PACKAGE OF PRACTICES
FOR ORGANIC RNR COMMODITIES

National Centre for Organic Agriculture
National Organic Flagship Programme
Department of Agriculture
Ministry of Agriculture and Forests

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EDITOR

1. Dr. Tayan Raj Gurung, Advisor, DoA
2. Dr. Sonam Tashi, Lecturer, CNR
3. Mr. Mahesh Ghimeray, Rice Specialist, ARDC-Bajo
4. Mr. Lakey, Principal Agriculture Officer, ARED, DoA
5. Mr. Tshetrim La, AO, NOFP-CU, DoA

TECHNICAL CONTRIBUTORS:

1. Mr. Tirtha Bdr. Katwal, PD, NCOA-Yusipang
2. Ms. Kesang Tshomo, PM, NOFP-CU, DoA
3. Mr. Passang Tshering, AO, ARDC-Bajo
4. Mr. Ganga Ram Ghalley, AO, ARDC-Samtenling
5. Mr. Tshering Tobgay, AO, ARDC-Samtenling
6. Ms. Tashii Gyelmo,Sr. HO, NCOA-Yusipang
7. Ms. Tshering Zam, Sr. AO, NCOA-Yusipang
8. Ms. Dawa Dem, HO, NCOA-Yusipang
9. Mr. Norbu, AO, NMC, Wangchutaba
10. Ms. Ganga Maya Rizal, Dy.Chief LO,DoL
11. Mr. Jambay Gyeltshen, PD, NRDCAN, DoL, Bhumthang
12. Mr. Jambay Gyeltshen, LPS, Haa
13. Mr. Sona Darjay, FO, Mongar
14. Mr. Deepak Rai, Specialist, NSC
15. Mr. Tshetrim La, AO, NOFP-CU, DoA
16. Ms. Nima Dolma Tamang, NCOA-Yusipang

ILLUSTRATIONS, LAYOUT AND DESIGN BY:

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

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FOREWARD

The Department of Agriculture is delighted to publish the first edition of package of practices (PoP) for organic RNR Commodities.

Organic Agriculture is a sustainable approach to food production with several positive ecological impacts. It promotes safe foods and reduction of pollutants in the food system, the social well-being and improves the livelihoods of farming communities and resilience in changing climatic conditions. The Bhutanese agriculture system being based on traditional knowledge, agro ecology and natural resources has a potential to adopt the organic agriculture practices as the way of living for the farming communities. Accordingly, the country has a long term vision to make Bhutanese agriculture fully organic and has accorded a high priority towards the development of Organic Agriculture.

Towards the promotion of Organic Agriculture, the government has approved the National Organic Flagship Program (NOFP) with the objective to commercialize the organic production. Therefore, in the current 12thFive Year Plan, development and promotion of organic farming has received the highest priority and there is a strong advocacy and enabling policy support for organic sector development. However, due to lack of proper technologies, innovations and constrained by absence of production protocol for organic RNR commodities, the take-off of organic agriculture has been very slow.

Considering the potential for Bhutan to develop the organic sector and the government's vision to commercialise organic farming, it is very timely that the packages of practices for organic production has been developed to facilitate the organic program. This POP will serve as the tool for organic operators and guide our commercial organic farmers, youths and entrepreneurs in undertaking organic farming. We also hope the contents in this book will serve as a useful source of information and reference to all the readers representing different disciplines.

The Department would like to thank the commodity coordinators and NOFP focal of central agencies under DoA and other Departments of MoAF for their hard work and contributions. Above all, the editor is commended for putting in extra effort in publishing this edition successfully.

Kinlay Tshering (Ms)
DIRECTOR

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ACRONYMS

OA	Organic Agriculture
AMC	Agriculture Machinery Centre
ARDC	Agriculture Research and Development Centre
BOS	Bhutan Organic Standard
BAFRA	Bhutan Agriculture and Food Regulatory Authority
DAMC	Department of Agriculture Marketing and Cooperatives
DoA	Department of Agriculture
DoFPS	Department of Forests and Park Services
DoL	Department of Livestock
Dz.	Dzongkhag (District)
EDP	Economic Development Policy
FAO	Food and Agriculture Organization
FYP	Five Year Plan
ILM	Integrated Landscape Management
LOAS	Local Organic Assurance System
MoAF	Ministry of Agriculture and Forests
MSSB	Minimum Seed Standard of Bhutan
NOFP	National Organic Flagship Program
NOP	National Organic Program
NPHC	National Post Harvest Centre
NPPC	National Plant Production Centre
NRDCAN	National Research and Development Centre for Animal Nutrition
NRCRLF	National Research Centre for Riverine and Lake Fisheries
NSC	National Seed Centre
NSSC	National Soil Service Centre
NWFP	Non-Wood Forest Product
LUC	Land Use Certificate
TBC	Trout Breeding Centre

INTRODUCTION

Organic agriculture is a globally accepted sustainable approach to food production as it generatespositive ecological impacts while promoting socially and economically sound production systems. Therefore, organic movement in Bhutan aligns well with the overarching development philosophy of Gross National Happiness. Bhutan decided to transition to organic farming in 2006 with the formulation of the National Framework for Organic Farming in Bhutan. The Ministry of Agriculture and Forests (MoAF) has ever since been pursuing the vision and aspiration to be organic following commodity and site specific approach in a phase wise manner to provide alternative to conventional farming for enhanced food and income security.

Hence, in an effort to promote organic agriculture as an alternative model responding to social, economic, health, environmental and sustainability concerns, the Royal Government of Bhutan (RGOB) has approved the National Organic Flagship Programme (NOFP) in the 12th FYP with atotal budget of Nu. 1billion.The main objectives of the NOFP are to commercialize the production of potential organic commodities, create access and availability to organic farm-inputs such as seeds, bio-fertilizers, bio-pesticides, feed and fodder by supporting in-country production through Private/PPP/FDI mode. The Flagship Programme will focus on selected commodities within the Land Use Certificate (LUC)programmesandselected dzongkhags linked with the potential export and domestic market.

Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects.Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. Currently there are around 25,667 acres of land under organic crops and livestock management, of which 19,366.9 acres comprise forest land for wild collection of various NWFPs. This organic management area is managed by 2,680 households who have been supported by the National Organic Programme (NOP)through training, provision of inputs, infrastructure, equipment, product development and marketing. The NOP has trained 1,442 farmers and 242 staffs in various fields of organic production till date. Currently there are 24 farmer groups/cooperatives, three retailers and one exporter involved in organic production and marketing. There are three small-scale organic fertilizer production units with annual production capacity of 20MT.

The NOP has launched the Local Organic Assurance System (LOAS) certification system in 2017 for locally produced organic products andhas also collaborated with the National Certification Body (BAFRA) for national certification. Till now, Bhutan has 10 products certified as organic, viz., potato, garlic and carrot from Gasa, turmeric from Zhemgang, sea buckthorn, chamomile andmint from Bumthang, green tea (*Camellia sinensis*) from Trongsa, (Balu) *Rhododendron anthopogon* from Thimphu, and lemongrass from Mongar.

1.1 Principles of Organic Agriculture

Organic Farming has fourprinciples namely:Principleof Health, Principle of Ecology, Principle of Fairness and Principle of Care.

The Principle of Health: Organic Agriculture (OA) should sustain and enhance the health of the soil, plants, animals, human and planet. These components are interconnected and said to be one and indivisible.

The Principle of Ecology: Organic Agriculture (OA) should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

The Principle of Fairness: Organic Agriculture (OA) should build on relationships and ensure fairness with regard to common environment and life opportunities.

The Principle of Care: Organic Agriculture (OA) should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generation and environment.

1.2 NOFP Focus Commodities

The 12 commodities are selected for NOFP for commercialization (Table 1). These commodities were selected based onfour criteria of production approach, scale, objective, means and potentials.

Table 1: The NOFP commodities and market type

Sl. No.	Sector	Commodities for Export Market	Commodities for Domestic market
1	Agriculture	Buckwheat	Asparagus
		Quinoa	Beans
		Ginger	Cauliflower
		Turmeric	Chilli
		Cardamom	
		Mushroom	
2	Livestock	Trout	
3	Non-Wood Forest Product (NWFP)	Lemon Grass Oil	

SECTION ONE:

GENERAL GUIDELINES, REQUIREMENTS AND STANDARDS FOR ORGANIC PRODUCTION AND CERTIFICATION

General Guidelines

All the organic producers/operators are required to fulfill/follow the Bhutan Organic Standard (BOS) in order to becertified as organic producers. The BOS is the norm for organic production, processing, labeling and marketing of agriculture, livestock and NWFP in Bhutan. It will be the basis for use of Bhutan Organic Mark by the Bhutanese organic operators. Some of the key norms of BOSwhich need to be complying by organic operatorsfor certification are as follow:

1. **Agriculture**

- Land preparation by burning the vegetation is not allowed. However, where needed flaming is allowed.
- Use water resources in a sustainable manner by following water conservation techniques.
- Operators should not use synthetic agro-chemical products.
- Appropriate measures should be taken by the operators to identify and avoid potential contamination. This includes barriers and buffer zones, cleaning of equipment and careful selection of farm inputs including water.
- Production of the same crop in organic and conventional plots on the same farm (parallel production) is not allowed.
- Traditional seeds or open pollinated seeds or local planting materials should preferably be used as they are naturally resistant to pests and diseases. (GMOs should not be used.)
- The length of the conversion period should be adapted to local agro-ecological condition, past history of landuse andexperience of the farmers or operators. In general conversion period for annual crops shall be a period of at least 12 months under organic management, and 18 months for perennial crops. However, conversion period may be extended by the confirmatory assessment body based on field assessment and verified with required test.
- Accumulation of heavy metals and other pollutants shouldbe prevented.
- Non-synthetic mineral fertilizers and fertilizers of biological origin shall be regarded as supplementary and not a replacement for nutrient recycling.
- Manures containing night soil (human excreta) and sludges shall not be used for organic farming.
- Plant or animal origin materials degraded through microbial action and/or other natural factors shall form the basis of the fertilization programme along with a

systematic crop rotation scheme.

- Pests, diseases and weeds should be managed by adopting different techniques such as physical, cultural, mechanical and biological practices appropriate to the specific location.
- When pests, diseases and weeds exceed the threshold limits, preparations of local plants, animals and micro-organisms that are prepared at the farm are permitted.
- Active substances that do not appear in BOS are prohibited for use on organic farms.
- Hydroponics and aeroponics systems are prohibited for terrestrial crops in organic farming.

2. **WildCollection**

- Collection of wild products should not threaten the species collected nor destroy the natural habitats of the wild species of plants and animals.
- Wild collection should follow NWFP Harvesting Guidelines and approved Community Forest Management Plan.
- Wild collection shall be from a clearly defined collection area and within the list of species that are permissible by the RGOB.
- The collection area shall be at an appropriate distance from conventional farming areas, pollution and contamination sources.

3. **Animal Husbandry**

- Animals shall be raised organically from birth. When organic livestock is not available, conventional animals may be brought in within themaximum age limits prescribed in BOS.
- Animal products shall be marketed as 'organic' only if the farm or relevant part of it has been under conversion and have been following the organic animal production standards.
- Maintain stocking rates, flock or herd sizes appropriate to the welfare and health of the animals.
- Breeding systems shall be based on breeds that can reproduce successfully under natural conditions.
- Mutilations shall not be done, except in some cases.
- Animals shall be fed 100% organic feed whenever possible.

- Select appropriate breeds or strains of animals suitable to the locality or region.
- The vaccines shall be used when the vaccinations are legally required in the region.Conventional veterinary medicines are allowed when no other justifiable alternative is available, but with increased withholding time.
- Operators shall not withhold medication or vaccination if the sickness could cause the death of animal or if the animal is under risk. Under such circumstance, the animal or animal products shall not be marketed as organic.
- The animals should be subjected to minimum stress during transport and slaughter. Each animal or group of animals shall be identifiable or traceable during all stages of transportation and slaughter.
- Animal shall have access to fresh air, water and feed and shall be handled according to the natural behaviour of the animal.
- Artificial insemination may be practiced on veterinary necessity.

4. **Aquaculture**

- The conversion period of the production unit shall be at least one life cycle of the organism or one year, whichever is shorter.
- Production units must be located at an appropriate minimum distance from contamination sources and conventional aquaculture.
- Operators shall take verifiable and effective measures to minimize the release of nutrients and waste into the aquatic ecosystem.
- Aquatic animal production systems shall use breeds and breeding techniques suited to the region and the production method.
- Aquatic animals shall be fed organic feed. However, if organic feed is of inadequate quantity or quality, operators may feed up to 20% of non-organic feed. Non-organic aquatic animal protein and oil sources must be from independently verified sustainable sources.

5. **Processing, Handling and Storage**

- Care should be taken not to mix non-organic products during processing, handling and storage.
- The integrity of the organic products shall be maintained throughout the whole value chain. The mixing of organic with non-organic products shall be avoided.
- The operator shall have a plan to prevent and control pollutants and contaminants.
- All the ingredients used in organic processing shall be organic in nature. The organic quality of ingredients shall be confirmed by the conformity assessment body before use.

- The microbial preparations and enzymes commonly used in food processing may be used but these microbial cultures shall be grown or multiplied or cultured by using ingredients of organic agriculture origin.
- Solvents used for extraction of organic products shall be either organically produced or food grade substances mentioned in BOS.
- Filtration equipment shall not contain asbestos or utilize techniques or substances that may negatively affect the product.
- Persistent or carcinogenic pesticides and disinfectants are not permitted.
- The packaging materials should be eco-friendly, reusable and recyclable.
- Polyvinyl chloride (PVC) and aluminum should be avoided.
- The label shall provide details of the person or company legally responsible for the production or processing of the product as well as the name of the Conformity Assessment Body.
- Organic label may be used for products wherein a minimum of 95% (wt) of the ingredients are of organic origin. Where the ingredients of organic origin comprise less than 95% but not less than 70% (wt), products may not be called "organic". The word "organic" may be used on the principal display in statements like "made with organic ingredients" provided there is a clear statement of the proportion of the organic ingredients. Where less than 70% of the ingredients are of organic origin, the indication that an ingredient is organic may appear in the ingredients list. Such product may not be called "organic".
- In the percentage calculations of organic ingredients, the water and salt added to the product shall not be included.
- The label for conversion products shall be clearly distinguishable from the label for organic products. Ingredients or products derived from wild production shall be declared as 'products of wild production'.

For details on Standards for Organic farming, refer Bhutan Organic Standard BOS 01:2019 published by the National Organic Programme.

6. Organic Production Approaches

6.1 Integrated Landscape Management (ILM)

Within the integrated mountain farming systems regime, no component of the farming system can be singled out and managed organically or otherwise. In the context of Bhutanese agriculture system, the integrated landscape management approach appropriately provides holistic scope to appreciate large-scale processes in an integrated and multidisciplinary manner, combining natural resource management with environmental and livelihood considerations. This approach protects vital ecosystem services and sustains livelihoods, tackling food security challenges while adapting to the likely future impacts of climate change. The principles of Integrated Landscape Management (ILM) are compatible to that of the organic farming, which considers ecology, health, fairness and care. In the ILM, a contiguous well defined landscape in a geog, dzongkhag, or watershed will be taken up as the ideal scale at which organic farming interventions will be designed and implemented. The entire production landscape, farming systems, other livelihood and enterprises and stakeholders will be targeted for organic farming. A landscape managed organically will facilitate organic certification of land which is fundamental for certification of products produced thereof.

6.2 Community- Based Organic Production

The principles of OA consider health, ecology, fairness and care of all the stakeholders engaged in a production system. Thevalues and ethics are fundamental principles of OA which have to be accepted and adopted at the community level. To ensure the integrity, social ethics and reduce contamination from conventionally produced products, Organic farming interventions require a community approach and should be implemented at the community level. Organic farming interventions have to be acceptable to the communities so that they lead the programmes. Community- based production will also help in generating the scale for market.

6.3 Crop Rotation

Crop rotation can be followed/practiced as one of the cultural tools to reduce pests and disease incidences as well as to increase the fertility of the soil when the rotation is done with leguminous crops as one of the components. For instance, rotating ground nut with maize will reduce the attack of white grub. Rotating pigeon pea or chick pea

with non-leguminous crop is a good practice. Crop rotation should follow the following principle: heavy feeder crops with light feeder; leafy crops with root/fruit crops; and no two crops from the same family.

6.4 Cover crops

In conjunction with crop rotation, cover cropping is central to organic farming. Cover crop not only arrest soil loss, erosion and degradation, but also helps in conserving soil moisture and modifying microclimates. Cover crops may be done with both leguminous and non-leguminous plants, including wheat and buckwheat.

SECTION TWO:

PACKAGE OF ORGANIC PRACTICES FOR AGRICULTURE, COMMODITIES

1. BUCKWHEAT

(*Fagopyrum esculentum*)

Introduction

Buckwheat (*Fagopyrum esculentum*) or common buckwheat is cultivated for its grain and as cover crop. Two species of buckwheat cultivated in Bhutan are *Fagopyrum esculentum* (sweet buckwheat) and *Fagopyrumtataricum* (bitter buckwheat). Buckwheat belongs to the family Polygonaceae.It is grown as a rainfed crop. Plants usually produce only pin flowers (short stamens with a long style) or thrum flowers(long stamens and a short style) and hence cross-pollination is predominant.

Land Requirement

Buckwheat is grown in both *Kamzhing* and *Chhuzhing*. It prefers well- drained sandy soil. Selection of field is very critical in organic buckwheat cultivation. Field with prior usage of inorganic fertilizers and pesticides should be avoided. In case, such fields are used, it should undergo conversion period of at least 12 months. If organic buckwheat is grown near a conventional fieldthen a buffer zone of appropriate distance should be maintained to avoid contamination.

Cropping System

Cultivation of buckwheat extends from humid to cool temperate agro-ecological zones. It is mostly cultivated in areas above 2,500 masl along with barley, wheat, mustard and potatoes. It is mainly grown in rotation with potato, maize, wheat, barley, mustard, rice and millets depending on the elevations. The different cropping patterns recommended are given in Table 2.

Table 2: Recommended crop rotation (1 year)

Agro- ecological Zone	Altitude (masl)	Cropping patterns
Cool temperate	2500- 3600	Wheat-buckwheat Bitter buckwheat-Fallow
Warm temperate	1800- 2500	Wheat-Sweet buckwheat
Dry subtropical	1200- 1800	Maize-Bitter buckwheat Maize- Sweet buckwheat Wheat-Bitter buckwheat Wheat-Sweet buckwheat Rice-Sweet buckwheat Sweet buckwheat-Quinoa
Humid Subtropical	600- 1200	Maize-Bitter buckwheat Maize-Sweet buckwheat Sweet buckwheat-Quinoa Rice-Sweet buckwheat
Wet Subtropical	150- 600	Maize-Bitter buckwheat Maize-Sweet buckwheat Sweet buckwheat-Quinoa

Varieties

In Bhutan only two indigenous varieties are cultivated.

i. Sweet buckwheat (*F. esculentum*)
ii. Bitter buckwheat (*F. tataricum*)

Seed

For organic buckwheat production we have to start with organic seed. Farmers can save their own seed for next season by selecting and processing seed from good fields. Farmers can also source organic buckwheat seed from organic farmers, National Seed Centre (NSC) or any authorized/ certified organic seed producers. Recommended seed rate is 16-21 kg/acre.

Sowing Time

Buckwheat is cultivated as summer and autumn crop. The summer crop is sown from March tillJuly and harvested in July till Novemberdepending on different agro–ecological zoneswhile the autumn crop is sown in August and harvested in December. The recommended sowing time for different agro-ecological zones is given in Table 3.

Table 3: Recommended sowing time

Agro- Ecological zone	Type	Seasons	Land use
Cool Temperate	Sweet buckwheat	July- November	*Kamzhing*
	Bitter buckwheat	March- July	*Kamzhing*
Warm Temperate	Sweet buckwheat	July- November	*Kamzhing*
	Bitter buckwheat	July- November	*Kamzhing*
Dry Subtropical	Sweet buckwheat	July- November	*Kamzhing*
		November- February	*Chhuzhing*
Humid subtropical	Bitter buckwheat	August- December	*Kamzhing*
	Sweet buckwheat	August- December	*Kamzhing*
		November- February	*Chhuzhing*
Wet subtropical	Bitter buckwheat	August- December	*Kamzhing*
	Sweet buckwheat	August- December	*Kamzhing*
	Bitter buckwheat	August-December	*Kamzhing*

Sowing Method

Broadcasting is the most prevalent method of seed sowing in buckwheat. The recommended sowing depth is 4-6 cm with a plant to plant spacing of 10 cm, which can be maintained by thinning.Foreasy weed management and intercultural operations, line sowing is recommended with a spacing of 50 cm between rows and 20 cm between plants.

Field preparation

Buckwheat grows well on light to mediumtextured soil which is neither compact nor too coarse or sandy. It requires a well-drained and levelled seed bed in order to avoid water logging. Twotimes ploughing followed by levelling is necessary for good field preparation.

Soil Fertility Management

Buckwheat is mainly grown as a second crop after the harvest of first crop without much additional manures and fertilizers. To obtain good yield,it is recommended to apply adequate amounts of farmyard manure (FYM) and other biomanures. Excessive use of nitrogen based bio-manure can lead to crop lodging.

Water Management

Buckwheat is predominantly grown as a rainfed crop.

Pest and Disease Management

The incidence of pests and diseases in buckwheat is not common. However, aphids, cutworms and fungal disease like powdery mildew can sometimes damage the crop. Use of diseasefree seeds, good field preparationand good soil fertility management can minimize the incidence of pests and diseases.

Weed Management

For effective weed control, at least one weeding and hoeing at 20-25 days after sowing is helpful. Weeding during the initial period is very crucial to minimize yield loss.

Post Harvest Management

Buckwheat is very susceptible to seed shattering and hence right time of harvesting is important to reduce loss.

- Buckwheat should be harvested when it attains 70-75% of physiological maturity.
- When the crop reaches physiological maturity stemcolour turns brown.
- After harvest the crop should be properly dried for threshing.
- Cleaning and winnowing should be done to separate the grains from unwanted materials.
- After cleaning the grains must be stored at low temperature and dry condition.
- The safe moisture content for storage is less than 16%.
- Storing of buckwheat seeds for long period is usually not recommended due to its susceptibility to rancidity.

