesting and post-harvest practices.

5.1. Harvesting time

Proper harvesting timing can increase seed viability, germination rate, and ultimately the yield of high-quality seeds. Harvesting too early can result in immature seeds that are not viable, while harvesting too late can lead to over-ripeness and poor seed quality.

The optimal time to harvest seed crops depends on various factors such as the crop species, cultivar, environmental conditions, and intended use of the seeds. It is important to monitor the crop regularly and harvest when the seeds have reached their maximum maturity. This can be determined by visual and physical indicators such as seed colour, shape, and size.

For example, for leafy green mustards and their family crops, seed harvest is when plants no longer have top flowers, their fruits turn yellow-green (straw yellow), and are full of seeds. For legumes, seed harvesting occurs when the pods turn yellow and become relatively dry. For crops like tomatoes, eggplants, peppers and cucurbits, the seeds are collected when the fruit is fully ripe.

When harvesting seed crops, weather conditions should be considered to ensure the best possible quality and quantity of seeds. Harvesting during wet conditions can increase the risk of seed spoilage and fungal diseases. It is best to harvest when the weather is dry and sunny.

Hmong mustard plants on the left are too young for harvesting seed as they are still green, while the plants on the right that have fruits turning yellow should be harvested

Stories from the field

Seed harvesting practices for enhanced seed quality

Previously, the timing of seed harvesting among the farmer groups participating in the project's joint experiments was based on convenience and their time availability rather than the actual maturity of the fruits such as changes in fruit color or changes on the plant. In Mai Son, Thai farmers often cut the seed plants and left them in the fields until both the plants and fruits are completely dry. In Sa Pa, the Dao and H'mong farmers wait for the plants to dry completely before harvesting. This practice resulted in a significant loss of seeds, as the seeds are often uneven in size, color, and prone to quick deterioration. Additionally, unpredictable weather conditions could lead to seed rotting. Farmers lacked knowledge regarding the optimal time for seed harvesting and often made decisions based on their own availability or the apparent dryness of the plant.

After participating in the project and conducting the joint experiments with researchers, most farmers have changed their seed harvesting practices. They now determine the optimal time to harvest seeds based on fruit ripeness, indicated by the yellowing of the fruit skin. Instead of leaving the plants in the field, they cut the entire plant, such as H'mong mustard, and bring it home for drying. If it is sunny, the plants are dried near their houses, and if not, they are hung in kitchen attics. This approach allows for better control over the drying and seed extraction process, minimizing seed loss and ensuring more uniformity in seed maturity and size.

The adoption of improved seed harvesting practices has yielded positive outcomes for the farmer households. By harvesting seeds at the optimal time when fruits are ripe and the fruit skin turns yellow, they have achieved higher seed quality. The reduction in seed loss and improved uniformity in seed maturity and size contribute to better seed performance and crop productivity. Furthermore, with enhanced seed quality, households have been more inclined to share seeds with their siblings, relatives, and neighbors, promoting local seed exchange.

Hmong farmers in a training session on seed harvesting techniques.

Link to reality
Group discussion

The purpose of this group discussion is to explore the factors to consider when determining the optimal time to harvest seed crops.

Instructions

1. Divide participants into groups.
2. Provide each group with a list of common vegetable seed crops or varieties, and their average days to maturity.
3. Ask each group to discuss the criteria they would consider when deciding when to harvest each crop for seed production. Encourage group members to share their own experiences and knowledge of each crop.
4. After 10-15 minutes of discussion, have each group present their recommendations for when to harvest each crop. Encourage group members to explain their reasoning and the factors they considered.
5. Facilitate a larger group discussion on the similarities and differences between each group's recommendations.
6. Discuss any disagreements if any, and the pros and cons of different approaches to determining the best time to harvest seed crops.

5.2. Harvesting process

The harvesting and post-harvest process of vegetable seeds can vary depending on the crop type. For crops such as H'mong mustard or other Brassica family crops, the plants are cut off and tied into bunches and hung upside down in a cool and dry place with good air ventilation to allow the seeds to ripen further and naturally dried. For legumes, such as beans or peas, the pods are harvested and the seeds are separated. For crops that produce fruits such as tomatoes, eggplants, peppers, and cucumbers, the fruits are harvested and the seeds are separated by cutting and pressing them. In some cases, such as with eggplants and tomatoes, the mature fruits may need to be fermented for 1-2 days to make it easier to get seeds.

