Training Manual on Organic Agriculture

National Centre for Organic Agriculture
Department of Agriculture
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EDITOR

1. Dr. Sonam Tashi, Associate Professor, CNR
2. Mr. Tenzin Wangchuk, Lecturer, CNR
3. Mr. Mahesh Ghimiray, Fixed Term Faculty, CNR

TECHNICAL CONTRIBUTORS:

1. Dr. Sonam Tashi, Associate Professor, CNR
2. Mr. Ongpo Lepcha, Lecturer, CNR
3. Mr. Tenzin Wanchuk, Lecturer, CNR
4. Mr. Mahesh Ghimiray, Fixed Term Faculty, CNR
5. Ms. Tshering Zam, Sr. AO, NCOA-Yusipang
6. Ms. Dawa Dem, HO, NCOA-Yusipang
7. Mr. Kinley Tshering, AO, ARDC-Bajo
8. Mr. Tashi Wangchuk, Sr. LO, NSSC
9. Mr. Tshetrim La, Sr. AO, NOFP-CU, DoA

ILLUSTRATIONS, LAYOUT AND DESIGN BY:

1. Mr. Tshetrim La, Sr.AO, NOFP-CU, DoA

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List of Acronyms

ARDC	Agriculture Research and Development Centre
BOGS	Bhutan Organic Guarantee System
BOS	Bhutan Organic Standard
BSB	Bhutan Standard Bureau
CB	Certification Bodies
COROS	Common Objectives and Requirements of Organic Standards
CU	Coordination Unit
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
FiBL	Research Institute of Organic Agriculture (Frick, Switzerland)
GNH	Gross National Happiness
ICIMOD	International Centre for Integrated Mountain Development
ICS	Internal Control System
IFOAM	International Federation of Organic Agriculture Movements
LCRDC	Livestock Commodity Research and Development Centre
LOAS	Local Organic Assurance System
LUC	Land Users' Certificate
MoAF	Ministry of Agriculture and Forests
MoEA	Ministry of Economic Affairs
NCOA	National Centre for Organic Agriculture
NOP	National Organic Program
NFOFB	National Framework for Organic Farming in Bhutan
NOFP	National Organic Flagship Program
OA	Organic Agriculture
PGS	Participatory Guarantee System
RNR	Renewal Natural Resources
SAP	School Agriculture Program
SDGs	Sustainable Development Goals
UN	United Nations

Preface

The training module on Organic Agriculture is designed for agriculture extension officials who have some understanding of organic agriculture and who have been working directly with farmers in implementing organic agriculture development activities.

The module broadly aims to provide knowledge and understanding of the concept, principles and practices of organic agriculture and its contribution to socio-economic and environmental sustainability. It also provides trainees in-depth understanding of cost-effective and eco-friendly crop protection and soil nutrient management strategies suitable for organic farming.

This manual has three modules comprising units and sub-topics. The first module is on understanding the concept of organic agriculture, policies and trends in OA development, the relationship between OA and SDGs and some of the OA practices. It also explains organic agriculture and regulatory system and covers topics related to different organic certification systems existing in Bhutan. The second module is on plant protection in organic agriculture. It aims to provide tools and techniques to diagnose damage symptoms caused by pests and pathogens, identify beneficial insects and pests, and describe various organic methods for pests including weeds. The third module is on soil nutrient management which provides knowledge and skills on improving the soil fertility of organic farms. It provides concepts and various soil management options in organic farming. The trainees will learn the methods of preparing organic fertilizer using locally available raw materials. They will also learn how to plan cultural methods of soil management to maintain soil fertility.

The training has provisions for several groups and individual activities to make the training effective and interactive. Moreover, the mode of delivery of the training will be a balance of theoretical and practical.

This manual is jointly prepared by professionals from the College of Natural Resources, Royal University of Bhutan and the National Centre for Organic Agriculture, Agriculture Research and Development Centre, Bajo, and National Soil Services Centre. Important reference materials used in developing this manual are provided at the end of the manual.

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MODULE I:

ORGANIC AGRICULTURE AND ORGANIC AGRICULTURE REGULATION AND CERTIFICATION

A. Learning methods

Powerpoint presentation, group discussion and individual participation.

B. Materials required

Powerpoint projector, white board, board marker pen, flip chart, marker, notebook, board sticker and pen.

C. Time allocation

16 hours (eight hours for the first five units and the remainder eight hours for Unit Six).

D. Learning outcomes

At the end of the module, the participants will be able to:

1. Explain the concept of organic agriculture and its contribution to socio-economic and environmental sustainability.
2. Explain the significance of the principles of organic agriculture.
3. Analyze the relationship between organic agriculture and Sustainable Development Goals.
4. Discuss the drivers of organic agriculture trend and movement in Bhutan and the world.
5. Describe Bhutan's approaches to and strategies for OA development.
6. Articulate the role of Dzongkhags in promoting OA in Bhutan.
7. Explain the importance of the Bhutan Organic Guarantee System and its application.
8. Describe and explain Organic Certification and its purpose.
9. Describe, explain and analyze the overview of organic registration and certification system in Bhutan.
10. Describe and explain LOAS and its application.
11. Apply skills and knowledge gained in the implementation of LOAS certification procedures in the field.
12. Describe and explain BAFRA Third Party Certification and its application.
13. Explain and interpret Internal Control System and its application.
14. Be able to initiate the institution of Internal Control System in promoting organic groups/cooperatives.

1. Unit I - Introduction

1.1 National Vision

Bhutan has inspired the international community in many ways. The development philosophy based on Gross National Happiness (GNH) paradigm must be by far the most inspiring of all. Beyond alleviating happiness over wealth, the GNH growth model most poignantly emphasizes on socio-economic and environmental sustainability in a holistic manner. Emanating from this GNH growth model are numerous developmental visions, including environmentally clean food production for sustainable livelihood and food security. In this regard, organic agriculture becomes most relevant for Bhutan and already organically produced food has become the priority of the government.

Organic agriculture is not only less harmful compared to most other forms of farming, but also offers multiple benefits and addresses several Sustainable Development Goals. Cognizant of its myriad positive roles, OA is increasingly being adopted across the world and for the first time in 2019, the global share of agricultural land under OA reached 1.5%.

1.2 Understanding Organic Agriculture

There are several definitions of OA with each agency emphasizing in the definition those elements that it thinks are important or align with its national objectives for promoting OA. But in a very simplistic term, OA is a low cost sustainable and holistic way of producing food, fibre and fuel relying and emphasizing mainly on the inherent capacity of the soil, biodiversity, local resources and inputs instead of external synthetic chemical inputs, Genetically Modified Organisms and artificial hormones.

Discussion (15 minutes)

Ask participants write on a piece of paper their idea of organic agriculture and its key elements, and paste these papers on a wallpaper. At the end of the module, ask the participants if they want to make any changes to their original idea of organic agriculture or not.

To fully understand the concept of OA and appreciate its practicality, the key elements of this definition can be interpreted as questions in the following manner: How OA is low cost? How OA contributes to sustainability? What is wholistic farming? What is the "inherent capacity of the soil"? Why OA does not encourage dependence on external inputs? Why GMOs and artificial hormones should be avoided?

1.3 Organic agriculture is sustainable

How OA contributes to sustainability? Sustainability basically refers to meeting the needs of the present without compromising the ability of the future generations to meet their own needs. Multiple studies have documented that organic agriculture contributes to socio-economic and ecological sustainability and sustainable food security. This is possible because of the emphasis of OA on diversified crop rotation, cover cropping, mulching, etc. which contribute to several positive impacts on land and water.

OA helps improve soil fertility and soil structure which are crucial for enhancing crop productivity and also for increasing stability to environmental stress. Soils farmed organically have the capacity

to retain more moisture, which results in 20-60% less irrigation requirements. Besides, less water pollution and nitrate leaching in ground water, soils of organic farms have the capacity to sequester more carbon – sequestering about 450 kg more atmospheric carbon per hectare per year.
The integration of animals on the farm, reliance of local resources and knowledge and avoidance of agro-chemicals also help OA to be more self-reliant and robust. The use of industrial chemicals for farming not only damages health of the ecosystem on which rests the livelihood of rests of living beings, but also these external inputs can be expensive and not economically viable in the long run.

1.4 Organic agriculture is low cost

What makes OA a low-cost farming system? In OA, since synthetic agro-chemicals and hybrid seeds are avoided, operating costs are significantly lower than conventional production, ranging from 50-60% for cereals and legumes, to 20-25% for dairy cows and 10-20% for horticulture products (Scialabba, 2015). Organic farms are generally expected to save their own seeds, recycle the waste and use family labor. In fact, on an average, organic farming helps to save up to 20% higher energy than conventional farming. However, organic certification could add to the overall cost of organic products.

1.5 Organic agriculture is holistic farming system

What makes OA a holistic farming system? Organic agriculture treats farm and all its components in the entire food systems value chain as one indivisible whole organism. These components are believed to be interconnected and therefore the well-being of one component is contingent on the well-being of another component and likewise the strength of one component is as well the strength of another component.

In such intertwined system, resource and energy do not go to waste. For instance, farm waste such as crop residues can be used as animal feed and the waste from animals can be used as manure. Besides the manure, animals on farm also play an important role of suppressing harmful worms and insects especially by free range chickens. Animals in general also add to nutritional diversity. The components (soil, water, animal, crop and trees) in the whole system should be designed and managed to complement each other so that the resulting synergetic effect could be harnessed.

1.6 Inherent capacity of the soil

Figure 1: Soil tilled in Barshong village, Trashigang Dzongkhag

Inherent capacity of the soil

What is the "inherent capacity of the soil"? Soil is supposed to be "full of life" with a handful of soil containing more living organisms than the people on the planet. The living organisms including microbes, worms and insects, through their complex web of operation help sustain the health of the soil and feed the plants. In organic farming, the idea is to maintain and nourish the health of the soil by maintaining organic matter levels, promoting soil biological activity and reducing damage to soil structure.

1.7 Risks of reliance on external inputs

Why is it important to not depend on external inputs? OA encourages a farm to be self-reliant and self-sustaining. This implies generating all the inputs required on/for the farm from and by the farm itself. If a farm depends on external inputs, be they seeds or fertilizers, the farm could be exposing itself to several risks in terms of quality, unknown pests/diseases, price fluctuation and timely supply.

Over reliance on external sources could mean surrendering a farm's sovereignty to the external supplier. The supplier would dictate the type of crop farmers should grow and the type and quantity of fertilizers farmers should apply. This way farmers could lose their sovereignty over food production. This is already happening in the industrialized nations. In supermarkets across Europe, one can find only one type of banana – Cavendish. In any rural market in the global south, there will be at least three-five different types of bananas.

1.8 Prohibition of GMOs in OA

Why GMOs and artificial hormones are not allowed in OA?

Genetically Modified Organism is a product produced artificially by splicing and combining different genes. Organic Agriculture has zero tolerance for GMOs and also the use of other artificial growth hormones, antibiotics, additives and preservatives are restricted as they convene the stipulations in OA principles.

Discussion (15 minutes)

Divide the participants into two groups and let one group work on the advantages of GMOs and the other group on the disadvantages. Post their work on the wallpaper and ask the participants to assess whether GMO should be allowed or not in Bhutan.

GMOs are suspected in genetic contamination through cross pollination and are also alleged in several other issues including pest resistance (which results in increased use stronger, more toxic pesticide combinations), human and environmental health and economy and productivity. Ultimately, over reliance on GMOs would result in farmers losing control over seed production and seed sovereignty and hence be perpetually dependent on seed companies for their seed needs and food production.

1.9 Principles of OA

What are the four principles of OA? Why principles are important? How do they relate to Bhutan's development goals?

Organic agriculture hinges on four principles, which are profound and go beyond farm and farming. The principles provide a strong motivation to look at farming as a way of life. These principles are also grounded on making OA socio-economically and ecologically sound and sustainable.

1.9.1 Principle of Health

The health of soil, plant, animal, human and planet is indivisible and interdependent and as such the role of OA, whether in farming, processing, distribution or consumption, should be to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings. This can be achieved by avoiding the use of synthetic agro-chemicals including animal drugs and food additives that may have adverse health effects.

1.9.2 Principle of Ecology

Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. Organic management must be adapted to local conditions, ecology, culture and scale. The reduction of inputs by reusing, recycling and the efficiently managing materials and energy will contribute to improved environmental quality and will conserve resources.

1.9.3 Principle of Fairness

This principle emphasizes that those involved in organic agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties – farmers, workers, processors, distributors, traders and consumers. It also insists that animals should be provided with the conditions and opportunities of life according to their physiology, natural behaviour and well-being. Natural and environmental resources that are used for production and consumption should be managed in a socially and ecologically fair way and should be held in trust for future generations. Fairness requires systems of production, distribution and trade that are open and equitable and account for real environmental and social costs.

1.9.4 Principle of Care

Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. Care should be taken in choosing new technologies so that they are safe, healthy and ecologically sound.

1.10 Organic Agriculture and Sustainable Development Goals

Agriculture development with new technologies and innovations has been unprecedented and has solved substantial hunger crisis leading up to the mid-20th Century. Along with solving the hunger problems, previously not fully anticipated environment, social and economic issues have also inadvertently emerged as a result of sophistication in agriculture development. These include soil degradation, water contamination, air pollution, biodiversity loss, increasing greenhouse gas emissions and other social and economic impacts. The conventional agriculture hailed hitherto as a paradigm for voluminous food production and a savior has to transform and a new alternative sustainable way of farming is seen to be organic agriculture.

There is now increased worldwide consensus that OA is the way forward in producing safer food with minimal adverse impacts on society, economy and environment. Thus, OA is seen as a part of the solution and a tool to address multiple SDGs. Whilst healthy and sustainable food has direct and indirect link to all the 17 SDGs, OA has more relevant and direct contribution to eight goals, which include SDG 2: Zero Hunger, SDG 3: Good Health and Well-being, SDG 6: Clean Water, SDG 8: Decent Work Conditions, SDG 12 Responsible Production and Consumption, SDG 13: Climate Action, SDG 14: Life below Water, and SDG 15: Life on Land. (See Box 1 for SDGs).

The OA's contribution to SDGs primarily comes from its prohibition of the use of synthetic agro-chemicals, which have multiple negative impacts on soil, water, biodiversity, environment and huma health. OA's potential to conserve resource and protect and sustain the health of ecosystem makes it an attractive tool through which to enhance farm productivity and nourish the growing global population.

Box 1: Sustainable Development Goals

In September 2015, over 150 world leaders adopted the 2030 Agenda for sustainable development comprising an action plan of 17 SDGs. The goals aim at addressing the global challenges and "call all nations to make our societies inclusive, equitable, sustainable and responsive in their approach to development and climate change" (FAO, 2018).

These 17 SDGs built on the Millennium Development Goals include SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 3: Good Health and Well-being, SDG 4: Quality Education, SDG 5: Gender Equality, SDG 6: Clean Water and Sanitation, SDG 7: Affordable and Clean Energy, SDG 8: Decent and Economic Growth, SDG 9: Industry, Innovation and Infrastructure, SDG 10: Reduced Inequalities, SDG 11: Sustainable Cities and Communities, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, SDG 14: Life Below Water, SDG 15: Life on Land, SDG 16: Peace, Justice and Strong Institutions, and SGD 17: Partnerships for the Goals.
There are four goals under each of Economy and Biosphere domains and eight under Society. The remainder 17th goal is for pulling together all the goals.

Numerous literatures also highlight the adaptation and mitigation potential of OA to climate change. Avoidance of synthetic agro-chemicals is attributed to significant reduction in amount of carbon dioxide emissions. Further, organically farmed soils consistently show high carbon sequestration potential than soils farmed conventionally. Soils rich in organic matter also can hold more moisture/ water, reduce surface run-off and erosion and hence can sustain supply during drought period.

1.11 Organic agriculture policy

Does Bhutan have a policy on OA? No, there is no direct/specific policy on OA development in the country (ICIMOD, 2018). The latest official document or paper of the government or MoAF on OA is the National Organic Flagship Program's *Sustainable Socio-economic development through the commercialization of organic farming*. On OA policy, this document makes references to either some old documents (NFOFB) or to some policies that have some connections to OA (Bhutan's conservation policy, Economic Development Policy 2016, etc.).

Lack of specific policy amongst others could also be contributing to declining budget allocation for NOP. Budget for NOP declined to Nu. 2.42 million in 2016-17 from Nu. 16.06 million in 2012-13. Without the policy, legitimizing OA activities may not receive the necessary support and more importantly the drive to envision OA developmental activities may lack seriousness that is required to further OA development in the country. In this regard the case of Sikkim, Bhutan's neighboring state could be interesting (See Box 2).

Box 2: Sikkim and Bhutan's OA conversion journey

Organic agriculture in Sikkim began in 2003, which is almost around the same time Bhutan informally embraced organic agriculture. Seven years later, Sikkim established the Sikkim Organic Mission to boost organic movement in the state. Around the same period, Bhutan also launched not just the National Framework for Organic Farming in Bhutan, but also the National Technical Working Group and the National Organic Program. Further, the review of the National Framework for Organic Farming in Bhutan was also completed by a team of senior researchers and Bhutan also declared to the international community to become a fully organic country by 2020.

However, despite all these developments, including strong political support from the three successive governments, OA movement in Bhutan didn't make much progress. While Sikkim continued the push for OA development resulting in launching of the State Policy on Organic Farming in 2014. And two years later in 2016, Sikkim's concerted effort in promoting organic agriculture culminated in claiming the grand status of being the 100% organic state. On the other hand, Bhutan continued to lag behind and as of 2022, six years after Sikkim became a fully organic state, Bhutan has brought a mere 5,560 ac of land under organic management and has certified just 10 farm produces as organic. The number of organic producers/ households remain dismal at 2,680.

Where did Bhutan go wrong in its quest for becoming a fully organic country? What lessons can Bhutan draw from Sikkim's successful experience? Would it had helped Bhutan if there was a separate policy solely for organic agriculture development?

1.12 Status of organic agriculture in Bhutan

Bhutan adopted organic farming in 2006, but the growth of organic agriculture in Bhutan has been rather slow and the initiative to push the organic agriculture movement forward has been rather lukewarm. Fortunately, the country's difficult terrain and limited capacity of the farmers contributed to Bhutan still being largely free from conventional approaches to farming. As of 2018, only 37% of the farmers used agro-chemicals in 19% of the cultivated land (ICIMOD, 2018), which indicates about 162,000 acres of the cropped land is chemical-free (NSSC, 2018).

> **Exercise (15 minutes)**
>
> Ask each participant to provide statistics on OA in their respective Gewog/Dzongkhag. The statistics should include amongst others organic crops, total area under organic production for various crops, number of households engaged in OA, etc. (See Table 1 as an example.) Identify which gewogs/Dzongkhags has the highest number of organic producers, area under OA and the number of products.

The land under organic crop and livestock management is around 5,560 acres and under wild collection it is around 20,107 acres. Around 2,680 households are engaged in organic farming (National Organic Flagship Program, 2018), and there are 24 farmers' groups and cooperatives, three organic retailers and one exporter. Three small organic fertilizer production units with an annual production capacity of 20 MT each have also been established. The National Organic Program also trained 1,442 farmers and 242 field officials on organic production.

The NOP has launched Local Organic Assurance System (LOAS) certification system in 2017 for locally produced organic products and collaborated with Bhutan Agriculture and Food Regulatory Authority (BAFRA) the National Certification Body for national certification. So far, 10 products have been certified as organic, and these include potato, garlic and carrot from Gasa, turmeric from Zhemgang, sea buckthorn, chamomile and mint from Bumthang, green tea (*Camellia sinensis*) from Trongsa, *Rhododendron anthopogon* from Thimphu and lemongrass from Mongar.