2. QUINOA

(*Chenopodium quinoa Wild*)

Introduction

Quinoa (*Chenopodium quinoa* Wild) is an annual herbaceous plant and belongs to the family Amaranthaceae. It is a dicotyledonous, erect plantwith a height ranging from 100–300 cm. It is mainly grown for its nutritious grains, but its leaves and tender shoots are also used as vegetables. This cereal is predominantly self-pollinated, but there is also 10-15% cross-pollination. Quinoa was introduced to Bhutan from Peru in 2015 by the Department of Agriculture (DoA) and is rapidly being promoted in different agro-ecological zones. Quinoa is locally called as Royal Quinoa in English, AshiHeychum in Dzongkha, Ashi Mo in Sharshop and Rani Bethu in Lhotsham.

Land Requirement

Quinoa is a versatile crop which can adapt to adverse climate and soil conditions. It is cultivated in dryland as a rainfed crop. Choice of land is important to produce high quality organic quinoa grains.For itsproduction, use of land where inorganic fertilizers and pesticides have been applied should be avoided. In case such fields have to be used, it should undergo a conversion period of at least 12 months. If organic quinoa is cultivated near any conventional fields then a buffer zone ofan appropriate distance has to be maintained to avoid contamination.

Cropping System

For organic quinoa production, it is important to follow crop rotation which will help in soil fertility, pests, diseases, and weed management. A good crop rotation will also contribute to the principles of organic agriculture. The potential one-year and two-year crop rotation are summarized in Table 4.

Table 4: Recommended one- year crop rotation for quinoa

Agro-ecological Zones	Altitude (masl)	Land Use Types	
		Kamzing	***Chhuzhing***
Cool Temperate	2600-3600	Barley/Wheat-Quinoa, Fallow-Quinoa	NA
Warm Temperate	1800-2600	Wheat/Barley-Quinoa Vegetables-Quinoa Potato-Quinoa	NA
Dry Sub tropical	1200-1800	Potato-Quinoa Maize-Quinoa Legumes-Quinoa Vegetables-Quinoa Buckwheat-Quinoa	NA
Humid Sub tropical	600-1200	Maize-Quinoa Millet-Quinoa Vegetables-Quinoa Buckwheat-Quinoa	Rice - Quinoa
Wet Sub tropical	150-600	Maize-Quinoa Millet-Quinoa Vegetables-Quinoa Buckwheat-Quinoa	Rice – Quinoa

The recommended two-year crop rotations for quinoa are:

- Vegetable and Quinoa
- Quinoa and Ginger
- Buckwheat and Quinoa
- Legumes and Quinoa

Varieties

There are four released varieties recommended for cultivation in Bhutan.

Table 5: Recommended quinoa varieties

Variety	Local Name	Maturity (Days)	Grain Colour	Potential Yield (kg/ acre)
Amarilla Marangani	AshiHeychum- AM	173	Yellow	750
Amarilla Saccaca	AshiHeychum- AS	170	Yellow	900
Ivory 123	AshiHeychum- 123	150	Brown-ish	900
DoA-1-PMB-2015	AshiHeychum- TW	140	Brown-ish	750

Seed

For organic quinoa production we have to start with organic seed. Farmers can save their own seeds for next season by selecting and processing seed from good plants. The grains should be properly dried without exposing to direct sunlight. The seed must be stored in clean and dry environment at low temperature and relative humidity. The safe moisture content for storage is less than 10%.Farmers can also source organic quinoa seed from National Seed Centre (NSC) or any authorized/ certified organic seed producers. The recommended seed rate for quinoa is 2 kg per acre.

Sowing Time

The time of sowing is very critical for successful crop production. Sowing time also depends on specific location. The general sowing time for different agro-ecological zones is presented in Table 6.

Table 6: Agro-ecological zones and sowing time for quinoa

Altitude(masl)	Agro-ecological Zones	Sowing Time
Above 2600 -3600	Cool Temperate	End April- Mid May
1800 -2600	Warm Temperate	Mid April- Mid July
1200 -1800	Dry Subtropical	Mid July-Mid September
Below 1200	Warm Subtropical, Dry Subtropical Wet Subtropical, Humid Subtropical	October- Mid November

Field Preparation

Quinoa requires a levelled field and well-drained seedbed in order to avoid water logging. It prefers neutral soil, althoughit can be grown on alkaline (up to pH 9) and acidic soils t (up to pH 4.5). When power-tiller is used for field preparation, first ploughing followed by soil pulverization with rotavator is sufficient. If bullocks are used for field preparation at least two times ploughing followed by levelling with locally made levelleris very important to prepare a good seed bed.

Sowing Method

Seed sowing is very critical in quinoa. Emergence of seedlings, plant density and final yield depends on the correct seed sowing. Superficial or very shallow sowing poses the risk of seed dehydration or burning by solar radiation and seed picking by birds. Deep sowing can prevent germination due to restricted growth. The sowing depth should be 1-3 cm. Quinoa seed can be broadcasted but line sowing is recommended for easy weed management and other intercultural operations. The recommended spacing between the rows is 50-60 cm and the plant to plant spacing should be maintained at 10 to 15 cm. The seeds germinate within 24 hours and seedlings emerge in 3 to 5 days. To maintain good plant population with proper spacing, thinning should be done when the seedlings attain 10 to 15 cm height.

Soil Fertility Management

Quinoa is generally grown in marginal soil. Use of sufficient quantity of farmyard manure (FYM) ensures higher grain yield. The recommended FYM is 3 to 5MTper acre.Quinoa crop requires high nitrogen for growth and development, so application of cow urine is beneficial. Green manuring with *Sesbaniaaaculeata* for drysubtropical, humid subtropical and wetsubtropical agro-ecological zones also improves soil fertility. To supplement the nutrient requirement of quinoa, other bio-manures like bio-slurry compost, chicken manure and vermi-compost can also be used in adequate amount as recommended by the National Soil Services Centre (NSSC). Suitable legumes such as peas and soybeans as cover crops before the main crop can also be used.

Water Management

Though quinoa is a rainfed crop, provision of one to two times irrigation at flowering and grain fillingis important to obtain good yield. Quinoa does not tolerate water logging and hence proper field drainage is very important.

Pest and Disease Management

The major insects that attack quinoa crop are leafminer (*Bedellia somnulentella*) and aphid (*Myzuspersicae*). These insects have to be managed through organic pest management practices which include cultural practices and use of bio-pesticides. Farmers can adopt the following cultural practices and use bio-pesticides to reduce crop damage**.**

- Crop rotation -Follow recommended crop rotations to reduce the buildup of pests and diseases.
- Trap crops-Use of trap crops like mustard for aphids and marigold for adult leaf miner will reduce the crop damage.
- Neem Oil Spray-Neem oil is a good insect repellent and anti-feedant. It is effective on a variety of crops. Neem Oil spray can be prepared as follows:
  - ✓ Mix 3L of neem oil in 100 L of water and stir well.
  - ✓ Add 100 g of local (Nepal sabun) soap into the solution.
  - ✓ Spray the solution in the evening hours.

Weed Management

Quinoa seed growth is very slow during the first two weeks during which weed pressure can severely affect the crop. For good crop growth and weed management,two to three times weeding with light hoeing using hand tools like spade is recommended. Rotary weeder can also be used when the seeds are sown in line. Organic mulches can also be used in line sowing.

Post Harvest Management

- Quinoa should be harvested when it reaches physiological maturity.
- The physiological maturity of quinoa is indicated by hard, dry grains and the moisture content at this stage will be about 15%.
- When the crop is matured, leaves turn yellow or red, depending on the variety.
- The appearance of grains on the panicle is also an indication of physiological maturity.
- Quinoa is very susceptible to pre-harvest seed germination and hence rain should be avoided during harvest.
- Immediately after harvest, curing should be done for at least 15 days. Curing can be done through sun drying or by hanging the bundles in the shade.

- After curing threshing can be done manually by beating with sticks to separate the grains.
- Winnowing is done to separate and clean the grains from bran and other unwanted materials.
- Cleaned seeds must be stored in clean and dry environment at a low temperature and relative humidity. The safe moisture content for storage is less than 10%.

3. ASPARAGUS

(*Asparagus officinalis*)

Introduction

Asparagus (*Asparagus officinalis*) belongs to family Liliaceae. Cultivated variety of asparagus was first introduced into Bhutan in 1971. It is a perennial vegetable, either erect (Mary Washington) or climbing (Bhutan's wild asparagus). Asparagus plants can be either male or female. Males are higher yielding than females and are identifiable only after one year. It has economic lifespan of 15 years and is grown for its shoots (spears). Asparagus is nutritionally well- balanced vegetable and high value crop with fewer incidences of pests and diseases. Asparagus has been promoted as major commodity under organic cultivation. This chapter will discuss the organic management aspects of asparagus.

Common practices such as burning the ferns after harvest should not be practiced in organic farming. Further, growing asparagus under apple plantation which is not under organic cultivation should be avoided.

Varieties

Proper varieties should be selected to limit weeds and pathogen problem. Mary Washington and UC-157 are the released asparagus varieties in Bhutan. However, Mary Washington is the most cultivated openpollinated variety among the two. Locally available wild asparagus is adapted to the local conditions and are resilient to adverse conditions of climate change.

Land Requirement

- The certified organic farm should have adequate buffer zone with a non-organic farm.
- The field history should be known. In case, the crop was grown in conventional farming practices, it requires a minimum conversion period of 18 months.

Sandy loam or alluvial soil, deep, rich, friable, well-drained with high fertility and an optimum pH of 6.0 to 6.7 is required. A sunny plot sheltered from strong windsuits best for the cultivation.

Climate and Ecology

Asparagus is well adapted in temperate regions and in the hills (from 1000 masl to 3000 masl) where freezing temperatures and drought terminate plant growth and provide rest period. It requires a temperature range of 16-24°C for most of the growing season. It can tolerate some shade, but full sun produces more vigorous plants and helps minimize disease.

Seeds, Planting Material Standards and Source

Asparagus can be propagated sexually from seeds and vegetatively from crowns/ seedlings. Seedling rate is approximately 10,000 to 12,000 seedlings per acre. Use certified organic seeds. Asparagus crowns are available from the National Seed Centre (NSC) at Paro and other certified organic seed and seedling producers. The seedlings should meet the following standards:

- The seedling should be 12 to 18 months old.
- Should be at least 1ftin height above ground with 4-6 stems.
- Should have well developed root system (crown with several large and wellformed buds) without any spot or off-color blemishes.
- The seedlings should not show any evidence of freezeinjury, serious mechanical damage or pest and disease infestation.
- Seedlings roots and crown should not be dry.

Seed Treatment

Seed treatment is widely practiced to protect the crop from seed-borne, soil-borne, fungal and bacterial diseases. Under organic farming, measures such as the use of diseasefree seeds, the use of resistant varieties, frequent rotation with non-host crops, and intercropping with nonhost or tolerant or repellent crops are recommended. Only under circumstances where the above practice cannot be adopted or have no significant effect, the following methods of indigenous seed treatment may be followed:

- Hot water treatment of the seeds at a temperature of 50°C for 20 minutes.
- 250g of turmeric powder in 1 L of water for 10kg seeds against fungal rot and wilt diseases.
- 250g garlic cloves in 1 L of mineral oil kept overnight can treat 20kg of seeds.
- Dilute 1 part cow urine in 5 parts water; soak the seeds for 15 minutes and sun-dry against soil- borne diseases and better germination.

- Treat seeds with 10g finely powdered wood ash in 500L water, sun-dry and sow the seeds. This helps in reducing seedling rot.

Agronomic Practices

Soil Preparation

Soil solarization can be practiced to prevent incidence of pathogen infestation. Pre-irrigation is necessary for deep ploughing of the land. Plough as deep as possible and pulverize the soil into fine tilth.

Nursery Preparation

Prepare raised beds of 1m width and convenient length by incorporating plenty of well -decomposed farmyard manure (FYM). Sow 0.5 kg of seed per 500m^2 of seedbed, to produce 12,500 crowns enough for 1 acreafter plant selection. The seeds are sown in rows of 15 to 22 cm apart and 1- 2 cm away from each other and at a depth of 2.3 cm. They are thinned to a spacing of 5 cm. Sowing time is March to April. Beds must be kept moist for at least a week. The seedlings are allowed to grow for one year in the nursery bed and are then planted at the permanent site. Seeds take 5 to 6 weeks to germinate. Keep the nursery beds free of weeds.

Trenching

A 45 cm wide and 45 cm deep trench should be dug up. The trenches should be 1-1.25 m apart. On slopes, it is advisable to make trenches horizontally along the slope depending on the steepness. Trenches should be filled with well-decomposed compost or FYM and thoroughly mixed with the top soil.

Transplanting

One year old seedling or crown should be planted from March to July. Plants which are uniform, disease free and have a good growth and branching should be selected. Single row planting is recommended with plant to plant distance of 45 cm and row to row distance of 75 cm. While transplanting the top soil and FYM mixture is put to the base of the plant and the base soil is put on the top. The crown roots should be spread well (Figure1). Irrigate immediately after planting. During the rainy season, earthing up should be done. By the end of the rainy season, the trench will be filled and the ground should be levelled again.

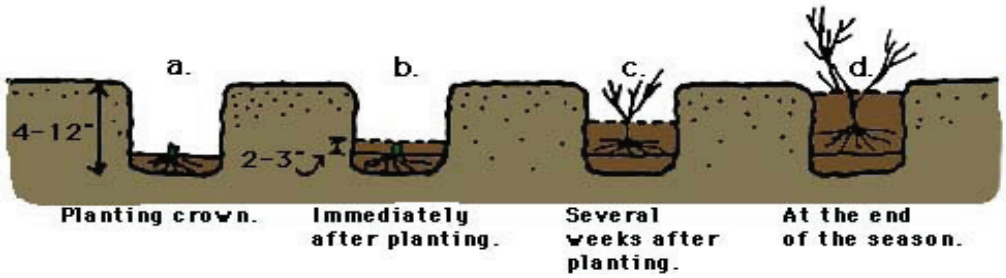

Figure 1: Asparagus crown growth.

Soil Management

Intercropping

Intercropping is done for the protection, enrichment of the soil and to diversify economic returns from the field. Bush bean and peas can be grown as a companion as it requires small space and fixes nitrogen in the soil. Tomato can also be used provided the crowns are not disturbed. The tomato plant repels some of the asparagus pests like beetles. Meanwhile, asparagus may repel some harmful root nematodes that affect tomato plants.

Organic Manure Application

A preliminary soil tests is required before planting the crop. Asparagus has high nutrient demand. Generous quantities of organic manures such as farmyard manure (FYM), compost, leaf mould, kitchen waste compost, bio-char, vermi-compost, jholmol and effective microorganisms could be used. In the first year, apply approximately 3-5 MTof FYM per acre in the trenches and mix with top soil and fill up the trenches. From second year provide 500 kg of FYM in the month of March-April followed by weeding and earthing up. Another 500 kg can be provided when earthing up is done after the removal of dried- up ferns in September/October. Mulching crowns with well decomposed manure should be done to protect them from frost.

Irrigation

- The water sources used for irrigation should be free of contaminants.
- Irrigation should be provided every two weeks, if not 50 mm of water should be supplied in the absence of rain.
- After the root system has been established, irrigation is needed only during extreme drought.

- Critical period of irrigation for asparagus is during spear and fern growth.
- During harvesting, 50 to 75 mm of water may be applied every 3 to 4 weeks if there is no rain. During the wet season ensure adequate drainage.
- Water harvesting tank can ensure adequate water during dry season.

Pests and DiseaseManagement

Prevention

Use of disease resistant varietiesand preventintroduction of weeds and disease infested tools in the farm. Asparagus plantation in previously cultivated area should not be practiced.

Table 7:Asparagus pests anddiseasessymptoms and management

Insect/Diseases	Symptoms	Management/ Control
Asparagus aphid	-The aphid feeds only on the fern. -Wrinkled and stunted growth of the plants.	-Spray soap solution or homemade 'garlic– chilli' concoction. -Removal of host debris after harvest. -Encourage the growth of repellent plants such as onion and garlic. -Use yellow colored traps. -Practice rotations with non-host crops. -Remove asparagus fern in late fall after it has dried. -Follow cultural practices to conserve natural enemies, e.g. parasitic wasps and predatory coccinellids.
Asparagus beetle	-Adults feed on the asparagus shoots. -The larvae feed on the leaves and stems.	-Good cultural practices. -Timely harvest practice to reduce and minimize the number of beetles that hatch in the spring.

Cutworm(*Agrotisipsilon*)	-Cut off asparagus spears below ground and even cause damage by feeding on the tips of spears above ground.	-Use well decomposed organic manure. -Plough the field multiple times for exposure to sun and natural predation. -Hand pick the larvae by digging 5-10 cm around the infested plants. -Trap crops – sunflower. -Neem oil spray/drenching in root region and applying garlic-chilli-ginger extract, ash or liquid manure can minimize the pest incidence.
Fusarium wilt/ crown rot	-Weak spindly spears in spring. Shoots exhibit yellow colouration and vascular discolouring. -Shoots may have *Fusarium* lesions near the soil line. Roots are rotten and discoloured (red violet colour).	-Use disease free planting materials. -Use areas with no history of this disease. -Proper irrigation practices with good drainage system.

Weed Management Practices

- Perennial weeds should be completely removed before planting the crown or seeds.
- After establishment the critical period to start weeding is when the spears start to grow through to harvest.
- Hand weed and pulverize the soil.
- Mulch with organic materials (straw, bark, and compost material).
- Intercropping, proper tillage, field sanitation and water management will also help reduce weed growth.

Post Harvest Management and Handling Operation

Maturity Indices

- Harvest when the spears are dark green and firm with tightly closed and compact tips.
- Stems are straight, tender and glossy in appearance. Spears with green butts are preferred over white butts.
- Typically, spears are cut when they reach 8-10 inches.

Harvesting Time

- Spears are harvested when temperature is cool (early morning or evening).

Harvesting Method

- The new asparagus crop is not harvested until the 3rd year (2nd year after planting the crowns in the productive field).
- Harvest time in general is from April to August. The spears are harvested manually using a cutting tool (sharp knife/hacksaw knife or sickle). The spears must be held gently with one hand and with other hand tilt the knife at 45 degrees to the soil surface and cut the spears at ground level or 2 inches below the soil surface. Cutting below the surface may damage spears that have not yet emerged, but leaves a woody base that may restrict water loss and slow the entry of decay organisms. Average yield is 0.5 to 1 tonne/acre.

Sorting and Grading

Freshly cut asparagus spears should be washed to remove soil particles before sorting and grading. Pre-sorting is usually done to eliminate injured, decaying, or otherwise defective produce (culls) before cooling or additional handling. `The spears should be graded according to the requirements of the client using tenderness, color and size (length and diameter of the stem) as grading parameters. Grading should be performed under cool environment to prevent deterioration of spears due to heat.

Packaging

Graded spears are either packed loose or bundled into unit weight of one kilogram. The spears are placed upright in the plastic crate with damp peat moss or blotter paper. This kind of packaging is suitable for temporary halt and transportation to nearby markets.

However, for long distance transportation and market spears, primary packaging is done by unit sizing spears into 1 kg bundle and wrapped with shrink wrapper. Further eight

such bundles are placed in corrugated fiber board boxes and transported immediately.

Storage

Asparagus can be kept for 3 weeks at 4-15 °C. It is subjected to chilling injury below 4°C for more than 10 days. Temperatures above 15°C desiccate and deteriorate the spears. The relative humidity should be maintained at 85 to 90% to prevent shrinkage. The asparagus butt or cut end can be kept on wet pads to maintain constant supply of moisture. Keeping spears in pan of cold water for too long may cause nutrient leaching or microbial infection.

Maintenance

From November to December when ferns turn yellow, cut ferns to ground level leaving a stump of 5cm. Following February to March raise soil (ridge) around crowns. Before harvest create mounds over plants of 10 cm high and 20 cm wide.

Seed Saving and Storage

To save seeds it can be selected from the healthy, disease freefemale plant. Asparagus fruit is called berry and turns red as it matures. It contains 3 to 6 seeds in a berry. Seeds are 3 mm in diameter, rounded base, flattened on one side and black in color. Matured, dried seeds should be stored in a cool, dark place. It can also be propagated from crowns. Crowns can be stored at 4ºC at 85 - 90% humidity in cool place protected from the sun.

4. BEAN

(*Phaseolus vulgaris*)

Introduction

Common bean (*Phaseolus vulgaris*) belongs to family Leguminosae. Its immature pods are consumed in cooked form or salad. Dried seeds are used for making soup.It is important crop in climate smart farming as it recycles nutrient by fixing atmospheric nitrogen into the soil with the help of rhizobia.

Varieties

Top Crop, Pole bean and Borlotto (determinate and indeterminate) are common released varieties in Bhutan. However, there are numerous locally available varieties with the farmers.

Land Requirement

The area for cultivation should be certified organic farm. It should be selected based on the suitability of the crop as well as taking into consideration the previous crop history and possible sources of contamination. In case, the crop is grown in field where conventional farming practices prevailed, it requires a conversion period of 12 months. If cultivation is done near conventional farms, a buffer zone of appropriate distance should be maintained.

Beans grow well in a wide range of well-drained, alluvial and friable soil. Sandy loam soil is more appropriate for early (February) planting but clay loam soil is suitable if it's planted from August onwards. It requires slightly acidic pH range of 5.5-6.0. Before cultivationsoil testingshould be carried out.

Climate and Ecology

Beans cannot tolerate frost and arealso sensitive to high temperatures and rainfall. Generally, it can be grown up to 3,000 masl. It thrives well in temperatures between 15-25ºC. Hot (>32ºC) and dry environment causes the flower and young pods to drop.

Cropping System

Bean- maize based cropping system is common in Bhutan. However, beans can be grown with any other heavy feeder vegetables and spices. Planting with other legumes should be avoided.

Seeds

Seed rate and spacing depends on variety and plant canopy. Seed rate is about 16-20 kg per acre for pole type and 32-35 kg per acre for bush type. Organically certified seeds of top crop, pole bean and Borlottoare available from the National Seed Centre (NSC) at Paro. It can also be sourced from any other certified organic seed producer.

