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Grant agreement No 771367

Guidebook to Participatory Plant Breeding for organic buckwheat in the EU

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Introduction

This guidebook is designed as a foundational resource for farmers, agricultural enthusiasts and anyone interested in sustainable agriculture. Whether you are a seasoned farmer or new to the field of organic farming, this guide aims to provide you with valuable insights into the practice of Participatory Plant Breeding (PPB) and how it can be effectively implemented in growing buckwheat organically, in line with EU standards.

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What is Participatory Plant Breeding (PPB)?

PPB is an innovative approach to plant breeding that actively involves farmers in the selection and breeding of crop varieties. Unlike conventional breeding programmes that are often conducted in research stations, PPB takes place in the field where the crops will be grown. This approach ensures that the developed varieties are well-suited to the specific conditions and needs of local farming systems. In PPB, farmers' knowledge and experience are valued and combined with scientific methods to create robust, resilient, and productive crop varieties.

Why focus on buckwheat?

Buckwheat, often considered a 'pseudo-cereal', is a highly versatile plant with numerous health and environmental benefits. It thrives in a variety of soil types and climates, making it an excellent choice for organic agriculture across different regions in the EU. Buckwheat is not only nutritious but also plays a significant role in soil health and biodiversity, making it a valuable crop in sustainable agricultural practices.

Organic farming and EU standards

Organic agriculture is a holistic approach to agriculture that emphasises the use of natural processes and materials, avoiding synthetic chemicals and promoting biodiversity. In the EU, organic agriculture is governed by strict regulations that ensure the environmental and health standards are maintained. This guidebook will help you navigate these standards, ensuring that your PPB practices for buckwheat are compliant and contribute positively to the environment and society.

Empowering farmers through PPB

This guidebook is more than just a manual; it's a tool to empower you, the farmer, in playing a crucial role in shaping the future of organic agriculture. By participating in breeding programmes, you are not only enhancing your own farming practices but also contributing to a broader movement towards sustainable, resilient and diverse agricultural systems.

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Buckwheat

What is buckwheat?

Buckwheat, or *Fagopyrum esculentum*, is a plant notable for its adaptability and nutritional benefits. Despite its misleading name, buckwheat is not a true cereal or grain. It is part of the Polygonaceae family, which places it closer to rhubarb and sorrel, distinguishing it from true cereals like wheat or rice that belong to the grass family (Poaceae) (Janovská et al., 2021).

Historical and global perspective

Historically, buckwheat cultivation dates back thousands of years in Asia, from where it expanded to Europe and North America. In Europe, particularly in France, Italy, and the Baltic regions, but also in the Czech Republic, Slovenia and Slovakia, buckwheat has become a popular crop, partly due to its versatility and environmental benefits (Bonafaccia et al., 2003, Kreft et al., 2003).

Nutritional profile

Buckwheat is celebrated for its nutritional qualities. According to the United States Department of Agriculture (USDA), it is a source of protein, dietary fibre and energy. The protein in buckwheat is high in essential amino acids like lysine, which is often limited in plant-based proteins. It's also rich in minerals such as magnesium, phosphorus and iron and contains bioactive compounds like rutin and quercetin, known for their antioxidant properties (USDA, 2023).

Buckwheat in organic agriculture

Organic agriculture values buckwheat for several reasons:

- **Soil health:** Its rapid growth and relatively broad leaves effectively help suppress weeds.
- **Pest management:** so far, there are few diseases and pests affecting buckwheat crops that align well with organic agriculture practices.
- **Biodiversity:** Buckwheat flowers attract beneficial pollinators, enhancing crop system biodiversity (Murphy et al., 2012).

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Adapting to European climates

Buckwheat's adaptability makes it suitable for the varied climatic conditions in Europe. It can thrive in less fertile soils making it an effective catch crop between main crop cycles (Vojtíšková, 2012). Given the EU's focus on sustainable agriculture and biodiversity, buckwheat is poised to play a significant role. Its utility in sustainable practices and nutritional benefits position it as a crop of growing importance in the EU's agricultural landscape (EU Commission, 2018).

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Principles of PPB in organic agriculture

Introduction to Participatory Plant Breeding (PPB)

Participatory Plant Breeding (PPB) represents a collaborative approach to crop development where farmers, breeders, and scientists work together. It contrasts with traditional breeding methods, where breeders make decisions often removed from the actual farming environment. PPB is particularly effective in organic farming systems where local adaptability and resilience are key. The approach is grounded in the principles of genetic diversity, local adaptation and farmer empowerment (Ceccarelli, 2015).

