APPROACHES ON VALIDATING AND SCALING OF FOOD CROPS INNOVATIONS IN ETHIOPIA

ZEWDIE BISHAW,[1] SEID AHMED,[1] YETSEDAW AYNEWE,[1] KINDU MEKONNEN,[2] MILLION GEBREYES,[2] ADDISU ASFAW,[2] TEMESGEN ALENE,[2] MOHAMMED EBRAHIM,[2] WORKNEH DUBALE,[2] NEGUSSIE TADESSE,[1] HAIMANOT SEIFU[2] AND PETER THORNE[2]

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Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition and income security, particularly for women and children and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

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Author's affiliations

1. International Center for Research in Dry Areas
2. International Livestock Research Institute

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FOREWORD

This extension module is prepared to target crop production and protection experts at district levels and young researchers. It is intended to provide a practical guide that outlines basic principles and practices of participatory crop variety selection, crop technology validation, community seed production and scaling of innovations of food crops in Ethiopia. The module is part of an Africa RISING (AR) Ethiopian highlands project to capacitate local development practitioners and young researchers in validating core (crop varieties) and complementary (good agronomic practices) innovations that boost the productivity and production of food crops. The module is developed mainly based on approaches used during the AR project implementation in the wheat based production systems in four zones of Amhara, Tigray, Oromia and Southern Nations, Nationalities, People's (SNNP) regions of Ethiopia. Some sections of the modules are developed from literature reviews which are relevant in conducting participatory variety selection (PVS), community seed production and scaling for impact.

ACKNOWLEDGEMENTS

We thank all contributors in preparing this extension module. We hope the module would be a useful guide to woreda level crop production and protection experts and young researchers to provide trainings, implement PVS or advisory services to their key stakeholders. We acknowledge the funding from the USAID in Washington to the Africa RISING project in the Ethiopian Highlands and funders for the Mixed Farming Systems through their contributions to the CGIAR Trust Fund.

HOW TO USE THE FOOD CROP INNOVATION MODULE?

The main target of this module are woreda level crop production and protection experts and young researchers who are expected to train development actors in implementing PVS on farmer fields and farmer training centres; quality seed production and scaling of food crops innovations cereal–legume mixed cropping system in Ethiopia. The module can also serve as a source of reference to supplement other modules available to train development agents, young researchers and other actors.

The module has three sessions and each session has self assessment questions, learning objectives, overview, contents. Users of this module are advised to read assessment questions to gauge their current understanding of food crops innovations and their scaling to bring impacts at farm and landscape levels.

MODULE LEARNING OBJECTIVES

After reading this module readers will be able to:

- Describe approaches to conduct on farm PVSs and identify farmer preferred varieties.
- List the current high yielding varieties of food crops available for validation, demonstration and scaling.
- Describe procedures of quality seed production through community seed production scheme.

MODULE OVERVIEW

This module provides practical guidance to woreda crop production and protection experts and young researchers on how to validate and promote farmer selected innovations; and carry out community seed production and scaling of cereals and food legumes. Since the content is largely based on experiences from AR project implemented in Tigray (South Tigray), Amhara (North Shoa), Oromia (Bale) and SNNP (Hadiya), the approach and the concept can be used on similar or other agro-ecologies.

The module covers innovations that can be adopted for validation, demonstration and scaling of cereals, food legumes and similar annual field and vegetable crops in rainfed production system. The innovations include quality seed production of better performing varieties of the selected crops through community or village based seed system; use of complementary agronomic, pest and disease management practices, promotion and capacity building through training and field days.

The module is structured in three separate but interlinked sessions; each with specific session learning objectives, preassessment, session overviews and session contents. The module also includes references for additional readings.

MODULE CONTENTS

- On farm PVSs
- Community based seed production
- Scaling of food crop innovations

SESSION ONE: ON FARM PVSS OF FOOD CROPS

SESSION LEARNING OBJECTIVES

After reading this session, readers will be able to:

a. Describe key PVS protocols that will be followed in selecting better performing food crop varieties.
b. List key agronomic and consumer preference traits used for ranking varieties.
c. Explain PVS selection processes to identity farmer preferred varieties.

PREASSESSMENTS

a. Do you know what PVS is?
   i. Yes; ii. No
b. Can you list the key reasons why large plots are used for PVS?
   i. Yes, I can list all the reasons; ii. Yes, but partially, iii. No
c. Can you list key traits of interest for variety selection in cereals and food legumes?
   i. Yes, I can list all key traits; ii. Yes, but partially, iii. No
d. Do you know why we involve male and female farmers in participatory variety evaluations?
   i. Yes; ii. No

If you miss one question from the above, then this module is for you. We encourage you to read further to get the answers.

SESSION OVERVIEW

In most cases, the national research systems variety development is based on limited on farm testing. To fill this gap, PVS is considered as one of the approaches used to select farmer preferred crop varieties with specific as well as wide adaptation PVS is linked to community seed production that creates opportunities of easy access of quality seeds. In this session, protocols followed in implementing PVS trials are described supported with examples from Africa Rising project.

SESSION CONTENTS

Defining PVS.
Importance of PVS.
Protocol for PVS of cereals.
Protocol for PVS for food legume crops.
PVS evaluation processes for cereals and food legumes.
Ranking methods in PVSs.
Food quality and consumer preference.

WHAT IS PVS?

PVS is a variety selection process that is carried out on farm with the participation of farmers. The recommendation is that the varieties to be tested under PVS to be recently released by the research system.