Seed Treatment

Seed treatment is widely practiced to protect the crop from seed-borne, soil-borne fungal and bacterial diseases. Under organic farming, measures such as the use of disease-free seeds, the use of resistant varieties, frequent rotation with non-host crops and intercropping with non-host or tolerant or repellent crops are recommended. Only under circumstances where the above practice cannot be adopted or have no significant effect, the following methods of indigenous seed treatment may be followed:

- Hot water treatment of the seeds at a temperature of 50^{o}C for 20 minutes.
- 250g of turmeric powder in 1 L of water for 10kg seeds against fungal rot and wilt diseases.
- 250g garlic cloves in 1 L of mineral oil kept overnight can treat 20kg of seeds.
- Dilute 1 part cow urine in 5 parts water; soak the seeds for 15 minutes and sun-dry against soil-borne diseases and better germination.
- Treat seeds with 10g finely powdered wood ash in 500L water, sun-dry and sow the seeds. This helps in reducing seedling rot.

Planting Season

Planting season differs based on altitude. In low hills (<800 masl) beans are sown from August-September and in mid hills (800-1,500 masl), beans can be sown in two different seasons i.e., from February-April and August-September. In high altitude (1,500-2,100 masl), it is sown from March-May.

Agronomic Practices

Soil Preparation

Requires 2-3 times deep ploughing each followed by planking and pre-sowing irrigation is essential. Making raised bed in heavy soil is recommended for rainy season cultivation. For indeterminate or pole bean, raised bed is suitable option for

both wet and dry season cultivation. Pit planting is suitable in the hills as it ensures efficient utilization of nutrients and helps minimize soil disturbance. A 20-25 cm deep pit can accommodate 0.5 kg of compost. Minimum tillage can also reduce soil erosion, conserve moisture and reduce labor requirements.

Seed Sowing

Line sowing is recommended as it has low seed requirement, easy for intercultural operations and harvesting. However, it is impractical in the mixed or relay cropping. For the pole bean, make a bed width of 120 cm with 30 cm furrows in between. Recommended row and plant distance are 100 cm by 15 cm for pole beans and 40 cm by 10 cm for bush beans. Sow 2-3 seeds in each mound at a depth of 5–7 cm. Provide mulching after sowing, leaving open space for emergence.

Thinning and Staking

Keep just one healthy seedling per mound by thinning out the weak seedling at two true leaf stage. Staking gives better yield in the case of pole bean and it has to be completed before vine development.

Soil Management

Organic Manure Application

Application of 800 kg of farmyard manure (FYM)/compost and 320 kg of vermi-compost per acre is recommended. Use of cow urine also enriches FYM and compost. Spread the compost in sun to dry and in the evening spray cow urine at 20L per tonneof compost. Leave overnight and apply it next day. Acidic soil can be improved by application of organic mulches while pine needle is recommended to reduce soil pH in alkaline soils.

Irrigation

Bean is sensitive to both excess water and water stress conditions. Water stagnation in the field for 6-7 hours is detrimental to bean plants. The critical time for irrigation is during pre-blooming, flowering and pod-filling stages. Irrigation water coming from the inorganic sources should be avoided. Surface irrigation should be provided through furrows or with a watering pipe. Mulching is used to reduce evaporation. Water harvesting ponds can be built to collect water for dry seasons.

Pest and Diseases Management Prevention

Use tolerant varieties and prevent introduction of weeds and disease infested tools in the farm . Areas where legumes were previously grown should be avoided. Adjustment of sowing time can be practiced to skip high pest and disease incidences. Some specific pest and disease management measures are listed in Table 8.

Table 8: Bean pest and disease symptoms and management

Insect/Diseases	Symptoms	Management/ Control
Aphid	-Wrinkled and stunted leaves. -Yellowing & browning of the leaves.	-Conserve natural enemies (parasitic wasps and predatory coccinellids). -Soap solution or homemade 'garlic–chilli' concoction. -Use black plastic mulch. -Field sanitation - remove host debris. -Repellent plants - onions and garlic. -Yellow colored traps. -Rotations with non-host crops. -Neem spray.
Pod Borer	-Bore holes in the pod and forages on the seeds inside. -Makes white silky cocoons on the leaves, pods and flower buds.	-Hand picking and destruction of eggs. -Deep summer ploughing. -Collection and destruction of infected plants and removal of alternate host and weeds. -Spray neem based (*Azadirachtin*) insecticides.

Anthracnose	-Small, reddish brown, slightly sunken spots on the pods and develop into large, dark-sunken lesions. -In wet weather, masses of pink spores develop on these lesions.	-Use disease free seeds. -Crop rotation-do not plant beans in areas with this disease for at least 2 years. -Mulching to avoid water splash during rainy season that help transmit the disease. -Wide spacing to reduce disease incidence. -Do not reuse staking materials from the infected field.
Bean rust	-Minute red pustules appear at the early stage and later become distinct, yellowish and circular on both sides of the leaves and pods. -Brown powdery substance in case of severe infection.	-Collect plant debris and bury them in a deep pit. -Avoid late sowing. -Do not reuse staking materials from the infected field.

Weed Management

Two to three rounds of weeding is recommended during the growing season. Proper field sanitation, tillage, intercropping, mulching withorganic mulches such as straw, bark and compost material will help reduce weed pressure and growth.

PostHarvest Management

Maturity Indices

The bean pod must be harvested when it reaches the desired marketable size or when the pod is green, fleshy, tender, and easily break or snap when broken apart by the hand.

Harvesting Time

Harvest early in the morning to take advantage of the cool temperature when the morning dew is off and the plant is thoroughly dry.

Harvesting

The pods are best harvested manually using a cutting tool (such as a pair of scissors or shears). The pod must be held by hand and cut off from the plant. Harvested pods must be directly placed in a collection container for transporting to a collection point.

Sorting and Grading

It is recommended that where possible, beans are sorted at the farm in order to remove low quality (diseased) or damaged (insect or ratdamaged beans). Sorting must be done in a shaded area away from the sun. A temporary shed/shelter or the shade of a tree near the harvest area can serve the purpose of providing shade. Grading is based on colour and length of the pod.

Packaging

Clean stackable plastic crates and bamboo baskets lined with soft cushioning material are best for bulk packaging. While packing, leave some space at the top of the crate for air circulation.

Storage

Beans are sensitive to temperature range of 5-10°C; hence they have to be stored at the optimum temperature range of 10-15°C and relative humidity of 85-90%. In the absence of a refrigerated storage system, a simple, low cost evaporative cooler can be used to maintain the freshness for about 4-7 days.

Transportation

Provision of space for air circulation and protection from rain and sun is important. Transporting the beans during the coldest part of the day is recommended.

Seed Saving and Storage

Farmers should select seed from healthy, true-to-type plants with marketable attributes. Bean seeds should be stored in a tightly sealed glass jar or other container away from direct sunlight. Different varieties of beans may be stored together but wrapped in individual paper packages and clearly labelled with their name, variety and collection date. It should be stored in cool and dry place at 0-5^{o}C.

5. CAULIFLOWER

(*Brassica oleracea var.botrytis*)

Background

Cauliflower (*Brassica oleracea* var *botrytis*) belongs to the mustard (Brassicaceae) family. The organic management aspects of cauliflower will be dealt in this chapter mainly for substituting the import ban.

Land Requirement

Land should be selected based on the suitability of the crop as well as taking into consideration the previous crop history and possible sources of contamination. In case, of conventional farming practices, a conversion period of 12 months will have to be observed. Once selected, the organic plots need to be maintained as organic at all times.

Cole crops can be grown on a variety of soils but does best on a well-drained, loamy soil well supplied with plenty of organic matter. Select land where crops of the brassica family are not grown in the previous years.The optimum pH for the crop is between 6-6.8; it is sensitive to high acidity. Liming of the soil is recommended for soils having pH below 5.5.

Cropping System

Follow crop rotation with legumes and non-host crops. Some options for the cauliflower-based cropping system can be cauliflower-legume and cauliflower-quinoa/buckwheat. Cauliflower-wheat/barley system or chilli-cauliflower or cauliflower-bean/soyabean based cropping system can also be adopted.

Available Varieties and Seed Source

Certified organic seeds should be used. If not available, open pollinated or traditional varieties should be sourced from organic or natural farming without contaminants. Use of hybrid seeds is not encouraged. Permission may be sought from the certifiers to use other seed sources if organic seeds are not available. The Open Pollinated Varieties, Wengkhar Meto Kopi 1 and 2 are also available (Table 9). Organic seeds may be sourced from the National Seed Centre (NSC) or other registered and authorized private seed growers.

Table 9: Available cauliflower varieties and their description

Variety	Important Characteristics
WengkharMe-tokopi 1(OP)	Matures in 90 days after transplanting and produces curds weighing on an average 600 g. Recommended for mid and low altitude areas.
Wengkhar Me-tokopi 2 (OP)	Matures in 110 days after transplanting and produces curd weight of 800 g. Recommended for mid and high altitude areas.
Snow Crown (F1)	Produces uniform, white and semi-dome shaped heads. Matures in 90 days, average head weight of 1 kg. Most suited for mid and low altitudes.
Snow Mystique (Hybrid)	Produces dome-shaped uniform heads. Matures in 100 days and produces head weight of 1 kg. Most suited for high and mid altitudes.

Field Preparation

It is recommended to adopt conservation tillage instead of continuous deep ploughing. Good drainage of the field is pre-requisite for cauliflower besides selection of soil type. The pH range of 6-7 is ideal since phosphorus availability is more in this range. It is recommended to grow cauliflowers on raised beds. Beds should be 15-20 cm high, 1 m wide and as long as convenient.

Recommended Seed/Seedling Rate

For 1 acre, about 180-200 g of good quality open pollinated cauliflower seeds will be required.

Seed Treatment

Seed treatment is widely practiced to protect the crop from seed-borne and soil-borne fungal and bacterial diseases. Under organic farming, measures such as the use of disease-free seeds, the use of resistant varieties, frequent rotation with non-host crops and intercropping with non-host or tolerant or repellent crops are recommended. Only under circumstances where the above practices cannot be adopted or have no significant effect, the following methods of indigenous seed treatment may be followed:

- Hot water treatment of the seeds at a temperature of 50°C for 20 minutes.
- 250g of turmeric powder in 1 L of water for 10kg seeds against fungal rot and wilt diseases.
- 250g garlic cloves in 1L of mineral oil kept overnight can treat 20kg of seeds.
- Dilute 1 part cow urine in 5 parts water; soak the seeds for 15 minutes and sun-dry against soil-borne diseases and better germination.
- Treat seeds with 10g finely powdered wood ash in 500 L water, sundry and sow the seeds. This helps in reducing seedling rot.

Nursery Preparation

A raised nursery bed of 1m width and convenient length should be prepared. Media for nursery raising should be solar sterilized by drenching with water and then covering with 100ụ UV stabilized transparent polythene sheet during April-May for 4-6 weeks. Nursery raising under poly-tunnels is recommended.

Sowing Time

The schedule on the sowing time for different agro-ecological zones is in Table 10.

Table 10: Cauliflower seed sowing schedule for different agro-ecological zones

Altitude (masl)	Sowing Time	Harvest Time
>1800	January-February (*under poly-tunnels*) March- *open conditions*	May-October
1200-1800	February-July	June-December
<1200	September-December	January-March

Transplanting/Planting

Seedlings are ready to transplant when they attain a height of 10-12 cm and 4-5 leaf stage. It is recommended to harden the seedlings before transplanting.

Spacing

Maintain a spacing of 50 cm between the rows and 40 cm between the plants. Spacing will vary depending on the varieties.

Planting Time

The preferable time of transplanting is during evening hours. Irrigation right after transplanting is necessary if the soil is not wetted as described earlier.

Planting under Protected Conditions

Planting in greenhouse condition is recommended to produce early season crop as well as to extend the growing season in higher elevations. In the warmer belts, protected structures with proper ventilation protect the plants from damage due to excessive rains.

Soil and Nutrient Management

A preliminary soil testing is crucial before planting the crop. The application of organic manures can be worked out based on the result of the soil test. Use fully matured/ decomposed compost. Partially-decomposed manure should be avoided since it harbors and aggravates pests and diseases incidence. Organic manure recommendations are listed in Table 11.

Table 11: Organic manure recommendation for OPV and hybrid cauliflower

Nutrient sources	Dosage for OPVs (tonnes/acre)	Dosage for hybrids(tonnes/acre)
Farmyard manure (FYM)/compost	3.2	4.8
Vermicompost	1.6	2
*For increased N contents in FYM/compost, it is advisable to treat the FYM or compost with cow urine. Spread the compost in sun to dry and in the evening spray cow urine at 50 L per ton of compost. Leave overnight and apply next day.		

Mulching: Organic or polythene mulching is recommended for its multiple advantages as listed below:

1. Encourages microbial activity and worms in favour of soil.
2. Evaporation is reduced maintaining moisture and temperature.
3. Prevents soil erosion.
4. If organic mulch is used, it provides valuable nutrients as the mulch breaks down.
5. Suppresses growth of weeds.

Irrigation/Water Management

For organic production, the source of irrigation water should be free of contaminants. Use of organic mulch materials or paddy straw @ 2400 kg/acre is recommended for moisture conservation. Irrigation right after transplanting is pre-requisite and daily irrigation is prescribed until the crop gets established. The subsequent irrigation should be given at 7-8 days intervals during summer and 10-15 during winter, depending on the soil moisture condition and frequency of rainfall. Irrigation should never be done during mid-day sun.

Pest, Disease and Physiological Disorder Management

There are a number of insect pests which attack cauliflower. It is always advisable to control such insectpests by adopting integrated pest management system (IPM). Some of the common pests and organic means of management are as depicted in the Table 12. While physiological disorders and management measures are listed in Table 13.

Table 12: Some of the common pests and organic means of management

Pest/Disease	Symptoms	Control measures
Cutworm(*Agrotis spp*)	-Toppling and dying of damaged seedlings.	- Apply only well decomposed organic manure/compost. - Plough the fields two-three times to expose larvae to hot sun. -Flooding the field. -Hand pick & destroy larvae.
Diamond-back moth (DBM- *Plutella xylostella*)	-Feeding underside & scrapping off of the epidermis of the leaves. -Papery structure of the infested plant.	-Hand picking of the larvae. - Intercrop with garlic, tomato or carrots. -Grow mustard as trap crop. - Prophylactic spray of neem oil-3% or soil application of neem cake @ 100kg/acre.

Cabbage White Butterfly (*Pieris brassicae*) -Complete defoliation and skeletal structure of plants due to excessive feeding. -Hand pick and destroy eggs laid in groups --Use tomato as intercrops. -Spray garlic bulb extract-2%, which will act as repellent for oviposition.		
Aphids (Brevicoryne brassicae)	-Yellowing, crinkling and browning of leaves and young tender shoots.	-Employ lady bird beetles as one ladybird beetle will feed on 25 aphids/day.
Club root (Plasmodiphora brassicae)	- Wilting of the plants during the day time. - Club-shaped deformation of the roots.	- Soil solarization. - Crop rotation. - Disinfecting all tillage equipment. -Liming of acidic soils.
Damping-off in nursery (Pythium sp. or Rhizoctonia solani)	- Wirestem or girdling of infected stems. -Toppled seedlings	- Raise nursery beds to provide better drainage. -Soil or nursery media sterilization. -Choose clean, disease-free site for nursery.
Black Rot (Xanthomonas campestris pv. campestris)	- Cholorotic lesions on leaves. -Typical black discoloration of veins and veinlets.	-Soak seeds in hot water (50^0C) for 20 minutes. -Remove & compost the crop residues from the field soon after the harvest. -Crop rotation for a minimum of two years. -Choose resistant cultivars.

Table 13: Physiological disorders, symptoms and management of cauliflower

Disorders/causes	Symptoms	Management options
Browning of curds -B & Ca deficiency -Exposure to sun	-Brown discoloration of curds.	-Use self-blanching varieties. - Cover the curds with leaves. -Apply FYM @ 4-6ton/acre to mitigate all the micro-nutrient deficiencies.
Pink curds - Low temperature	-Choose the resistant varieties.	-Choose the resistant varieties.
Riceyness -High temperature, humidity and excessive nitrogen	-Development of white flower buds.	- Balanced application of nutrients. -Manipulation of the planting time to avoid high temperature and humidity during curd formation.
Whip-tail -Mo deficiency in acidic soils	-Restricts leaf growth & curd development. -Only midrib develops.	- Application of lime to raise soil pH. -Apply FYM @ 4-6ton/acre to mitigate all the micro-nutrient deficiencies.
e) Fuzziness -High temperature -Late harvest/over-maturity	-Velvety appearance of curds.	-Planting at optimum time. -Harvest curds at the right stage.
Buttons -Over mature seedlings -N deficiency, overcrowding	-Formation of small and poor quality curds.	-Transplant at the right stage. -Maintain adequate supply of nitrogen. -Avoid overcrowding of the plants.

Weed Management

To reduce weed pressure under organic management, mulching with organic mulch materials is suggested. This will not only reduce weed and disease pressure, but will also conserve moisture. Ideally, 3-4 weeding cum hoeing is required for a good crop growth. First weeding at 20-25 days after transplanting and subsequently at 35-40 and 50-55 days after transplanting.

Harvesting

Maturity Indices

Harvest when curds attain good size, usually 12-15 cm in diameter and are still compact by cutting the curds before it begins to discolor.

Time

Harvest during the cooler period of the day, either in the early morning or late evening.. Do not harvest when the field is wet or is raining.

Method

Cut the curds along with the 3-4 leaves surrounding it for protection required during transportation and handling. The curd should not be touched by the hand or by the cutting tool to minimize physical damage.

Yield

Following good crop management practices and applying the recommended dose of inputs, cauliflower can yield up to 7 MT per acre.

Post Harvest Management

Field Sorting

Field sorting of cauliflower curds should be done on farm to cull out unmarketable curds (diseased, insect-infested or ratdamaged). Performing this operation in the field will also minimize hauling cost.

Trimming

Trimming is the removal of unwanted parts which may otherwise make the cauliflower curd unappealing to consumers or may cause the curd to deteriorate rapidly. Cauliflower should be trimmed of excessively long stems as well as the leaves that are still attached to the stem. General recommendation is that the cauliflower head or curd should be well trimmed with 10 mm stem and a maximum of four wrapper leaves.

Sorting and Grading

Cauliflower curds should be sorted and classified based on certain standards of quality. The quality standard may be institutionalized nationally or provided by the importing countries. Cauliflower is categorized into different grades based on color of the curd, diameter of the curd and compactness of the curd.

Packaging

Bulk packaging is probably one of the weakest links in the postharvest chain. Losses and quality defects that result from inappropriate use of bulk packaging materials include: bruising, wounding (cut, puncture, crack, split, breakage), distortion, compression damage and abrasion. The extent of this damage increases when the packages areeither under-filled, over-filled or if the packaging material has rough surfaces and when the packages are dropped during handling. Plastic crates and bamboo baskets are ideal materials for bulk packaging.

Storage

Store cauliflower in cool, clean area protected from direct sunlight and rain for temporary holding. Cauliflower can be stored for 14-21 days under refrigerated cold store at temperature of 2-6°C and relative humidity of 90-95 %.

Transportation

Transport cauliflower in rigid containers, avoid overfilling and under filling to reduce compression and vibration damages. The produce should be protected from direct sunlight and rain. Provide adequate ventilation to aerate the produce and remove heat and moisture.

Seed Saving

Seeds from the open pollinated varieties can be saved for future use while it is not recommended to save seeds of the hybrids.

6. CHILI

(*Capsicum annum*)

Background

Chilli *(Capsicum annum*) is the most valuable spice crops which belong to the genus *Capsicum* under the Solanaceae family. In Bhutan, it is one of the most important vegetable crops. In 2016, the import ban on this commodity following high pesticides residues has led to the Winter Chilli Commercialization Movement in the southern belts of the country. The focus of chilli production under NOFP is to meet the dual objectives of up-scaling the production of winter vegetable for import substitution as well as to popularize and add value to the popular traditional chilli varieties.

Land Requirement

Select lands that are free or away from the source of contamination. In case, the crop is grown withconventional farming practices, it will require a conversion period of 12 months. Chilli can be grown in all types of soil but well-drained loamy soil rich in organic matter is best. The pH range of soil for growing chilli is 5.5 to 7. Chilli is a warm season crop, which requires day time temperature of 26-28°C and night temperature of 16-18°C. For germination of seed, the temperature requirement is 23-30°C.

Cropping System

Practice regular crop rotation with legumes or crops belonging to different family. The cropping system for chilli for higher altitude could be chilli-maize; chilli-other non-solanaceous vegetables (cauliflower); chilli-beans/legumes and for lower altitude chilli-ginger; chilli-millet could be followed. Higher preference may be accorded to the choice of other target commodities under NOFP so that the production of most of the commodities is augmented simultaneously.

Available Varieties and Seed Source

Certified organic seeds should be used. If not available, open pollinated or traditional varieties shall be sourced from organic or natural farming without contaminants. The use of hybrid seeds is not encouraged. Permission may be sought from the certifiers to use other seed sources if organic seeds are not at all available.

The following list of OPVs as well as hybrids is available for cultivation:

1. Hot wax
2. Sha Ema
3. Super Solo
4. Yangtse Ema
5. SV 2319 HA
6. PAN 1498
7. SHP 4884
8. Indian chilli

Hybrids

Seed Treatment

Where resistant seeds are not available, the seeds will have to be treated as follows:

- Hot water treatment of the seeds at a temperature of 50°C for 20 minutes.
- 250 g of turmeric powder in 1 L of water for 10kg seeds against fungal rot and wilt diseases.
- 250g garlic cloves in 1 L of mineral oil kept overnight can treat 20 kg of seeds.
- Dilute 1 part cow urine in 5 parts water; soak the seeds for 15 minutes and sun-dry against soil borne diseases and better germination.
- Treat seeds with 10g finely powdered wood ash in 500 L water, sun-dry and sow the seeds. This helps in the reduction of seedling rot.

Nursery Bed Preparation

The seeds may be sown either under low cost plastic tunnels or greenhouses. A nursery bed of 1m width and convenient lengthshould be prepared. Apply well decomposed Farmyard Manure (FYM)/chicken manure and sand at 2:1 ratio and mix thoroughly with nursery soil. The use of plug trays for nursery raising is also recommended. The media for nursery raising should be solar sterilized by drenching with water and then covering with 100µUV stabilized transparent polythene sheet during the hot months for 4-6 weeks. The seed rates and sowing time for the different chilli varieties are given in Table 14.