After the seeds are harvested and separated from the fruit/plant, they must be properly dried, as excess moisture can lead to spoilage and reduce seed viability.

Drying

Drying is a crucial step in seed management that aims to adjust the moisture content of seeds to a storable level, usually around 6 - 15 %, depending on the crop type [9]. The moisture content of the seeds is a critical factor in seed storage and longevity, as high moisture levels are favourable for fungal pathogen growth and other forms of seed deterioration.

Vegetable crops, such as beans, peas, typically require the drying of the pods before the seeds can be extracted. Once the pod is cut off from the plant, it still contains moisture that can lead to mold growth or rotting of the seeds, or seed germinating when fruits/pods are still on the plants (e.g., for French bean, pumpkin) if not properly dried before threshing.

One simple drying method involves spreading the vegetable pods out in a thin layer on a sheet, tray, mat, or flat basket in a well-ventilated area for 1-2 days. The thin layer will help the seed pods dry faster. However, it is essential to avoid placing the pods and seeds directly on a concrete or brick floor, as they may get dirty, wet, or eaten by animals or get burnt if it is too much sunlight.

Farmers spreading French bean pods on a tray for sun-drying.

If the weather is not favourable for outdoor fruit/ pod and seed drying, such as during rainy and humid periods, pods can be dried indoors with the aid of an electric fan to prevent damage to the seeds from too high air humidity. Soft or immature pods should be removed as they may cause the seeds to spoil during drying. After drying, the seeds can be extracted from the pods and can be dried a bit further to be fully dried before being stored in a cool, dry place until they are used or sold.

Threshing

Threshing is the process of separating seeds from their pods and other parts of the plant. Before threshing, it is important to ensure that the fruits/ pods are thoroughly dried to prevent damage and spoilage. Depending on the type of crop and the scale of production, different methods can be used. Small-scale threshing can be done by hand, such as using a wooden stick to beat the seed heads against a hard surface or rubbing them between hands to release the seeds. For larger scale production, threshing machines or specialized equipment may be used to separate the seeds from the plant or fruit.

Winnowing

After threshing, the seeds should be windowed to remove entirely chaff, debris, weeds, or empty seeds. This can be done manually by tossing the seed and debris mixture in the air and allowing the wind to blow away the chaff, or by using mechanical equipment such as a fan.

A Thai farmer winnowing French bean seeds after threshing

A Hmong farmer using her fingers to check seed dryness before storing the seed

Seed dryness checking prior to storage

Seed drying is an important step in seed management because it reduces the moisture content of the seed to an acceptable level for safe storage as mentioned above.

There are several drying methods:

- **Air-drying:** This method involves laying the seeds out in a single layer on a clean, dry surface and allowing them to dry naturally in a well-ventilated area.
- **Sun-drying:** Seeds can also be dried in the sun by laying them out in a single layer on a clean, dry surface in a sunny, well-ventilated area.
- **Mechanical drying:** Commercial seed producers may use mechanical dryers that use heat and air circulation to dry large quantities of seeds quickly and uniformly.

Sun-drying is the most common method for small-scale farmers. To ensure that seeds dry evenly, they should be raked and turned on a regular basis. To avoid spoilage, it is critical to check the dryness of the seeds before storage. One method is to use a seed moisture meter, which measures the moisture content of the seed which is normally done in a laboratory.

A simple seed break test can also be performed by gently pressing the seed with your fingers. If the seed is sufficiently dry, it should be fragile, with the outer layer easily peeling off. It is critical to protect the seeds from being exposed to rain or dew while they are drying in the sun by covering them with a tarp or bringing them inside. Seeds should be stored in a cool, dry place after drying to prevent moisture absorption and maintain seed viability and seed longevity.

Stories from the field

Overcoming weather-related challenges: The case of Hmong farmers in Sa Pa

The Hmong farmers in Sa Pa township, located in the Northern mountainous region of Vietnam, encounter challenges in producing quality vegetable seeds, especially in post-harvest handling and storage, due to the region's prolonged rains and humid weather conditions. The humid air makes it difficult for the seeds to dry properly, which can decrease seed vigour and longevity, negatively impacting their seed production. To ensure successful seed production, it is crucial to find solutions to help the seeds dry quickly.

