PACKAGE OF PRACTICES FOR FIELD AND HORTICULTURE CROPS OF BHUTAN

DEPARTMENT OF AGRICULTURE
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FOREWORD

The Department of Agriculture is pleased to publish the first edition of Package of Practices (PoP) for major Field and Horticulture Crops of Bhutan.

The Department of Agriculture has an important role in enhancing the food and nutrition security of the country. Efforts to facilitate and enhance agriculture production continue with adoption of policies and interventions in keeping with evolving circumstances. The growth in agriculture sector and the progress so far is a result of various interventions made by the Royal Government of Bhutan and its development partners.

However, we still continue to experience many challenges such as labour shortages, water scarcity and crop depredation by wild animals. Notwithstanding these, agriculture production has increased over the years. Bhutanese farming has transitioned from small scale subsistence farming to semi commercial and commercial farming. Strategies are implemented to efficiently utilize the limited resources in increasing current production and also to support key cross-sectorial thrust areas such as irrigation, farm mechanization, organic farming, agriculture enterprise development and land development. Our plans today are envisioned to be implemented holistically with an emphasis on commercial crops, and commercial crops are required to be grown in the right environment supported by appropriate farming practices. The Department of Agriculture has thus, compiled a package of practices for major field and horticulture crops including some of the widely grown medicinal and aromatic, and spices crops.

Let me take the opportunity to thank and congratulate all the commodity coordinators and commodity focals of the department for all their hard work and dedication in coming up with this publication. I hope the contents in this book will serve as a useful source of information and reference to all the readers representing different disciplines, particularly the youths wishing to take up farming as an enterprise. We hope the agronomic practices recommended in this PoP will guide our commercial farmers which eventually will contribute towards and enhanced food and nutritional security.

Tashi Delek.

Kinlay Tshering

DIRECTOR

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SECTION ONE

PACKAGE OF PRACTICES FOR FIELD CROPS

1. **Rice**

Background

Rice is the staple food for more than half of the world's population. In Bhutan, rice is the most important cereal crop which plays a critical role both at household and national food security. In terms of calorific value, rice constitutes at least 55 % of the daily dietary energy requirement of Bhutanese people. The annual per capita consumption of rice is estimated at 140 kg. The country is only 47 % self-sufficient in rice, while the remaining requirement is met from imports. Rice is produced in the following three main agro-ecosystems.

- The high altitude zone (1600-2600 m) with warm temperate climate, which accounts for 20 % of the total rice area, for example, Paro and Thimphu.
- The medium altitude zone of valleys and foothills (800-1600 masl) with dry sub-tropical and humid sub-tropical climate, which accounts for 45 % of the total rice area, for instance, Wangdue-Punakha valley, Tsirang and Dagana.
- The low altitude zone (below 800 masl) with wet sub-tropical climate, which accounts for 35 % of the total rice area, for example, Samtse and Sarpang.

Rice Varieties

We have 28 modern rice varieties for the entire rice growing areas of our country. Popular modern varieties are listed below.

High Altitude varieties	:	Yusirey Kaap1, Yusrey Kaap2, Yusirey Maap1, Yusirey Maap2, Khangma Maap, No 11, Jakar Rey Naab, Yusirey Kaap 3 and Yusirey Kathra-Mathra.
Mid Altitude varieties	:	Bajo Kaap1, Bajo Kaap2, Bajo Maap1, Bajo Maap2, IR 64, IR20913, Wengkhar Rey Kaap6, Wengkhar Rey Kaap1, Khangma Rey Kaap2, Wengkhar Kambja1 and Wengkhar Kambja2.
Low Altitude varieties	:	Bhur Rey Kaap1, Bhur Rey Kaap2, Bhur Kambja1, Bhur Kambja2, BR 153 and Sokha Rey

Climate

Rice is a crop of tropical climate. However, it is also grown successfully in humid to sub-humid regions under subtropical and temperate climate. Rice requires fairly high temperature, ranging from 20° to 37°C. The optimum temperature of 30°C during day time and 20°C during night time is more favorable for the development and growth of rice.

Soil

Rice can be grown under diverse soil conditions. Soils having good water retention capacity with good amount of clay and organic matter are ideal for rice cultivation. Clay or clay loams

are most suited for rice. Such soils are capable of holding water for long and sustain the crop. Rice plant can tolerate wide range of soil reactions, but it has a preference for slightly acidic soils. It grows well in soils having a pH range between 5.5 and 6.5.

Field preparation

Land or field preparation is one of the important factors that influences rice yields. It provides good physical, chemical, and biological conditions of the soil for optimum plant growth. Benefits of proper land preparation include:

- Water management: It is easier to manage water in the field where land preparation is properly done. Rice fields build a 'plough pan' from subsequent tilling operations which help to retain water in the field.
- Weed management: Land preparation is a good way of weed management. Tillage or ploughing considerably reduces weeds by killing germinating seeds.
- Land levelling: Field levelling is a key aim in land preparation which helps in water management, thereby controlling many weed species.
- Residue breakdown: Crop residues and weeds are broken down during land preparation which aids in decomposition of organic matter and adds fertility.

Steps for field preparation

- Pre-irrigate the field, if it is dry, before ploughing.
- Plough the field 20-25 cm deep using bullock-drawn implements, power tiller or tractor depending on land terrain and available farm resources. Ploughing exposes eggs of harmful insects, pests and seeds and rhizomes of weeds.
- Dig the corners of the field manually where the plough may not have reached. Also, get rid of the weeds and grasses from the bunds and walls which may later harbour rodents. Bunds should also be repaired for impounding water in the field.
- Flood the field thereafter and keep flooded or saturated for a few days. This will help in decomposition of crop and weed residues.
- Drain the water slightly and puddle the field using a rotovater or other implements as needed to break clods and ensure a fine soil tilth. Ideally, puddling should be done about two weeks before the date of transplanting. Puddling is an important operation for transplanted rice to create ideal growing conditions.
- Repair and maintenance of bunds and the incorporation of chemical fertilizers, if any, should be done before the final puddling.
- Level the field prior to transplanting using a mechanical leveller or wooden leveller. Land levelling improves water management which improves weed suppression and control, crop establishment, nutrient use efficiency, crop uniformity and maturation, drainage and ultimately rice yields.

Seed rate and sowing time

The optimum seed rate for rice in raising seedlings is 20-24 kg per acre (or 50-60 kg per ha) depending on the seed quality. Seed selection can be done using saline water. Put seeds in a bucket of saline water, stir the seeds and discard seeds that float on the surface.
Refer the following guide for nursery sowing in different areas:

- High altitudes (above 1600 masl): Mid-April to mid-May
- Mid altitudes (800-1600 masl) : May to mid-June
- Low altitudes (below 800 masl) : Whole of June

Nursery management

There are several methods of producing rice seedlings. Farmers in Bhutan, particularly in the high altitude zone, commonly practise dry-bed method where seeds are sown onto dry fields without beds and irrigation. Seed bed duration is long, up to 90 days. Wastage of land and seeds, weeds and blast are common problems using this method. Following are recommended methods for more efficient seedling production, depending on altitude, temperature and water availability.

i. Semi-dry bed method
ii. Wet bed method
iii. Tray method
iv. Poly tunnel method
v. Dapog method

Transplanting

Transplanting can be done manually or using a mechanical rice tranplanter. In Bhutan, transplanting is largely done manually, but some farmers in Paro, Wangdue and Punkaha also use rice trans-planters. Seedlings need to be raised in trays for machine transplanting.

Methods of transplanting

- Rice can be transplanted at random or in straight rows or lines. In Bhutan, random transplanting is the most common method, which requires less labour compared to planting in lines.
- Traditional or random method of transplanting can be adopted if the weed pressure is expected to be low, if herbicide such as Butachlor is intended to be used for weed control and where rice terraces are narrow and small.
- Avoid wide spacing in random transplanting. A plant density of 25-35 hills per square meters is optimum.
- Line planting is recommended where the aim is to control weeds using a rotary weeder. Line planting also enhances the attainment of an optimum plant population and facilitates weeding and other operations.
- Maintain row spacing of 20 cm and plant to plant spacing of 15-20 cm within the rows. Transplant 2-3 seedlings per hill at a depth of 2-3 cm.

- Increase the number of seedlings per hill if transplanting is delayed or if the seedlings are old to compensate for reduced tillering.
- There is no single spacing recommended for all varieties – it will depend on the variety, soil fertility and planting season.
- If a rice trans-planter is used, allow the mud to settle for a day before transplanting to avoid sinking of seedlings. Land preparation has to be thorough and seedlings need to be raised in trays.

Time of transplanting

The time of rice transplanting depends on the altitude and also the variety. Use the following guide for different rice growing zones.

- High altitudes (>1600 masl): Mid-May to mid-June
- Mid altitudes (800-1600 masl): June to July
- Low altitude (< 800 masl): July to early August

Weed management

Weeds are the worst competitors of rice plant. They compete for water, nutrients, sunlight and other growth requirements and hence reduces grain yields.

Recommendations

- Where weed pressure is expected to be low or moderate, 2 hand weeding at 20 and 40 days after transplanting are sufficient. It needs to be stressed that if hand weeding is to be done, plants should be close spaced and the first weeding performed not later than 30 days after transplanting.
- Concentrate on the use of line planting and rotary weeding where weed pressure is expected to be high. Two rotary weedings 20 and 40 days after planting are recommended.
- Where grass and sedge weeds are expected to be severe, Butachlor will be very effective. It should be applied at the rate of 10 -16 kg of 5 % granule "Punch" per acre 3-6 days after transplanting.
- Indirect or complementary weed control methods like good land preparation, proper water management, use of weed-free seedbeds and seeds should be emphasised.

Nutrient management

Rice requires a balanced supply of nutrients, water, air and sunlight to grow well. Nutrients can come from either organic or inorganic sources. Organic sources include biological nitrogen fixation sources such as green manures and blue green algae, compost and animal manures. Nutrient composition varies with the sources. Green manures such as *Sesbania aculeata* can accumulate 80–100 kg N/ha in 45–60 days of growth. The advantage of organic sources of nutrients is that they can provide a wide range of nutrients, whereas inorganic fertilizers only produce a single or few nutrients. Organic sources also provide "bulk" matters

that are important for soil organic matter. Soil fertility status is subject to change from one location to another and from one cropping season to the next. Ideally, analysis of soil would determine the nutrient requirements of a specific field but may not be possible all the time

Fertilizer recommendations

Based on the field experiments done by NSSC and present knowledge, the following fertilizer recommendations for rice are made:

- For local rice varieties, the general recommended rate is 30-20-8 kg NPK per acre.
- For improved rice varieties, the general recommended rate is 36-25-12 kg NPK per acre.
- However, fertilizer doses should be determined based on soil analysis results. NSSC provides free soil analysis services for farmers.
- Apply the entire dose of P and K as basal dressing during land preparation. If half the N is applied basally, top dress the remaining half at active tillering stage (20-35 days after transplanting) or after first hand weeding. Further splitting of N into equal doses at tillering and PI stage can improve rice yields.
- To improve soil structure and water retention capacity, use FYM or compost prior to or during land preparation. Generally, 2-3 tons of FYM per acre is recommended. Supplementing with N topdressing @ 14 kg per acre after 30-40 days of transplanting can lead to higher yields.
- Wherever possible, use green manures like *Sesbania aculeata* (Dhaincha) as a pre-rice manure. Sow dhaincha in April-May @ 20-25 kg/acre and incorporate in the soil after 6-8 weeks. Transplant rice after about 2 weeks of incorporation.

Water management

Water is a critical input for rice production. However, it is becoming increasingly scarce and expensive and it is important to find methods to reduce water consumption without compromising yields. Unlike the conventional thinking of our farmers, it is not necessary to keep the rice fields flooded all the time for higher yields. Recent research has shown that water use can be greatly reduced without affecting grain yield. Keeping rice fields moist or in field capacity saturation without standing water saves water. However, if the soil drops below field capacity saturation, yield potential can be reduced and weeds can compete more freely.

Irrigation methods

There are generally three types of irrigation and water management practices commonly followed, depending on water availability:

Continuous flooding with standing water: there is continuous water in the field at varying depths of 3-8 cm. It is practised where there is abundant and assured irrigation water.

Intermittent irrigation: It is also called alternate wetting and drying (AWD) method and involves applying water rapidly in sufficient quantities to the field from 4-7 days. This is then

stopped and water is completely depleted until the next irrigation period. It is common in water scarce areas where rotational water sharing is practised by farmers. Intermittent irrigation helps to reduce *shochum* pressure.

Rain fed water management: involves impounding rainwater in the field for irrigation, either directly or through a network of channels. This practice is influenced by the onset and withdrawal of monsoon and the amount of rainfall in the season.

- Water is most critical during land preparation, vegetative, reproductive and ripening stages of the rice crop. Land preparation requires a large amount of water.
- After transplanting keep the water level as minimum as possible for about 3-6 days until the seedlings recover.
- If drought occurs after the root establishment stage, rice plants can withstand the stress and resume normal growth as irrigation water is reapplied.
- Water level should be gradually increased as the crop grows ensuring adequate soil moisture from panicle initiation to dough stage. Flowering is the most critical stage when moisture stress should be avoided.
- It is beneficial to drain water at maximum tillering stage so that tiller formation is not hampered.
- Drain water from the field 10-15 days before harvest. This will ensure dry field conditions during harvesting and other operations.

Plant protection

Integrated management is recommended to manage pest and diseases which will minimize crop losses. The management should start from nursery till crop harvest. Constant field monitoring and surveillance is important for disease and pest management which will also help to determine the requirement of control measures. Integrated management includes good cultural practice and use of resistant varieties. Disease pathogens are mostly viruses, bacteria and fungi that are parasitic and live in or on rice plants which limit yield and affect grain quality. Their development depends on environmental factors such as temperature, humidity and light. Common diseases in the country and their management are described below.

Rice Blast (*Pyricularia oryzae* or *Magnaporthe grisea*)

Blast is one of the most important diseases of rice and it attacks all aboveground parts of the rice plant at any growth stages. In Bhutan leaf, node, neck and panicle blast are common. *Echinochloa* species are alternate host for blast.

Symptoms

- Leaf blast - the lesions are elliptical or spindle shaped with brown borders and white centres which enlarge and eventually kill the leaves [Pic (a) and (b)]**.**
- Collar blast - pathogen infects the collar that can kill the entire leaf blade [Pic (c)]
- Node blast -node turns blackish and breaks easily [Pic (d)]**.**

- Blast on the neck of the panicle - greyish brown lesion on the neck and the panicles break when severe [Pic (e)].
- No grain formation if disease occurs during flowering stage
- Brown lesions - on the branches of panicles and on the spikelets.

Favourable factors

- Cloudy and overcast skies, frequent rain, and drizzles favor the development of rice blast.
- Relative humidity of 90 % or higher and long duration of leaf wetness favours development of blast disease.
- The optimum temperature required for spores to germinate is 25-28°C.
- Excess amount of nitrogen fertilizer is conducive for blast development.

Cultural management

- Planting resistant varieties
- Proper management and sanitation of the field
- Proper crop residue management after the harvest
- Do not apply over dose of nitrogen fertilizer as it enhances the development of blast disease
- Apply balance dose of fertilizer
- Soak seeds in hot water at 55^0C for 1 hour.

Chemical

- Treat seed with solution of *Tricyclazole* @ 3g/1kg seed
- Spray *Tricyclazole* @ 1gm/1lit of water 1-2 times depending on the environmental condition. Use stickers like mustard oil or sandovit to prevent washing away of the chemicals due to rainfall.

Brown spot (*Helminthosporium oryzae*)

Brown spot is one of the common diseases of rice in poorer soils. Disease occurs both in the nursery and transplanted field. Infected seeds lower the grain quality and cause yield loss.

Symptom

- Fungus produces small, circular to oval, dark brown or purplish brown lesions about the size and shape of sesame seed. Sometimes the symptoms are similar to blast lesions in certain rice varieties
- Fully developed spots are brown with gray or whitish centers surrounded by a reddish brown margin
- Infected seedlings are stunted or killed
- Infected panicles are with brown spots
- It can infect roots and causes a black discoloration
- It may infect the glumes and grain causing dark brown to black oval spots causing a black discoloration**.**

Favourable factors

- High relative humidity (86-100 %), cloudy weather, and continuous temperature of 16-36°C
- Use of infected seeds, volunteer rice and rice debris
- The disease is common in nutrient-deficient soils and water stressed soil but rare on rice grown on fertile soils.

Cultural management

- Presoak seed before planting in cold water for 8 hours
- Hot water seed treatment (53-54°C) for 10-12 minutes is effective before sowing
- Proper management of straw and rice debris by burning or removing from the field
- Use resistant varieties
- Proper management of fertilizer by using silicon fertilizers (use e.g.- calcium silicate slag).

Chemical

- Seed treatment with captan, thiram, carbendazim, or mancozeb.
- If severe, spraying of mancozeb and tricyclazole at tillering and late booting stages.

Sheath blight *(Rhizoctonia solani)*

Symptom

- Irregular large spots on leaf sheath
- Small ovoid, water-soaked greenish-gray lesion near the water line
- Older lesions - elliptical or ovoid with a grayish white center and light brown to dark brown margin
- Severely infected plants produce poorly filled or empty grains, especially those on the lower portion of the panicles
- Rotting on the leaf sheath enclosing the young panicles.
- In cases of severe infection, the panicle may fail to emerge completely
- Panicles rot, and florets turn red-brown to dark brown and grains become sterile, shrivelled, partially or unfilled and discolored
- Whitish powdery growth may be found inside affected sheaths.

Favourable factors

- High Relative humidity and temperature (28-32°C) with high leaf wetness favours development of the disease.
- High nitrogen fertilizer
- Disease is soil borne and the pathogen can be spread through irrigation water along with soil and infected crop residues.

Cultural management

- Optimized Seeding rate or plant spacing to avoid closer plant spacing or dense crop growth

- Maintaining field sanitation by removing weeds, infected stubbles or crop residues

Chemical

- When severe, spray fungicides such as Carbendazim @ 0.5 g/1lit of water.

In Bhutan pre-harvest loss due to insect pests is estimated between 20-30 % and post-harvest losses due to storage pest is about 10-20 %. Ecological conditions in the low subtropical belt encourage development of pest incidences. Important insect pest are stem borer, leaf folder, case worm, rice bug and army worm.

Stem Borer (*Scirpophaga incertula*)

There are different types of stem borer such as white, yellow, purple, striped and dark-headed. These insects attack rice plants at tillering and ripening stages causing dead-hearts and white heads respectively.

Damage symptoms

- Cutting and drying of the central tiller during the vegetative stage (dead heart)
- Bore into the stem at reproductive stage leading to unfilled panicles (white head) which can be easily pulled from the base.

Favourable factors

- High nitrogen favours population build-up of the stem borers
- Infested stubbles that remain in the field act as source of infestation.

Cultural management

- Early planting avoids infestation
- Ploughing and flooding the field will control eggs, larvae and pupae from developing
- Harvest crop at ground level to remove the larva in stubble
- Grasshoppers, ants, birds and toads feed on the pest
- Pheromone traps will, attract the stem borer which can be collected and destroyed to reduce the population in next season.

Chemical

- When severe (10 % hills affected or 1 panicle/hill) or (4 egg masses/hill) spray insecticide such as Dimethoate 30 EC @ 1ml/ 1lit of water.

Rice Case worm (*Nymphula depunctalis*)

Rice case worm is found in irrigated and rainfed rice with standing water. The larvae are semi-aquatic which stay inside the case built from cutting of rice leaves. During severe cases it causes patches of defoliation resulting in stunted growth and death of plant.

Damage symptoms

- Cutting off leaf tips to make leaf cases
- Field looks whitish due to leaves scrapping

- Leaves look as if cut with a pair of scissors
- Older larvae are enclosed within the case and feed by scraping leaf tissues or biting through leaf sheaths
- Leaf cases can be found floating on water.

Favourable factors

- rice field with standing water
- transplanting young seedlings also favours pest infestation

Cultural management

- Avoid overcrowding and maintain wider spacing during transplanting
- Maintain proper drainage
- Cases can be destroyed by moving a rope or long stick on crop and collecting and destroying the larvae
- Spiders, dragonflies, and birds eat the adults.

Chemical

- When severe (>25% leaves damaged or 10 leaves/hill) spray insecticides such as Chlorpyrifos 20 EC @ 4ml/ 1lit of water.

Rice Leaf Folder (*Cnaphalocrocis medinalis*)

Leaf folders are common in the wet sub-tropical rice ecozone. There are three species of leaf folders. It infests at early crop stages and their damage does not cause significant yield loss. Crop generally recovers from this damage**.**

Damage symptoms

- Folds the leaves and stitch the leaves sides ways
- Translucent larvae remain inside the leaf fold and feed on green matter
- Distortion and whitening/yellowing of margins of young leaves
- Faecal matter present.

Favourable factors

- heavily fertilized fields
- high humidity and shady areas
- Presence of grassy weeds from rice fields and surrounding borders.

Cultural management

- Drain and dry field
- Flood and plough field after harvesting if possible
- Remove grassy weeds from fields and borders
- Reduce density of planting and use balanced fertilizer.

Chemical

- When severe (>25% leaves damaged or 10 leaves/hill) spray insecticide such as Chlorpyrifos 20 EC @ 4ml/ 1lit of water.

Army Worm (*Mythimna separata*)

Army worms occur mainly in the southern belt. Out breaks depend on periods of long dry spells during the rainy seasons. They can damage crops from seedling to grain ripening stages.

Damage symptoms

- Cutting off leaf tips, leaf margins, leaves and even the plants at the base
- Cutting off rice panicles from the base.

Favorable factors

- Periods of drought followed by heavy rains.

Cultural management

- Do not allow the field to be dry
- Grasshoppers, ants, birds and toads feed on the pest.

Chemical

- When severe (two damaged leaves/ m2) spray insecticide such as Malathion 50EC @ 2ml/ 1lit of water.

Rice Bug (*Leptocorisa acuta*)

Rice bugs infestation occurs during reproductive stages of plant development. It is one of the major pests in Bhutan. Slender and brown-green nymphs and adults feed on endosperm of rice grains during milky stage which causes empty grains.

Damage symptoms

- Feeding causes deformed or spotty grains at the soft or hard dough stage
- An odour is often emitted indicating their presence
- Feeding causes empty or small grains during the milking stage
- Grains become dark, deformed or spotty and erect panicles.

Favourable Factors

- Warm weather, overcast skies, and frequent drizzles presence of alternate hosts
- Weeds in and near the field.

Cultural management

- Grasshoppers, ants, birds and toads feed on the pest.
- Dried twig of *Artemisia vulgaris* (khempa shing) is burned to repel the insect
- Attract rice bugs to traps, baited with spoiled fish, decaying meat, or chicken manure.

Chemical

- When severe (> 2 bug or nymph/ hill) spray insecticide such as Malathion 50EC @ 2ml/ 1lit of water
- Spray with Cypermethrin 10 EC @0.5 ml/ 1lit of water

Harvesting

Harvest the crop when at least 85 % of the upper portion of the panicles turns golden yellow or straw coloured. The moisture content at harvest should at least be 20-25 %. Some leaves and stems may still be green at maturity particularly of improved varieties.

- Do not delay harvesting as grain shattering leads to yield loss and also affects milling quality.
- After harvesting, dry the crop for 3-4 days depending on weather condition.
- Threshing can be done using pedal thresher, machine or manually.

Post-harvest management

Post-production includes all operations starting from harvesting: cutting, field drying, stacking or piling, hauling or transporting, threshing, cleaning, drying, storage, milling, and grading. Correct timing of operations to manage grain moisture content is important shown in the table below.

Operation	Desired Moisture Content (%)	Primary Cause of Losses
Harvesting	20-25	Shattering if grain is too dry
Threshing	20-25 for mechanical threshing (varies slightly with variety) <20 % for manual threshing	Incomplete threshing, grain damage and cracking/breakage
Drying	Final moisture content is 14% or lower	Spoilage, fungal damage, discoloration, smell
Storing	<14% for grain storage <13% for seed storage <9% for long term seed preservation	Fungal, insect & rat damage, smell
Milling	14%	Grain cracking and breakage

Timely harvest and post-harvest operations should be done to avoid field losses due to shattering and also to maintain the grain quality of rice. Immediate threshing will reduce losses from birds, insects and rodents. Crop piling (2-4 days) after the harvest, will lead to grain discoloration, germination and spoilage due to mould development.

Seed production

Farmers avail seeds through two main supply systems: formal and informal. Formal seed system comprises the certified seeds supplied by government (research, extension, projects) and private agencies. However, the supply of seed in rural communities is normally met

through informal system whereby farmers save their own seed or exchange with another farmers.

2. Maize

Background

Maize is one of the most widely cultivated food crops in Bhutan. More than 69 % of the rural households grow maize. In Bhutan maize is cultivated in an area of 66,042 acres with a total production of 94,052 Mt and the average national yield is 1.42 Mt per ac. It is a major food crop cultivated widely in the six eastern districts accounting up to 45 % of the total maize area and over 57 % of the total production. Currently there are four released maize varieties in the country.

Variety	Breeding line(s)	Year of release	Yield MT/ac	Maturity (DAS)	Recommended agro-ecology (MASL)
Yangtsepa	Suwan 1	1992	1.2-1.6	120-130	<1800
Chaskarpa	ICA V 305 (Entry 38)	2012	2.81	180-185	1200-1800
Shaphangma Ashom	SO3TLYQAB05 (Entry 35)	2012	2.75	170-180	>1800
Bhur Ashom 1	Arun 4	2015	1.30	90-100	<1200

Climate

Maize has a wide adaptation and in Bhutan the cultivation ranges from 300 to 3000 masl. Maize environment can be categorized into three zones namely (i) sub tropical zone I (<1200 meter above sea level (masl)), (ii) sub-tropical zone II (1200-1800 masl) and (iii) highland zone III (>1800 masl). A moderate temperature, adequate moisture are the basic needs of Maize crop. Maize is susceptible to water logging condition, thus it should be avoided.

Soil

Maize requires a well-drained sandy loam soil with organic matter. It thrives well in soil pH between 5.5 to 8.0

Field Preparation and Manuring

Field preparation is one of the important factors that influence the maize yield. It provides good physical, chemical and biological conditions of the soil for optimum plant growth. Two ploughing is required few weeks ahead followed by final land preparation, break clods, remove weeds, and apply manures and fertilizers and do the final ploughing. It is recommended to apply FYM of 2-3 tones /acre to provide the nutrient requirements and to maintain and to improve the soil structures. For general dose of chemical fertilizer, apply 25

kg Urea, 100 kg SSP and 20 kg MoP per acre during the final land preparation. Apply additional amount of 15 kg Urea during the first weeding and if necessary top another 15 kg Urea during the second weeding.

Method of Planting

Time of Sowing: Follow normally sowing time like for the traditional varieties from February to March

Seed Rate: 12-15 kg per acre. Optimum plant population should be maintained by thinning at "knee high" stage of the crop.

Cultural Practices

Weed control: The interval between 25 -45 days after crop emergence is crucial because the crop and weed competition during the period is maximum. Therefore the first weeding should be done at about three weeks after crop emergence and second weeding at three to four weeks after first weeding depending upon the weed pressure.

Plant Protection

Gray Leaf Spot and Turcicum Leaf Blight

- Planting resistant varieties such as Chaskarpa and Shaphangma ashom
- Destroying the infected crop residues by burning or burying deep in soil while ploughing
- Crop rotation
- Spray systematic fungicide Tilt (active ingredient Propiconazole) @ 2 ml per litre of water with sandovit sticker @ 2 ml per litre of water. A minimum of one spray 3 weeks before flowering or at silking time or as soon as spots appear on lower leaves.

Head Smut and Ear rot

- Use clean seeds
- Collect the infected plants and burn it
- Avoid continuous maize cropping
- Select seeds from healthy cobs

Army worm

- Spray Cypermethrin at 1 ml/1 Litre water. Since the armyworm larvae usually feeds at night, the best time to spray is late in the day.

Harvesting

Maize is ready for harvesting even when the stacks and leaves are somewhat green but the husk cover has dried and turned brown. Shell maize when the moisture content ranges between 15-20 %. The maize ears should be preferably dried for 3-4 days after harvesting to improve grain recoveries and reduces breakage losses during shelling.

Seed Selection

Maize seed selection can be done when the crops are in the field and after the harvesting of the crop. For the selection in the field, use a ribbon or any thread available to tag the most preferred plant in terms of plant height, ear length, husk cover. Tag the most desired plant. Harvest the tagged plant separately for seed. For seed selection after harvesting, select the cob with tight husk cover, desirable cob size. Once the husk covers are removed, the two edges of the cobs are cut out and the centre part of the cob is used for seed. Dry the seed.

It is important to consider the following points for seed selection:

- The continuous usage of same seed over and over again will deteriorate the seed quality due to out-crossing with traditional maize. Farmers should be asked to change seed annually wherever possible.
- The varieties tend to show open husk covers which contributes to the incidence of ear rots. Farmers should strictly discard the cobs with open husk and should not select for seed
- Select good cobs with good husk cover
- While selecting seed, select over 1000- 1500 cobs. Dehusk and further select good ears. Reject those with ear rots, unfilled ears and ears with mixed grains. The selected ears can be hanged separately or shelled and grains should be stored good seed bins. Before storing grains or ears should be thoroughly. High grain moisture predisposes the infestation and the infection by storage pests and diseases. Similarly, before storing the produce, the store and the containers should be thoroughly cleaned to ensure safe storing. Lime at rate of 10 g/kg of seeds can be used to prevent insect-pest attack during storage.

3. Quinoa

Introduction

Quinoa (*Chenopodium quinoa* Willd.) is native to the Andes Mountains of Bolivia, Chile, and Peru . Quinoa is considered the world's healthiest food. Quinoa is highly valued for its high nutritional status. Quinoa has gained worldwide popularity and is rapidly spreading beyond its center of origin after the United Nations declared 2013 as the International Year of Quinoa. Quinoa is sometimes referred as a "pseudo-cereal" because it is a broadleaf non-legume that is grown for grain unlike most cereal grains which are grass family. It is similar in this respect to the pseudo-cereals such as buckwheat and amaranth.

Quinoa was introduced to Bhutan from Peru in 2015 by the Department of Agriculture (DoA) with the support of the Food and Agriculture Organization (FAO) of the United Nations. Quinoa is known for its high nutritional quality, genetic variability and versatility to adapt to adverse climate and soil conditions. Since Quinoa is an introduced exotic crop, the Ministry of Agriculture and Forests (MoAF) has given Bhutanese names in different local languages (Royal Quinoa, Ashi Heychum, Ashi Mo, Rani Bethu). In Bhutan the wild relative of Quinoa *Chenopodium album* is found abundantly as weed in the cultivated drylands.

Varieties

Of the 12 varieties evaluated four varieties are provisionally recommended for cultivation in Bhutan.

Provisionally recommended varieties

Variety	Origin	Plant Height (cm)	Maturity (Days)	Grain Colour	Yield Kg /acre
Amarilla Marangani	Peru	188	173	Yellow	750
Amarilla Saccaca	Peru	165	170	Yellow	900
Ivory 123	India	122	150	Brownish	900
DoA-1-PMB-2015	Unknown	120	140	Brownish	750

Recommended varieties

- For high altitude areas above 1200 masl Amarilla Marangani and Amarilla Saccaca are more suitable
- Amarilla Marangani and Amarilla Saccaca have interrelated genetic base and are very similar
- For areas below 1200 masl Indian variety Ivory123 and DoA-1-PMB-2015 is more suitable
- For autumn planting after harvest of potato in areas above 1200 masl aslIvory123 and DoA-1-PMB-2015 are recommended

Climate

Quinoa is a versatile crop and can adapt to different types of climate. It can adapt under desert, warm and dry, cold and dry, temperate and rainy, temperate with high relative humidity and high mountain areas. There are varieties or ecotypes adapted to each climate.

Soil

Quinoa grows best in loam soil with good drainage and high organic matter, with moderate slopes and average nutrient content. It prefers neutral soils although it is usually grown on alkaline (up to pH 9) and acid soils (up to pH 4.5).

Seed rate

Quinoa seed is very small in size and is similar to millet. Seed rates vary depending on the method of planting. When Quinoa is sown in line or rows the seed rate is lower. The general recommended seed rate for Quinoa is 3-4 Kg per acre. A higher seed rate should be used to get good crop stand which can be maintained later through thinning.

Sowing time

The time of sowing is very critical to obtain good yield. Sowing time depends on a specific location and only general recommendations are made .