Table 1: Bhutan Organic Data – Crop, area, producers (Example)

Dzongkhag	Gewogs	Crops	Area (ac)	No. of hhs.
Bumthang	Chumey	Wheat	34	19
		Potato	100	41
	Gyetsa	Barley	45	
		Potato	111	
	Tang	Buckwheat	33	
		Wheat	47	
	Ura	Potato	120	
		Barley	41	
Chukha				
…				
Zhemgang				
TOTAL (Bhutan)				

With the existing organic-based sustainable agriculture, Bhutan is best positioned to use organic agriculture as tool to fulfill the global commitment to at least eight SDGs (1: No poverty, 2: Zero Hunger, 3: Good health and well-being, 6: Clean water, 8: Decent work conditions, 12: Responsible production and consumption, 13: Climate action, 14: Life below water and 15: Life on land) in particular and others in general.

1.13 Global trend in organic agriculture

Worldwide the growth of organic agriculture is positive. Land under organic management is increasing and in tandem production, number of producers and marketing are increasing too. The latest report published by the IFOAM and FiBL (2021) show that as of 2019, organic agriculture activities were recorded in 187 countries and the land under OA had increased to 72.3 million ha (amounting to 1.5% of the total global agricultural land) from 11 million ha in 1999, when the first official record keeping on global OA began.

In terms of land under OA country-wise, Australia leads (35.7 million ha) followed by Argentina (3.7 million ha) and Spain (2.4 million ha). However, in terms of organic share of total agricultural land, Liechtenstein leads (41%) followed by Austria (26.1%) and Sao Tome and Principe (24.9%). For the first time in 2019, the organic share of the global agricultural land crossed 1% and reached 1.5%.

The total organic producers also increased to 3.1 million in 2019 from 0.2 million in 1999. India has the highest number of producers (1,366,266) followed by Uganda (210,353) and Ethiopia (203,602).

Discussion (15 minutes)

Ask participants to write answer to the question – *What is driving conversion to OA worldwide?* Paste these answers on a wallpaper and ask one-two participants to read a few of the answers and initiate a short discussion on these answers.

In 2019, global organic market also set a new record by crossing 100 billion euros and reaching 106.4 billion (B) euros from 15.1 B in 2000. The US has the largest organic market at 44.7 B euros followed by Germany and France at 12 B euros and 11.3 B euros, respectively.

The global per capita consumption of organic food stood at 14 euros and top three countries in this category are all based in Europe namely Denmark (344 euros), Switzerland (338 euros) and Luxembourg (265 euros).

1.14 Why (promote) organic agriculture?

Conventional agriculture through the use of synthetic agro-chemicals can destroy the very production base (land, water, air and biodiversity). Due to excessive concentrated salts in these agro-chemicals, most beneficial microbes and living organisms in the soil, which are important in breaking down and releasing plant nutrients will be destroyed.

Synthetic agro-chemicals besides being toxic are also expensive and have to be imported at the cost of huge ecological footprint. Also, dependence on imports is not always reliable as was experienced during the COVID-19 pandemic when farmers in many parts of the country could not access such imported products.

Organic agriculture on the other hand has the potential to ensure food security, enhance biodiversity, and bring about socio-economic and environmental sustainability (See Box 3). Based on several environmental indicators, OA has a superior environmental performance per unit area than conventional agriculture, meaning per unit food production is higher under OA. OA contributes substantially to at least eight Sustainable Development Goals and strategies.

Box 3: Socio-economic and environmental benefits of OA

Social benefits

- Rural employment
- Preservation of traditional knowledge and culture
- Good working condition
- Gender balance

Economic benefits

- Low cost because there is no need to purchase synthetic agro-chemicals and expensive hybrid seeds
- Good and consistent yield
- Good market demand

Ecological benefits

- Reduction in ground water contamination
- Reduction in land and air pollution
- Soil structure and biology improvement
- Biodiversity promotion
- Waste and energy recycling

Organic products are high in demand both in the local and international markets thus creating export opportunities. Exported organic products command a high premium price sometimes touching up to 20% or higher compared to the products from conventional farms. Return per unit of land therefore is substantially high, which translates to increase family income and the local food security.

1.15 Questions on becoming a 100% OA country

In 2008, Bhutan declared to the international community to be the first fully organic agriculture country by 2020. It is two years since the end of the deadline for becoming a 100% organic, the country is still nowhere near achieving that ambitious goal. The ambition has not waned yet because the country has proposed the same target to be achieved by 2035.

Discussion (20 minutes)

Divide the participants into two groups. Let the first group discuss on the proposal to convert fully to OA and the second group on the reasons for not converting to fully organic. Each group will have to critically analyze the benefits of converting or not converting to OA. Ask one representative from each group to present their group's work.

So, can we achieve our goal this time around? How can be achieve the 100% organic dream? What should we do to achieve that goal? Or, some might ask if we should really become a fully organic agriculture country in the first place? One may also like to reflect on why Bhutan couldn't achieve its first goal of becoming a 100% organic by 2020? What when wrong? What contributed to the failure and what lessons can we draw so that this time we will surely succeed? Or have we at all reflected on our failure?

1.16 Yield comparison between organic agriculture and conventional agriculture

Yield is a function of many factors and comparing it needs to be looked at from very context-specific cases. Besides quality seeds, timely management and implementation of all production activities such as sowing, manuring, irrigation, weeding and plant protection affect yield.
Generally, organic yields are 20% less as compared to high-input systems in industrialized countries. Studies show that yields decline in the initial years of conversion to organic farming. Once the agro-ecosystem stabilizes and organic management practices are implemented then the yield significantly increases. But in countries like Bhutan where the conversion takes place in a low- input system, yields under organic farming would be more stable compared to conventional management regime.

It has also been documented that during drought and weather extremes, OA outperforms CA in terms of yield as a result of stable soil condition brought about by organic soil management practices.

1.17 Perception of agriculture extension officials on converting to fully OA

What agriculture extension agents think of the vision to convert to fully OA? The agriculture extension officials work very closely with the farmers in the field and so they have the firsthand experience of the realities of the field. It would therefore be important to seek their views, thoughts, expectations and opinions on the country's vision to eventually become a fully organic agriculture country.

EAs' Experience sharing (15 minutes)

Pass a piece of paper and ask the participants to share their thoughts on the following questions pertaining to converting to a fully organic country: First, is it or will it be possible to convert fully to organic country? Second, should Bhutan convert fully to OA or not? Why? How ready each participant is to take on the challenge, if the government seriously pursues the plan to convert fully to OA?

2 Unit II - Organic Agriculture Practices

Organic agriculture is less harmful and more sustainable owing to multiple practices and systems approach it relies on. Organic farming emphasizes on being self-reliant and therefore depends on practices that help to recycle resources and conserve energy. Returning carbon to soil and enhancing biodiversity through various practices as listed below are central to organic farming.

The most common organic agriculture practices include diversified crop rotation, legume integration, cover cropping, minimum tillage, intercropping, multiple cropping, agro-forestry, crop-animal integration, recycling farm wastes, mulching, green manuring, composting, using biofertilizers, etc. Each of these practices serves more than one purpose in making an organic farm truly resilient and robust. For instance, proper crop rotation not only helps to break pest-host cycle, but also helps to maintain soil health by drawing plant nutrients from different soil depths; likewise, multiple cropping which involves growing different plants together not only helps to maintain natural check and balance of pests and diseases, but also helps to ensure land use maximization and nutritional diversity of the farm household. Multiple cropping also helps in addressing marketing issue.

All organic agriculture practices are easy and cheap to adopt and are suitable for small landholdings. However, organic agriculture is knowledge-intensive and so one should have good knowledge and experience. It would be naïve to expect to become a successful organic farmer, particular if a person is new to farming because in organic farming, the person has to have a good understanding and knowledge of the relationship and dynamics between land, water, crops, animals, climate and other elements.

Each of these practices will be discussed in more detail in a separate technical module. There will also be practical on many of these practices.

Figure 2: A diversified agriculture farm, Yadi, Mongar Dzongkhag

3 Unit III - Approaches for Implementing NOFP and Organic Sector Development

The government approved Nu. 1 billion National Organic Flagship Program to be implemented over four years starting 2019 through to 2023. However, due to COVID-19 pandemic, the budget allocation was later slashed by 50% to Nu. 500 million. The flagship program aims to further develop organic sector through commercialization of select group of crops, engagement of youth, enhancement of access to farm inputs, value addition, innovation and technology generation, and capacity building.

The flagship program being implemented has assumed a project model with the title *Sustainable Socio-economic Development through the Commercialization of Organic Farming*. For effective implementation of the activities, the project has developed five approaches and 12 strategies.

3.1 Integrated Landscape Management

Landscape management is critical in organic farming to address cross contamination issues and also to ease management and organic certification. Under this approach, a continuous stretch of well-define area in a Gewog, Dzongkhag or watershed will be selected in its entirety for targeted organic farming interventions.

Five approaches

1. Integrated landscape management
2. Align organic production with LUC program
3. Community-based organic program
4. Commercial organic farming
5. Group approach for organic production

3.2 Align the Organic Production with LUC Program

The implementation of the organic flagship program activities will be through LUC groups where 205 young entrepreneurs are engaged. There are 13 LUCs across 10 eastern, western and southern Dzogkhags covering a total 187 acres.

Eight LUC programmes are in six eastern Dzongkhags namely Mongar, Trashigang, Trashiyangtse, Lhuntse, Pemagatshel and Samdrup Jongkhar covering over 104.5 acres. Five LUC programmes in four western and southern Dzongkahgs include Paro, Chukha, Sarpang and Samtse covering over 82.5 acres. A total of 155 youths is engaged in the eastern LUC programme and around 50 youths are engaged in western and southern LUC programme. The selected commodities will be cultivated in the LUC programme areas.

3.3 Community-based Organic Production

Organic farming interventions have to be acceptable to the communities so that they lead the program. Community-based production will not only help in generating the scale for market, but will also ensure integrity, social ethics and reduce cross contamination.

3.4 Commercial Organic Farming

Commercial organic farming will be implemented through LUC programs and will include a select group of enterprises and commodities having potential for commercial trading both in the export and domestic market. Criteria such as market feasibility, agro-ecology suitability, community interest and acceptance will be used in selecting the potential enterprises and commodities. This approach also aims to make farm inputs available besides focusing on value addition and product development.

3.5 Group Approach for Organic Production

> **Discussion (15 minutes)**
>
> Ask participants to reflect on five approaches and discuss the challenges of implementing each of these approaches.

In addition to involving youth engaged in LUC programs, in selected Dzongkhags, farmers' groups and cooperatives will be formed to produce selected organic commodities. Production as a group/cooperative will ensure volume that is required to justify marketing. Individual farmers, FDIs or farmers groups/cooperatives and other agencies will be encouraged to operate bio and other farm inputs enterprise.

4 Unit IV - Strategies for Implementing NOFP and Organic Sector Development

4.1 Integrate and operationalize NOP across all sectors

- Link together the three principal sectors under MoAF namely agriculture, livestock and forestry.
- Station NOFP Coordination Unit at the Department of Agriculture headquarters under the leadership of the Director, DoA.
- Create National Organic Board with appropriate institutional representations under the chairmanship of Secretary, MoAF.

Twelve Strategies

1. Integrate and operationalize NOP across all sectors
2. Integrate livestock in organic farming
3. Integrate forest in organic farming and initiate activities that support organic production
4. Enhance production, availability and access to bio-inputs and organic seeds
5. Enhance soil nutrient management at LUC program sites through integrated approaches
6. Organic research and development program in all the sectors
7. Promote cooperative/group-based organic production
8. Promote organic management of weeds, diseases and insect pests
9. Develop organic value chain and market system
10. Strengthen advocacy, awareness on organic farming technologies, products and success stories
11. Strengthen farm mechanization to address labour shortage for farming
12. Develop and operationalize organic certification systems

4.2 Integrate livestock in organic farming

- Promote integration of a few heads of livestock in the farm to not only derive organic manure but also to diversity income and nutritional requirement.

4.3 Integrate forest in organic farming and initiate activities that support organic production

- Use of Sokshing.
- Integrate organic farming in all watershed management plans.
- Introduce organic management in protected areas.
- Promote plant species with bio-pesticidal properties.
- Expand agro-forestry.

- Explore export market for lemon grass oil as a wild collection product.


Figure 3: Integrated farm, Yadi village, Mongar

4.4 Enhance production, availability and access to bio-inputs and organic seeds

- Provide suitable organic alternatives to synthetic agro-chemicals.
- Encourage the use of bio-control agents, cultural practices (green manuring, mulching, catch crop) cropping systems (such as crop rotation, multiple cropping) and field sanitation.
- Develop 19 small-scale organic fertilizer production plants in LUC program areas (one each) and other selected Dzongkhags.
- Develop additional two large-scale plants in strategic location (Chukha and Samdrup Jongkhar).

4.5 Enhance soil nutrient management at LUC program sites through integrated approach

- Improve composting processes to enhance the quality and efficiency.
- Promote the use of cover crops, green manures, animal manures and crop rotations, soil and water conservation techniques.
- Create awareness on nutrient re-cycling through proper management of crop residues.
- Develop and implement a comprehensive soil fertility strategy.


Figure 4: Oak-forest for leaf litter collection, Drepong, Mongar

4.6 Organic research and development program in all the sectors

- Promote research on organic technology development, packaging and promotion.
- Establish permanent demonstration plots in ARDCs, LCRDCs and strategic Dzongkhags for the development and promotion of organic technologies.
- The organic program components under the line departments should ensure and operationalize a vibrant organic research program. ARDCS and LCRDCs should foster network with regional and international organic research institutions.

4.7 Promote cooperative/group-based organic production

- Encourage voluntary group participation in production.
- LUC focal will facilitate in reorienting LUC programs towards organic production systems.

4.8 Promote organic management of weeds, diseases and insect pests

- Adopt Prevention, Avoidance, Monitoring and Suppression (PAMS) practice.
- Encourage the use of mechanical and physical practices (mulch, intercultural operations).
- Promote suitable and affordable bio-pesticides/ ethnoveterinary.

4.9 Develop organic value chain and market system

- Study the entire value chain and marketing systems for organic and put in place an efficient organic market system.
- Develop an efficient supply and distribution system for organic inputs in strategic locations and selected areas with support from DAMC, SOEs (FMCL, BLDCL) outlets and Farm shops.
- Connect producers, consumers, suppliers and market.
- Explore to address poor investment in organic agriculture development.
- Provide certain level of subsidy to bio-inputs and other organic farm inputs production.
- Promote private sector investment in organic agriculture through the development of viable business opportunities focused on organic enterprises.

4.10 Strengthen advocacy, awareness on organic farming technologies, products and success stories

- Create awareness on the benefits of organic farming and organic products through advocacy, education and promotional programs engaging producers, consumers and other marketing strategies.

4.11 Strengthen farm mechanization to address labour shortage for farming

- Identify, demonstrate and promote suitable farm machineries and tools suitable for women and smallholder farmers.
- Identify and promote suitable weed management machineries.

4.12 Develop and operationalize organic certification systems

- Expedite the setting up of an accredited certification system with required testing facilities for providing assurance for organic products.
- Urgently adopt standards for organic products and develop Standard Operation Procedure (SOP) to streamline and strengthen Organic Certification System.

5 Unit V - Institutional Support for Implementing National Organic Flagship Program

Organic agriculture development, particularly the implementation of the NOFP, will be through the engagement of LUC, selected Dzongkhags, School Agriculture Program (SAP), and other interested youth. And a three-tier institutional arrangement comprising macro, meso and micro structures with specific mandates and responsibilities will be adopted.

<table>
<tr><th colspan="3">Three-tier Institutional arrangement to support organic agriculture development under NOFP</th></tr>
<tr><td rowspan="3">Level</td><td>Macro</td><td>The National Organic Program which looks after the overall organic program of the country is supported by National Organic Board.
The NOP will implement the NOFP through the creation of a Coordination Unit (CU).
The CU will be housed in the Department of Agriculture and the Director of DoA will be the Coordinator of the CU.
A team of technical experts representing all the departments under the MoAF, known as the National Technical Working Group, will support the CU.</td></tr>
<tr><td>Meso</td><td>Central programs of respective departments and Dzongkhags will engage in related task and conduct necessary research for organic production related technology generation.
These agencies will also facilitate the monitoring and evaluation, and certification of the program.
Dzongkha administration will facilitate coordination and implementation of the program at designated production site.
Respective sectoral staff at the Dzongkhag will also facilitate capacity development, monitoring and evaluation and coordination at Dzongkhag level.</td></tr>
<tr><td>Micro</td><td>At the field level, Integrated Landscape Management committees will be established with a broad mandate to coordinate amongst different groups and stakeholders operating in the landscape.
Specialized farmers groups/cooperatives will be established which will manage the implementation of the flagship activities with the agreed SOP and NOFP framework.
Specialized group can also establish contracts as deemed necessary to promote organic marketing.</td></tr>
</table>

5.1 Role of Dzongkhags in promoting OA

Agriculture staff at the Dzongkhag headquarters and in the field work with and have direct access to the grassroots communities. Therefore, they would be a very critical partner in translating the organic vision into a reality. Their key role in promoting OA in the country include amongst others creating awareness on the imperatives of adopting OA, facilitating, implementing and coordinating activities, providing technical assistance or linking farmers to technical experts, monitoring field activities, maintaining proper records, LOAS registration and assisting in marketing of the local produce.

Motivation (15 minutes)

Ask each participant to think of ideas for promoting OA in his/her Gewog/Dzongkhag taking into account the present realities. Post these ideas on a wallpaper and ask one-two participants to discuss some of these ideas in terms of significance, practicality, etc.

In order to effectively fulfil their roles, the field staff must be trained and also provided refreshers' course from time to time.

Discussion (15 minutes)

Ask individual participant the support that they require in the field to successfully convert to organic farming. Paste their comments on the board and ask one-two participants to further analyze the listed support requirement.

6 Unit VI - Organic Agriculture and Regulatory System

With the growing demand for organic food in national and international markets, it has become necessary to ensure that the agricultural products labeled as “organic” comply with the basic standards of organic production and the entire production process is verified by independent certification agencies. The Bhutan Organic Guarantee System (BOGS), launched in 2019 was the first such quality assurance initiative of the Ministry of Agriculture and Forests, Royal Government of Bhutan. The BOGS not only provides the institutional framework for accreditation of certification agencies and operationalization of certification program but also ensures that the system effectively works and is monitored on regular basis.

To make the certification system affordable and accessible and also to promote organic farming, the certification systems are managed by the Ministry of Agriculture and Forests and is provided free of cost to the farmers and organic processors. Currently, the Ministry operates two kinds of certification namely (i) Local organic certification system (LOAS) aimed at certifying products for domestic market and (ii) BAFRA (Bhutan Agriculture and Food Regulatory Authority) Third Party Certification aimed at certifying products for export market. Besides these two certifications, organic operators (farmers, processors, exporter) could also avail the service of international certifying bodies, depending on the need of the target market but they have to pay for the service.

Both the certifications are managed separately − LOAS is implemented by the National Centre for Organic Agriculture (NCOA) while the BAFRA Third party is implemented by BAFRA. Although separately managed, these two systems are linked, which means the farmers certified under the LOAS can process BAFRA third party certification without having to wait for conversion period. Further, all the organic growers in the country have to register with NCOA before processing the Third-Party certification.

Organic certification will not replace other food safety requirements, as such, organic food manufacturer should comply with all the food safety rules and regulation of the country or the international market.

6.1 Organic Certification

Organic certification is a process certification intended for producers of organic food and other organic agricultural products. Requirements for the certification vary from country to country and generally involve a set of production standards for growing, storage, processing, packaging and marketing that include:

i. Prohibition of synthetic chemical inputs (e.g., fertilizer, pesticides, hormones, antibiotics, food additives, etc.) and genetically modified organisms;
ii. Keeping detailed written production and sales records (audit trail);
iii. Undergoing periodic on-site inspections;
iv. Use of farmland that has been free from synthetic chemicals for a number of years (often, two or more); and
v. Maintaining strict physical separation of organic products from non-certified products.

6.2 Purpose of Certification

Organic certification addresses a growing worldwide demand for organic food. It is intended to assure quality and prevent fraud. For organic producers, certification identifies suppliers of products approved for use in certified operations. For consumers, "certified organic" serves as a product assurance. Certification is essentially aimed at regulating and facilitating the sale of organic products to consumers.