Table 14: Sowing time, seed rate and planting distance for different chilli varieties

Sl. No.	Varieties	Sowing time	Seed rate(g)		Remarks
1	Super Solo	March	90-110	45 x 60	For northern region-summer production
2	Hot Wax	March	90-110	45 x 60	
3	Indian Chili	March	150-180	45 x 60	
4	Sha Ema	February end-March end	400-500 (low viability)	45 x 60	

Main Field Preparation and Transplanting (Rainy Season)

Prepare raised bed of 25-30 cm high with 1 m width and convenient length depending upon size of the bed. The bed preparation in summer should ensure that water does not get stagnated in order to control damping off and blight disease. The gap between beds can be maintained at 40-50 cm.

Main Field Preparation and Transplanting (Dry Season)

Prepare raised bed of 15-20 cm high with 1 m width and convenient length depending upon the size of the field.

Soil and Nutrient Management

A preliminary soil testing is crucial before planting the crop. The application of organic manures can be worked out based on the result of the soil test and the recommendations made bythe National Soil Service Centre (NSSC). Partiallydecomposed manures should be avoided since it harboursand aggravates pest and disease incidence. Besides, intercropping or cover cropping with legumes can be practiced.Organic manure recommendations for chilli are as listed in the Table 15.

Table 15: Organic manure recommendation for chilli.

Nutrient sources	Dosage for OPVs (tonnes/acre)
Farmyard manure (FYM)/compost	3.2-4
Vermicompost	1.6
*For increased N contents in FYM/compost, it is advisable to treat the FYM or compost with cow urine. Spread the compost in sun to dry and in the evening spray cow urine at 50 L per ton of compost. Leave overnight and apply next day.	

Mulching: Organicor polythene mulching is recommended for its multiple advantages as follows:

1. Encourages microbial activity and worms in favour of soil.
2. Evaporation is reduced maintaining moisture and temperature.
3. Prevent soil erosion.
4. Provides valuable nutrients as the mulch breaks down .
5. Suppresses growth of weeds.

Water Management and Recommendations

For organic production, the source of irrigation water should be free of contaminants. Use of organic mulch materials or paddy straw @ 2,400kg/acre is recommended for moisture conservation. Drip irrigation is recommended.Irrigate the field right after transplanting. Later, irrigation should be given at 7-10 days interval during summer and 10-15 days during winter. Chilli is highly sensitive to water stagnation and cannot stand water logging even for a day.

Weed Management and Recommendations

It is recommended to have 2-3 times weeding along with hoeingfor the entire crop season. To minimize labour cost for weeding and to derive the associated benefits, we can use plastic mulch technology as well as paddy straw and debris of plant as mulch materials.

Pest and Disease Management

Major chilli pests and control measures

Table 16: Major chilli pest and control measures

Pest	Symptoms	Control measures
Thrips *(Scirtothrips dorsalis)*	-Upward curling of leaves as they suck sap from the leaves, stems and fruits. -Hardened damaged stems and fruits.	- Use yellow sticky traps and light traps. -Reflective mulching with grey or silvery plastic. - Natural enemies' conversation.

Aphids (*Aphis gossypii*)	- Wrinkled and stunted leaves due to sap sucking. -Yellowing and browning of the leaves.	-Conserve and use natural enemies, eg. parasitic wasps and predatory coccinellids. -Spray soap solution or homemade 'garlic–chilli' concoction. -Use black plastic mulch. -Removal of host debris after harvest. -Repellent plants - onions and garlic. -Use of yellow coloured traps. -Practice rotations with non-host crops.
Cut worms (*Agrotis ipsilon*) -Cutting the seedlings at the basal portion and the plant dies.		-Apply only well decomposed organic manure. - Plough the fields 2-3 times. -Flooding the field. -Hand pick and destroy larvae.
Chilli Pod Borer (*Helicoverpa armigera*)	-Circular hole at the base of the pedicel. -Premature dropping of flowers and pods. -Fruits turns to white colour.	-Deep ploughing of field before (1 week) -Flooding the field kills the pupae. -Collect and destroying the infested chili pods & parts -Collect and destroy the egg masses form the underside of the leaves. -Mass trapping using pheromone traps. -Conserve and promote natural enemies- parasitic wasps (*Trichogramma* sp) and predators/

Mites	-Downward curling of leaves as mites suck sap from the leaves. -Scarring of the stem and fruit skin under severe cases.	- Frequent watering of plants during the dry weather helps to reduce the pest population. -Conservation of natural enemies. -Water sprays or soap solutions can help manage the pest.

Common chilli diseases and their management

Table 17: Chilli common diseases and control measures

Diseases	Symptoms	Control measures
Anthracnose (*Colletotrichum capsici/C.piperatum*)	-Characteristic sunken, circular spots on the pods.	- Crop rotation and the use of disease free seeds. -Proper spacing and aeration of plants.
Damping off (*Pythium, Rhizoctonia and Fusarium*)	-Toppling over, wilting and dead of young seedlings.	- Plant high quality seeds or vigorous transplants and -Avoid soil that is poorly drained and damp soils. -Solarization of nursery beds.
PhytopthoraBlight (*Phytopthora capsici*)	- Leaf blight, fruit rot and root rot. - Brown or black spots that may kill a localized portion of the leaves. -Affected area covered by white mold.	-Beds of 1.2m wide and 30cm high. -Avoid water accumulation. -Keep at least 30 cm spacing between beds for drainage. -Avoid excess watering and poorly drained soil. -Avoid high seedling rate.

Bacterial wilt (*Pseudomonas solanacearum*)	-Browning of the vascular system. -Yellowing of lower leaves. -Sudden wilting of the whole plant	-Deep ploughing and exposure of soil to hot sun. -Removal and burning of crop debris. -Rotation with french beans reduces incidence. -Foliar application of cow urine @ 5L/100L water/acre.
Alternarialeafspot (*Alternaria solani*)	-Small brownish-black concentric lesions on leaves. -Dark sunken stem lesions. -Basal girdling, seedling death.	-Summer ploughing. -Healthy seeds selected from disease-free fruits -Crop rotation with non-host crops. -Burning of infected crop debris.

Harvesting

Maturity Indices

Select chilli with the desired maturity for the intended market. Maturity is generally judged according to physical traits such as size, shape, colour, and texture. Most mature green chilli should be firm and dark green in colour. Green chilli can be harvested 65-80 days after transplanting and the subsequent harvesting at 10 days interval. Harvest at 105 days after transplanting or when the colour changes to bright red for drying and seed purpose.

Harvesting Time and Method

Harvest fruits during the cooler period of the day, morning or evening hours. Avoid picking if the field is wet. Chilli is harvested manually by holding the fruit in the palm, pressing the index finger at the point of attachment and pulling upwards. Harvested fruits are collected in a basket. Field container should be kept under shade to reduce moisture loss and shrinkage.

Yield: The average yield per acre can be around 1.6MT.

Post Harvest Management

Sorting and Grading

Field sorting is crucial to remove diseased and damaged fruits. Grading is based on colour and size. However, being climacteric, the colour changes quickly if harvested at colour-break stage.

Packaging and Transportation

Chilli for fresh market should be packed in rigid containers such as bamboo basket and plastic crates to avoid weight loss and shrivelling and transported to markets immediately. The produce should be protected from direct sunlight and rain and provide adequate ventilation to aerate the produce and remove heat and moisture during transportation.

Cooling and Storage

Fresh chilli is a highly perishable commodity. Proper cooling extends the shelf life by slowing respiration, water loss, colour change, and decay. Temperatures higher than21°Cgreatly accelerate ripening through respiration and ethylene production. The optimum storage conditions for fresh chilli ranges between 7-10°C and 90 - 95% relative humidity. Chilling injury occurs at lower temperatures. Most chilli can be stored only for 3 to 4 weeks at optimum storage condition, without much deterioration.

Processing

Both green and red chilli can be processed into pickle, chutney and sauce. Red chilli is dried for processing into chilli powder, off-season consumption and extraction of seed. Chilli can be sun dried, however, it takes longer time and quality of the produce deteriorates. Electric dehydrators provide fast drying and clean produce.

Seed Saving and Maintenance

The seeds from hybrid varieties cannot be reused again. The open pollinated varieties can be used to save seeds. By principle, the seed fields should be isolated from the fields of the other varieties by 200m for certified seed production to prevent cross pollination. However, seed production in isolation of individual green houses can be done as maintaining the standard isolation distance seems impractical in our conditions. Isolation by netting or individual flower bagging are other options.

True to type fruits, depending upon shape, size, colour, free from disease and pest are kept for seed extraction. Such fruits are harvested at red ripe stage and are either dried, crushed and seeds separated by winnowing or the seeds are extracted manually from the freshly harvested fruits. The directly extracted fruits should be dried before storage. Spread the fresh seeds on flat surface indoors and away from direct sunlight in a well-ventilated room without humidity.

Roguingor removal of off type plants has to be done at vegetative, fruiting and full maturity stage.

Storage

Seeds for longterm use should be stored in air tight containers and for shorter term, store in the baggies or envelops. Store them in cool, dark, dry place, such as cupboard or refrigerator. Storing in refrigerator keeps the seeds viable for approximately 2 years, though it is best to use it within a year as the genetic material can degrade and the viability decreases with the aging.

*****Winter chilli production for import substitution.***

For enhancing winter chilli production in the southern belts mainly for import substitution, an arrangement has been made for now to allow the use of hybrid seeds. This is mainly due to the lack of available varieties that are suitable for winter production. The southern belts opting for winter chilli may use the following information in addition to the usual package of practices (Table 18).

Table 18: Seed rates, spacing and time of sowing for different chilli varieties

Sl no	Variety	Nursery Raising Time	Seed rate/acre (gm)	Spacing (RxP)-cm	Remarks
	S H P - 4884	August-December	80-100	60 x 60	For southern region-winter production
	P A N - 1498	August-December	80-100	60 x 60	
	SV-2319 HA	August-December	80-100	60 x 60	

General recommendation of organic manure for hybrid chilli seeds is given in Table 19

Table 19: Organic manure recommendation for hybrid chilli.

Nutrient Sources	Recommended dose for hybrids(ton/ acre)
Farmyard manure (FYM)/composts	4.8-5.6
Vermicompost	2

***** The rate of application is higher in hybrids as they are heavy feeders.

Planting under Protected Conditions

For the warmer belts, the use of protected structures for winter chilli cultivation is recommended to enhance yields as well as to shorten the growing period. A three years assessment report on winter chili reveals that there is significant difference in the yields under protected and open field conditions. The slower growth and lower yield in winter is attributed mainly to the lower than optimum night temperatures.

The use of plug tray or plastic cups for nursery raising is recommended. A seed per cup or plug hole should be sown due to higher germination percentage of hybrid seeds.

Note: The seeds should be sown only after removal of the chemical coating using any of the seed treatment methods.

7. LARGE CARDAMOM

(*Amomum sabulatum Roxb.*)

Introduction

Large cardamom is a perennial herb with subterranean rhizomes and leafy shoots which belongs to Zingiberaceae family and is native to moist deciduous and evergreen forest of Sub-Himalayan tracts. Attributes of the crop include high value, low volume, non-perishable, less dependency on external inputs, does not require expensive infrastructures and assured market.

Large cardamom flower is bisexual which is pollinated by bumble bees. Anthesis occurs in the morning hours. Large cardamom is popularly grown in India, Nepal and Bhutan, which lies in the Sub-Himalayan region in South-East Asia. In Bhutan, it is grown on a large-scale as a plantation crop in its natural habitat under shade. It is one of the main export crops in the country.

Growing Environment

Large cardamom prefers humid subtropical, semi-evergreen forests on medium to steep hills of Eastern Sub-Himalayan region. Cardamom is a shade loving (Sciophyte) plant. It is also grown under hill shade or sparse shade conditions (50% shade). North-west and south-west aspects are appropriate. Aspects that receive sunlight throughout the day are not preferable.

Site Selection

Adequate buffer zone must be provided between certified organic fields and non-organic fields toprevent drift of prohibited materials. Gentle slopes facing north are most favorable for its growth.

Climate and Soil Requirement

- Well distributed rainfall spread around 200 days with a total of about 3000-3500 mm/year.
- Grown depending upon the cultivars in the altitude ranging from 600 to 2000 masl.
- Prefers deep well drained soils with loamy texture.
- Soil should be rich in nitrogen and organic matter should contain more than 1% of organic carbon, medium in available phosphorus and medium to high in available potash with a pH range of 4.2-6.8.

- A preliminary soil testing is crucial before planting the crop. The crop requires at least moderate deep (0.6m) top soil for its good performance.

Cropping System

The agro-forestry based cropping system is highly recommended. Uttis/himalyan alder/gamashing (*Alnusnepalensis*) is the most recommended shade tree which also fixes nitrogen into the soil. Other trees recommended as shade trees are Panisaj (*Termaliamyriocarpa*), Pipli (*Bucklandia*sp.), Malito (*Macaranga denticulata*), Argeli (*Edgeworthiagardneri*), Asare (*Viburnumerubescens*), Bilaune (*Maesacheria*), Kharane (*Symplocos*sp.), Siris (*Albizialebbeck*), Faleto (*Erythrina indica*), Jhingani (*Eurya japonica*), Chillowne/Zalashing (*Schima wallichi*), etc.

Varieties

There are mainly eight popular cultivars (Ramsey, Ramla, Sawney, Varlangay, Seremna and DzonguGolsey and two high yielding varieties ICRI Sikkim 1 and ICRI Sikkim 2) in the world. However, there are two cultivars (Varlangay and Golsey) officially notified in Bhutan. The brief varietal characteristics are provided in Table 20**.**

Table 20: Characteristics of different cardamom varieties cultivated in Bhutan

Characteristics	Ramsey	Ramla	Sawney	Varlangay	Seremna	Dzongu-Golsey
Morphology	1.2 - 2 m tall, robust with large no. of tillers.	1.5 – 2 m tall, robust with large no. of tillers.	1.5 – 2 m tall, robust in nature.	1.5 – 2.5 m tall, robust in nature.	1.5 – 2 m tall.	1 – 1.5 m tall, not robust like other cultivars.
Tiller/stem colour	Maroonish tillers and narrow leaves.	Maroonish tillers and broad and long leaves, capsule darkish pink.	Tillers maroon in colour, leaves are ovate and broad.	Tillers maroon in colour, leaves are narrow with wavy margins.	Green tillers, leaves are mostly drooping type.	Green tillers, leaves narrow and erect.
Seeds/ capsule	25-40 (32)	30-40 (35)	35-50 (42)	50-70 (60)	65-70 (67)	50-70 (60)
Altitude suitability	High altitude (1515m asl)	High altitude	Medium (975 -1515masl)	Mid to high altitude (>1515m asl)	Low altitude	Low altitude (>975m asl)

Flowering time	May	May	March - May	May (Mid altitude) June (High altitude)		March
Harvesting time	October-November	October	September-October Mid altitude) October-November (High altitude)	September-November (Mid altitude) November (High altitude)		September –November
Plant population (suckers/ acre)	1200-1300	1200-1300	1200-1300	1200-1300	1700-1900	1700-1900

Planting Materials

- Quality planting materials are to be raised in the nurseries or to be collected from BAFRA certified nurseries.
- Select disease resistant and locally demanded varieties which are chemical free.
- Suckers/seedlings are planted by scooping a little soil from the center of the pits and planted up to collar zone.
- Deep planting should be avoided. A mature tiller with 2-3 immature tillers/ vegetative buds is used as planting unit.

Planting Time

Planting of large cardamom is done in May-June when there is enough moisture in the soil. Staking is needed to avoid lodging of plants from heavy rain and wind. Mulching is done at the plant base.

Cultivation Practices

The land selected for planting is cleared of all under growths and weeds. Pits of size 30 cm × 30 cm × 30 cm are prepared along the contours at a spacing of 1.5 m × 1.5m from the center of the pits.

- Wider spacing of 1.8 m × 1.8 m is recommended for cultivars like Ramla, Ramsey, Sawney and Varlangey.
- Spacing of 1.45 m × 1.45 m for non-robust cultivars like Golsey, Seremna. Pits are left open for weathering for a fortnight and then filled with topsoil and FYM.

Filling operation should be completed by the third week of April before the onset of pre-monsoon showers.

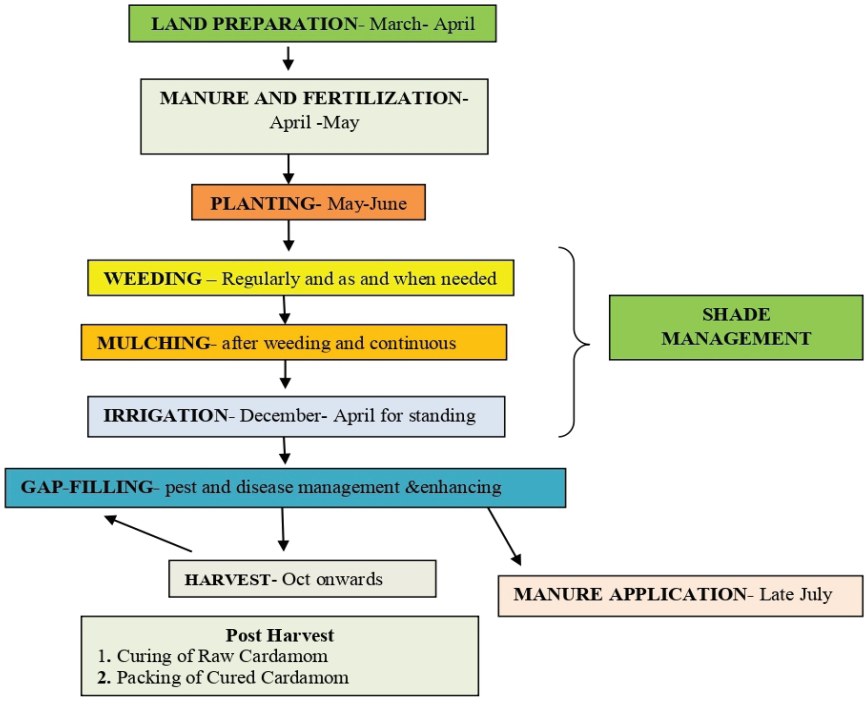

Figure 2: **Graphical representation of cardamom cultivation practices**

Soil Nutrient Management

- Well-decomposed cattle manure/compost or organic manures treated with cow urine for increased N contents in farmyardmanure (FYM)/compost.
- Spread the compost in sun to dryin the evening and spray cow urine at 50 L/ tonne of compost.
- Leave overnight and apply next day @ 2 kg/plant at least once in two years (April-May). Recycle the crop residues in the plantation for maintaining rich organic matter content.
- If the organic carbon content is less than 1%, apply 8-10 tonnes/acre of FYM and plough the field 2-3 times to mix the manure thoroughly.

- A soil base with gentle slope from the plant is beneficial for application of inputs to the plants likeFYM, vermi-compost, etc. If the land is not terraced, soil base may be made by removing top soil from the upper half to be placed on the lower half.
- Mulching with bio-degradable materials at the plant base helps to retain moisture and prevent topsoil erosion.

Irrigation

- Water sources that are free from contaminants should be used for irrigation.
- Apply hose irrigation at the rate of 40–50L per plant at fortnightly intervals during the dry season.
- For sprinkler, irrigation equivalent to 35–45 mm of rain once a week is recommended depending on the soil thickness.
- Dig numerous pits of varying sizes (1.5 ft x 1.5 ft x 1.5 ft) within the farms so as to harvest water during the rainy season or even in winter.
- In the first year of planting, watering is required at least once in 10 days during dry months from September to March for better growth in coming months.

Pest and Disease Management

Pests Management

- The incidence of leaf eating caterpillar is noticed in May-July and October-March. Infested leaves with caterpillar may be collected and destroyed regularly.
- Remove and destroy the infested tillers.
- Avoid the use of infested planting materials.
- All management measures should be adopted on community basis for better result.
- Never harm bumble bees, wild bees or honey bees as they are the pollinators.

Disease Management

Regular field monitoring/scouting is important.

- Monitor the plantation regularly, particularly during rainy season and carefully identify the diseased plants.
- Adopt regular roguing of infected plants as soon as symptoms appear (uproot affected plants and destroy).

Quarantine measures:

- Establish nursery about 500 m away from the main plantation in order to avoid aphid colonization.
- Maintain clean clumps by removing old tillers with loosened leaf sheath so that aphid will not colonize.

Use of resistant varieties:

- The Golsey variety (crinkled leaf pattern) is more susceptible to pathogens than Sawney (smooth leaves).

Use of clean planting materials:

- Propagation through suckers is recommended only through certified nurseries.
- Use seedlings produced in certified nurseries. Never collect planting material from an infected plantation or apparently healthy plants from severely infected gardens.

Phytosanitary measures:

- The mature and bearing tillers cut during harvesting should not be used as mulching materials.
- Collect and burn the harvested tiller after harvesting.

Mechanical Control:

- Collect and destroy the infected plant debris.
- Raising the soil pH to 8.2 by using dolomite and ash is recommended to reduce disease incidence.

Sanitation

- Use of clean field equipment is highly recommended.
- Mass uprooting and destroying of infected plants at the village/community level could be taken up to reduce disease pressure/ inoculums to help reduce disease incidence.

Weed Management

- Three rounds of weeding are recommended for effective control of weed growth in initial two to three years.
- Weeding is generally done by using a sickle or by hand depending upon the

intensity of weed growth.

- Clean weeding is not advised as the crop is found to be a good colonizer.
- While weeding, dried shoots and other thrashed materials are used as mulch. During flowering period, the thrashed materials should not cover the inflorescences.

Harvesting and Post Harvest Practices

Maturity Index

When the seeds of top most capsules turn brown or dark grey, it is ready for harvest.

Harvesting Method

- Bearing tillers are cut at a height of 30-40 cm from ground and left for another 10-15 days for full maturity.
- The spikes are harvested by using harvesting knives.Avoid damage to the flower buds for the next season.

Separation of capsule

Heap the harvested spikes under shade.

- Carefully remove the capsule from spike by using hand.