Nowadays, there are many methods that are used to create new varieties in agriculture. However, as shown in Annex 1 of the Position paper of IFOAM on Compatibility breeding techniques in organic systems (IFOAM, 2017), not all available methods and practices are acceptable for organic farming conditions. Organic breeders mostly deal with crossbreeding. However, not only the actual breeding method is important, but also the principle. In some European countries, the method of participatory plant breeding (PPB) has started to be used in breeding. This method emerged in the early 1980s as part of a movement promoting the concept of participatory research in response to criticism of the failure of research conducted at experimental stations to address the needs of poor farmers in developing countries. PPB has gained recognition as an activity that is mostly supported by social scientists and agronomists working with non-governmental organisations (NGOs). As a result, PPB was seen from the beginning as the opposite of conventional breeding, instead of being seen as an additional option in breeding. Even now, more than thirty years later, this view is still common (Ceccarelli et al., 2009).

Differences between conventional breeding and PPB

The principle of conventional breeding is a closed system where all decisions are made at the breeding station. The principle of PPB, on the other hand, is that from the crossing of the parent components, farmers, processors and other PPB participants are involved in selecting and deciding which materials from a cross they consider most suitable for their cultivation/processing method.

The differences between conventional breeding and PPB are shown below (Ceccarelli & Grando, 2007). Conventional plant breeding often follows a supply-driven approach, where new varieties are developed and released without first determining farmers' preferences or acceptance. In contrast, participatory plant breeding operates on a demand-driven model. In this approach, the final phase of introducing new varieties is guided by their initial adoption by farmers, which occurs after a complete cycle of selection.

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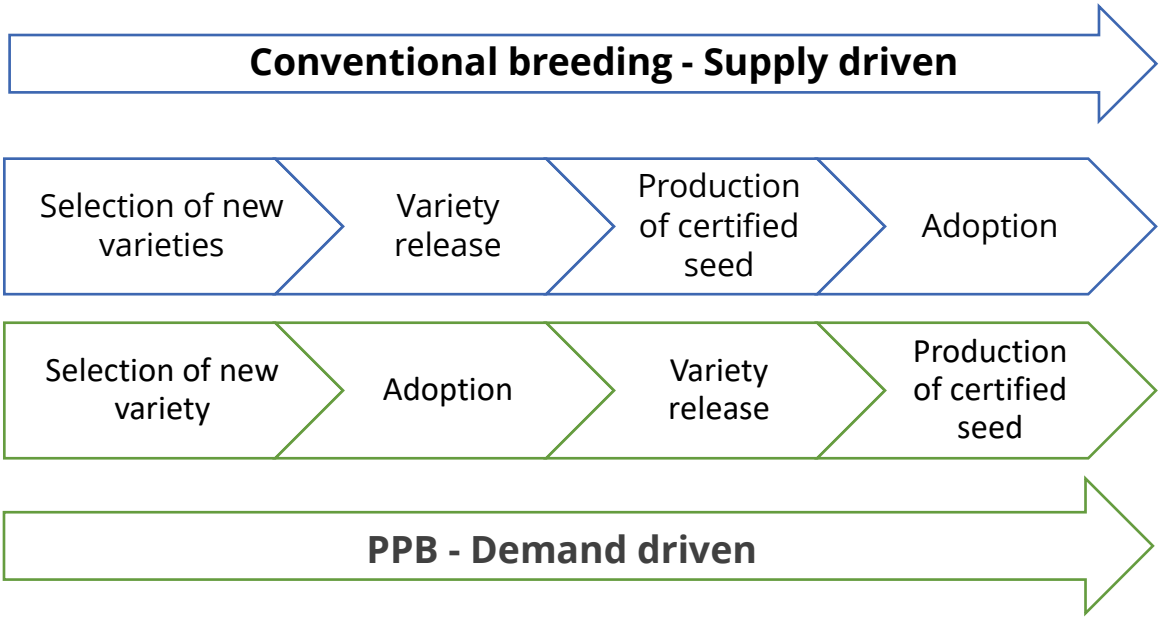

Relevance of PPB in organic agriculture

For organic farming, PPB is especially relevant. Organic farming systems, being diverse and variable, benefit from crops that are specifically adapted to local conditions. PPB can address specific challenges such as pest resistance, soil adaptability and climatic resilience, which are particularly crucial for organic farmers (Desclaux et al., 2008).