IMPORTANCE OF PVS

Participatory varietal selection assumes that varieties exist that are better than those currently grown, but which farmers have not had the opportunity to test or adopt. The highlands of Ethiopia have varied ecologies and difficulties to address the innovation needs of farmers because of the limited number of research stations. Hence, PVS is very important to identify high yielding varieties adapted to a given agro-ecologies. The rational for PVS are:

1. Existence of heterogeneous environments that require specific solution.
2. Breeders may miss some important traits that are preferred by farmers.
3. Extension officers and seed companies are keen to know farmers preferred traits of crop varieties to multiply seeds and market for scaling.
4. Rapid and cost effective approach in identifying farmer preferred varieties.
5. Male and female farmers are involved in evaluating PVS trials that can increase the chances of adoption. and
6. PVS is linked to community seed production and farmers can have quality seeds that derive scaling of crop innovations.

HOW TO CONDUCT PVS?

PROTOCOL FOR CEREAL PVS

GENERAL PROTOCOL

1. List and prioritize key production and quality constraints smallholder farmers are facing.
2. Make sure to have access of seeds of recently released crop varieties from research centres and other sources.
3. Assemble materials (string, measuring tape, pegs, measuring scale) for PVS planting.
4. Proper site selection with good soil fertility, no waterlogging, uniform slope, no shade and soil erosion.
5. In a sloppy land, the alignment of plots should be across the slope.
6. Sites should be accessible with moderate efforts.
7. Farmer training centres and/or host farmers (3–4 representative sites) are recommended to implement PVS trials.
8. PVS can be done in collaboration with research centres.

SPECIFIC PROTOCOL

1. Plot size: We recommend a plot size of 25 m2 (5 m × 5 m) per variety.
2. Plant wheat and barley varieties with 20 cm between rows and drill the seeds.
3. Make a clear demarcation between plots of different varieties (0.5 m) apart.
4. We recommend minimum of 4 recently released varieties and one poplar variety in the area.
5. Seeding rate: 125 kg/ha for wheat, malt (100 kg/ha) and food barley (125 kg/ha).
6. Planting date: Follow the recommended planting dates based on rainfall onset in your locality.
7. Method of planting: Row planting is recommended.
8. Fertilizer application should be based on recommendation for the locality.

9. Weed management as recommended (minimum two hand weeding and/or herbicides) for the locality.
10. Pest management: Pesticide spraying is not recommended for diseases and insect pests that can be controlled through host plant resistance. If the crop has no known resistance to a given disease or insect pest (e.g. Aphids), it is advisable to control the pest using pesticides.
11. Fortnightly monitoring of trials.
12. Collect data on key agronomic and related traits.
13. Harvesting: Harvest the whole plot or exclude the outer two rows of each plot to determine seed and biomass yield. Example: If you plant 20 rows, only harvest 18 rows by excluding one row from each from side of the plot.
14. Threshing and measuring yield: It is done manually and avoid mixture.
15. Summarize farmer evaluation and yield data and rank varieties and select the top 1–2 varieties for demonstration and community seed production.

Key agronomic and yield data to be recorded by the expert

- Days to heading (50% of the plant are heading in each plot).
- Days to maturity.
- Biomass yield (quintal/ha). Harvest and measure above ground plants.
- Seed yield (quintal/ha).

PROTOCOL FOR FOOD LEGUME CROP PVS

GENERAL PROTOCOL

1. Proper site selection with good soil fertility, no waterlogging, uniform slope, not sprayed with herbicide in the previous season and no shade and erosion.
2. In a sloppy land, the alignment of plots should be across the slope.
3. Sites should be accessible with moderate efforts.
4. Make a clear demarcation between plots of different varieties (0.5 m) apart.
5. We recommend a minimum of 4 recently released varieties and one popular variety in the area.

SPECIFIC PROTOCOL

1. Plot size: We recommend a plot size of 25 m2 (5 m × 5m) per variety
2. Spacing:
    a. Faba bean: 40 cm between rows and 10 cm between plants
    b. Field pea: 30 cm between rows and 5 cm between plants
    c. Chickpea: 40 cm between rows and 10 cm between plants
    d. Lentil: 30 cm between rows and drill the seeds
3. Seeding rate: For small seeded varieties 175 kg/ha and for large seeded varieties 200 kg/ha
    a. Faba bean: Small seeded 150 kg and large seeded 200 kg/ha
    b. Field pea: 150 kg/ha
    c. Lentil: 100 kg/ha
    d. Chickpea: for small seeded (110 kg/ha) and large seeded (200 kg/ha)

4. Planting date: Follow the recommended planting date based on rainfall onset in your locality
5. Method of planting: Row planting is recommended
6. Fertilizer rate: Inorganic fertilizer (NPSB: 121 kg/ha) and organic fertilizer (biofertilizer: 1 kg/ha)
7. Weed management: Non parasitic weed management as recommended (minimum two hand weeding and/or herbicides) for the area
8. Harvesting: Harvest the whole plot of each variety at maturity stage
9. Threshing and measuring yield data: It is done manually to avoid mixture
10. Summarize farmer evaluation and yield data and rank varieties and select the top 1–2 varieties for demonstration and community seed production

Key agronomic and yield data to be recorded for PVS of food legumes

- Days to emergence
- Days to 50% flowering in each plot
- Days to maturity
- Biomass yield (quintal/ha). Harvest and measure above ground plants
- Seed yield (quintal/ha)

PVS EVALUATION FOR CEREALS AND FOOD LEGUMES

1. Organize farmers evaluations at crop maturity stages.
2. Select young and old, male and female, as well as knowledgeable and experienced farmers and community leaders.
3. Form separate male and female groups for evaluations.
4. We recommend 5–7 farmers in each group.
5. Each variety should be given a code not a name.
6. Selection criteria are set by farmers involvement.
7. The expert only facilitates the evaluation process and records score values using the recommended format.
8. Organize field days after farmer evaluations.