Curing or Drying of Capsules

Curing to remove moisture from the capsule can be done using traditional structure commonly known as *Bhatti*. However, due to high heat the quality may be compromised. Currently electric dryers (National Post Harvest Centre) as well as improvised traditional dryers (Agriculture Machinery Centre) are available. The capsules should be cured to a moisture content of 10-12%.

Yield: The average yield of large cardamom varies from 320-400 kg/acre (dry weight).

Packaging and Storage

Dried cardamom capsules should be packed in air tight containers and stored in cool, dark area. A polyethylene lined jute bags are also recommended.

8. GINGER

(*Zingiber officinale*)

Introduction

Ginger is herbaceous perennial crop and is a member of the plant family *Zingiberaceae*. The edible part of ginger is the modified stem or rhizome that grows in the soil. Ginger is used in numerous forms as a fresh spice, dried, pickled, powdered and as an important ingredient for herbal products. In Bhutan, ginger is entirely grown under traditional farming system which can be easily converted to certified organic production by taking some minor precautions.

Land Requirement

Ginger is mostly cultivated in *Kamzhing*(dryland). Ginger prefers a soil with pH range from 5.5 to 6.5. For organic ginger cultivation, land with a history of prior usage of inorganic fertilizers, pesticides and herbicides should be avoided. If such areas are to be chosen for organic ginger production, the land should undergo a conversion period of at least 2 years. It is recommended that a buffer zoneof appropriate distance should be maintained to prevent the soil and water contaminants from conventional fields or other sources.

Climate

Ginger prefers warm and moist climate. In Bhutan it can be grown from less than 100 m in the humid sub-tropical zone upto 1,500 masl in the dry subtropical zones. The crop performs best at 20^{o}C to 30^{o}C. Ginger requires a minimum total rainfall of 1500-3000 mm during the growing season.

Cropping System

Ginger is mostly cultivated as mono crop but can be intercropped with maize, millet and vegetables such as onion, garlic and pumpkin. Ginger can also be cultivated in rotation with legumes like mung bean and rajma beans in a year. Ginger is a heavy feeder of nutrients and successive cultivation on same land should be avoided.

Varieties

There are no improved ginger varieties released in Bhutan. The most popular planting materials used are the localgenotypes which are well adapted to their locality. These known genotypes are Tsirang/Damphu type and Chuzergang/Barshong type. All these genotypes or cultivars are known to yield high. Chuzergang type is small to medium-sized with high fibre content and pungency, while Tsirang type is larger- sized with less fibre content and low pungency.

Planting materials

Ginger is propagated through rhizome which is referred as seed rhizome.To start organic ginger production, the seed rhizome should be sourced from certified organic suppliers, organic farms or organic farmers. Seed rhizomes should be healthy, matured, clean and disease free. The seed rhizome should have at least one bud. The recommended rate is 600-1,000 kg/ acre of seed rhizome.

Seed Treatment

For successful crop establishment, treatment of seed rhizome before planting is very important. For organic cultivation, the seed rhizomes can be treated with diluted cow urine for half an hour before planting for good germination and to reduce incidence of diseases.

Planting Season

Planting time differs with altitude of sites. Generally, it is planted from March to April in warm and humid subtropical agro-ecological zone. In the dry subtropical agro-ecological zone planting is done from end of February to second fortnight of March.

Planting Method

Ginger is planted in rows at row to row spacing of 25-30 cm. Ridging should be done like in potato to cover the rhizomes.

Field Preparation

Generally, 2-3 times ploughing followed by harrowing is recommended to obtain good seed bed. For rainfed crop, land is divided into raised beds of 1 m width of convenient length (3-6 m) and 15 cm height and spaced at 30 cm to maintain drainage channels.In irrigated crop, the row or ridges spacing used is 40-45 cm.

Soil Fertility Management

Soil fertility management is important in ginger because it is an exhaustive crop. Application of 3MT/acre of well decomposed Farmyard Manure (FYM) is recommended along with 5 kg of wood ash as a source of potassium. Additional application of 800 kg/acre of neem cake will result in good yield. Green manuring with dhaincha *(Sesbaniaaculeata)* which should be incorporated 2 or 3 months prior to plantingis a very good option for good soil fertility management.

Intercultural Operations

Mulching and earthing-up are two most important intercultural operations in ginger cultivation.

Mulchingis a very good traditional practice that is inherently associated with ginger cultivation. Soil mulching reduces soil moisture loss, reduces soil erosion, suppress weed growth and enhance the soil organic matter. Mulching should be done with locally available materials.

Earthing-up is done to cover the rhizomes and control weeds. At least 2-3 earthing up is recommended during the cropping season. The first earthing-up should be done 35-40 days after planting. Harvesting of mother rhizomesshould be followed by second earthing-up to enable the growth of remaining rhizomes.

Weeding

Weed pressure high in the first 2-3 months after planting. Mulching and timely earthing-up reduces weed pressure.

Irrigation

Ginger is a rainfed crop but in case of erratic rainfall pattern or prolonged drought, irrigation is needed. Irrigation can be done at an interval of 4-10 days depending on the soil conditions. Water stagnation should be prevented by providing proper drainage between the ridges.

Pest and Disease Management

The major insects that feed on ginger are shoot borer and white grub. The major diseases that affect ginger are soft rot, bacterial wilt and leaf spot.Promotion of good cultural practices is the most pragmatic pest and disease management approaches for organic ginger cultivation. The most common cultural practices are use of healthy seed, seed treatment, soil solarization, light traps, neem oil, mustard cakes and ash.

Soil solarization can be adopted where the seed bed is completely covered with polythene sheets and exposed to sun for a period of 20-30 days to check soil borne pathogens and pests. Other pest and diseases have to be managed through organic practices.

Shoot Borer - Larvae feeds on tender emerging leaves from the core and resides in pseudo-stems. Light traps can be used to attract and collect adults. Spraying of neem oil (0.5%) at two weeks interval can reduce the incidence.

White Grub - It feeds on the rhizome and makes deep scars. Deep ploughing is recommended to expose different stages of the insect. Use of un-decomposed FYM should be avoided.

Soft Rot - It is the most destructive disease and caused by fungus, *Pythium* spp. Yellowing of leaves and pseudo-stems of infected plants get easily detached from the rhizome. Yellowing of leaves starts from the leaf margin and gradually covers the entire leaf. Rhizome growth is retarded due to poor photosynthesis and finally dries out. Soft rot can be managed by adopting following practices:

- Use of healthy seed rhizomes.
- Soil solarization for 20-30 days after bed preparation to reduce fungus inoculums.
- Application of 800 kg of mustard cake mixed with 20 kg prickly ash per acre of land in the planting furrows.

Bacterial Wilt - It is caused by *Ralstonia solanacearum.* At early stages, leaves start wilting and the margin drops downwards. Pseudo-stems get dried which brings the rhizome development to halt. When the infected rhizome is squeezed by hand pus like viscous liquid oozes out. This disease can be managed by:

- Use of healthy seed rhizomes.
- Soil solarization for 20-30 days after bed preparation.
- Adoption of crop rotation for three years. Do not include solanaceous crops in the rotation.
- Seed rhizomes can also be disinfected by dipping them for 10 minutes in hot water (50^{o}C).

Leaf Spot- It is caused by *Phyllostrictazingiberi.* Small spindle to oval spots appear on younger leaves. The spots have white papery center and dark brown margins surrounded by yellowish halos. The spots later increase in size and coalesce to form larger spots which eventually decrease the photosynthetic area. In case of severe infection, the entire leaves dry up. The disease can be managed by:

- Planting the crop under partial shade.
- Restricted spray of Bordeaux mixture (1%) 3-4 times at interval with the initiation of the disease.

Harvesting and Curing

Ginger takes 9-10 monthsfor maturity and will be ready for harvest when 75% of the pseudo-stem dries up. During harvesting. the rhizomes are lifted up with a digging fork or a spade. To avoid the exposure of rhizomes to strong sunlight that cause rhizome dehydration, harvesting should be done in the morning or evening. The average ginger yield recorded in Bhutan is about 2,063 kg/acre. Depending on the uses of the rhizome, staggered harvesting at different stages are recommended.

- Harvesting at 6-7 months after planting - Immature rhizomes may be harvested for sale at nearby market if they fetch very high price for fresh consumption, and for ginger candy preparation. Early harvest yields low but can maximize crop intensification.
- Harvesting at 8-8.5 months after planting- Ginger rhizomes harvested at this stage is matured and can be used for dried ginger preparation. Farmers could harvest at this stage for long distance markets or for a short storage period.
- Harvesting after 9 months after planting- Seed rhizome should be harvested at this stage is mainly for seed purpose.

Curing is done by soaking rhizomes in water to facilitate the removal of skin. The skin is scrapped off with pieces of sharpened bamboo. It is washed and dried in sun for 3-4 days and hand rubbed. It is again steeped in water for 2 hours, dried and then rubbed to remove all the remaining bits of skin. Peeling should be done with great care and skill. Steel knives are not used as they are found to stain the produce. Storage of ginger for longer periods is not desirable.

Post Harvest Management

Storage

Proper storage is important to avoid post-harvest losses. Ginger can be stored safely for 5-6 months in 65-70% relative humidity at temperature of 12-14^{o}C. It is commonly stored in pits.

- The pit should be dug in a shady area with a gentle slope to avoid water stagnation.
- The recommended pit size to store 350 kg of ginger rhizomes is 1mx 1mx 1 m.
- The pit wall may be coated with cow dung.
- At the bottom of the pit 3-4 cm layer of rice husk, saw dust, straw or dry grass should be placed to serve as cushion.
- Ginger rhizomes are placed in layers with 1-2 cm of straw in between.
- After putting the rhizomes in the pit it is covered by a wooden plank with holes for aeration and plastered with soil or cow dung.
- Temporary thatched roof is made over the pit to protect from rain.
- The pits have to be inspected at least every 20 days to remove shriveled and disease affected rhizomes.

9. TURMERIC

(*Curcuma Longa L*)

Introduction

Turmeric is an herbaceous perennial belonging to the family Zingiberaceae and a native of South Asia, particularly India. The edible part of turmeric is the modified stem or rhizome. It is used in diversified forms as a condiment, flavouring, colouring agent and as a principle ingredient in Indian culinary as curry powder. It has anti-cancer and anti-viral properties and hence used in the drug industry and cosmetic industry.

In Bhutan, turmeric is entirely grown under the traditional farming system which can be easily converted to certified organic production. Turmeric powder is widely recommended organic compounds for agricultural purposes such as bio-pesticides.

Climate

Turmeric can be grown in diverse tropical conditions from sea level to 1,500 masl, at a temperature range of 20-35°C with an annual rainfall of 1,500 mm or more, under rain-fed or irrigated conditions.

Soil

Though it can be grown on different types of soils, it thrives best in well-drained sandy or clay loam soils with a pH range of 4.5-7.5 with good organic status.

Cropping system

Crop Rotation: Turmeric can be grown in rotation with chilli, onion, garlic, vegetables, pulses, wheat and maize. It is cultivated as a subsidiary crop to ginger.

Intercropping: Crops like chilli, onion, brinjal and maize can be intercropped with turmeric. However, it can also be intercropped with plantation crops like arecanut.

Varieties

The varieties grown in Bhutan are still unknown. However, there are two types of locally available turmeric (orange and yellow type) grown which can be identified through the colour of fingers.

Planting Material

Seed rhizomes should be selected from high yielding local varieties which are free from pests and diseases sourced from organically cultivated farms. In turmeric cultivation, both mother and finger rhizomes are used. The fingers are cut into pieces, each 4-5 cm long with 1-2 buds. Mother rhizomes are planted as whole or split into two, each having one or two buds. Mother rhizomes are preferred since they give 50% more yields than the finger rhizome and also give good growth. Large sized, healthy mother rhizomes at least 100g in weight should be used.

The recommended seed/ rhizome rate varies according to type of planting material, spacing and weight of rhizomes:

- Mother rhizomes: 800-1000 kg/ acre.
- Finger rhizomes: 600-800 kg/ acre.
- As an intercrop in fruit garden: 160-200 kg/ acre

Seed Treatment

For successful crop establishment, treatment of seed rhizome before planting is very important. For organic cultivation, the seed rhizomes can be treated with diluted cow urine for half an hour before planting for good germination and to reduce incidence of diseases.

Planting Season

Planting time differs with altitude of sites. Generally, it is planted from March to April in warm and humid subtropical agro-ecological zone. In the dry subtropical agro-ecological zone planting is done from end of February to second fortnight of March.

Planting Method

Flat Beds Method: It is practiced under rain-fed conditions where soils are light. In this method, flat beds of 1 m width and convenient length are prepared and the rhizomes are placed at 25 cm x 25 cm.

Ridges and Furrows Method: It is practiced under irrigated conditions usually in levelled, plain field and heavy soil. The rhizomes are laid on ridges and furrows at a distance of 40-60 cm x 25 cm. Rhizomes are planted at l/3 height of ridge.

Field Preparation

While preparing the land, minimum tillage operations may be adopted. Field preparation should be done with onset of early rains in the plains. Field should be ploughed 15-20 cm deep with 2-3 crosswise harrowing. Temporary ridges can be made to prevent soil erosion on sloppy lands. At the time of planting, seed rhizomes may be put in shallow pits and covered with well rotten cattle manure.

Soil Fertility Management

Application of completely decomposed Farmyard Manure (FYM) or compost at the rate of 2-3 tonnes /acre is recommended along with 5 kg wood ash as source of potassium. As a mixed crop it can be also grown or rotated with green manure/ legumes crops or trap crops enabling effective nutrient built up and pest or disease control. When grown in a mixed cultivation system, it is essential that all the crops in the field are also subjected to organic methods of production. Proper soil and water conservation measures by making conservation pits in the interspaces of beds across the slope have to be followed to minimize the erosion and runoff. Water stagnation has to be avoided in the low lying fields by taking deep trenches for drainage.

Intercultural Operations

Mulching with bio-degradable waste should be chosen to enhance germination of seed rhizomes, prevent runoff/ erosion due to heavy rains, adds organic matter to the soil and conserves moisture during the dry period. Cow dung slurry may be applied on the bed after mulching to enhance microbial activity and nutrient availability. Weeding may be carried out depending on the intensity of weed growth. Soil solarization is beneficial in minimizing the multiplication of pests and diseases. Earthing up is done after 2-2.5 months from date of planting to avoid exposure of developing underground rhizomes to sun due to soil erosion is recommended.

Buffer zone: In order to avoid contamination of organically cultivated plots from neighboring non-organic farms, a suitable buffer zone with definite border is to be maintained. Crop grown on this isolation belt cannot be treated as organic. In sloppy lands adequate precaution should be taken to avoid the entry of runoff water and chemical drift from the neighbouring farms. Proper soil and water conservation measures by making conservation pits in the interspaces of beds across the slope have to be followed to minimize the erosion and runoff. Turmeric requires a conversion period of twelve

months being a perennial crop.

Weeding

Normally 5-6 times of weeding should be done depending on the intensity of weeds.

Irrigation

If the irrigation facility is available, first irrigation should be done before and after planting. Subsequent irrigations are given at 7-10 days interval depending on soil moisture content and 20-25 times irrigation is necessary during the crop life.

Pest and Disease Management

The appropriate approach for pest and disease management under organic production is based on a range of preventive and other management strategies to minimize the incidence of pests and diseases. Regular field surveillance, adoption of phytosanitary measures combined with understanding the life cycles of both pest and its predators forms the main strategy under organic production system to intervene and manage the pests population.

Common pests of turmeric are:

- Shoot borer
- Leaf roller
- Scales

Pest management

- Regular field surveillance
- Adoption of phytosanitary measures
- Shoots may be cut open and larvae picked out and destroyed.
- Neem oil 0.5% may be sprayed at fortnightly intervals.

The most common diseases of turmeric are:

- Leaf blotch
- Leaf spot
- Rhizome rot

Disease management

- Regular field surveillance
- Adoption of phytosanitary measures

- Use of resistant varieties
- Controlled by restricted use of Bordeaux mixture 1%

Harvesting

Depending upon the variety, the crop becomes ready for harvest in 7 to 9 months. Early varieties mature in 7-8 months, medium varieties in 8-9 months and late varieties after 9 months.

Usually the land is ploughed and the rhizomes are gathered by hand picking or the clumps are carefully lifted with a spade. Harvested rhizomes are cleaned of mud and other extraneous matter adhering to them.

Normally, the yield ranges from 10-12 tonnes per acre for fresh rhizomes and after curing there will be 20-25% reduction in weight than fresh rhizome.

Post-Harvest Management

Proper storage is important aspect to avoid post-harvest losses in turmeric. It can be stored safely for 5-6 months in 65-70% relative humidity at temperature of 12-14^{o}C. Traditionally, the finger rhizomes are separated from mother rhizomes and later are stored as seed material for next growing season.

Rhizomes for seed are generally heaped under the shade of trees or in well-ventilated sheds and covered with turmeric leaves. Sometimes, the heap is plastered over with earth mixed with cow dung. The seed rhizomes can also be stored in pits with sawdust. The pits can be covered with wooden planks with one or two holes for aeration.

10. OYSTER MUSHROOM

(*Pleurotus ostreatus*)

Introduction

Oyster mushroom (*Pleurotus ostreatus*) is known by the name *Naki shamong* in Dzongkha. It is one of the most commonly cultivated mushrooms in Bhutan and by far the easiest to cultivate. Oyster mushroom can be grown on various agricultural wastes. In Bhutan it is commonly grown on paddy straw. Besides, paddy straw, other materials like saw dust, wheat straw, banana leaves and dried grasses are being used. It is widely grown in both lower and higher elevations as it is cultivated in a controlled environment. Oyster mushroom farming in Bhutan, to a large extent is already organic.

Site Requirement

Oyster mushroom farm should be established in places without contaminants and pollutants. The farm should not be located near places where there is use of chemicals. Unlike shiitake, one shed is enough for oyster mushroom. The shed can be made of various materials depending on the altitude. Floor of the shed should be cemented and structure like shelves should be constructed for better management and higher yield. To prevent contamination, the shed should be disinfected with organic disinfectants like bleaching power, Neem oil and other available organic disinfectants. The cemented floor sheds can be washed properly before cultivation in order to avoid the contamination.

Cropping System

The following strains are available for oyster mushroom cultivation in Bhutan;

- PBN – Pleurotus Bhutan and Nepal
- WOI – White Oyster India
- BOI – Black Oyster India
- PJ – Pleurotus Japan
- Pink oyster
- Yellow oyster
- BOJ – Black Oyster Japan
- Sajorcaju
- Oyster Nepal

Cultivation and Management Practices

Selection of substrates

Oyster mushroom can be grown on wide number of substrates such as saw dust, wheat straw, paddy straw, banana leaves and even on dry grasses. Whatever material one chooses to use, the materials should be organic, free of pests and diseases and of superior quality.

Chopping of the substrates

Irrespective of the types of materials used as substrate for oyster mushroom production, the substrate should be cut to a length of 5-6 cm.

Soaking

The main aim of soaking is to bring the moisture content of the substrate to 65%. Normally, for paddy straw, the time of soaking is about 15 to 20 minutes.

Heaping

The soaked materials are heaped together to remove excess water overnight under shade.

Sterilization

The materials are filled in netted bags and sterilized in a drum. Small amount of water is poured into the drum and wooden frame is placed in the drum. The netted bags are kept on the frame to avoid the bags from getting soaked. Sterilization is carried out to remove competitive and disease- causing micro-organisms. Although sterilization can be done in boiling water, it is not preferred as it could lead to dissolving and loss of nutrients and additives. Sterilization begins once the water starts to boil, and at this time opening of the drum is sealed with a plastic sheet. The materials should be sterilized for duration of 2-3 hours in summer (more contamination) and 1 hour in winter (less contamination). Using inorganic methods of sterilization should be prevented.

Cooling

After sterilization, the materials are taken out and let to cool down in a clean room overnight.

Inoculation

In plastic bag inoculation, a layer of straw is added which is pressed down and a small quantity of organically produced spawn is added to it. Inoculation should be carried out in a clean room to avoid contamination. The amount of spawn added is 2% of total weight of the materials. Number of layers depends on the size of the plastic being used. Normally, it reaches 3 to 4 layers. The mouth of the plastic is closed by using a rubber band and small holes are made after 7 to 10 days for aeration. The plastic should be stored in a room away from direct sunlight. The ideal temperature required is between 20 to 25^{o}C.

Incubation

The plastic bags are then incubated for 21 to 30 days in a clean room for the mycelium to recover. Plastic bags are hanged or kept on shelves.

Fruiting

In 1 to 2 weeks, white cotton like fluffy mass will form in the substrate. This is a sign of good mycelium run. After 3 weeks, the whole substrate should turn white signalling the completion of spawn run. The temperature should be brought down by watering to initiate pinhead formation. A small cut should be made at the place where pin heads has formed to enable mushroom (fruiting body) to grow. Water should be from an uncontaminated source and watering should be carried out depending on the humidity level of substrate and the environment. However, care should be taken to prevent the water from collecting at the base as it could lead to disease development.

Harvesting

After the mushroom fully develops, harvest the mushroom without causing damage to the substratum. Oyster mushrooms are harvested when the fruiting body becomes curled under the edges and gills are well-formed. Hand picking is not encouraged as it damages the cap of the mushroom. Harvesting is done with a sharp tool such as knife.

Resting

After the first harvest, the substratum should be stored in cool and dry place for about 10 to 15 days for resting after which it can be made to sprout again by watering (flush). There can be about 3rd to 4th flush after which the substratum can be thrown away or used as manure. The size of the substratum will keep on decreasing after each flush as it is consumed by the mycelium.