General sowing time for different agro-ecological zones

Altitude (masl)	Predominant Farming System	Sowing Time	Remarks
2600 -3600	Livestock & Barley, wheat or Potato Based	Mid April - Mid May	Main Crop
1800 -2600	Potato Based	Mid March - Mid April	Main crop
1200 -1800	Maize Based	Mid July - Mid August	After Maize
< 1200	Maize & Rice Based	October - November	After Maize and Rice

Field preparation

The field preparation methods for Quinoa are very similar to that for mustard and wheat. When power tiller is used first ploughing followed by soil pulverization with rotovator is sufficient. When bullocks are used first ploughing followed by a second ploughing and then levelling with locally made leveller is very important to prepare a good seed bed. Since Quinoa seed is very small in size, soil clods should be thoroughly broken to make the soil fine for good seed germination. Quinoa requires a levelled field, well-drained seedbed in order to avoid water logging.

Sowing method

Quinoa can be sown in line and broadcasted like mustard, however, line sowing is recommended for easy weed control and other intercultural operations like earthing up and thinning. The recommended spacing between the rows is 50-60 cm and the plant to plant spacing should be maintained at 10-15 cm by thinning. For line sowing there is no need to use a rope or a string. Like in the case of potatoes, line can be drawn with the help of a spade by approximately keeping a space of 50-60 cm or 2 feet between the two lines. A shallow broad furrow of 2-3 cm depth should be marked with a spade and Quinoa should be evenly broadcasted on the marked furrow. After the seed is broadcasted it should be covered by the soil with the help of a hard broom. The sowing depth is 2-3 cm.

When plants germinate and attain the height of 10-15 cm, thinning should be done to maintain a good plant population.

Fertilizer

Our experiences in cultivating this crop and studies from other countries indicate that Quinoa is highly responsive to mineral fertilizers. Use of sufficient quantity of Farm Yard Manure (FYM) ensures higher grain yield. It is recommended that light application of well rotten FYM in the furrows immediately after the seeding gives good seed germination as it helps the conservation of soil moisture.

Weed control

This is a very critical operation for a successful harvest. Weed control in Quinoa field is difficult since plants grow slowly during the first two weeks after emergence. Competition from weeds is greater when Quinoa is planted later in the growing season. Two to three hand weeding will be necessary for good crop growth and weed management. Sowing seeds in line makes hand weeding easy and facilitates the use of hand tools. During the weeding operations, the soil in between the furrows should be loosened with spade for good weed control and growth of the crop

Pest and disease

Four major pest incidence observed on Quinoa cropin Bhutan are Leaf miner (*Bedellia somnulentella*), Armyworm (*Spodoptera frugiperda*), Aphid (*Myzus persicae*) and Locust (*Shistocerca gregaria*). The larvae and the insect feed on the foliage and severely defoliating the plant. The problem is more severe in the lower elevations below 1500 masl . Leaf miner and army worm can be controlled by spraying the recommended insecticide available at the National Plant Protection Center (NPPC) before the initiation of panicles. Besides insect attack, severe lodging of crop has been observed in many locations. In the lower elevations windstorm causes crop lodging while in the high elevations heavy monsoon rains predispose the crop to stalk lodging.

Harvesting

The maturity of the crop depends on variety and location. In the high altitude areas above 1200 masl , short duration varieties takes 120 to 150 days to mature while the longer duration varieties mature in 170-180 days. In the warm areas below 1200 masl , the crop matures much faster. Quinoa is ready for harvest when its leaves turn yellow or red depending on the variety, the leaves on the panicles dry and the grains can be seen in the panicle. Another method to judge the crop for harvest is to tap the panicle with the hand, if the grains drop on gentle tapping the crop is ready for harvesting. When the crop is ready, the crop can be harvested manually with sickles by cutting the plants 10-15 cm above the soil and leaving the stubbles on the soil.

Rain should be avoided during harvest because mature Quinoa seed will germinate within 24 hours after exposure to moisture. If harvesting is delayed and the matured grains are wetted or moisten by rain it leads to premature sprouting of gains on the panicles or "Vivipary" in Quinoa. Vivipary is the premature germination or sprouting of seeds on the panicles prior to harvest. Vivipary deteriorates grain quality, leads to poor drying and yield loss.

Drying or stacking

Immediately after harvesting the crop, it should be sun dried or made into bundles and hanged for drying and curing. The harvested crop can be hanged on ceiling of the house like farmers practices for wheat and barley. It can also be stacked in heaps and covered by polythene sheets to avoid wetting. Curing and drying of the crop should be done for at least 15 days for easy threshing.

Threshing

Threshing operation involves the separation of the grains from the panicles. At present mechanical threshers have not yet been introduced in Bhutan and hence threshing is done manually by beating the dried panicles with a stick. Dried panicles can also be trampled by feet to shred the grains. Once the grains are properly threshed the stubbles can be used as soil mulch, animal bedding or chopped and put into the compost pit to prepare compost.

Winnowing

Winnowing is done to separate and clean the grains from the bran and other unwanted materials. Winnowing is done manually by locally made winnowers.

Storage

After winnowing clean grains are obtained. The grains should be properly dried without exposing to direct sunlight in order to maintain the product quality. Grains should be stored in clean and dry environment. The dried grains can be stored in polypropylene bags or plastic bins. The filled grains bags should be stacked properly on wooden planks.

Milling

Milling is the last step before the Quinoa grains are ready for cooking. Milling involves the separation of grains from the seed cost or pericarp or de-husking. Seed coats or the pericarp are usually covered with bitter Saponin compounds that must be removed before human consumption. Saponin gives bitter tastes if not removed properly. Milling can be done manually using a locally made de-husking device used in villages to de-husk rice and millet. Quinoa grains should be properly dried before milling.

Milling can also be done mechanically using a de-husking mill. Four small-scale Quinoa de-husking machines have been introduced and are being demonstrated to the farmers through the three Research and Development Centers and National Post Harvest Center (NPHC).The milling recovery from this milling machine is 50-60 %.

Yield

Quinoa yield varies with variety, quality of crop management and location. Trials conducted in nine different countries have reported an average yield of 1.07 t ha^{-1} for all varieties and all countries combined. In Bhutan, we have recorded experimental yields of Quinoa ranging from 750 to 1100 Kg per acre. In the farmers field under farmers management practices grain yield ranging from 500 to 600 Kg per acre has been recorded at different locations across the country.

SECTION TWO

PACKAGE OF PRACTICE FOR HORTICULTURE CROPS

1. Potato

Background

Potato is one of the widely produced, consumed and traded horticultural crops in Bhutan. It provides more nutrition from less land in less time compared to wheat, maize or rice. This is possible due to the existence of favorable conditions for the production of high quality potato for in-country consumption and as well as for export. Potato production is concentrated in 2000 – 3500 masl and is the most important crop for the farmers in the altitude above 2500 masl. It is grown by more than 34,000 households in all 20 districts of Bhutan. Its contribution to national economy is more than other horticultural crops for rural household income. Famers in some Dzongkhags like Bumthang and Haa rely on potato crop for their livelihood since they buy cereals through the revenue generated from potato and thus potato acts as the food crop indirectly

Potato varieties and their agro-ecologies

There are four main potato varieties grown in Bhutan. These four varieties are suited for different agro-ecological zones and differ in their yield potentials. However, old varieties have been observed to be very susceptible to late blight and the new varieties have some level of resistance to the disease.

Four potato varieties of Bhutan

Sl#	Variety	Year of release	Releasing agency	Yield potential (t/ac)	Days to maturity	Recommended agro-ecology (masl)
1	Desiree	1988	BNPP	15-18	90	1000-2000
2	Khangma Kewa Kaap	2002	RDC Wengkhar	16-20	100-105	600-2500
3	Nasephey Kewa Kaap	2014	National Potato Program	15-23	160-180	All agro-ecologies
4	Yusi Maap	2017	National Potato Program	12-17	120-140	Mid and high altitudes

Cropping season

In high altitude Dzongkhags like Bumthang and Haa, potato is planted in February/March and is harvested in July to September, depending on the variety grown. However, in mid-altitudes like Trashigang and Chapcha, it is planted in December/January and the crop is harvested from June to July, depending on the variety grown. For winter potato production in Southern Dzongkhags like Samtse and Sarpang, it is recommended to plant the crop in late October to November and harvest in January and February. Again, there is no single recommendation for

each agro-ecological zones because different varieties differ in their days to maturity; one variety may mature in three months whilst other may take more than six months (Table 1).

Land preparation

Since potato is a tuber crop, it requires a deep, loose, friable and well-aerated soil. Potato is shallow rooted plant. It is well suited to light soils with high organic matter content for ease of soil penetration and for tuber formation. Farmyard manure (FYM) or other organic manures should be spread evenly across the field before ploughing so that ploughing operation can incorporate the manure into the soil. Usually potato farmers use power tillers and bullocks for tilling their land. The land should be tilled at least twice; large clods should be broken by harrowing or manually.

Seed rates and planting specifications

Potato tubers of 35 to 65 g/tuber or tuber diameter of 25 - 50 mm should be selected as the seed potatoes. Normally, seed rate of potato is 800 to 1000 kg per acre used. Before, planting soil is prepared into raised ridges (rows) with the distance of 50-70 cm between the ridges. Potato tubers are generally planted with a distance of 15-20 cm between the plants. That is, maintaining the plant-to-plant distance of 15-20 cm and ridge-to-ridge distance of 50-70 cm.

Manure and fertilizer management

Potato being one of the most important cash crops, soil nutrient management for potato production is not a major production constraint. Crop fertilization requirements need to be correctly estimated according to the expected yield and the potential of the variety planted. Crop nutrition management should embrace integrated nutrient management system where organic manures and mineral fertilizers should both be applied to produce optimum yield. Well-decomposed FYM/compost should be applied at six to eight tons per acres. For mineral fertilizers, the recommended rates from the National Soil Services Centre (NSSC) is provided in Table below.

NSSC fertilizer recommendation rate for potato (kg/acre)

Dzongkhags	Low resource farmers (High return)			High resource farmers (High profit)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Bumthang	40	32	24	32	36	16
Chhukha	32	20	12	24	16	8
Gelephu	32	24	16	24	20	8
Haa	32	24	12	24	16	8
Paro	40	32	32	28	28	12
Thimphu	40	28	12	28	20	8
Trashigang	40	32	32	36	32	12
Tsirang	40	32	12	32	24	8
Wangdue	40	32	32	28	24	12

Source: A Guide to Fertilizer Recommendation for major crops (NSSC, 2013)

Nitrogen is the first limiting nutrient for optimum potato growth in most Bhutanese soils. The calculated dosage for nitrogen should be broken into basal dose and top dressing to avoid losses leaching of through the soil profile and is gaseous form. Phosphorus is the second most limiting nutrient and the potassium the third. Therefore, the three most limiting nutrients are to be supplemented through application of mineral fertilizers for optimizing potato productivity.

Weeding and earthing up

Weeds in the potato crop should be removed manually by weeding at one and half months after planting. During the first weeding earthing up should be done to reinforce to ridges. The earthing up operation should be done carefully to avoid disturbing the stolons and roots. Since potato is a modified stem, it needs to be covered with soil in order to enhance productivity. Earthing up improves soil aeration reduces weed pressure and increases stem density. Second weeding can be done as soon as the crop gets weedy. However, earthing up operation should be avoided once the plants approaches/reaches flowering stage to prevent disturbance/damage to the stolons or the tuber formation process. The third and last the last weeding may be necessary before harvesting to facilitate smooth harvesting. Weeds can be also controlled using a specific herbicide. A pre- or post- emergence herbicide Metribuzin 70 WP should be applied at 200 to 400 litres per acres can be to manage weeds and the concentration should 1 g/litre of water. For pre-emergence, control of weeds, Metribuzin should be applied three to four days after planting and soil should not be disturbed after the application.

Crop protection measures

Infestation of crops by wild boar is a serious problem for potato farmers in Bhutan. Wild animal crop damage adds significantly to the total cost of potato production because the farmers have to guard the crop. The wild animal infestation is a serious issue that force farmers to abandon their land. Where possible, electric-fencing is recommended to be erected to protect the crop instead of relying on guarding.

In terms of disease of potato, late blight is the most damaging disease. There are a number of control measures that can be used: that are chemical control and cultural management. Late blight can be treated using Metalaxxyl 8 % + Mancozeb 64 % at 200 to 400 litres per acres and the concentration should 2 g/litre of water. Early blight can be also treated in the same way. However, it should be remembered that this treatment may not be 100 % curative. Cultural method can include growing of resistant varieties like Nasephey Kewa Kaap and Yusi Maap instead of growing the susceptible varieties like Desiree and Khangma Kaap. Crop rotation is another way of breaking the host for blight pathogen.

In harvesting stage or during storage infestation by potato tuber moth (PTM), formation of glycoalkaloids due to over exposure of potatoes to the sun, and invasion of tubers by fungi, bacteria, insects and other organisms, are the other major causes of post-harvest losses. PTM readily attack fresh potatoes and spread rapidly, owing to the lack of appropriate storage facilities and control measures. Control of post-harvest losses is becoming an increasingly

difficult task, since the use of pesticides is not considered good practice due to consumer concern for food safety and hygiene. Infested seed tubers are the main source of re-infestation in the field as well as in storage. In order to reduce infestation, only healthy tubers should be used as seed. Planting at the depth of 10 cm with earthing-up of the soil can greatly reduce field infestation. But, seed should not be planted too deep which could hinder the germination. Harvesting of potato should be done as soon as the crop is ready and not storing in the soil could help. Tuber should not be left exposed overnight. Pheromone traps could be used to monitor moth populations of PTM and mass trapping @ 6traps/ langdo could control moth population. Pesticides are used as last option to control PTM. Cypermethrin (1 ml/2 litres of water) or Chlorpyrifos (4 ml/1 litre of water) can be applied to control the pest in the field conditions. The pesticide recommendations presented in this paper are based on the recommendations of the National Plant Protection Centre (NPPC) and for further consultation one should contact the NPPC.

Harvesting

Harvesting takes place after potato tubers reach maturity. The harvesting time can be determined by assessing the maturity of the tubers by looking at the plant; i.e. when the haulm turns yellow and dies. Harvesting is mostly done by household members using a power-tiller or long handled spade or a hoe to unearth the plant and shake the soil from the tubers. Most farmers collect the tubers in the basket and bring to the store immediately after harvest. Different sizes, shapes and tenderness of the potato make it a difficult crop to harvest and handle. Minimizing the damage/injury at harvesting and handling should be prime objective of the potato grower. It is also important to time the harvesting operation in a sunny and dry weather, although weather is beyond control. To ensure that harvest potato does not get wet, it is advisable to prepare store before the commencing harvesting operation.

Curing

In curing process, the harvested tubers are spread and allowed to be dried. This process will help hardening of the tuber skin; remove soil adhered with the tubers and heal the minor injuries and bruises. Best curing takes place at 15 to 18 ^{o}C. For fuller curing, the potatoes need to be placed in heaps in shade, in a ventilated place but not in windy situation where excessive evaporation of moisture from the tuber might lead to shrinkage. For good curing, it takes 10 to 15 days depending upon the temperature of the place.

Sorting and Grading

Post-harvest handling, which includes different activities (sorting, grading, packing, storing, carrying to the road heads, transportation, loading and unloading), is mainly done by the growers themselves. After harvesting, potatoes are collected in bamboo baskets and carried to the potato store. Most of the growers use the ground floor of their dwelling house as a potato store; however some have built separate sheds. Most farmers store potatoes on wooden planks or bamboo mats separating large, medium and small potatoes into different portions. They

also partition the chamber to separate red and white potatoes. The potatoes should be graded into following three categories to fetch the best price while selling:

- Grade tubers >65g/tuber or >50 mm in tuber diameter as table size which is marketed for consumption purpose.
- Grade tubers of 35 to 65g/tuber or tuber diameter of 25 mm to 50 mm into seed category which is saved or sold as seed potato.
- Grade <35 g/tuber or <25 mm in tuber diameter into non-commercial category which can be used as animal feed or sometimes consumed.

Storage and marketing

Potatoes are to be spread out on the dry floor of the storage area to prevent them from rotting. It is better to store them in a dark, cool place in order to keep the glycol-alkaloid content low. Under exposure to light, potatoes turn green in colour due to increased levels of chlorophyll, which can also indicate higher levels of solanine and chaconine. Since glycoalkaloids are not destroyed by cooking, they spoil the taste and give a negative impression to consumers. Graded potatoes are sold in local market or sold through the FCBL auction yard

2. Cole crops (Cabbage, Cauliflower, Broccoli)

Background

Cabbage (*Brassica oleracea* L. var *capitata* L.); Cauliflower (*Brassica oleracea* var *botrytis*); and Broccoli (*Brassica oleracea* var *italica*) are collectively termed as Cole Crops. Cabbage and Cauliflower were introduced to Bhutan in 1966 and Broccoli was introduced much later. Some of the other cole crop members are Knol-khol, Brussel sprouts, Collards, Kale, Mustard, Turnip, Watercress.

Owing to the similar genetic background, cole crops have similar growing environment and cultivation practices requirement. Thus, the agronomic practice of three major cole crops; Cabbage, Cauliflower and Broccoli are clubbed together to avoid repetition as well as for ease of comprehension.

Available Varieties

Cabbage Varieties & their description

Variety	Important Characteristics
Golden Acre (OP)	Characterized by smooth, round, compact and small head; early maturing; average head weight of 850 gram; Maturity duration: 75-85 days after sowing . Sensitive to bolting when planted early in the spring particularly in high altitude areas, and hence, it is suitable for altitude lower than 2600 masl.
Golden Cross (F1)	Round Head and is the earliest of all the golden acre types. Good for spring to early summer harvest. Produce average head weight of 500 gram in 55 to 60 days after transplanting.
Lucky Ball (F1)	Round head and early maturing variety. Produces head of 1.0 kg in 80-100 days after sowing. Resistant to Fusarium Yellow, Black Rot and Bottom Rot diseases.
Bondey Cross (F1)	Round head; medium to early maturing. Produce head weight of 1.3 kg in 90-110 days after sowing. It is suitable across all agro-ecological zones (AEZ)
Green Coronet (F1)	It's one of the leading varieties all over the world. Late maturing with oblate deep green heads. Produces uniform heads of 1.7 kg on an average in 80-90 days after sowing. It's an excellent variety for harvesting in late fall to winter in higher altitudes, and suitable across all AEZ.
Copenhagen Market	One of the largest early maturing round head varieties. Produces head of 1.4 to 1.8 kg heads. Maturity duration of 75-85 days after sowing. It is suitable for altitude lower than 2600 masl.

Cauliflower varieties & their description

Variety	Important Characteristics
Wengkhar Metokopi 1(OP)	Matures in 90 days after transplanting and produces curds weighing on an average 600 gram. Recommended for mid and low altitude areas.
Wengkhar metokopi 2 (OP)	Matures in 110 days after transplanting and produces curd weight of 800 gram. Recommended for mid and high altitude areas.
Snow Crown (F1)	Produce uniform, white, & semi-dome shaped heads. Matures in 90 days with an average head weight of 1 kg. Most suited for mid and low altitudes.
Snow Mystique (Hybrid)	Produce dome-shaped heads with high degree of uniformity. Matures in 100 days and produce head weight of 1 kg. Most suited for high and mid altitudes.
Shutoko	Produce flat and compact heads of 1.8-2 kg. Suited for altitude above 1800masl in summer and for lower elevation sin winter. Seeds produced from F1 to F4 have good compact heads.

Broccoli varieties & their description

Variety	Important Characteristics
Dessico (OP)	Produce small loose heads in 90 days after transplanting. Recommended for organic culture.
Centauro (F1)	Produce large, compact and semi-dome-shaped heads suitable for early SPring to late fall in high altitude areas; year round in mid-altitudes and for winter in low altitudes. Matures in 90-100 days after sowing.

Climate

Cabbage can tolerate comparatively harsher climate and the optimum mean day temperature required is 12-25^{o}. However, for cauliflower and broccoli, the optimum monthly temperature should be 15-20^{o}C.

Soil

Cole crop does best on a well-drained, loamy soil well supplied with plenty of organic matter. It is also important to take into consideration the selection of land where member of the Brassica family was not grown in the previous years. This is mainly to contain the rampant soil-borne Club root disease.

Field preparation

The field should be ploughed until the soil is brought to a fine tilth since cole crops are shallow rooted and are confined to a soil depth of 30-45 cm only. Good drainage of the field is pre-requisite of Cole crops. The pH in the range of 6-7 is ideal since phosphorus availability is

more in this range. Hence, it is recommended to grow cole crops on raised beds. The beds of 1 m width should be raised to a height of 15-20 cm and made to a length of convenient sizes.

Recommended seed/seedling rate

About 180-200 grams of good quality Cabbage, Cauliflower and Broccoli seed is required for planting in an area of 1 acre. Approximately, 100 gram of seed might contain up to 3500 individual seeds

Nursery management

Bed Preparation

The area designated for Cole crop nursery, preferably an area where Brassica crops haven't been grown previously, should be brought to a fine tilth by breaking the clods. A raised nursery bed of 1m width & convenient length shall be prepared. All the pebbles & stubbles should be removed to render the soil porous & fine for the easy emergence of the seedlings.

Nursery raising under poly-tunnels is recommended for the ease of hardening. This is commonly practiced by farmers to produce off-season Cole crops.

Cropping Calendar for Important Cole Crops

	Variety	Altitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Recommended planting Space(cm)
Cabbage 	C.Market	>1800													50cm(RR)X 40cmPP
	Golden Acre	1200-1800													
	Green Coronet	<1200													
Cauliflower 	Khangma Late,	>1800													50cm(RR)X 40cmPP
	Snow mystique	1200-1800													
		<1200													
Broccoli 	Dessico	>1800													50cm(RR)X 40cmPP
	Centurao (Hybrid)	1200-1800													
		<1200													

Sowing under normal season / **Transplanting** — **Sowing under poly-tunnels** — **Harvesting**

Irrigation

Nursery beds should be either thoroughly wetted before sowing or covered with rug sack before wetting with fine spray using watering can. This is to avoid the seeds getting displaced by water splashes. The subsequent irrigation should be given as and when required depending on soil type and weather conditions. The principle is to just keep the soil moist, without over-watering to avoid rotting of seedlings.

Transplanting

Cole crops seedlings are ready for transplanting 5-6 weeks after sowing. However, it might take longer at higher elevations experiencing extreme temperatures. Seedlings are ready to transplant when they attain a height of 10-12 cm and four to five leaf stage. It is recommended to harden the seedlings for a period of week before transplanting. This can be achieved easily when the nurseries are raised in poly-tunnels, where the overlying plastic sheet can be removed to expose the seedlings to the outside environment. However, when the nurseries are raised in green houses, hardening can be achieved by uprooting the seedlings and re-potting it to be kept outside before finally transplanting.

Spacing

Maintain a spacing of 50 cm between the rows and 40 cm between the plants. The spacing, depending on the field characteristics, will accommodate roughly a plant population of 17,000. However, the spacing and plant population per acre will vary depending on the varieties.

Field Preparation

Layout the field into raised beds of 1 m width and convenient length for ease of intercultural operations. Farmers in the West are adopting the practice of boring a small hole, maintaining the recommended spacing, & then adding organic manure and copious wetting of the soil for seedlings to be transplanted. This also ensures that the seedlings are given adequate water and nutrients to recoup from transplanting shock.

Planting time

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

Cultural practices

Weed Management

Ideally, three to four weeding and hoeing is required for a good crop growth. Care should be taken not to damage the roots during the operation due to the shallow-rooted nature of the crop.

Nutrient management

An acre of field needs to be incorporated with at least 6 MT of well decomposed farm yard manure (FYM) or fully matured compost. Partially-decomposed manures should be avoided since it harbours and aggravates pest and disease incidence. Around 20kg N and 30 kg P_2O_5

per acre before final land preparation should be added. In addition, around 22 kg urea in two equal split doses; one dose before transplanting by mixing with soil and the other 40 days after transplanting.

Water management

Irrigation right after transplanting is required for good crop establishment. The subsequent irrigation should be given at regular intervals, depending on the soil moisture condition and frequency of rainfall.

Plant protection

There are a number of insect pests which attack cole crops. It is always advisable to control such insects and pests by adopting integrated pest management system (IPM), which takes into incorporation cultural, mechanical and biological means of pest control instead of resorting to chemical methods in the first place. Chemical pesticides should be kept as the final resort to avoid chemical residual effect on human health.

Harvest

Maturity Indices

Cabbages are ready for harvest when they have developed firm and compact heads. Harvest cauliflower when curds attain good size, usually 12-15 cm in diameter, and are still compact by cutting the curds before it begins to discolour. Broccoli matures in 60-90 days depending on the time of year and the variety planted and picking in tender stage when the buds are still small and tightly closed. Heads should be tight, and the individual flowers in the clusters should not have yellow petals. Side heads develop rapidly in varieties like Dessico following the removal of terminal head, and harvesting may continue for 2-3 weeks. Cabbage can yield up to 25-30 MT, cauliflower 7MT and broccoli 5 MT per acre if good management practices are carried out.

Time

The best time of harvesting is either in the early morning or late evening when the field heat is lower. It is also advisable not to harvest when the field is wet or when it is raining.

Methods

Cabbages are harvested by cutting below the heads with a sharp knife. The cauliflower curds shall be cut along with the leaves surrounding it for protection required during transportation. Harvest Broccoli heads by cutting the tender and tightly closed buds along with the stem below.

Post-harvest management

Packaging/Marketing

For fresh market, it is advisable to wrap both cauliflower and broccoli heads individually in newspaper and keep in upright position. In case of the self-blanching types of cauliflowers, curds are wrapped in the leaves surrounding it before packing in plastic crates or bamboo

basket. Cabbage and Broccoli should be dispensed immediately to market before it discolours. Cabbages, on the other hand can store for quite long.

Seed maintenance

Seed Production

Cole corps are cross-pollinated crops and they readily intercross with the members of the Brassica family. Hence, it is not possible to produce pure seeds of cabbage, cauliflower and broccoli in the same field or even in the periphery of each other at a distance of 1000m.

Sowing for seed production should be timed so that the crop receives sufficient vernalization, and to allow for the plants to survive hard weather and also to reach anthesis to produce seeds in suitable weather conditions. The plants with healthy and disease free heads or curds should be selected. If the seed is to be produced from hearted cabbage, it is necessary to give an incision in the mature heads after checking the trueness to type. This can be done by cutting the top of cabbage head in the form of a cross, however, without damaging the growing point inside. The plant must have grown at least six to eight weeks at a minimum temperature of 4-7^{o}C or lower after which the heads will slowly grow branching spikes, which when mature will start flowering. Low temperature stimulus or vernalization requirement is characteristic of most cole crops for flower initiation.
The selection of plants for seed production should be as per the following specifications;
Cabbage: Good shape, tight head and pure.
Cauliflower: It should be white, large and compact head and pure
Broccoli: Curd should be green, large, tight and pure (not mixed with other cole crops).
In our condition, 1400-2000m is best for seed production. Broccoli can do well in slightly lower altitude than cabbage and cauliflower. It will take about 10 month from sowing to seed extraction in total.

Seed Processing

When seeds have matured, harvest the plants along with the pods in the evening and sun dry the pods for easy extraction of seeds. Thereafter, the seeds should be extracted by hands or pounded collectively inside a sack or net bag to prevent from scattering.

Seed Storage

The seeds should be dried enough to reach moisture content of less than 10 % at the time of storage and stored in a cool dry place.

3. Chili

Background

Chili (*Capsicum annum*) is one of the most valuable spice crop which belongs to the genus Capsicum under the solanaceae family. Chili is cultivated in all the Dzongkhags in Bhutan. It is a favoured cash crop for most farmers, as the potential returns are high and profit can be achieved in one season. The total cultivated area of chilli in 2016 was 5,538 acres with production of 9,907 MT (RNR statics 2016).

Chili is an excellent source of natural, micronutrient, antioxidants, vitamins c, e and carotenoids which appear to be critically important in preventing or reducing chronic and age-related diseases. The pungency of the chilli plant is used in traditional medicine and currently used in modern herbology and conventional medicines.

Varieties

Hot wax, Sha ema, Super solo, Yangtse Ema, SV 2319 HA, PAN 1498, SHP 4884

Climate

Chilli is a warm season crop which requires day temperature of 26-28 degree Celsius and night temperature of 16-18 degree Celsius. For germination, the temperature requirement is 23-30 degree Celsius. The temperature for fruit set at day is 20-28 degree Celsius and night temperature for fruit set is 15-20 degree Celsius.

Soil

Chili can be grown in all type of soil but a well-drained loamy soil rich in organic matter is best. The PH range of soil for growing chili is 5.5 to 7.

Field preparation

Nursery field preparation

Plough or dig the field for 2-3 times about two weeks ahead of plantation and level the field. Apply well decomposed Farm Yard Manure/chicken manure and sand in the ratio 2:1 and mix thoroughly.

Sowing, irrigation and management of nursery

Prepare the beds of 20-25 cm high with 1 meter width and convenient length. Break the soil clods and make the soil very fine particle. Prepare line of 2-3 cm deep and 10-15 cm (RxR spacing) gap from one to other line. Sow the seeds in line and cover it by fine soil particle. Irrigate the nursery by using water cane early in the morning and evening in a day. Visit the nursery site once in a day and do weeding whenever the weeds germinate. Open the poly tunnel when the temperature rises and close it when the temperature drop and when it rains.

When the nursery is kept inside the protected structure, hardening of the seedlings, one week before the time of transplanting is very important. The process of hardening seedlings is by taking the seedling in open condition and decrease the application of water. The reason of hardening, is to prevent the seedling from transplant shock

Seed rate and sowing time

Sl/no	Variety	Nursery raising time	Seed rate/acre	Remarks
1.	SHP-4884 (hybrid)	August 3rd week-September 2rd week	80-100 g	For southern region
2.	PAN-1498	August 3rd week-September 2rd week	80-100 g	
3.	SV-2319 HA	August 3rd week-September 2rd week	80-100 g	
4.	SHP-4884 (hybrid)	2nd week-4th week December	80-100 g	
5.	PAN-1498	2nd week-4th week December	80-100 g	
6.	SV-2319 HA	2nd week-4th week December	80-100 g	
7.	Super solo	March 1st week to March end	90-110 g	For northern region
8.	Hot wax	March 1st week to March end	90-110 g	
9.	Indian chili	March 1st week to March end	90-110 g	
10.	Sha ema	March 1st week to March end	90-110 g	

Note: The varieties Sha-ema, Super solo and Hot wax are not suitable in the southern region

Bed preparation and transplanting (rainy season)

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

Bed preparation and transplanting (dry season)

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

Transplanting time

Variety	Nursery raising time	Transplanting time	Seedling age	Spacing
SHP-4884 (hybrid)	August 3rd week-September 2rd week	Sep 4th week to Oct 3rd week	30-35 days old	60 cm x 60 cm (RxP)
PAN-1498	August 3rd week-September 2rd week	Sep 4th week to Oct 3rd week	30-35 days old	60 cm x 60 cm (RxP)
SV-2319 HA	August 3rd week-September 2rd week	Sep 4th week to Oct 3rd week	30-35 days old	60 cm x 60 cm (RxP)
SHP-4884 (hybrid)	December 2nd week-4th week December	Jan 3rd week to Feb 1st week	30-35 days old	60 cm x 60 cm (RxP)
PAN-1498	December 2nd week-4th week December	Jan 3rd week to Feb 1st week	30-35 days old	60 cm x 60 cm (RxP)
SV-2319 HA	December 2nd week-4th week December	Jan 3rd week to Feb 1st week	30-35 days old	60 cm x 60 cm (RxP)
Super solo	March 1st week to march end	April 1st week - April end	30-35 days	45 cm x 60 cm (RxP)
Hot wax	March 1st week to march end	April 1st week - April end	30-35 days	45 cm x 60 cm (RxP)
Indian chili	March 1st week to march end	April 1st week - April end	30-35 days	45 cm x 60 cm (RxP)
Sha ema	March 1st week to march end	April 1st week - April end	30-35 days	45 cm x 60 cm (RxP)

Cultural practices

2-3 times weeding is required for entire crop season. To minimize labour cost for weeding, we can use plastic mulch, paddy straw and debris of plant. 1- 2 times earthing up is required to loosen the soil.

Nutrient management

Apply well decomposed farm yard manure @ 4 tones/acre during the field preparation time. Apply NPK @ 28:24:24 kg/acre, apply full dose of P and K as a basal dose during field preparation and N in 3 split doses. 1st during transplantation, 2nd one month after transplanting and 3rd during flowering time.

Water management

Irrigation should be done on the basis of field condition. Normally irrigation is provided every after 3-4 days gap.

Plant protection

Major chili pest and control

Some of the major chili pest includes mites, thrips, aphids and fruit borer. The common diseases in chili are anthracnose, bacterial wilt, damping off, phytopthora blight and should be managed using IPM technologies

Harvesting

Harvesting of chili depends on the purpose of chili. Picking of green chilies starts from 65-80 days after transplanting and the interval for 1 harvest to another harvest of green chilies can be done within 10 days interval. The hybrid chili can be harvested about 2 to 3 months and the open varieties can be harvested 1 to 2 months. The red chili can be harvested 105 days after transplanting with 15 days of interval from 1 harvest to another harvest. The chilli is harvested manually by picking fruits along with the stalk.