PVS RANKING METHODS

In this module we introduce two ranking methods. The first ranking is a 1–5 rating scale where 1 = Very poor, 2 = Poor, 3 = Good, 4 = Very good and 5 = Excellent. The 1–5 rating was used in AR project to rank varieties of cereals and food legumes as well as other crops. Since participating farmers do not give equal importance to all the traits, a weighted ranking is used for final selection. A variety with the highest total weighted score value of farmer evaluation together with yield data are recommended for demonstration and community seed production. The above selection process and ranking were used to select farmer preferred varieties for community seed production and scaling of cereals and food legumes in AR project (Tables 1 and 2).

Table 1. Farmer preferred cereal varieties selected using weighted score in AR project

Crops	Varieties	Bale zone	Hadiya zone	North Shoa zone	South Tigray zone
Bread wheat	Deka	X	X	X	
	Wane	X	X	X	X
	Lemu	X	X		
	Kingbird				X
Durum wheat	Utuba	X		X	
	Mangudo	X		X	X
	Bullaallaa	X		X	
	Fetan	X		X	
Food barley	HB1307	X	X	X	X
	Adoshe	X			
	Hagere			X	
Malt barley	IBON174	X		X	X
	HB1964	X			

Table 2. Farmer preferred food legume varieties selected using weighted score in AR project

Crops	Varieties	Bale zone	Hadiya zone	North Shoa zone	South Tigray zone
Faba bean	Gebelcho	X	X	X	X
	Dosha	X	X	X	
	Gora	X		X	X
	Tumsa		X		
Field pea	Bilalo				X
Kabuli chickpea	Arerti	X			
	Habru	X			
Lentil	Alemaya	X			
	Derash	X	X	X	X

Photo 1. Evaluating food barley and bread wheat PVS by male and female farmers.

Photo credit: ICARDA.

Photo 2. Evaluating faba bean PVS by male and female farmers.

Photo credit: ICARDA.

The second ranking of crop varieties is the use of Preference index (PI). At physiological maturity of the crops, male and female farmers are invited. The ranking is done by placing cards of different colours given to each farmer. The number of each colour equal to the number of varieties in the PVS. For example, if there are three varieties in the PVS, we can have three colours (green, yellow and red). If a farmer prefers a variety, he/she puts a green card inside an envelope prepared for this purpose. If the farmer hesitates about the variety, yellow card is used so that the variety will be reevaluated in the following season. If a red card is given, the variety is rejected. After the evaluation is completed, the number (N) of green, yellow and red cards are counted per variety and PI is calculated for male, female or both using the following formula:

$$PI\ (\%) = \frac{(100 \times [N\ green + 0.5 \times yellow])}{(Total\ number\ of\ voting\ participants\ in\ target\ group)}$$

The PI ranged from 0 to 100%, with 0% meaning complete rejection and 100% meaning approval by all participants. If the two extreme values are not recorded, varieties with highest per cent PI values will be selected for next phase of evaluation. In addition, interviews with individual farmers (female and male) can be taken to know the reasons of selection or rejection.

FOOD QUALITY AND CONSUMER PREFERENCE

During variety selection it is advisable to include sensory evaluation by panels. The 9 point hedonic scale is the widely used method for scaling consumer preference and food acceptability. The values and their correspondent descriptions are: 9, like extremely; 8, like very much; 7, like moderately; 6, like slightly; 5, neither like nor dislike; 4, dislike slightly; 3, dislike moderately; 2, dislike very much; and 1, dislike extremely. It is recommended that crop varieties with a scaling of 9 and 8 can be advanced for production.

SESSION TWO: COMMUNITY BASED SEED PRODUCTION

SESSION LEARNING OBJECTIVES

After reading this session readers will be able to:

- Describe the different seed systems in Ethiopia
- Explain the importance of community seed production
- List procedures to produce quality seeds through community seed production scheme

PREASSESSMENT

1. Do you know the difference between formal and community seed production?
   Yes / No

2. Do you know different classes of seeds?
   Yes / No

3. Can you list key seed quality parameters?
   Yes, I can list all parameters; Yes, but partially and No.

4. Do you know the reason why seed quality parameters are important in seed production and marketing?
   Yes / No

5. Can you list the key protocols you follow in quality seed production?
   Yes, I can list all parameters; Yes, but partially and No.

If you missed one question from the above list, then this module is for you. We encourage you to read further to get the answers.

SESSION OVERVIEW

Quality seed is one of the critical inputs in boosting crop productivity and production of cereals and food legumes. Access to sufficient quantity and quality seed at the appropriate time, place and price is a challenge through the formal seed system. In this module, concept of seed system and procedures of quality seed production through community seed production is explained.

SESSION CONTENTS

- Importance of community seed production
- Establishing and operationalizing community seed production
- Seed quality components
- Seed production
- Seed processing
- Seed quality assurance

WHAT IS COMMUNITY BASED SEED SYSTEM?

Community based seed production are many forms of semi-informal system other than organized regular public or private sector seed production where seeds of different crops are produced, marketed, exchanged and used by farmers for their different needs.

Note: Four classes of seeds (breeder, prebasic, basic and certified) are recognized in Ethiopia seed system. Variety maintenance, production and distribution of breeder, prebasic and basic seed are carried out by the public breeding institutions or private seed sector whereas the certified seed is produced by public seed enterprises and private sector (companies, cooperatives, communities).