Key principles of PPB

Genetic Diversity

Genetic diversity is the cornerstone of PPB. By incorporating a wide range of genetic traits, PPB enhances the crop's ability to adapt to different environmental conditions and challenges. This diversity is particularly beneficial in organic agriculture, where reliance on synthetic inputs is prohibited (Wolfe et al., 2008).

Local Adaptation

Local adaptation involves selecting and breeding crops that perform well under local environmental, climatic, and soil conditions. This principle is critical in organic agriculture, where the focus is on utilising natural ecological processes (Dawson et al., 2008).

Farmer Involvement

Farmers play a central role in PPB. Their knowledge of local conditions and needs is invaluable in selecting traits and varieties that are most suitable for their specific contexts. This involvement also ensures that the developed varieties align with their practical and market requirements (Morris & Bellon, 2004).

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Benefits of PPB in organic agriculture

PPB offers several benefits in organic agriculture:

- **Enhanced crop resilience:** Varieties developed through PPB are often more resilient to local pests, diseases and climatic stresses.
- **Sustainability:** PPB supports the broader goals of organic agriculture, such as biodiversity, soil health and reduced dependence on external inputs.
- **Economic viability:** By developing varieties that perform better and meet market demands, PPB can enhance the economic viability of organic farms.

Implementing PPB in organic agriculture

Implementing PPB in organic agriculture involves several steps:

- **Initial assessment:** Understanding local environmental conditions and farmer needs.
- **Variety selection and breeding:** Collaboratively selecting and breeding buckwheat varieties with desired traits.
- **Field trial evaluation:** Conducting field trials on organic farms and gathering data for informed selection decisions.

Challenges and solutions

While PPB offers numerous benefits, it also presents challenges such as resource limitations, the need for continuous farmer engagement and balancing scientific rigor with practicality. Addressing these challenges requires strong collaboration, capacity building and support systems for farmers participating in PPB programmes.

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Getting started with PPB

Introduction to starting with PPB

Before diving into PPB, it's crucial to understand your local farming environment. This includes soil types, climate, common pests and diseases and specific challenges or advantages of your region. Gathering this information will guide your decisions throughout the PPB process.

Selecting initial varieties

The choice of initial buckwheat varieties to include in your PPB programme is a critical step. Consider the following:

- **Local adaptation:** Choose varieties that are known to perform well in conditions similar to yours.
- **Diversity:** Include a diverse range of varieties to maximise genetic diversity and potential for adaptation.
- **Organic suitability:** Ensure that the chosen varieties align with organic agriculture principles, such as non-GMO status and natural resilience to pests.

Conducting field trials

Field trials are at the heart of PPB. Here's how to get started:

- **Trial design:** Set up small plots for each buckwheat variety, ensuring they are representative of your farming conditions.
- **Documentation:** Keep detailed records of planting, growth and any observations throughout the season.
- **Evaluation criteria:** Decide on the traits you're focusing on, such as yield, disease resistance, or grain quality. For inspiration on which traits to choose for your field evaluation of buckwheat, you can check out buckwheat genetic resources catalogue.

Data collection and analysis

Accurate data collection is crucial. Use simple yet effective methods to record data on plant performance. Analyse this data to identify the best-performing varieties and traits.

Be prepared to navigate challenges such as variable weather conditions, pest outbreaks, or unexpected results. Flexibility and adaptability are key in PPB.

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Moving forward

After the initial trials and evaluations, the next steps involve selecting the best performers for further breeding and trials. This iterative process is the essence of PPB, where each cycle brings you closer to developing varieties that are ideally suited to your organic agriculture needs.

Selecting and breeding buckwheat varieties

Introduction to selection and breeding

In Participatory Plant Breeding (PPB) programs for buckwheat, a crucial aspect is the selection and breeding of varieties. Given buckwheat's predominantly cross-pollinated nature, this process becomes dynamic and offers a great opportunity for diversity. Suitable buckwheat varieties for breeding can be obtained by purchasing standard organic certified seed, from genebanks, seed banks and other sources of seed material.

Criteria for selection

Identifying desirable traits

Key traits for buckwheat variety selection might include:

- **Yield:** Grain production.
- **Disease and pest resistance:** Inherent resistance to local biotic stressors.
- **Drought tolerance:** Resilience in water-limited conditions.
- **Nutritional quality:** Levels of protein, minerals and bioactive compounds.
- **Adaptation to soil and climatic conditions:** Suitability to local environmental factors.