Post-harvest management

The ripened chilies are harvested and stored overnight to develop uniform colour. The fresh chillies are spread on clean threshing floor for sun drying. The injured chillies infected by disease and pest are sorted from good quality fruits. Frequent stirrings are given during day time so that drying is uniform. Heap the fruits together at night and cover with tarpaulins or gunny bags to protect from rain or night dews. The quality of chilies can be maintained when dried on cement floor or tarpaulin, rather than drying on CGI sheets. This is because the colour of the chilli becomes dull red instead of bright red when dried on zinc sheet roof. Dry the fruits for 5 to 15 days depending on the weather conditions.

Seed maintenance

The seeds from hybrid varieties cannot be reused again. The open pollinated varieties can be used to keep seeds. The seed fields should be isolated from the fields of the other varieties by 400 and 200 m in case of chilies for foundation and certified seed production respectively to prevent cross pollination.

Removal of off type plants has to be followed during various stages of plant growth. A minimum of 3 field inspection are required for these crops. In the earlier period of the growth, roguing may be based on leaf and stem characters, second roguing may be based on fruiting habit, fruit size, shape and colour. The last inspection can be made at full fruit maturity stage. True to type fruits, depending upon shape, size, colour, free from disease and pest are kept for seed extraction.

Harvest the fruits at red ripe stage. The fruits are either dried, crushed and the seed is separated by winnowing or the seed is extracted manually from the freshly harvested fruits. When directly extracted from the ripe fruit, the seeds 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.

4. Tomato

Background

Tomato (*Lycopersicon esculentum*) falls under Solanaceae family. The tomato is a native of the lower Andes, cultivated by the Aztecs in Mexico. Tomato is one of the most important additive vegetable in the Bhutanese dish. They are also eaten raw as salad. In Bhutan tomato cultivation occupies around 347 acres. The production cannot fulfill the local demand and hence major portion of tomatoes are imported from India.

Varieties

The available varieties are*:* PS 61, Rattan, and Roma

Climate

Tomatoes can be grown in wide range of temperature and soils, but it grows well when the day temperature is between 13ºC to 35ºC.

Soil

Tomato grows well in loam and sandy loam soils and the best soil pH range for tomato is 6.0 to 7.0. Apply dolomite powder at the rate of 1.5 mt per acre if the soil pH is below 5.

Field Preparation

Plough the field three to four times to pulverize the soil. Good drainage of the field is important and is a pre-requisite for cultivation of solanaceous crops especially in summer. It is advisable to grow solanaceous crops on raised beds of 15-20 cm height and 1 m width. The length of the beds depends upon the field condition.

Recommended Seeds

200 g of seed with minimum germination of 75 % is enough for one acre.

Seed Treatment

Seed should be treated either in hot water or with Thiram or Captan (fungicide) dust at the rate of 2 gram per kg seed before sowing to protect seedlings from damping-off disease or phomopsis wilt in the nursery.

Nursery Management

The nursery should be prepared thoroughly before sowing the seeds. Remove the stones or clods and other unwanted materials for uniform and healthy growth of the seedlings. Raise nursery beds of 15-20 cm high, 1 m wide and convenient length. Sow the seeds 1.5 cm deep and 8-10 cm apart in rows. The growing season varies depending upon the altitudes. At an altitude above 1500 masl, (growing season April to September) start nursery preparation from the first week of April.

At an altitude of 1000-1500 masl (growing season March to October) sow the seeds from first week of March till end of May. The altitude below 1000 masl (growing season October to April) sow the seed in the first week of October till mid of December.

It is advisable to use poly tunnel having semi-circular structure of bamboo sticks at a distance of 1 m over the nursery bed at higher altitude above 1000 masl. The plastic sheet is laid over the structure and the sides are covered with the soil. Open the plastic during the day time and close it in the evening. Do not use semi-decomposed organic manures or compost made out of city waste in the nursery soils. Irrigate the nursery as and when require based on the soil condition.

Plant Spacing

Transplant the seedlings on the raised beds with the row to row distance of 50 cm and plant to plant 40 cm.

Weed Management

Two to three weeding is necessary depending upon the weed pressure. Weed manually or use garden hoe without damaging the roots.

Pruning/Training

All indeterminate varieties are trained with wires, strings or stacks to prevent lodging and loss of fruits by coming in contact with soil. It is done by providing individual stack or by erecting 2-2.5 m long poles on either side of ridges for stretching G1 wire. Branches of plants are supported on poles or strings with twine. Pruning is also generally followed in indeterminate varieties to improve size, shape and quality of fruits. It is removal of unwanted shoots to enhance vigor of plants.

Nutrient Management

About 10 tonnes of FYM or vermi compost/compost @ 1-1.5 t per acre is applied at the last ploughing. Green manuring is recommended for areas with assured rainfall and also for irrigated crop. 20:24:15 kg of NPK per acre as basal dose in the form of Urea, SSP and MoP. Top dress with additional 26 kg nitrogen after one month of transplanting. Top dressing of nitrogen should be done in the forms of rings around the plants and cover with soil.

Water Management

Water the young plants at field capacity for few weeks after transplanting to encourage good vegetative growth. Reduce the amount of irrigation and frequency in 4-5 weeks after transplanting to provide little water stress which will enhance tomato flowering and production.

After the fruit set, maintain uniform soil moisture to avoid blossom-end rot, fruit cracking and to improve fruit quality. Reduce irrigation slightly towards the time of harvest to get good flavour and less watery fruits.

Plant Protection

Insect pests

The common insect pests in tomato are cutworm, and fruit borer while diseases mainly damping off, wilt, blight and blossom end rot should all be managed using IPM technologies.

Harvest

Tomato starts yielding by 70 days after planting. Harvesting maturity depends on the purpose whether for fresh market, processing, long distance transport etc.
Following maturity standards are recognized in tomato:

- Mature green: Harvested for long distance market.
- Breaker stage: Harvested for long distance market.
- Pink stage**:** Harvested for local market.
- Light red: Harvested for local market.
- Red ripe or hand ripe: Harvested for processing and seed extraction.

Post-Harvest Management

After picking, the matured fruits are graded into cracked, bruised, injured and well matured fruits. The good quality fruits can be marketed either as fresh vegetable/salad purpose for processing. Fruits can be stored for-two weeks and four weeks at 10-13^{o}C when harvested at red stage and green stage respectively. Pre-cooling of fruits before storage and transportation enhances storage life. Use of tomato for processing is increasing day by day and a variety of products like puree, paste, syrup, juice, ketchup etc.

Seed Maintenance

Select good quality disease free and well matured tomato and extract the seeds. Wash the extracted thoroughly and dry under shed. Moisture content of the seed should be less than 10 %.

5. Egg Plant

Background

Brinjal or Eggplant *(Solanum melongena*) is member of the Solanaceae or nightshade family. It is grown for its edible fruits botanically classified as berry. Its origin is considered to be in India. It is versatile crop adapted to wide agro-climatic regions. It grows up to 40 to 150 cm (1.3 to 4. ft) tall with large coarsely lobed leaves that are 10 to 20 cm.

Available Varieties:

There are number of brinjal varieties cultivated in Bhutan. Two most popular cultivated cultivar of brinjal are Manryo and Nagako (Japanese variety) in Bhutan.

Climate

Optimum growing temperature range is 21-30^{0}C with maximum of 35 and minimum of 18 degree Celsius. Young seedlings are sensitive to frost. The optimum temperature for seed germination is 24 to 32^{0}C. It requires a long growing season with the high average day and night temperatures. Its seed germinates well at 25^{0}C temperature.

Soil

Any types of soils are suited for growing eggplant, however well drained loamy soils are preferred for better production. Sandy soils are best adapted for eggplant

Field preparation

Plough and harrow the field alternately depending on soil type and soil moisture to obtain good soil tilth. The soil pH should not "be higher than pH 5.5 to 6.0 for its better growth and development. When the field is well prepared and levelled, the beds of suitable size are made in the field before transplanting.

Recommended seed/seedling Rate

The 700 grams to 1000 grams seed required to raise the seedlings for 1 ha, area

Nursery management

Seed Rate

The 700gms to 1000gms seed is required to raise seedlings for 1ha, area.

Bed preparation

Ridges and furrow type of layout is used. Seedlings are raised on bed. Spacing is about 75cm by 60cm to 75cm by 75cm.

Sowing Time

Brinjal seeds are sown in Mid Feb to Mid-March

Irrigation

Irrigate the field every after third or fourth day. Timely irrigation is important to obtain high yield.

Transplanting /planting

Spacing

Eggplant seeds should be placed in the ground four or five inches apart, in rows spaced 24 to 36 inches apart. This will produce more eggplant bushes than desired. Extra plants will be thinned later in the growing season. Seeds should be planted 1/4 to 1/2 inch below the surface of warm, well-drained soil. Seedlings should be spaced 18 to 24 inches apart in rows 24 to 36 inches away from each other.

Panting Time

It is transplanted in April.

Cultural practices

Weed management

Inter-tillage or hoeing should be done with some hand drawn implement. Weed 2-3 times during growing season or as necessary. Partial control of weeds can be done by hilling up 3-4 weeks after transplanting. Mulching can also be done to minimize weed growth and maintain uniform soil moisture.

Thinning/pruning/Training

Once the plants have grown to be 6 inches tall, they must be thinned. Ideal plant spacing is 18 to 24 inches apart in a single row. Thinning of eggplant is carried out by clipping the seedlings with sharp pruning shears.

Nutrient Management

Incorporate organic fertilizer (FYM/Compost) with soil one –two weeks before planting at 120 bags per hectare. In brinjal 60kg nitrogen, 50kg phosphorus should be applied per hectare.

Plant Protection

Brinjal Fruit and Shoot Borer

It is one of the major and serious insect pest of brinjal. A short pinkish caterpillar bores into the terminal shoot and eats internal tissue; it bores into the young fruit through the calyx .leaving on visible signs of infestation. The large holes usually seen on the fruits are the exits holes of caterpillar. The insect affected fruits become unfit for consumption.

Control Measures:

Eggplant can be grown economically even without pesticides. The insect affected part should be clipped along with insect and destroyed any fruit with holes should be picked and destroyed. Proper sanitation should be maintained in the field.
Brinjals should also be protected against insect such as brinjal stem borer and leaf eating beetle.
Hand picking of egg and larval is the best method to control this pest if infestation occurs only in few plants.

Diseases of Brinjal

Damping off mainly occurs in nursery bed. The disease infects seedlings at ground level and then the plants fall over ground. The seedlings die in patches. The control measures are as below.

- The seed bed should be treated with Formalin before sowing of seeds.
- The seeds should be treated without water (30 minutes @ 52°C) or Agrosan G.N. before sowing of seed.

The disease is transmitted by leaf hoppers and the affected plant produces numerous tiny yellow leaves and does not bear fruits.
In order to manage the disease, the affected plants should be destroyed. The insect vector should be controlled by spraying the crop with Dimethoate (Rogor-30 EC) disease resistant variety should be cultivated.

Harvest

- Maturing indices: Fruits are harvested when they are immature. Fruits are allowed to attain a good size and color till they do not lose their bright, glossy appearance and become dull. Harvesting can be done once or twice a week. More frequent harvesting can reduce damage from fruit borers.
- Time: Harvested during the month of June-July
- Methods: Fruits should be severed from the plant by cutting with small shears or a knife.
- Yield: 250 to 300 quintals/ ha.

Post-Harvest Management

Threshing: Eggplants are immature fruit. If left on the plant too long the seeds gets hard dark and the flesh becomes spongy. All eggplants have a smooth, glossy skin with no stomata or lenticels. This makes them relatively resistant to moisture loss. However, only a small amount of dehydration can result in noticeable softening, reducing quality.

Cleaning/grading: empty and dead seeds are removed by letting them float on bucketful water.

Storage: Eggplants are chilling sensitive, with storage life generally between 8–12 °C. It is packed in zipped plastic bag at about 10 to 20 g per packet and stored at dew fridge at require temperature. Chilling damage symptoms include the appearance of light brown patches over the skin, sunken pits in the flesh, increased disease and darkening of the flesh and seeds.

Seed maintenance

Seed selection: seed should be extracted from good shaped fruits.
Seed processing: seed should be thoroughly cleaned and washed with water. Dead and empty seed should be removed by floating on water.

Storage: after packaging in zipped plastic bag at about 10 to 20 g, it has to be stored at 8-12 °C in refrigerator.

6. Onion

Background

Onion is commercial crop and one of the important vegetables. It is used as salad or cooked in various ways in curries. It is also used in processed form e.g. flakes, powder, paste, crush and pickles. Onion has great therapeutic value. They are stimulants and mild counter-irritant. It has been used as herbal remedy for centuries in colds, coughs, bronchitis and many other diseases. The demand for onion is worldwide. It has been cultivated in Bhutan from decades. It is used both in raw and mature bulb stage as vegetable and spices. The pungency in onion is due to a volatile oil known as ally-proopyldisulphide.

Available varieties

There are only two varieties of onion released in our country namely Pune red & Bombay red.

Soil:

To get the good yield sandy loam soil having sufficient organic matter is required. It can be well grown on light loam, deep fertile and fertile soil rich in organic matter.

Land preparation

One deep ploughing is required after that 2-3 ploughing of rotavator.

Climate

The ideal temperature for vegetative growth 12.8-23 °C but requires little higher temperature 20-25 °C for bulb development

Sowing time and seed rate

The seed generally sown in raised nursery bed. The surface beds should be smooth and well leveled.

October -November is the best time for seed sowing and the seed rate at 10-12 Kg per ha.

Seed treatment

Seed treatment with 3 g Captan

Manure and Fertilizer

Application 20-25 tons of FYM/ha. In soil considered adequate. FYM should be applied one month before transplanting and mixed in the soil. A dose of NPK (150:60:60: Kg/ha.) applied better bulb development. Whole quantity of phosphorus, potash and half nitrogen should be mixed in the before transplanting. Rest half doses of nitrogen should be given as top dressing in two equal split doses, first dose should applied at 30 days after transplanting whereas second dose at 45 days after transplanting . The top dressing must be completed before initiation of bulbing.

Transplanting

The best time of transplanting is in between December end to first week of January. Planting of 15x10cm spacing is considered to be the best.

Weed control

2-3 times manual weeding is required.

Irrigation

First irrigation is applied immediately after transplanting. The subsequent irrigation should be provided in 10 to 12 day's interval.

Disease

Purple blotch is a common disease that affects onions. In order to manage, spray Dithane M-45 @ 0.25 % after mixing sendovit 1.0ML per litre of water.

Insect

Thrips is a major insect pest in onion. Spray Dimethoate 2ML per litre of water to manage the pest.

Harvesting

The crop generally is ready to harvest in 100-120 days after transplanting.

Average yield

300- 400 quintal/ha.

7. Garlic

Background

Garlic (*Allium sativum*), is a species in the onion genus Allium. Its close relatives include onion, shallot, leek, Chive and Rakkyo. It is widely used around the world both for culinary and medicinal purposes. The most commonly used part of the plant is the bulb, which is divided into fleshy segments called as cloves.

The garlic is an indispensable component for most of the dishes in Central and South –East Asian countries. Likewise, it also forms a basic constituent of the typical Bhutanese cuisine. Given its aroma, it is used as seasoning along with onion, tomato and chili particularly for non-vegetarian dishes. Although the consumption of garlic is relatively high in the country, our domestic production is low. Today the garlic is cultivated only in few regions and at subsistence level.

Variety: The only known released variety is the Local selection, which was released by NASEPP in 1990. However, more than 4-5 unidentified varieties are being grown by the farmers across the country as of now.

Climate

Garlic can be grown at elevation range 1200- 2000 meter above sea level. It requires short days cool (12-18 °C) moist period during vegetative growth. For bulb formation it requires dry weather conditions.

Soil

It prefers well-drained, friable sandy loam soil rich in organic matter. This facilitates bulb expansion without becoming misshapen. Ideal soil pH range is between 6-7.

Seed rate

500-600 kg/ha

Field preparation

Planting

Garlic does not produce true seeds but it is propagated through cloves. Each bulb usually has around dozen or more depending upon the cultivar. Cloves from the bulb must be separated before planting. Choose clean, healthy and disease free cloves for planting. Larger the size of the clove, bigger would be the bulb size during the harvest, hence it is important to choose ideal sized cloves for planting. Small cloves less than 5mm should be discarded. The Land should be well ploughed, mixed with adequate fertilizers as per the recommended dosage, 15 tons/ha. Depending upon the convenience, prepare furrows and ridges or beds at 30cm spacing and of favorable sizes.

Plant the cloves at 15 cm x 10 cm spacing. The smaller end of the garlic should be pointed upward and the top of the clove should be at least 5cm below the soil surface.

Cultural practices

Weed management

Weed management is vital for the proper development of garlic plants. Garlic has shallow root system hence it doesn't compete well with the weeds. Hand picking, hoeing and mulching are some fundamental approaches to check the weeds. Another important method of weed management is mulching.

Water management

It is very important to know when to water in garlic since both excess and shortage of water has detrimental effect on the plant. It needs steady supply of water to get market sized bulbs. The application of 1 inch of water per week during dry periods will ensure good sizing. Avoid water during bulb formation as it will discourage bulb diseases. Some common method of water application includes flooding, drip irrigation and sprinkler.

Nutrient management

Garlic requires heavy fertilization; for commercial production FYM 50 ton/ha, NPK mixture (15:4:11) @ 300-400 kg/ha is recommended.. Soil tests should be conducted and phosphorus, potassium, and lime applied and incorporated before planting. Green manure before the soil tillage would ameliorate the soil nutrients.

Scape removal

Garlic scapes are the flower bud of the garlic plant. Like the bulb, they are also edible and taste almost alike. However, if the scape is allowed to develop it will compete with the bulb for nutrients, resulting in a reduction in bulb size and quality. Therefore, it must be removed as it starts to form a curl

Harvesting

Maturity Indices: Garlic is ready to harvest when 40-60 percent of the leaves have yellowed or turned brownish (garlic generally has 6 leaves. It can be also checked by digging up few bulbs and examining. Average yield is 8-12 tons per ha.

Plant protection

Crop rotation is very important to reduce disease and pest transmission. Avoid planting garlic where other *Alliums* (onions, leeks, chives, etc.) have grown in the past three years. Be sure to plant garlic from a reliable source. Garlic is particularly susceptible to white rot (*Sclerotium cepivorum*), basal rot (*Fusarium culmorum*) and viruses, among other soil-borne pathogens.

The fundamental principle of Integrated Pest and Disease Management should be practiced. The first approach should be always preventive measures through various means such as cultural practice, organic control etc. The use of pesticide and chemical must be kept as the last resort. There are different manuals, guidelines prepared by National Organic Programme (NOP), National Plant Protection Center (NPPC), hence it is recommended to follow their guidelines for plant protection guidelines.

Post-harvest management

Cleaning

Gently brush soil off from around the roots and lay plants in a dry, shady spot. Never wash the garlic. The moisture should minimized to prevent rotting and development of mould.

Drying and curing

One very important step after the harvest is curing. Hang the garlic in a dry, well-ventilated area. Allow the bulbs to dry for a few weeks to improve storage ability. Use a fan in the curing space if necessary while low heat could be supplied if the area is located in humid regions. There are some post –harvest curing and storage structures that have been designed by National Post Harvest Center (NPHC).

Sorting and Grading

Garlic bulbs after curing are run over a grader or graded manually before their storage or marketing. The thick- necked, splitted, injured, diseased or bulbs with hollow cloves are sorted out. Size grading is done after sorting.

Storage

Before storing, clean the remaining soil off bulbs gently with a soft bristle brush, preserving as many layers of the papery skin as possible. Thereafter, garlic with leaves intact should be hung in a well-ventilated room while those without leaves (tops) could be stored in nylon netted bags as it provides good air circulation. Ideal storage conditions are 45-55°F at about 60 % relative humidity to deter both rot and dehydration. Garlic stored below 40°F, or in the refrigerator, will sprout.

Seed saving

Garlic is grown from cloves, so some good quality seeds must be provisioned to be used for the next season.

Packaging

Garlic can be packaged in different packaging materials depending upon availability and affordability. Some common material used are wooden crate boxes, Nylon-netted bags etc. In foreign countries, plastic-woven bags are very commonly used. These have good strength and are also attractive. Since garlic needs less ventilation compared to onion, there is a need to develop suitable packaging to reduce driage loss.

Seed maintenance

Since garlic hardly produces fertile seeds, the propagation is commercially done through cloves. Therefore it is important to provision good quality bulbs for next season propagation. Store it in well-ventilated, dry room conditions. While cleaning, curing ensure that the papery skin of the bulbs are not destroyed. This helps in prolonging the storage time , minimizing collateral damage.

8. Pumpkin

Background

Pumpkin (*Cucurbita moschata* Dutch. Ex Poir) belongs to cucurbitaceae family. Pumpkin is one of the most common crops widely cultivated by the farmers. Pumpkins have diverse uses. It is used in making soup and stew from fresh produce. It can be processed by slicing and drying to be consumed during vegetable scarce season and it also is fed to animals as feed.

The available varieties are:

1. Tetsu Kabuto
2. Wengkher Kakur
3. Ebisu

Climate

Pumpkins are warm weather crops and easily damaged by light frosts. They require a temperature range of 18 – 27 °C for growth, the ideal being 18 - 20.5 °C. Therefore, a prolonged warm season is essential to obtain quality pumpkins. At temperatures above 35 °C, male flowers sometimes predominate, resulting in fewer fruit for that period.

Soil

Sandy loam or well-drained loamy soils, ideally deeper than 30 cm are ideal for pumpkins. However, heavier soils can also be used as long as the drainage is adequate. The optimum soil pH is between 5.5 and 6.8.

Field Preparation

Plough the field to pulverize the soil. Good drainage of the field is of great importance and is a pre-requisite for cultivation of the crops especially in the summer months. Avoid using fields in which muskmelon, squash, cucumber or other cucurbits have been planted.

Seed Rate

1 kg per acre with expected of 70 % germination.

Sowing Time

Nursery seeding is done during first week of February and transplanted in mid-March till early April. Temperature and moisture control is important and excess moisture during germination can kill the seed. If sowing is delayed the plants start flowering and thereby incurs loses.

Plant Spacing

Maintain a plant to plant distance of 1.5 m and row to row distance of 2 m. Pumpkin cultivation can be done either through nursery raising or direct seedling.

Weed Management

The first weeding should be carried out 15 days to 20 days after seed sowing. A total of three weeding are required. Weed manually or use garden hoe without damaging the roots.

Pruning/Training

The excessive vine growth should be pruned; manually pinch off the apical shoot leaving 4-5 side shoots which can lead to higher fruit yield. Fruiting before the 12^{th} node should be removed while those from 15-17 nodes are best. To maintain uniform fruit size, keep only 2-3 fruits per vine.

Nutrient Management

On each mound, apply well decomposed farm yard manure (FYM) or fully matured compost @ 8 kg per mound (Equivalent to 8 Mt/acre or 1300 mound/acre). In the absence of organic manures or FYM, farmers should apply 50g of suphala per mound before final land preparation.

Water Management

Water immediately after sowing then followed by irrigation on the third day and then subsequent weekly irrigation may be followed. Irrigation should be reduced when fruits are maturing.

Plant Protection

Some of the major pest and diseases are red pumpkin beetles, melon fruit fly, leaf miner, powdery mildew and downy mildew and should be managed accordingly using IPM technology.

Harvest

Most pumpkins attain maturity after three to four months of sowing. Harvest the fruit when the skin becomes hard and lose its shiny appearance. The fruit should not be left on the ground too long after the foliage has died down as wet soils and sun scald can damages the fruit and reduce storage qualities. Collection of pumpkins needs to be delayed until the vines are completely dried off.

Post-Harvest Management

Handle the fruit carefully from harvesting until marketing, as any injury to the skin will promote rotting. Grading can be done based on size, shape, colour and appearance. Injured or over mature are discarded. Most markets prefer the small to medium-sized fruit, while canners and bakers prefer the large ones. Usually, pumpkins are handled in bulk or loaded into bulk bins directly from the field. Pumpkins are normally packed in cardboard containers or green net bags

For best results with storing, the air-moisture content should be 50 - 70 and the temperature of 6 °C to 13 °C.

Seed Maintenance

Seeds are extracted from good matured fruit, washed under the running water and immediately dried under shed. The drying should be continued until the seed moisture content does not exceed 13-14 %.

9. Summer squash

Back ground

Summer Squash is a tender, warm season vegetable which is usually grown in warm, frost free season. It grows on bush type plants and do not spread unlike pumpkin and winter squash. It is a vegetable which requires a short season to become a marketable crop. Bhutanese farmers have already started to cultivate this vegetable and it is being sold in the local market. It can be consumed raw or cooked, shaved or cubed, hot or cold. It is very versatile in kitchen and can be used in many delicious recipes.

The available varieties are: Anna303, Davinch, Early Green, Suigyak, Zucchini and China

Climate

Summer squash is a warm season crop and therefore requires a warm growing season. It is very susceptible to frost. A daily mean temperature of 20 to 30oC (35oC) is most favourable for successful production. In low altitudes two cropping are possible.

Soil and Field Preparation

Choose light, loose and well-drained sandy loam soil with high organic matter content and pH ranging from 5.8 -6.8. Avoid using fields in your rotation in which muskmelon, squash, cucumber or other cucurbits have been planted. In soil with good tilth, prepare 'mounds' at a height of 15 cm and with a diameter of 50 cm. The spacing for the mounds should be 1.5x 2m. The spacing maintained between the plants should be 60 cm and between the rows it should be 100 cm.

Seed Rate and Treatment

The seed rate for summer squash is usually 2.2 kg per acre.

Sowing and Transplanting

Direct seeding can be done when the soil temperature exceeds $18^{O}C$ or use appropriate protective structures like poly tunnel.

Cultural practices

Two to three hands weeding and earthing up becomes necessary depending upon the weed pressure. Initial weeding is of great importance as young plants are sensitive to weed growth which either weaken the crop or lead to death of young plants. While weeding care must be always taken to avoid damage to the roots. A weed free condition is necessary till the plants have reached the root or bulb formation stage.

Nutrient Management

In one acre, there will be around 1300-1800 mounds. On each mound, apply well decomposed farm yard manure (FYM) or fully matured compost @ 8 kg per mound which works out to around 12 Mt per acre. Semi- decomposed organic manures should not be applied as it causes insect pests and disease problems and nitrogen deficiency for time being. In the absence of organic manures or FYM, farmers should apply 40 kg N, 40

kg P_2O_5 and 14 kg K_2O per acre before final land preparation which is equivalent to 87 kg Urea, 250 kg SSP, and 24 kg MoP, as basal dose to fulfil the nutrient requirement of the crop.

Water Management

Water immediately after sowing then followed by irrigation on the third day and then subsequent weekly irrigation may be followed. Irrigate two times a week from flowering to fruiting and should be reduced when fruits are maturing.

Plant Protection

Leaf miner, blossom end rot and powdery mildew are some of the common problems

Harvesting and Packing

It is important that fruits are harvested at proper stage of maturity after which the quality starts deteriorating. Generally, fruits will be ready for harvest for the fresh market in 50-60 days however it depends on temperature. Summer squash should be picked when they are small and fresh before their skin hardens and their cores get pithy and full of seeds. Once the squash plant begins blooming, monitor their progress regularly as they grow very quickly. Do not let them to get too large as they can become very seedy and gain mealy and undesirable taste. On average, 9-10 fruits per plant with an average 300 g fruit weight kg per fruit are produced.

Seed Production

Summer squash is a day-neutral plant and therefore there is no problem in flower initiation. However, plant and fruit development are poor when ambient temperatures are less than 25oC. The flowers are insect pollinated, mainly by honeybees. The plants are self-compatible, but because flowers are unisexual a high percentage of cross-pollination occurs. The minimum recommended isolation distance intended for seed production is 1000 m. The drying should be continued until the seed moisture content does not exceed 10 %.

10. Bitter gourd

Background

Bitter gourd (*Momordica charantia* L.) is the native crop of tropical Asia, particularly in the Indo Burma region. It is widely grown in India, Indonesia, Malaysia, China and tropical Africa. Fruits are considered as a rich source of vitamins and minerals. Bitter gourd fruits have medicinal value and are used for curing diabetes, asthma, blood diseases and rheumatism. Drinking fresh bitter gourd juice is recommended by naturopaths. Roots and stem of wild bitter gourd are used in many ayurvedic medicines. In Bhutan bitter gourd is grown in small scale for home consumption only.

Varieties

No varieties are released till date in Bhutan. The indigenous varieties are cultivated across the country.

Climate

Bitter gourd is a tropical and sub-tropical crop. Warm and dry weather with temperature range of 30oc to 35oc is optimum. Crop can be grown even in places of slightly lower temperature and high rainfall areas. Production of female flowers, fruit set and growth of plant are seen affected above 35oC and will be susceptible to viral infections. As seeds have a hard seed coat, germination is affected below 10oC. It cannot tolerate frost.

Soil

Well drained loamy soil and rich in organic matter is best suited for its cultivation. Soil pH range of 6.0 to 7.0 is optimum.

Field Preparation

Plough the land to a fine tilth and apply Well rotten farmyard manure @ 20 t/ha.

Irrigation

Bitter gourd cannot tolerate drought or water stagnation. Frequent irrigation at 2-5 days interval especially at fruiting stage is necessary for high yield.

Recommended Seeds.

2.5 kg/acre.

Seed Treatment.

Application of Azospirillium + Phosphobacteria to improve yield and quality of fruit.

Plant Spacing/ Sowing Time

Prepare the pits of 60 cm diameter and 30-45 cm depth at a spacing of 2 m between plant to plant and row to row. Sowing time differs between the different agro-ecological zones**.**
Low hills: February-March
Mid hills: March-May
High hills: April

Weed Management

Two to three weeding is necessary depending upon the weed pressure.

Pruning/Training

Bitter gourd develops many side branches that are not productive. Remove lateral branch until the runner reaches the top of the trellis. Leave 4–6 laterals and cut the tip of the main runner to induce early cropping. Removal of lateral branches in the first 10 nodes has a positive effect on total yield. Without pruning, most of the female flowers occur between the 10^{th} and 40^{th} nodes, or at a height of 0.5–2.0 m.

Nutrient Management

Apply 10 k of FYM per pit (20 t/ha) 100 g of NPK 6:12:12 per pit as basal and 10 g of N per pit 30 days after sowing.

Water Management

- Irrigate immediately after sowing/planting.
- Irrigate once a week depending on soil moisture.
- Drip irrigation is preferred than flood irrigation

Harvest

Bitter gourd fruits are harvested when they are immature after attaining good size and colour. They should be firm, and the outside colour glossy green. Its surface should not lose its bright and glossy appearance. At harvesting, the calyx and stem-end are left attached to the fruit. Over mature fruits are spongy and seedy.

Post-Harvest Management

Fruits after harvest are packed in thin gunny bags or baskets for marketing. The keeping quality of fruits is less, so it should be marketed without any delay as far as on the same day of harvest. If the marketing time is delayed the tubercles will be dropped and freshness and appearance of fruits will be adversely affected.

Seed Maintenance

Fruits are harvested when it turns yellow in colour. Seeds along with red placenta are rubbed against a hard surface and washed in running water and dried under shade.

11. Cucumber

Background

Cucumber belongs to cucurbitaceae (gourd family). Most cultivars are monoecious, with separate male and female flowers in the same plant. Gynoecious or "all-female" cultivars produce only female flowers resulting in up to 13 times more female flowers than those obtained in monoecious cultivars. Cucumber is mainly used as salad and pickling. It has a cooling effect, prevents constipation, useful in jaundice and its seeds have a number of ayurvedic uses.

Varieties grown in Bhutan

Shabi Genchu, Santon No. 1 and Frontier (F1)

Climatic Requirements

Cucumber is a warm season crops and grows best having temperature range between 20° to 25°c. Prolonged temperatures below 15^0 C and above 32^0C will slow down the growth of the plant and increase the bitterness of the fruit (cucurbitacin).

Soil

Though it is grown in a wide range of soil types, deep, fertile soils with good drainage and the pH ranging from 6.5-7.5 are ideal for its growth.

Field preparation

The field must be prepared well with 2-3 ploughings in order to bring the soil to fine tilth. In case if the field is covered with cover crops or green manure crops, it should be turned over 2-4 weeks prior to planting cucumbers to allow for litter decomposition.

Seed sowing

Seeds are sown in Feb-March or June in the foothills. The soil is well pulverised and beds raised 15-20 cm high, 1m wide and 4-5 m long. The seeds are then sown in rows 10 cm apart. Nurseries can also be raised in pluck trays where the media is prepared with the ratio 1:1:1 (FYM: soil: sand)

Cucumbers can be either direct seeded or grown from transplants but transplants can result in an earlier crop given that the seedlings are well hardened before shifting it in the main field. For direct seeding, sow 2-3 seeds per hole on ridges or raised beds at a depth of 1 inch and spaced 60cm between seeds.