IMPORTANCE OF INFORMAL SEED SYSTEM

National seed system, composed of formal, semi-informal, or informal sectors, should be context specific based on agro-ecology, farming systems, crops and farmers socio-economic characteristics and political constructs. There is no one seed system that fits all. Community seed production builds on farmers traditional knowledge and experience in seed production and seed trade or exchange at local level. It focuses on local demand for varieties and seeds; and serves as variety demonstration, seed production and promotion/marketing tool creating the awareness and building the confidence of the farmers.

WHY COMMUNITY SEED PRODUCTION?

In Ethiopia, we find a mix of federal and regional public seed enterprises, small to medium domestic private seed companies and large-scale foreign private seed companies and a wide range of semi-informal licensed or nonlicensed small seed enterprises of different shapes and scales operated by cooperatives or farmer associations which are involved in seed supply. After 5 decades of operation, the Ethiopian seed sector is still dominated by the public sector and focus on two major crops, wheat and maize which account close to 90% of the seed supply by the formal sector. Currently neither the formal sector nor the private sector meets the seed demand of diverse group of farmers and crops in the country; and hence, this module advocates for a variety of alternative farmer based seed production. These schemes are operating at local level to ensure availability and access to varieties and seeds by farmers for less commercial crops, less favourable environments and/or remote areas. They are: Participatory: mobilize and involve small farmers in target environments;

Decentralized: multiply well adapted and farmer preferred varieties at local levels;
Market oriented production: link to seed demand from local and nearby communities;
Cost effective: lower transport, marketing and distribution costs, thus reducing seed prices;
Relevant quality: adopt seed quality standards appropriate to farmer requirements;
Appropriate technology: use low cost cleaning/treatment equipment to improve seed quality;
Sustainability: ensure farmers' empowerment and ownership in seed business;
Evolution: develop into small, privately owned small- to medium-scale seed enterprises.

ICARDA's seed section established the framework and critical steps for establishing and operating business oriented village based seed enterprises (VBSEs) and demonstrated their performance in terms of their technical feasibility and economic profitability which ensures long-term sustainability and their eventual transformation to small and medium enterprises (SMEs) as they grow, diversify and expand their operations.

In Ethiopia, seed producer cooperatives (SPCs) emerged as the major and most effective seed delivery partners where they need to be promoted and supported for gradual evolution into the SMEs. Introducing quality declared seed (QDS) provided greater space for meaningful contribution of SPCs to seed delivery particularly of legume crops.

ESTABLISHING AND OPERATIONALIZING COMMUNITY SEED PRODUCTION

Similar to the formal system, any kind of successful seed business requires skilful management of physical, financial and human resources. Therefore, it requires the following to be conducted before hand:

1. ***Seed system analysis:*** The seed system analysis should be conducted before establishing VBSEs, to assess whether there is a seed demand or 'seed gap' through a multistage and multistakeholder consultation.

2. ***Stakeholders' consultation:*** Convene a multi-institutional and multistakeholder consultation meeting to identify who might have an interest in and would support VBSEs; build the consensus and determine their roles and responsibilities in supporting operations and implementations.

3. ***Identifying target areas and groups, VBSEs should target:***
    a. Less commercial crops neglected by the public and/or private sector
    b. Less favourable areas with limited commercial crop production
    c. Remote and isolated areas with poor infrastructure
    d. Resource poor small-scale farmers with limited opportunities and
    e. Farmers lacking access to improved crop varieties and seeds.

Selecting farmers: Participating farmers must be interested in setting up seed production and marketing enterprises as alternatives to grain production; and must be selected based on the following criteria: reputation in the community, experience in farming and seed production, relatively bigger/better land holdings, possession of equipment, entrepreneurial skills and financial resources:

1. ***Forming seed producer groups:*** Farmer participation and empowerment are key elements of the VBSE program. Farmers should take responsibility and leadership and elect their own leaders whereas partners facilitate, provide guidance and advice.

2. ***Selecting seed production sites:*** The land selected must be suitable for quality seed production, better/fertile soils, reliable rainfall (or irrigation), low incidence of diseases, pests and parasitic weeds, proximity and accessibility to main roads/facilities.
3. ***Preparing a business plan:*** The business plan assesses all factors and serves as a guide to strategic planning which may affect the enterprise—business potential, strengths, weaknesses, risks, products (crops, varieties), potential markets, demand, costs, sales and potential profits. It also includes risk assessments and sets out details of ownership, management and legal structure, staff, equipment and the budget.
4. ***Producing and marketing seed:*** All seed production and marketing operations are carried out by the members of the VBSE. Promotional efforts and marketing are the final prerequisite to ensure success.

Note: Ethical values of community seed producers

- Openness—The cooperative does not hide that it is not correct.
- Honesty—The cooperative is honest about what it does and the way it is done.
- Social responsibility—People are encouraged to take responsibility for their own community and work together to improve it.
- Caring for others

SEED QUALITY COMPONENTS

Genetic quality: Inherent genetic make-up of the variety which may consist of attributes such as plant type, duration of growth cycle, seed colour and shape.

Physical quality: Seeds must be free from contamination with other crops, common and particularly noxious and parasitic weed seeds, required seed size, seed weight and seed lot uniformity.

Physiological quality: Viability, germination and vigour of seed, which determines the potential germination and subsequent seedling emergence and crop establishment in the field.

Health quality: The absence of infection/infestation with seedborne pests (fungi, bacteria, viruses, nematodes, insects, weeds).

SEED PRODUCTION

1. Site and field selection to find suitable area or land for seed production.
2. Isolation to avoid contamination.
3. Roguing to remove contaminants.
4. Limited generations of multiplication to reduce contamination.
5. Ensuring cleanliness of machinery to avoid admixtures during planting, harvesting, cleaning, treatment and storage.
6. Production arrangements using specialized growers. and
7. Maintaining seed quality by applying rigorous quality assurance systems.