One commonly used method by the Hmong farmers is to hang the seeds over their kitchen fireplace. However, it is essential to note that direct contact with heat or fire can harm the seeds, leading to reduced quality. Therefore, the project has advised the farmers to hang the seeds away from the fire, using a fabric or mesh bag to allow for gradual drying of the seeds. This method helps to avoid direct exposure to heat while promoting proper air circulation, allowing the seeds to dry uniformly, effectively, and efficiently.

H'Mong farmers' practice of hanging seeds over their kitchen fireplace can reduce seed quality

5.3. Storage

Seed storage is a critical ultimate stage in seed management to maintaining seed quality and ensuring the long-term viability of seeds. When seeds are stored properly, they can remain viable for years, allowing farmers to save and reuse seeds, which helps to reduce seed loss, costs while enhances seed sovereignty of farmers.

Storing seeds in sealed jars or zip bags with a desiccant (silica gel) helps maintaining seed quality and avoiding seed losses

Before storing the seeds, ensure that they are completely dry (as discussed above). When storing seeds, there are several factors to consider ensuring their longevity.

- **Dry environment:** Seeds must be stored in a dry environment, with low air humidity and adequate air circulation. High air humidity can make seeds absorb moisture, which can result in mold growth and seed damage.
- **Cool temperature:** The temperature of the storage location is very important. Seeds should be stored in a cool, dark place, away from direct sunlight and heat sources.
- **Clean and sealed containers:** Proper storage containers are necessary to prevent moisture fluctuation and insect damage. Seeds can be stored in glass or plastic bottle, ceramic jar or in a zip bag. Seed containers should be airtight, durable, and made of materials that do not emit harmful chemicals that could damage the seeds over time.

Stories from the field

Improving seed storage practices: A case study in the Hmong community of Sa Pa

In Sa Pa, the Hmong farmers traditionally stored various types of seeds, including vegetable seeds, in cloth bags, open nylon bags, plastic bottles, or bamboo tubes. These storage containers are typically kept inside houses or hung near the kitchen. In the first year of the project, we collected the seeds that farmers saved and witnessed that some households experienced almost complete seed damage, with seeds being infested by pests (weevils) and mould, resulting in very low germination rates.

To address this challenge, the project provided guidance on thorough seed drying, cleaning, and proper storage practices in the second year of implementation. Farmers were encouraged to store seeds in sealed bags with moisture desiccants, such as silica gel packets, to prevent moisture-related damage. The implementation of improved seed storage practices in the second year yielded significant improvements. The percentage of damaged seeds among the Hmong community decreased from an average of 45-50% to less than 12%. The germination rates of the stored seeds showed remarkable improvement, and seed quality became more consistent.

This prompted the H'mong farmers to share their knowledge on using moisture desiccant packets for seed preservation with their neighbors, friends, and relatives This knowledge dissemination had a positive impact, leading to an increased number of H'mong households participating in the project's joint experiment in the second year.

Storing seeds in sealed bags with desiccant packets helps reduce seed damage.

Link to reality

Group exercise: Checking seed dryness

The objective of this exercise is to help participants understand the importance of checking seed dryness before storage and provide hands-on experience in assessing seed moisture content.

1. Divide participants into groups.
2. Provide each group with a set of seeds that vary in moisture content. You can use seeds from different crops, such as beans, corn, or rice, and dry them to different moisture levels using a seed dryer or by air-drying them in the sun.
3. Instruct the groups to assess the dryness of the seeds using various methods such as visual inspection, fingers, weighing the seeds, or using a moisture meter if available.
4. Give the groups 20-30 minutes to assess the seeds and record their findings.
5. After the allotted time, have each group present their findings to the larger group. Ask them to share the methods they used to assess the seed dryness and to discuss any challenges they faced.
6. Facilitate a group discussion on the importance of checking seed dryness before storage and the various methods that can be used to assess seed dryness.

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- How did the timing of the harvest affect the quality and viability of the vegetable seeds?
- What challenges did you face during the harvesting process and how did you overcome them?
- What challenges did you face during the seed storage and how did you overcome them?

SECTION 6: SEED PRODUCTION FOR COMMERCIAL PURPOSES

Vegetable production can provide a source of income for individuals, and seed production also holds promise. Currently, Vietnam heavily relies on the importation of vegetable seeds, especially hybrid varieties or those difficult to produce locally. Beyond self-saved seeds, local markets and sellers are the primary sources for farmers' vegetable seeds. Many local vegetable varieties, such as different types of gourds, pumpkins, and beans, are of good quality but struggle with issues like unstable seed sources and limited commercial availability.