Seed treatment

Before sowing seeds, treat them with the suitable chemical to protect them from pest and disease and to increase viability. Seeds are treated with *Trichoderma viride* 4g/kg or *Pseudomonas fluorescens* 10g/kg or Carbendazim 2 g/kg of seeds.

Hardening

Harden the seedlings for 5 days (Gradually reducing the frequency of water and exposing them to more sunlight). A good seedling is in the 4 or 5 leaf stage (about 4 weeks old), vigorous, disease-free, stocky and without flowers

Transplanting

The seedlings with 12-15 cm height with 4-5 leaves should be transplanted in the field. Transplanting is usually done in the evening or early morning to reduce transpiration rate. The seedlings are spaced 30cm apart and 120cm row to row. The seeding rate for transplant production is 2.2kg/ha whereas 3-5kg/ha for direct seeding

Application of fertilizers

Fertilizer applications should be based on crop nutrient demands and stage of crop growth. It should be applied after having the soil tested. The general recommended rate in the region as per the NSSC (Soil fertility and Nutrition, 2013) is 10 t/ac of FYM and18:14:10 kg NPK/ac as basal. Top dress 4-6weeks after planting (12 kg N 2/ac).

Cultural practices

Cucumbers are susceptible to damage from wind and need the protection provided by windbreaks in wind-prone areas.

Mulching

Cucumbers can be directly planted on a bare ground but the most effective planting method would be with the use of mulch (dry grass/plastic mulch)

Weeding

3-4 weedings/hoeings is done depending upon the soil types, texture, structure and climatic conditions of the locality.

Irrigation

The frequency of irrigation depends upon the type of soil and weather conditions. In general, for sandy soils with dry weather, the fields should be irrigated at least every other day if not more often at a rate of 1-2 inches per week. Plants have a higher demand for irrigation during pollination and fruit development.

Staking

Cucumber needs staking as it increases harvesting efficiency and yields, improves pest management, uniform fruit colour and reduce the incidence of soil diseases. It should be done before flowering.

Flowering/sex expression of the plant

Cucumber varieties are either monoecious or gynoecious in their flowering patterns. For monoecious type plants, pollinators like bees play a very vital role in pollinating. Thus care must be taken to protect bees from nearby insecticide application as it will hamper the activity of the pollinators. It is not recommended to apply insecticide during the pollination

period. However, if necessary, it is advised to apply late in the day as the bees pollinate actively most in the morning and early afternoon.

Many cucumber hybrids are gynoecious which produces large numbers of female flowers and have fairly concentrated flowering period. The female flowers of the gynoecious varieties still need to be fertilized with pollen from male flowers, so a certain percentage of monoecious plants need to be planted along with the gynoecious plants to serve as pollinizers The green house cucumbers are usually seedless as they set and develop fruit parthenocarpically (without pollination).

Pest and diseases

Pest and diseases are one of the factors that contribute to low yielding in cucumber. Cucumber beetles, pickle worm, fruit fly, mozaic viral disease, angular leaf spot, scab, gummy steam blight and black rot and downy mildew are some of the common pest.
Basic Techniques for Cucumber Pest and disease Control and Prevention:

- Use clean seeds
- Crop rotation with non-cucurbits
- Rough and destruction of diseased plants
- Early detection of insect and disease problems.
- Use resistant or tolerant varieties where possible
- Proper weed management.
- Clean farm machinery and tools to prevent soil-borne pathogen spread.

Harvesting

The fruits can be harvested as quickly as 35-40 days from date of planting depending on the variety and weather conditions. Cucumbers are harvested at a variety of stages, from quite young to mature before seeds reach final maturity and harden depending upon the market demand. Frequent harvesting is necessary because fruits mature quickly. So, timely harvest keeps the plants in a productive mode since cucumber plants have a limit to the number of fruits they can support at any one time.

Maturity

The fruits (slicing cucumbers) are harvested when the size ranges from 6-10 inches in length and 1.5-2.5 inches in diameter. It should be fresh, crisp, of medium size, well formed, uniform and of a deep green colour. A light green or yellow skin colour is an indication that the fruit is over mature for picking.

Yield

3.5-4 t/ac in 80 to 90 days after the date of planting.

Post-harvest management

Pre-cooling of cucumber under the shade is necessary before taking it to the packing house to maximize shelf-life. Decayed fruit should be discarded and then washed in chlorinated water.

Storage

The fruit should be firm, straight, uniformly smooth and deep green. It can be stored for 10-14days at temperatures 10-13^{o}c with 95 % relative humidity.

Packing

In some of the countries, cucumbers are waxed as the water loss from the fruit is reduced by 50 %. Shrink-wrapping with polyethelene film, a common practice with greenhouse European cucumber, also extends fruit shelf life by preventing water loss.

Seed maintenance

Seed maturity

For consumption, cucumbers are harvested when immature while for seeds purpose it is harvested when fully matured. As the seeds develop and reach full maturity, the fruits will eventually change its color to yellow and lose firmness. The fruits can also be left on the vine in the garden while they continue to mature and soften if the weather conditions are favorable. Mature cucumbers will pull easily from the vine when ripe.

Seed extraction

- Scoop out the cucumber seeds into a container with some water
- Ferment (open container) it for 1-3days to remove the pulp from the seeds
- After fermentation, add more water to the container and stir the mixture (discard the pulp and seeds that floats)
- Rinse the seeds (viable) which have settled at the bottom of the container and dry it until it can be cleanly snapped in half.

12. Mustard Green

Background

Mustard Greens (*Brassica juncea*) is also referred as 'Rai sag' by locals. It is grown by most Bhutanese farmers both in low and high-altitude zones. The other important member of the group is Spinach (*Spinacia oleracea*).

Variety: Wengkhar Petse I and Wengkhar Petse II. Both varieties has been released in 2004

Climate

Mustard Greens germinate quickly when soil temperature reaches 7^{O}C. Sowing is generally done with the onset of monsoon.

Soil and Field Preparation

It requires a well prepared, well drained, loose, friable loamy soil. It is not compulsory to make raised beds to sow mustard greens in well- drained and levelled terrace or on gentle slopes, instead they can be sown straight in the field with furrows made in the surroundings and across the field for proper drainage. However, growing on raised beds of 40 cm wide about 15 cm high will ensure good drainage and facilitate good crop husbandry.

Seed Rate and Treatment

About 1 kg of good quality seed for direct seed sowing, with minimum germination of 75 %, is required for one acre.

Sowing

The seeds should be sown 1 cm deep in rows of 50 cm apart and the plant to plant spacing should be maintained 45 cm apart.

Cultural practices

Two to three weeding is always necessary depending upon the weed pressure. Softly dig out the weeds with your hands, ensuring that the roots are removed as well. Maintain uniform soil moisture for tender growth and optimum nutrient availability for proper growth and development of the crop.

Nutrient Management

In one acre, apply at least 8 Mt of well decomposed farm yard manures (FYM) or fully matured compost. Semi-decomposed organic manures should not be applied as it causes insect pests and disease. In addition, we can also apply 20 kg N per acre before final land preparation which is equivalent to 44 kg Urea. The optimum range of soil pH is 6.0 to 6.8 and if the soil pH is below 6.0, farmers are advised to apply dolomite powder @ 1.5 Mt per acre.

Water Management

Mustard greens require 2 inches of water per week to thrive. Always make sure that they receive adequate water. Maintaining uniform soil moisture is important for proper growth.

Plant Protection

Aphids

If the infestation is not severe, they should be controlled by application of botanical insecticides. Pound and extract juice of 1 kg roots of French Marigold (*Tagetes patula*), mix with 1 litre water and spray to the leaves and soil. In severe incidence, spray insecticides such as Malathion EC or Cypermethrin @ .5 ml per litre of water. After spraying insecticides, farmers must not harvest the crop within 21 days from the date of spraying. Aphids appear mainly during flowering stage

Powdery mildew

Powdery mildew occurs during flowering period
Control: Foliar fungicide applications can help when under severe disease pressure.
Spray Sulphur based fungicides.

Harvesting & Packing

Mustard Greens usually takes around 50 days to harvest during first thinning and thereafter weekly harvest is possible.

Seed Production

It takes longer duration compared to other leafy vegetables and need continuous irrigation. It flowers later than Cauliflower and can be harvested by end of May to 1st week of June. The seeds are cleaned, dried and packed in small air-tight plastic packets and stored in the gene bank.

13. Lettuce

Background

Lettuce (*Lactuca sativa*) is a common cool season salad crop. It is a nutritious leafy vegetable, rich in mineral and a source of vitamin.

Available Varieties

Great lake, a crisp head type is available in Bhutan. Besides, ARDC-Yusipang has released 4 varieties of lettuce viz. Biscia Rosa, Flashy trout, Green oak leaf and Blushed butter oak.

Climate

Lettuce does well in a relatively cool growing season with a monthly average temperature of 12.8 to 15.6^{0}c. Higher temperature induces bolting and cause bitter taste in the leaves and accelerates the disorder 'tip burn' and rot. Seed germination is also affected at temperature above 27^{0}c.

Soil

Lettuce can tolerate a variety of soil but performs best when grown on a rich friable and well-drained soil. Soils rich in organic matters have a high water holding capacity and ensure uniform moisture supply. These conditions are best suited for it, as it has a very shallow root system. Lettuce is sensitive to high acidity and thrives well in soil pH of 5.8 to 6.6. The yield is low at pH of 5 or above 7.

Field preparation

Prepare well pulverized raised beds of 1 m wide with convenient length. Sow seeds during the first and second week of February. Sow the seeds in rows of 15 to 25 cm part about 1 cm deep on raised beds.

Transplanting

Plough field a week before planting and incorporate well decomposed FYM @ 6-8ton/acre**.** Prepare raised beds of 1m wide with convenient length. Transplant seedlings during April, when it has attained 4-5 leaves. During winter the seedlings will be ready by 4 -6 weeks after sowing. Maintain plant to plant spacing of 40 cm and row to row spacing of 30 cm.

Recommended seed/seedling rate

Approximately 250g of seeds is sufficient to cover an acre.

Cultural Practices

Weed Management

Lettuce is a short duration crop and one of the easiest crops to grow. Weeding and hoeing 1-2 times will be enough.

Nutrient management

Adequate nutrients and a continuous moisture supply are essential for vigorous growth. Application of 10-15 tonnes of FYM and NPK @ 25:90:25kg/ha is recommended as basal dose. At the time of head/rosette formation, a dose of 25-30kg N/ha should be applied.

Water Management

Lettuce is a high water demanding crop therefore frequent irrigation during spring will optimize the production. Lack of soil moisture will result in bolting of plants.

Plant Protection

Lettuce is attacked by aphids, armyworms, imported cabbage worm, and loopers. The pest pressure on summer and fall crops is much greater than on spring crops. Damping-off is a serious disease of young seedlings, whereas mildews and sclerotinia are serious on the more mature plants.

Harvest

Maturity Indices

Heading types of lettuce can be harvested depending on the head/rosette size, firmness, solidity and flavor.

Time

Lettuce can be harvested after one and half months of transplanting, however optimum yield can be obtained after three months of transplanting. It is better to avoid harvesting when there is rainfall or dew because the leaves become crisp and break easily on handling.

Yield (kg/Acre)

On an average, head lettuce yields 4-4.8mt/ac. Generally, leaf type lettuce gives comparatively higher yields.

Post-Harvest Management

Remove the diseased and injured leaf/heads. Market the produce as soon as harvesting is done. Lettuce can be stored for 3 to 4 weeks under refrigerated conditions.

Seed Selection

It is important to rogue off-types or inferior plants during head formation or rosette development stage. The features used in the assessment of trueness to type of lettuce seed crops are mainly based on morphological characters observed during the vegetative stages of plant growth up to and including hearting.

Seed Storage

Seeds shall be stored in a cool dry place after packing in an air-tight container.

14. Radish

Background

Radish (*Raphanus sativus* L.) is a fast-growing, annual, cool-season crop. Radish is an important vegetable crop in the Bhutanese diet and has been grown in Bhutan for many years. It is widely grown mostly for home consumption and domestic market. Some surpluses are also marketed to India.

Variety: The available radish varieties are Minowase, Autumn Radish, SPTN, Ivory White, Shoguin, Bajolaphu-1 and Sakurajima.

Climate

The Radish is a cool-season crop, which is best grown in the spring and autumn and will tolerate light winter frosts. The whole part of radish is edible but mostly grown for roots. The high temperatures of summer cause the plant to develop small tops, and roots rapidly become pithy and strongly pungent after reaching maturity. It attains best flavour, texture and size at 10-15^{0}C. Long days as well as high temperature lead to bolting without adequate root formation.

Soil

Radish can be grown on a wide range of soils, but the best results are obtained on light friable loam soil. Heavy soils produce rough, mis-shapen roots with a number of small fibrous laterals and, therefore, such soils should be avoided. The soil needs to be free of rocks, well-drained and have an optimum range of soil pH of 6.6 to 6.8.

Field Preparation

Soil should be ploughed thoroughly so that no clods to interfere with root development. Add well decomposed FYM during first ploughing. A fine tilth of soil is necessary for good root growth and to avoid misshapen roots. Raise about 15-20 cm high ridges in 30 cm apart or 1 m wide beds of about 15-20 cm high. Raised beds or ridges are necessary for uniformly irrigating the crop and at the same time ensuring good drainage of the field. A proper drainage should be made to avoid water logging to have quality root development.

Recommended Seed Rate

About 2.8 kg of good quality radish seed, with minimum germination of 70 % is required for one acre

Sowing

Sowing time of radish depends on the variety. Radish is mainly cultivated in colder seasons. There are some varieties which are also cultivated throughout the year. Seeds of Radish are sown directly on well prepared raised bed and ridges. Seeds are sown at a depth of about 2 cm or on raised beds at the same depth in rows 25-30 cm apart.

Cultural Practices

Maintain regular weeding activities. Two to three careful hands weeding and earthing up should be done in early crop growth stages depending on the weed pressure.

Nutrient Management

In one acre, farmers should apply at least 5 Mt of well decomposed farm yard manures (FYM) as basal dose. In addition, farmers may apply 20 kg N, 20 kg P2O5 and 20 kg K2O per acre before final land preparation which is equivalent to 44 kg Urea, 125 kg SSP, and 34 kg MoP, as basal dose.

Plant Protection

The crops should be protected from thrips, aphids, white rust and root rot using IPM technologies

Harvesting

Radish crop becomes ready for harvesting in about 50 to 60 days depending on variety. Roots must be harvested before they become pithy, bitter and fibrous. Radish is harvested manually by uprooting individual plant. A light irrigation may be given a day before harvesting to facilitate lifting of roots. Around 6-15 tons of radishes can be expected per acre of land. The yield depends upon the variety used and the management of crop.

Post-Harvest and storage

After harvest, the radish must be cleaned thoroughly. Keep foliage attached for fresh sale but remove it for storage. Radish cannot be stored for more than 2-3 days under normal room temperature. It is better to market them immediately after harvest.

Seed Production and Maintenance

For radish seed production, both 'root to seed' and 'seed to seed' systems can be used. The 'root to seed' system is used for basic seed production by lifting and selecting the roots in the late winter, the tops and half of the root is taken off and then replanted immediately. When selecting plants according to their external morphology, care must be taken to ensure that those with pithy roots are rejected. After selection, the plant's leaves are twisted off (leaving the growing point undamaged) and are then planted up and grown-on for seed production. The 'seed to seed' system is used for final multiplication stages where inspections of the mature root are not considered necessary. In this method the stock seed is sown in the late summer and grown *in situ* through the following winter. The plants flower the following spring and seed is harvested in the summer of the year following sowing. The plant generally requires a cold period for flower initiation. The flowers are cross-pollinated by bees and some other insects. Therefore, the recommended isolation is 1000 m. When the radish seeds are nearing maturity the seed pods turn from green to brown, lose their fleshy appearance and become parchment-like. The pods do not shatter very readily and it is therefore better to harvest under very dry conditions. The dry pods are then relatively brittle and seed extraction is easier. Harvested seed pods are dried properly and thrashing is done followed by winnowing and drying. Dried seeds are packed in air tight container and stored in cool room.

15. Turnip

Brief Description

Turnip (*Brassica rapa*) is a cool-weather root crop generally cultivated in temperate, sub-tropical and tropical regions. In Bhutan turnip is primarily grown as fodder. Apart from roots, leaves are also consumed.

Available Varieties

Purple Top White Globe (PTWG)

Climate

Turnip prefer cool and moist climate. It can also be cultivated where summers are mild. It is resistant to frost and requires temperature below 10^0C for seed germination. The optimum temperature for best flavour, texture and size is 10^0-15^0C and require a rainfall range of 350 to 4100mm. Short day length and cool weather favour proper root development while long day length and high temperature induces bolting prior to root development.

Soil

Turnips can be cultivated on a wide range of soil types. However, well drained sandy loam soils with sufficient humus are best for their cultivation. Turnips do not thrive well in very light sandy soils or too heavy soils. Turnips grow best in mildly acidic soils, with an ideal pH between 6.0 and 6.5.

Field preparation

Plough with disk or harrow to produce a field that is fine, firm and free of weeds and clods. The soil need to be loose, well drained and rich in organic matter. Flat beds can be used for sowing turnip, but if the fields are located in low lying areas or seeds sown in rainy season, ridge planting is recommended.

Recommended seed/seedling rate

The recommended seed rate for turnip is 4 to 6 kg/ac. Seeds are sown in ridges or rows 30 cm apart with a plant to plant spacing of 5-7cm. Seeds can be mixed with sand or ash to facilitate uniform sowing.

Cultural Practices

Weed Management

Weeds are generally not a problem once the turnip crop is established. However, sod and annual weeds should be controlled chemically and/or culturally before planting. Tillage before planting can be used for weed control. Mulch the field heavily in order to suppress weeds.

Thinning/Pruning/Training

Thin the plants after 10-15 days of germination or when the plants reach a height of 10 cm. maintain a plant to plant spacing of 10-15cm.

Nutrient management

A basal dose of 8-10Mt of FYM should be applied at the time of land preparation. Supplement by applying 70-100 kg of nitrogen, 22kg of phosphorus and potassium in an acre of field. The complete dose of P, K and half of nitrogen should be applied before sowing. Apply the remaining nitrogen in 2 split doses; first at the time of root formation and second one during development of root knobs.

Water Management

For rapid growth and high quality root production, turnips must have adequate soil moisture. Many growers use sprinkler irrigation to establish seedlings in the field, and then switch to furrow, sprinkler, or drip irrigation once the plants are established. Keep soil lightly moist, watering at a rate of 1 inch per week to prevent the roots from becoming tough and bitter.

Plant Protection

Common pests of turnips include aphids, flea beetles and red turnip beetle. Control for these pests may involve i) applying insecticides to the soil at planting, ii) fall or early spring cultivation helps to control the red turnip beetle. Volunteer rape and weeds of the mustard family should be controlled, especially in summer-fallow or stubble fields. Turnips suffer from clubroot, root knot, leaf spot, white rust, scab, anthracnose, turnip mosaic virus and rhizoctonia rot. To prevent problems with diseases, Brassicas should not be grown on the same site for more than two years in a row. Proper rotations, field selection, sanitation, spacing, fertiliser and irrigation practices can reduce the risk of many diseases. Fields can be tested for the presence of harmful nematodes.

Harvest

Maturity Indices

Harvest turnips when the roots have attained marketable size. Normally, roots are harvested when they are 5 -10 cm in diameter depending upon the variety. Harvesting should not be delayed as it leads to tough and fibrous root. Delayed harvesting also leads to infection of the crops by fungal diseases.

Yield (kg/Acre)

The yield of turnip differs from cultivar to cultivar. On an average it yields 800-1600 kg/ac.

16. Carrot

Background

Carrots (*Daucus carota L.*) are a popular root vegetable that is easy to grow as long as it is planted in loose, sandy soil. Carrot is rich in sugar, and a great source of vitamins and carotene. Carrot is widely grown in Bhutan by the farmers.

Varieties: New Kuroda (OP), Wengkhar Laphu Maap 1 (OP) and All Season Cross (F1)

Climate

Carrots grow best under cool conditions. Temperature and soil moisture influence the shape, colour and quality of carrots. The best quality carrots are obtained when weather conditions favour regular uninterrupted growth.

Soil

Carrot grows well in deep, loose sandy loam. Shallow, compacted or heavy soil causes the thick taproot up out of the ground, turning them green due to their exposure to sunlight. Soil pH ranges between 5.8 and 6.5 provides the best conditions for growing healthy carrots.

Field Preparation

Soil should be ploughed thoroughly atleast 30cm depth to allow good root development. Add well decomposed FYM during first ploughing. Raise about 15-20 cm high ridges in 30 cm apart or 1 m wide beds of about 15-20 cm high.

Recommended Seed Rate

About 0.47 kg of good quality carrot seed, with minimum germination of 70 % is required for one acre.

Sowing

Sowing time of carrot depends on variety. Carrots are annual cool season crop, half hardy to frost and light freezes. Seeds are sown directly on well prepared raised bed and ridges at a depth of about 2 cm or on raised beds at the same depth in rows 25-30 cm apart.

Cultural Practices

It is important to control the weeds in the early stages of crop development because early competition can adversely affect plant growth and result in the lowering of crop yields. Earthing up is necessary to loosen the soil around the root zone and to cover exposed roots, otherwise the roots will turn green. If possible, mulch the crop to retain moisture, weed control, speed germination and block the sun from hitting the roots directly.

Nutrient Management

Well decomposed Farm yard manure should be applied during the field preparation. In one acre, farmers should apply at least 8 kg N, 4 kg P_2O_5 and 24 kg K_2O per acre before final land preparation which is equivalent to 15 kg Urea, 25 kg SSP, and 40 kg MoP, as basal dose.

Harvesting

Carrots are usually harvested when they are immature and generally ready to harvest after 2-3 months after sowing.

Post-harvest and storage

After harvest, carrot tops should be removed and roots should be washed carefully to avoid bruises. Carrot can be stored for as long as 3 months after removing the foliage and storing in a box of sand in cool temperatures.

Seed production and maintenance

Carrot seed production can be done from both roots to seed and seed to seed method. The root to seed system is used for basic seed production by lifting and selecting the roots in late winter, the selected roots are replanted followed by light irrigation. Seed to seed method is used for final multiplication stages where inspections of the mature root are not considered necessary. In this method the stock seed is sown in the late summer and grown in normal condition through the following winter.

17. Okra/Lady finger

Background

Abelmoschus esculentus, is an herbaceous annual plant in the family malvaceae which is grown for its edible seed pods. Only the tender unripe fruit is eaten. The vegetable is grown in about an area of 501 ha with a production of 5972 MT.

Available Varieties: Kranti

Climate

Okra is a warm season vegetable crop and requires a long warm growing season. Low lying areas with evenly distributed annual rainfall of up to 1000 mm and temperatures between 25-35^{0}c are most suitable.

Soil

It is grown on sandy to clay soils but relatively light, well-drained, rich soils are ideal. Well-manured loamy soils with pH of 6.0-6.8 (slightly acidic) are recommended.

Field Preparation

The land should be given 2 to 3 ploughings to get the soil to fine tilth stage and remove any weeds from previous crops. Incorporate well-decomposed manure at 20 MT/ha to improve the soil texture and aeration.

Recommended seed/seedling rate

3-5 kg/ha depending on variety and seed viability.

Nursery management

Okra is direct seeded into the field. Hence nursery management is not required.

Planting

Soak seeds for 24 hours in water or 30 mins in ethyl alcohol and acetone. Sow directly into moist soil at a depth of 2-5 cm. After germination, thin out to one plant per stand.

Spacing: 0.30m x 0.45m

Planting time: March-December

Cultural Practices

Weed management: Weeds should be controlled till crop canopy covers fully. This can be done by frequent hoeing, weeding and earthing up. Carrying one hand weeding @ 45 days after sowing the seeds proved more effective.

Thinning/Pruning/Training: Plants are thinned to an in-row spacing of 12 inches apart for dwarf cultivars and 18-24 inches for larger cultivars. *Before flowering,*

- Check the general plant height and habit, pigmentation of leaves, petioles and stems; remove plants with virus symptoms.

- Flowering
  Check the relative size and color intensity of flowers; remove plants with virus symptoms.
- Fruiting
  Check that fruit is true to type; remove plants with virus symptoms.

Nutrient Management

The general fertilizer requirement are as follow:

FYM @ 4000 kg/ha, NPK @ 100:150:50 kg/ha

Water Management

Irrigation is very important especially at the time of flowering and fruiting stage of okra growth. During flowering and fruit set plants should receive at least 1.5 inch per week of water to ensure fruit set and development. Water stress will drastically impact the growth of okra plants, size of vegetables and yield. Immediately after sowing, field should be irrigated and subsequent irrigations should be given at fixed intervals depending on the type of soil and weather conditions. Drip irrigation is most widely used because it helps reduce foliage diseases and overhead irrigation is used as needed.

Plant Protection

Diseases	Insect Pests
Root rot	• Boll weevil
Pod rot	• Pink boll worm
Fusarium wilt	• Corn earworm
Verticillium wilt	• Flea beetle
Powdery mildew	• Cotton aphid
Dry rot	• Stem borer
Cercospora blight and leaf spot	• Leafhopper
Alternaria leaf spot	• Spider mite
	• Whitefly

Harvest

Maturity indices: Harvest pods while still tender, usually, 5-6 days after flower opening. Okra should be harvested 2-3 times/ week. Regular picking increases yield. Picking of okra in the morning is advisable.

Yield (Kg/Acre): Yields of okra are dependent on cultivar, time and frequency of harvest. An average of 6-12 tons/ha can be obtained.

18. Beans

Back ground

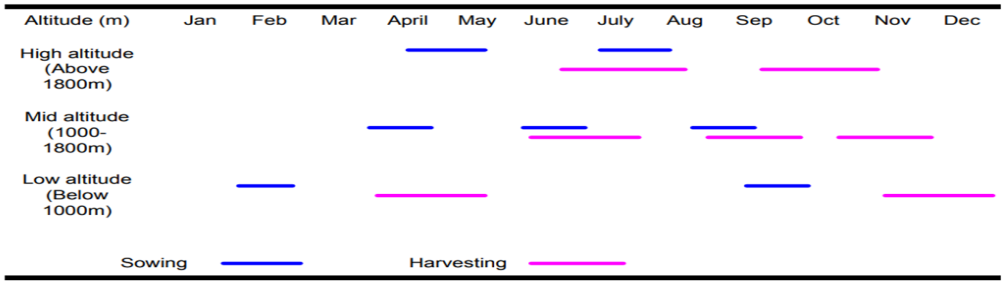
Phaseolus Bean (*Phaseolus vulgaris* L) is one of the main leguminous crops grown as vegetable in Bhutan but it is regarded as a vegetable when it's immature and tender pods are eaten. Phaseolus beans are often called as kidney beans or common beans and they are widely distributed and have the broadest range of genetic diversity. They are cultivated under different cropping systems from monocrop of bush bean (commonly called as French bean) to complex association of indeterminate or climbing beans with maize.

Bean varieties are broadly divided into dwarf (determinate) in which the terminal meristem is reproductive and climbing (indeterminate) in which the terminal bud is vegetative.
Varieties: Grey Pole, White Pole, Borloto(Bush)

Climate

Common beans grow under a wide range of climatic conditions. However the best pod setting is obtain when day temperature is between 15 and 30ºC.

Growing season for beans



Soil and Field Preparation

A well prepared, well drained, loose, friable loamy soil with pH ranging from 5.5 to 6.8 is best suited for growing beans.

Seed Rate

Seed rate for beans is usually 12 Kg per acre. However, seed rates are different for bush beans and climbing beans. About 8-10 kg of good quality bush bean seed, with minimum germination of 75 %, is necessary for one acre whereas for pole bean 4-5 kg seed is adequate for one acre.

Spacing

There is a slight difference in the spacing between bush bean and pole bean. In case of bush bean, seeds should be sown in rows 50 cm apart and the plant to plant spacing should be 25-30 cm where as in the case of pole bean, seeds should be sown in rows 80 cm apart and the plant to plant spacing should be 30-40 cm. Pole beans require external support during plant growth which is provided in the form of stakes.

Cultural Operations

Two to three weeding cum hoeing is necessary depending upon the weed pressure. The crop should be maintained weed free till the stage of appearance of flower buds after which the crop should not be disturbed.

Nutrient Management

In one acre, it is advised to apply at least 8 Mt of well decomposed farm yard manures (FYM) or fully matured compost. In addition, for a good crop, apply 10 kg N and 30 kg P_2O_5 per acre before the final land preparation.

Water management

Beans are shallow rooted crops and are sensitive to excess soil moisture. Therefore, the water requirement is very low. Applying irrigation immediately after sowing adversely affects germination and therefore should be avoided. Irrigation should be made available prior to blooming, flowering and pod development stage as these are the critical stages of their growth.

Plant Protection

A good crop rotation will help prevent and minimize pest and disease occurrences. A bean crop should not follow crops which belong to Leguminosae family. It should be rotated with crops from different family such as tomatoes, cabbage, carrot and pumpkin. Beans should be protected against thrips and aphids, pod borer, powdery mildew, rust and anthracnose.

Harvesting

On average beans usually take around 60 days to reach the Harvesting stage. Always pick beans when they are tender with an appropriate size to consume as vegetable. To determine when to harvest, examine by opening several pods. As the pods attain marketing stage, hand picking of pods should be carried out at 7 to 10 days interval. By harvesting pods frequently, it will provide a continual production all season.

Depending upon the variety and the level of crop management, the yield of the beans may range between 2 to 4 tons per acre. Pole beans give a higher yield over a longer harvest period than do bush beans.

Seed Production

It is important that adjacent cultivars should be at least 20-50 m apart with the distance increased to at least 100-150 m for basic seed production. Harvesting normally commences when the majority of pods have dried and become parchment-like. Cut the crop when the earliest pods have dried to the parchment stage and the foliage is starting to dry off, characterized by a reduction in the intensity of green in the leaves and haulm. Sample pods should contain fully developed seeds which are firm, taste starchy and are readily detachable from their pods. Thresh or pound the dried plants for extraction of seeds and dry up the seeds maintaining about 10 % of moisture content. Pack the dried seeds in small air tight plastic bags and store in the gene bank for future use.

19. Pea

Background

Pea *(Pisum sativum),* also called garden pea is herbaceous annual plant belong to the family Fabaceae, grown worldwide for its edible seeds. Peas are botanically fruit, since they contain seeds and develop from the ovary of a flower. The pea plant is hardy leafy annual with hollow trailing or climbing stems that reach up to 1.8 meters in length.

Available varieties

1. Arkel
2. Usui

Climate

The seeds can germinate at minimum temperature of 5 degree celsius and can withstand relatively low temperature with light frost during seeding stage. The optimum monthly temperature for good growth is between 10 and 20 degree celsius. Peas thrive best when there is slow transition from cool to warm weather in spring. Cultivation of pea is not possible when the day temperature is above 30 degree Celsius.

Soil

Pea can be grown in medium to heavy soils. It grows best in well drained loamy soil. Water logging is not suitable to the crop. If the soil is acidic, liming has to be done after soil analysis. Favorable PH range for pea growing is between 6.0 and 7

Field Preparation

Thoroughly prepared seed bed is required for pea cultivation. First ploughing should be given by soil inverting ploughs and harrowing. It needs a fine tilth soil free of clods. In well drained and well levelled terrace or gentle slopes, pea can be sown straight in the field with furrows made in the surrounding and across the field for drainage. However, growing on raised bed of 1m wide about 15 cm high will ensure good drainage and facilitate good crop husbandry.

Layout and Spacing:

Flat-bed layout is used. Spacing is 45 X 20 cm.

Recommended seed/seedling rate

The seed rate of 75 to 80 kg /ha is recommended. In case of bold seeded varieties, seed rate can be increased up to 100 kg/ha.

Sowing Time

Pea is direct seeded crop usually cultivated on raised beds. It is sown usually in October and harvested in May

Spacing:

Seed should be sown at the depth of 3 to 6cm depending upon soil moisture. Seeds should be sown in rows about 30cm apart for dwarf varieties (Arkel**)** and 45 cm apart for tall varieties (Usui)**.** The plant to plant distance should be maintained at 10 cm.

Method of Sowing:

The pea is generally sown by broadcasting. But it may also be sown by dibbling or behind the plough. The seeds are soaked in water overnight before sowing for better germination. Seeds treated with Rhizobium culture give higher yield.

Irrigation

Water requirement of pulse crops are higher than cereals. The water requirement of pea depends largely on agronomic condition of the locality. The crop may be irrigated at both 10 days interval. Where rainfall is low, irrigation is very necessary at flowering and grain development stage.