Limitation of generations: Seed production follows a generation system. In Ethiopia we follow the Organisation for Economic Co-operation and Development (OECD) seed scheme which recognizes four seed classes (breeder, prebasic, basic and certified seed but also adopted the ‘quality declared seed’). The later would provide an opportunity for farmer based seed production where conventional comprehensive seed certification would be replaced with more responsibility given to seed producers.

Choice of sites: Apart from agro-ecological and climatic adaptation, the area selected for seed production should be free from natural hazards like floods, drought, frost, salinity and diseases and insect pests, etc. to prevent any damage to the seed crops.
Warm areas are preferable because warm weather favours flowering, pollination, seed setting and ripening. The area should be fertile, well drained and levelled. Areas with dry and cool weather conditions during ripening and harvesting are ideal for maintaining seed quality. Availability of irrigation facilities are key factors for selecting fields for seed production. Accessibility and proximity of the land for supervision and suitability for transporting the seed quickly and economically is also essential.

Choice of growers: Seed production is carried out by community members or under contract with specialized seed growers who are knowledgeable and experienced and have necessary facilities. They usually incur additional costs because of the extra care and attention required to produce quality seed (isolation, roguing); and therefore, should receive premium over the grain price to cover the extra costs for managing seed production.

Selecting seed production fields: Selecting fields with the right cropping history and suitable crop rotation is necessary; and if possible, these two should be combined. The right previous cropping is necessary to avoid genetic, mechanical and pathological contamination in seed production, whereas crop rotation is mainly practiced maintaining soil fertility and control soil and/or seedborne diseases. A seed crop should preferably follow another crop species to avoid admixtures (e.g. cereals after legumes or vice versa). The land selected for seed production should be free from varieties of the same crop species for at least one or two years prior to planting unless the previous crop is of the same variety. A field used for seed production should also be free of noxious weeds and seed/soilborne diseases. This will help control volunteer plants (which may reduce varietal purity) and prevent buildup of seedborne diseases and noxious weeds including parasitic weeds such as striga and Orobanche depending on crop species.

Isolating seed production fields: The practice of growing of a seed crop separately from all sources of contamination, is one of the fundamental seed production techniques. An appropriate isolation (in space and/or time) should be maintained to prevent contamination (admixture and/or cross pollination) based on the pollination habit of the crops, field size and presence of natural or physical barriers. Selfpollinated crops need small distances while crops with high percentage of outcrossing require long isolation distances (Table 3).

Table 3. Recommended isolation distances in producing quality seeds of self- and cross-pollinated crops

Mode of pollination	Crops	Recommended isolation distance (in metres)
Self pollination	Wheat, oat, barley	2–5
	Field pea, chickpea, lentil, common bean	2–5
Partially cross pollinated	Faba bean and grass pea	100–200

Roguing: It is a systematic examination of seed fields and removal of undesirable plants. The purpose is to maintain varietal purity and ensure freedom from seedborne diseases, from other varieties, other crop species of similar growth habit and parasitic weeds. Undesirable plants, commonly known as 'rogues', are:

1. Off types of genetic variants of the same variety.
2. The varieties of the same crop species.
3. Other crops with similar growth habit and seed characteristics.
4. Noxious weeds difficult to remove during cleaning. and
5. Plants infected with seedborne diseases.

Roguing can be performed at various stages of crop growth, but the most effective stages are flowering, post flowering or maturity, when it is easier to see important morphological characteristics (inflorescence type, flower colour, ear shape) that will help differentiate between the variety and the rogues. During roguing, the whole plant with all lateral tillers should be removed, taken out of the field and burned. The roguing crew must be well trained to examine the seed crop carefully and remove contaminants.

Cleanliness of equipment: All farm machineries for seed production from planting (tractors, cultivators etc.) to harvesting (threshes, combiners) to transporting (trailers) as well as seed cleaning and treatment equipment should be cleaned between different operations to avoid varietal admixtures.

Selecting adapted varieties: The variety must be selected based on the results of PVS from a list of recommended varieties. Apart from its adaptation, the variety should have high yield potential, tolerance to biotic (fungal, bacteria, viral) and/or abiotic (cold, frost, heat, drought, salinity) stresses and have good marketability and consumer preferences to ensure wider adoption and demand for seed.

Selecting source seed: Good quality seed from a known source, where the field is inspected and the seed is cleaned and tested. Basic seed purchased from the agricultural research centre or certified seed from the formal sector, is recommended, since it assures good quality seed with high varietal purity, physical purity and germination.

Crop and pest management practices: Good agronomic practices should be applied to produce high quality seeds.

Sowing date, rate and method: The time of sowing depends on the variety and area of adaptation. A seed crop must be planted at its recommended time, otherwise growth and development may be affected, thus reducing seed yield. Matching varietal maturity to the sowing date is a key element for maximizing seed yields in dryland farming and it helps in reducing risks. Seed rates may also differ among varieties depending on seed size and the method and time of sowing. The recommended seed rate should be used when a crop is sown at normal time to achieve the right plant population for adequate competition with weeds and for better yield.

Irrigation: Availability of irrigation water is important for a good seed crop. The irrigation regime should be scheduled according to the crop growth stages. The seed crop must receive ample water at two critical stages of crop growth, i.e. during establishment/vegetative growth and early phase of seed development. Moisture stress at these two stages will adversely affect the yield and quality of the seed. Less water during flowering promotes seed setting while ample water after flowering will ensure the development of the greatest possible number of seeds, thus increasing seed yield. On the other hand, irrigation at physiological maturity will delay harvest maturity. In Ethiopia irrigation in the dry season can be used to fast track early generation seed production.