Pest and Disease Management

Oyster mushrooms are generally very prone to pests and diseases (Tables 20 and 21). It occurs due to inattentiveness and the incorrect management practices. A holistic approach looks at the overall system and solves the problem at the source. Chemical control methods are often expensive, hard to carry out and are used to cure the symptoms, but not to solve the problems. There are many good cultural management practices which can be adopted for organic mushroom production which include:

- Good sanitation practices
- Use of disease and pest free substrates
- Sanitation of equipment and tools after every use
- Keep the shed free from any infected mushroom debris
- The cultivation shed should not be over wet and humid
- The cultivation shed should not be over dry in wet seasons
- Allow good ventilation in the shed
- Proper watering methods and amounts
- The surroundings of the shed should be cleaned
- Workers should stay clean
- Prevent entry of the flies in the shed
- Avoid exposure of substratum to direct sunlight
- Sterilize the shed
- Remove infected bags

Table 20: Oyster mushroom disease management

Disease	Causal Organism	Causes	Symptoms/ Infections	Control
Green mould	*Trichoderma spp.*	-Reduced airflow, wet and warm conditions.	-Dense mycelium followed by dense green sporulation areas. -Patches of unproductive areas. -Kills actively growing mycelia and competes for nutrients and space.	-Sterilization of the shed, removal of infected bags and inoculating in the cooler months.
Olive-green mould	*Chaetomium spp.*	-Wet and warm conditions. -Common in old or poorly stored straw (exposed to rain/environment). -Common during storage of straw and incubation periods.	-Some are heat resistant and hard to remove by sterilization. -Small olive-green to black burrs found on the straw. Burrs contain spore that spreads through air. Colonizes straw in storage. Oyster mycelium spawn run may be delayed and less dense.	-Maintain dry conditions and use fresh straw.

Slime mould	*Various species.*	-Areas exposed to rain which are highly humid - Substrate which are at the end of its life cycle.	-Initially looks like slime, Later fruiting body becomes powdery and releases spores that cause diseases. -Reduce fruiting significantly and often lead to no fruiting.	-Correct cultivation at the correct moisture content and cultivation in cooler months.
Pink mould	*Monilia* spp. *Neurospora* spp.	-Wet and warm conditions. -Problem both during incubation and fruiting periods.	-Mycelium may be white, grey or pink in colour. -Once spores are formed infections are easily spread -Large reduction in harvestable product.	-Destroy infected bags, thorough and repeated cleaning and disinfection of the area..
Bacterial rot	*Various species. Eg. Bacillus* spp., *Pseudomonas* spp.	Areas exposed to rain which are highly humid -Substrate which are at the end of its life cycle.	-Wet, water soaked, with slime like appearance of spawn bag. -Strong, unpleasant, rotting odour may be present.	-Adequate steaming, good, clean, aeration, and ensuring roof is not leaking and removal of infected bags.

Table 21: Oyster mushroom pest management.

Pest and insects	Infections	Management
Mushroom fly	-Spread mites, damage mycelium, turn substrate into swampy masses, foul odour.	-Use wire mesh on windows and trapping.
Rodents	-Consumes the substratum and remove a great deal of mushroom spawn from the bags. Eats immature mushrooms growing in the bags or destroy them.	-Traps, sanitation, removing grains from substrates.

Post Harvest Management

Oyster mushrooms are delicate and perishable in nature. For this reason, it cannot be keptfresh for more than 3 to 5 days even with ambient conditions. The deterioration starts with the formation of brown colouration affecting the quality and the marketability. Therefore, it is important to follow relevant post-harvest management activities such as:

- Proper harvesting time and stage
- Grading
- Storage: stored in refrigerated cold stores for 2-3 weeks at 0 to 2°C at 85 to 90% Relative Humidity.
- Packing: done in well ventilated rigid containers. It should be clean, light but also strong.
- Transport in refrigerated van.
- Oyster mushrooms are often dried as a whole or as slice.
- Preserved in brine and vinegar.
- Canned in aluminium cans.
- Also processed into pickles.

11. SHIITAKE MUSHROOM

(*Lentinus edodes*)

Introduction

Shiitake mushroom, (*Lentinus edodes*) is known as oak mushroom in English and Sokey Shamong in Dzongkha. Although Bhutan is located at low latitude, it comprises high-elevation areas and is habitat to several tree species that can be used as bed-logs; thus, it possesses environment that is suitable for shiitake mushroom cultivation. The most commonly used log species is *Quercus griffithii*. If appropriate cultivation methods are employed, shiitake mushroom cultivation has the potential to become an important industry in Bhutan. Shiitake mushroom is grown all over Bhutan covering 16 dzongkhags. Shiitake mushroom cultivation has been done organically and the mushrooms have high value as food and contain many nutrients that are beneficial to human health.

Location of Farm

Shiitake mushroom farm should be located where it is free from contaminants and pollutants. The establishment of farm near orchards and agriculture farms where chemicals are excessively used should be avoided.

Construction of Mushroom Shed and Soaking Tank

For shiitake mushroom cultivation, 2-3 sheds are required which includes the incubation room, fruiting room and resting room. The temperature and humidity inside the shed should be maintained as per the requirement. The material for construction of shed depends upon the altitude range and climatic conditions. The soaking tank is necessary for shiitake mushroom cultivation and the size will depend upon the size of the farm.

Cropping System

Shiitake mushroom should be solely grown in one farm throughout the year. To avoid high risk of cross contamination, other mushrooms should not be grown with shiitake mushroom. The mushroom is normally cultivated during winter season, where management and production goes year round.

Strains

As of now, five different strains of shiitake mushroom spawn are used all over Bhutan, namely: 465, M290, A577, H600 and A910.

Spawn

Organic shiitake mushroom spawn produced by competent organic spawn producer-the National Mushroom Centre (NMC) or spawn which is certified by NOP and BAFRA should be used.

Spawn Rate

One bottle of spawn is used for five logs.

Yield

The expected yield of shiitake mushroom is 300 g/billets.

Cultivation and Management Practices

Shiitake mushroom cultivation and management practice includes the following 8 steps:

Selection of Substrates

Organic substrate should be used for production of organic shiitake. The recommended substrates are either sawdust or wooden logs. If sawdust is used, itshould be from broad leafed trees such as oak, *Catanopsis, Alnus* and Himalayan hazel. The best wood species recommended for shiitake production are *Quercus griffithii* and *Corylux ferox.*

Collection of logs

Shiitake mushroom logs are normally collected during autumn and winter season when the tree is dormant and the barks are firm. Branches of 7 to 25 years old trees are preferred depending upon the thickness of the bark and health of the tree. If the bark is too thick the spawn may not reach the woody part of the log and if it is too thin it can scale off. Regardless of age, the logs of 6-20cm thickness in diameter are recommended. If the cultivation is delayed, there is high risk of infection as the temperature favors the growth and development of other competitors.

Inoculation

The walls of the inoculums holes can be kept sterile and at an appropriate temperature by periodically dipping in sterile water so that it does not become too hot. While removing inoculums from the container, discard the old seed culture on the surface. The scraping tool used to do this must be sterile. For each container, first wipe the tool with a clean cloth or cloth soaked in 70% alcohol, sterilize using a flame, and scrape out the inoculums. The tools used for inoculation should be sterilized in the same manner. All workers engaged in inoculation work must exercise care to ensure that the inoculums do not become a source of contamination and is kept sterile until the sealing wax is applied. One should keep it in mind that the inoculation place should be free of contaminants and pollutants. The inoculation equipment used for shiitake mushroom cultivation are: electric drill machine, compressor, automatic gun injector and hand injector. In addition, steps must be taken to prevent infection by *Hypoxylon*, etc. The melting temperature of the sealing wax and the amount used must be carefully managed so that it does not run out or crack upon drying, i.e. if the temperature is too high, it will flow too readily; if the temperature is too low, it will crack. The ratio of wax to rosin is 4:1. The inoculums should not be placed in direct sunlight. After inoculation, the logs should be covered or otherwise protected from exposure to direct sunlight. Inoculation process includes drilling of holes, spawning and waxing or sealing.

Pre-incubation

Inoculated logs must be managed according to the diameter. This is because moisture loss from the logs varies according to diameter. The purpose of pre-incubation is to encourage the inoculums to colonize the log. The ideal log moisture content for shiitake colonization is lower (36 to 38% relative moisture) than the moisture at the time of cutting/cutting to size (42 to 45% relative moisture). The methods that encourage rapid moisture loss must be used for large-diameter logs (crib staking), while methods that prevent sudden moisture loss must be used for small-diameter logs (vertical bulk staking).

At this time of year, spores of *Hypoxylon* spp. (major antagonist of shiitake growth), which are ubiquitously suspended in the air, can be carried in and will germinate. Thus, care must be taken so that logs do not reach temperatures that are optimal for spore germination. The spores of *Hypoxylon* spp. readily germinate at 15°C and above. More than 90% of spores germinate after two days at 25 to 35°C. The bark exudates of

Quercus spp. is particularly favorable nutrient source, resulting in 98% germination. It can be seen that the mycelia of *H. truncatum* grow at double the rate of shiitake mycelia between 25 and 30°C. This observation underscores the need to pay attention to and prevent high temperatures during this period (pre-incubation). Germinated spores grow quickly under a relatively dry condition. Thus, attention also needs to be focused on preventing the surface from drying out too rapidly. Meanwhile, most *Trichoderma* spp. which are hostile to shiitake, parasitizing and causing shiitake to wilt, grow vigorously under hot (25°C and higher) and humid (70% and higher) conditions. In some cases, *Trichoderma* spp. can attach themselves to shiitake mycelia during pre-incubation and later cause shiitake mycelia to die during the main incubation and soaking, after the mycelia have spread, by taking advantage of heat stress or other stresses on shiitake. Therefore, vigilance is required to detect even small attachments of *Trichoderma spp.*

The removal of moisture from large-diameter logs is challenging. Moisture loss must be encouraged by providing a certain amount of air flow, while also keeping the bark surface and log ends from becoming overly heated or from drying out too rapidly. The bark of larger diameter *Quercus* spp. logs contains numerous deep grooves, causing rapid entry and exit of moisture from tissues just beneath the bark. Thus, care must be taken to keep the surface from drying out. Small-diameter logs lose moisture rapidly, with the thin bark rendering the tissue underneath the bark especially sensitive to changes in ambient temperature. Thus, care must be taken to avoid excessive dry conditions and hot temperatures.

Accordingly, in low-lying warm areas, large-diameter logs do not need to be covered and should instead be cross-stacked. To prevent moisture loss, small-diameter logs should be covered to retain heat and humidity until the room temperature reaches 15°C. The cover must be removed when the temperature rises above 15°C. Otherwise growth of the above mentioned fungal contaminants will be encouraged. Intermediate elevation areas experience dramatically different daytime and nighttime temperatures during pre-incubation, which encourages drying. Small-diameter logs must be covered with a sheet to retain heat and humidity. Moisture loss for intermediate and large diameter logs is performed slowly and only requires logs of this size to be encircled with a sheet (leaving the top open) in locations that experience strong winds. In cool, high-elevation areas, steps must be taken to maintain warm temperatures to promote colonization by the inoculums. These measures must be continued until the average ambient temperature reaches 15°C. Irrespective of location, logs must be regularly inspected and careful

attention must be paid to detect the harmful fungal species mentioned above.

Main Incubation

The purpose of the main incubation is to promote the spread of shiitake mycelia inside the logs and to stimulate the formation of primordia under the outer bark (in the inner bark). As the wood loses moisture and the cells die, the shiitake mycelia colonizing the inoculums holes enter the dead cells and take up nutrients as they grow. While the spread of mycelia toward the cork layer is fast, growth toward the log center is slower. The mycelia spread in a spindle-like pattern, spreading rapidly in the longitudinal direction of the wood fibers and slowly in the transverse direction across annual tree rings. When the mycelium encounters live wood, it stops growing and does not resume until the wood dries up and dies. Much of the moisture in a log exits via the log ends. If the inside of a log is too wet, mycelia near the log ends are unable to grow towards the log center and grow out of the log end. This is often mistakenly seen as a sign of favorable growth. In reality, it is healthier if the shiitake mycelia grow towards the log center. If a log that has been completely colonized by shiitake mycelia is kept for a long time under hot, humid conditions, the mycelia will be stressed, rendering them vulnerable to attack by *Trichoderma* spp. and other parasites. For this reason, attention should be paid to the area around the logs to ensure that the logs are not subjected to high temperatures for long periods of time during the main incubation period. After shiitake mycelia have completely colonized a log, a certain cumulative temperature is required before primordia are formed. This value, expressed by Σ (daily mean air temperature -5°C), is approximately 3,000°C for high-temperature strains (for example M465) and 4,500 to 5,000°C for mid to low-temperature strains (M290). The number of days required to achieve these values are the target durations for incubation. The primordia of fruiting bodies are actively formed at temperatures between 15°C and 25°C.

Shiitake requires more moisture than other mushroom species. The moisture content under the outer bark where the primordia form must be 35% or higher. During the dry season, measures to maintain high moisture levels such as watering must be implemented.

Soaking

Soaking is performed to supply moisture and to provide low-temperature stimulus, as well as vibration stimulus through movement, which are needed for shiitake primordia development and the formation of fruiting bodies. As such, a water temperature of 20°C

or lower is recommended. The required soaking time depends on the age and size of each log: 1 to 2 years old logs require 8 to 15 hours of soaking with shorter times being recommended with decreasing log diameter. Logs that are 3 years or older need to be soaked for 16 to 24 hours. “Steeping” (step in which logs are wrapped to retain heat and humidity) is required after soaking in cool, dry areas and is unnecessary during the rainy season. Although, the preferred log arrangement for fruiting body harvest is to stand them on their ends, if there is not enough space, the logs can be cross-stacked. As light is needed for fruiting body formation, the room where fruiting is induced should be brighter than the room used for incubation. Clean source of water to be used for soaking and watering of mushroom billets.

Harvesting

The best time to harvest fresh shiitake is right before the endothelial membrane covering the gills on the underside of the mushroom caps starts to tear. In case of dry shiitake, harvest is done after the gills have become horizontal but before the edges of the caps have started to flare. It is best to harvest the type of shiitake that is in demand in the local market. If the fruiting bodies are not harvested at the appropriate time and are left to grow, they will become a breeding ground for microbial contaminants and insect pests. Thus, it is important not to delay harvest in the hopes of saving labor. In addition, watering at harvest time reduces mushroom quality and should not be performed. The fruiting bodies should be harvested from the bottoms of the stems so that no uncut remnants remain on the log.

Resting

After the logs have been harvested, they are allowed to rest. The purpose of this rest period is to relieve any stress on the shiitake mycelia and to allow the mycelia to recover before forming primordia again. As such logs that did not produce a lot of fruiting bodies at one time, primordia can be re-induced immediately following harvest. However, logs that yielded a lot of fruiting bodies of a high-temperature strain at one time must be allowed to rest at temperatures around 20°C to relieve heat stress and managed so that the moisture content does not fall below 35%. Logs whose moisture content increased excessively during the previous soaking step (logs that have become too heavy) should be managed so that some of the moisture is lost. Logs are typically allowed to rest for 30 to 40 days, during which time the moisture content is kept at 35% or higher, before being re-induced to form primordia.

Cultivation Season

Shiitake mushroom is cultivated during winter season (December-April) as the tree is dormant and the barks are firm. It is also said that there will be less contamination during winter season as the temperature is low.

Pest and Disease Management

To prevent pest and diseases in shiitake mushroom farm, one should clean the shed as and when required. Provide proper ventilation inside the mushroom shed. Use of wire mesh over the windows and doors will help to reduce the entry of insect pests. Avoid over wet conditions inside the shed or create proper drainage system to drain out excess water from the shed. In case of mushroom flies, it is recommended to use sticky trap or light trap. Some common pest and disease of shiitake mushroom are as follows:

Pest:

- Mushroom flies
- Bark beetle
- Termites
- Snail
- Rat

Disease:

- *Hypoxylon*
- *Trichoderma (Green mould)*
- *Hypocrea*
- *Diatripe*
- *Graphostroma (Black rot)*
- *Schizopora (White rot)*
- *Slime mould*

Table 22: Shiitake mushroom disease management

Name of diseases	Environment	Characteristics	Control measures
Hypoxylon	Ascospores on logs germinate under high temperature. Germination ratio of ascospores at 25°C-35°C is greater than 90% within 3 days. ≥70% germination after 10 continuous days at 15°C or higher.	-Forms black band upon contact with shiitake and other mycelia. -Prefers dry conditions. Grows inwards as the log ends and inner bark begin to dry.	-Do not allow log surface to become hot in the fall or spring. -If mycelia of this fungus (greenish grey to greenish yellow) are observed on log end or bark surface, keep log surface from becoming hot and drying out.
Trichoderma and *Hypocrea*	Occurs in hot, humid environments Takes advantage of heat and other stresses on shiitake mycelia to attack. Also parasitizes and kills fungi other than shiitake.	-Parasitic fungus. Kills shiitake mycelia. -Narrow "highly-active" temperature range. Grows vigorously in high-temperature, high-humidity environments. -Becomes highly active at ≥25°C and≥85% humidity.	-Does not heat stress shiitake mycelia (especially after log colonization has been completed).

Diatrype and *Graphostroma*	*Diatrype* ascospores germinate between log cutting and inoculation as a result of being exposed to direct sunlight, with subsequent mycelial growth under high-temperature, dry conditions. *G. platystoma* tends to occur in hot regions, and exhibits slower growth than D. stigma.	-*Diatrype* produces conspicuous red spore horns on bark surface in the spring and summer; thus, it is easy to detect. -After this, the bark starts to peel, revealing the underlying stroma. -This fungus does not attack shiitake mycelia. However, the spore horns and stroma can serve as entry points for *Hypocrea spp.,* which parasitize shiitake and, thus, should be monitored carefully.	-Accelerate shiitake mycelia growth. To do this, perform early inoculation. -Do not allow the bark surface to dry out rapidly. Exposure to direct sunlight can cause rapid drying of the surface, especially in the spring.
Schizopora &Phelebia	Both species occur after 1 to 2 years under hot and humid conditions.	-Has strong ability to break down wood and quickly damages logs. -Spreads through contact. Wood colonized by these species is prone to bacterial contamination.	-Do not leave logs under hot, humid conditions for longer period of time. Because these species spread through contact, infected logs must be quarantined as soon as they are found.

Slime mould	Occur on logs that have been infected by *Hypocrea* spp. and *Trichoderma* spp. Under extremely humid conditions, they are prevalent in logs that have been weakened by shiitake mycelia.	-In logs where this slime mould is observed, the wood under the bark is severely rotted and smells strongly of bacteria. -In many cases, the rotting is so severe that the wood falls apart when touched.	-After logs have been completely colonized by shiitake mycelia, ensure adequate air flow to prevent stress due to high temperatures and/or oxygen deficiency (excessive moisture). -If detected, do not store the infected logs near others logs (quarantine or discard) to prevent the spread of *Trichoderm*a spp. or *Hypocrea spp.*

Harvesting/Post Harvest Management

Maturity Indices

Most mushrooms are harvested when the cap is well rounded and partial veil completely intact for both fresh market as well as for preservation. However, for local and fresh consumption mushrooms are allowed to grow beyond physiological maturity. Shiitake mushroom is harvested when the cap diameter is 2 to 3 inches for international market. The caps should still be rolled under on the edges or still attached to the stems

Harvesting Method

Mushrooms are harvested by cutting the stem above the point of growth with a sharp tool such as knife and placed in a well-ventilated rigid container. Hand picking is not encouraged as it damages the mushroom especially the cap. One should avoid watering 1-2 days prior to harvesting. Fruiting bodies must be carefully packed for shipping so that the caps do not become damaged or separated from their stems. The fruiting bodies should be cleaned of any dirt and handled gently so as not to cause bruising of the caps or stems.

Packaging and Transportation

It is best to pack mushroom in well ventilated rigid containers. The containers should be clean, light in weight and strong. Mushrooms are highly perishable and have shelf life of 3-5 days under ambient condition. Therefore, they should be marketed or cold stored immediately after harvesting. Long distance transportation of fresh mushroom requires refrigeration.

Storage

Mushroom can be stored in refrigerated cold stores for 2-3 weeks at 0-2 °C temperature and 85-90 % relative humidity.

Processing and Preservation

Mushroom can be preserved in brine and vinegar and canned in aluminum cans. Due to short production season they are dried either as whole or sliced for off-season marketing and consumption. Mushroom can also be processed into pickles.

SECTION THREE:

PACKAGE OF ORGANIC PRACTICES FOR FORESTRY COMMODITIES

1. LEMONGRASS - COCHIN GRASS

(*Cymbopogon flexuosus*)

Introduction

Lemongrass (*Cymbopogon flexousus)* grows in nature underneath chirpine forest and belongs to Poaceae (Graminae) family.It is harvested and distilled to obtain lemon grass oil, with the chief chemical compound being citral and is considered an economically important Non Wood Forest Product (NWFP). There are opportunities for premium prices and access to international markets since lemongrass from Bhutan is harvested from a clean and pristine natural forest and the citral content is usually found to be higher than 60%, which meets the most international quality standards.

Plant Description

It is a perennial, tufted, aromatic grass with numerous erect culms arising from a short, thick rhizome. The culms (stem) are up to 2.5-3 m tall, reddish or whitish, smooth and glabrous, but often short-bearded at the nodes. It grows in clumps of up to 2 m in diameter, while the leaves are up to 1m in length.

Growing Environment

It grows in wild at altitudes ranging from 600 to 1,700 m. It grows well in a variety of soils with good drainage under sunny, warm and humid conditions. It can be mostly found in Mongar, Trashigang, Lhuentse .

Species

There are six species in Bhutan including *Cymbopogon khasianus, C. flexuosus, C. pendulus, C. bhutanicus, C. munroi, and C. jwarancusa.* Among the six lemon grass species*, the Cochin grass (C. flexuosus) and C. distans* (*C. bhutanicus*) are harvested and distilled.

Trashiyangtse dzongkhags of Eastern Bhutan.

Propagation

Generally, it is propagated through naturally regenerated seeds. If desired, cultivation can be done through raising seeds in nurseries. Around 10-12 kg seeds is needed to produce seedlings for 1 ha. It is also vegetatively propagated by splitting the clumps into slips. These are planted at a spacing of 60 cm x 80 cm. About 55,000 slips are required for planting 1 ha.

Uses

Lemongrass oil is used for manufacturing of air sprays, soaps, cosmetics, toiletries, perfumery, pharmaceuticals and the food industry. The oil is applied as a fumigant against flies and mosquitoes. Spent grass is dried and used as an animal feed, cattle bedding material for manure and also to fuel the distillery. It is also planted to lessen the effects of soil erosion.