Cultural practices:

Trailing and Staking:

This is an important operation to be done when vines were about two month old and are at spreading stage. Generally the plants should be supported on bamboo sticks. Delay in this operation will reduce the yield considerably.

Weed Control:

Hand weeding is generally practiced to control the weeds in pea.

Nutrient Management:

15-20 t/ha of well decomposed FYM should be applied at the time of soil preparation. 25 kg N, 50 kg P and 50 kg k/ha should be applied half dose or full dose P and K should be applied at the sowing. Remaining half nitrogen applied one month after sowing. Full dose N, P and K are given at the time of sowing.

Plant protection

Some of the common insect pest and diseases are pod borer, leaf miner, aphids and powdery mildew.

Harvest:

Maturity indices: Peas are harvested for table use when the pods are filled and the young tender peas change from dark to light green. Hand picking of pods should be carried out at 7 to 10 days interval. Pod becomes ready for harvesting in about 100 to 120 days after sowing.

Yield kg/acre: Depending on the variety and level of crop management, the yield may range between 1.6 to 3.2 MT/acre.

Post-harvest Management:

Threshing -

Threshing of pea in Bhutan is usually done manually after drying properly in the sun.

Storage Temperature – Peas do best with a storage temperature of about 3 °C to 7 °C. At higher temperatures the rate of respiration is faster which in turn leads to more rapid degradation and loss of quality. However, if the storage temperature drops below -0.5 °C the peas may be subject to freeze damage.

Relative Humidity – Peas and beans thrive at a cooling and storage relative humidity of about 95 %.

Handling – To prevent damage and loss of quality it is important that peas and beans be handled carefully during harvest and storage. Depending on the storage conditions and the particular peas and beans they will typically have a shelf life of about 5 to 10 days.

Seed production:

Seeds are produced from healthy and disease free plants. Harvest ripened crops and dry up harvested plants. Pound the dried plants for extraction of seeds and dry up the seeds maintaining about 10% of moisture content.

SECTION THREE

PACKAGE OF PRACTICES FOR FRUIT AND NUTS

1. Apple

Background

Apple (*Malus domestica*) is commercially the most important temperate fruit and second among the income generating fruits produce in Bhutan after Mandarin. The main apple-growing areas are Thimphu, Paro and Haa.

At present, apple is mostly sold as fresh fruit to Bangladesh and India. The domestic market for agro processing of apple is drastically growing up. Apple export over the years has declined drastically due to various reasons such as loss of orchard area to urbanization, poor management practices and disease and pest incidence. However, the opportunities to increase the production are available by expanding area in other higher altitude and adopt technology such as high-density cultivation.

Apple varieties

Sl.No	Variety	Harvest	Altitude
1	Red Delicious	September	2000-2800
2	Royal Delicious	September	2000-2800
3	Golden Delicious	Sep – Oct	2000-2800
4	Red chief	Sep – Oct	2000 -2500
5	Red free	Mid- August	2000 - 2500
6	Anna	August	1000 - 1500
7	Lobo	Late September	2000 - 2500
8	Fuji	October	2000 - 2500
9	Mutsu	October	2000 - 2500

Climate

An area with a warm and mild summer, followed by a cold winter is ideal. Winter chill (1000-1500 hours between 0 – 7.2 Degree Celsius) is essential for apple in winter while at dormant stage to avoid from frost damage. Thus, avoid areas where frosting is common after March. In Bhutan, ideal zone for apple cultivation ranges from 1900 to 2700 masl above mean sea level

Soil

The ideal soil texture for Apple is loam with a pH between 6-6.5. However, texture from a sandy loan to a silt loam will produce good crops provided the subsoil is well-drained.

Field preparation

Field should be prepared well in advanced incorporating enough FYM. A pit size of 1 m^3 must be dug. While filling up pits, top soil should be added first followed by sub soils.

Recommended seedling rate

Normally spacing of 6 m x 6 m is recommended. However, for dwarf varieties in high density planting, even 3 m x 3 m spacing is adopted. Depending on the spacing, one acre of land can accommodate 112 to 449 plants

Nursery management

For high quality produce, vegetative method of propagation such as grafting and budding are recommended in apple. Grafting is usually done during dormant season from January to March. Budding is also practiced in apple propagation. It is done in June to August.

Planting

Usually planting is also done from January to March during dormant season to avoid damage to the plants. After planting, it is good to provide mulching to prevent growth of weeds and also to retain moisture in the soil. For better productivity, pollination is critical in apple cultivation. Hence, 10-15 % of the total plants should be planted with pollinizers. Good pollinizers include Golden Delicious, Granny Smith and Jonathan

Cultural practices

Pruning and training are essential components of cultural practices in apple cultivation. In the first year of planting, head back branches to 90-100 cm and in the second year, head back the central leader at 40-50 cm from last point of head back. Follow same techniques of heading back at 40-50 cm in the 3rd and 4th year. This will result in balanced scafold development. A tree is trained to its desired shape by letting branches grow in the desired direction using ropes and pegs. For maintenance of required fruit size and to mitigate biennial bearing, fruit thinning must be practised. Remove weak, misshapened and crowded fruits to maintain good balance of leaves and fruits ratio. Regular proper orchard floor management should be done through weeding, making of basins around the plants and providing mulch.

Nutrient management

Fertilizer application should be done within the tree canopy about 10 to 15 cm from the tree trunk. Fertilizers especially chemical fertilizers should not come into contact with tree trunk. Soil should be moist at the time of application so that they are absorbed by the plants.

Water management

Enough irrigation should be provided especially at the time of flowering, fruit formation and development stages, during the dry season.

Plant protection

Fruit Tree Red Spider Mite (*Panonychus ulmi*) Feeding by mites on the leaves of the apple causes the foliage to become dull green and later silvery brown. The leaves may fall prematurely and heavy infestations will reduce fruit yield and fruit bud formation. The outbreak of this pest was first noticed in a single orchard in 1985 in Semtokha. It is now observed in many orchards, especially in Thimphu. Leaf symptoms are most evident in July – September, and attacks are particularly serious in a hot and dry summer.

Control:

The build-up of this pest in apple orchards is associated with the use of pesticides to control other pests, particularly where the pesticide used kills the natural enemies of red spider mites, but not the mites themselves. The use of such pesticides should be avoided as far as possible. For serious infestations, the following acaricide is recommended.

Chemical	Trade Name	Application Rate
Dicofol (18.5% EC)	Kelthane	2ml/1 L of water

Woolly Aphid

This pest is observed in most orchards with varying infestation levels. Feeding by this insect produces small round galls on the bark of trees and on the roots, and, if sufficiently large numbers build up in summer, fruits may be so covered with aphids. On young trees and nursery stocks, galling may seriously disfigure or stunt the growth of plants. The aphids overwinter as nymphs, sheltering in cracks or under loose barks or on the roots in the soil. During summer they colonize on twigs and branches above ground.

Control:

Some control can be achieved by removing suckers from the base of the tree where nymphs can find shelter during winter, and a routine spray application of light diesel oil combined with malathion, as recommended for control of San Jose scale, will give added protection. For small scale infestations, mechanical control can be carried out by rubbing off colonies from the tree with a piece of rag soaked in a mixture of water with little kerosene. In case of serious infestation the following chemicals are recommended for the application in June. Only infested trees should be sprayed and not the whole orchard.

Chemical	Trade Name	Application Rate
Chlorpyrifos (20%EC)	Durmet	4ml/1 litre of water
Malathion (50%EC)	Cythion	2ml/1 litre of water

Trunk Borer (*Anoplophora* sp.)

The long-horned adult is about 3 cm long, with antennae up to 10cm long. It is grey with rows of black dots. Eggs are laid on the trunk, just above soil level. The young larvae tunnels superficially in the layer between bark and wood. The older larvae tunnel into the heart wood. The superficial tunneling, especially in young trees, can result in the tree dying due to ringing of the trunk. The damage can also permit diseases to enter. Affected trees turn yellow and parts of or even the whole tree can die.

Control:

Control of the trunk borer should start as soon as the first damage is observed. Weeds around the trunk should be cleared regularly to monitor the damage. At the time frass (sawdust like powder) and resinous exudation is seen. Young larvae which have tunnelled deeper inside the tree can be poked out with a piece of wire. A piece of cloth soaked in kerosene or diesel should be pushed in the hole. The hole should then be closed with mud.

San Jose Scale *(Quaaraspidiotus pernicious)*

With heavy attacks on twigs and branches, the tree may suffer from some dieback of twigs and leaves. Scales also feed on fruits and the feeding site is surrounded by a round red spot, spoiling the appearance of the crop.

Control

Most scale insects are difficult to control with pesticides due to their thick, waxy, immobile protective covering. Some control can be achieved by means of high volume spray of light diesel oil (LDO) with malathion in early spring when the buds have begun to swell. A good coverage to all twigs, branches and trunk is essential, making sure that the spray penetrates into cracks. It is important that the spray is not applied too late in the spring to avoid damaging new foliage.

Chemical	Trade Name	Application Rate
LDO water + malathion (50% EC)	Hindustan petroleum oil + Cythion	20ml LDO/1 litreof water + 1ml of malathion

Diseases

Apple scab *(Venturia inequalis)*

On leaves and fruits:

The new and tender leaves in spring and summer are most susceptible to infection. Light brown to olive green powdery spot symptoms develops, usually on the under surface of the leaf. Later infection could be seen on both surfaces. Leaf distortion, dwarfing, premature yellowing and finally defoliation occur under severe infection.
Infection occurs early in the season and the fruits often develop spots around the blossom end of the fruits, but later infection could occur anywhere on the fruit surface. Severely scabbed fruits appear miss-shaped, and often cracks appear, allowing secondary infection.

Control:

In autumn the fallen leaves must be gathered and burned as the disease overwinters on fallen leaves. It is also possible to collect the leaves and spray a solution of urea (50kg/100L of water) on them to enhance decomposition. Spraying is probably necessary where a serious infection of scab has been observed in the previous year. Tentative recommendations are:

Sl. no	Tree growth stage	Chemicals	Dosage (In g/100L water)
1	Green tip	Baycor	75
2	Pink bud-early bloom	Captan*	200
3	Full bloom	Mancozeb	200
4	Petal fall	Carbendazim	50
5	Fruit set	Carbendazim + mancozeb (equal portion)	125
6	Fruit development	Mancozeb	200
7	Pre-harvest (3-4 weeks before harvest)	Baycor	75
8	Post-harvest	Urea	5kg

*Captan should not be applied on the Red Delicious variety, as it may cause leaves burned.

Powdery Mildew

When young leaves emerge from infected dormant buds, fungus develops at the same time, producing white powdery patches on the leaves. These leaves are distorted, and defoliation can occur. Fruits are prone to infection under severe conditions.

Control:

When the presence of fungus is observed, prune off silvered terminals and burn them. Application of pesticide is usually not necessary, but Karathane can be sprayed at the rate of 1.5ml/10 liters of water during late dormancy, at bud swell, at petal fall and two weeks later.

Collar rots (*Phytophthora cactorum*)

In orchards where rots are prevalent, improved management is usually needed. This may include;

- Provision of better drainage to avoid water logging
- Proper planting methods, so that the grafting point is not buried in the soil
- Effective weed control around the trunk, enabling it to dry quickly after rain
- Effective control of other pests and diseases, including prevention of damage to trunks by rodents (rats and mice), deer.
- Avoidance of mechanical injury to the trunk, sunburn etc
- Proper application rates and methods of FYM and fertilizers

Harvest

Time and weather condition for harvesting is very important. Apple should not be harvested in high day temperature or raining. High day temperature will increase the rate of respiration and consumes more power during pre-cooling. Harvesting during rain will transport harmful pathogens from the field to stores. The best time of the day to harvest apple is during morning hours after disappearance of the morning dew and towards afternoon when the heat is low. Fruits should be picked with care to avoid injury and bruises which would reduce shelf life. Apple fruits are harvested in 145 to 160 days from full bloom. Also, when TSS is more than 12 % it is time to harvest. Change in the colour of fruits also indicates maturity but it depends on the variety. On average, the yield is about 35 to 60 Kg per tree depending on the variety.

Post-harvest management

Sorting of damaged fruits, diseased, misshaped and fruits without colour is very important before grading. Grading of apple is done based on size and colour. Normally grading requirement comes from the importing country. Most super markets have standard grades as per the desire of the consumers. Grading can be done manually using sizing rings with machine. Pre-cooling is done to remove field heat from the fruits and also to enhance the efficiency of cold store. Apple can be stored at room temperature for about a month without much deterioration. Apple can be stored in different storage facilities at varying length of time. Apple can be stored for 3 to 4 months, 4 to 5 months and 10 to 12 months under zero energy cold stores, refrigerated cold store and controlled atmosphere store respectively.

2. Pear

Background

The fruit belongs to Rosaceae family. Two major species commercially cultivated are: **a) European Pear** (*Pyrus communis* L.) and **b) Asian Pear** (*P.* (Burm. f.) Nak. [syn. *P. serotina L.*]. There are about 35,141 pear plants in the country and which produced 482 MT of fruits on an average of 50 kg per tree.

Varieties

6 varieties of Pears (Kosui, Hosui, Bajo Lhee 1, Zhey Lhee, Wengkhar Lhee 1 and Shinko) are released for commercial cultivation. In addition, there are also other varieties of pear such as Niitaka, Kikusui, Yakumo, Neijisseiki, Atago, Okisankichi and Meigetseu and Williams Pear which are under evaluation.

Climate

The cultivation zone of Asian Pears ranges from 1600-2500m above mean sea level. However, the ideal altitude for pear cultivation is 1700-2300 masl amsl. It requires an optimum annual mean temperature of 14 - 18^{o}C. It has annual precipitation requirement of 1000-2000 mm and 1300-1500 chilling hours at 7.2^{o}C. In areas where there is persistent fog especially during the fruit development and maturation stages, the fruits are found to be predisposed to diseases and pests.

Soil

Pears can be grown under a wide range of soil types but should avoid water logged conditions. Soil rich in organic matter, weakly acidic (pH range of 6-7.5), well drained and deep in tilth is preferred.

Field preparation

Field should be prepared at least one month ahead of planting with incorporation of well decomposed manures. For ideal growth and development, pit size of 1 m^3 is recommended.

Recommenced seedling rate

Pear saplings are planted at a spacing of 5 x 5 m or 6 x 6 m. The distance between the fence/border and the plants on the side should be half that of plant to plant distance. If the terrain is steep, then contour planting is recommended. An acre of land can accommodate more than 112 to 161 plants depending on the spacing.

Nursery management

Pear is usually propagated through grafting. For raising rootstock, seeds should be collected from healthy plants and extracted from mature fruits in November. To get better germination rate, seeds should be stratified before sowing. Both small and large fruited local pears can be used as rootstocks. Scion woods should be collected from healthy mother plants that have come into bearing. Scion wood should contain 2 to 3 buds. Side veneer grafting is done from end of January to early March. Local pears both small and large fruited ones can be used as rootstocks.

Planting

Seedlings are planted about 30cm above the ground by making a mound of soil rather than deep into the pit. The graft union/joint of the plant, if any, should not be buried into the soil. While planting, fill the pit first with the top soil and then followed by sub-soil mixed with FYM. To prevent the growth of weeds around the plant and to prevent loss of water from the soil, mulching of soil with grass and other debris is recommended. Once planted, the sapling should be decapitated at about 40 cm above the ground. Planting is usually recommended from January to March.

Cultivation practices

For proper growth and development of the plant, a basin should be made around the tree trunk. Basin making keeps the floor clean and enables proper irrigation and manuring. Ideally the size of the basin should be equal to the size of the tree canopy.
Normally Asian pears are trained to vase-shape or open centre type. If trees are growing excessively then pruning should be reduced to encourage fruit spur development. Fruit thinning must be done to maintain the health of the plants and fruit quality. First thinning should be done after the first natural fruits drop and second thinning when the fruits attain the size of walnut or Ping-Pong ball size. Fruits that are malformed, diseased, crowded and weak ones should be removed as well.

Nutrient management

Apply compost or FYM sometime in December-January followed by split application of a mixture of chemical fertilizers 2-3 weeks before flowering when new shoots emerge and the second dose after the fruit thinning or at fruit growing stage.

Recommended fertilizer application

Age of the Plant	FYM (Kg/tree)	NPK (g/tree)
2-3	10	100
4-7	30	300
7-10	50	500
Above 10 years	50	500

Water management

There should be enough moisture in the soil. Water is critical during flowering and fruit development. Lack of moisture during these periods will cause flowers and fruits to drop and also limit cell division leading to smaller fruit size with poor quality

Plant protection

In our conditions, there are no serious incidence of pests and diseases except fruits depredation by birds, rodents and wasps. Bagging of fruits with newspapers and if possible netting of orchards is recommended to protect against birds. It is also advisable to spray winter oils and apply Bordeaux paint on the trunk above the ground level.

Harvest

Grafted trees come into fruiting in the second or third year after planting. Early varieties like Kosui can be harvested by the end of July and late cultivars like Okusankichi can be harvested in mid-November. Harvest the fruits when skin colour changes from green to yellowish green or russet brown depending on the varieties. Fruits are handpicked by giving a twist rather than pulling. Use of harvester is recommended. While picking, care must be taken not to bruise or injure the fruits since Asian pears are susceptible to bruising and discoloration. Unlike European Pears, Asian pears are non-climacteric and mature on the trees. On an average, a pear tree can yield 50 to 80 Kg depending on the varieties and management practices.

Post-harvest management

Fruits should be graded based on size and colour. Fruits with larger size and minimal surface blemishes fetch better prices in the market. Wooden, plastic or cardboard boxes should be used for packaging. Fruits should be packed in layers with cushions in between, sides, top and the bottom. Fruits can be stored for 120-245 days at -1^{o}C and 85% relative humidity. As a general rule, the later the variety matures, the longer it can be stored. Asian pears can store up to 3 weeks at room temperature.

3. Pecan

Background

The pecan (*Carya illinoensis*) is a deciduous sub-tropical plant. It belongs to the walnut family Juglandacae but is more closely related to hickories than walnuts. Pecans are the largest tree (30 to 40 meters) in the hickory family with compound pinnate leaves, composed of nine to 17 leaflets, and are 33 to 50 cm long. Pecans are native to lower Midwest and South-eastern United States. It is one of the most desirable trees to plant, due to their size, nutritious nut and natural beauty as a shade tree in home yards.

Variety

In Bhutan, pecan nut cultivation is limited only to research stations and few back-yard farms. Five exotic cultivars namely; Desirable, Cheyenne, Wichita, Kiowa, and Western Schley were introduced and established at ARDC Bajo in 2002. However, promising variety selection continues to be a major challenge as the data from the multi-locations trials greatly vary.

Climate

Pecan tree grows satisfactorily at an elevation ranging from 900-1700 masl and require warm temperate climate. It requires about 500-600 hours of chilling hours below 7^0c to break the dormancy. It also grows well in areas with short, cold winters and long, hot summers.

Soil

Pecan can be grown in varied soil that are deep, well drained and aerated. Soils that allow water penetration to depth of one to two meters are optimum. The pecan roots will be in the top one to two meters of the soil. Poor drainage will result in poor root development which may result in stunted tree growth and less production.

Field preparation

Before planting pecans, soil should be prepared to fine tilth by giving two to three deep ploughings, supplemented by adding well decomposed farm yard manure (FYM) and compost. It is recommended to do soil testing to analyze soil characteristics and nutrient deficiencies. Pit size of 1meter x 1meter x 1meter should be dug and filled with mixture of soil, well decomposed FYM/compost (20-25 kilogram), and 200g of single superphosphate.

Nursery management

For better germination, seeds require stratification for about 3-3.5 months to break dormancy. Successful stratification requires seed to be stored in moist and aerated medium at chilling temperature of 4^OC for 60-70 days. Pecan seeds should be planted in raised bed or in containers from mid-February to mid-March. Seeds should be planted 10 cm to 15 cm apart in rows and 7 to 10 cm deep. Planting depth should be shallower in clay soils than in sandy soils. For raising seedlings in one-acre nursery, about 3300 nuts may be needed. Like any other fruit tree nurseries, weeding and irrigation is necessary for proper growth of the seedlings.

Planting

The spacing of pecan trees depends on geographical locations, and the soil fertility status. Square system is adapted in plains, and triangular or counter system in slopes planted at a distance of 7 to 8 meters in poor soils and 8-10 meters in fertile soils, which is equivalent of 70 trees per acre and 50 trees per acre respectively.

The Pecan nuts are planted during February- March or before normal bud break. Plant roots need sufficient time to acclimatize to soil environment. The seedling should be about one meter tall with trunk diameter of 1.5-2 cm above the graft union. When handling trees keep root system moist, and never let dry out. Dig a hole to accommodate the roots and fill with water. Plant the tree by spreading the roots, and refill using the soil that was removed. Keep the graft union about 5 cm above the soil. Mulching the tree with saw dust, dry straw or crop residues for conserving moisture and weed control.

Cultural practices

Keep orchard clean as desired as weeds compete with pecan for water and nutrients and reduce growth and kernel development. Clean orchard also reduces pest problems. Most practical used system of orchard floor management is the cultivation of shallow rooted vegetable crops. It is also recommended to grow green manure crops (daincha) which can be incorporated into the soil through ploughing. Such practices not only improve soil structure but also add nutrients for plants.

Nutrient management

Nitrogen: Pecans must have nitrogen to grow well. Apply nitrogen at bud break in April and again in May and June. About 4.5 kilograms (Kg) of actual nitrogen is needed in June to produce 45 Kg of pecans per acre. For heavy crops, apply it in July and August also.

Young trees should receive small, frequent applications in response to growth from bud break to late July. Later applications will expose young trees to greater risk of freeze injury.

Potassium and phosphorus: Potassium fertilizer may be needed every 1 to 3 years, especially on sandy soils. Monitor both elements regularly through soil and leaf analysis.

Water management

Pecan trees need adequate supply of water for proper growth and nut production. Flood and furrow irrigation are preferred methods of water application. Sprinklers can be used, but must run for considerable time to ensure that water penetrates up to one to two meters deep. Water is important during spring season when the bud sprouts, and during late summer when nuts began to fill.

Plant protection

Not many insect pests and diseases were observed in the trial area in ARDC Bajo except trunk borer and scab diseases.

Trunk borer (*Batacera rufomaculata)*

Trunk borer is sporadically observed on pecan-nut trees. The first sign of infestation is red-brown granular excretions around the base of the trunk. This discharge comes from the pink

color larvae which have burrowed into the trunk and branches of the trees. The tunnels vary in size according to the age of the larvae and can be as much as pencil thickness

Control

Removing larval excreta around the stem and injecting of cypermethrin (1 ml/litre of water) solution into the hole was found effective. In young trees a piece of soft wire can be used to kill the larvae in the tunnels. This method was found to be very effective and must be undertaken during winter when the tunnels and the excreta are more noticeable.

Scab diseases

Scab is caused by a fungus (*Cladosporium caryigenum*) and is important disease in pecan. Early symptoms are the appearance of numerous small, brown to black spots, especially on the underside of the leaves. The spots become larger and merge until the entire leaf turns black. The immature leaves drop off.
Similar spots are visible on the shell of the nut. Such nuts suffer from delayed development and they are misshapen. Immature nuts may drop off and have no commercial value.

Control

Keeping the orchard clean by collecting all the dead twigs and leaves from the orchard floor and burning is important control measures. Management of tree canopy for proper airflow and sunlight will keep the orchard from fungal growth. Spray fungicide carbendazim at the rate 0.2 % before flowering and after fruit set.

Harvest

Pecans must be harvested as soon as the shuck begins to open. Although pecans are slow perishable nut crop, it will develop problems like sprouting, embryo rot, and darkening of kernels if left for weeks in warm and damp fields. Picking pecans from the ground by hand is still an effective method of harvesting. The ground must be cleaned from any plant residues which could interfere with nut harvest. When about 60 to 70 percent of the nut clusters have open shucks, harvesting can be done. Shake the tree branches to drop the nuts. Some varieties will drop almost all their nuts with shaking the branches, while other varieties require two to three times shacking. The average yield varies between 230-30 kg per tree.

Post-harvest management

Cleaning

Remove small sticks, leaves, clods, shucks sticking to some nuts, light nuts, cracked nuts, nuts with weevil holes, and other damaged nuts.

Grading

Pecan nut must be graded for sale in the market. Pecans are graded according to size, colour and shape of the nut and percentage of kernel content.

Drying

The nuts are dried in a partial shed to remove excess moisture content in the kernel. The moisture content should be 4% for the nuts to develop eating quality and prevent moulding.

4. Persimmon

Background

The persimmon (*Diospyros kaki* D) belongs to the family Ebenaceae and genus *Diospyros*. The three most important fruit bearing species of the genus are *Diospyros kaki,* the Oriental or Japanese persimmon; *Diospyros virginiana*, the American persimmon and *Diospyros lotus*, the Date plum. Broadly, persimmon can be categorized into two groups: astringent types in which fruits can be consumed only when fully ripened and non-astringent type in which fruits can be consumed like apple, once matured. Currently there are about 5,632 plants in the country and the annual production is 152 MT with an average yield of 35 Kg per plant.

Variety

The commercial varieties of non-astringent types were released in 2004. Commercial varieties available in Bhutan are *Fuyu, Jiro* and *Wengkhar Anday 1*.The variety *Zejimaru* is often used as pollinizer.

Climate

Persimmon adapts to warm climate with lots of precipitation. It is best grown in areas between 1500-2200 masl with an average mean temperature of 15-18^{o}C. Moderately good sunshine and without fog are preferred. Non-astringent varieties grown in places with an annual mean temperature below 14^{o}C tends to become astringent.

Soil

Persimmon can be grown in a wide range of soil types preferably a well-drained, lighter soils which have good subsoil containing some clay is preferred. Soil pH of 6.0 – 6.8 is optimum for persimmon cultivation

Field preparation

Ideally field should be well protected with fencing and should have access to irrigation. Field should be prepared at least one month ahead of planting with incorporation of well decomposed manures. For ideal growth and development, a pit size of 1 m^3 is recommended

Recommended seedling rate

Persimmon saplings are planted at spacing of 5 x 5 m. The distance between the fence/border and the plants on the side should be half that of plant to plant distance. If the terrain is steep, then contour planting is recommended. An acre of land can accommodate more than 161 plants.

Nursery management

Persimmon is propagated through grafting. Seeds should be collected from healthy and mature fruits to raise the rootstock. Persimmon seeds are semi-recalcitrant and hence should be sown immediately after extraction for better germination. Local astringent persimmon seeds can be used as rootstocks. Scion woods should be collected from healthy mother plants that have come into bearing. Scion woods should contain 2 to 3 buds. Side veneer grafting is done between Januarys - early March. Ensure that graft union is not disturbed and remove

grafting tapes after proper joint has been formed in about 6 months. Enough irrigation should be provided in the nursery especially during dry season.

Planting

Seedlings are planted about 30cm above the ground by making a mound of soil rather than deep into the pit. The graft union should not be buried into the soil. While planting, fill the pit first with the top soil and then followed by sub-soil mixed with FYM. Once planted, the sapling should be decapitated at about 40 cm above the ground. Planting is usually done during the dormant stage from January to March at a spacing of 5 x 5 m.

Cultivation practices

For proper growth and development of the plant, a basin should be made around the tree trunk. Basin making keeps the floor clean and enables proper and irrigation and manuring. Ideally the size of the basin should be equal to the size of the tree canopy.
Pruning is needed to encourage a strong central leader with tiers of branches at about 30 cm intervals up to the trunk. The usual times to prune are late November to January. The first pruning is just after planting. If there is no branching within 50 cm of the ground, cut the single stem at that height. If the central leader is not the highest point, the tree should be pruned to ensure it is. Over the next two to three years the central leader should be pruned about 70 cm to encourage branching at those positions. Train persimmon tree in winter while you carry out pruning using materials such as thin bamboos, thin straight poles or sticks stacked criss-cross to maintain crotch angle of 45^{o} (angle between the branch and the trunk) and to form a low head by heading back at 50cm from the ground at the time of planting. This system of training is called a modified central leader system.
For year-round production, maintaining health of the plants and quality of fruits, fruit thinning must be done. First thinning should be done after the first natural fruits drop and second thinning when the fruits attain the size of walnut or Ping-Pong ball size. Fruits that are misshapen, diseased, crowded and weak ones should be removed as well.

Nutrient management

Apply compost or FYM sometime in December-January followed by split application of a mixture of chemical fertilizers 2-3 weeks before flowering when new shoots emerge and the second dose after the fruit thinning or at fruit growing stage.

Age of the Plant	FYM (Kg/tree)	NPK (g/tree)
2-3	10	100
4-7	30	300
7-10	50	500
Above 10 years	50	500

Water management

Water is critical especially for flowering and fruit development. Lack of moisture during these periods will cause flowers and fruits to drop and also limit cell division leading to smaller fruit size with poor quality

Plant protection

In our conditions, there is no serious incidence of pests and diseases except fruits depredation by birds, rodents and wasps. Bagging of fruits with newspapers and if possible netting of orchards is recommended to protect against birds

Harvest

Harvest persimmon from early October to late November when fruits turn yellow to reddish. On an average, persimmon tree yield about 30 to 60 Kg depending on the varieties.

Post-harvest management

Persimmons can be stored for about two weeks. Proper packaging should be done to avoid damages during transport. Pack fruits as per the size and the quality in proper packaging materials such as boxes or trays with proper protective materials to ensure that they are not bruised. Astringent types of persimmon can be dried to removal astringency. In other countries, dry ice is also used to remove astringency.

5. Walnut

Background

Walnuts (*Juglans regia*) is a tree nut. Its origin is Mediterranean regions and Central Asia. Soft shell walnut is not a traditional fruit crop of Bhutan. It was introduced in Bhutan from Kashmir, India in the early 1970s, through the initiative of the Royal Government of Bhutan. Today soft shell walnuts are grown in almost all the dzongkhags. Walnut is often called as king of nuts as it is rich in omega -3 fats and contains higher amounts of anti-oxidants compared to most other foods.

There are about 24,072 walnut trees in total of which about 7984 trees are in bearing stage. Based on the recommended spacing of 10 m x 10 m, it estimated that there are in total about 482 acres of land under walnut cultivation. The total production of walnut (Agriculture Statistics 2016) is 181 MT which works out to about 23 kg/tree.

Varieties

Soft shell varieties, Kanthel Selection and Yusipang-1 has been released.

Climate

Walnuts can grow well in areas which experiences winter chilling hours between 600 and 800 at temperatures within 0°C and 10°C. There should be frost-free period during flowering time and the temperature should be below 38°C during summer months. At temperature 38^0 C and above, it will result in the sun burning of hulls and shrivelled kernels. It is recommended to grow walnut in altitudes ranging between 1,400 and 2,500 masl.

Soil

Walnut can be grown best on deep, friable loamy soil where roots can develop to 3-4 m depth. Soil should be slightly acidic with pH between 5.5-6.5. Walnut cannot tolerate wet soils or water logging conditions. A few hours of water-logging can cause severe damage to the plant.

Field preparation

Where possible choose a site with south-west facing slopes. It helps to extend growing season in the higher altitudes by warming up faster in spring and cools down slowly in autumn. North-East aspects tend to be colder and more prone to frost damage at higher altitudes. Dig pit size of 3 feet deep and 3 feet in diameter. While digging pits, keep the top soil separate from the sub-soil. Mix the top soil with well decomposed FYM at a ratio of 2:1 and fill the pit. If possible, it is recommended to dig pits well in advance preferably one year before planting.

Recommend seedling rate

For walnut, 7 m x 7 m spacing is recommended. For high density planting, 6 m x 6 m can also be planted. One acre of land can accommodate 82 to 112 plants depending on the variety and spacing adopted.

Nursery management

Walnut is propagated through grafting and budding. Both local and soft-shelled walnut seeds can be used to raise seedlings for rootstocks. During September to October, collect the seeds from healthy mother plants and stratify them for better germination. Stratified seeds are sown from February to March. Once the rootstocks attain pencil size thickness, grafting should be done from March to April depending on the temperature. For proper callus formation, temperature of 20 to 30^{o} C is required. Hence, hot callusing technique is adopted sometimes, which is expensive. In walnut, the bleeding (sap flow) occurs which leads to failure of graft union. Hence, bleeding is controlled by either cutting off the rootstock 5-8 cm above the grafting site about two weeks before grafting or making few slanting cuts in the rootstock through the bark into the wood as low as possible below the grafting point. If any lateral bleeding happens, it occurs through these cuts. Also, stop irrigation for about two weeks prior to grafting.

Planting

The best time of planting is during the dormant period or early spring season. Graft/bud union should not be buried under the soil at the time of planting. Hence, mound planting is recommended. Spacing of 6 m x 6 m or 7 m x 7 m can be adopted.