Fertilizer application: A well balanced supply of nitrogen, phosphorus and potassium is essential for seed production, as it has an influence on seed development, seed quality and yield. Fertilizer application to seed crops should be based on local recommendations.

Weed control: Seed is one of the most important means of introducing common, noxious and parasitic weeds into agricultural lands. Weed seeds can be classified into three: objectionable weeds (not permitted), noxious weeds (permitted with specified standards) and common weeds (no standards). Avena, Bromus, Lolium and Phalaris spp in small grain cereals and Orobanche and Cuscuta spp in food legume are considered noxious weeds and are often difficult to control once established in the field.

Managing seedborne diseases: Freedom from pathogens, especially seedborne diseases, is one of the most important seed quality attributes and standards. Lack of proper disease management in quality seed production, may adversely affect the productivity, quality attributes and standards of the harvested seed. Producing a healthy seed includes a combination of a different practices:

1. Use of disease free seed lots,
2. Zoning of seed production areas,
3. Off season seed production,
4. Proper rotation and isolation of seed fields,
5. Roguing of diseased plants,

6. Spraying to avoid disease buildup,
7. Field inspection and testing,
8. Efficient cleaning of lots and
9. Seed treatment with chemicals

Harvesting: Whether the seed is harvested and threshed manually or mechanically, the most critical factors to be considered are the seed moisture content, mechanical damage and cleanliness (of equipment). The following instructions must be followed when harvesting high quality seed:

1. Start harvesting when the seed moisture content is reduced to approximately 12% (cereals and legumes) to avoid mechanical damage and maximize storability.
2. Set the concave clearance and speed of the threshing drum to reduce mechanical damage as much as possible. Mechanical damage influences physiological quality such as germination and vigour.
3. Adjust the air and screening system to minimize losses and maximize physical purity.
4. Harvest crops/varieties in a sequence that minimizes mechanical mixing between them.

Seed processing

Cleaning includes the removal of inert matter; seed of weeds, other crops, other varieties and seeds of the same variety which are shrivelled, damaged, deteriorated or diseased, to improve and upgrade seed quality.

Seed treatment: Seed infection may lead to low germination, reduced field establishment, severe yield loss, or a total crop failure. It is important to:

1. Use seed treatment chemicals with a strong dyeing colour to discourage human consumption or use for animal feed.
2. Use simple seed treatment machines, which can be properly cleaned between varieties.
3. Adjust the rate and coating systems properly to ensure good pesticides application.
4. Treat seeds in a sequence that minimizes mechanical mixing of varieties and crop.

Seed packaging: Proper packaging is important for safe handling, storage, marketing and distribution. Using proper packaging material contributes to minimizing quantitative and qualitative losses.

Seed storage

Cleaned and treated seed should be stored until it is marketed and distributed. Maintaining the quality of the seed during storage is important using proper storage management. The principle of cool, clean and dry (CCD) for storage facility and the first in first out (FIFO) of seed stock should be applied for storage management. Monitoring the storage temperature and moisture content of the seed as well as monitoring pest infestation and control need to follow.

***Managing seed storage**:* Adequate planning and management are essential to avoid losses and keep seed free from insect pests during storage. The following preventive and remedial measures should be taken to:

1. Ensure that all seed storage structures are clean, cool and dry.
2. Locate seed storage sites in cool and dry (low relative humidity) areas.
3. Clean and spray all storage structures thoroughly with insecticides, followed by a regular spray of residual insecticide.
4. Maintain proper sanitation in and around seed stores to deny insects any shelter for multiplication and to control rodents.
5. Clean the seed and reduce its moisture content to a level that will allow safe storage for the required period.
6. Use new bags to avoid both insect infestation and mechanical mixtures. Seed should be bagged in a thick weave cloth bag without loose weaves.
7. Keep seed bags on wooden pallets at least 50 cm away from walls, with aisle space of 1 m, to ensure adequate aeration.
8. Inspect seeds upon entry. They must be free from storage pests. Check stored seed at least once a week, for insects and if found, fumigate immediately.
9. Apply sound rodent monitoring and control program during seed storage.
10. Store seed of high germination and vigour only.
11. Immediately dispose of poor quality seed.
12. Maintain seed identity by labelling each bag, keeping up to date records and using stack cards.

Fumigation: Fumigants are insecticides used to control storage pests. In seed production, phostoxin (aluminium or magnesium phosphine) is widely used. It is popular because it is easy to handle, has no influence on germination and the seed can be fumigated repeatedly. Phostoxin is applied at the rate of 3–6 tablets per tonne of seed (2–4 tablets per m3). For larger stacks, under suboptimal conditions (i.e. low moisture contents), or when eggs or pupae must be killed, the exposure time should be extended. The relative humidity of the air should not be lower than 30% because no gas will be released from the tablets. At 30% RH, exposure time should at least be 10 days. In very dry areas, insufficient moisture may be present and it may be necessary to place a container of water under the fumigation sheet. To sum up, the factors determining the success of fumigation are:

1. Hygienic conditions,
2. Proper dosage and exposure time,
3. Adequate sealing and
4. Correct temperature and sufficient moisture.

Seed certification

Since farmers have difficulty assessing the physical or genetic qualities of seeds before they are planted and grown, certification of seed quality is essential to provide users with quality assurance and a means of redress if expectations are not met. A quality assurance system ensures that certified seed meets prescribed national quality standards. In Ethiopia, regional regulatory agencies provide seed quality assurance and certification. This includes documentation regarding seed sources, inspections of seed production fields during the growing season and laboratory tests of seed after cleaning. The main features are:

Field and seed standards are maintained.
Evaluating seed production.
Enforcing quality standards during marketing.