6.3 Certification system in Bhutan

Figure 1 provides the overview of organic registration and certification system in the country. The NCOA-Yusipang, under the Department of Agriculture, MoAF, is the apex body (aspiring to be National Accreditation Body) for organic agriculture in Bhutan. As per the overall Bhutan Organic Registration and Certification system, the apex body is guided by the National Working Group, National Organic Board and also consists of an Evaluation Committee. Organic Operators can be registered and certified either through LOAS as well as Third Party Certification (National or International Third-Party Certification bodies with foreign accreditation). These operators also have opportunity to register with the Ministry of Economic Affairs (MoEA) for Brand Bhutan. If there is mutual recognition of BOGS and other countries' standards and certification system, then there is opportunity to facilitate export and import of organic commodities. Both National and International Certifying Bodies (CB) are also required to register with the NCOA-Yusipang.

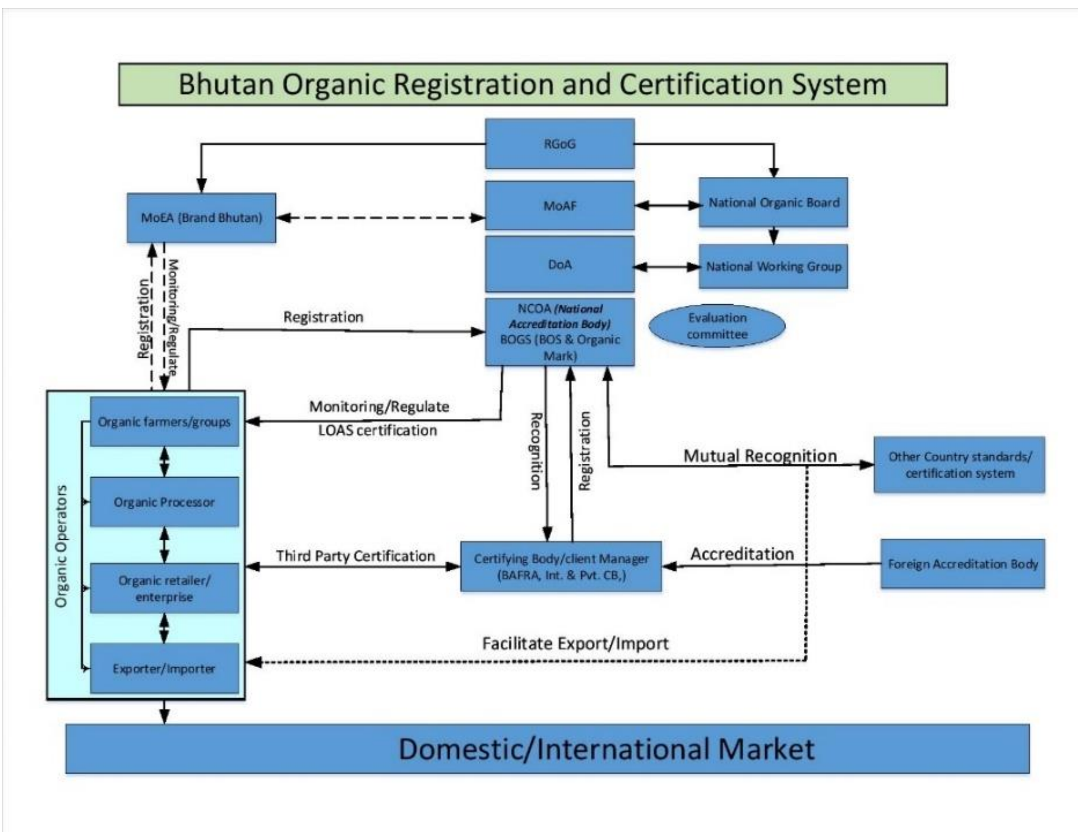

Figure 5: Bhutan Organic Registration and Certification System

6.3.1 Local Organic Assurance System (LOAS)

With the local market flooding with an overwhelming amount of imported and generic farm produces, one of the biggest challenges that the consumers face at the moment is identifying whether the products are organic or not, and not all local products are organic. In order to address this challenge, the LOAS is put in place.

This assurance system provides a low-cost (free of charge) and effective mechanism of certification for organic operators in Bhutan since the cost is fully borne by the government. This system is managed and implemented by NCOA. It makes use of the existing network of extension officials and organic focal in Dzongkhags and Agriculture Research and Development Centre (ARDCs) under the MoAF.

LOAS is applicable for commodities that are unprocessed or have only undergone simple on-farm processing (drying, shelling, grinding, cutting and curing) without using any additives.

Organic operators opting for LOAS certification should first get registered and signed voluntarily pledge to qualify for certification. It is a primary requirement for organic operator to abide by Bhutan Organic Standards (BOS). The NCOA uses the BOS as the basis for its certification procedure and to qualify for certification.

The organic operators seeking LOAS certification will be provided with adequate information by concerned Dzongkhags, ARDCs and NCOA, to enable them to comply with applicable standards. It is mandatory for all the inspection and monitoring official to have full information on LOAS manual before implementing in the field.

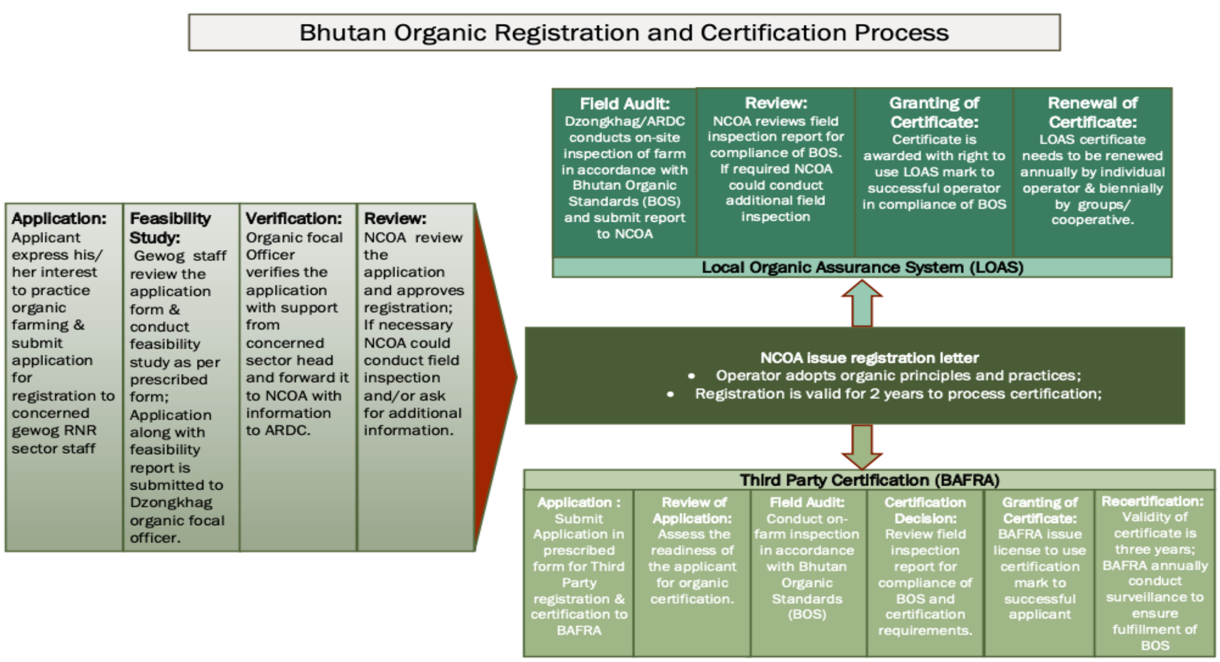

Figure 6: Bhutan certification process

6.3.2 Fast Tracking

There are instances where an interested applicant has no history of chemical use on his/her farm or the applicant is farming on a virgin land which warrants exception and consideration in comparison to farms under conversion from conventional to organic way of farming. Fast tracking for LOAS certification in organic farming would address this need and enable interested organic operator(s) to certify his/her commodities without having to undergo the mandatory 1-year period provided the farms are managed in accordance with the requirements prescribed in the BOS. However, the farms are subject to inspection and monitoring by relevant officials/authority for the purpose of registration and certification for fast-tracking.

6.3.3 BAFRA Third Party Organic Certification

BAFRA provides third party organic certification in the country. The certification under BAFRA is provided both for producers and processors. The organic operators engaging in processing can directly apply to BAFRA for certification.

The applicants should submit an application in a prescribed formats (application format along with the supplementary questionnaire format) to BAFRA for third-party organic certification. After the application is registered, a quality plan for certification depending on the characteristics of the certification schemes and the product requirements is prepared including evaluation of the quality management system. Inspection of organic production process is carried out based on Bhutan Organic Standard and following the guide and audit checklist for Bhutan Organic. The audit of the farm/facility is done by a competent BAFRA official.

Following the decision to grant certification, BAFRA issues a statement of conformity in the form of a license on the Prescribed format after signing the Certification Agreement. Subsequently the license is uploaded on the BAFRA website. After the license has been granted, the certified client may display the organic certification mark on the product subject to conformity of the product to the requirements. BAFRA provides the standard mark together with the license and mode of application of the standard mark on the product.

6.4 International Organic Certification

Currently, international certification for Bhutanese organic products is provided by international certifying body such as IMO. Although, BAFRA is a certified CB, its certification is not accepted by many countries. To facilitate international certification, BAFRA has to get accredited by importing countries and conduct the field inspection as per their standards.

In order to facilitate export of Bhutanese organic products in ASEAN countries, BAFRA and NCOA is working with Certification Alliance (CertAll) to establish BAFRA as Client Manager. As a client manager, BAFRA could manage and conduct field inspection using CERTALL standards and requirements and submit the report to CERTALL. CERTALL in return will provide the right to use their certification mark which will facilitate the Bhutanese organic operators to export their organic products to ASEAN market such as Thailand, Singapore, Malaysia, etc. Such arrangement will reduce time and cost for organic operators and provide much needed market for organic produces. Similar arrangement could be established in future with other international CBs by BAFRA other private CBs in Bhutan.

6.5 Mutual Recognition

Mutual recognition (MR) is a special arrangement between countries where organic standards and conformity assessment process is mutually recognized by importing and exporting country to facilitate export/import of organic products. Bhutan currently is working on establishing MR with India. Once the organic standards and conformity assessment (LOAS, BAFRA certification) are recognized by India, then the Bhutanese Organic Operators can directly export the LOAS/BAFRA certified products to Indian market.

6.6 Internal Control System (ICS)

According to the International Federation of Organic Agriculture Movements (IFOAM), ICS is defined as a "documented quality assurance system that allows the external certification body to delegate the annual inspection of individual group members to an identified body within the certified operator".

To practice this system, the farmers' group basically put in place an internal mechanism to monitor the compliance to a specific standard by all group members through proper documentation. The ICS implementation helps in reducing the cost for certification without compromising the organic integrity. The external certification body following their protocol audits whether ICS has been properly implemented by the farmers' group for fulfillment of the standard requirements.

The ICS in the group will consist of five office bearers who shall be nominated from among the group members who will take up different roles and ensure compliance with the BOS 01:2019 by all its members. Figure 3 shows the ICS structure.

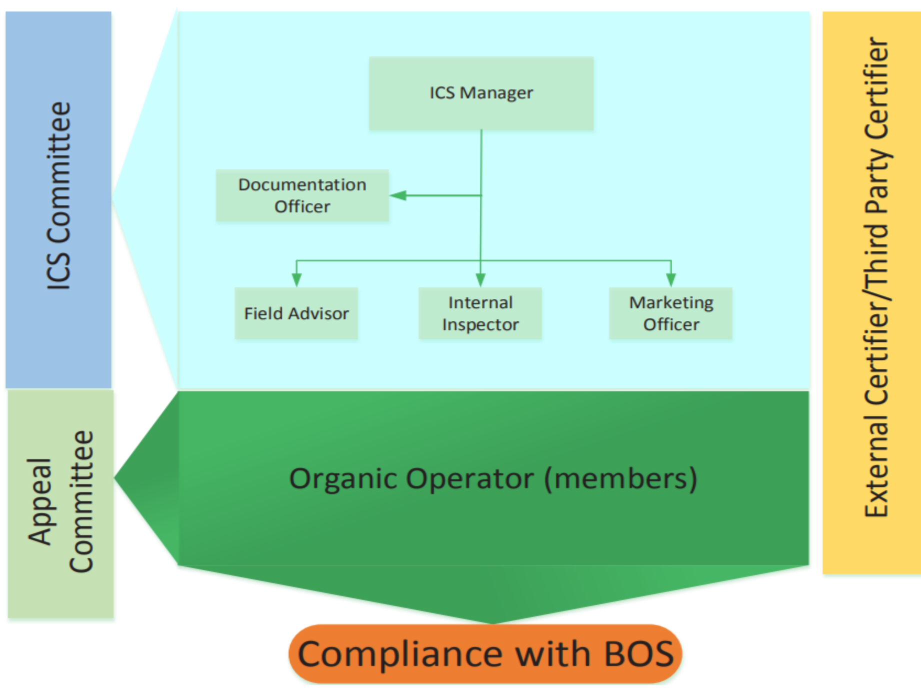

Figure 7: Structure of ICS

6.7 Bhutan Organic Mark

The Bhutan Organic Mark (see Fig. 4) is a certification mark and the property of the MoAF and is a legally protected logo.

The word organic is not regulated in the country so the distinction between trustworthy organic products and other products will therefore be based on the use of the Bhutan Organic Mark on products that are guaranteed organic in accordance with the official Bhutan Organic Guarantee System (BOGS) decided by the Government of Bhutan.

Figure 8: Bhutan Organic Mark

The Bhutan Organic Mark is useable for promotion and education activities related to organic agriculture in Bhutan, as well as for the marketing of organic products verified in accordance to the Bhutan Organic Guarantee System

The Bhutan Organic Mark can be assessed when the product is produced in Bhutan in compliance with BOS and verified through LOAS, third party organic certification and products which are produced in Bhutan in compliance with the standard approved in the IFOAM Family of Standards, and verified through third party certification by a certification body registered with and approved by the NCOA.

Any product bearing the Bhutan Organic Mark must also display the Unique Identification Number provided by the CB.

6.8 Bhutan Organic Standard

The Royal Government of Bhutan (RGOB) having concern for the health, well-being and happiness of its citizens finds it necessary to institute a system to assure them a supply of food and food materials free from unnatural treatments or additives or synthetic agro-chemicals, which cause series of health and environment hazard. Considering the growing demand for safe produce and desire to support farmers of Bhutan with organic agriculture technologies, it was felt important to develop a domestic organic standard. Thus BOS was developed from IFOAM norms, Codex Alimentarius and AROS.

BOS is the basis for domestic verification in Bhutan, including verification through the Local Organic Assurance System, PGS, and certification by third party certification body for the domestic market. The BOS is owned by the Ministry of Agriculture and Forests and is updated under the lead of the National Centre for Organic Agriculture-Yusipang, in accordance with the Procedure to update and approve the Bhutan Organic Standard. Bhutan Organic Standard is now enlisted into the IFOAM Family of Standards after undergoing a series of the Common Objectives and Requirements of Organic Standards (COROS) assessment.

The Bhutan Organic Standard covers the following areas: primary production, mushroom cultivation, wild collection, processing of food and feed, packaging and labelling, warehousing, transport and distribution, social welfare and approval of prior certification for the purpose of sourcing organic ingredients or imported final products.

7 Practical Session

As a part of practical session, the participants shall be provided with the hands-on training in doing the registration of different organic operators with field exercise and also the training for internal control system for the organic group operators.

Participants will be divided in groups and field exercise in filling of forms such as registration, feasibility report, inspection and monitoring with their observation made at the farmers field so that it will be within the requirement of Bhutan Organic Standard and basic organic principles and practices.

The internal control system required for the group will also be demonstrated to all the participants so that it would benefit the participants in implementing the lessons learned in their respective places of work.

1. Filling up registration application form
    a. Individual /farm form.
    b. Group/Cooperative form
    c. Institution form
2. Understanding and filling up feasibility report format.
3. Filling up Farmer's diary
4. Understanding and filling up Inspection/Field Audit format

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MODULE II:

PLANT PROTECTION IN ORGANIC AGRICULTURE

A. Learning methods

Powerpoint presentation, group discussion, individual participation and hand-on practise.

B. Materials required

Powerpoint projector, white board, board marker pen, flip chart, marker, note book, board sticker and pen.

C. Time allocation

12 hours (Theory and practical).

D. General Objectives of the module:

This module aims to provide trainee in-depth understanding of cost effective and eco-friendly crop protection strategies suitable for organic farming. This module will also teach trainee on how to identify and differentiate damaged symptoms in the plants, methods to diagnose the actual cause of the symptom and give correct recommendation to the farmers. They will also learn how to carry out pest and disease sampling, prepare remedies to pests and disease by using locally available raw materials.

E. Learning outcomes:

At the end of this module, the trainee should be able to

1. Diagnose different damage symptoms exhibited by crops.
2. Differentiate damage symptoms made by insect pests and pathogens.
3. Identify beneficial insects and non-beneficial insects (pests)
4. Describe different crop protection strategies suitable for organic farming
5. Prepare biopesticides and biofertilizers
6. Describe different weed management strategies that are suited for organic farming.

1 Unit: I Introduction to Crop Protection in Organic Farming

1.1 Principles and strategies of crop protection in the organic farming system

Crop protection in organic agriculture is not a simple matter. Effective organic pest and disease control requires a thorough understanding of pest life cycles and interactions. It depends on a thorough knowledge of the crops grown and their likely pests, pathogens, and weeds. Successful organic crop protection strategies also rely on an understanding of the effects that local climate, topography, soils, and all aspects of the production system are likely to have on crop performance and the possible host and pest complexes. Organic farming tends to tolerate some pest populations while taking a longer-term approach. Organic pest and disease control involve the cumulative effect of many techniques, including:

1. Allowing for an acceptable level of pest and disease damage.
2. Encouraging predatory beneficial insects to control pests.
3. Encouraging beneficial microorganisms and insects; by serving them nursery plants. and or an alternative habitat, usually in a form of a shelterbelt, hedgerow, or beetle bank.
4. Careful crop selection, choosing disease-resistant varieties.
5. Planting companion crops that discourage or divert pests.
6. Using row covers to protect crops during pest migration periods.
7. Using pest regulating plants and biologic pesticides, fungicides, and herbicides.
8. Using no-till farming, and no-till farming techniques as false seedbeds.
9. Rotating crops to different locations from year to year to interrupt pest or disease reproduction cycles.
10. Using insect traps to monitor and control insect populations that cause damage as well as transmit diseases.

Each of these techniques also provides other benefits such as soil fertility improvement, water conservation, and conservation of beneficial insect-like predators, parasitoids, pollinators, etc, which increase pollination and fruit set in crops.

Pests and diseases are generally not a significant problem in organic systems, since healthy plants living in good soil with balanced nutrition are better able to resist pest and disease attacks. However, major pest and disease damage is sometimes seen in organic crops, which are very susceptible to damage. Pest and disease problems can be particularly severe in large holdings, where several hectares of a single crop species may be grown. Pest and disease control strategies in organic farming systems are mainly preventative rather than curative. The balance and management of cropped and uncropped areas, crop species and variety choice and the temporal and spatial pattern of the crop rotations used all aim to maintain a diverse population of beneficial organisms including competitors, parasites, and predators of pests. Damaging populations of pests and pathogens are less likely to establish in soils that sustain high levels of beneficial organisms. Break crop choice and rotation design can have a major impact on the incidence and severity of certain types of pest problems. The less mobile pests or those which have a specific or narrow host range are particularly susceptible to crop rotation. Highly mobile, often non-specific pests such as aphids are less affected or unaffected by rotation design. Reactive treatments for pest outbreaks, including natural pesticides, are permitted under regulations for specific situations in organic systems, but cultural pest prevention techniques including the use of break crops within balanced rotations will remain the most important means for pest control in organic systems.