Collection Area

Lemongrass is collected from approved Community Forests (CF) and Non Wood Forest Product (NWFP) management areas as well as from the State Reserved Forest (SRF) land. Prior to collection of grasses, with the assistance of forestry officials, the communities and existing CF/NWFP management groups have to map and calculate the potential area, assess the resources and prepare management plan as per the NWFP Collection and Management Guidelines and Forest and Nature Conservation Rules and Regulations, 2017.

How to do Participatory Forest Resource Mapping?

- Resource mapping can be done by Google Earth. Show Google Earth map printed in colour or over a projector to all the lemongrass distillers.
- Discuss the boundaries of the areas that are customarily used by each distiller in the group and let the communities locate and name the areas of lemongrass resource collection area.
- Also mark other important features (water source, sacred sites, etc.) on the map.
- Copy on a chart and locate the resources simultaneously from the Google Map (barren land, Tsamdro, Sokshing, water sources, forest types, plantations, etc.).
- At the end of this stage, the Google Map shows the resources collection location, boundaries and the names of important physical features including the village.
- Then demarcate the boundaries and agree upon them in the field during field checks.

Area Measurement

Area can be measured by using a GPS and by a Google Earth/ArcGIS software based confirmation.

Resource Assessment

Measure and estimate the quantity of grasses that can be collected and/or the quantities of oil that can be produced from a certain area in a sustainable manner. According to research data, the oil yield in the wild is up to 9 kg from 1ha. Data can be collected for about 5 years, the average can be calculated and used as a reliable resource assessment.

Management Plan

The management plan has to be developed as per the NWFP Collection and Management Guidelines with assistance from the forestry officials. It has to be endorsed by the Gup and submitted to the concerned Chief Forestry Officer for seeking approval from the Department of Forest and Park Services (DoFPS). After approval of management plan by the DoFPS, the management plan certificate shall be handed over to the concern NWFP management and marketing group for implementation.

Collection/Harvesting Guidelines

The lemongrass will be harvested based on the approved CF/NWFP management plan and in the event where the communities are not interested, individual/company shall be considered. The harvesters have to follow the guidelines below:

- The appropriate month for harvesting is June to September.
- Maximum two cuts per year; it is thought that the flowering capacity of the lemon grass is halted when more cuts occur each year.
- Cut the grass at a height of about 20 cm as cutting at this height minimizes contamination with soil borne diseases and there is enough green left for assimilation, which will ensure the further growth of the grass for the next cut.
- Leave at least 3 to 4 flower stalks per clump.

Beside the above prescribed harvesting guidelines the following conditions has to be taken into account:

- During harvesting remove the unwanted species (weeds) invading and reducing grass production such as *Chromolena*, *Perthenium* and *Lantana* species to prevent nutrient competition.
- For regeneration purpose after cutting of grasses and making into bundle or putting inside basket, physical shaking of grass is advised for seed dropping.
- A buffer zone has to be maintained from conventional farming and other

contaminated areas.

- Avoid littering while harvesting and clean the littered waste in the designated area.
- Forest fire has to be prevented as burning and slashing of grasses is prohibited in the designated area as it is against the principles of organic practices.
- Any pests anddiseases outbreak in designated area should be treated by organic pesticide prescribed by the concerned authority.

Post-Harvest Management Practices

Transportation

- Collected grasses should be transported in a clean basket or sacks.
- Use clean tarpaulin sheet to avoid cross contamination by vehicle.
- The collected grass should be cleaned and sorted free from insects and weeds.

Storage

- Store in properly constructed shed and avoid heaping in open dusty area.
- Grass collected from designated area should be kept separately.

Distillation

- Arrange and set up the distillation units in convenient place where there is continuous flow of clean water.
- The distillation equipments have to be washed properly to avoid contamination and keep in safe place after the season.
- The extraction of oil is done through steam distillation process (continuous heat and water is required).
- Lemon grass oil should have a minimum citral content of 60% to meet the required quality.
- The oil obtained should be stored in a safe and clean container preferably made of a non-corrosive material such as glass, steel, iron, etc.

Packaging and Labelling

The distilled oil can be stored in clean glass bottles (preferably brown color) or containers made up of stainless steel or aluminium or galvanized iron, depending upon the quantity of oil to be stored. The oil filled up in the containers should be kept away from direct

heat and sunlight in cool/shaded places. Properly label the organically produced oil mentioning the name of a CF/NWFP group, gewog/dzongkhag with contact number.

Advocacy on Organic Practices and Bringing Lemongrass growing areas under Organic Management

- Trainings on the specifications and requirements of the Bhutan Organic Standards (BOS) should be given to CF and NWFP Management Group Members.
- The lemongrass growing areas will be brought under organic management through registration with the National Organic Programme.
- These areas will then be brought under organic certification either locally or under international standards to certify the lemon grass growing in these areas as organic.

SECTION FOUR:

PACKAGE OF ORGANIC PRACTICES FOR LIVESTOCK COMMODITIES

1. RAINBOW TROUT

(*Onchorhyncus mykiss*)

Trout (Photo courtesy: Jimmy Jacobs, 2018)

Introduction

Rainbow trout farming in Bhutan is a new practice and is still under promotion. Scientifically, *Onchorhyncus mykiss* or locally called trout is a cold, fresh water fish under the family Salmonidae. Rainbow trout thrives well in fresh and perennial water within the water temperature of 12-25°C. The potential rearing areas of trout ranges from 1,200 maslto 4,000 masl and is feasible in Punakha, Wangdue, Tsirang and some parts of Samtse and Dagana. Currently, rainbow trout is cultured at government farm under the Department of Livestock (DoL), Haa Dzongkhag.

Conversion

The rainbow trout was introduced under aquaculture system and hence there is no need for conversion/transition period. Since, rainbow trout is not released in the fresh natural water bodies like brown trout, conversion of rearing system for rainbow trout is not required.

Breed/ Strains

The Trout Breeding Centre (TBC), Haa, currently maintains the following two strains of rainbow trout, and are available for farming:

- Sterile: for breeding purpose
- Non-sterile: for table purpose

Fingerling Production

The TBC at Haa produces and supplies trout fingerlings. The fingerlings weigh approximately 25-30g when supplied to the farmers (2nd stage of life). Currently, the centre produces and supplies fingerlings capable of producing about a total of 5 MT table fish annually.

Support from National Research Centre for Riverine and Lake Fisheries,Regional Livestock Development NRCRLF, RLDCs) and Dzongkhags on organic trout production

Besides, fingerling (fish seed) production, the TBC also provide technical support and liaise with RLDCs/dzongkhag for site identification and feasibility study for establishing trout farms. The centre also provides training to interested farmers on trout production/ farming.

Infrastructure Requirement for Trout Farming

The quality of water has a major influence on the growth of rainbow trout. Unlike, warm water fish culture, rearing of trout in the earthen pond is not feasible since water quality cannot be maintained. Therefore, rectangular series type raceway is preferred for trout rearing. The details are as given in Table 23. Rivers that are clean and do not carry industrial pollutants and sewage wastes are utilized for production of organic trout.

Table 23. Raceways specification for trout production ≤1 MT per harvest.

Sl. No	Fish Production Analysis	Production Capacity (<1 MT)
1	No. of Raceways	1
2	Actual Volume of Raceways (20m*2m*1.3m)	52
3	Water Volume of Raceways (20m*2m*1m)	40
4	Total Water Volume (cu.m) in Raceways(s)	40
5	Stocking Density (No./cu.m)	80
6	Fingerling Required (Nos.)	3200
7	Average weight of fingerling when stocked	0.03
8	Rearing Mortality (%)	20
9	Average Individual Weight at Harvest (kg)	0.250
10	Expected Biomass at Harvest (kg/cu.m)@ 20% rearing mortality and 0.250 as average individual weight at harvest	16.00
11	Expected Production (kg)	640

Fish Raceways

Although the concrete raceways are expensive, they are indispensable. Different sizes of raceways can be designed for different production capacities as required by the farmers/individuals/ entrepreneurs. The recommended fish pond sizes and the rearing condition are seen in the picture below.

Figure 4: **Typical Raceways in Haa Fishery**

Trout Nutrition

For the trout production to be organic, the trout feed has to be organic. Therefore, organic feed production is essential and indispensable. The feed for trout needs to be organically produced or sourced/procured from a certified producer. The feeding regime and nutrition requirement specification for rainbow trout should be followed as given below (Tables 24 and 25).

Table 24: Feeding regime of rainbow trout

Sl. No.	Feed Category	Size	Fish age	Feeding rate (%BW)	Remarks
1	Starter (powder)	0.1- 0.5 mm	1-6 months	4-5%	These stages is reared at NRCR&LF, Haa
2	Fingerling (pellet)	Crumbs (0.6-1mm)	7-12 months	2-3 %	
3	Grower (pellet)	2-4 mm	14-18 months	2 %	Handed over to farmer for table fish production
4	Finisher/Broods (pellet)	5-8 mm	2-5 years	1 %	Broodstock maintained with NR-CRLF, Haa

***Body Weight**

Table 25: Nutrient requirement for Cold Water Carnivorous Fish (trout)

Nutrient	Fry	Fingerling	Production
DE (kcal/kg)	3100	3100	2800
CP (%)	42	40	35
Lysine (%)	2.96	2.78	2.66
Meth (%)	1.5	1.20	1.87
Ca (%)	0.8	0.9	1.0
Available P (%)	0.7	0.80	0.8
Lipids %	8	5	5
Ascorbic acid (g/100 kg)	24	24	24

Source: NRC, 1995. Bhutan Standards for Animal Feeds, 2017

Fish Health Management

Precaution to keep the fish farm free of diseases is of utmost important to ensure fish welfare and their productivity. Occasional incidence of fin rot is experienced by rainbow trout which is a secondary bacterial infection caused by cannibalism (nutritional disorder post breeding). Isolation and treatment using brine (salt) solution is found effective and recommended. On the other hand, stringent measures should be put in place to prevent any outbreak of fish infections through construction of separate rooms for equipment, fishing gears, medicines, changing rooms for workers. However, no antibiotics, anthelmintics and other chemicals shall be used in the trout farm.

Post Production

The trout rearing period extends from 12 to 14 months, and when the fish attends 250 to 300g the trouts are harvested. The fishes are hand-collected from the raceways. Use of approved materials (BOS, Section 9) for collecting trout is recommended while harvesting, processing and storage to maintain the organic status.

Bio-Security

The organic trout farm must have stringent bio-security to prevent spread of diseases. However, use of unapproved chemicals as foot-dip, disinfectants, etc. shall be avoided as per the BOS.

SECTION FIVE:

PACKAGE OF ORGANIC PRACTICES FOR ORGANIC INPUTS PRODUCTIONS

1. ORGANIC SEED PRODUCTION

Introduction

To support organic agriculture development, availability of organic seeds is crucial as it is the key to organic crop production. Organic production of seeds and seedlings of cereals, oilseeds,legumes,vegetables and fruit plants following the organic package of practices can be undertaken with the available natural resources in the country in landscape mode. The organic certified dzongkhag like Gasa, organic cluster villages or organic farms, Agriculture Research and Development Centres(ARDCs) and National Seed Centre(NSC) can be targeted for organic seed production for above listed commodities.

The production areas have to be registered and certified as organic farm by the authorized agency (Bhutan Agriculture Food Regulatory Authority) as per the Bhutan Organic Standard. The crops chosen for seed production should be primarily based on the annual demand of the country, clients, production potential and have high economic value and presence of pristine environment and available local practices.

The crops chosen for seed production should be usually local varieties,land races and Open Pollinated Varieties.

The package of practice describesthe general activities and methods to be followed for certified organic seed production of identified organic commodities by RSGs, individual farmers and any private entrepreneurs. For more precise and commodity specificrequirements,OrganicPackage of Practices of identified crops must be followed for successful organic seed production.

Land Requirement

- The land used for seed production should be chosen as per the climatic conditions and crop suitability.
- Land should be organically managed.
- The area or soil should be virgin or new site or should not have been cultivated with the same crops in the previous season unless they are of the known varieties and cultivars to avoid seed mixture due to volunteer plants.
- Avoid low lying land to avoid water contamination from other conventional farming.
- The seed plot should not be burnt of any crop debris as it destroys the beneficial microbes. The uprooted stubbles and debris should be burnt outside the seed field or plot.

- The field should be deep ploughed and exposed to sun for sterilization and finally developed into fine tilt.
- Well decomposed FYM and compost should be applied during the land preparation.

Risk and Contamination

For seed production, there are chances of contamination of seed plots due to pollen flow and spraying activities from the conventional plots. Therefore, it is important to maintain buffer zone or protect the seed plot.

- A buffer zone of adequate size and space should be maintained between conventional and organic seed plots.
- Wind barriers are useful to protect from contamination.
- Contamination can be prevented from spraying activities of conventional plot by scheduling spray activities when no strong winds are blowing.
- The equipment or implements used for organic management shall be thoroughly cleaned before use.

Cropping System

For seed production, the cropping pattern of respective organic sites can be followed which are currently practiced in the country. Some of the existing cropping patterns followed at the organic production sites are:

Some examples:

1. Millet-Buckwheat/Quinoa (Bongo and Chhukha)
2. Maize –Buckwheat (WangphuGewog)
3. Wheat/Barley-Buckwheat (High Altitude, Haa, Paro)
4. Maize-Vegetables
5. Vegetables-Vegetables
6. Rice- Wheat
7. Rice-Mustard
8. Maize-Green Legumes (beans)
9. Quinoa-Buckwheat
10. Maize + Ginger/Turmeric (Intercropping)
11. Maize + Soybean (Intercropping)
12. Maize + Potato (Intercropping)

Varieties

Any landraces, local varieties and improved OPVs can be taken up for organic seed production based on the yield potential, local and export demand. It is recommended that only notified varieties recommended by the Variety Release Committee (VRC) of the Department of Agriculture and subsequently approved by the National Seed Board (MoAF) can be used for seed production.

Hybrids and genetically modified crops, transgenic plants or plant materials are restricted for organic seed production.

Seed and planting material Source

To start organic seed production, the source ofseeds and planting materials will have to be obtained from the certified organic sources like National Seed Centre, ARDCs and organic farmers.In case of unavailability of organic seed and planting materials, untreated seeds from conventional farm could beused for first year.

Growing Season and Cultivation

Organic Package of Practice of respective commodities should be followed for seed production and Bhutan Organic Standard and Minimum Seed and Seedlings Quality Standardshave to be met.For successful seed production, the following activities have to be followed as per the crop specific organic package of practices:

Time and Method of seed sowing

For seed production, crops are sown as per the specific season like spring, summer and autumn. There are various methods of sowing and spacing of crop; certain depth of sowing, furrow sowing, broadcasting, line planting , recommended plant to plant and row to row spacing to maintain desired plant population per unit area for obtaining maximum yield and effectively manage pest and disease and in adopting mechanized harvesting. Therefore, it is essential to follow the right season, time and method of seed sowing as per the prescribed Organic Package of Practices of respective commodities.

Isolation Distance

For self- pollinated crops like quinoa, rice and wheat, isolation distance can be minimum 3-5 m and cross-pollination is minimum 5% which is acceptable whereas for cross-pollinated crops like maize, mustard, the isolation distance canbe more than 100 m (Table 26).

Table 26: Isolation distance for different crops

Crop	Isolation Distance(m)
Quinoa	3
Buckwheat	-
Asparagus	300
Beans	5
Cauliflower	1000
Chili	200

Therefore, to produce pure seed, follow recommended isolation distance as per crop species for maintaining seed purity and quality. Time isolation can also be done if distance isolation is not possible.

Roguing

Roguing is carried out at regular intervals of crop growth and normally two to three numbers of rouging are practiced in seed production plots. It helps in establishing pure and desirable healthy plant population for production of high quality seeds.Always follow recommended roguing at different stages of plant growth to remove off types, diseased and volunteer plants.

Pest, Disease and Weed Management

Management of pests, diseases and weeds are critical to ensure thatorganically produced seeds have high yield and quality. Weed can be managed through mulching, hand weeding coupled with mechanical cultivation. For mulching, leaves, bark, nut shells, weeds, grasses, wood chips, silage, paper, pine and conifer needles, paddy or wheat straw, rice husk, coir dust, saw dust, banana and sugarcane leaf trashes, etc, which are available in the locality can be used. Pests and diseases can be prevented, reduced and controlled by following recommended packages of practices of respective POP of organic commodities.

In organic agriculture the pests and diseases can be managed by cultural practices adopting suitable crop rotations, intercropping, planting trap crops and planting pests and diseases resistant and tolerant varieties and using a variety of plants (weeds) which have pesticide value and strong odourcan be used.

For e.g., we can use plants like *Parthenium, Lantana, Vitex, Eupatorium, Artemesia*andstinging nettle - 3 kg mixed with 3 kg cowdung and 20 L water to make organic formulation and spray to prevent varieties of pests.

Other pest repellents like *Artemisia* leaves, dollaychilli,garlic brew and marigold extract can be used. For preparation and method of application, please refer Training Manual of Organic Production Technology in Bhutan. We can also use various microbial bio-pesticides (bacterial, fungal and viral)like entomopathogenic viruses of baculovirus group, bacterial insecticides, particularly *Bacillus thuringiensis,*entomo-fungal pathogens, protozoans and insect parasitic nematodes to control important pests of crops.

Soil Fertility Management

For organic seed production, management of soil nutrients is very much crucial factor to determine the seed yield and quality of seed crops. Unlike conventional practices, the soil nutrients can be managed from various organic sources. Generally, green manure plants like dhaincha, sun hemp and other leguminous plants can be grown and ploughed to increase the soil fertility. Also green leaf manuring can be donewherein the green leaves, tender green twigs collected from shrubs and trees grown on bunds, waste lands and nearby forest are ploughed into the soil. The common shrubs and trees used are glyricidia (*Glyricidiamaculata*), subabool (*Leucanialeucocephalla*), *Acacia sp.,*etc, that are locally available in the production sites.

For organic farming in Bhutan we can use imported bio-fertilizers like *Rhizobium, Azospirillum*, *Azotobacter,* Phosphate solubilising bacteria (Phosphobacteria like *Bacillus polymyxa, Pseudomonas striata)* and fungi belonging to the genus *Penicillium sp*. and *Aspergillus sp*. possess the ability to transform the insoluble P to soluble forms by secreting organic acids. Phosphate solubilising microorganisms are recommended for all crops and can solubilise 20-30% of insoluble phosphate in the soil.

For soil fertility and nutrient management for specific seed production, follow the recommended package of practices of respective crops.

Water Management

The irrigation schedule of different seed crops have to be carried out as per the crops' specific critical irrigation requirement like during crown root initiation, booting stage, tillering and grain filling stages and following efficient water use methods. For different commodities, the critical water requirement varies, and therefore, follow the recommended water requirement or irrigation schedule as mentioned in the organic package of practices.

In addition, always ensure use of clean water free of industrial and surface contaminants and also do not use water flowing from/through the conventional fields. It is always advisable to follow drip irrigation system where ever applicable for better safety and water use efficiency.

Seed Processing, Storage and Supply

Seeds (raw seeds) should be harvested as per the physiological maturity of respective crops and care must be taken to avoid physical mixture. The crops should be separated / threshed without breaking and inducing mechanical injuries to the seeds and also avoid seed shattering bycutting at the stalk in the green stage and leave in the field for dryingand uniform maturity of seeds.

- First and foremost processing plant has to be certified as organic from the relevant authority (BAFRA).
- Raw seeds should be dried in sun, shade or mechanical dryer as per the prescribed moisture content (10 or less % depend upon crop types) for safe storage(Seed Potato should not be dried in the sun as tubers turn green due to poisonous chemical (Solanine). Dry potato tubers in shade, away from sunlight.)
- Seeds should be cleaned manually or with machines like winnower, gravity separator or sieve, hand picking (for bolder seeds) and should possess the prescribed quality standards.
- Once seeds are harvested, threshed and extracted, they should beevaluated to determine the physical purity. All seeds should be single units and all should be stored according to their individual temperature/humidity requirements.
- Seeds should be packed in bio-degradable, recyclable materials like cloth bags, paper bags, gunny bags , shredded paper , Moss and as per the following packing units and stored safely in the seed store.
    - Vegetable seeds: 5 g, 10 g and 50 g
    - Cereals seeds: 20 kg, 50 kg
    - Seed potatoes: 50 kg
    - Oilseeds: 5 kg
    - Seedlings: 10 plants bundle, 50 plants bundle, 100 plants bundle with prescribed number of pollinizer plants.
- Seeds store should be cleaned and disinfected with organic disinfectants.
- Organic seed and inorganic seeds cannot be stored in one store.
- Seeds are usually stored at 4-10 ℃ with 40-50 % RH.

Examples of seeds which cannot be stored for long period are corn, onion, parsley, chilli

Seeds lasting for 3-4 years are asparagus, beans, broccoli, carrot, celery, peas, spinach:

Long lasting seeds are cabbage, radish,cucumber, egg plant, lettuce, tomato .

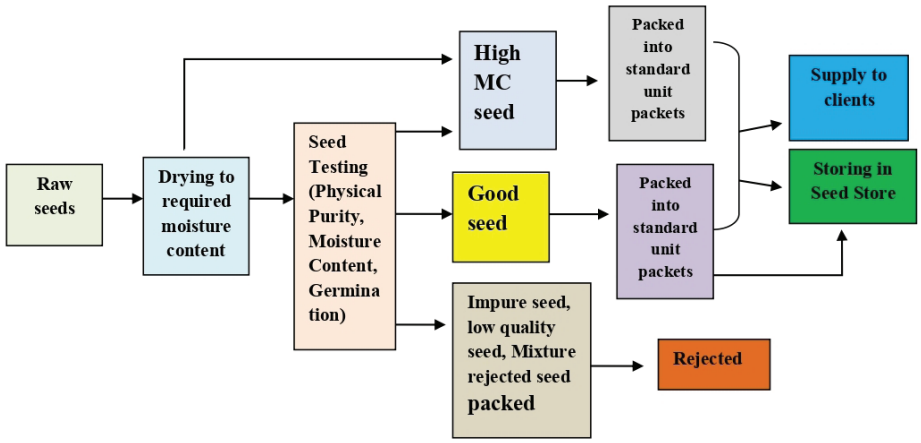

Figure 3: Flow chart of seed processing

Post Harvest Management

- Clean and dry seeds as per their specific moisture percent , and stack and store properly .
- Regular germination percentage of the seed lots have to be monitored for quality assurance.
- Check regularly for any damage due to storage pests like rodents and weevils.
- Pack seeds in biodegradable package and label as per BOS and Organic Seed Standardsand supply as per thedemand within the country and outside the country for export.