The ecologically favorable conditions in mountainous regions in Northern Vietnam present potential for seed production. For example, the seed production region in Dien Bien province shows that areas with similar ecological conditions can engage in commercial seed production, supplying seeds for both local and nearby regions. Moreover, there is significant demand for seedlings in the market, offering high value and additional income for farmers.

This section discusses the potential for commercializing vegetable seeds and seedlings, exploring income opportunities as circumstances allow. It also outline the fundamental criteria for seeds/seedling to be commercialized and to gain a competitive advantage in the market.

Section learning objectives

By the end of the section, the participants will be able to:

- Describe the requirements for seed quality according to commercial standards.
- Identify possible ways to generate income from seed commercialization.
- Analyse and identify challenges and opportunities for generating income from selling vegetable seeds or seedling.

6.1. Quality requirements of commercialized seed

Understanding the quality requirements of commercialized seed is crucial for farmers who are interested in selling seed for income. Meeting these standards can increase the farmers' chances of selling their seeds and earning a steady income from seed sales. Producing quality seeds can also increase the reputation of the farmer as a reliable seed supplier, leading to more business opportunities in the future. In addition, being able to describe requirements for quality seed/seedlings would be beneficial for farmers when they would need to buy seed and/or seedlings from external sources, e.g., local markets or vendors.

The requirements for seed quality according to commercial standards are discussed in section 1 and are summarized as followed:

- **Physical characteristics:** Seeds should be clean and free from impurities, broken seeds, and debris, weed seeds.
- **Physiological characteristics:** Seeds should be healthy and have a high germination rate, with seedlings that grow quickly, uniform and have a high rate of successful transplanting. The germination rate requirement for vegetables such as cabbage is >80%, and for beans and pumpkin, it is >95%.
- **Purity:** The seeds should be genetically pure and have uniform characteristics in the subsequent plant generation.
- **Sanitation (seed health)**: The seeds should be free from any disease-causing organisms, especially in large vegetable production areas where the presence of disease can cause significant losses.

The general requirements for quality of seedlings that can be commercialised are found below.

- Well-developed roots and roots are not damaged, broken, or show any symptoms of disease infection
- Healthy green leaves without any damages, symptoms of disease or pest infections
- (Normally) having 3-4 true leaves
- A large root collar diameter
- Having desired leaf shape as being expected to be the right varieties (this criterium is dependent on the specific crop/variety)
- A balanced ratio of root and shoot length

Farmers packaging the seeds they produce for sale.

Link to reality

Group discussion

This activity aims to encourage participants to share their experiences and challenges in meeting commercialized seed quality requirements.

Instructions

1. Gather the participants as one group.
2. Ask the following questions. Encourage everyone to share their insights.
   - What are some of the common challenges that you face or may face in meeting seed quality requirements?
   - How do or would these challenges affect your ability to sell your seeds or seedlings?
3. Summarize the group's points by the end of the discussion.

6.2. Opportunities for income generation from producing quality seeds and seedlings

Selling vegetable seeds and seedlings can be a potential source of income for farmers. There are three ways for farmers to generate income from producing quality vegetable seeds:

Selling seeds. The demand for vegetable seeds is quite high in both local and other regions. This is particularly true for crops either difficult produce or preserve seeds such as French beans, turnips, corn, parsnips, kale, Chinese cabbage, cabbage, carrot, and bok choy. These crops require a long growth period equire a strict period of low temperatures for flowering, as well as good storage conditions. As a result, most of the seed/seedlings for these crops is imported/purchased.

The mountainous areas of northern Vietnam have potential for commercial vegetable production, especially for these crops, thanks to their mild and cool climate. Hence, if the farmers there can improve their skills and knowledge of vegetable seed production to meet market demands, there is potential for increased income from seed sales.

Selling seedlings. The market demands for seedlings of specific crops (e.g., French beans, radish, kale, Chinese cabbage, cabbage, carrot, and bok choy) are high, as not all farmers are able to produce their own seedlings and need to buy seedlings instead. Another reason leading to the high demand of seedlings right before the season start is that they cannot be stored for long periods and the number of seedlings for sale is often limited. Moreover, in areas with harsh climates, such as heavy rainfall or extreme cold, the production of seedlings at the locality can help farmers better access to and sell seedlings to nearby vegetables growers. Hence, this is a potential source of income from selling seedlings, especially in places like Sa Pa or Mai Son (the project sites).