1.2 Differences between organic and conventional farming concerning plant protection

Conventional farming is generally associated with high-input modern agriculture which includes the use of synthetic chemical fertilizers, fungicides, insecticides, and herbicides. Conventional farming is contrasted with organic farming as the latter prohibits the use of synthetic fertilizers and pesticides. Approved certification bodies certify producers based on a set of production standards. Organic agriculture relies on healthy living systems, taking advantage of biodiversity and recycling. Differing in terms of input levels, several nonorganic management strategies for crop cultivation can be distinguished.

Criteria	Conventional	Organic Farming
Farming Technique	Involve methods based on synthetic inputs to increase production.	Depends on organic ways, rejecting all things synthetic
Fertilizers Used	Chemical fertilizers like DAP, Urea, and Suphala	Only fertilizers are obtained through organic ways, like manure and compost.
Use of GMO	Use of inbreds, hybrids and GMOs for better yield and enhanced disease resistance.	Strict No to GMO. Instead, apply methods that boost bio-diversity and good bacteria in the soil
Sustainability	No sustainability. Focused more on yield.	Sustainability is the main focus. Food production while caring for ecology and the environment is the main principle.
Disease Resistance	More adapted to disease resistance, thanks to pesticides.	Vulnerable to disease and pest attacks
Health Concerns	Heavy use of chemical fertilizers and pesticides poses extensive health risks	No health risk because of the absence of harmful chemicals.
Environmental Concerns	Intensive farming methods prove detrimental to land, soil, and water	Improve the overall ecology thanks to safe farming techniques

Table 1: Overview of the difference between Conventional farming and Organic farming

1.3 Crop protection practices in organic farming

Organic production relies primarily on systems-based nonchemical methods of control, although some organically approved pesticide materials are used for aboveground arthropod pests and foliar pathogens Organic disease management is built around maintaining crop and soil health, use of resistant cultivars, sanitation, and cultural controls.

Although pesticide applications are infrequent in organic systems, they are important for the control of key foliar pathogens. Notably, copper, sulfur, and bicarbonate-based compounds are frequently used for control of late blight, downy mildew, and powdery mildew, sometimes in conjunction with other measures, including temporal and spatial plant diversity, induced resistance, variety selection, and cultural management.

1.4 Identification and monitoring of crop pests

Regular monitoring of pests and diseases is the basis for effective management. To be able to manage pests and diseases, information is needed on the specific pest and diseases present in the crop fields and the associated damage they cause.

1.5 Typical signs of pest attacks on crop plants

Most crop pests belong to insects, mites, and nematodes. However, in Bhutan, mammals (like elephants, monkeys, or wild boar), and birds (like sparrows, starlings, and crows) can also damage crops. Insect damage can be categorized by biting and chewing (e.g., caterpillars, weevils), piercing and sucking (e.g., aphids, psyllids) and boring (e.g., borer, leaf miner) species. Some are slow-moving (e.g., caterpillars), fast-moving (e.g., fruit flies), hidden (e.g., stem borer), or easy to observe (e.g., caterpillars, weevils).

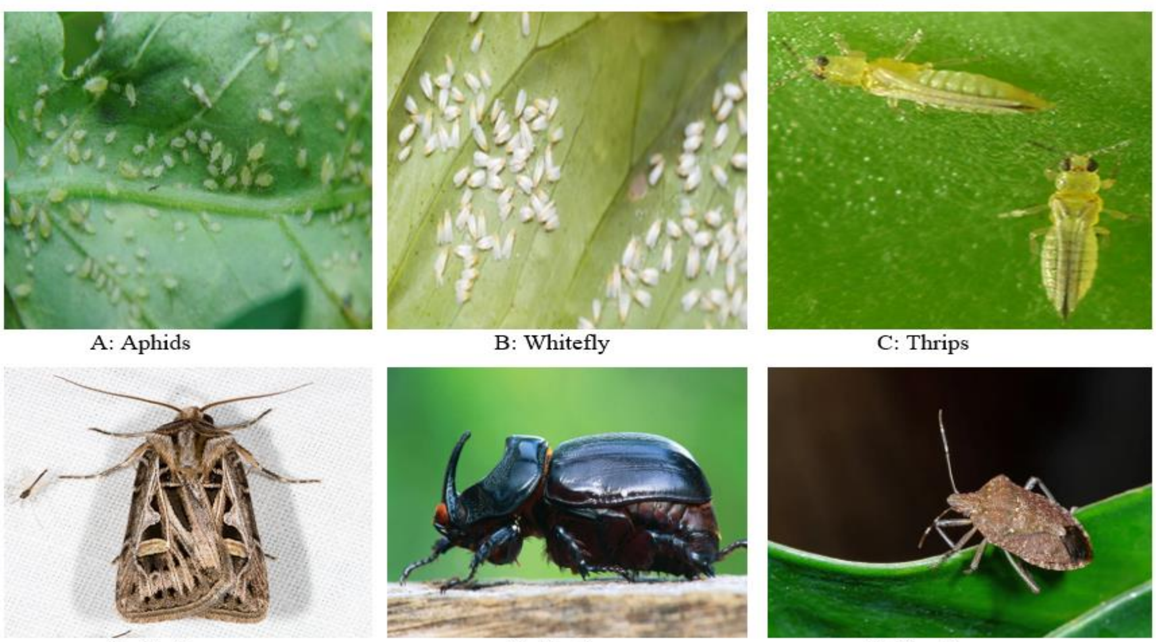
A: Aphids B: Whitefly C: Thrips
D: Moth E: Beetles F: Plant bug

Figure 9: Showing different types of insect pest that damage the crops

a. Pest damage

Pest damage is often species-specific: leaves with holes or missing parts are an indication of caterpillar or weevil damage; curled leaves are an indication of aphids; damaged or rotten fruits are often caused by larvae of fruit flies; withering plants can also be caused by larvae of noctuid or the stem borer, and branches or trunks with holes may be an attack by lignivorous insects.

b. Mites

Mites are very small and cannot be seen with the naked eye. However, some mite species (spider mites) weave a typical tissue on attacked plant parts and can, therefore, easily be detected. If mites are present on plants, leaves and fruits become yellowish.

c. Nematodes

Nematodes are also very small and therefore, they are not easy to observe with the naked eye. They mostly attack plant roots; plants become yellow, wither, and die.

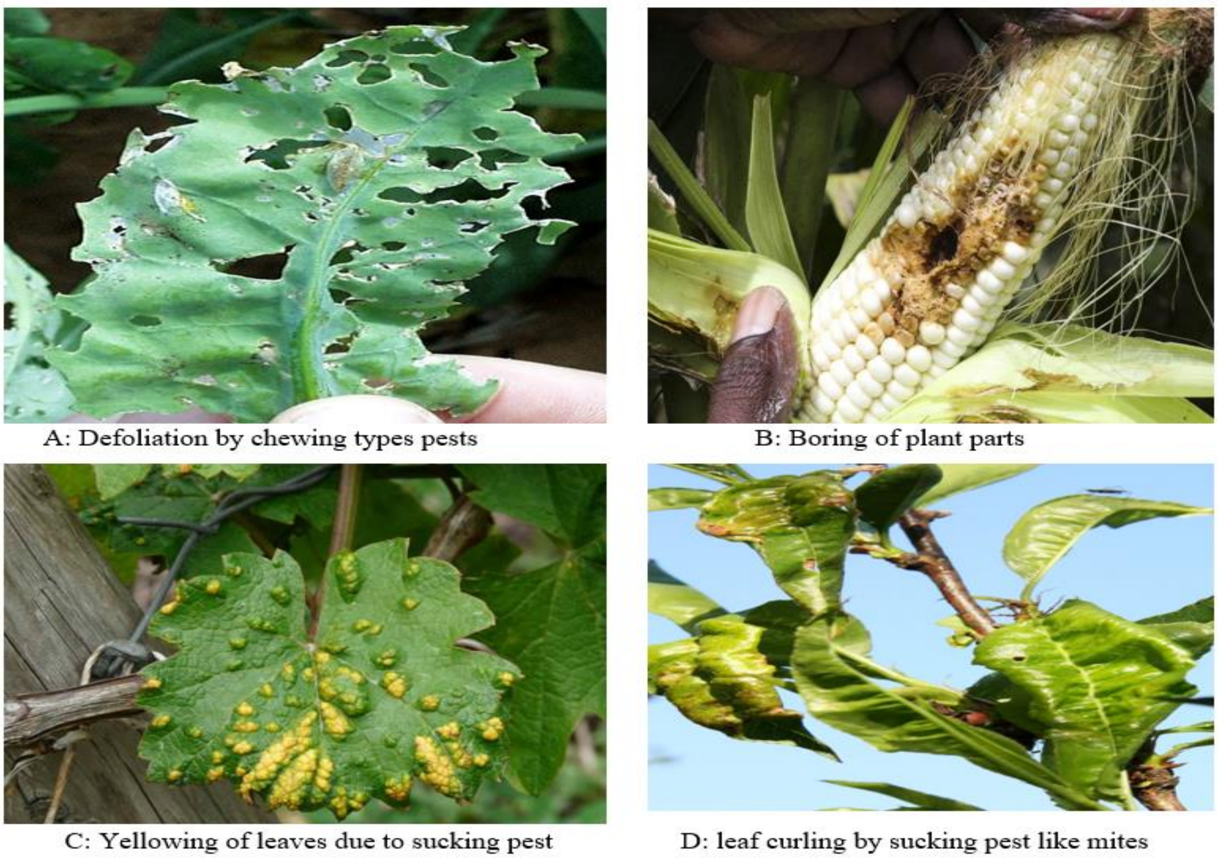

Figure 10: Showing signs of pest attacks on crop plants

1.6 Typical signs of disease attacks on crop plants

Most crop diseases are caused by fungi, bacteria, or viruses.

a. Fungi

Fungi cause the great majority, estimated at two-thirds of infectious plant diseases. They include all white and true rusts, smuts, needle casts, leaf curls, mildew, sooty mould, and anthracnose. In addition, they are responsible for most leaf, fruit, and flower spots, cankers, blights, wilts, scabs, and root, stem, fruit, wood rots among many others. Parts of plants or the total crop plant can wither and die.

b. Bacteria

Bacteria cause any of the four following main problems. Some bacteria produce enzymes that break down the cell walls of plants anywhere in the plant. This causes parts of the plant to start rotting (known as 'rot'). Some bacteria produce toxins that are generally damaging to plant tissues, usually causing early death of the plant. Others produce large amounts of very sticky sugars; as they travel through the plant, they block the narrow channels preventing water from getting from the plant roots up to the shoots and leaves, again causing rapid death of the plant. Finally, other bacteria produce proteins that mimic plant hormones. These lead to the overgrowth of plant tissue and form tumors.

c. Viruses

Viruses mostly cause systemic diseases. Generally, leaves show chlorosis or a change in colour of leaves and other green parts. Light green or yellow patches of various shades, shapes and sizes appear on affected leaves. These patches may form characteristic mosaic patterns, resulting in a general reduction in growth and vigor of the plant. Careful and continuous monitoring of pest and disease levels during critical times of growth of a crop is the key to successful management. This can be done through regular scouting of the field by the farmer. It helps the farmer to intervene early enough before the pest and/or disease cause significant damage.

1.7 Insect sampling techniques

Insect sampling is also sometimes referred to as scouting or monitoring. Sampling is important because it is of utmost importance for farmers and pest managers to understand insect activity in their crops and fields before they can make cost-effective and environmentally sound pest management decisions. There are many different insect sampling techniques and sampling equipment that can be used to detect insects in the air, on plants, and even on and beneath the soil. Row crop growers often use sweep nets to sample insects on plants like soybeans and cotton, because sweep sampling (i.e., a given number of sweeps per sampling location) is quicker and more cost-effective for larger fields than inspection of individual plants. Small-scale vegetable growers more commonly sample a given number of individual plants per sampling location in the field. One must know general sampling methods that will provide a "relative" estimate of insect population density based on the sampling unit (i.e., numbers per leaf, per plant, etc.).

1.8 Frequency and time of sampling

The optimal timing of sampling depends upon the life history and behaviour patterns of the pest or beneficial insect and also on the crop and environmental conditions. Both insects and plants develop quickly under warm conditions and more slowly when it is cool. But in general, it is a good idea to begin sampling as soon as the crop is transplanted into the ground or when plants emerge from the soil if direct-seeded.

Sampling should be done at least once per week and preferably at least twice during warm growing conditions. More frequent sampling is usually needed if insect pest numbers are in the low-tomoderate range and on the increase. Insect pest populations can develop very quickly, and once-a-week sampling may not detect a surge in insect numbers until it is too late.

1.9 Sampling procedures

Different sampling procedures can be used depending on the crop, size of the field, etc. Farmers usually develop their customized sampling plans once they have experience with a particular crop. Here are some guidelines for getting started.

a. Upon entering the field make a quick visual examination of the field.
b. Look for any atypical areas that might affect your sampling pattern, i.e., areas with poor stands, obvious topographical variation in the field, varietal growth differences, etc.
c. Sampling can be done in these areas but any unusual conditions that could affect insect numbers should be noted on the sampling sheet.
d. Once you have an idea of the field conditions and layout, think about an efficient sampling pattern for the field. For example, "W" or "U" shaped sampling patterns are more commonly used in a square-shaped field. In a long narrow field, a "zig-zag" or “Z” sampling pattern is usually more efficient.
e. A single sample could be a visual count of all insects on one plant. A subset of samples could be a visual count of all insects on each of 5 adjacent plants at each location. Subset samples can provide a better population estimate for insects that are not randomly distributed in the field but have an aggregated or clumped distribution.
f. For most pests, it is important to walk a few rows into the field before sampling the first plant to avoid edge effects. However, edge sampling is commonly done for pests like spider mites that commonly invade the field from the field borders. You may wish to keep a separate data sheet for sampled plants on the field edges.

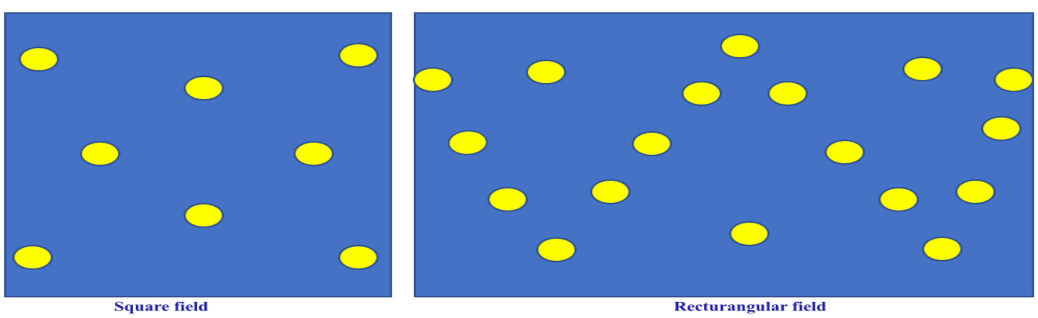

Figure 11: Showing types of sampling methods for pest

1.10 Recordkeeping

Develop a field data sheet template that you can use to record insect counts. It will probably require a few sampling periods to refine the datasheet for a particular crop, pest, and beneficial insect system. Datasheets are most commonly organized in a matrix format with sample numbers along one axis and labels for key pests and beneficials (by life stage) along the other axis. Thus, at each sample location, the actual numbers of each specific insect and stage can be entered. It is helpful to include a “total” column for each insect and stage to facilitate the calculation of averages. Averages can be used as a relative measurement to determine population trends over time.
The datasheet should also include the sample date, time of day, field number or field location if sampling from separate locations, plant growth stage, and space to record other pertinent information such as atypical environmental conditions. Entering sampling data into a computer

spreadsheet helps in simplifying data analysis, storage, and retrieval. The sample of the data collection is given in Table 2.

Sample Data Sheet											
Date:	Field#				Time:				Crop:		Growth stage
Weather/field Observation:											
Pest 1	1	2	3	4	5	6	7	8	9	10	Total
Larvae											
Adults											
Parasites/Predators											
Parasites/Predators											
Note:											

Table 2: Insect sampling datasheet

1.11 Disease sampling methods

Disease scouting has two important parts, disease scouting in the field and laboratory diagnosis. Field scouting of disease is based on the characteristic symptoms caused by the presence of pathogen, however, there are other biotic and abiotic factors which might result in similar characteristic symptoms. It is very difficult to identify specific pathogens that cause plant disease. Therefore, a sample collected should be sent for further diagnosis in the laboratory for confirmation. In this chapter, we will discuss the advantages, procedures and how the sample should be packed for laboratory diagnosis.

Scouting allows you to:

a. Accurately identify disease symptoms early in the growing season so you have time to decide regarding plant protection measures before the disease becomes well established in your crop and economic losses occur.
b. Determine the effectiveness of your organic pesticide program. This will aid your decision about whether subsequent applications are needed when they should be applied and what product to choose.
c. Save time and money in the end.

1.12 Frequency of plant disease sampling

Scouting should occur weekly from crop emergence to maturity. A good time to start looking for unusual crop growth is during the emergence stage while carrying out weed control operations. Keep a notebook handy and record areas you would like to return to later.

1.13 Sampling procedures

a. Choose specimens showing various stages of disease symptoms such as light to severe symptoms. Include some healthy specimens for comparison.

b. Submit whole plants including the roots to determine if a root pathogen is a cause.

c. Record the parts of the plant that are affected, the distribution of the symptoms within the field and the cropping history of that field.

d. It is important to include information on chemical use both in the present cropping season and for the previous four years, fertilizer timing and rates and any extreme weather events noted.

1.14 Packaging and handling

a. Wrap specimens in a dry paper towel or a paper bag. Do not add moisture and do not use plastic bags. The exception to this rule is if a viral or bacterial disease is expected.

b. Try to keep the plant material as fresh as possible. Wrap the sample in a slightly moistened paper towel and submit it to the lab as quickly as possible.

c. When including a root/soil ball, tie this portion off in a plastic bag leaving the above-ground parts loosely packed in a dry paper towel.

d. Submit the sample in a rigid container like a cardboard box or Styrofoam cooler. Loosely pack newspapers or paper towels around the plant sample to prevent it from moving during shipping.

2 Unit: II Strategies of Pest and Disease Management in Organic Farming

2.1 Cultural pest control (Resistant varieties)

The goal of cultural control is to alter the environment, the condition of the host, or the behaviour of the pest to prevent or suppress an infestation. Organic management and control of pests are based strongly on strengthening the plant to enhance its self-defence and thereby prevent the outbreak of the pest. The use of resistant or tolerant cultivars, where such cultivars are available, is an easy and inexpensive practice for controlling plant pest problems. The term resistance or tolerance does not mean that the plant is completely immune to pests. A tolerant plant may still become infected, but it can overcome the effect of the pathogen to some degree. No variety is resistant to all pests and diseases. Resistant or tolerant varieties have certain traits which prevent the entry of pathogens or help prevent the spread of the pathogens in the host body. For instance, some plants have thick cuticle which interferes with pathogen entering the cell or pest feeding on it. Another is the dying of the infested cell walls, which causes the pathogen to die also, and thus reduce its spread.

Plant resistance and tolerance ability can be enhanced by conventional breeding methods, however, this process is very time-consuming. Quality-based resistance can be induced in plants through the management of nutrients and irrigation. Several resistance-inducing substances can be prepared by the farmers themselves. Some are plant extracts made from *Hedera helix*, *Rheum rhabarbarum*, *Reynoutria sachalinensis*. Compost teas and herbal teas are tools that can be made on the farm to enhance crop health and fertility and to inoculate the leaves and roots with soluble nutrients, beneficial microorganisms, and beneficial metabolites (products that aid in the growth and development of plants).

Figure 12: Showing the difference between resistant varieties vs susceptible varieties (source: phys.org)

Preparation of compost extract

1. Mature compost is mixed with water at a ratio of 1:5 to 1:8 (1L of compost for every 5 to 8 L of water) and well stirred before it is left to ferment for 3-7 days.
2. One spoonful of molasses can be added per litre of liquid because this enhances the development of the microorganisms. The fermentation site should be shaded and safe from the rain.
3. After the fermentation period and before the application, the extract is well stirred, then filtered and diluted at a ratio of 1:5 to 1:10.
4. Plant extracts can be obtained from stinging nettle, horsetail, comfrey, clover, seaweed, and others, alone or mixed with marine by-products such as fish waste or fishmeal.
5. Dilutions of 1:10 or 1:5 are used as foliar spray or soil drench. As a general rule, it is recommended to apply compost extracts or teas every 7 to 10 days to prevent diseases from developing and as a way to enhance soil microorganisms.