Field observations and farmer knowledge

Farmers' observations are invaluable in identifying plants that exhibit desirable traits. This hands-on approach helps in pinpointing varieties that perform well under specific organic conditions.

Breeding techniques for buckwheat

Managing cross-pollination

Given buckwheat's cross-pollinating nature, breeders can manage pollination to combine desirable traits:

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- **Controlled cross-pollination:** This involves isolating flowers and manually transferring pollen from one plant to another to encourage specific trait combinations. This should be done in isolated conditions, e.g. in a greenhouse , where pollinators do not have access. Even so, the flowers must be insulated with netting after pollination.
- **Bee line breeding:** Utilising bees as natural pollinators in controlled environments can also be an effective method for breeding buckwheat. In this case it is necessary to observe the principle that the range of the bee is up to 3 kilometres, so it is necessary to make sure that there is no other buckwheat crop in this radius. In that case, net isolation is necessary.

Seed selection and multiplication

Selecting seeds from the best-performing plants, especially those showing desired traits after cross-pollination, is crucial. These seeds are then multiplied the next season for further trials and eventual distribution.

Maintaining genetic diversity

Ensuring genetic diversity is a fundamental aspect of PPB:

- **Diverse genetic base:** Start with genetically diverse varieties to ensure a broad range of traits. This means, for example, obtaining buckwheat seeds from different sources, countries, etc.
- **Regular introduction of new genetics:** Continuously introduce new genetic material to maintain and enhance diversity. In order not to reduce the quality of the varieties, it is necessary to continuously work on obtaining new sources of original materials.

The participatory approach

Continuous engagement between farmers and breeders is vital:

- **Feedback mechanisms:** Regular feedback helps align breeding efforts with the actual needs and conditions of organic farmers producing buckwheat as well as with buckwheat processors.
- **Joint decision-making:** Collaborative decisions in the selection and breeding process ensure the development of varieties that are practical and beneficial for farmers as well as for buckwheat processors.

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Documentation and record-keeping

Keeping detailed records of breeding activities, plant performance and observations is essential for tracking progress and making informed decisions in future breeding cycles.

Creating a data collection plan

Begin by establishing what data you need to collect. This typically includes information on growth patterns, yield, disease resistance and other relevant agronomic traits. Define clear criteria and scales for measurement to ensure consistency.

Tools and equipment

Simple tools like measuring tapes, scales and notebooks are essential. Additionally, digital tools like smartphones or tablets can be used for recording and storing data electronically.

What to observe

- **Growth and development**: Monitor the growth stages of buckwheat, from germination to flowering and seed maturation. Note the timing of each stage and any deviations from expected patterns.
- **Yield measurements**: Record yield data by measuring the weight of harvested grain from a standard plot size. This provides a direct assessment of productivity.
- **Disease and pest resistance**: Keep an eye out for signs of disease or pest infestation. Document the severity and impact on the plants, noting any resistance observed in particular varieties.
- **Environmental and soil conditions**: Record environmental conditions like rainfall, temperature and any specific soil characteristics. This data helps in understanding how different varieties perform under various conditions.

Data analysis and interpretation

Analysing the collected data helps in identifying the best-performing varieties and understanding their characteristics. Look for trends, correlations, and significant differences among varieties. In PPB, sharing data with other participants, such as fellow farmers, breeders and researchers, is crucial. Collaborative analysis can provide deeper insights and foster collective learning.

Anticipate challenges like inconsistent data recording or environmental variables affecting the data. Address these by standardising procedures and training all involved in the data collection process.

Use the insights gained from data analysis to continuously improve your PPB practices. Adapt your breeding strategies based on what the data tells you about the performance of different buckwheat varieties.

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The records might contain information as shown in the following diagram.

Breeding

- Date and location of breeding activities.
- Description of parent varieties used.
- Methods of cross-pollination or selection techniques employed.
- Environmental conditions during breeding.
- Any challenges or deviations from the planned process.

Plant Growth and Development Journal

- Weekly or bi-weekly entries detailing plant growth stages.
- Photographic records for visual tracking.
- Notes on weather conditions and their potential impact on growth.
- Observations on plant vigour, disease resistance and other notable traits.

Yield and Performance Record

- Harvest dates and yield data (weight/volume of grains harvested).
- Assessment of grain quality attributes.
- Resistance to pests and diseases.
- Adaptability to specific soil and climatic conditions.