Cultural practices

Weeding, mulching and basin preparation around the plants are essential practices to keep the orchard clean. Training and pruning is also important parts of cultural practices. It is very important to train the trees at the initial stages. Tree training is done to obtain a desired shape or good tree frame. After the first year, train the walnut plant using the Modified Central leader System. Head back the first year's growth to 2m of its height. Remove all the lateral shoots on the leader, leaving one or two shoots at lower level on the trunk to provide shade on trunk's south and west sides. To avoid narrow crotches, remove all primary buds above 1.5 m from the ground to encourage growth of secondary buds. Select main scaffold limb 1.6 m above ground. Choose primary scaffold limbs in all directions on the trunk. Ensure that limbs have angles more than 30 cm apart vertically on the main trunk. Pruning and training are carried during the dormant stages. Prune off diseased or crisscrossed branches and apply Copperoxychloride or Bordeaux paste on the cuts.

Nutrient management

Generally fertilizers are not applied to walnut. However in order to obtain higher yields of quality nuts, it is important to apply manure and fertilizers. If possible, fertilizers should be applied based on soil test results. But, in the absence of plant and soil nutrient analysis information, use the following guide as an indicative amount for application of NPK to the walnut trees.

Nutrient management

Year	N Dose (g/tree)	P Dose	K Dose	Location: circle around the tree (m)
1	100	100g/tree	100g/tree	0.5
2	200	100g/tree	100g/tree	1.0
3	300	100g/tree	100g/tree	1.5
4	400	100g/tree	100g/tree	2.0
5-7	500	100g/tree	100g/tree	2.5
7-9	600	100g/tree	100g/tree	3.0
10-full production	900	100g/tree	100g/tree	3.0

Water management

It is necessary to provide supplemental irrigation in dry spring and early summer before the start of monsoon period (April to June). Irrigation is not necessary from June until harvest since this is the monsoon season.

Plant protection

Incidences of pests and diseases on walnuts are quite common in Bhutan. Since recent past, some of the following pests and diseases have been causing major problem in management of walnut trees in Bhutan.

Dieback

Symptoms of this disease includes the change in bark colour from normal greenish-brown to reddish-brown and finally grey in colour. The infected walnut tree dies slowly causing branch by branch drying up.
Natural control measures are:

- Pruning out infected branches promptly.
- If the disease reaches the trunk, the whole tree needs to be removed
- Consult Agriculture Extension Agent / National Plant Protection Centre

Bark Beetle

Dark brown beetle bore the young twigs and cause wilting symptom in young twigs. The larvae bore into sapwood, which can girdle branches.
Natural Control measures:

- Remove and burn severely infected trees
- Peel bark from the stumps of infected trees.
- Consult Agriculture Extension Agent / National Plant Protection Centre

Trunk borer (*Anoplophora sp.***)**

It is the most damaging pest to the walnut trees and kill the plants outright if not detected early and controlled in time. The symptom of trunk borer infestation is the presence of saw dust like fuss on the trunk. It can be controlled manually by plugging the holes with cotton

ball dipped in petrol and seal the hole with mud paste. Before plugging the hole with cotton ball, clean the hole with the help of a thin wire by inserting it through the hole.

Harvest

Grafted or budded walnut plants will come into fruiting in about 3 to 4 years and full economic bearing in 6 to 7 years' time. Depending on the place, walnut is harvested from August to October in Bhutan. When matured, nuts start to dehisce and fall. On an average, a walnut tree yields about 40 to 60 Kg.

Post-harvest management

Collect the nuts from the ground. Clean, wash, and dry the nuts on a sheet or dry floor to dry them up to 8% moisture level. Nuts are graded according to size, colour, and variety.

6. Pineapple

Background

Pineapple (*Ananus comosus*), is a herbaceous perennial crop of humid tropics belonging to the family Bromeliaceae. Pineapple is popularly known as "queen of fruits" because of its excellent flavour, taste and shape of the fruit. Pineapple is believed to have originated from Brazil.

Varieties

Currently two cultivars, Queen and Giant Kew are grown by farmers in Bhutan

Climate

Pineapple is a tropical or near tropical plant limited to low elevations. Temperature range of 18-45°C is most favourable, though the plant can tolerate cool nights for short periods. Prolonged cold retards growth, delays maturity and causes the fruit to be more acidic. Generally, pineapples are grown below 1000 masl, however it can be grown up to 2300 masl but at higher elevations the fruit becomes acidic in nature. Pineapples grown between 1350-1700 masl produce good flavor suitable for canning.

Soils

Pineapple plants grow best in moderately fertile, well-drained sandy loam soils with soil pH of neutral to mildly acid.

Field preparation

Depending on the nature of land, trenches of convenient length, about 90 cm width and 15-30 cm depth are prepared. In flat areas, the land is prepared by ploughing or hoeing before planting. But on the hills, the land should either be terraced or cut into strips of suitable width by constructing contour trenches with a depth of 45-50 cm and a width of 30 cm. These serve the purpose of catching the surface runoff. On hill slopes, only individual pits are prepared for placing the planting material instead of digging the whole area, as it may cause unnecessary soil erosion.

Nursery management

The pineapple is propagated through vegetative propagation. The propagation of pineapple can also be done from seeds but it is generally propagated through vegetative part such as slips, suckers and stem sections.

1. *Slips*: leafy branches attached below the fruit, on the peduncle, grouped near the base of the fruit, sometimes produced from basal eye of the fruit (collar of slips); commonly preferred; may produce fruit within 14-16 months after planting.
2. Ratoon suckers: shoots produced at or below ground from the stem will produce fruit in 12-14 months after planting.
3. Side shoots or suckers: shoots originated from leaf axils. It will produce fruit in 18-20 months after planting.

Recommended seedling rate

Spacing of 1 m x 1 m is recommended however for high density planting, the distance of 0.5 m x 0.5 m is maintained depending on the topography. One acre of land can accommodate more than 4040 to 16,160 plants depending on the spacing.

Planting

There are two systems of pineapple planting viz, single row system and double row system. Double row system is recommended since it is profitable, allows maximum use of land, less weed infestations and protect from sunburn.

Cultural practices

Weeding

Pineapple plants are slow growing and do not cover the ground well enough to suppress weeds from developing. Weeds compete with the pineapple plant not only for nutrients, but also for water and sunlight and can cause considerable reduction in the growth of the pineapple. Chemical or mechanical control of weed is recommended in pineapple orchards.

Mulching

Mulching pineapple plants helps retain soil moisture, reduces weed problems next to the plant, and improves the soil near the surface. Mulching with a 5-15 cm layer of straw, grass, bark, wood chips, or similar mulch material is recommended. Keep mulch 20-30 cm away from the base of the plant.

Pruning

The leaves can be pruned to avoid leaf sprawling and also ground suckers can be pruned.

Nutrient management

The pineapple orchard should be applied with compost/cattle manure at 25 MT/ha as basal dressing and for fertilizers, NPK, 8:4:8 g/plant/year or 320:160:320 kg/ha/year should be applied. A small amount of compost and or top soil may be incorporated into the soil before planting. This will aid in root development and improve the water and nutrient-holding capacity of the soil.

Water management

Since pineapples are grown as rainfed crops, it should be watered during extended dry periods lasting for more than 6 or 7 days during hot weather and every 10 or 12 days during the cooler winter months for best plant growth and fruit production.

Plant protection

Pineapple should be protected against mealy bugs, scales, nematodes and diseases mainly root rots.

Harvest

The fruit can be harvested twice in a year, first in July-August (main season) and second harvest in December-January (off season) in Lingmethang region. The pineapples take more

than three months from flowering to fruit maturity. It is difficult to judge when the pineapple matures because the size and change in colour are not fully reliable indicators. In general, for the fresh fruit markets, the summer crop is harvested when the eye shows a light pale green colour whereas the winter crops are slower to mature so the fruits are picked when there is a slight yellowing around the base.

It is advisable to renew the plantation every 5-6 years. In most commercial plantings, the plants are not allowed to produce more than 2-3 crops due to reduction in fruit size and uniformity. The yield in the traditional system is about 6 MT per acre.

Post-Harvest Management

For canning purpose, the fruits are harvested when there is a slight colour change at the base of developing fruits. The fruits used for table purpose are retained till they develop golden yellow colour. Fruits for canning are acceptable at a more advanced stage. The fruit recovery rate as analyzed at Lingmethang is about 55% for Queen cultivar and 66% for Kiew cultivar which can be used for canning or juice production. Overripe fruits are deficient in flavour and highly perishable. For optimum fruit sweetness, pineapple fruit should be harvested when 1/3 to 2/3 or more of the peel has turned from green to yellow.

Alternatively, fruit may be picked at a late mature green stage (fully mature, full size but not turning yellow) and allow to ripen at room temperature. Complete ripening may then be allowed at room temperature (26-28°C) before refrigeration. The ideal storage temperature is at 7^{o}C and 80-85 relative humidity and can be stored up to 20 days. Immature (green fruit) should not be placed in the refrigerator because this may cause chilling injury and the fruit will not ripen properly.

7. Litchi

Background

Litchi (*Litchi chinensis*) is native to South China. The trees grow to a height of 6-9m with spreading branches and have dense light green shining leaves. In Bhutan production of litchi is about 134 MT from a total area of 385.1 acres.

Varieties:

Bhur Litchi 1 (Muzafarpur) and Bhur Ltichi 2 (Bedana). Bhur Litchi 1 bears rosy red fruits while Bhur Litchi 2 bears vermillion fruits. Both the varieties can be harvested from May to June.

Climate

It is well adapted in wet to humid sub-tropical region of the country altitude ranging from 150-1000 masl. Suitable growing regions are Samtse, Sarpang, Samtse, S/Jongkhar and in the lower belts of Zhemgang receiving rainfall of 1000-2500 mm annually. It prefers moist climate. It grows profusely at a temperature of 30^{o}c. Temperature has direct impact on flowering. Night temperature of 15-16^{o}c for 2 months is essential to induce flowering in Litchi.

Soil

It can be grown on wide range of soil from acidic to alkaline soil with pH range of 5.5-7.0. However, deep well drained loamy soil rich in organic matter is ideal for litchi cultivation.

Field preparation

Pit size of 1 m^3 or 0.5 m^3 are dug and filled with well decomposed manure and top soil. The seedlings are planted by making a small hole in the center of the pit sufficient to accommodate the root ball. It is then immediately followed by watering of plants. Organic mulching around the basin of the plant will be helpful to conserve the moisture and also control the growth of weeds.

Recommended seedling rate

Spacing of 7 m x 7 m or 8 m x 8 m is recommended. Thus, one acre of land can accommodate 63 to 83 plants depending on the spacing.

Nursery management

Litchi is commercially propagated through air-layering. Air layering of litchi is done after the harvest of the fruit in June –July coinciding with the monsoon season.

Planting

Seedlings are usually planted in May to July maintaining spacing of 7 m x 7 m or 8 m x 8 m. Pits should be prepared at least one month ahead of the planting season.

Cultural practices

Modified Central Leader system of training is followed in litchi which allows ample of sunlight to penetrate inside the canopy of the tree which improves the fruit quality. Training

and pruning of young litchi trees are done to establish a good structural frame. It involves removing crisscrossed and diseased branches.

Nutrient management

The right time to apply fertilizer is right after the harvest which encourage flushing of new shoots in the summer. Nitrogenous fertilizers are applied in split doses: 2/3rd dose in mid-February during the initiation of flushing and 1/3rd s after harvesting of fruits. Potassium fertilizer also applied in two split doses: Half dose after fruit setting and another half dose after the harvest of the fruits. Recommended dosage is given below:

Age of the plant (in years)	Manure/Fertilizer applied (per plant/year in kg)			
	FYM	CAN (Calcium ammonium nitrate)	Super phosphate	Muriate of potash
1-3	10 - 20	0.3-1.00	0.2-0.6	0.05-0.15
4-6	25 - 40	1.0-2.0	0.75-1.25	0.20-0.30
7-10	40 – 50	2.0-3.0	1.50-2.0	0.35-0.45
Above 10	60	3.5	2.25	0.60

Water management

January end to the onset of monsoon is critical period for irrigation. Generally weekly irrigation should be given during the dry period of the year. It also requires irrigation at fortnightly interval during fruit development stage.

Plant protection

Litchi fruit borer: *Conopomorpha sinensis* (Lepidoptera: Gracillariidae)

Nature of Damage and symptom: Adult are active during August to February and they mine the leaf. They lay eggs on the calyx end the developing larva feed on it with the excreta on it.

Management:

- Orchard sanitation by collection and destruction of fallen fruits
- Pruning of trees after the harvest of the fruits
- Use of parasitoids *Trichogrammachilonis* @ 50000eggs/ha during flowering and color break stage followed by spraying neem-based insecticides like Nimbicidine @ 3ml/L
- Application of neem cake @ 1kg or Castor @ 4kg per tree after the first shower
- In sever infestation it can be sprayed with the chemicals like Deltamethrin @ (0.0028 per cent) 1ml/l or Fipronil @ (0.01 per cent) 2 ml/l or Flubendiamide (0.008 per cent) 1ml/5 l of water after fruit set and second spray may be given before 15 days harvest. (Shashank et al. 2015, Patel & Srivastava, 2015)

Fruit crack

Fruit crack is sometimes a major problem as it is accompanied by rotting and fungal infection. It is caused by heavy rains/irrigation after prolonged dry spell, Boron deficiency, dry and desiccating winds blow during the fruit development and hailstorm during fruit development

Management:

- Field should be irrigated during fruit growth and in early summer
- Spraying growth regulator like 2,4 D @ 10 ppm, GA_3 @ 20 ppm and Boron @ 0.4 % reduces the fruit cracking.

Harvest

Litchi fruits usually take 50-60 days to ripen from the day of fruit setting. Litchi is non-climacteric fruits and therefore it has to be harvested only after full ripening. Once it is ripened the fruit peel turns green to pinkish red. On an average, a tree of Litchi can yield 40 to 80 Kg depending on the variety

Post-harvest management

Pre-cooling to reduce filed heat is necessary. It can be done at the storage temperature or with hydro cooling by dipping the fruit in the water. Sorting: Fruits with pulled stems, crack and insect damaged should be discarded. Fruits damaged by insect and moth shows tissue darkening within 24hours of harvesting. It is then kept in humid place at 5^oc temperature. Litchi can be packed with bunches in the corrugated fiber boxes. Under ambient condition litchi can be stored only for 2-3 days. But it can be stored for 5 weeks at temperature of 1.6 to 7.2^oC.

8. Mango

Background

Mango (*Mangifera indica*) is one of the most important fruit crops. It is considered as the king of fruits. Mango is ever green tree that reaches up to a height of 15-30 m with a crown radius of 10m. In Bhutan, cultivation is confined to wet tropical to dry subtropical regions in a total area of 402 hectares. Country's total mango production accounts to 644MT.

Varieties

Varieties commonly grown in Bhutan are Bajo Aumchkuli 1 (Dashehari), Bajo Aumchukuli 2 (Langra), Bajo Aumchukuli 3 (Amrapali) and Chausa. Among the 4 varieties, Chausa is a late maturing variety.

Climate

It is well adapted to wet humid sub-tropical region of the country with an altitude ranging from 150-1200 masl. Low temperature during flowering stage will damage the reproductive organs. Optimum temperature for growth ranges from 24-27 ^{o}C. Mango is one of the fruit crops pollinated by house flies and hover flies. Hence, above 1200 masl, mango might face pollination problem.

Soil

Crop can be grown on alluvial as well as laterite soils. Clay and black cotton soil are not suitable due to poor drainage and poor aeration. Ideal soil for mango is loamy soil with pH ranging from 5.5-7.5

Field preparation

A pit size of 1 m^3 should be filled with well decomposed manure and top soil. The plants are planted by making a small hole in the center of the pit sufficient to accommodate the root ball. The graft union must be 15 cm above the ground level while planting grafted plants. It is then immediately followed by watering of plants. Organic mulching around the basin of the plant will be helpful to conserve the moisture and control the growth of weeds.

Recommended seedling rate

Mango plants are normally planted at a spacing of 8 m x 8 m. In high density planting, dwarf varieties can be planted at a spacing of 5 m x 5 m. One acre of land can accommodate 63 to 162 plants depending on the spacing and the variety.

Nursery management

Mango is commercially propagated through soft wood grafting. Seedling of 3 to 4 months old can be used for grating.

Rootstock preparation

Mango seed is collected and raised in the nursery bed where it is prepared by mixing top soil, sand and FYM in a ratio of 2:1:1. It is sown on the prepared nursery bed and covered by mosses. Germination starts within 6-15 days after sowing. When it attains four coppery leaf stages it is transplanted in the poly pot. The medium used for potting is top soil, sand and

FYM mixed in the ratio of 2:1:1. Mango stones can be directly planted in the poly pot in the above mixture and directly grafted as well.

Scion wood collection

Identify a highly productive, healthy mother tree of the desired variety and quality. The scion woods with intact petiole can be stored for seven days wrapped in a moist tissue paper or newspaper in a zip lock plastic bag or polythene bag in a cool, dark place. This procedure is called scion wood curing during which the food gets translocated to the bud from petiole. When scion wood is ready the petiole will fall of easily.

Planting

Since mango is evergreen, seedlings should be planted along with the earth ball around the root system for better survival. Seedlings are usually planted during rainy season at a spacing of 8 m x 8 m or 5 m x 5 m depending on the variety.

Cultural practices

Training of young mango trees is necessary to establish a good tree structure. Usually modified central leader system of training is adopted in mango.

Nutrient management

The right time to apply fertilizer is right after the harvest which encourage flushing of new shoots in the summer. Nitrogenous fertilizers are applied in split doses: one in mid-February during the initiation of flushing and second dose after harvesting of fruits.

Recommended dose of fertilizer

Tree age (years)	FYM (Kg/plt/yr)	N (g/plt/year)	P (g/plt/year)	K (g/plt/year)
1-3	5-20	50-100	40-80	100-200
4-6	25-50	100-200	80-100	200-400
7-9	60-90	200-250	120-160	400-600
10 & above	100	250	160	600

Water management

Regular and frequent watering should be done at the initial year of establishment. Under the conventional method watering should be done twice a week and the frequency of irrigation can be reduced when it is established.

Plant protection

Mango stem borer (*Batocera rufomaculata*), (*Cerambycidae, coleopteran*)

Damaging symptoms: Drying of terminal shoots in the early stage, protrusion of excreta, wilting of whole tree and complete death of the tree

Management:

- Cut the infested branches and destroying the grubs
- Applying paste made of chlorpyriphos @ 2ml/L, neem oil @5ml/L, copper oxy chloride on stem during June-July to prevent egg laying from basal portion at 3ft height.
- Application of carbofuron @ 15-20g or Phorate @ 10-15g per tree
- Put cotton swab soaked in chemicals like dicholrovas or carbofuron @ 5g per bored hole and sealed with mud.

Mango fruit fly (*Bactrocera dorsalis* (Tephritidae, Diptera))

Damaging symptom: Liquid oozes from the fruit, dark brown rotten patches on the fruit, premature dropping of the fruits and rotting of fruits

Management:

- Installing the Fly T trap using the pheromone Baco lure
- Destroy the fallen fruits
- Rake or plough the basin and between the tree once or twice during flowering and pre-harvest to kill the pupa.
- Male annihilation technique: Methyl eugenol and malathion is mixed in the 250ml bottle both at the rate 1ml. Then this 100ml solution is hang in the field during April to June (4 Bottles per acre)
- Bait spray: spraying 45days and 80days prior to harvest with malathion @ 2ml/L or Carbaryl @ 4g/L or Dimethoate @ 1.7ml/L with jiggery @ 10g/L

Mango stone weevil (*Sternochetus mangiferae*) (Curculionidae, Coleoptera)

Damaging symptoms: T shape marking on the marble size fruits, exit hole on mature fruits and fruit drooping at marble stage

Management:

- Spraying on main trunk prior to flowering (Nov-December) with chloropyriphos @ 2ml/L to control the weevils hiding in the bark
- Destroy the dropped fruit after the harvest
- Spraying on fruits at marble size stage with acepahate @ 1g/L or Carbaryl @ 4g/L

Biennial Bearing

It is also term as alternate or irregular bearing habit. It is tendency of bearing of heavy fruit in one year (on year) and very little or no crop in the seceding year (off year)

Cause:

- In mango trees the branches that bear fruit do not produce any new shoots. Even if the new shoots are produced they fail to flower in the coming season. That is because new vegetative flush requires certain duration (usually 8-10 months) for flower bud differentiation.
- Heavy bearing habit during on year exhaust the plant nutritionally and thus fails to produce new flush.
- It is also attributed genetically

Management:

- Reducing the flowering in on year (de-blossoming) so that the crop load will be reduced and flowering will be balanced in the subsequent year.
- Pruning after the harvest helps to produce new shoots which will mature in the next flowering season.
- Soil application of Paclobutrazol (PP_{333}) @ 5-10g/tree during September – October promote flowering.
- Nutrient foliar spray with KNO3 @ 12.5g/L or Urea @ 2-4% induce flowering

Powdery mildew (*Oidium mangiferae)*

Symptoms: It attacks leaf, buds, flowers and also fruits. The affected parts are initially covered with white powdery parts consisting of conidiophore and conidia. Affected flower sheds before fruiting. In addition the affected fruits do not develop normally and drop off

Management:

- Spraying wettable sulphur @ 0.3% or Carbendazim @ 0.1% at pre-blossom, post-blossom stage at 15days interval

Harvest

Mango usually takes about 120-130 days to mature after flowering. Mango is climacteric fruit and it should be harvested once it is matured. At maturity, fruit colour changes from green to yellow/red depending on the varieties. Fullness of cheeks (when the fruit shoulder swells upwards creating depression on the calyx end) also indicates maturity. During harvesting care should be taken to avoid any latex oozing from the calyx end to fall on fruits that will deteriorate the fruit quality. On an average, the yield of mango in Bhutan is 50-80 Kg/tree.

Post-harvest management

Pre-cooling right after the harvest to reduce the field heat of the produce is necessary. It reduces the respiration rate of the produce and reduces the incidence of spongy tissue. It will increase the shelf life of the produce. It can be done by keeping the produce under the shade for few hours or treatment such as passing cold air around the produce and immersing in water. The optimum temperature for pre-cooling is just above the temperature at which the freezing injury takes place. The freezing injury in mango takes place at temperature below 15^{o}c.

9. Banana

Background

Banana (*Musa paradisiaca*) belongs to Musaceae family and is the fourth most important food crops in the world after rice, wheat and maize and the fifth agricultural commodity in the world trade after cereals, sugar, coffee and cocoa. The present-day edible cultivars of bananas are mostly cross between the *Musa acuminata* and *Musa balbisiana*. They are said to have originated from Malaysia and Indonesia. In Bhutan banana is cultivated in an area about 315 ha. Total production accounts to about 3076 MT with the average earning of Nu.19million both from the domestic market and with 3 percent from export value.

Varieties

Varieties commonly available in Bhutan are *Chinichampa*, *Jajikola,Gheukola*, *Dhusery* and *Grand Naine*. *Chinichampa* gives fruits in about 16 to 17 months whereas *Jajikola, Gheukola* and *Dhusery*and *Grand Naine* takes about 12 to 13 months to fruit. *Grand Naine* is more productive than rest of the varieties.

Climate

Banana is sub-tropical fruit crop that are well suited for cultivation from wet to dry subtropical agro-ecological zones up to 2000m above the sea level and annual rainfall ranging from 2000-2500mm. It requires 12 hours of bright light with relative humidity of 75-85%. The ideal temperature ranges from 26-30^{o}C.

Soil

Banana is a calcifuge/ericaceous/lime hater crops (that does not tolerate alkaline soil). It prefers a soil with a pH ranging from 5.5-7.5. Moreover, low pH soil makes banana more susceptible to panama diseases. Deep well drained loamy soil is ideal for its cultivation

Field preparation

The land should be well ploughed and labelled before laying out the orchard for banana cultivation. Prior to planting, it is recommended to plant green manure crops such as daincha and cowpea. In areas with nematode infection, it is recommended to treat soil or pit with nematicides and fumigants. It is also helpful if the pits are left exposed to solar radiation where harmful insect are killed and soil borne diseases are reduced.

Recommended seedling rate

Normal spacing of 2 m x 2 m or for high density planting 1.5 m x 1.5 m is recommended depending on the variety. Therefore, one acre of land can accommodate about 1000 to 1800 plants depending on the spacing and the variety.

Nursery management

Sword suckers are usually used as planting material. Sword suckers are considered to be superior in quality, vigour, precocious, high yielding and has higher degree of tolerance to abiotic and biotic stress as compared to the water suckers. Sword sucker is collected when they reach a minimum of 15cm diameter and 50cm height. It is cut away from the mother

plant with the sharp knife and is treated with fungicides before planting. Banana is also propagated through tissue culture.

Planting

A pit size of 30cm x 30 cm x 30 cm is dug and filled with the mixture of top soil, well decomposed FYM and sand in the ratio 1:1:1. Furrow and trench method of planting is practiced. Recommended spacing of 2 m x 2 m or 1.5 m x 1.5 m is followed depending on the variety. Banana is usually planted in June to July simultaneously with the onset of monsoon.

Cultural practices

Timely irrigation and other cultural practices are necessary for commercial banana cultivation. The weeds in the orchard affect the growth of the banana plants and reduces yield up to 40-50 % as it competes for the water and nutrients. Other cultural practices like propping to support plants from falling particularly with increase in weight of banana bunch and de-suckering to remove surplus or unwanted suckers till it reaches height of about 1.5 m is practiced. Earthing up should be carried out to cover the exposed rhizomes

Nutrient management

Banana requires high potassium especially during the finger filling stage. It is applied in 4 split doses: 100 g/plant in 2 split doses at vegetative stage and another 100 g/plant in 2 split doses at reproductive phase. Nitrogen is applied in 3-4 split doses at vegetative phase (150 g/plant) and reproductive phase (50 g/plant).

Water management

Bananas require constant water supply throughout their growth period. For the first 6 months, use hose and basin irrigation systems. Put enough water in each basin (25 litres of water every 2-3 days). The most efficient method of water management is drip irrigation. Drip irrigation coupled with application of mulch has proven to improve water efficiency with saving of 56 % of water and contribute to yield increase by 20 – 30 %. Generally, Bananas require a minimum of 2000 – 2500 mm water annually or 25 mm per week. The Banana plants do not bear fruit under water stress condition. Irrigating 6 months for about 6 to 8 hours every three to four days is advised for quality banana production. While the recommended amount of irrigation is important, excessive water will cause root-rot in Banana.

Plant protection

Banana rhizome weevil (*Cosmopolites sordidus*: Curculionidae, Coleoptera)

Damaging symptoms: Symptoms include yellowing of leaves, development of small holes on the rhizome and rotting of rhizome

Management:

- Adopting prolinage technique (removing older leaves, roots and other soil particles adhered with the sucker) before planting of sucker. Dip the sets in the cow dung or mud slurry and dry in the shades. Apply carbofuron/Phorate (10-15g) in the field.

- Avoid collecting suckers from the infested mother plants
- Clean orchard management is recommended
- Trap the adult by keeping the chopped pseudo stems in the garden
- Drenching the base of the infested plants with chloropyriphos (2ml/L) or application of carbofuron/Phorate (10-20g)

Pseudostem borer (*Odioporus longicollis*: Curculionidae, Coleoptera)

Damaging symptoms: The symptoms are development of small pin head size holes, exudation of gummy like substance from the holes, tunnelling in the leaf sheath and pseudostem, rotting of pseudostem.
Management:

- Management is similar to rhizome weevil except drenching or application of carbofuron/phorate is not recommended at later stage
- Spraying on the pseudostem with chloropyriphos (2ml/L) one month after planting is recommended. Two to three sprays should be done at an interval of 15-20 days.

Diseases of banana

Panama wilt (*Fusarium oxysporium* f.sp. cubensis)

Symptoms: symptom is noticed as yellowing of leaves from margin and later covers entire leaves. The affected leaves wilt and petiole buckle. The leaves hang between pseudostem which middle lamina is still green. The pseudostem may show longitudinal splitting at the outer leaf base above the soil level. When cut open the affected rhizomes transversely will give brown discolouration of vascular bundles.
Management:

- Selection of suckers from healthy fields
- Application of lime (1.5kg/pit)
- Flooding of field (provide flood irrigation and allowing water to stagnant which will create anaerobic condition and production of acetic acid that reduces the fungus)
- Crop rotation with paddy and maize
- Application of neem cake, pongamia cake and bio agents. This will produce anti biotic like musarium and monomycin that will destroy the pathogen
- Avoid injury to the rhizome
- Dipping of sucker in 0.1 % bavistin or drenching of soil in 0.1 % carbendazim for every alternate month

Harvest

Banana is ready for harvest 100-150 days after flowering. The time of harvest depends on flowering time, variety and conditions such as temperatures, availability of irrigation and amount of nutrients available. Maturity indices include change in colour from green to yellow or red depending on the variety. A banana plant yields about 20 to 40 Kg depending on the variety.

Post-harvest management

After the harvest of the bunch, pre-cooling is recommended to reduce the field heat. This will reduce the respiration rate of the produce and enhance the shelf life. Several methods like hydro cooling, air blast cooling, vacuum cooling and liquid CO_2 cooling can be used based on the availability of the technologies. Hydro cooling is done by rinsing/immersing/spraying cold water over the banana bunches. In air blast cooling banana bunch is subjected to a jet of cool air for the removal of field heat. It is then packed in the boxes of 11-20 kg. The ideal temperature for the storage of banana is 13-14^{o}c. It can also be stored at 20^{o}c with relative humidity of 80 %.

10. Dragon fruit

Background

Dragon fruit (*Hylocereus undatus*) is a climbing-vine cactus belonging to family Cactaceae. It is native to Central America, from Southern Mexico to Northern South America. It is a healthy food with high vitamin C, fibers and antioxidants. It has high tolerance to drought. Dragon fruit is a new crop to Bhutan and crop was introduced from Thailand in 2008.

Variety:

The variety was released in 2017 as Wengkhar Gyalwa Ri-nga based on its economic potential and increasing popularity among Bhutanese growers. The variety is a pink type, is the only variety released in the country.

Climate

Dragon fruit thrives well in poor soil and under varied temperature conditions. Comparing to other tropical and subtropical fruits, it has greater adaptability. Hence, it can be grown up to 1500 masl. However, tropical type of climatic region is best for its cultivation with an ideal temperature range of 16 to 30 ^{o}C.

Soil

Similarly, it can be grown on a wide range of soils from sandy loam to clay loam. However, sandy soils with good organic matter content and drainage are best for its cultivation. Soil pH of 5.5 to 8 is best for its cultivation. However, it is sensitive to water logging and saline conditions.

Field preparation

Ideally, pits should be prepared at least one month ahead of planting. The dimension of pit should be about 0.6 m deep and 0.6 m wide. The planting system depends on the topography of land. However, square system of planting is widely used in flat land. Similarly, the plant spacing also depends on the variety, training systems adopted and the desired plant structures. For the convenience of intercultural operations, a spacing of 3 m from plant to plant and 3 m between rows is recommended.

Recommenced seedling rate

One acre of flat land can accommodate more than 448 plants at a spacing of 3 x 3 m. More intensive planting of 3 x 2 m can also be adopted, which would accommodate more than 673 plants.

Nursery management

Commercially, dragon fruit is propagated by cuttings. 15 to 30 cm long cuttings obtained from one-year old stem should be used. The cuttings should be planted in a poly pot containing clean media mix (soil, compost and sand in the ratio of 2:1:1). The cuttings require full sun shine for optimum growth and must be regularly irrigated.

Planting

Planting of cuttings should be done only after proper development of roots, which would take about a year. The cuttings usually start bearing fruit from second year on-wards. Cuttings are planted at a spacing of 3 x 3 m or 3 x 2 m. Plating is usually done during rainy season. However, potted plants can be planted in any season, as long as enough irrigation is provided.

Cultivation practices

Proper maintenance of field is essential for growth and development of the plants. It will also prevent occurrence of pests and diseases.

Dragon fruit can be trained to any system of growers' convenience. However, single post trellis system of training is quite common. Plants are trained along a single upright pole to about 2.5 m height, then branches are allowed to spread over a square frame fixed on top the post. Pruning is mainly done to cut off lateral branches to encourage upright growth in the first year, remove dead or diseased branches to maintain proper sanitation; and thin out crowded branches to improve air circulation and better penetration of sunlight

Nutrient management

Application of about 20 Kg of well decomposed farmyard manure or compost at the time of planting and regular top-dressing with well decomposed manure annually is necessary for proper growth and higher yields. Normal rate of inorganic fertilizer is 46:16:12 N: P: K.

Water management

Dragon fruit is a member of the Cactus family and, compared to other fruit crops, has high tolerance to drought. However, their root system is distributed in the top 15-30 cm of the soil and thus irrigation is crucial to ensure adequate soil moisture content especially during the dry periods.