Field inspection: Regional regulatory agencies conduct field inspections through visiting seed production fields to ensure that it meets the field standards:

Fields meet standards for cropping history, isolation distance and varietal purity;
Evaluation for seed production fields for off types and other varieties, other crops, noxious weeds and seedborne infected plants.

Laboratory seed testing: Regional seed regulatory agencies can take seed samples from cleaned seed and conduct laboratory testing for seed standards such as physical purity, germination, moisture content and seed health.

Moisture content test: Simple tests that are applicable for seed moisture tests are as follows:

Bite test: Pinch seeds between the finger and bite. If the harvested seed is hard or cracks, then it can be stored. If the seed is soft then it needs more drying.

Salt test: Fill a quarter of a clean dry jar with salt, add seeds to reach half of the jar close to the lid and seal tightly. Shake the jar well and leave for 10 minutes and if damp salt adheres to the inside of the jar, it indicates the seed needs further drying. If no salt adheres on the jar, the seed is adequately dried for storage.

Physical purity test: For physical purity tests you may follow the following procedures:

Draw a working sample from a submitted sample according to the species.
Weigh the working sample and separate the seed sample into three fractions: pure seed, other crop seed and inert matter.
Weigh each fraction separately and calculate the percentage weight of each fraction.
The percentage of pure seed fraction is the physical purity of the seed sample.

Germination test: The germination test you may follow the following procedures:

1. Count 400 seed from submitted sample and divide them into 4 replicates of 100 seeds (eight replicates of 50 seeds).
2. Moisten a paper towel so that it is damp but no dripping water when you shake.
3. Place the seeds on paper towel in a line and in the middle not touching each other.
4. Fold the paper over the seeds, roll the paper towel up loosely and place it in open plastic bag vertically.
5. Put the rolls at room temperature or in a controlled room with 20–30°C and ensure that the paper towels do not dry out.
6. In each replicate count the number of normal seedlings (with normal roots and shoots), abnormal seedlings, fresh ungerminated seed and dead seeds at the final count.

7. Calculate the average percentage for each category for all replicates, the average per cent normal seedlings of the replicates is the germination of the seed lot.

The percentage physical purity and the percentage germination can provide the pure live seed and shows the number of pure seeds which can germinate and produce the normal seedlings as follows:

$$\frac{\text{Pure live seed} = (\%\ \text{purity} \times \%\ \text{germination})}{100}$$

It can be used as a measure of seed quality among different seed lots and calculate the seed rates.

Photo 3. Cluster of community seed production of malt barley (left) and durum wheat (right) varieties selected from PVS in AR project.

Photo credit: ICARDA.

Note: Early generation seeds include breeder seed, prebasic and basic seed and are the critical link between variety development and large-scale certified seed production and distribution of varieties to farmers.

Basic seed is generally multiplied to produce Certified seed 1 which can be further multiplied to Certified seed 2 (Certified seed 3 in some cases) which are used for commercial crop production.

SESSION THREE: SCALING OF FOOD CROPS INNOVATIONS

SESSION LEARNING OBJECTIVES

After reading this session readers will be able to:

- List the types of scaling methods used for promoting crop innovations.
- Describe how PVS is linked to scaling through community based seed production.
- Explain the potential of digital extension services in crop innovations scaling.

PREASSESSMENTS

1. Do you know the different types of scaling?

   Yes, I can list all parameters; Yes, but partially; No

2. Do you know the reason why we carry out scaling?

   Yes / No

3. Can you list all procedures in scaling?

   Yes, I can list all procedures; Yes, but partially; No

4. Do you know the new method in agricultural extension?

   Yes / No

If you miss one question from the above list, then this module is for you. We encourage you to read further to get the answers.

SESSION OVERVIEW

Cereals and food legume crop productivity and production are low in Ethiopia. To boost crop productivity, seeds of farmer selected varieties together with improved crop management practices are required. In this session, key elements of scaling of crop innovations and potential roles of mechanization and digital extension are described.

SESSION CONTENTS

- What is scaling?
- Preparatory work for scaling.
- Awareness creation, dissemination and follow up
- Mechanization.

What is scaling?

Scaling crop innovation includes upscaling, out scaling and downscaling. Out scaling refers to the spreading of cereal and food legume innovations in the target production system whereas upscaling refers to creating favourable enabling conditions to scale the innovation at higher levels. If the newly validated innovations become part of the national extension packages, we call the scaling as upscaling.

Importance of scaling

Most of the released cereal and food legume varieties in Ethiopia are not in the hands of farmers for many reasons. Among the key factors are farmers are not aware of the varieties; limited adaptation of varieties and poor access to quality seeds.

Scaling of crop is done to promote crop innovations. As a result, it will help to create awareness and enhance adoption and ultimately increase productivity.

Procedures for scaling crop innovations

Scaling of crop innovation involves three major activities:

Preparatory work

Training of farmers, village based development agents and seed growers.

Ensuring availability of quality declared seeds of farmer preferred crop varieties.

Establishing the scaling field

Good land preparations.

Applying recommended agronomic practices: applying the recommended fertilizer rates (inorganic and organic); applying recommended seed rate based on seed size; pest and weed management as well as mechanization if available.

Awareness creation, dissemination and follow up

Using digital extension as part of group and mass extension. In general, four types of digital extension tools could be applicable for agricultural extension and advisory services:

a) Short text or audio messages.
b) Visual delivery via mass media (TV); and video including animation that can take 1 to 30 minutes.
c) Audio programs like radio.
d) Digital applications on a smartphone, digital tablet or the internet used directly by a farmer or indirectly by an extension agent, community seed growers.