2.2 Mechanical and physical pest control

One of the simplest methods of physical or mechanical pest control is handpicking insects. This method works best in those situations where the pests are visible and easily accessible. Physical or mechanical disruption of pests also includes such methods as mowing, hoeing, flaming, soil solarization, tilling or cultivation, and washing. Devices that can be used to exclude insect pests from reaching crops in organic farming include row covers, protective nets with varying mesh sizes according to the pest in question, and sticky paper collars that prevent crawling insects from climbing the trunks of trees. Water pressure sprays can be employed to dislodge insect pests such as aphids and mites from the plant surface. Insect vacuums, on the other hand, could be used to remove insects from plant surfaces and collect them into a collection box.

a. Light traps

Light traps can be used to catch moths such as armyworms, cutworms, stem borers and other night-flying insects. Light traps are more efficient when placed soon after the adult moths start to emerge but before they start laying eggs. However, light traps have the disadvantage of attracting a wide range of insect species. Most of the attracted insects are not pests. In addition, many insects that are attracted to the area around the light traps (sometimes from considerable distances) do not fly into the trap. Instead, they remain nearby, actually increasing the total number of insects in the immediate area.

b. Colour traps

Colour and water traps can be used to monitor adult thrips. In some cases, thrips can even be reduced by mass trapping with coloured (blue, yellow, or white) sticky traps or water traps in the nursery or field. The colour spectrum of the boards is important for the efficacy of the sticky traps. Bright colours attract more thrips than darker ones. Sticky traps with cylindrical surfaces are more efficient than flat surfaces. They are best placed within a meter of crop level. Traps should not be placed near the borders of fields or near shelter belts.

c. Water traps

The water trap should be at least 6 cm deep with a surface area of 250 to 500 cm^2, and preferably round, with the water level about 2 cm below the rim. A few drops of detergent added to the water ensure that thrips sink and do not drift to the edges and escape. Replace or add water regularly.

d. Yellow sticky traps

Yellow sticky traps can be used to control whiteflies, aphids, and leaf-mining flies. Yellow plastic gallon containers mounted upside down on sticks coated with transparent car grease or used motor oil, are one such trap. These should be placed in and around the field at about 10 cm above the foliage. Clean and re-oil when traps are covered with flies. Yellow sticky boards have a similar effect. To use, place 2 to 5 yellow sticky cards per 500 m^2 field area. Replace traps at least once a week. To make your sticky trap, spread petroleum jelly or used motor oil on yellow painted plywood (size 30 cm x 30 cm). Place traps near the plants but far away enough to prevent the leaves from sticking to the board. Note that the yellow colour attracts many insects. Note that the yellow colour attracts many insect species, including beneficial insects, so use yellow traps only when necessary.

e. Fruit bagging

Fruits bagging prevents fruit flies from laying eggs on the fruits. In addition, the bag provides physical protection from mechanical injuries (scars and scratches). Although laborious, it is cheap, safe and gives a more reliable estimate of the projected harvest. Bagging works well with melon, bitter gourd, mango, guava, star fruit, avocadoes, and banana (plastic bags used).

Figure showing types of insect traps: A. Pheremone trap, B:Light trap, C:Water trap, D:Yellow sticky trap

2.3 Biological pest control (Predators, parasitoids)

Biological control is the use of natural enemies to manage populations of pests. Insect pests can be managed by using natural enemies of insects-like predators, parasitoids, and parasites. They can also be managed/controlled by using microorganism which causes disease, they are termed entomopathogens. Entomopathogens includes fungi, bacteria, nematodes, virus etc. But in this chapter, we will discuss more on parasitoids and predators such as ladybird beetles, predatory gall midges, and hoverfly larvae and how we can improve the agroecosystem to maintain their populations. The organic farmer should try to conserve natural enemies already present in the crop environment and enhance their impact. This can be achieved with the following methods:

1. Minimize the application of natural pesticides (chemical pesticides anyway are not permitted in organic farming).
2. Allow some pests to live in the field which will serve as food or host for natural enemies.
3. Establish a diverse cropping system (e.g., mixed cropping).
4. Include host plants providing food or shelter for natural enemies (e.g., flowers which adult beneficial insects feed on).

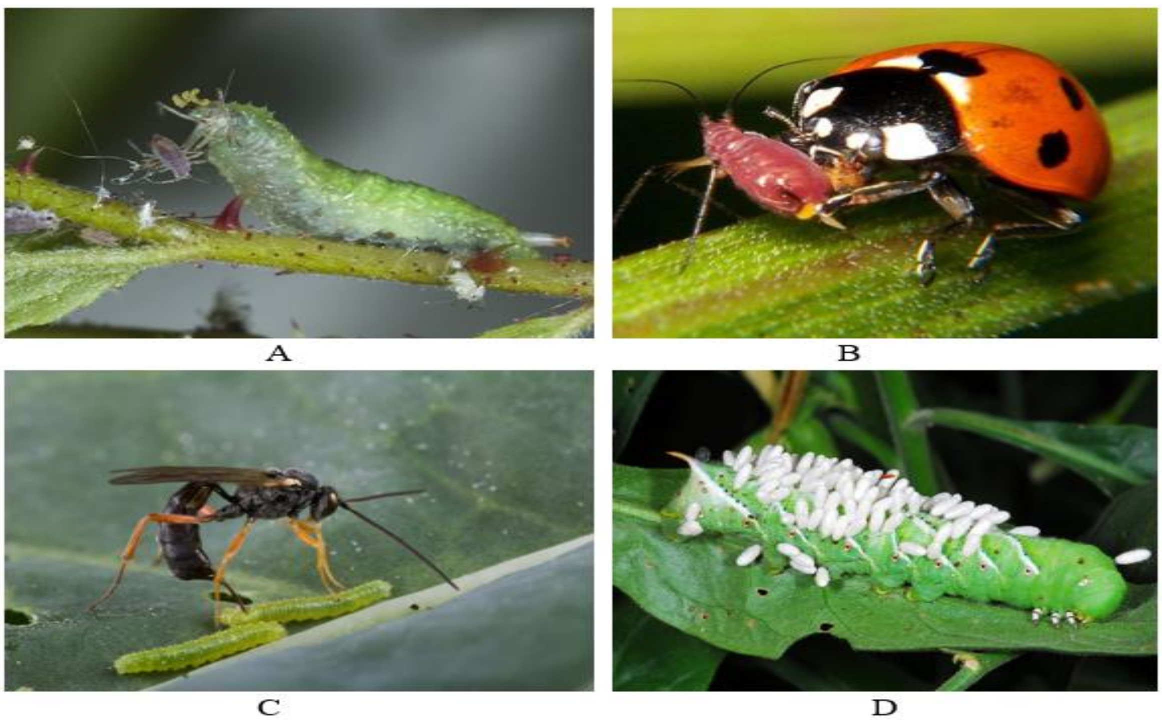

Figure 13: Showing predator and parasitoids: A:Larvae of Syrphid fly feeding on aphids, B: ladybug feeding on aphids, C: Parasitoids wasp laying eggs on the larvae of diamond backmoth, D:Larvae carrying eggs of the parasitoids

Natural enemies (predators, parasitoids, and predators) and other beneficial insects are attracted to an ecosystem rich in floral diversity. There are many possibilities to enhance floral diversity within and along the boundaries of crop fields.

- ***a. Hedges*** - Use indigenous shrubs known to attract pest predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys. Most flowering shrub species have this property. However, care should be taken to not use plant species known to be alternative hosts of pests or diseases.

b. ***Beetle banks*** - Strips of grass in the neighbourhood of crop fields harbour different natural pest enemies groups like carabids, staphylinid beetles and spiders. To lower the risk of weeds and plants known as host plants of crop pests and diseases, one to three native grass species can be sown in strips of 1 to 3 m.
c. ***Flower strips*** - Use indigenous flowering plant species known to attract predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys. Most flowering plant species have this property. However, care should be taken not to use alternative hosts of pests or diseases. Three to five native flowering plant species can be sown in well-prepared seed beds, arranged in strips of 1 to 3 m on the boundary of the crop field. After flowering, seeds can be collected to renew the strip or create new ones.
d. ***Companion plants*** - Natural pest enemies can also be attracted by companion plants within a crop. These companion plant species can be the same as used in the flower strips. A few (1 or 2 per 10 m^2) flowering companion plants within a crop serve as a 'service station' for natural pest enemies

Figure 14: showing flowering plants planted along the border of the main crop to attract beneficial insect

2.4 Bio-pesticide control (organically approved pesticides, Botanicals)

Some plants contain components that are toxic to insects. When these toxic components are extracted from the plants and applied to infested crops, these components are called botanical pesticides or botanicals. The use of plant extracts to control pests is not new. Neem, Chilli, Garlic, Turmeric, Rotenone (*Derris* sp.), nicotine (tobacco), and Pyrethrin (*Chrysanthemum* sp.) have been used widely both in small-scale subsistence farming as well as in commercial agriculture. Most botanical pesticides are contact, respiratory, or stomach poisons. Therefore, they are not very selective but target a broad range of insects. This means that even beneficial organisms can be affected. Yet the toxicity of botanical pesticides is usually not very high and their negative effects on beneficial organisms can be significantly reduced by selective application. Furthermore, botanical pesticides are generally highly bio-degradable, so they become inactive within hours or a few days. This reduces again the negative impact on beneficial organisms, and they are relatively environmentally safe compared to chemical pesticides.

The preparation and use of botanicals require some know-how, but not much material and infrastructure. It's a common practice under many traditional agricultural systems. Some commonly used botanicals are:

a. Neem

Neem derived from the neem tree (*Azadirachta indica*) of arid tropical regions, contains several insecticidal compounds. The main active ingredient is Azadirachtin, which both deters and kills many species of caterpillars, thrips, and whitefly. Both seeds and leaves can be used to prepare the neem solution. Neem seeds contain a higher amount of neem oil, but leaves are available all year. A neem solution loses its effectiveness within about 8 hours after preparation, and when exposed to direct sunlight. It is most effective to apply neem in the evening, directly after preparation, under humid conditions or when the plants and insects are damp. There exist different recipes for the preparation of a neem solution.

Preparation of neem pesticides

Pound 30 g neem kernels and mix them in 1 L of water. Leave it overnight. The next morning, filter the solution through a fine cloth and use it immediately for spraying. It should not be further diluted.

b. Pyrethrum

Pyrethrum is a daisy-like Chrysanthemum. In the tropics, pyrethrum is grown in mountain areas because it needs cool temperatures to develop its flowers. Pyrethrin is insecticidal chemicals extracted from the dried pyrethrum flower. The flower heads are processed into a powder to make dust. This dust can be used directly or infused into water to make a spray. Pyrethrin causes immediate paralysis in most insects. Low doses do not kill but have a "knock down" effect. Stronger doses kill. Pyrethrin breaks down very quickly in sunlight so it should be stored in darkness. Both highly alkaline and highly acid conditions speed up degradation so pyrethrin should not be mixed with lime or soap solutions. Liquid formulations are stable in storage, but powders may lose up to 20% of their effectiveness in one year.

Preparation of Pyrethrum pesticides

Pyrethrum powder is made with dried ground flowers. Use pure or mix with a carrier such as a talc, lime or diatomaceous earth and sprinkle over infested plants. To make liquid pyrethrum extract (mix 20 g pyrethrum powder with 10 L of water), add soap to make the substance more effective. Strain and apply immediately as a spray. For best effects, this should be applied in the evening. Pyrethrum can also be extracted by alcohol.

Preparation of Chilli pesticides

To make the chilli extract grind 200 g of chillies into fine dust, boil it in 4 L of water, and add another 4 L of water and a few drops of liquid soap. This mixture can be sprayed against aphids, ants, small caterpillars, and snails.

Preparation of Garlic pesticides

Garlic has antifeedant (insect stop feeding), insecticidal, nematicidal and repellent properties. Garlic is reportedly effective against a wide range of insects at different stages in their life cycle (egg, larvae, adult) This includes ants, aphids, armyworms, diamondback moth, whitefly, wireworm, and termites. Garlic is non-selective, has a broad-spectrum effect and can kill beneficial insects as well. Therefore, it should be used with caution.

To make the garlic extract, grind or chop 100 g of garlic into 0,5 L of water. Allow mixture to stand for 24 hours, add 0,5 L of water and stir in liquid soap. Dilute at 1:20 with water and spray in the evening. To improve efficacy, chilli extract can be added.

There are many other extracts of plants known to have insecticidal effects like tobacco (*Nicotiana tabacum*), yellow root (*Xanthorhiza simplicissima*), fish bean (*Tephrosia vogelii*), violet tree (*Securidaca longepedunculata*), and nasturtium (*Nasturtium trapaeolum*) which are traditionally used to control pests in Africa. Some of the plant biopesticides.

Table 3: Common plants which can be used as biopesticides

Sl. No.	Common name	Botanical name	Useful plant parts
1	Neem	*Nerium thevetifolia*	Flower, fruit, root
2	Pongamia	*Pongamia pinnata*	Leaf and flower
3	Nishida, Chinese chaste tree, horse shoe vitex	*Vitex nugundo*	leaf & flower
4	Lantana	*Lantana camera*	leaf & flower
5	Datura	*Datura metal*	Leaf, fruit, flower
6	Congress grass	*Parthenium sp*	Plant before flowering
7	Artemesia	*Artemesia vulgaris*	Tender shoots & leaves
8	Vasaka, Malabar nut	*Adathoda vasica*	Leaf
9	Milkweed	*Calatropis gigantea*	leaf, tender stem, flower
10	Nux vomica, Poison fruit,	*Strychnos nuvomica*	Seeds

2.5 Plant protection products (PPPs) authorized in organic farming

Besides extractions of plants, there are some other natural pesticides, which are allowed in organic farming. Although some of these products have limited selectivity and are not fully biodegradable, there are situations, when their use is justified. However, in most cases, the desired effect is best reached in combination with preventive crop protection methods. Some examples are:

Soft soap solutions: against aphids and other sucking insects.

Light mineral oil: against various insect pests (harms natural enemies!).

Sulphur: against spider mites (harms natural enemies!). The acaricidal effect of Sulphur is best at temperatures above 12° C. However, Sulphur has the potential to cause plant injury in dry hot weather (above 32° C). It's also incompatible with other pesticides. Sulphur should not be used together or after treatments with oil to avoid phytotoxicity.

Sulphur is mostly used against plant diseases like powdery mildew, downy mildew, and other diseases. The key to its efficacy is that it prevents spore germination. For this reason, it must be applied before disease development for effective results. Sulphur can be applied as a dust or in liquid form. It is not compatible with other pesticides. Lime-Sulphur is formed when lime is added to Sulphur to help it penetrate plant tissue. It is more effective than elemental Sulphur at lower concentrations. However, the odour of rotten eggs usually discourages its use over extensive fields.

Plant ashes: wood ashes from fireplaces can be efficient against ants, leaf miners, stem borers, termites, and potato moths. Ash should be dusted directly on pest colonies and infested plant parts. The ash will dehydrate the soft-bodied pests. Wood ashes are often used when storing grains to deter storage pests such as weevils. In addition, ashes are used against soil-borne diseases.

Bordeaux mixture (Copper sulphate and lime) has been successfully used for over 150 years, on fruits, vegetables, and ornamentals. Unlike Sulphur, the Bordeaux mixture is both fungicidal and bactericidal. As such, it can be effectively used against diseases such as leaf spots caused by bacteria or fungi, powdery mildew, downy mildew, and various anthracnose pathogens. The ability of the Bordeaux mixture to persist through rains and to adhere to plants is one reason it has been so 7effective. Bordeaux mixture contains copper sulphate, which is acidic, and neutralized by lime (calcium hydroxide), which is alkaline.

Acidic clays have a fungicidal effect due to aluminium oxide or aluminium sulphate as active agents. They are used as an alternative to copper products but, are often less efficient.

Milk has also been used against blights, mildew, mosaic viruses and other fungal and viral diseases. Spraying every 10 days with a mixture of 1 L of milk to 10 to 15 L of water is effective.

Baking soda has been used to control mildew and rust diseases on plants. Spray with a mixture of 100 g of baking or washing soda with 50 g of soft soap. Dilute with 2 L of water. Spray only once and leave as long gaps as possible (several months). Do not use during hot weather and test the mixture on a few leaves because of possible phytotoxic effects.

2.6 Organic weed management

Weeds need to be controlled to reduce their impact on crop yield and quality. Organic farmers should give priority to the prevention of the introduction and multiplication of weeds. The management practices aimed at keeping the weed population at a level that does not result in an economic loss of the crop cultivation or harm its quality. The goal is not to completely eradicate all weeds, as they also have a role to play on the farm. For example, weeds provide cover that reduces soil erosion. In addition, weeds provide food and shelter for beneficial insects and beneficial soil-borne microorganisms like mycorrhiza fungi. Parasitic wasps, for example, are attracted to certain weeds with small flowers. Most of the biological diversity in our crop fields comes from the presence of weeds. Field experience has shown that the number of predators attacking insects increases and the number of aphids and leafhoppers decreases on certain crops as the diversity of weeds increases. Research has shown that outbreaks of certain crop insect pests are more likely in weed-free fields. Because weeds offer pollen and nectar they allow biocontrol insects to maintain their populations and, therefore, serve as a valuable instrument in controlling pests.

However, weeds may also alter the environment of the crop negatively. Light and air circulation, for example, are reduced between the crop plants. In this darker and more humid environment, diseases find ideal conditions in which to spread and infect plants. A basic working principle in organic farming is to prevent problems, rather than cure them. This applies equally to weed management. Good weed management in organic farming includes creating conditions which hinder weeds from growing at the wrong time and in the wrong place and then become a serious problem for crop cultivation. Competition by weeds doesn't harm the crop throughout the whole cultivation period in the same way. The most sensitive phase of a crop to weed competition is in its early growth stage. A young plant is vulnerable and depends highly on an ideal nutrient, light, and water supply for good development. If it has to compete with weeds at this stage, the crop may grow weak, which also makes it more vulnerable to pest and disease infections. Weed competition later in the cultivation period is less harmful. However, some weeds may cause harvesting problems and reduce the crop yield in that way. Therefore, weeds should not be completely ignored after the most critical growth period of the crop, but in general, they become less important. These considerations should influence the selection and timing of weed management measures. In general, such measures aim at keeping the weed population at a level which doesn't result in an economic loss of the crop cultivation or harm its quality.

2.7 Preventative Methods

Several preventive measures may be applied at the same time. The importance and effectiveness of the different methods depend to a large extent on the weed species and the environmental conditions. However, some methods are very effective for a wide range of weeds and are therefore regularly used:

Choice of crops and varieties: tall crops and varieties with broader leaves will compete better with late occurring weeds than small varieties with narrow leaves. Some varieties will inhibit and suppress weeds while others will tolerate them. For example, there are witchweed (Striga) resistant maize and cowpea cultivars in many countries of Africa, which give better performance at the same level of weeds where other varieties are more affected

Mulching: the weeds find it difficult to receive enough light to grow and may not be able to pass through the mulch layer. Dry, hardy material, that decomposes slowly, keeps its effect longer than fresh mulch material.

Living green cover: The cover competes successfully against the weeds for light, nutrients, and water and therefore helps to prevent weed growth by winning the competition for resources. The cover crops usually used are legumes, which improve soil fertility on top of suppressing weeds. For example, a ground cover of Desmodium (*Desmodium uncinatum*) or silver leaf, inter-seeded among maize, reduces Striga weed and fixes nitrogen at the same time.

Crop rotation: Rotation of crops is the most efficient measure to regulate seed and root weeds. Changing the conditions of the crop interrupts the living conditions of the weeds thus inhibiting their growth and spread.