Plant protection

Insect-pest is not a major concern under Bhutanese condition. However, some diseases such as anthracnose, brown spots, stem and fruit rots can sometimes be problem in wet areas. However, the incidence of these diseases can be avoided by maintaining proper sanitation in the orchard and spraying with broad spectrum fungicide such as Mancozeb at the rate of 2 grams per litre of water

Harvest

Unlike other fruits, it has long harvest period. Thus, fruits can be harvested from August till October. The fruits have good shelf life. When it is matured, fruit become bright pink (pink type). To avoid damage to the fruits, use of fruit harvester is recommended. On an average, the yield of dragon fruit is about 20 Kg per plant.

Post-harvest management

Dragon fruits have good shelf life and can be stored up to 1 week under room temperature and 3 weeks under refrigerated condition without losing freshness and quality. Fruits are graded by size and pre-cooled before packing.

11. Kiwi

Background

Kiwi also called "Chinese gooseberry", is native to the mountains and hills of south western China. Given its proximity, wild kiwi fruits are also found in many parts of Bhutan in the wild especially above 1800 m. However, wild kiwi fruits are very small and hardly consumed by people. Modern commercial planting of kiwi fruits started in New Zealand about 1930s. Kiwi (*Actinidia deliciosa*) is a berry and belongs to family Actinidiaceae.
Kiwi cultivation in Bhutan is quite new. Two commercial varieties were released by Agriculture Research and Development Centre, Wengkhar in 2015.

Varieties:

- Zhimpeykotong Sep has yellow flesh and fruits do not have hairs
- Zhimpeykotong Jangkhu has green flesh with hairs on the fruits.

In addition to the released variety, farmers also grow Hayward and Enza Red varieties. Hayward cultivation was promoted under Chukha Dzongkhag by BCCI with support from ICIMOD in Nepal. Few farmers in Dagana and Tsirang also grow Enza Red which has red flesh.

Climate

Kiwi grows well in the warm temperate region. It requires 700-800 chilling hours below 7ºC. In Bhutan Kiwi can be planted in an elevation of 1300 - 2400 m masl. However, for commercial purpose, Kiwi must be grown above 1500 masl (North facing) and below 2300 masl.

Soil

The soil should be well drained and loam type. Heavy clay soils make plants much more prone to root rot. The plants are sensitive to water logging. Plants perform best when the soil pH is around 6.5

Field preparation

Field should be prepared at least one month ahead of planting with incorporation of well decomposed manures. For ideal growth and development, pit size of 1 m^3 is recommended. Spacing of 6 m x 6 m may be adopted. However, for intensive planting, 6 m x 3 m can also be adopted.

Recommenced seedling rate

Number of seedlings per unit area depends on the plating system adopted and the spacing maintained between plant to plant and row to row. For spacing of 6 m x 6 m, one acre can accommodate more than 112 plants, whereas spacing of 6 m x 3 m can accommodate more than 224 plants.

Nursery management

Kiwi plants are raised through both sexual and asexual means. However, to get true to type plants, kiwi vines can be easily raised through side veneer grafting. In order to raise the

rootstocks, seeds are collected from mature fruits. Kiwi seeds should be sown as soon as possible since they lose variability with storage time. Since the kiwi seeds are very small, they are sown in line on a finely prepared, preferably, on a wooden nursery box. Once seedlings attain pencil thickness size, plants are grafted through side veneer method. Grafting is done from December to March.

Planting

Kiwi is a deciduous plant and hence usually planted during dormant season from January to early March. Mound planting is recommended and the graft union should not be buried under the soil since it will lead to infection. Plant should be properly staked to prevent dislodging and maintain required shape. Spacing of 6 m x 6 m or 6 m x 3 m is recommended. Kiwi plants are functionally dioecious plants, hence for every 9 to 10 female plants, there should be at least 1 male plants for proper fruit set and productivity.

Cultivation practices

Training, pruning and basin making form an important cultural practices in kiwi plantation. A single shoot is trained up along each post or stake to the top of the trellis by removing any lateral growth. A shoot which is tied will form the trunk and prevent it from winding around the post. At the top of the trellis, train the shoot along the center wire in one direction. The following year a shoot will be trained along the center wire in the opposite direction. These two shoots will form the permanent leaders on the vine. Prevent these leaders from twisting around the center wire, since this can weaken the vine in future years. The lateral canes that develop from these leaders are tied perpendicular to the leaders to the outer wires. These canes will be the fruiting canes in the following year.

Vines that are crisscrossed heavily and diseased ones are pruned off. In kiwi, fruits are borne mainly on current season growth that arose from previous year's growth, and some from spurs. Only basal 3-6 buds are productive. Shoots developed on older wood by heading back normally do not fruit in the first season. A shoot dies gradually if it is pruned just beyond the fruiting bud. Hence, prune at least two vegetative buds after last fruit bearing leaf axil.

Nutrient management

Fertilizer application is very important in fruit cultivation. Fertilizers when it comes into contact with the trunk may cause injury to the plants. Apply compost or FYM sometime in December-January followed by split application of a mixture of chemical fertilizers 2-3 weeks before flowering when new shoots emerge and the second dose after the fruit thinning or at fruit growing stage.

FYM/Compost application

Age of the plant	Quantity (kg/tree)	
2-3	10	
4-7	30	
7-10	50	Pruning
Above 10 years	50	

Fertilizers application rate (NPK)

Age of the plant	Quantity (g/tree)
2-3	100
4-7	300
7-10	500
Above 10 years	500

Water management

Enough irrigation should be provided for proper fruit set and productivity. Irrigation is critical especially during dry season and at the time of bud differentiation, flowering and fruit development stages.

Plant protection

Till date, no major pest and diseases incidences have been reported. In other countries, *Phytophthora rot* is a major issue. Hence, need to maintain sanitation and avoid water logging which predisposes to the disease.

Harvest

Fruits can be harvested when still hard. Usually fruits are harvested when the hairs on the fruits can be easily rubbed off. To avoid injury to the fruits, it is recommended to use harvester than rather pulling out with hands. On an average one kiwi plant yields about 25 to 45 Kg depending on the variety.

Post-harvest management

Kiwi fruits can be stored up to six weeks unlike other fruits. Fruits are usually consumed fresh. Fruits with more than 100 g per piece are usually considered as grade A.

12. Passion fruit

Background

Passion fruit, native to South America belongs to family Passifloraceae and it is one of the high export value crops. There are two distinct forms of *Passiflora edulis* Sims, the standard yellow (*Passiflora edulis* f. flavicarpa Deg.) and the purple (*Passiflora edulis* f. edulis), differing in acidity and starch content. The annual production is about 120 MT.

Variety

In Bhutan, there are two types of passion fruit, Purple type and Yellow type. However, purple type is the most common types grown in Bhutan.

Climate

Purple type can be usually grown from 900 to 2000 masl and Yellow type below 1000 masl. Temperature of 18-23ºC is favourable for flower initiation and fruit set in purple passion type while relatively high temperature is necessary for promoting juice production and improvement in quality.

Soil

Passion fruit is grown on many soil types but light to heavy sandy loams, of medium texture are suitable. Soil with a pH of 6.5 to 7.5 is the most suitable.

Field preparation

The land should be well prepared by deep ploughing, levelling and incorporation of manures. Areas with high winds should be avoided to prevent from damages and vine training works. Pits of 45 cm x 45 cm x 45 cm are dug at a spacing of 3m x 2m or 3 m x 3 m on hill slopes or plains. The pits are filled up with a mixture of three parts of top soil and one part of compost.

Recommended seedling rate

The seedling rate will vary with the type of training system adopted and the cultivars. Kniffin system of training is commonly used. In this system of training and a spacing of 2m x 3m, it would accommodate about 670 plants/acre.

Nursery management

Nursery can preferably be established under green house with good access to water facility. All types of Passiflora species can be propagated from seeds, cuttings, air layering or by grafting. The rootstocks are produced exclusively from seeds.

Seeds

Fruits are collected from superior vines in respect of yield and quality. The pulp is extracted and allowed to ferment for 72 hours for seed separation from pulp. The passion seed is then thoroughly washed, dried and sown in well prepared seed beds as soon as possible during March-April. The seedlings after attaining 4-6 leaves stage are transplanted in 10 cm x 22 cm polybags filled with a mixture of soil, compost and sand (2:1:1). The seedlings will be ready for transplanting in the main field in about three months.

Cuttings

Semi-hardwood cuttings of about 30-35 cm size with 3-4 nodes are ideal. The cuttings are to be first placed in sand beds/pots for root initiation and then transferred to polybags for better root development.

Grafting

Grafting is also a means of perpetuating hybrids as well as reducing pest and diseases damage, by using resistant passion fruit rootstock. Rootstock material should be planted in a separate area to avoid crossing with other fruit cultivars. Scion woods are collected from the plant of desired variety. Cleft or wedge grafting is the most efficient method of grafting.

Planting

Planting is done preferably on cloudy days during June-July after the onset of monsoon so that the plants are well established by the end of the monsoon.

Cultural practices

Passion fruit is a woody vine that requires support and trellising for good growth and fruiting. Among the different types of trellising, Kniffin system is most economical. This training system requires 2½ m long poles which are erected 6 m apart and 8-10-gauge wire is fixed on the poles.

Pruning

Pruning is generally done twice in a year, first in March and April and another in October-November depending upon the harvest of the crop.

Nutrient management

Application of organic manure is essential to have vigorous plants and optimum yield. In the first year of plantation, 10 Kg of FYM per vine and from second year onwards 15 kg of FYM per vine is recommended. The manure should be applied in February-March.

Water management

The crop requires a well-distributed rainfall of 750-1250 mm. Prolonged dry spell during January-March may reduce main summer crop and adversely affect the flower development, encourage premature fruit drop and shrivelling. Supplementary irrigation like drip irrigation is very useful during the dry periods. On an average, passion fruit requires irrigation of 12-15 litres/vine/day in summer and 6-8 litres/vine/day) in winter.

Plant protection
Pest

No severe pest problem has been reported in passion-fruit. There are damage reports from stink bug puncturing young passion-fruit, but the fruit usually continues to develop more or less normally without any control measures required.

Diseases

The most common disease in passion fruit is Brown spot disease caused by *Alternaria macrospora Simes*. It occurs mainly in spring and early summer. The disease appears as concentric brown spots with greenish margin. Girdling of branches and premature defoliation occurs in severe cases. The affected branches should be pruned and burnt. The other disease is Root rot caused by *Phytophthora nicotianae var. parasitica* which ultimately kills the plants. Drenching with 1 % Bordeaux mixture helps in checking the disease. The affected plants should be mounded with soil to encourage new root formation. Wilt or Collar rot, is a devastating disease caused by *Fusarium oxysporum/ F.passiflorae*. The affected plants die immediately within a day or two. There is no control measure except having tolerant/resistant varieties or use of resistant root stocks.

Harvest

The vines start yielding fruits after 10 months of planting and bearing reaches optimum by 16-18 months. Fruit takes about 80-85 days to reach maturity after flowering. Slightly purple coloured fruits along with a small portion of stem/pedicel should be picked up. The fruit will quickly turn from green to deep purple (or yellow) when ripe and then fall to the ground within a few days. The rind becomes wrinkled on drying but the pulp remains in good condition for several days. 3-7 MT per ha can be produced. The normal productive life is 3 years in tropical climates and up to 8 years in subtropical climates.

Post-Harvest Management

Passion fruit is generally not consumed as a table fruit. It has good commercial value especially as raw materials in processing industries for preparation of juice, concentrates, squash, ice cream and confectionery etc. The purple passion-fruit can be stored up to 5 weeks with little loss of mass at 5°C maintaining humidity of 80-90 %. The yellow passion-fruit can however be stored for about a week at 5-7.5°C.

SECTION FOUR

PACKAGE OF PRACTICE FOR MAPS

1. Large cardamom

Description

Large cardamom *(Amomums abulatum* Roxb.) belongs to *Zingiberaceae* family & is native to moist deciduous and evergreen forest of Sub-Himalayan tracts and it is one of the main cash crops cultivated in south-western region of Bhutan. The crop gained its economic importance in the early seventies mainly due to following attributes of being high value, low volume, non-perishable, less dependent on external inputs, do not require expensive infrastructures and assured market

The crop was introduced to Bhutan centuries back from Sikkim and its cultivation gradually started in other parts of Bhutan covering mainly southern foothills. The present cultivation of crop is based on the inherent indigenous knowledge of the farmers which was derived and adopted from farmers in Sikkim. As a result, package of practices were developed to provide information on cultivation practices of the crop. Cardamom plantations in Bhutan covered an area of about 13,880 acres with an annual production of 2,245 MT in 2017. Samtse, Chukha, Dagana, Tsirang, Sarpang and Trongsa are the major large cardamom growing Dzongkhags. Large cardamom is grown only in India, Nepal and Bhutan. Bhutan is third after Nepal and India in production of large cardamom in the world.

Varieties

There are mainly eight popular cultivars in the world viz., Ramsey, Ramla, Sawney, Varlangey, Seremna and Dzongu Golsey and two high yielding varieties ICRI Sikkim 1 and ICRI Sikkim 2. However, there are just two cultivars of large cardamom viz. Varlangay and Golsey which are officially notified in Bhutan. Varlangey is the most popular variety in Bhutan.

Climatic Requirement

Large cardamom prefers humid subtropical, semi-evergreen forests on medium to steep hills of eastern sub-Himalayan region. It is a shade loving plant (Sciophyte) grown in tracts with well distributed rainfall spread around 200 days with a total of about 3000-3500 mm/year. The plants are usually grown along small springs, in moist and shady sides of mountain streams and along hilly slopes. It is grown successfully depending upon the cultivars in the altitude ranging from 600 to 2000masl

Soil requirement

Deep and well drained soils with loamy texture are best for large cardamom cultivation. The crop requires at least moderate deep (0.6 m) top soil for its good performance. Large cardamom soil should be rich in organic matter and nitrogen, medium in available Phosphorus and medium to high in potash. Soil pH should range from 4.5 to 6.0, have high exchangeable iron and aluminum. Even though the crop can be grown in undulating and steep terrains, land with moderate slope is preferred.

Site Selection

Large cardamom grows best in forest loamy soils with gentle to medium slopes. Slopes facing north are the most favourable for its growth as they prevent direct sunlight during the

day time. Luxuriant growth is observed nearby perennial water sources. However, water logged condition is detrimental to the plants' growth. It performs well under partial shade (50 %). Thus, the agro-forestry based cropping system is highly recommended

Land preparation

The land selected for planting is cleared from under growths and weeds. Old large cardamom plants, if any may also be removed. Pits of size 30 × 30 × 30 cm are prepared on the contours at a spacing of 1.5 × 1.5 from the center of the pits. Wider spacing of 1.8 × 1.8 m is recommended for robust cultivars like Ramla, Ramsey, Sawney and Varlangey etc. while closer spacing of 1.45 × 1.45 m is advised for non-robust cultivars like Dzongugolsey, Seremna etc. 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

Planting

Planting of large cardamom is done in May- June when there is enough moisture in the soil. A mature tiller with 2-3 immature tillers/vegetative buds is used as planting unit. For better production, quality planting materials should be raised in nurseries or collected from certified nurseries. 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. Staking is needed to avoid lodging of plants from heavy rain and wind and mulching is done at the plant base

Mulching

A soil base with gentle slope from the plant is beneficial for application of inputs to the plants viz., FYM, vermin-compost, neem cake, mustard cake, 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 followed by mulching. Mulching at the plant base helps to retain moisture and the prevent erosion of topsoil. Mulching improves the soil condition and the soil fertility. Dried organic matter, leaves, weeds, etc., can be used as mulching materials

Manures and fertilizers application

For a sustained good yield and to compensate nutrient loss from the soil, replenishment of nutrients is very essential. Well-decomposed cattle manure /compost or organic products @ 2 kg per plant and mustard cake @ 500 g per plant at least once in two years in April-May are beneficial. If all crop residues are recycled in the plantation and FYM/organic materials are applied, application of inorganic fertilizers may not be necessary. However, in plantation with high productivity, fertilizers @ 20:30:40 kg N, P and K per hectare may be applied in two splits, full P in April and half N and K in April and September

Irrigation

Large cardamom plants cannot thrive well under water stress conditions. 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. It is observed that the productivity is higher in plantations where irrigation is provided. Depending on availability of water source, hose or sprinkler irrigation and irrigation through small channels are advised. Water harvesting pits

can be made in between four plants during rainy season can support the water requirement of the crop in the dry season to some extent

Shade management

Large cardamom performs best under the partial shade. About 50 % shade is ideal. Uttis, Himalyan alder (*Alnus nepalensis*) is the most recommended shade trees. The other trees recommended as shade tree are Panisaj (*Termalia myriocarpa*), Pipli (*Bucklandia sp*.), Malito (*Maxaranga denticulate*), Argeli (*Edgeworthes gardneri*), Asare (*Viburnuse ruberens*), Bilaunce (*Maesacheria*), Kharane (*Symplocos sp*.), Siris (*Albizzia lebbeck*), Faleto (*Erythrina indica*), Jhingani (*Eurjata panica*), Chillowne/Zalashing (*Schime wallichi*), etc. If the crop is cultivated in marginal lands, intercropping with fruit crops like mango, banana, citrus, avacado, etc., can also be practiced

Both heavy shade and less shade are not good for crops growth. Lopping of branches of shade trees is very important and should be done before onset of monsoon during June-July. Over exposure of plants to direct sunlight causes yellowing of leaves, invites pest and diseases leading to poor growth and production. Therefore, judicious shade management is very important for good growth, timely flowering and for better crop

Weed management

Weed control in the plantations is an important operation for maximum utilization of available soil moisture and nutrients by the plants. Three rounds of weeding is 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. The plant base weeds are pulled out by hand and in inter-space slashing with sickle are practiced. 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 around the plant base which will help to conserve moisture in the ensuing dry months, cover the exposed roots and prevent weed growth around the plant base. During flowering period, the thrashed materials should not cover the inflorescences.

Plant protection measures

Diseases of Large cardamom

Colletotrichum blight

Colletotrichum blight has devastated the large cardamom plantation and is the cause of concern for severe crop loss and decline in plant population in early 1990s. The disease appears generally with the initiation of pre-monsoon showers in April-May and progresses rapidly during the rainy season. However, in some areas the incidence starts during winter months (January-March). As a whole, the affected clumps and the entire plantation look dry. The disease mostly affects the bearing tiller of the clump while the new tillers remain apparently healthy.

Management of the Colletotrichum blight

- Most of the cultivars were found susceptible to the disease under natural conditions.
- Phyto-sanitary measure is the most important in managing the disease.

- The mature and bearing tiller cut during harvesting should not be used as mulching materials as it will be the source of disease inoculums.
- It is advised to collect and burn the harvested tiller after harvesting.

Leaf Steak

Leaf streak is caused by *Pestalotiopsis royenae* (D.Sacc.) Steyaeri. The symptoms of leaf streak are characterized by the presence of numerous elongated translucent streaks on young leaves along the veins. Within 3-4 days the streaks turn reddish brown and develop a straw coloured necrotic area in the centre which is surrounded by prominent dark brown margins.

Management

- The golsey variety, with a crinkled leaf pattern is more susceptible to the pathogen than the Sawney variety, which has smooth leaves.
- Fungicides like carbendazim (0.1 %), zineb (0.25 %) are effective.

Wilt

This is one of the important diseases of large cardamom in nursery and field. Maximum damage to the nursery occurs in February and March. The intensity of the disease is severe in plantations from October to February. Sudden wilting of the plant or individual leaf is the characteristic symptom of the disease.

Management

- Follow long crop rotations.
- Collect and burn the infected plant debris.
- Addition of oil cakes in the soil and rising of soil pH to 8.2 is also found effective in reducing the disease incidence.
- Coriander varieties/ lines like MP 5365 and UD 373 showed least infection to the disease and can be used in breeding programme for developing resistant varieties.
- Treat the seed with carbendazim (0.2 %) followed by sprays with carbendazim (0.1 %) reduce the disease.
- Seed treatment with *Trichodermaviride* (4g/kg seed) was also found effective in reducing the disease incidence.

Pest of large of large cardamom

Leaf eating caterpillars (*Artona chorista* Jordon)

Initially, the caterpillar of the moth feeds on the leaf lamina from under side of the leaf and finally defoliates the leaves completely leaving only the midribs. Their incidence is noticed in May-July and October-March. For effective management of this pest, infested leaves with caterpillar may be collected and burnt regularly. This method is effective because,

- Caterpillars remain in congregation in clusters. So large number of caterpillars can be collected from a single colony.
- Infested leaves can be identified easily by their transparent epidermis.
- Caterpillars are sluggish in nature.

Stem borer (*Glyphipterix* sp)

The larvae bore into the pseudo stem above the collar region and feed on the central part of the pseudo stem causing dead heart. Sometimes, excreta can be seen near the holes at the base of the pseudo stem. Phytosanitation i.e. removal and burning of infested tillers is helpful for managing the pest.

Points to be considered for pest management

- Do not apply chemicals especially in cocktails and repeatedly.
- Give emphasis on phytosanitation.
- Pest infested plants/plant parts should be destroyed immediately.
- Do not use infested planting materials for new plantation.
- 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.

Harvesting and curing

The indication of time of harvest is when the seeds of top most capsules turn brown. As soon as the brown colour appears and to enhance maturity, 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. The harvested spikes are heaped and capsules separated and dried. The cured capsules are rubbed on wire mesh for cleaning and removal of calyx (tail)

Traditionally cardamom is cured in Bhatti, where capsules are dried by direct heating. Under this system the cardamom comes in direct contact with smoke which turns the capsules dark brown or black with smoky smell. Improved curing techniques developed by NPHC and AMC are presently available in which cardamom is processed to give good quality and appearance.

Drying is done till moisture content of the produce is brought down to 10-12 % level and gives metallic sound while shuffling

Post-harvest management

The properly dried capsules are cooled and then packed in polythene-lined jute bags. The bags may be stored on wooden platform away from sidewall to avoid absorption of moisture and to avoid fungal growth on the stored produce.

2. Ginger

Brief description

Ginger (*Zingibe rofficinale Rosc.)* is a herbaceous perennial belonging to the Zingiberaceae family. Ginger is associated with many health benefits and used in ayurvedic preparations. The rhizomes are mainly used as spices. It is used in the preparation of pickles, beverages, medicines and confectionaries, but in Bhutan it is used mainly for fresh consumption. Processing of fresh ginger into dried ginger powder, ginger tea sachets and ginger pickles are some of the value added products explored & processed by National Post Harvest Centre & Bio Bhutan in Bhutan. For Bhutanese farmers, ginger is important mainly because of low perishability and ready markets across the border in India

Ginger is one of the important cash crops for the farmers of sub-tropical region in Bhutan. In 2017, about 3,970 MT of ginger has been exported at the mean unit price of Nu. 44, valued at Nu. 175 million which contributes to 11.46 % of GDP earned through export of Agriculture products. Chhukha**,** Samdrupjongkhar**,** Samtse**,** Sarpang & Pemagatshel, are the major Ginger growing areas in Bhutan and together contribute about 90.8% of the total ginger production of the country**.** According to the Agriculture statistics, 2017 about 7,859 MT of Ginger has been harvested from 3,809 acres. The average productivity in Bhutan is about 2,063 Kg per Acre.

Available varieties

Although there are no identified ginger varieties in Bhutan, several cultivars of ginger are grown in different parts of Bhutan and they are generally named after the local area where they are grown. Some of the prominent indigenous cultivars are *Tsirang type* which fetches better with the local customers while Chuzergang type fetches better price in auction yards. Tsirang type is fleshy with less fiber & high water content while Chuzergang type is more fibrous and pungent and preferred in Indian market

Climate

Ginger grows well in warm and humid climate and is cultivated from sea level to an altitude of 1500 masl. Ginger can be grown both under rain fed and irrigated conditions. For successful cultivation of the crop, a moderate rainfall at sowing time till the rhizomes sprout, fairly heavy and well distributed showers during the growing period and dry weather for about a month before harvesting is necessary. The crop performs well at temperature range of 19 °C- 28 °C and humidity of 70-90 %.

Soil requirement

Ginger thrives best in well drained soils like sandy loam, clay loam, red loam or lateritic loam. A friable loam with a pH of 6.0 to 6.5 rich in humus is ideal. However, being an exhausting crop it is not desirable to grow ginger in the same soil year after year. Ginger grown in red soil is considered better quality in the auction yard. The crop cannot withstand water logging and hence soils with good drainage are preferred for its cultivation.

Field preparation

The land is to be ploughed 4 to 5 times or dug thoroughly with receipt of early summer showers to bring the soil to fine tilth. Beds of about 1 m width, 30 cm height and of convenient length are prepared with an inter-space of 50 cm in between beds. In the case of irrigated crop, ridges are formed 40 cm apart. In areas prone to rhizome rot disease and nematode infestations, soil solarization of beds for 40 days using transparent polythene sheets is recommended

Recommended seed/ seedling rate

The seed rate varies from region to region and with the method of cultivation adopted. The seed rate is 1,500-1,800 Kg per acre in Bhutan. At higher altitudes the seed rate may vary from 2000 to 2500 kg/ha.

Planting time

The best time for planting ginger is during the first fortnight of April with the receipt of pre-monsoon showers. Under irrigated conditions, it can be planted well in advance during the middle of February or early March. Early planting with the receipt of summer showers during February-March results in higher yield and reduces disease incidence.

Irrigation

Ginger is cultivated as rain fed crop in high rainfall areas (uniform distribution for 5 to 7 months) and irrigated crop in less rainfall areas. Ginger requires 1300-1500 mm of water during its crop cycle. The critical stages for irrigation are during germination, rhizome initiation (90 DAP) and rhizome development stages (135 DAP). The first irrigation should be done immediately after planting and subsequent irrigations are given at intervals of 7 to 10 days in conventional irrigation (based on prevailing weather and soil type). Sprinklers and drip system can also be employed for better water use efficiency and enhanced yield.

Planting

Ginger is propagated by portions of rhizomes known as seed rhizomes. Carefully preserved seed rhizomes are cut into small pieces of 2.5-5.0 cm length weighing 20-25 g each having one or two good buds. The seed rate varies from region to region and with the method of cultivation adopted. The seed rhizomes are treated with mancozeb 0.3 % (3 g/L of water) for 30 minutes, shade dried for 3-4 hours and planted at a spacing of 20-25 cm along the rows and 20-25 cm between the rows. The seed rhizome bits are placed in shallow pits prepared with a hand hoe and covered with well decomposed farm yard manure and a thin layer of soil and levelled.

Transplanting

Single bud sprouts (about 5 g) transplanting technique in ginger has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-

40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on planting material

Cultural practices

Weed management

Weeding should be done just before fertilizer application and mulching. 2-3 hand weeding is required at 45, 90 & 120 Days after planting, depending on the intensity of weed growth.

Earthing up

Earthing up is essential to prevent exposure of rhizomes and provide sufficient soil volume for free development of rhizomes. It is done at 45 and 90 days after planting immediately after weeding and application of fertilizers.

Mulching

Mulching the beds with green leaves or organic wastes is essential to prevent soil splash and erosion of soil due to heavy rain. It also adds organic matter to the soil, checks weed emergence and conserves moisture during the latter part of the cropping season. The first mulching is done at the time of planting. Green leave mulching is to be repeated at 45 and 90 days after planting, immediately after weeding, application of fertilizer and earthing up.

Removal of mother rhizome

Mother rhizome removal, called *mau* extraction is an age old practice in Sikkim and Darjeeling. Almost all the farmers in Sikkim and Darjeeling adopt higher seed rate, i.e. 2-2.5 t/ha of rhizome as against the normal rate of 1.5 t/ha. By the end of May or June, i.e. when ginger crop attains 60 days age or 3-4 leaves, farmers remove mother rhizome, leaving the sprouted piece of rhizome in the soil. The removed *mau* is sold in local market.

This practice is believed to give proper space to the developing rhizome and although the quality of rhizome is inferior, farmers get income due to off-season price advantage. Fifteen days after *mau* extraction, FYM is applied once again and earthed up

Inter cropping and crop rotation

Ginger is commonly rotated with tapioca, paddy, maize and vegetable. In Bhutan it is mainly intercropped with Dhaincha (*Sesbania aculeata*). However, crop rotation using tomato, potato, chillies, Brinjal and peanut should be avoided, as these plants are hosts for the wilt causing organism, *Ralstonia solanacearum*.

Nutrient Management

At the time of planting, well decomposed cattle manure or compost @ 25-30 tonnes/ha has to be applied either by broadcasting over the beds prior to planting or applied in the pits at the time of planting. Application of neem cake @ 2 tonnes/ha at the time of planting helps in reducing the incidence of rhizome rot disease/ nematode and increasing the yield.

As the soil fertility varies with the soil type, agro ecological conditions or management systems, site specific nutrient management based on the soil test results for major nutrient is advocated. The fertilizers are to be applied in 2 to 3 split doses. Full dose of phosphorous is

applied as basal dose at the time of Planting. Equal split doses of N and K is top dressed at 45, 90 & 120 Days after planting (DAP).

Plant Protection

Diseases: The diseases that commonly affects ginger are soft rot, bacterium wilt and leaf spot. Nematode pest also damages ginger in addition to shoot borer, rhizome scale and root grubs.

Harvest

Time

Ginger attains full maturity in 210-240 days after planting. Harvesting of ginger for vegetable purpose starts after 180 days based on the demand. However, for making dry ginger and preparation of ginger oil, oleoresin, dehydrated and bleached ginger the matured rhizomes are harvested at full maturity i.e. when the leaves turn yellow and start drying (210-240days).

Methods

Irrigation is stopped one month before harvest and the rhizome clumps are lifted carefully with a spade or digging fork. The dry leaves, roots and soil adhering on the rhizomes are manually separated. Late harvest is also practiced, as the crop does not deteriorate by leaving it for some months underground. In India, domestic market prefers fresh green ginger for culinary use while two types of dried ginger i.e. bleached and unbleached are produced for export purpose. The most important criteria in assessing the suitability of ginger rhizomes for particular processing purposes is the fibre content, volatile-oil content and the pungency level. The relative abundance of these three components in the fresh rhizome is governed by its state of maturity at harvest.

Yield

The average productivity recorded in Bhutan is about 2,063 Kg per Acre with the highest average yield recorded from Samtse dzongkhag (3,235 kg/acre) and lowest average yield was recorded from Punakha Dzongkhag (220 kg/acre)

Post-Harvest Management

Seed selection

For seed material, bold and healthy rhizomes from disease free plants are selected immediately after harvest. For this purpose, healthy and disease-free clumps are marked in the field when the crop is 6-8 months old and still green. Select disease free and vigorous plants for next year seed and harvest them 10-15 days before harvesting bulk rhizome and store them in dry and shady places. Before planting, stored seed rhizomes are sorted, rhizome that is large, shiny, free from spots or marks, bud or eye injury are selected for planting. Handle seed rhizomes carefully to avoid damage to buds.

Storage

There are three traditional methods of seed rhizome storage.

Storage in soil pits:

In pit storage, either a circular or rectangular pit (1-2 m depth) is dug. A thin layer of straw is spread over the bottom of pit and rhizomes are placed into this in layers just below ground level. Again a thin layer of straw covers the rhizomes. The final covering is done with the soil little above the ground level (as roof). The pits are opened at the time of next year sowing. In this method, the rhizomes get spoiled in two ways, i.e., around 25-30 % rhizomes rot in the pit itself and about 10-15 % rhizomes sprout in the pit and are rendered useless for sowing. Some farmers in Meghalaya observed that ginger stored in pits along with sand protect the ginger from rotting.

Storage in a dry and shaded place:

For the larger growers but there is a problem of rhizome drying. The seed rhizomes are stored along with the leaves of local neem.

In situ storage:

By in situ storage (delayed harvest), farmers harvest the rhizome according to market demand and allow the rest of rhizomes remain unearthed in the field. This method is prone for rhizome rot, rhizomes start sprouting in course of time and harbour insect pests.

3. Turmeric

Background

Turmeric (*Curcuma longa* L) is an herbaceous perennial belonging to the family Zingiberaceae and a native of South Asia particularly India. Turmeric is considered as ancient and sacred spice of India and it is known as 'Indian saffron' due to its commercial importance. It is used in diversified forms as a condiment, flavouring and colouring agent and as a principal ingredient in Indian culinary as curry powder. It has anti-cancer and anti-viral activities and hence finds use in the drug industry and cosmetic industry. 'Kum-kum', popular with every house wife, is also a by-product of turmeric. It finds a place in offerings on religious and ceremonial occasions. A type of starch is also being extracted from a particular type of turmeric. The increasing demand for natural products as food additives makes turmeric as ideal produce as a food colourant

Turmeric cultivation in Bhutan is mostly carried out in backyard kitchen garden for home consumption. As a result, production statistics is negligible and it's not reflected in the country statistics. The use of processed turmeric in Bhutanese diets is rare and most of the current consumption is imported from India. In fact, cultivation of the turmeric was not taken up due to unavailability of processing equipment along with the limited consumption population. However, with the recent development and health benefits of turmeric in the Bhutanese society, the commercial cultivation is slowly taken up by some elite farmers in the region.