Progressing post-breeding

Successful varieties undergo:

- **Wider field testing:** Testing in different conditions and at various scales to ensure stability and performance.
- **Community engagement:** Sharing seeds and knowledge about new varieties within the farming community for broader benefit.

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Harvesting and seed saving

Harvesting buckwheat

In Participatory Plant Breeding (PPB) for organic buckwheat, the final stages of the cycle - harvesting and seed saving - are crucial.

Timing of harvest

Harvest timing is critical in determining the quality and quantity of your buckwheat yield. Buckwheat is ready for harvest when most seeds have matured, typically turning from green to brown. However, due to uneven maturing, some green seeds may still be present.

Harvesting methods

Depending on the scale of your operation, harvesting can be done manually or with machinery. For small-scale farms:

- **Manual harvesting:** Cut the plants near the base using scythes or sickles. Bundle the plants and allow them to dry for a few days before threshing.
- **Mechanical harvesting:** If available, a combine harvester can be used, especially for larger fields.

Threshing and cleaning

Threshing separates the seeds from the plant. This can be done by beating the dried plants over a tarp or using mechanical threshers. After threshing, winnowing helps to clean the seeds by removing chaff and debris.

Seed saving for PPB

Selecting seeds for saving

Choose seeds from the healthiest, most robust plants that best exhibit the desired traits. This selective process is integral to PPB, as it directs the future course of your breeding programme.

Seed quality and viability

Ensure that the seeds are fully mature and dry before storing. Test a sample for germination rate to assess seed viability. High-quality, viable seeds are critical for successful future planting.

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Seed drying and storage

Dry the seeds thoroughly to prevent mould and store them in a cool, dry and dark place. Use airtight containers to protect them from moisture and pests. Label the containers with the variety name and date of harvest.

Documenting seed information

Maintain detailed records of the seed-saving process, including the parent plant's characteristics, harvest date and any observations relevant to PPB. This information is invaluable for future breeding efforts.

Legal considerations and seed sharing

Be aware of any legal regulations regarding seed saving and sharing in your region, especially under EU organic agricultural policies. Sharing seeds with other farmers can help spread resilient, locally adapted varieties and foster community resilience.

Challenges in harvesting and seed saving

Address challenges such as variable seed maturity, weather conditions during harvest, and pest infestations during storage. Develop strategies to mitigate these risks, such as staggered planting for a more uniform harvest and secure storage solutions.

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EU organic standards and compliance

Key aspects of EU organic standards

In Participatory Plant Breeding (PPB) for organic buckwheat, adherence to EU organic standards is essential. Regulation (EU) 848/2018 effective from January 1, 2022, lays down the rules for organic production and labelling, emphasising environmental protection, preservation of natural resources and animal welfare. For organic farmers, it means adhering to specific practices that avoid synthetic chemicals, promote biodiversity and ensure ecological balance.

Prohibition of GMOs

The use of genetically modified organisms (GMOs) is strictly prohibited in organic agriculture. This includes the use of GMO seeds or any GMO-derived inputs in the breeding and cultivation processes.

Use of Organic Seeds

Organic farmers are encouraged to use organic seeds. However, under certain conditions, non-organic seeds may be used if organic varieties are not available. This is particularly relevant in PPB, where developing new organic varieties is a core objective.

Organic Heterogeneous Material (OHM) in PPB

Definition and importance

OHM refers to plant reproductive material, such as seeds, not fulfilling the definition of a variety in the conventional sense i.e. (DUS distinct, uniform and stable). OHM is crucial in PPB as it allows for greater genetic diversity and adaptability to local conditions, which are key in organic agriculture.

Compliance with OHM standards

When using OHM in PPB, it's important to ensure that it complies with organic agriculture standards. This includes maintaining biodiversity, ensuring the material is GMO-free, and adhering to organic cultivation practices.

Record-keeping and traceability

Maintain detailed records of all farming activities, including seed sources, breeding methods and cultivation practices. This traceability is crucial for compliance with EU organic standards and for potential inspections or certification.

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Challenges and solutions

Organic certification can present challenges, especially for small-scale farmers engaged in PPB. Solutions include seeking guidance from local agricultural bodies, joining organic agriculture associations, and participating in training programmes on organic standards and compliance.