Intercropping (mixed cropping and under-sowing): Intercropping with fast-growing weed suppressive species ("smoother crop" or "living mulch") between rows of main crop species is effective in weed control. There are different examples known to work in Africa, for example, sowing cowpeas and pumpkins as intercrops in cassava to reduce weed occurrence.

Sowing time and density: Optimum growing conditions enhance the optimum crop plant development and their ability to compete against weeds. Proper crop spacing will ensure that minimum space is available for the growth of weeds and will minimize competition with weeds. This will effectively restrict weed development. To apply this approach, the limiting weeds must be known and the seasons in which they occur. A weed calendar of the area or region, if available, might be of help. It will be used to manage weeds in a targeted fashion with proper timing and effect.

Balanced fertilization: it can support the ideal growth of the crop, which promotes the growth of the crop over the weeds.

Soil cultivation methods: It can influence the total weed pressure as well as the composition of weeds. For example, minimum-tillage systems can increase weed pressure. Because weed seeds can germinate between soil cultivation and the sowing of the crop, weed cures before sowing can be effective at reducing weed pressure. The use of superficial stubble treatment works against persisting weeds. It should be done under dry weather conditions to allow the weed roots which have been brought to the surface to dry out.

Pasturing: in perennial crops like coffee, mangoes, avocadoes or cocoa, the use of sheep and goats to reduce rampant weed growth is becoming common. In the case of cattle, broadleaf weeds tend to predominate due to the cattle's preference for grasses. Therefore, it is necessary to rotate with sheep and goats which prefer broadleaves to overcome this selective grazing

Prevent insemination of crops by weeds by avoiding the introduction of weed seeds into the fields through tools or animals, and by using only weed-free seed material.

2.8 Biological Control of Weeds

a. Beneficial organisms

Little research has been conducted on using predatory parasitic microorganisms or insects to manage weed populations. However, this may prove to be a useful management tool in the future. Natural enemies that have so far been successful include a weevil for the aquatic weed Salvinia, rust for skeleton weed and probably the most famous, a caterpillar (*Cactoblastis* sp.) to control prickly pear. There is also considerable research effort aimed at genetically engineering fungi (myco-herbicides) and bacteria so that they are more effective at controlling specific weeds. Myco-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment.

Weeds are subject to disease and insect attacks just as a crop are. Most biological control of weeds occurs in range or non-crop areas. As a result, biological control has little relevance for vegetable growers. Geese have been used for weeding trees, vines, and certain row crops. Most types of geese will graze weeds, but Chinese weeder geese are considered the best for row crops. Chinese weeder geese are smaller than other types and tend to walk around delicate crop plants rather than over them. Geese prefer grass species and rarely eat crops. If confined, geese will even dig up and eat Johnson grass and Bermuda grass rhizomes. Care must be taken to avoid placing geese near any grass crops such as corn, sorghum, or small grains, as this is their preferred food. Fruiting vegetables, such as tomatoes when they begin to colour, might also be vulnerable, so geese would have to be removed from tomato fields at certain times. Geese require drinking water, shade during hot weather, and protection from dogs and other predators.

b. Allelopathy

Allelopathy is the direct or indirect chemical effect of one plant on the germination, growth, or development of neighboring plants. It is now commonly regarded as component of biological control. Species of both crops and weeds exhibit this ability. Allelopathic crops include barley, rye, annual ryegrass, buckwheat, oats, sorghum, sudan sorghum hybrids, alfalfa, wheat, red clover, and sunflower. Vegetables, such as horseradish, carrot and radish, release particularly powerful allelopathic chemicals from their roots.

The allelopathic effect can be used to an advantage when oats are sown with a new planting of alfalfa. Allelopathy from both the alfalfa and the oats will prevent the planting from being choked with weeds in the first year. Buckwheat is also well known for its particularly strong weed suppressive ability. Planting buckwheat on weed problem, fields can be an effective cleanup technique. Some farmers allow the buckwheat to grow for only about six weeks before plowing under. This not only suppress and physically destroys, weeds; it also releases phosphorus and conditions the soil.

c. Use of microbes

The soil-borne fungus has been isolated and used for weed management. Some important soil microbes can be identified, isolated, formulated and registered for weed management. In other countries there are many fungi which is available commercially as mycoherbicide (Table 4). This mycoherbicide is on the way to being formulated and registered in different countries. Rhizobacteria capable of suppressing germination of Witchweed (Striga spp.) seeds or destroying the seeds are particularly promising biological control agents since they can be easily and cheaply formulated into seed inoculants. *Pseudomonas fluorescens putida* isolates significantly inhibited germination of *Striga hermonthica* seeds. However, currently no biocontrol product is available.

Trade name	**Pathogens**	**Target weeds**
Devine	*Phyophthora palmivora*	*Morreria odorata* (Strangler vine) in citrus
Collego	*Colletotrichum gleosporoides f.sp. aeschynomene*	*Aeschynomene virginica* (northen joint vetch) in rice and soyabean
Biopolaris	*Biopolaris sorghicola*	*Sorghum halepense* (Johnson grass)
Biolophos	*Streptomyces hygroscopius*	General vegetation(non-specific)
LUBAO 11	*Colletotrichum gleosporoides* f.sp. *Cuscuttae*	Cuscutta sp. (Dodder)
01	*Alternaria cassiae*	*Cassia abtusifolia*
ABG 5003	*Cercospora rodmanii*	*Eichhornea crassipes* (water hyancinth)

Table 4: Commercial Mycoherbicide

2.9 Mechanical Control

With the necessary preventive measures, weed density can be reduced, but it will hardly be enough during the critical periods of the crop at the beginning of cultivation. Therefore, mechanical methods remain an important part of weed management.

Manual weeding is probably the most important one. As it's very labour intensive, reducing weed density as much as possible in the field will bring less work later on and should therefore be aimed at. There are different tools to dig, cut and uprooting the weeds; hand, ox-drawn and tractor-drawn tools. Using the right tool can increase work efficiency significantly. Weeding should be done before the weeds flower and produce seeds.

Flame weeding is another option: Plants are heated briefly to 100°C and higher. This provokes coagulation of the proteins in the leaves and bursting of their cell walls. Consequently, the weed dries out and dies. Although it is an effective method, it is quite expensive, as it consumes a large amount of fuel gas and needs machinery. It is not effective against root weeds.

2.10 Status of organic crop protection technologies in Bhutan

Crop protection in organic agriculture is not a simple matter. It depends on a thorough knowledge of the crops grown and their likely pests, pathogens, and weeds. Successful organic crop protection strategies also rely on an understanding of the effects which local climate, topography, soils, and all aspects of the production system are likely to have on crop performance

Bhutan agriculture remained subsistence for very long time. There is not a large difference between locally produced Bhutanese produce and what is produced as 100% organic. Soil improvement, crop protection relied mostly on natural source rather than synthetic fertilizers and pesticides. Many farmers practice integrated approaches in managing pest and disease. Crop rotations, maintaining field sanitation, use of quality seed, managing weed, Intercropping, manipulation of sowing date for are some of common approaches used by the farmers in managing pest and diseases. Use of microbes and biopesticides are encouraged by government to replace chemical. Biopesticides based on Neem, garlic, Chilli, Artemesia are commonly used by farmers.

2.11 Impact of pest management in organic farming on the environment

As mentioned earlier in this chapter, pest management in organic farming depends mainly on crop husbandry and biological control. The prohibition of synthetic fertilizers and pesticides leads to the conservation of natural enemies including predators and parasitoids. The absence of harmful pesticides also increases the diversity of pollinators of crops and minimizes pesticide residues in food products. The community of microorganisms flourishes well in organically managed farms leading to increased organic matter decomposition, soil fertility, and sustainability of the ecosystem. Organic farming enhances the biodiversity of the ecosystem through multicopying and growing hedges and refuges for beneficial insects as well as wildlife. Preserving biodiversity contributes much to reducing the initial invasion and subsequent establishment of organic farms by pests and diseases.

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MODULE III:

SOIL FERTILITY MANAGEMENT IN ORGANIC AGRICULTURE

A. Learning methods

PowerPoint presentation, group discussion and individual participation and hand-on practice.

B. Materials required

PowerPoint projector, white board, board marker pen, flip chart, marker, notebook, board sticker and pen.

C. Time allocation

12 hours (Theory and practical).

D. General Objectives of the module:

This module aims to provide knowledge and skills on improving the soil fertility of organic farms. The module will teach concepts and various soil management option in organic farming. The trainee will learn the methods of preparing organic fertilizer using the locally available raw materials. They will also learn how to plan cultural methods of soil management to maintain the soil fertility.

E. Learning outcomes:

At the end of this module, the trainee should be able to

1. Explain the principles of soil nutrient management
2. Identify different cultural methods for soil fertility improvement
3. Make crop rotation plan for a given farm
4. Identify suitable green manure and cover crops for their location
5. Prepare simple organic fertilizers using the locally available resources

1 Unit I: Soil Fertility Management in Organic Agriculture

1.1 Background

Organic farming aims at ensuring the long term sustainability of own food production through good soil fertility management practices. In such a system, "*feeding the soil'* is more important than feeding the plant. Maintaining soil life contributes to improve soil fertility and its resultant increase in crop productivity. Organic farmers approach soil fertility management by conserving and protecting their soils from abiotic stress and feeding it with organic material in an appropriate way. However, nutrient management in organic farming systems is a huge challenge, as the use of inorganic fertilisers is not permitted, and the existing alternatives do not provide immediate results. Therefore, organic farmers must optimise a range of nutrient management options which will guarantee optimum crop yields and minimise losses to the environment. Some of the simple and very effective techniques are mulching, green manures, cover crops and composting which can be implemented by the small holders by utilizing the local resources. Additionally with improving research and development, organic fertilizers are also available in the market for use.

1.2 Principles of sustainable soil management:

1. **Soil testing** – Before adopting any soil management options, soil testing is of paramount importance. It is critical to understand the soil nutrient status that will guide the nutrient management practices in the particular land.

2. **Foster soil nutrient balance** - Rationalize application of soil amendments based on the soil nutrient status and crop requirements to maximize soil health and crop yield. Nutrient application methods, types, rates and timing should be appropriate to limit losses and promote balanced crop nutrient uptake.

3. **Enhance soil organic matter (SOM) content** – SOM plays a central role in maintaining soil functions and preventing soil degradation. So, ensure to build up and maintain SOM through addition of farmyard manure, compost, cover crops or straw incorporation. The minimum SOM content in arable land should not be less than 3%.

4. **Preserve and enhance soil biodiversity** - Soil microorganisms play a key role in soil and promotes life in the soil. They are essential for maintenance of soil structure, transformation and mineralization of organic matter, making nutrients available for plants.

5. **Improve soil water management** - Soil moisture is critical for efficient uptake of nutrients in the soil. A sustainably managed soil has rapid water infiltration, optimal soil water storage of plant available water and efficient drainage when saturated.

2 Unit II: Soil Fertility Management Practices in Organic Agriculture

2.1 Cultural methods

The focus of organic agriculture is on 'feeding the soil' that helps in improving the soil quality resulting in better crop yield. Therefore, maintaining high organic matter content in the soil with appropriate soil management techniques is key to the success of organic agriculture. Cultural methods of soil fertility management refer to improving soil fertility through simple crop management techniques such as crop rotation, intercropping, mulching, incorporation of green manures in soil, etc. These are simple practices that can be easily implemented by the small holder farmers by preparing proper farm planning and utilizing the local resources. Such practices are a key component of organic operations, especially on farms missing livestock or when the capacity to purchase organic fertilizer is limited.

2.1.1 Crop Rotation

Crop rotation is an important feature of all organic cropping systems because it serves as the principal mechanism for building soil quality. In addition, it is used as a measure to control the spread of pests and disease, and a variety of other benefits. Crop rotation is defined as an ordered succession of crops on a certain field to enhance inherent soil fertility. However, to derive the benefits of crop rotation, long term strategic planning on crop sequence is crucial.

Why Rotate Crops?

For organic farmers, crop rotation is necessary to maintain field productivity. The main benefits of following a proper crop rotation can be categorized under two broad headings as follow:

a. Enhancing soil fertility
   - Nutrient cycling
   - Nutrient accumulation (N fixation through legumes)
   - Enhancing soil organic matter
   - Improving soil structure
   - Reducing soil erosion (through cover crops)

b. Enhancing production
   - Improve diversity
   - Spread revenues and reduce risks
   - Spread labour demands
   - Prevent build up of weeds
   - Minimize impacts of soil born pests and diseases

General Principles of Crop Rotation

- Follow a legume crop with high nitrogen demanding crop.
- Grow less nitrogen demanding crops in the second or third year after a legume sod.
- Follow a tap root (deep rooted) crop with a fibrous (shallow rooted) crop
- Don't follow one crop with another closely related species.
- Use crop sequences that promote healthier crops.

- Use crop sequences that aid in controlling weeds.
- Use longer periods of perennial crops on sloping land.
- Try to grow a deep-rooted crop as part of the rotation.
- Grow some crops that will leave a significant amount of residue.
- When growing a wide mix of crops, try grouping into blocks according to the plant family, the timing of crops, (all early season crops together, for example), type of crop (root vs. fruit vs. leaf), or crops with similar cultural practices.

Also, consider:
- suitability of individual crops with respect to climate and soil condition
- harvest and sowing dates of the selected crop
- balance between cash and cover crops
- labour requirements and availability

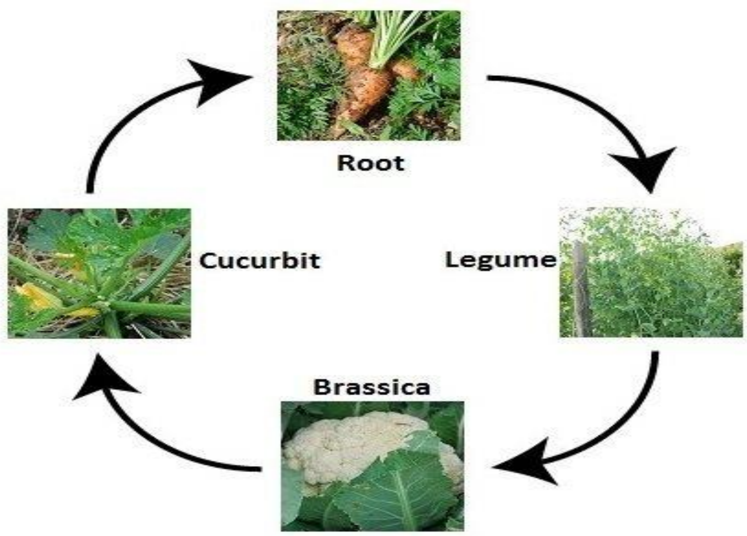

Figure 15: Showing sample crop rotation plan based on family

Planning of crop rotation

Use the following steps when you sit down to make your crop rotation plan.

1. Write down your goals. Describe what are you trying to achieve with your rotation. Some examples of goals could be: Conserve and build organic matter, Add nitrogen, Control diseases, Reduce labor, Reduce weed pressure, Minimize off farm inputs, Increase profits, Economic stability, etc
2. Prioritize your goals: Which goals are most important for your farm?
3. List crops you plan to grow and how much you plan to grow.
4. Create rotational groups: Group crops by family, planting arrangement, nutrient needs, timing, or other important qualities.
5. Check for excessive acreage of one crop family.
6. Make a map of your farm or garden: Google maps can be used. Add additional information such as soil types and field sizes on the map.
7. Divide your farm or garden into equal-size rotational units.

8. Define the land area (rotational units) needed for each grouping of crops.
9. Identify conditions on your farm that will affect which crops are grown where on the farm (e.g. wet and dry fields, diseases or pests problems. Note these conditions on your farm map.
10. Make multiple copies of your farm map.
11. Using copies of the farm map, compare possible rotations.
12. Keep the following in mind:
    - Timing of field operations and equipment required for different rotational units
    - Inclusion of cover crops and their effect on subsequent crops
    - How long the rotation must be between crops/groups to avoid/ameliorate disease
    - Inclusion of fallow periods, rotation between weed-prone and competitive crops, and rotation between crops grown in different seasons for weed management
    - Rotation in time and space of susceptible crops to keep insect pests from returning to crops the next year or moving from crop to crop in the field
    - Alternatively, use a field conditions/field futures worktable or a fields table with a time axis.

2.1.2 Intercropping

Intercropping provides a potential option for sustainable crop production (Lithourgidis et al., 2011). Intercropping is defined as the simultaneous cultivation of two or more crops on the same field with partial or complete overlap during the growing period. Intercropping increases crop productivity, enhances biodiversity and provides ecosystem services such as suppression of pest and diseases (Boudreau, 2013; Stomph et al., 2020).
Furthermore, intercropping provides better ground cover than monocultures, in order to protect the soil from erosion. Growing more than one crop at a time in the same field helps in maximizing water use efficiency and improving soil fertility.

Types of intercropping

a. *Mixed intercropping:* intercropping with no distinct row arrangement.

b. *Row intercropping:* intercropping with component crops planted in alternating rows.

c. *Strip intercropping:* intercropping with component crops planted in alternating strips of rows (wide enough to permit independent cultivation but narrow enough for the components crops to interact).

d. *Relay intercropping:* growing two or more crops simultaneously during part of their life cycle. The second crop is sown when the first crop has reached its reproductive stage but before its maturity.

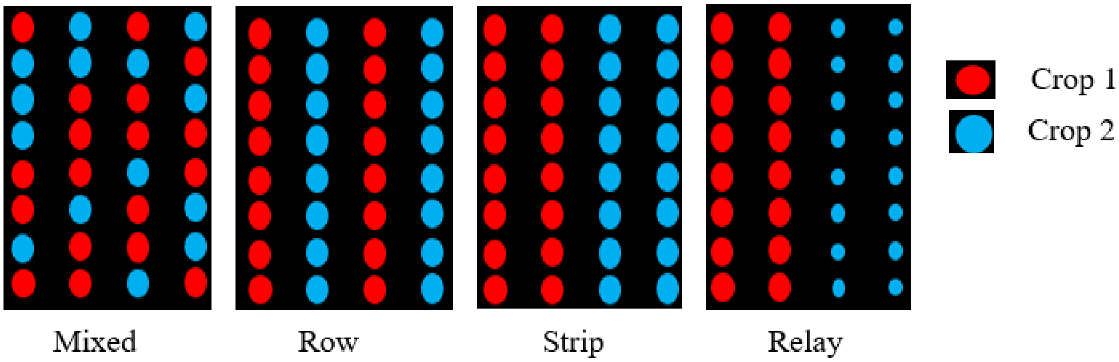

Figure16: Showing four types of intercropping system

How can intercropping improve soil fertility?

Growing legumes as one of the component crops in intercropping is the main mechanism of improving soil fertility, especially in nitrogen limiting soils. Legumes serve as a host for *Rhizobium* bacteria, which has the ability to fix the atmospheric nitrogen in the soil. Studies have shown that a certain portion of the fixed nitrogen is transferred to the adjacent crop while the remaining portion is left in the soil, which is used by the succeeding crop. (Eskandari et al., 2009a).

Cereal-legume (e.g., maize-bean) intercropping is reported to be the best crop combination for soil with low nitrogen. In such combination, legume crops do not exert competition on the limited soil nitrogen with cereals crops as they can rely on nitrogen fixed by *Rhizobium* bacteria. However, relying fully on nitrogen fixation by the legumes is not enough to maintain soil fertility. Additional nutrient source such as manures and organic fertilizers is required for better crop yields.

Benefits of intercropping

1. Enhance resource use efficiency
2. Modification of microclimate
3. Enhance light interception and radiation use efficiency
4. Pest management

2.1.3 Green manure

Green manuring is a practice of growing and incorporating vegetative parts of a plant into the soil with the objective to maintain, improve or restore the physical, chemical and biological properties of the soil. The vegetative biomass is called green manure or green leaf manure.

Generally, green manuring is practiced as a part of crop rotation, in which cash crops are cultivated after incorporating the green manure into the soil. The commonly used green manure crops belong to *leguminous* family as they fix nitrogen from air. Amongst the green manure crops, sunhemp and daincha are commonly used as they are best at biomass production. Weeds such as parthenium (*Parthenium hysterophorus*), which grows abundantly in Lobesa can also be used as a green manure, provided it is harvested and used before the reproductive growth stage.