Varieties

Although, there are about 30 turmeric varieties grown in India, the varieties grown in the region are still unknown as they are locally located. However, the two types of turmeric grown in the region can be identified though the colours of fingers. If the finger colour is orange, it is named as orange type and similar to yellow fingers.

Climate

Turmeric is a tropical crop which requires warm and humid climate. It performs well at temperature range of 24ºC to 28°C. Growth ceases when, temperature falls below 20°C, and hence early-planted turmeric gives good yield. It thrives well in areas with annual rainfall of 70 - 225 mm and can be grown at an altitude of 1200m above sea level.

Soil

It performs well in sandy loam to clay loam or alluvial soils. Well-drained loamy soils are the best. Soil should be rich in organic matter and uniform in texture. Rich loamy soils having natural drainage and irrigation facilities are the best. It cannot withstand water stagnation or alkalinity.

Recommended seed rate

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 such or split into two, each having one sound bud. Mother rhizomes are preferred since they give 50 % more yields than the finger rhizome and also give good growth. Large sized, plumy and healthy

mother rhizomes at least 100 g in weight should be used. Rhizomes can be treated with Lindane and Bavistine powder (2 g/1 of water). The planting material should be dipped for 15-20 minutes for prevention of pest and diseases incidences.
The seed rate varies according to type of planting material, spacing and weight of rhizomes:

- Mother rhizomes: 2000-2500 kg/ha.
- Finger rhizomes: 1500-2000 kg/ha.
- As an intercrop in fruit garden: 400 - 500 kg/ha.

Field preparation and planting

Field preparation should be done with/onset of early rains in 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.
There are two types of planting methods followed in turmeric cultivation:
Flat Beds method: It is practiced under rain-fed conditions where soils are light. Flat beds of 1 m width and convenient length are prepared.
Ridges and Furrows method: It is practiced under irrigated conditions usually in levelled and plain field and heavy soil. The rhizomes are laid on ridges and furrows. Rhizomes are planted at l/3rd height of ridge on broad ridge.

Spacing

- Flat Beds: (25 x 2.5 cm) in each direction.
- On ridges and furrows: 40-60 x 25 cm.

Planting time/ season

In southern foothill region, planting should be carried out in March – April.

Irrigation

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

Cultural Practices

Field should be kept clean for the first 4-6 weeks from the date of planting and 5-6 weeding should be done depending on the intensity of weeds.

Earthing Up

The intercultural practices are done with light digging after 2 - 2.5 months from date of planting to avoid exposure of developing underground rhizomes to sun due to soil erosion.

Manure and fertilization application

Sl. #	Time	Manure (tones/Ha)	N (kg/ha)	P (kg/ha)	K (Kg/ha)
1.	At preparatory tillage i.e. before last harrowing	30	-	-	-
2.	Basal application at planting	-	-	50	50
3.	One month after planting	-	60	-	-
4.	Two months after planting	-	60	-	-
	Total	30	120	50	50

Intercropping

Chilli, onion, brinjal and maize can be intercropped with turmeric. However, it can also be intercropped with plantation crops like areca nut.

Plant Protection

Disease: Turmeric should be protected against diseases such as leaf blotch, leaf spot, rhizome rot and insect pest mainly shoot borer, leaf roller and scales

Harvesting

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

Yield (kg/ acre)

Normally, the yield ranges from 25000-30000 kg per hectare for fresh rhizomes and after curing there will be 20-25 % reduction in weight than fresh rhizome.

Post-harvest management

Curing

Fingers are separated from mother rhizomes. Mother rhizomes are usually kept as seed material. The green turmeric is cured for obtaining dry turmeric. Curing involves boiling of green rhizomes in water and then drying in the sun.

The contemporary method of curing is as follows: The cleaned rhizomes are boiled in copper or galvanized iron or earthen vessels, with water upto the surface of rhizomes, just enough to soak them. Boiling is stopped when froth comes out and white fumes appear giving out a typical odour. The boiling lasts for 45-60 min when the rhizomes are soft to finger pressure. The stage at which boiling is stopped largely influences the colour and aroma of the final product. Overcooking spoils the colour of the final product while under cooking renders the dried product brittle resulting in a higher percentage of pieces

The improved scientific method of curing turmeric: The cleaned fingers (approximately 50 kg) are taken in a perforated trough of size 0.9 x 0.55 x 0.4 m. The trough is made of GI or MS sheet with extended parallel handle. The perforated trough containing the fingers is then

immersed in the pan. The alkaline solution prepared by dissolving 100 g of sodium bicarbonate or sodium carbonate in 100 litres of water is poured into the trough so as to immerse the turmeric fingers. The whole mass is boiled till the fingers become soft. The cooked fingers are taken out of the pan by lifting the trough and draining the solution into the pan. Alkalinity of the boiling water helps in imparting orange yellow tinge to the core of turmeric. The drained solution in the pan can also be used for boiling another lot of turmeric along with the fresh solution prepared for the purpose. The cooking of turmeric is to be done with two or three days after harvesting

The rhizomes may also be placed in baskets with perforated bottom and sides, and then dipped in covered tanks when the quantity is large or may be put directly into the vessels when the quantity is small. The bulbs as whole or cut longitudinally into halves and the fingers are generally cured separately

Drying

The cooked fingers are then dried in the sun by spreading in 5-7 cm thick layers on bamboo mat or drying floor. A thinner layer is not desirable, as the colour of the dried product may be adversely affected. During night time, the material should be heaped or covered. It may take 10-15 days for the rhizomes to become thoroughly dry, when they become quite hard and brittle.

Polishing

Dried turmeric has a poor appearance and a rough dull outer surface with scales and root bits. The appearance is improved by smoothening and polishing the outer surface by manual or mechanical rubbing

Manual polishing consists of rubbing the dried turmeric fingers on a hard surface or trampling them under-feet wrapped in gunny bags. The improved method is by using hand operated barrel or drum mounted on a central axis, the sides of which are made of expanded metal mesh. When the drum filled with turmeric is rotated, polishing is effected by abrasion of the surface against the mesh as well as by mutual rubbing against each other as they roll inside the drum. The turmeric is also polished in power-operated drums. The yield of polished turmeric from the raw material varies from 5-25 per cent

Colouring

The colour of the turmeric powder is main component which attracts the buyers. Yellow colouring is given externally to the rhizomes while polishing by a dry or wet process. Turmeric powder is added to the polishing drum in the last 10 minutes of drying process. In wet drying process turmeric powder is suspended in water and mixed by sprinkling inside the polishing basket. For giving a brighter colour, boiled, dried and half polished fingers are taken in baskets which is shaken continuously when an emulsion is poured in. When the fingers are uniformly coated with the emulsion, it is then dried in the sun. The composition of the emulsion required for coating 100 kg of half boiled turmeric is: Alum 0.04kg, turmeric powder 2 kg, castor seed oil 0.14 kg, sodium bisulphate 30 g and concentrated hydrochloric acid 30 ml

Quality of Powder

The processed turmeric powder should be negative to chemichrome test, total ash content should be less than 9 % and moisture content should be less than 13 %.

Turmeric oil

Turmeric oil is volatile and it is obtained by steam distillation of ground turmeric after 8-10 hours. The oil is pale yellow to orange yellow in colour. The aroma of oil is due to tumerone and artumerous. Turmeric oleoresin is obtained by solvent extraction method and is highly valued.

Seed maintenance

Rhizomes for seed are heaped in the shade of trees or in well ventilated sheds and covered with turmeric leaves and it can be heaped in some containers and plastered over with earth mixed with cow dung to avoid from insects damage. The seed rhizomes can also be stored in pits with saw dust and the pits can be covered with wooden planks with one or two holes for aeration

SECTION FIVE

PACKAGE OF PRACTICES FOR CITRUS MANDARIN

1. Citrus Mandarin

Background

Citrus represents Bhutan's largest fresh fruit export, significantly contributing to Bhutan's economy by generating annual export revenue of Nu. 464 Million. It is one of the main sources of income for more than 38.5 % of rural households and benefits more than 60 % of the population. These include growers, traders, processors, and other people gaining employment in the citrus industry.

The average annual citrus production over the last 10 years has been about 41,077 MT, and the area as of 2017 is 13,992 acres. Bhutan has potential to increase the citrus production both through area expansion and orchards management improvements. The production can be expanded beyond the presently cultivated areas with increasing temperature in higher elevations favouring citrus growth, and with diversification of varieties suited to different agro-ecological zones. Diversification to early and late bearing varieties will help narrow the fresh fruit supply gap both for domestic and exports markets. Development of processing varieties will reduce the import of processed citrus products and enhance industrial development and employment opportunities for youths. Apart from the existing well-established export market in Bangladesh and India, a recent interest shown by Thailand to import citrus from Bhutan as "Brand Bhutan", is an encouraging signal to expand the citrus industry.

However, the citrus industry in Bhutan is experiencing rapid decline mainly due to climate change impacts leading to increased pest and disease outbreaks; drought and erratic rainfall; change in growth habit and limited management options. In order to overcome these challenging issues, the Department of Agriculture has established a modern functional National Citrus Repository (NCR) to source high health bud wood; introduce Public Accession Varieties (PAVs) from ex-countries for diversification, and relocated the citrus production nursery to higher elevation to safeguard planting materials from Psyllids spreading citrus greening disease. These important arrangements are crucial not only for current sustainability, but also to the future development of the citrus industry. Therefore, citrus is considered as the priority horticultural commodity for Bhutan, not only to reduce rural poverty, but also to enhance employment and income opportunities by maintaining and expanding citrus production as an important agricultural enterprise.

Varieties

The mandarin that belongs to the species *Citrus reticulata* 'Blanco' is the most widely grown citrus in Bhutan. There are two varieties; Sikkim mandarin and Khasi mandarin. The earlier variety is concentrated in the south west districts while the latter one dominates the south-central and south-east districts. Farmers prefer these varieties due to their ease of management and availability.

Climatic condition

- The optimum temperature for growth is generally between of 13 ^{0}C and 35 ^{o}C.
- Little growth occurs on trees at temperature below 13 ^{o}C.

- Citrus vegetative and fruit growth are dependent on the amount of heat received and each variety has an optimum temperature range.
- Avoid the site experiencing frequent frosts and freezing temperature (<-2^{o}C). Frost and freezing temperatures can damage fruit, burn foliage and kill mature trees.

Soils

- A complete soil survey is important before citrus to analyse the soils depth, soils profile, textures and chemical properties. It is important to identify any potential problems such as pH, fertility, and drainage to take up remedial actions before planting.
- Most preferred soil types for citrus are sandy loams, loams and clay loams which generally have good drainage, water holding and nutrient storage capacity.
- At least one meter of well-drained soil is needed to support the roots system.
- Avoid heavy clay soils or soils with impermeable layers as these can be subjected to water logging and poor aeration.
- Citrus will do best in soils with a pH in the range of 5.5-7.0, as this will ensure most minerals are available for use.
- Correct acid soils by adding lime or dolomite to bring pH above 6.
- Correct alkaline soils by adding more organic matter.
- Soil depth and drainage can be improved by "mounding" in the tree row. Avoid digging the clay layers when mounding.
- Mounding could be done by heaping up topsoil in the tree row to form a continuous ridge above the unsuitable subsoil layers.
- Ridge should be 40-60cm high and 2.5-3.5m wide, and the crest of the ridge should be slope slightly to the sides to allow excess water to run off.

Orchard establishment

Planning

Proper planning is highly important for the establishment and success of citrus orchards. It is important to fully assess the soil and climatic conditions before planting, as citrus orchard establishment is a costly exercise. Grafted trees bear fruits by 4-5 years and seedling bears by 9-10 years after planting. Well-managed and healthy orchards are long lived and have a productive life of 35 years and even up to 60 or more years for some orchards. The production plan should be based on the market demand, both in terms of varieties and volume requirement. Apart from knowing the sources of inputs such as planting material, fertiliser, chemicals, etc. it is important to consult the land users right policy and funding subsidies from government or banks. Therefore, good planning will save both time and money in the long term.

Site selection

It is important to fully assess the soil and climatic conditions before developing a plantation. In Bhutan, citrus are grown right from 300m to 1800mamsl; however, it will again depend on the micro-climatic condition and choice of varieties.
For site selection;

- It should be either flat or gently sloping. Steep slope can be used either by terracing or following the contouring methods of plantations.
- The site should be preferably of "south easterly aspects" for better sun lights during winter months and should have easy access to clean irrigation water sources.
- Avoid sites with frequent temporary or prolonged periods of water logging.

Drainage

Water logging occurs whenever the water enters the soils at faster rate than it can drain away. Excess water is caused by heavy rainfall, over-irrigation, flooding or due to the presence of a permanent or temporary (perched) high water table. The water logging limits root growth, and affects roots ability to absorb water and nutrient.

- Orchard drainage can be improved by using surface or subsurface drains or combinations of both;
- Surface drains: removal of excess water caused by heavy rainfall or intercepting water caused from the flows from higher grounds, or runoff from other sources, by developing surface drains.
- Sub surface drain: removal of excess subsurface water by installing corrugated slotted PVC pipes, tile drains, mole drains, interceptor drains, ground water pumps by installing into specific depth.

Water and irrigation

Mandarin trees need a reliable supply of good quality water all round for good tree growth and production of high quality fruit. Water use is highest in the warmer months of April to September and lowest during winter. It is important to understand that;

- Water is critical for successful bud initiations, flowering, and fruit set and fruit growth.
- Water stress during critical growth stages of flowering, fruit set cell division and early stages of cell expansion causes significant impact on the tree yield and fruit quality.
- The ability of the tree to withstand water shortages or water logging also depends on rootstocks used.

Prior to the development of irrigation;

- Water samples should be taken from any water source intended for irrigation and tested by accredited laboratory, and irrigation water should be monitored regularly for any changes to its chemical properties.
- A comprehensive soil survey should be carried out to design an irrigation system specific to site conditions. Otherwise, drip system or micro-sprinklers could be used to irrigate the orchards.

Scion and rootstock selection

It is very important to select and plant the right trees. Before ordering and buying any trees there are two important decisions to be made:

i. Selection of rootstocks
ii. Selection of scion variety or clone

Rootstocks

The choice of suitable rootstocks is important for the long-term health and productivity of the orchard. The choice should consider;

- Scion compatibility
- Horticultural performance (e.g. yield and quality)
- Local soil conditions
- Local climatic conditions
  - *Rootstocks affect tree growth, productivity, fruit size, quality and maturity.*
  - *Rootstocks vary their resistance to diseases, nematode and tolerance to soil pH, salinity, water logging, water stress, etc.*

Scion Selection

The selection of the scion variety should be based on:

- Market requirement (fresh consumption, processing purposes, time of maturity, seediness, etc.)
- Local climatic conditions
- Specific management requirements (e.g. isolations or requirement for netting to reduce seediness)
- Susceptibility to fungal diseases

Propagation Methods

Citrus is propagated through;

1) Seed

Seeds should be sown first in primary nursery and then seedlings should be transferred to the secondary nursery, normally in container/poly pots.

2) Grafting and Budding

- Whip and Tongue' Grafting method us used for grafting
- Either T budding or cheap budding method could be used for budding.
- The rootstock seedlings are ready for budding within 1 to 2 years.

Planting density

Due to the topography, the contour system of planting is preferred in Bhutan. Planting distance are adjusted based on slopes, soil types, encountering rocks or hard surfaces. Different layout and designs could be practiced depending on the landscapes.

Planting distance in citrus

Type of planting materials	Spacing	Total Trees (per ac*)	Total Trees(per ha**)
Grafted Plant	4m x 4m	252	625
Seedlings	6m x 6m	112	277

* 1 acre (ac)=4046.86m^2; **1 hectare (ha)=10000m^2 (Estimation: No of plants per acre=4046.86/(4x4)=252)

Manure and fertilizer

Apply farmyard manure (FYM) or compost around the trees in winter. Either of the following methods could be used:

i. **Circle banding method in flat/plain areas:** Apply by preparing a furrow (10cm depth and 20cm wide) around the tree in circular band. The furrow should be 10cm inward from the periphery of canopy zone. Cover/mix with soil and lightly irrigate.

ii. **Trenching method for hilly areas:** Prepare a semi-circular/straight trench (10 cm depth and 15cm wide) 10cm inward from periphery of canopy zone. Apply fertilizer and cover with soils followed by a light irrigation. Manure/compost could be applied around or on the slope (above side) from the tree trunk.

It is recommended to follow the manure and fertilizer application rate given below:

Recommended manure rate and application schedule

Tree age (Years)	Farm Yard Manure (Kg/Tree)	Time of Application (Season)
2-3	5	Mid-late Winter
4-7	10	Mid-late Winter
8-12	15	Mid-late Winter
Above 12	20	Mid-late Winter

Fertilizer rate and application schedule for citrus

Fertilizer Combination	Rate of Application	Non - bearing Trees	Bearing Trees	Splits	Time of Application
Suphala	g/tree/year	150-350	350-650	100%	Mid-late Winter
Urea	g/tree/year	60-120	120-350	50%	Mid-late Winter
				25%	At fruit setting stage
				25%	During fruit growth stage
Micro-nutrients	Based on soil & plant analysis				Fully expanded leaf stage

To calculate out how much fertiliser is required or the amount of nutrient applied, use the following formulae:

$$\text{Amount of nutrient applied} = \frac{\text{amount of fertiliser(g/tree)}}{100} \times \text{\% Nutrient in fertiliser}$$

$$\text{Amount of fertilizer applied} = \frac{\text{amount of nutrient (g/tree)}}{\text{\% nutrient in fertilizer}} \times 100$$

Frost protection

Frost mitigation strategies need to be put in place to reduce the risk to trees and fruit if frost free sites are not available. Two main types of frosts are:

Advection frost: occurs when large body of cold air moves into an area replacing the warmer air present.

Radiation frosts: are more common and occur when there are clear skies, low humidity and little or no wind.

Managing frost:

- Turn on the overhead-sprinklers or under tree sprinklers when the temperatures drop to 1^0C and keep it running until the risk of frost has passed.
- Keep the soil moist.
- Remove weeds and keep inter-row areas mown short.
- Remove any impediments to the cold air flow.
- Thin any windbreaks that could stop the flow of cold air

Protective netting and greenhouse production

Depending on the economics, netting could be used to improve the fruit quality if there is assured higher returns. Similarly, greenhouse cultivation could be done to improve the fruit quality and productivity.

- Protective netting could be used to produce seedless fruit (Afourer mandarin, Nuke clementine) by preventing cross pollination with other citrus varieties by bees.
- The other option is to grow in isolations from other compatible varieties.
- Netting is also used to protect from hails, wind and bird to improve the external fruit quality.

Wind protection

Wind damages are one of the most important causes of citrus fruit blemish. Wind causes fruit scaring, reduced tree growth and yield, limb breakages and roots damage in young trees. The main purposes of the windbreak are to filter and break the force of prevailing winds but not to stop air flow completely. Wind breaks are developed by;

- Using artificial materials such as netting or mesh.
- Planting a living windbreak of suitable tree species.
- Using grasses to mainly protect young trees as short term wind break while the main windbreak is being established.

Weed management

Citrus trees have a relatively shallow fibrous root system. It is important to manage as weeds compete with trees for water and nutrient. It can also be the host of some pests (e.g. thrips and mites) and pathway for some insect pests to enter tree canopy.

- Plant citrus trees in rows to keep weed free with inter-row area typically planted with a permanent sod of grasses, clovers, medics. Some grasses are good for pollen sources for predatory mites when they are flowering.

- Use selective herbicides.
- Apply mulches of straws, rice hulls or composts to suppress weed growth in young plantings. Mulch adds organic matters to the soil, improving water and nutrient holding capacity, keeping root surface cooler, provide food sources for soil micro-organisms and generally improving soil health.
- Young trees (<3 years old) are sensitive to herbicidal damages and should avoid reaching the plant

Orchard maintenance and redevelopment

Regular annual pruning extend the productive capacity of the trees by continually renewing the fruit bearing wood and reducing shading in the canopy. Ideally an orchard should have no more than 20 % of the trees in a non-bearing state. Tree replacement can be done either by replanting or reworking existing trees. Rejuvenation is practiced to sustain the life of tree by maintaining re-growth of the same variety after heading back and training.

Replanting

Citrus trees generally grow more poorly when planted on soils that have been growing citrus, which could be due to high pests and pathogens, soil conditions, toxins from decaying roots and residual herbicides.

- Before replanting old citrus soil, it is best to rest the block for at least 18 months.
- Remove old trees and rip the soil deep to remove any residual tree roots.
- Plant the field with green manures like legumes or bio-fumigant brassica crop to improve the soil.
- The rootstock choice should be matched to the soil conditions.

Reworking or top working trees

A new scion re-worked on existing healthy trees should make good growth because of the well-established root system and produce good yields of fruit in 3-5 years. This is an alternative to planting new trees and could change the variety if found either unsuitable or unproductive.

- Re-working carried out on healthy productive trees using ‘high health status, good quality bud wood of commercial importance.
- It should be compatible with existing scions.
- Re-working mostly with Navel or Valencia oranges over mandarin proved successful.
- Grapefruit and lemon scion should not be reworked over to mandarin.
- All pruning and grafting equipment should be sterilised with minimum of 1 % Sodium Hypochlorite Solution (NaOCl).

Following methods are practiced for reworking:

Budding into regrowth shoots

- Cut back the tree in late winter/early spring to a height of 1-1.2 m leaving 3-5 scaffold limbs.

- Select two strong shoots from the spring re-growth on each limb and remove remaining shoots.
- Stake the shots to prevent breakage.
- In the summer/early autumn, insert a bud of the new scion into the base of each shoot using shield bud.
- Cover the bud completely with budding tape; remove the tape after 4-6 weeks when the bud has taken.
- Prune back the new shoots to encourage branching.
- Constantly remove the suckers below the bud sites.

Crown Grafting

- Cut off the tree through the trunk below the scaffold limbs.
- Three to five grafting sticks of new scions are inserted under the bark around the perimeter of the trunk following same method used for limb grafting

Limb budding

Young trees (<5years old) can be reworked without the need for severe pruning.

- Do the budding on the tree in spring or late summer /early autumn.
- Select 3-5 scaffold branches (<40mm in diameter) and remove the growth above budding site prior to budding.
- Follow the latter part of methods used in budding into re-growth shoots.

Limb Grafting

This is the most common method used for reworking trees.

- Prune back to their main scaffold branches in late winter or early spring, leaving 1-2 limbs as nurse branches.
- Graft one year old bud sticks into the scaffold branches in early to late spring when the bark is easily lifted.

Patch budding

This is practiced to change mandarin trees over to a new variety

- A patch bud of bark (30 mm x 40 mm) containing at least one bud from the new scion is grafted onto selected scaffold branches (on a tree to be reworked) prepared with a patch (prepared by removing rectangular patch of bark) when the cambium is actively growing in late spring/early summer.
- Held the patch in place with tape wound around the whole branch and tape is removed after the bud takes.

Rejuvenation

This is general method practiced to rejuvenate old/aged trees of desired variety to continue with its production.

Option 1:Phase-wise rejuvenation- if the tree is still bearing some fruits:

- Cut back selective scaffold branches of tree in late winter/early spring to a height of 1-1.2 m from the main trunk leaving 3-5 scaffold healthy limbs.
- Select two strong shoots from the spring re-growth on each limb and remove remaining shoots.
- Stake the shots to prevent breakage.
- The remaining scaffold branches could be headed back on when the newly developed limbs get stabilised.

Option 2: Complete heading back- if the tree is old and bearing no fruits/very low fruits

- Completely cut back all the scaffold branches to encourage the new growth on each of the scaffold branches, or cut off the tree through the trunk below the scaffold limbs if the scaffold branches are too old and weak to bear the new growth.
- Select 2-3 healthy shoots from the spring re-growth on each limb and remove remaining shoots or retain 3- 5 spring re-growth if the tree cut off is through the trunk.
- The shoots attending a height of 0.5-1 meter could be headed back to encourage lateral growth and scaffold branching.

Orchard management practices

It is important to align management practices to key phenological or growth stages of citrus trees. The phenological stages will depend on varieties and location of the plantation. Therefore, it is important to record the phenology of citrus trees for following management practices.

- Training and pruning
- Application of manure and fertilisers
- Application of irrigation
- Monitoring of pests and diseases and their management
- Harvesting

"The management schedules explained on a monthly period basis are based on the general phenological stages observed in overall citrus growing areas in Bhutan. Growing citrus beyond current growing zones will need new records to adjust the management plans accordingly. There is change in phenological stages due to the impact of climate over a period of time, and also the phenological stages of different varieties usually vary**".(refer key phonological stages figure)**

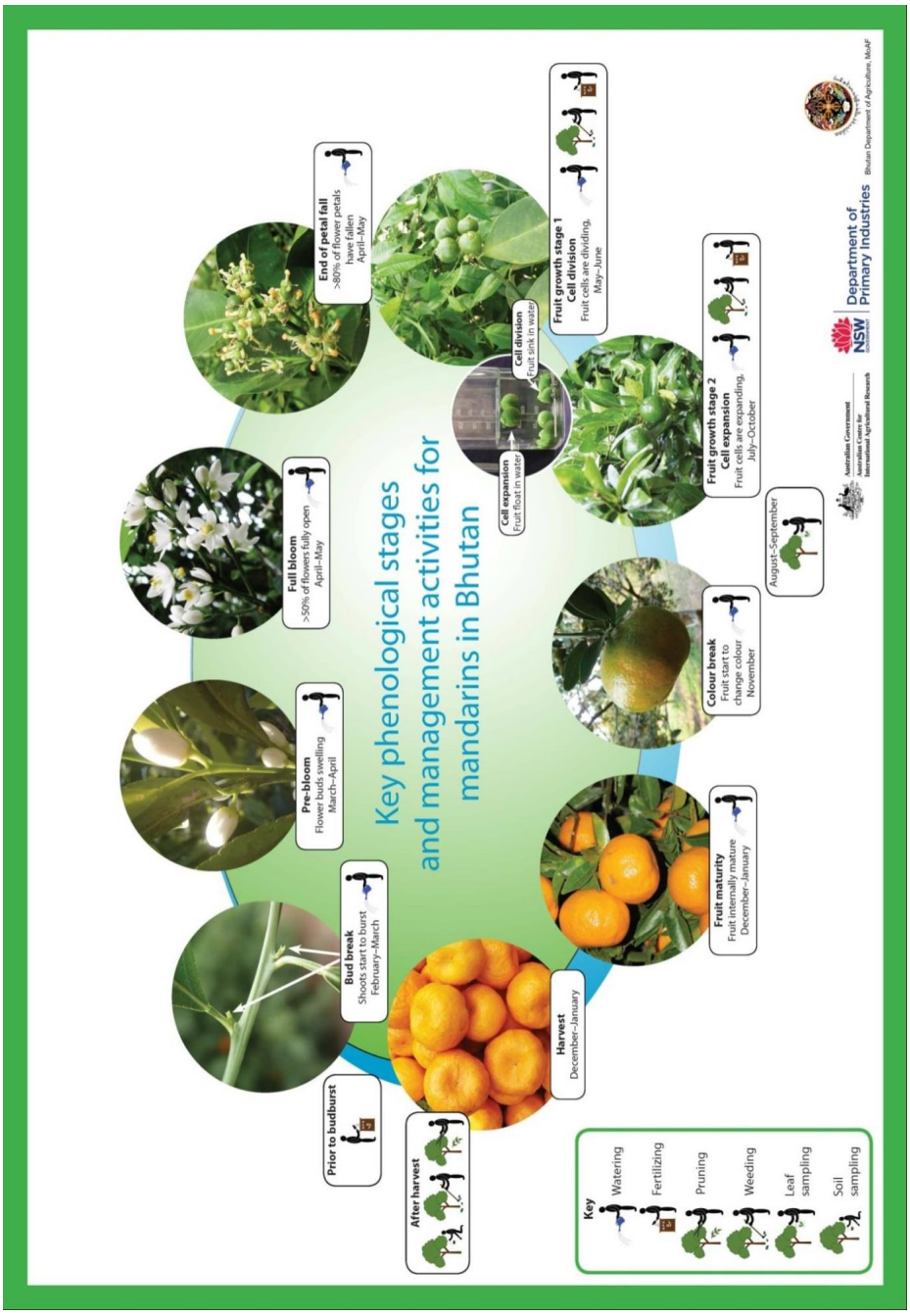


Figure 1: Key phenological stages and management activities for mandarin

Plant Protection

Psyllid

Asiatic citrus psyllids are vectors of Huanglongbing (also known as citrus greening diseases). Psyllids mainly feed and lay eggs on the young leaves and on the new flushes. Adult psyllid sits with their body raised at an angle of 30^{o} to the leaf surface.

- Check new growth for psyllids; if present apply Dimethoate (2 ml/L of water) during the peak leaf flush beginning in mid-March (this period can vary with altitude) followed by a second spray three weeks later.
- Further spays are only recommended if visual monitoring of young flush growth are detected with the presence of the Psyllids.

Powdery Mildew

- Monitor new growth and young fruit-lets for the presence of powdery mildew.
- Upon detection of powdery mildew, spray with Wettable Sulphur as shown in the table below.

Chemical	Recommended rate	Spray interval	Total sprays
Wettable Sulphur	0.3% (3.75 g/Lt water)	Weekly	6 sprays

Note: Avoid spraying sulphur at high temperatures (more than 35^{o}C) as it may cause phytotoxicity to plants.

Insect Pest

Shield Bug

- From April to June monitor for Shield bugs. The young nymphs gather early in the morning on the trunk of mandarin trees, at this stage of development they cannot fly.
- Swatting with a piece of wood can easily kill nymphs. Spot spraying using a contact insecticide can be used instead of swatting when young nymphs group together particularly early in the morning.
- Cover sprays are usually not effective as it interferes with natural predators like Red tree ants. Adult shield bugs can fly making spraying them difficult.

Citrus trunk borer

- Signs of borer include tiny wet or swollen spots on the lower trunk of the tree. A small knife can be used to scrape away the bark and kill the larvae.
- Poking established borer holes with wire to kill the larvae and then filling the holes with cotton soaked in petrol and plugging the holes with mud or a mix of mud and cow dung can be effective.
- Monitor treated holes for fresh frass (excreta); if it occurs re-treating the hole is required.

Citrus fruit fly

Chinese citrus fruit fly lay their eggs in mandarin fruits between mid-June and late July (depending on region). It has been observed that female fruit fly starts laying eggs when fruits are between 10-15 mm in diameter (marble sized fruits).
Following control measures are suggested:

- Spray protein bait (prepare bait solution by adding 5gm protein Hydrolysate, 2ml Malathion and few drops of Sandovit in 1 litre of water).

Time of spray: Weekly spot spraying from mid-April to mid-May, followed by fortnightly spray until mid-August.

- Apply the mixture on every alternate tree, using two or three splashes on each tree.
- If observed heavily infested, apply 1-2 (two weeks interval) tree cover sprays to sufficiently reduce adult fly population with appropriate chemical.
  - Place fruit fly traps at very high density to help reduce fly population. A combination of male attracting pheromone traps and female biased protein traps could be appropriate to use.
  - Pick and destroy the dropped fruits at ten-day interval to prevent larvae from moving into the soil.

Orchard establishment cost estimation

	Operating costs					Material costs				
Operating costs	operation time (min)	per acre	in hrs	Man days	Costs	qty	per acre	Rate	Amount	
Management practices	Per tree	110 trees				material	110 tree	Nu	Nu	Remarks
Bush clearing	20	1200	20	2.5	750					One time cost
Pit digging	48	2880	48	6	1800					
Filling (FYM/Organic manures/leaf litter)	5	300	5	0.625	187.5	1 basket (15kg)	3 tons	800	2400	
Planting	5	300	5	0.625	187.5	Plants (Seedlings)	110	50	5500	
Soil management (basin preparation)	15	1650	27.500	3.438	1031.250					Recurrent cost
Canopy management	15	1650	27.500	3.438	1031.250					
FYM application	5	550	9.167	1.146	343.750	7.5 kgs	1.5 tons	800	1200	
Chemical sprays (pests and diseases)	7	770	12.833	1.604	481.250	2	2	60	120	
Fertilizers application	2	220	3.667	0.458	137.500	1.5	165	16.8	2772	
Weeding	15	1650	27.500	3.438	1031.250		B=			
Irrigation	12	1320	22.000	2.750	825.000				11992	
Mulching	4	440	7.333	0.917	275.000					
				A=	**8081.250**					
Total costs of production (A+B)					**20073.250**					
Cost of production per tree {(A+B)/110}					182.4841					

Note: costs based on current market price (2015)-cost of production may vary from place to place