However, commercial seedling quality must meet the requirements of buyers in terms of uniformity, vigour, and acceptable prices. It is therefore important for farmers to pay attention to seed selection and the good seedling management during in the nursery.

Selling vegetables: Producing quality seeds is a crucial step for farmers to earn income from selling vegetables. Quality seeds lead to uniform and healthy plant growth, which ultimately results in high-quality produce that is more visually appealing and has better taste. This translates to higher demand and better prices from buyers, increasing the income for farmers. Moreover, quality seeds have higher germination rates and seedling formation rates, leading to better crop establishment, lower crop failure rates, and increased yield potential. All these factors combined make quality seeds an essential prerequisite for successful commercial vegetable production and provide farmers with opportunities to generate income from the sale of their vegetables.

A farmer producing seedlings for sale

Link to reality

Group discussion

This activity is designed to encourage participants to share their experiences and challenges in selling seeds or seedlings for income.

Instructions

1. Divide the participants into groups.
2. Ask the participants the following questions:
    - What are the benefits of producing quality seeds and seedlings for farmers and the wider community?
    - What are some of the challenges that farmers face when it comes to producing quality seeds and seedlings for commercial purposes?
    - What are some of the potential barriers to entry for farmers who want to start producing quality seeds and seedlings for commercial purposes? How can they be overcome?
    - What supports do farmers need to generate income from selling seeds/seedlings?
3. Summarize the key points after the group discussion.

Reflections

The questions below can be used for open discussion as an assessment of the participants' existing knowledge of the training topics at the beginning and/or to evaluate their understanding of key learning points at the end of the training session.

- What are the key requirements for seed quality in commercial seed production?
- In what way producing high-quality seeds and seedling helps farmers generate income?

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ANNEX: PROGRAM

Based on the content of the module, below is the suggested training program if all sections are conducted. This is estimated to take 20 hours, excluding time for field visits and on-farm practicals if applicable.

Note: It would be best if the seed production training combines in-class lessons with field activities. In this case, the training program would span an entire crop cycle.

Session	Minutes
Welcome and introduction	15
1. Seed type, quality, and influencing factors	
1.1. Seed types and their characteristics	30
Link to reality - Group exercise: Vegetable sorting based on practical reproduction means	20
1.2. Seed quality	30
Link to reality - Group exercise: Seed quality comparison	30
1.3. Varietal purity of seeds	30
Link to reality - Group discussion	30
1.4. Factors that influence crop growth and seed development	30
Link to reality - Group discussion	45
Reflections	10
2. Preparation before planting	
2.1. Seed selection and treatment	30
Link to reality - Group discussion	30
2.2. Crop seasonality and timing of seed sowing	20
Link to reality - Group discussion	30
2.3. Land selection, land preparation and isolation	20
Link to reality - Group discussion	30
2.4. Pre-planting fertilization	30
Link to reality - Group discussion	30
Reflections	10
3. Seed sowing and seedling management	
3.1. Direct seed sowing	20
3.2. Nursery raising of seedlings	30
Link to reality - Group discussion	30
3.3. Transplanting	30
Link to reality - Group discussion	30
Reflections	10

ANNEX: PROGRAM (CONTINUED)

Session	Minutes
4. Management of crops for seed production	
4.1. Watering	15
Link to reality - Group exercise: Developing watering schedules	45
4.2. Top-dressing fertilization	20
Link to reality - Group exercise: Fertilization and nutrient management practices	30
4.3. Pest and disease management	30
Link to reality - Group exercise: Developing pest and disease management plans	45
4.4. Rouging	20
Link to reality - Rouging practice exercise	45
Reflections	10
5. Seed harvesting and storage	
5.1. Harvesting time	30
Link to reality - Group discussion	30
5.2. Harvesting process	25
5.3. Storage	30
Link to reality - Group exercise: Checking seed dryness	45
Reflections	10
6. Seed production for commercial purposes	
6.1. Quality requirements of commercialized seed	20
Link to reality - Group discussion	30
6.2. Opportunities for income generation from producing quality seeds and seedlings	15
Link to reality - Group discussion	30
Reflections	10
Wrap up and closure	10

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