Selection of green manure
All plants at vegetative phase can be used as green manure. However, to select the best type of plant for green manure, following characteristics should be considered.

1. Rapid vegetative growth that generates large amounts of biomass (green and dry matter) and efficient soil cover
2. Easy to grow and manage in the field
3. Deep penetrating and well-developed root system
4. Ability to grow in low soil fertility and be adapted to degraded soils.
5. Resistance to attacks by pests and diseases and not act as a host to commercial crops

2.1.4 Role of green manure in soil fertility

Growing green in the cropping system aims at preparing good soil quality for subsequent crops. Green manures store nutrients from soil and air, later tilled into the soil while they are still green. When turned back into the soil, plants slowly decompose and gradually release these nutrients to the next crop. The decomposed plant materials increase soil organic matter that ensures soil fertility by improving its biological and physical properties. Growing of green manure crops in off season also helps to reduce weed growth.

Basic steps for making green manure work

- For green manuring, a combination of a legume and a grass species works well, the legume provides nitrogen.
- Growing a green manure crop is as easy as throwing out a handful of seed onto freshly cultivated ground, followed by raking to cover the seed.
- "Digging the crop in" at the end isn't necessary, as by cutting the plants at the base while still green and lush, usually just as flowers form.
- leaving the green manure crop on the surface and you can have 'instant' mulch.
- Green manures can be used to interrupt pest and disease cycles in much the same way as crop rotation.

2.1.5 Cover crops

Cover crops have been used to improve soil and the yield of subsequent crops in many successful organic farms across the world. In Bhutan, adoption of cover crops in the cropping system is very minimal (mostly nil), mainly due to limited land holding and economic cost associated. However, the existing practice of keeping land fallow after growing cash crops (especially paddy) could be replace with growing suitable cover crops.
Cover crops refers to growing plants mainly to keep the soil cover and incorporate the vegetative biomass into soil, rather then harvesting. The main objectives of growing cover crop is to protect and improve the soil with living vegetation during a time of the year when it would otherwise kept fallow and to minimize runoff and soil erosion. Cover crops provides myriad benefits as shown in the figure below:

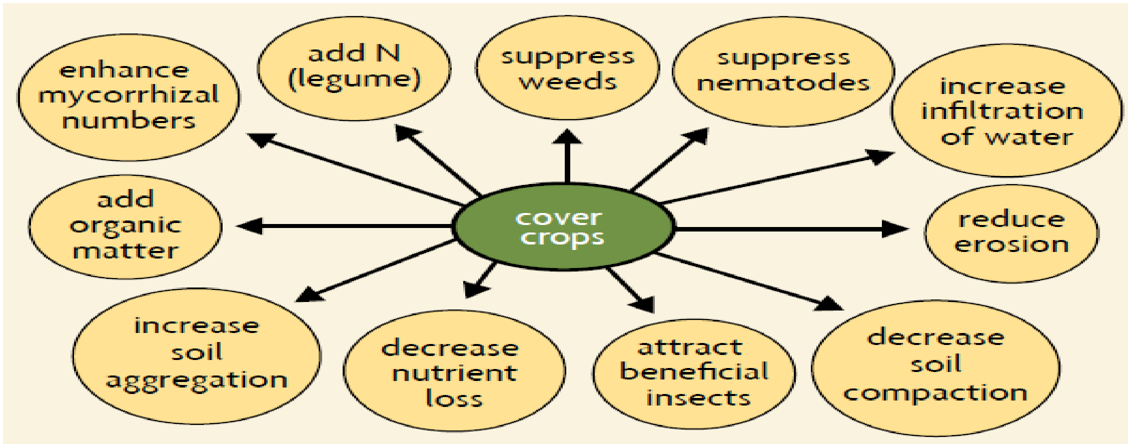

Figure 17: Indicating the benefits of adopting cover crops in the cropping system. (Source: adapted from Magdoff and Van, 2000)

Examples of some commonly grown cover crops are:
Legumes: cow pea, field pea, mung bean, lupin, vetch, white clover and alfalfa
Root: raddish, turnip, beet and carrot
Broadleaf: buckwheat, squash, mustard and sunflower
Grass: barley, cereal rye, oat and millet

Basic Steps for Selecting Cover Crops

Before growing cover crops, following steps should be fulfilled:

- Define your goals for planting cover crops
- Make selection of cover crops based on soil conditions, climate and your purpose
- Plan the timing to the plant the cover crops
- Plan the timing to kill or incorporated planted cover crops into the soil
- Determine the cash crop to be grown after the cover crop

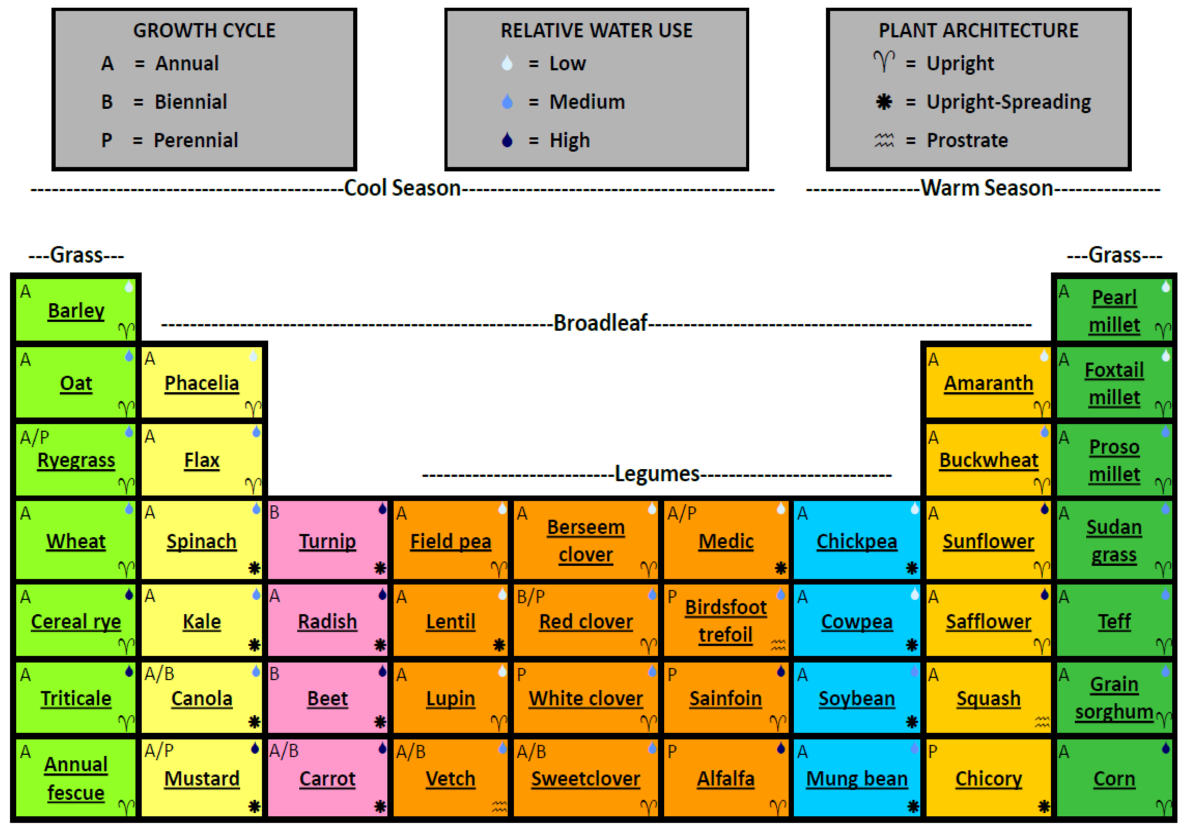

Figure 18: Cover crop chart which can be used while planning the cover crop in the cropping system. (Source: Agricultural Research Service's Northern Great Plains Research Laboratory)

2.1.6 Mulching

Mulching is a protective covering, usually of organic matter such as leaves, straw, or peat, placed around plants. These mulch materials are easily available locally and reduce the cost of external inputs.

In organic farming mulch is used in vegetable and fruit production, and provides following benefits:

1. Reduces the deterioration of soil by preventing runoff and soil loss,
2. Minimizes the weed infestation and
3. Controls the soil moisture loss through evaporation
4. Helps to regulate soil temperature
5. Improves physical, chemical and biological properties of soil,
6. Adds nutrients to the succeeding crop

The mulches should be applied uniformly after the first weeding which generally occurs after 2-3 weeks of sowing/transplanting. For mulching one hectare area of any agricultural crop about 4-5 tonnes of the biomass is required (Thimmaiah, 2010). There are also inorganic sources of mulches of which plastic mulching is widely used for vegetable production in Bhutan. The use of plastic mulches has drastically reduced the cost of weed control in vegetable production. However, over use of plastics mulches are not a viable sustainable option as they are environmentally destructive and impose future threats to soil quality.

Picture showing the use of forest leaf litter as mulching material in chilli cultivation, Kabesa, Punakha

2.2 Organic fertilizer production

Organic fertilizers are fertilizers derived from vegetable matter (compost, crop residues), animal excreta (farmyard manure), and animal matter (slaughter house wastes). Naturally occurring organic fertilizers include peat, which is a brown deposit resembling soil, formed by the partial decomposition of vegetable matter in wet acidic conditions. Organic fertilizers also include biofertilizers which are substances containing living micro-organisms which, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere and promote growth by increasing the supply or availability of primary nutrients to the host plant. Organic fertilizers improve the bio-physical and chemical properties of the soil, which are important for not only enhancing the nutrient and water holding and infiltration capacity of the soil, but also for improving the overall health of the soil. Therefore, relying on organic fertilizers enhances a farm's resilience.

2.3 Status of organic fertilizer production in Bhutan

The production of the organic fertilizers as of 2022, is mostly concentrated in southwestern region and a few units in central and eastern regions with a total production capacity of 2,806 MT. Besides, there also exists 30,000 MT of FYM and leaf litters that farmers use (source: NOFP Blueprint). The National Soil Services Centre (NSSC) also promotes bio-digester for liquid fertilizer production.

The Bio-FMCL, an FDI company was approved in 2021, to set up a bio-fertilizer production plant in the country (Athang Gewog under Wangdiphodrang Dzongkhag). The company is a partnership between FMCL and the BNB Korea. The production capacity of the plant is 432 MT per year

2.4 Standards for organic fertilizers

Under the National Organic Flagship Program, which was launched in 2019, organic fertilizer production is expected to rapidly increase. As the fertilizer production becomes commercial, factories will use a wide range of raw materials of varying quality sourced from different places. Therefore, in order to ensure quality and protect farmers/users from sub-standard products, it is of utmost importance to develop and regulate quality control by way of approved technical regulations for both organic and bio-fertilizers.

Any product in solid or liquid form of plant (except by-products from petroleum industries) or animal origin that has undergone substantial decomposition can supply plants with nutrients such as nitrogen (N), phosphorus (P) and potassium (K). This may be enriched by microbial inoculants and naturally occurring minerals such as lime, dolomite and rock phosphate. Addition of synthetic chemical or inorganic fertilizer materials to the finished product is not permitted.

Minimum Requirements
Table 5. shows the minimum requirements for important parameters of organic fertilizers.

Table 5: Specifications for organic fertilizer

Parameter	Limits	
	Vermi-compost	Composts
pH	6-8	6-8
Total Nitrogen (as N) % by wt.	1	1
Phosphorus (as P_2O_5) % by wt.	1	0.5
Potassium (as K_2O) % by wt.	1	0.5
Organic carbon, % by wt.	18	12
Organic matter content, % by wt.	60	60
Carbon: Nitrogen ratio	<20	<20
Moisture % by wt.	<35	<35
Temperature (degree Celsius)	20-25	20-25

Table 6. shows the allowable level of heavy metals that may be present in the organic fertilizers. The sources of these heavy metals in the organic fertilizers could mainly be the contaminants in the raw materials for composts.

Table 6: Allowable level of heavy metals for organic fertilizer

Parameter	Limit, mg/kg
Arsenic	10
Cadmium	5
Chromium	50
Copper	300
Lead	100
Zinc	1000
Mercury	0.15
Nickel	50

2.5 General requirements for organic fertilizers

a. A standard organic fertilizer should be based on composted livestock and/or plant materials supplemented with only natural products.
b. A high-temperature (70-80°C) aerobic composting technique should be employed to produce composts within the first couple of days thereby killing the pathogens, hormones, antibiotics and weed seeds.
c. All composts should be fully matured during which the compost should be turned at least once.

d. All well prepared and well matured composts should have the following characteristics:
   - It should be dark in colour.
   - It should be free from foul smell.
   - Homogenous in texture which should pass through 4.0 mm sieve.
   - The compost should be free from weed and contaminants, which include but not limited to residual hormones, antibiotics, pesticides and disease organism/pathogen.
   - Should be free from impurities and foreign materials like sand, stone, twigs/stem, plastic, rubber, glass, aluminum wrapper etc.

2.6 Labelling for organic fertilizers

The packages should be legibly and indelibly labeled with the following information:

- Name of the manufacturer/packer/importer
- Nutrient content (N, P, K)
- Carbon/Nitrogen ratio
- Organic matter content
- Moisture content
- Batch number
- Percentage inert materials (gravel, plastic etc.)
- Date of Manufacture, and Expiry date

2.7 Classification of organic fertilizers

i. Bulky organic manures (FYM, cattle/sheep/goat and poultry manure, compost, vermicompost).
ii. Concentrated organic manures (both edible and non-edible oil cakes and slaughter house wastes such as blood meal and bone meal).
iii. Biofertilizers
   a. Nitrogen Fixing Bio-fertilizers
   b. Phosphate Bio-fertilizers
   c. Phosphorous Solubilizing Bio-fertilizers
   d. Phosphorus Mobilizing Bio-fertilizers
   e. Bio-fertilizers for Micro-nutrients
   f. Plant Growth Promoting Rhizobacteria
   g. Compost Bio-fertilizers/Enrichers

2.8 Production of different organic fertilizers

a. Compost

Compost is made by decomposing organic materials by micro-organisms such as bacteria, fungi and protozoa. It requires carbon, nitrogen, oxygen and water, and occurs in 3 phases: mesophilic, thermophilic and maturation.

There are two broad categories of organic solid waste as raw materials: green waste and brown waste. Green waste is generally considered a source of nitrogen and includes food waste, grass clippings, field biomass, fresh leaves etc. whilst brown waste is a carbon source and typical examples include dried vegetation and woody material such as fallen leaves, straw, woodchips, twigs, logs, pine needles, sawdust etc. The most efficient composting occurs at a CN ratio of about 25:1

Types of composting

Composting may be divided into two categories based on the nature of the decomposition process, namely anaerobic and aerobic composting. In anaerobic composting, decomposition occurs where oxygen is absent or in limited supply. Under this method, anaerobic micro-organisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. In the absence of oxygen, these compounds accumulate and have a strong odour and some phytotoxicities. Moreover, the process usually takes longer than aerobic composting.

Aerobic composting takes place in the presence of ample oxygen. In this process, aerobic microorganisms break down organic matter and produce carbon dioxide, ammonia, water, heat and humus, the relatively stable organic end product. Although aerobic composting may produce intermediate compounds such as organic acids, aerobic micro-organisms decompose them further. The heat generated accelerates the breakdown of proteins, fats and complex carbohydrates such as cellulose and hemi-cellulose. Hence, the processing time is shorter.

Compost preparation

Materials required

i. Green biomass – 1,000 kg (nitrogenous)
ii. Dry Biomass – 1,000 kg (carbonaceous)
iii. Cow dung – 25 kg
iv. Water - 100 L

Procedure

i. Demarcate an area of 2 m wide and 3 m long. Depending on the availability of the materials the length of the heap can be extended.
ii. Place a layer of stones or wooden logs within the demarcated area as a basal layer to provide aeration.
iii. Prepare a dung slurry by mixing 25 kg of dung in 100 L of water.
iv. Spread uniformly a layer of dry biomass up to a height of 30 cm and moistened it with dung slurry.
v. Spread green biomass on top of the dry biomass layer and moisten it with dung slurry.
vi. Similarly, lay alternate layers of dry and green biomass up to a height of about 1-1.5 m.
vii. When the heap has reached a desired height, cover it with soil or straw.
viii. To prevent the loss of nutrients by volatilization, make the heap in a shaded area.
ix. Depending on temperature the compost will be ready in 2-3 months.

b. Vermicomposting

The term vermicomposting means the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day, e.g., 1 kg of worms can consume 1 kg of residues every day.

The excreta (castings) of the worms are rich in nitrate, available forms of P, K, Ca and Mg. The passage of soil through earthworms promotes the growth of bacteria and Actinomycetes. Actinomycetes thrive in the presence of worms and their content in worm casts is more than six times that in the original soil.

The commonly used earthworms such as *Eudrillus* sp. *Perionyx* sp., *Eisenia* sp. or any locally available surface feeding (epigeic) earthworms can be collected from nearby soil and then used in vermicomposting. Not all earthworms can be used for vermicomposting. Therefore, it is very important to know and use the right kind of worm.

Vermicompost preparation

Materials required

i. Cattle dung, green and dry leaves (1 MT)
ii. Earthworms (1 kg)
iii. Wooden/concrete bed (2 m x 1 m x 0.4 M (LBH))
iv. Shovel and spade
v. Jute sack/banana leaves

Procedure

i. Collect the cattle dung.
ii. Keep the dung for about 7-10 days to let it cool or to let it partially decompose.
iii. Prepare beds/rows of dung and crop residues/leaves of about 2 m x 1 m x 0.4 m (LBH).
iv. Layer the crop wastes such as leaves, straws, etc. alternatively with the dung to thus make a height of about 0.4 m. Keep the beds as such for 4-5 days to let it cool.
v. Sprinkle the water to let the compostable matter to cool down.
vi. Put the earthworms on the top of the manure row/bed. Inoculate about 1 kg of worms in a meter long manure row.
vii. Cover it with banana leaves/jute sack and leave it undisturbed for 2-3 days.
viii. Open the bed after 2-3 days. Loosen the upper portion of about 10 cm of manure with the help of suitable tool.
ix. Cover the bed again. The worms feed on an upper bed of about 10 cm. This portion becomes vermicasted in about 7-10 days.
x. Remove the vermicasted manure portion and collect near the bed. Loosen another upper portion of 10 cm and cover it again with the leaves.
xi. Maintain the moisture in the bed by regularly sprinkling water (but it should not be too wet).
xii. Remove the vermicasted portion again in another 7-10 days.
xiii. In 40 days, about 30 cm of the bed is converted into vermicompost and is collected on 3-4 occasions.
xiv. The remaining bed of about 10 cm height contains earthworms mixed manure.
xv. Put the fresh manure mixture/organic residues, etc. on the residual bed containing earthworms of about 10 cm to restart the composting process
xvi. Sieve the vermicompost collected from the bed to make it free from worms and uncomposted or foreign matter.
xvii. Pack the screened manure in a suitable bag or polythene to use/ sell it.

Simple vermicomposting shed

Vermicomposting beds

Preparation of medium with cow dung

Adding a layer of dry and green leaves

Introduce right earthworm species

Cover medium with jute sack/leaves

Best practices for high quality vermicompost

i. Construct the tank of approximately 2 m × 1 m × 0.4 m with the available materials such as bricks or stones. The base of the tank should have a slight slope directing towards two drainage holes.
ii. Select the right sort of worms and the bedding material.
iii. Keep the raw materials in piles and allow the temperature to reach 30-40°C for 7-10 days to ensure partial decomposition of raw materials.

iv. Maintain the optimum moisture level (40-45%) and temperature (28-30°C), as higher or lower temperature reduces the activity of earthworms.
v. Stop watering two to three days before emptying the beds as this practice will force 80% of the worms to the bottom of the bed, and remove the rest of the earthworms from the compost with the help of hand.
vi. Make floor leakproof and provide shade to regulate the temperature and to protect against accumulation of water during rainy season.
vii. Collect the excess water that has been leached along with the earthworm extracts from the concrete flooring and recirculate it as this ensures high N content in the finished product.
viii. Ensure that the contents are not soggy or moist as it results in anaerobiosis of earthworms causing mortality.
ix. Cover the tank with wired mesh to prevent the feeding by rodents and birds.
x. Use the undiluted urine for moistening organic waste during the preliminary composting period (before the addition of worms) and use diluted urine (Urine diluted with an equal quantity of water) after the initiation of worm activity to enhance N content and to harvest the vermicompost at least10 days earlier than normal methods.