PPB plays a vital role in advancing organic agriculture in the EU. By developing locally adapted, resilient buckwheat varieties through organic methods, PPB contributes to the broader goals of sustainability, biodiversity and ecological balance as outlined in the EU organic regulations.

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Sharing and learning

Participatory Plant Breeding (PPB) for organic buckwheat is not just about developing new varieties; it's also about building a community of knowledge and practice. Share success stories and case studies with the farming community. Highlighting achievements and lessons learned can inspire and guide others in their PPB endeavours.

Building a PPB community

Networking with other farmers

Connect with other farmers engaged in PPB and organic farming. This can be done through local agricultural co-operatives, on-line forums, or PPB-focused groups. Sharing experiences and techniques can lead to mutual learning and support.

Collaborating with researchers and breeders

Establish partnerships with agricultural researchers and professional breeders. Their scientific expertise can provide valuable insights into the PPB process and help address complex challenges.

Forums and social media

Use on-line forums and social media platforms to connect with a broader PPB community. These platforms offer opportunities for sharing experiences, asking questions, and staying informed about the latest developments in organic buckwheat farming.

Webinars and online training

Attend or host webinars and on-line training sessions focusing on PPB and organic agriculture topics. These digital resources make learning accessible to a wider audience and facilitate the exchange of knowledge across different regions.

Participatory workshops and field days

Organise or participate in workshops and field days where farmers, researchers and breeders come together to share knowledge, demonstrate techniques and discuss advancements in PPB and organic farming practices.

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Conclusion

The PPB in organic buckwheat breeding is ongoing. As the agricultural landscape evolves, so too will the practices and techniques of PPB. The continuous learning, adaptation and innovation inherent in this approach will guide farmers in meeting future challenges.

In conclusion, the empowerment of farmers through PPB is a transformative force in agriculture. It leads to more resilient, sustainable and productive farming systems, benefiting not just the farmers themselves but also their communities and the broader environment. The future of agriculture is bright, with farmers leading the way in creating a more sustainable and food-secure world.

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Appendix

Glossary

A

Agronomy: The science and technology of producing and using plants for food, fuel, fibre, and land reclamation.

B

Biodiversity: The variety of life in the world or in a particular habitat or ecosystem.

Bioactive compounds: Chemical compounds present in small quantities in plants and certain foods that have actions in the body and can promote good health.

Buckwheat (*Fagopyrum esculentum*): A plant cultivated for its grain-like seeds and as a cover crop. Not a true cereal or grass, it is a pseudocereal.

C

Cross-pollination: The transfer of pollen from the flower of one plant to the flower of another plant of the same species, resulting in fertilisation.

D

Decentralised field trials: Agricultural experiments conducted in various locations under different environmental conditions to test the adaptability of plant varieties.

E

EU Regulation 848/2018: The European Union regulation that sets the standards for organic production and labelling, emphasising sustainable practices.

G

Genetic diversity: The total number of genetic characteristics in the genetic makeup of a species. It is important for the survival and adaptability of a species.

Genetic resources: The genetic material of plants, animals, or other organisms that have actual or potential value for breeding, scientific and preservation purposes. In agriculture, this refers to the diversity of genetic material within crop species, including different varieties, which are crucial for breeding programs like PPB.

H

Harvesting: The process of gathering mature crops from the field.

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L

Local adaptation: The process through which plant varieties become better suited to the local environmental conditions in which they are grown.

O

OHM (Organic Heterogeneous Material): Plant reproductive material, such as seeds, that does not conform to the typical definition of a variety but is used in organic farming for its biodiversity and adaptability.

Organic Farming: A farming method that involves growing and nurturing crops without the use of synthetic based fertilisers and pesticides.

P

Participatory Plant Breeding (PPB): A collaborative approach to plant breeding where farmers, researchers and breeders work together to develop varieties suited to specific conditions.

Pest resistance: The inherent ability of a plant variety to resist damage caused by pests.

Pseudocereal: A non-grass plant that is used in much the same way as cereals (true grains).

S

Seed saving: The practice of saving seeds from vegetables, grain, herbs and flowers for usein subsequent years.

T

Threshing: The process of separating edible grain from the chaff, or the inedible parts of the plant.

Y

Yield: The amount of crop produced on a given amount of land.

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Additional Resources: List of resources for further reading and support.

Organic Eprints**.** URL: http://www.orgprints.org/

FAO Plant Breeding and Farmers Participation. URL: https://www.fao.org/3/i1070e/i1070e.pdf

URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0848

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Grant agreement No 771367