Seed Treatment

To protect the seeds from seed-borne disease, storage pest and diseases, seed treatment should be done with the materials from organic sources as per the prescribed dosages. Seed treatments also help optimize ease of handling and accuracy of planting in small seed and improve germination.Some of the organic seed treatment methods that can be practiced are as follows:

Seed Priming: It is the process of controlled hydration of seeds to a level that permits

pre-germination metabolic activity to proceed but prevent actual emergence of radical. In simple term, soaking of seeds in water and other organic solutions.

Table 27: Seed priming techniques for different crops

Sl.No.	Crop	Seed Priming Techniques
1	Tomato	Hydro Priming (48 hours)
2	Brinjal	Sand Matric 80% (3 days)
3	Chillies	Sand Matric 80% (3 days)
4	Onion	Sand Matric 80% (3 days)
5	Carrot	Hydro Priming (36 hours)
6	Beetroot	Hydro priming (12 hours)
7	Okra	Sand Matric 60% (3 hours)
8	Radish	Hydro priming (12 hours)
9	Mustard	Hydro priming (12 hours)

Pelleting

Seed pelleting is done using clay mixed with other inert materials, including soilsthatstreamlinethe size, shape and uniformity of small non-round seed like lettuce, carrot, onion, many herbs and flowers. Pelleting helps in more accurate mechanicalseed rate and uniform sowing enabling easy intercultural operation like weeding.

Hot water treatment

The use of hot water treatment is to eradicate seed-borne diseases, particularly those caused by plant pathogenic bacteria. While the technique does not work for large-seeded vegetable crops, it has proven effective for brassicas, carrots, tomatoes, peppers, and to a lesser degree, celery, lettuce, and spinach. The typical procedure consists of:

a. Warming the seed in37°C water.
b. Heating the seed for 20-25 minutes, depending on the crop species, in a 122°F water bath.
c. Cooling the seed for 5 minutes in cold water, and
d. Rapid drying. Precision in temperature and timing are important, as the seed embryo may be killed in hotter water or the disease incompletely eradicated in cooler water.

Table 28: Required temperature for Seed Treatment and treatment duration

Vegetable seed	Temperature (°F)	Duration of treatment (Min)
Broccoli	122	20
Kale	122	20
Mustards	122	20
Collards	122	20
Turnip	122	20
Cabbage	122	25
Cauliflower	122	20
Brussels sprouts	122	25
Pepper	122	25
Tomato	122	25
Eggplant	122	25
Carrot	122	20
Celery	122	30
Lettuce	118	30

SeedCertification

All seeds produced should be certified by the Authorized Agency based on the Bhutan Organic Standard and Minimum Seed Standards of Bhutan (MSSB) 2019as applicable for each specific seed crop before supply to the clients.

The minimum standards of the organic seeds are prescribed as per the specific requirement of crops based on MSSB (2019):

Table 28: The minimum standards of the organic seeds based on MSSB 2019

Crops	Germination Percent (min) (%)	Pure seed (min) (%)	Inert matter (max) (%)	Other crop seeds (max) (Nos/kg)	Other distinguishable varieties (maximum) (Nos/kg)	Weed seeds (max) (Nos/kg)	Moisture content (%)
Quinoa	80.0	97.0	3.0	20	-	20	12.0
Buckwheat							
Asparagus	70.0	96.0	4.0	10		10	8.0
Beans	75.0	98.0	2.0	Nil	10	Nil	9.0
Cauliflower	70.0	98.0	2.0	10	-	10	7.0
Chili	60	98.0	2.0	10	-	10	8.0

Asparagus Seedling Standards

i. The seedlings should be 12 to 18 months old.
ii. The seedlings should be at least 1ft in height above ground with 4-6 stems.
iii. The seedlings should have well developed root system (Crown with several large and well-formed buds) without any spots or off-colour blemishes.
iv. The seedlings should not show any evidence of freeze, injury, serious mechanical damage or pest and disease infestation.
v. Seedling roots and crown should not be dry.

Cardamom Rhizome Standard

Table 30: Rhizome standard for different cardamom varieties

Variety	Diameter of rhizome (mm)	Diameter of pseudo-stem (mm)	Height of the Planting slip (cm)	Nos. of pseudo-stems	Nos. of leaves/ pseudo-stem
Bharlange	30-75	5-17	25-110	1 and above	1 and above
Golsey	20-65	5-15	20-100	1 and above	1 and above
Sawhney	30-75	5-15	25-100	1 and above	1 and above
Ramsey	30-75	5-17	25-110	1 and above	1 and above

TurmericRhizome Standard

Table 31: Turmeric rhizome parameters for certification.

Parameter	Certified
Appearance	healthy& turgid
Uniformity (Minimum)	85.0%
Dry rot (Maximum)	5.0%
Scales (Maximum)	5.0%
Mealy bugs (Maximum)	5.0%

Note:

i. In a seed lot, rhizomes not conforming to specific characteristics of a variety shall not exceed 0.5% and 1.0% (by number – maximum) for foundation and certified seed classes, respectively.
ii. The seed material shall be reasonably clean, healthy and firm.
iii. Cut, bruised, or those damaged by insects shall not exceed more than 1.0% (by weight).

Ginger Rhizome Standard

Table 32: Ginger rhizome parameters for certification

Parameter	Certified
Appearance	healthy & turgid
Uniformity (Minimum)	85.0-95.0%
Dry rot (Maximum)	5.0%
Phyllosticta (Maximum)	10.0%
Scales (Maximum)	5.0%
Mealy bugs (Maximum)	5.0%

Note:

i. In a seed lot, rhizomes not conforming to specific characteristics of a variety shall not exceed 0.5% and 1.0% (by number – maximum) for foundation and certified seed classes, respectively.
ii. The seed material shall be reasonably clean, healthy and firm.
iii. Cut, bruised, or those damaged by insects shall not exceed more than 1.0% (by weight)

General seed standards for fruit crops and planting materials:

- The seedlings should have strong and well established root system without any deformities.
- The stem diameter of the planting material should be at least 10-15 mm above the graft / bud union.
- The height of the seedlings should be 0.6-1m from the first lateral roots.
- The height of the grafted planting materials should be at least 0.6-0.8 m from the first lateral roots.
- The graft union must be at least 10-15 cm from the first lateral roots.
- The planting material should have straight trunk.
- The seedlings/grafted planting materials should be free from visible pests and diseases.
- The planting materials should be treated with appropriate insecticide and fungicide prior to distribution.
- The planting materials should be raised from notified/released varieties and properly labelled.
- The graft union should be properly established and grafting tapes should be removed once proper union if formed.

2. ORGANIC TROUT FEED PRODUCTION

Introduction

Production of organic trout entails requirement of organic feeds. In Bhutan, organic trout feeds can be produced using raw materials which would have beenorganically produced. They are wheat/barley (bulk components/raw materials), fish meal, fish oil (floating agent), vitamins, trace minerals and essential amino acids. The feeds for different categories of trout shall be formulated according to their nutrient requirements and as provided in the "Bhutan Standards for Animal Feeds" of the Department of Livestock (Table 33).

Table 33: Nutrient requirement for Cold Water Carnivorous Fish (trout)

Nutrient	Fry	Fingerling	Production
DE (kcal/kg)	3100	3100	2800
CP (%)	42	40	35
Lysine (%)	2.96	2.78	2.66
Meth (%)	1.5	1.20	1.87
Ca (%)	0.8	0.9	1.0
Available P (%)	0.7	0.80	0.8
Lipids %	8	5	5
Ascorbic acid (g/100 kg)	24	24	24

Source: NRC (1995). Bhutan Standards for Animal Feeds, 2017

Electricity, waterand other infrastructure requirements

Operation of feed mill machineries requires supply of three phase electricity and hence it is necessary to install this provision in the proposed establishment. Water is also required in the feed plant for the steaming and other purpose. Road Access is also necessary for the transportation of raw materials and feeds. On the other hand, the location of the feed mill should be at least about 200 m away from the town or human settlement for maintaining proper bio-security of the feed mill.

Mill house

The size of the mill house will depend on the production capacity of feed plant. Currently, there is less demand for trout feeds since there are only few trout farms. Hence, a small-

scale feed mill 200 kg/hrwill be adequate to supply trout feed for the next 5-10 years. For a small -scale feed plant, the mill house would externally measure 25 m (length), 10 m (width) and 12 m (height) to accommodate the required machineries, raw materials and the finished products. The mill house can be a concrete structure made of stones, wood, bricks and cement. The floor plan of the mill house is provided in annexure II. The house should be constructed in such a way that there is good ventilation, adequate light and minimum possible rodent infestation and contamination. The CGI sheets would be used for roofing the house. The site development should be done in such a manner that the incoming ingredients and the outgoing finished feeds are conveniently handled and transported. The house could also serve as the store for the ingredient and the finished feeds.

Machineries and equipment

The list of machineries required for operating a small -scale feed mill is given in the Table 2. The machineries include hammer mill (grinder), bucket elevators, weighing balances, storage bins, mixers (horizontal or vertical), extrusion equipment, bag sewing machines, motors of different capacities and an electrical control panel. Other accessories such as trolleys, bag hooks and other safety gears may also be made available.

Table 34: List of machineries required for feed production

Sl. No.	Equipment Details	Capacity	Quantity	Amount (Nu.)
1	Hammer Mill	200 kg /hr	1	
2	Elevator	-	2	
3	Weighing Balance	100 kg	2	
4	Storage Mixer Bin	200 kg	1	
5	Mixer (Horizontal/vertical)	200 kg	1	
5	Bag sewing Machine	-	2	
6	Motor	5 to 25 HP	4	
7	Electrical control panel	3 phase	1	
8	Extrusion machine	200 kg/hr	1	

Sourcing of raw materials

Thetwo major raw materials for trout feed production are wheat/barley and fish meal. All raw materials should be procured from organic sources within or outside the country. The list of raw materials for trout feed production is given in the Table 35.

Table 35: Raw materials for trout feed production

Feed Type	Raw materials/ ingredients	Source
Energy feeds	Wheat and barley	Domestic (organically produced)
Protein Feeds	Fish meal, fish oil, soybean meal (expeller),	From India
Trace minerals and vitamins	Trace minerals, mineral-vitamin premixes and vitamins	From India
Feed binders	Sodium alginate	From India

Feed processing/milling

Appropriate organic protocols should be followed while processing the feeds organically. The machines and equipment should be cleaned before processing the feed to ensure the machines and equipment free of any chemical contaminants while the use of any chemicals should be avoided. Strict bio-security measures should also be implemented to avoid any contamination of feeds.

Feed formulation and feeding regimes for rainbow trout

The feeds should be formulated and manufactured to fulfill the nutrient requirements of different category of fish (rainbow trout). Hence, the feed should confirm to the nutrient requirement specifications for trout mentioned in the "Bhutan Standards for Animal Feeds" Department of Livestock (Table 33).

The feeding system of trout is different from other livestock species and their feeding regime is given in the Table 36. Since the digestive system of early fry is not developed, exclusive feeding of fish meal or along with earthworm is recommended.

Table 36: Feeding regime of rainbow trout

Life stage	Fish size (g)	Feed type	Feed size (mm)	Feeding rate (% body weight)	Feeding frequency (no./ day)
Fry	0.3–1.0	Crumble	0.3–0.7	5	10
Fingerling	1.0–25.0	Pellet	0.7–2.0	3	4
Grower	25–1 500	Pellet	2.0–4.5	2	2
Brood stock	>1 500	Pellet	5	1.5	2

Source: FAO, 2019. Aquaculture Feed and Fertilizer Resources Information System.

Post production, storage and transportation of feeds

Proper handling of feeds is necessary to avoid degeneration of quality. The feeds should be stored in a cool and dry environment using pellets. Direct sunlight should be avoided during storage.Further, feeds should be protected from rain/moisture to avoid molding and rancidity during transportation.

Raw material production

Barley and wheat are two cereals suitable for trout feed production which could be produced domestically. Accordingly, if these cereals are to be produced organically in the country, the following organic protocols/guidelines should be followed (Annexure I):

Annexure I: Organic production of wheat/barley

Approach: Landscape approach (involve whole chiwog/village)

Cropping System:(Barley/Wheat -Quinoa)

Source of Seeds/planting materials: Registered/relevant Seed Producers/National Seed Centre

Varieties: Local /traditional varieties and others as recommended/released by DoA

Seed Type: Organic / traditional (produced naturally where chemical fertilizers and pesticides are not used)

Important features of Wheat and Barley

Parameters	Early	Late	Quinoa
Duration (Days)	150 days (sown in February, *Dwarf type*)	190 days (sown by October end/ early November)	
Yield under organic condition (kg/acre)	300-400 kg/acre	400-500 kg/acre	

Cultural practices of wheat and barley production

Seed rate (kg/acre)	40-45 kg/acre		
Land preparation	Well ploughed, finely prepared		
Seed treatment using bio-inputs	Optional		
Sowing/ planting	Broadcast (preferred)		
Fertilizer application	FYM and other organic fertilizers	2-3 tractor loads per acre	Local preparation of organic fertilizers may be explored
Weeding	Hand weeding where necessary		
Irrigation	No irrigation since it is rain-fed		

Pest and disease control	Rust	Bio-pesticides if available	
Post production mgt.	Normal sun drying and de-hulling, packaging		

REFERENCE

FAO, 2011. *Quinoa: An ancient crop to contribute to world food security*. Food and Agriculture Organization, Regional Office for Latin America and the Caribbean. July 2011.

Katwal, T.B, Wangdi, N. and Giri, P.L.(2018).*Adaptation of Quinoa in Bhutanese Cropping Systems.* Bhutan Journal of Agriculture. Issue II Volume I. In Press . Department of Agriculture, Ministry of Agriculture and Forest.

Katwal, T.B. (2018). *Quinoa. General Information and Package of Practices,* 2018. Field Crops Program, Research and Development Center, Yuispang. Department of Agriculture, Ministry of Agriculture and Forests, Thimphu.

Katwal, T.B. (2013). *Popularizing Multiple Cropping Innovations as a Means to Raise Crop Productivity and Farm Income in Bhutan.In Popularizing Multiple Cropping Innovations as a means to Raise Crop Productivity and Farm Income in SAARC Countries. Eds. Musa, M., Azad, A.K and Gurung, T. (2013)*. SAARC Agriculture Centre, Dhaka, Bangladesh.

Atlantic Provinces Agriculture Services Co-ordinating Committee. (n.d.). *Vegetable crops production guide for the Atlantic Provinces.* Advisory Committee on Vegetable Crops.

Ministry of Agriculture and Forest. (2009). *Vegetable production guideline for home gardeners.* Horticulture Division, DoA.

Ministry of Agriculture and Forest. (n.d.). *Organic asparagus production training manual*. Yusipang, Thimphu: National Organic Program.

Thapa. L. (2019). *Asparagus production*.

Vincent, A., Fritz., Carl, J., Rosen., William, D., Hutchison., Terry, N. (2013). Asparagus production guide. *Agriculture, Food and Natural Resources. University of Minnesota Extension*.

Seaman, Abby, Editor. (2016). *Production guide for organic beans for processing*. Publisher: New York State Integrated Pest Management Program, Cornell University (New York State Agricultural Experiment Station, Geneva,NY). 50 pages.

Khatiwada, P. P., Chofil, P., Joshi, S. R., Bhuchar, S., Samdrup, T. (2017). *Package of practices for climate resilient value chains development of selected vegetable crops and ginger in Barshong, Bhutan.*

ICIMOD Manual 2017/9. Kathmandu: ICIMOD.

Chandra, K. (2005). *Organic manures*. Hebbal, Banglaore-24. Regional Centre of Organic Farming

ICAR-Indian Institute of Farming Systems Research. (n.d.). *Package of practices for*

organic production of crops and cropping systems. Modipuram, Meerut-250 110 (UP). ICAR-Network Project Organic Farming.

Ministry of Agriculture and Forest. (2012). *Training manual: organic production technologies in Bhutan.* Thimphu. National Organic Programme.

Chandra, K. (2005). *Organic* Chandra, K. (2005). *Organic manures*. Hebbal, Banglaore-24. Regional Centre of Organic Farming

Dass, H., Yadav, A. K., & Singh, Y. P. (2015). *Cultivating organic vegetables: Package of Practices*, pp 292, Westville Publishing House, New Delhi.

Entomology unit. (n.d.). *Chilli pod borer (Helicoverpa armigera)* [Ento,Leaflet 4]. Simtokha, Thimphu: National Plant Protection Centre.

DoA. 2018. *Large Cardamom Cultivation Manual*. Medicinal, Aromatic Plants and Spices Program, Agriculture Production Division, Department of Agriculture, Ministry of Agriculture and Forests, Thimphu. United Printing Press, Thimphu Bhutan.

ICCOA. (N.D). *Organic Package of Practices for Large cardamom.* International Competence Centre for Organic Agriculture (ICCOA), Banglore.

KIRAN. (N.D). *Cultivation of large cardamom in Sikkim*. Knowledge Innovation Repository of Agriculture in the North East.

Sharma, G., Joshi, S. R., Gurung, M. B., and Chilwal, H. C. (2017). *Package of Practices for promoting Climate Resilient Cardamom Value Chains in Nepal*, ICIMOD Manual 2017/3.

FAO and WHO. (2007). *Guidelines for the production, processing, labelling and marketing of organically produced foods.*Organically produced foods (3rd ed.). Codex Alimentarius Commission. Retrieved from http:// www.codexalimentarius.net.

FAO. (2019). *Ginger farming guide.GCP/RAS/296/JPN. Bangkok.*

ICAR. (2013). *Package of practices for organic production of important crops in NEH region.* ICAR Research Complex for NEH Region, Umiam, Meghalaya.

ICAR. (N.D). Package of practices for cultivation of ginger. Krishi Vigyan Kendra, Wokla, ICAR Research Complex for NEH Region, Nagaland.

Mawlong, M. (2017). *Ginger cultivation in Umroi, Ri Bhoi District, Meghalaya*.

IOSR Journal Of Humanities And Social Science, 22 (7), 36-45. Retrieved fromwww. iosrjournals.org.

NERCORMP. (2006). *Package of practices for organic cultivation of arecanut , ginger , large cardamom, passion fruit and pineapple.* Prepared by North Eastern Region Community Resource Management Project.

Purushottam P. Khatiwada,P.P., Chofil, P., Joshi, S. R., Bhuchar, S. and Samdrup, T. (2017). *Package of Practices for Climate Resilient Value Chains Development of Selected Vegetable Crops and Ginger in Barshong*, Bhutan, ICIMOD Manual 2017/9.

Rahman, H., Karuppaiyan, R., Kishore, H. and Denzongpa, R. (2009*). Traditional practices of ginger cultivation in Northeast India.* ICAR Research Complex for NEH Region, Sikkim Centre, Gangtok, Sikkim., Indian Journal of Traditional Knowledge, 8 (1), 23-28.

Rakesh, K. N., Dileep, N., Nawaz, A. S. N., Junaid, S. and Kekuda, T. R. P. (2013). *Antifungal activity of cow urine against fungal pathogens causing rhizome rot of ginger.*Environment & Ecology 31 (3) , 1241—1244. Retrieved from https://www.researchgate.net/publication/259345135_Antifungal_Activity_of_Cow_Urine_Against_Fungal_Pathogens_Causing_Rhizome_Rot_of_Ginger.

Yadgirwar,B.M., Pacharne, M. M., Rathod, S.D. and Shirke, M.S. (2017). *Study on package of practices adopted by ginger growers of Satara District*. International Journal of Chemical Studies; 5(6), 1282-1285.

Central Plantation Crop Research Institute (CPCRI). (1985). *Package of Practices for turmeric*. (Pamplet No.10). Kasargod, Kerala, India: CPCRI. Retrieved from http://14.139.158.118/docs/Frepub/pamphlet/pamphlet10%20turmeric.pdf

Jayashree E, Kandiannan K, Prasath D, Sasikumar B, Senthil Kumar CM, Srinivasan

V, Suseela Bhai R and Thankamani C. K. (2015). *Turmeric - Extension Pamphlet,* ICAR- Indian Institute of Spices Research, Kozhikode, Kerala.

Sharma, A., Rabi, K. and Pongen, I. (N.D). *Organic Production of Turmeric*. Krishi Vigyan Kendra Dimapur. ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Medziphema, Nagaland. Biotechnology led Organic Farming in North East Hill Region, print21, R. G. Baruah Road, Ambikagiri Nagar, Guwahati.

Diplock,N *(n.d).Mushroom Diseases in Bhutan. A guide to identiication and management*.National Mushroom Centre, Department of Agriculture, Ministry of Adriculture and Forests, Thimphu.

National Mushroom Centre(n.d). *Flowchart on Mushroom Diseases and Management*. Wangchutaba,Thimphu, Bhutan: Japanese experts, JICA Partnership Program.

National Mushroom Centre(n.d). *Mushroom cultivation manual* Wangchutaba,Thimphu: Japanese experts, JICA Partnership Program and staffs of NMC.

Dhungyel D. (2013). *Impact of Lemon Grass Harvesting, Distillation and Marketing on the Livelihood of Poor Farmers in Eastern Bhutan* - Journal of Renewable Natural Resources Bhutan 9 (2013) 141- 146.

FRDD. (2008) *Guidelines for resource assessment and management of lemongrass*. Thimphu: Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.

Plant Use. *(2016). *Cymbopogon Flexuosus (PROSEA)*.Retrieved from https://uses.plantnet-project.org/en/Cymbopogon_flexuosus_(PROSEA)

SFD (2011) *Interim framework for management and Marketing of Non Wood Forest product*. Thimphu: Department of Forests & park services, Ministry of Agriculture.

Yangzom, K., Krug, I. Tshomo, Setboonsarng, S. (2008) *Market-based Certification and Management of Non-Timber Forest Products in Bhutan:* Organic Lemongrass Oil, Poverty Reduction, and Environmental Sustainability - ADB Institute Discussion Paper No. 106.

Jacob, J. (2018). *Early Seasons Options for Rainbow Trout*. Retrieved from

https://www.gameandfishmag.com/editorial/early-season-options-for-rainbow-trout/191173