Characteristics of good vermicompost

i. The vermicompost should be black, granular, lightweight, and humus rich with no particles of the original residue present.
ii. The moisture content should range between 30-35%.
iii. The total Nitrogen content should be 1.0 to 2.5%.
iv. The total Phosphorus content should be 1.0 to 1.5%.
v. The total Potassium content should be 1.0 to 1.5%.
vi. The pH value should be between 5.5 and 6.5
vii. Odor should be slightly musty or earthy like forest soil.

c. Vermiwash

Vermiwash is a liquid extract produced from vermicomposting in a medium where earthworms are richly populated in earthen pots or plastic drums. Extract contains major micronutrients, vitamins (such as B_{12}) and hormones (gibberellins) secreted by the earthworms. Earthworms produce bacteriostatic substances. The vermiwash can protect against bacterial infections. Vermiwash can be sprayed on crops and trees for better growth, yield and quality.

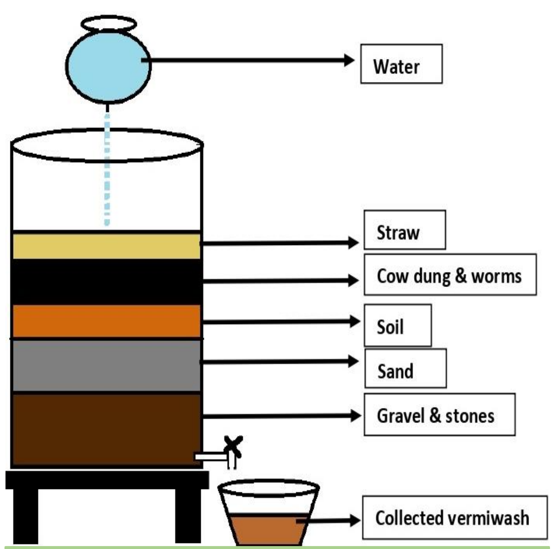

Figure 19: Showing a vermiwash unit

Vermiwash preparation

Materials required

i. Plastic barrel fitted with tap
ii. Different sized stones/gravels
iii. Sand and top soil
iv. Cow dung and straw
v. Plastic bottle

Procedure

i. Use a plastic barrel of 200 L capacity to prepare vermiwash. Attach the tap at the bottom /lower side of the barrel to collect the vermiwash.
ii. Place bigger sized stones layer up to 30 cm at the bottom (or 15% of the container). Then place layer of small gravels up to 10 cm (5%) over the stone layer.
iii. Place 30 cm (15%) of sand layer and 30 cm (15%) top soil over sand.
iv. Spread a layer of partially decomposed cow dung up to 50 cm (25%).
v. Introduce 500 g/ 300-400 earthworms.
vi. Then cover the dung with 20 cm (10%) of straw.
vii. Keep the tap open for the next 15 days and add water every day to keep the unit moist.
viii. On the 16th day, close the tap and on top of the unit, suspend a perforated container at the base as a sprinkler.
ix. Allow 4-5 L of water to gradually sprinkle on the barrel overnight.
x. Open the tap of the unit the following morning and collect the vermiwash and close the tap.
xi. Refill the suspended pot with 4-5 L of water and repeat the same processes.

Layer of bigger sized stones

Layer of small gravels

Layer of sand

Layer of top soil

Layer of cow dung

Introduce earthworms

Best practices

i. Refill the pot with water once it is empty.
ii. Store the vermiwash in cool dry place.
iii. Dung and straw could be replaced periodically based on need. The entire set up can be emptied and reset between 10 and 12 months of use.
iv. Loosen the dung for aeration.

Characteristics of vermiwash

i. The vermiwash is brown colored liquid fertilizer.
ii. It contains high amount of enzymes, amino acids, vitamins and hormones.
iii. Microbes like nitrogen fixers and phosphate solubilizers are present.
iv. It contains soluble NPK and micronutrients.

Uses of verminwash

Root dip/stem dip

Dip seedlings in vermiwash solution which is diluted 5 times with water for 15-20 minutes and then transplant it. Similarly dip cuttings in the solution before transplanting.

Foliar spray

Dilute the vermiwash 5 times with water and spray it on the foliage of crops as it provides the plants with vital nutrients and helps to control plant diseases.

Soil drench

Dilute the vermiwash 10 times with water and drench soil with the solution to prevent some of the soil-borne pathogens.

2.9 Biofertilizers

Biofertilizers are carrier-based (powder or liquid) preparations containing effective strains of living microorganisms like bacteria, fungi and algae alone or in combination in sufficient count (see examples in Table 6.1). When applied to seeds, plant surfaces, or soil, bio-fertilizers colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. They also add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth-promoting substances. They also increase the nitrogen and phosphorus available to plants more naturally than other sources.

Bio-fertilizers are also called bio-inoculants/culture, microbial inoculants and are easy to use, even for novice growers. They do not pollute the soil or environment unlike synthetic chemical fertilizers, which often result in too much phosphate and nitrogen in the soil. Bhutan does not have production facility for biofertilizers as yet, however, a production plant is planned to be set up in Wangdue soon.

Table 7: Major bio-fertilizers with examples

Bio-fertilizer group		**Example**	**Function**
N2 fixing bio-fertilizers			
1	Free-living	*Azotobacter, Beijrinkia, Clostridium, Klebsiella, Anabaena, Nostoc*	Increase soil N level; fix the atmospheric N in the soil and make it available to the plants
2	Symbiotic	*Rhizobium, Frankia, Anabaena, Azollae*	
3	Associative symbiotic	*Azospirillum*	
P Solubilizing bio-fertilizers			
1	Bacteria	*Bacillus megaterium* Var. *phosphaticum, Bacillus subtillis, Bacillus circulans, Pseudomonas striata,*	Solubilize the insoluble phosphate from organic and inorganic phosphate sources; release insoluble P in soil and make it available to plants; secrete organic acids and lower pH to dissolve bound phosphates in soil
2	Fungi	*Penicillium* sp., *Aspergillus awamori*	
P Mobilizing bio-fertilizers			
1	Arbuscular mycorrhiza	*Glomus* sp., *Gigaspora* sp., *Acaulospora* sp., *Scutellospora* sp., and *Sclerocystis* sp.	Transfer P from soil to the root cortex, penetrate cortical cells of the roots and increase surface area of roots.
2	Ectomycorrhiza	*Laccaria* sp., *Pisolithus* sp., *Boletus* sp., *Amanita* sp.	
3	Ericoid mycorrhiza	*Pezizella aricae*	
4	Orchid mycorrhiza	*Rhisoctonia solani*	
Bio-fertilziers for micro-nutrients			
1	Silicate and Zinc solubilizers	*Bacillus* sp.	Degrade silicates and aluminium silicates in soil.
Plant growth promoting rhizobacteria			
1	Pseudomonas	*Pseudomonas fluorescens*	*Improve nutrient availability, suppress plant diseases and produce phytohormones.*

Production and application technology of biofertilizers

Biofertilizer production technology includes:

a. isolation of bacteria/other microbes
b. selection of suitable effective strain
c. preparation of mother or seed culture
d. mass multiplication of culture
e. quality checks
f. carrier preparation and their mixing
g. curing, packaging, storage and dispatch.

2.10 Jholmal production

Jholmal is a homemade biofertilizer that improves crop yield while lowering the production cost and reducing the use of harmful chemicals. It is based on local traditional practice in Nepal that is being promoted by the International Centre for Mountain Development (ICIMOD) as an alternative, environmentally friendly and low-cost technology which is highly applicable in organic farming in the Himalayas. It contains large quantities of the main macro-nutrients required by plants (Table 8).

Jholmal technology was introduced at Yusipang by ICIMOD through the Resilient Mountain Solution (RMS) in 2019. In the same year, demonstration of the technology was conducted at Longpa Nobgang village (Model Organic Village), Haa.

There are three types of Jholmal namely Jholmal 1, Jholmal 2 and Jholmal 3. Jholmal 1 is a biofertilizer while the latter two are biopesticides. Jholmal 1 is a combination of cow dung, cow urine and water at a defined ratio, which needs to undergo a month-long fermentation.

Table 8: Nutrient content of Jholmal 1

Analyzed parameters	Jholmal 1
N (%)	1.92
Available P (kg ha^{-1})	2.37
Available K (ppm)	161.4
OC (%)	22.28
pH (H_2O)	8.11

Source: Namgay, 2021

Jholmal 1 preparation

Materials required

i. Plastic Bucket (50 L) or any Barrel
ii. Cow urine
iii. Bhutan Agro Microbial Solution (BAMS)/ Effective Microorganisms (EM)
iv. Farmyard manure/ cow dung

Cow urine functions as both fertilizer and pesticide. It contains nutrients such as nitrogen, potassium and phosphates as well as antibacterial, antioxidant, anthelminthic and antifungal agents.

A mix of beneficial microbes found in natural conditions act as catalytic agents to accelerate the decomposition process. The key ingredients of BAMS/EM are lactic acid bacteria, photosynthetic bacteria and yeast. The microbes are non-poisonous and harmless to ecosystems. If BAMS/EM are not available then it can be left out.

Procedure

i. In a 50 L drum or bucket, mix the following ingredients:
- 17 kg well decomposed FYM or cow dung
- 16 L cow urine, 16 L water and 1 L EM

ii. Mix all ingredients thoroughly in the drum/ bucket and allow the mixture to ferment for 15 days.

iii. When Jholmal is ready, smell of compost disappears and green color texture appears at the top of slurry.

Figure 17: showing Ingredients required for Jholmal 1 preparation

Application of Jholmal

Before applying, dilute Jholmal 1 with water at a ratio of 1:1. Apply Jholmal 1 on soil at the base of plant.

In one acre land, 1,000 L Jholmal (20 buckets of 50 L each) will be enough.

Jeevamrut

It is a liquid organic fertilizer with an excellent source of nitrogen, phosphorous, potassium and several other micro-nutrients required for the crops. It is considered environmentally-friendly. It is made by mixing water, cattle dung and urine with some mud from the same area in a defined ratio. Jaggery or flour is also added to the mixture as a food for the microbes to speed up their growth.

Jeevamrut technology is an adaptation from India and introduced at Yusipang by Mr. Anant Gulve (Jeevamrut expert) in 2019. It produces liquid manure in a semi-automatic machine by a process known as fermentation. Jeevamrut technology has been demonstrated to several organic farmers.

Table 9: Nutrient content of Jeevamrut

Analyzed parameters	Jeevamrut
pH	5.99
Ash content (%)	00.24
Available phosphorus (P_2O_5 mg/kg)	173.78
Available calcium	135.72
Total carbon (g/kg)	00.10
Total nitrogen (g/kg)	00.10
Total potassium (mg/kg)	567.68
Total magnesium	288.76
Total iron	00.56
Total Zinc	9.80
Total Copper	27.63

Source: Suchet Agro LLP, India

Figure 20: showing Jeevamrut ready for application

Table 10: Nutrient contents of jeevamrut

Analyzed parameters	Jeevamrut
N (%)	2.52
Available P (kg ha^{-1})	2.04
Available K (ppm)	113.73
OC (%)	29.3
pH (H_2O)	4.19

Source: Namgay (2021)

In the country, Ashish Horticulture is the main agent or dealer for Jeevamrut.

Jeevamrut preparation

Materials required

i. 1,000 L drum and 500 L drum for large scale farming
ii. 1,000 L drum acts as a fermentation tank/unit where the ingredients of Jeevamrut are fermented.
iii. 500 L drum acts as a filtration tank/unit where it receives filtered solution.
iv. For small scale farming, Jeevamrut can be prepared in 50 L bucket
v. Automatic stirring machine
vi. Using the power supply stirring machine automatically stirs the ingredients present in the fermentation tank

vii. Filtration set
viii. Filters the slurry prepared in fermentation tank thereby obtaining clear solution called Jeevamrut
ix. Water pipe
x. Connect between fermentation tank and filtration tank
xi. Flush valve
xii. Draining and cleaning of unit/tank

Ingredients required for 1,000 L tank

i. 1,000 L drum - 1 no.
ii. 500 L drum - 1 no.
iii. Jaggery - 20 kg
iv. Cow dung - 300 kg
v. Cow urine - 300 L
vi. Chickpea flour (Besan) - 20 kg or buttermilk - 20 L
vii. Handful of soil from same land

Figure 21: showing the ingredients of Jeevamrut

Materials and ingredients required for 50 L bucket (small farming)

i. 50 L Bucket- 1
ii. Jaggery- 1 kg
iii. Cow dung-15 kg
iv. Cow urine-15 L
v. Besan- 1 kg
vi. Handful of soil from same land

Procedure

i. Mix all the ingredients of required quantity in the fermentation tank and let it ferment for 5 days. After 5 days we can use the liquid fertilizer.
ii. Stir the mixture 2-3 times in a day.
iii. Then pass the fermented solutions through filtration system in filtration tank by opening the valve connected to two tanks to obtain clear liquid called Jeevamrut (filtrate machine is set in filtration tank).
iv. Liquid is filtered and ready to be used as bio-fertilizer.
v. Liquid manure can be directly applied to the field through drip irrigation or sprinkler irrigation.
vi. Liquid manure can be used for 8 days effectively

Jeevamrut preparation in 50 L bucket

i. Mix all ingredients thoroughly in the bucket
ii. Stir the mixture using wooden stick in clockwise and anticlockwise direction
iii. Preparation time and application rate are same as in the tank preparation.

Application of Jeevamrut

Jeevamrut can be applied in different ways, such as mixed in irrigation water or as direct application on soil surfacel. In one acre of land, 200-250 L of solution is applied through irrigation water or direct soil application at a ratio of 1:1 (Jeevamrut: Water). Start applying after one month of sowing or transplanting. Apply once at an interval of 15-21 days. It can be also applied in compost making.

Precautions

Jeevamrut has a short shelf life (10-12 days) and hence should not be kept for extended period.

Rice Husk Biochar Production Technology

Biochar is a form of charcoal produced from biomass, by a process known as pyrolysis. Pyrolysis means heating in the absence of oxygen, which prevents complete burning of the organic biomass. It is rich in a stable form of carbon which is not oxidized by soil micro-organisms. Biochar has unique properties that make it not only a valuable soil amendment to sustainably increase soil health and productivity, but also an appropriate tool for sequestering atmospheric carbon dioxide in soils to mitigate climate change. Biochar improves soil structure, water penetration and water retention in soil.

Different biomass feedstock can be used for making biochar, including manures, wood, crop residues and rice husks. Nutrients in biomass increase when converted to biochar (Table 11).

Table 11: Chemical properties of rice husk and rice husk biochar produced at 400°C

Analyzed parameters	Rice husk	Rice husk biochar
pH	6.5	8.6
Ash content (%)	11.5	27.5
Available phosphorus (P_2O_5 mg/kg)	605	895
Available silica (SiO_2 mg/kg) 0.1 M $CaCl_2$	1004	1306
Total carbon (g/kg)	410.8	541.1
Total nitrogen (g/kg)	2.7	4.9
Total potassium (mg/kg)	2397	4211

Biochar preparation

Equipment and materials required

i. Metallic cone - It is an integral part of rice husk biochar production and therefore should be made from quality metal which can resist high temperature (300°C and above).
ii. Metallic barrel -The diameter of the top part of metallic cone must be slightly lower than the diameter of the chimney pipe
iii. Chimney set - Consists of lower chimney pipe with smoke regulator and upper chimney pipe with chimney cap. The metal used must be of good quality.)
iv. Rice/wheat straw (3-4 bundles)
v. Rice husk (50 kg)
vi. Lighter
vii. Water (10 L)
viii. Plastic sheet (size: 2 m x 2 m) and
ix. Rope/threads (Length: 3 m)

Figure 22: showing the equipment required for Biochar preparation

Procedure

i. Place the cone inside the barrel.
ii. Add feedstock (rice/wheat straw) into the cone. Pack it tightly until it reaches the neck of the cone. Thereafter, loosely insert feedstock to ensure air supply during ignition.
iii. Add rice husk around the cone in the barrel.
iv. Ignite the feedstock from top of the cone.
v. Fix chimney pipe onto the cone once the feedstock on top has burnt and ensure that fire is alive even after chimney fixation.
vi. Within 30-60 minutes, rice husk on the surface will start turning black. This is a good indication that carbonization has started. Additional husk can be added after that.
vii. With a rod, mix the rice husk to ensure uniform carbonization.
viii. Once the entire rice husk has carbonized, the biochar is ready.
ix. Add about 5 liters of water to stop the burning process.
x. Remove the chimneys.

xi. Add about another 5 liters of water inside the cone.
xii. Cover the barrel with a plastic sheet and secure it with a rope to make it as airtight as possible.
xiii. Leave it to cool for three to four hours.

Basic application of Biochar

Hydroponic media

Rice husk biochar can be used as a medium for raising seedlings for hydroponic system.

Potting mix

Add a few handfuls to your normal recipe. In general, 20% of the potting mix volume is recommended for biochar application.

Planting seeds

Make hole, add small handful of biochar fertilizer, cover with dirt, place seeds, cover with dirt, and sprinkle a small handful of biochar fertilizer on top.

Planting seedlings or trees

Dig large hole, replace one half of the dirt with biochar fertilizer.

Mechanical field planting and orchards

In an acre of paddy field, mix 800 kg of biochar fertilizer into mud one month before transplanting. In orchard trees, spread 10 kg of biochar fertilizer in shallow trench around tree at the 'drip line', cover with dirt, repeat every 3 months. It helps in sequestration of atmospheric carbon and storing it in soil. Biochar is resistant to decomposition.

Figure 23: Showing Watermelon seedlings raised on 100% rice husk biochar

Precautions

- ✓ Utmost care must be taken while handling fire.
- ✓ Frequent cleaning of equipment increases its life span.
- ✓ Dried straw and husks must be used for easy production.
- ✓ Only waste biomass must be utilized for biochar production.
- ✓ Heat energy generated during the process should be used as much as possible.

Bokashi production

Bokashi is a Japanese term for fermented organic matter. It is produced by converting food waste and similar organic matter into a soil amendment which adds nutrients and improves soil texture. It differs from traditional composting methods in several respects, the most important being that the input matter is fermented by specialist bacteria, not decomposed. This fermented organic fertilizer can work very quickly, effectively and efficiently alone or in combination with chemicals for crop production.

Instead of using large amount of manure or compost, bokashi is sufficient in smaller quantities and acts quickly as a result of the anaerobic fermentation process.

Bokashi preparation

Materials

i. Rice Bran (freshly from mills) 100 kg
ii. Water (60^{o}C hot water is recommended) 20 L
iii. Molasses 1L (or sugar 1 kg + salt 50 g)
iv. Seed yogurt 100 g , dry yeast 20 g, fermented bokashi 100 g, over ripened fruits 200 g (or EM 1 L)

Procedure

i. Prepare (Water + molasses + seed yogurt) mixture
ii. Mix thoroughly with rice bran
iii. Pack in plastic bucket and keep under airtight condition for 1 month

Application of Bokashi

Bokashi for Hydroponics system

Soil is not used in hydroponics system. Bokashi forms an important nutrient source in substrate culture of hydroponics cultivation.

Other Applications

Fertilizer: for basal and top dressing with or without chemicals

Disease control: soil sterilization, manure decomposition, top dressing and furrow application (antagonistic microbe functions)

Pest control: sprinkle bokashi from the top of leaves for army worms (young instars) and hairy caterpillars
Composting agent: use with green manure and compost application for the better and quick decomposition

Bokashi Storage

After fermenting for two weeks, bokashi has to be dried and packed for later use or sale. It should stored in airtight bag and kept away from direct sunlight and low humidity condition and temperature. It can be stored for one year.

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