Carrying out conventional extension through extension agents, field days, community seed growers and volunteer farmers.

Carrying out monitoring, evaluation and learning.

Training of farmers at FTCs.

Note: Digital extension tools include phone calls, WhatsApp groups and specialized smartphone applications that help farmers or extension actors to share, access or discuss agricultural information or knowledge.

Photo 4. Scaling of malt barely (left), bread wheat (middle) and durum wheat (right) varieties selected by famers supported by AR project.
Photo credit: ICARDA.

Photo 5. Scaling of faba bean varieties selected from PVS supported by AR project.

Photo credit: ICARDA.

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APPENDIX 1. AGRONOMIC AND YIELD DATA RECORDING SHEET FOR PVS USING 1–5 SCORES

Plot No.	Varieties	Date of 50% flowering	Plant height (cm)	Disease and insect pest infestation/plot (%)	Drought tolerance	Shattering (%)	Biomass yield (kg/plot)	Biomass yield (quintal/ha)	Seed yield (kg/plot)	Seed yield (quintal/ha)	Remarks

APPENDIX II. DATA COLLECTION SHEET FOR FARMER PARTICIPATORY CEREAL VARIETY SELECTIONS USING 1–5 SCORES

Selection criteria	Variety 1	Variety 2	Variety 3	Variety 4	Local check	Rank
Crop stand						
Tillering						
Disease resistance						
Drought tolerance						
Number of kernel/spike						
Spike length						
Seed colour						
Days to 50% heading						
Days to maturity						
Plant height (cm)						
Frost tolerance						
Lodging resistance/tolerance						

APPENDIX III. EXAMPLE OF USING 1–5 SCORES TO RANK CROP VARIETIES BY 13 MALE FARMERS IN AR PROJECT

Example 1. Ranking of durum wheat varieties by 13 male farmers using weighted values

Selection criteria	Varieties*			
	Utuba	Mangudo	Tate	Ginchi
Height	5 × 11, 4 × 1 = 55 + 4 = 59	3 × 11, 4 × 1 = 33 + 4 = 37	5 × 13 = 65	2 × 13 = 26
Crop stand	3 × 13 = 39	3 × 13 = 39	5 × 13 = 65	2 × 13 = 26
Disease resistance	5 × 13 = 65	4 × 13 = 52	3 × 13 = 39	4 × 13 = 52
Maturity	5 × 12, 3 × 1 = 60 + 3 = 63	3 × 13 = 39	4 × 13 = 52	2 × 13 = 26
Lodging resistance	5 × 13 = 65	4 × 13 = 52	2 × 13 = 26	3 × 13 = 39
Spike length	5 × 13 = 65	5 × 13 = 65	4 × 13 = 52	1 × 13 = 13
Tillering capacity	3 × 13 = 39	3 × 13 = 39	5 × 13 = 65	4 × 13 = 52
Seed/spike	4 × 13 = 52	3 × 13 = 39	5 × 13 = 65	2 × 13 = 26
Total	447	362	429	260
Rank	1	3	2	4

* Score value multiplied by number of male farmers give the score for each trait and varieties.

APPENDIX IV. DATA COLLECTION SHEET FOR FARMER PARTICIPATORY FOOD LEGUME VARIETY SELECTIONS USING 1–5 SCORES VALUES

Selection criteria	Variety 1	Variety 2	Variety 3	Variety 4	Local check	Rank
Crop stand						
Branching						
Disease resistance/tolerance						
Insect resistance/tolerance						
Drought tolerance						
Number of pods/plant						
Number of seeds/pod						
Seed size (small, medium and large)						
Days to 50% flowering						
Days to maturity						
Plant height (cm)						
Frost tolerance						
Lodging resistance/tolerance						

APPENDIX V. EXAMPLE OF USING 1–5 SCORES TO RANK CROP VARIETIES BY 4 FEMALE FARMERS IN AR PROJECT

Example 2. Ranking of field pea varieties by 4 female farmers using weighted values

Selection criteria	Varieties*				
	Bilalo	Mageri	Markos	Gume	Burkitu
Plant height	$3 \times 4 = 12$	$2 \times 4 = 8$	$3 \times 4 = 12$	$3 \times 4 = 12$	$4 \times 4 = 16$
Crop stand	$3 \times 4 = 12$	$3 \times 4 = 12$	$4 \times 4 = 12$	$4 \times 4 = 16$	$5 \times 4 = 20$
Disease resistance	$3 \times 4 = 12$	$3 \times 4 = 12$	$4 \times 4 = 12$	$4 \times 4 = 16$	$5 \times 4 = 20$
Maturity	$2 \times 4 = 8$	$3 \times 4 = 12$	$3 \times 4 = 12$	$4 \times 4 = 16$	$5 \times 4 = 20$
Insect resistance	$2 \times 4 = 8$	$3 \times 4 = 12$	$3 \times 4 = 12$	$3 \times 4 = 12$	$5 \times 4 = 20$
Number of pods/plant	$2 \times 4 = 8$	$3 \times 4 = 12$	$4 \times 4 = 16$	$4 \times 4 = 16$	$5 \times 4 = 20$
Number of seeds/pod	$2 \times 4 = 8$	$3 \times 4 = 12$	$4 \times 4 = 16$	$4 \times 4 = 16$	$5 \times 4 = 20$
Branching capacity	$2 \times 4 = 8$	$3 \times 4 = 12$	$4 \times 4 = 16$	$4 \times 4 = 16$	$5 \times 4 = 20$
Total	76	92	116	120	156
Rank	5	4	3	2	1

* Score value multiplied by number of female farmers give the score for each trait and varieties.

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