MANUAL ON BREEDER, FOUNDATION AND CERTIFIED SEED PRODUCTION

FIELD AND HORTICULTURE CROPS

Department of Agriculture
Ministry of Agriculture and Forests
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Foreword

Agriculture is one of the most important sectors providing livelihood to more than 50 percent of the Bhutanese population and contributing about 17.8 percent to the country's overall Gross Domestic Product (GDP). The farm inputs are entry points in the overall development of the agriculture sector. The Department of Agriculture (DoA) considers seeds and planting materials as extremely important inputs in achieving an inclusive food and nutritional security. Recognizing the critical role that improved seeds and planting materials play, the Department focussed on seed system development right from the commencement of the first five-year plan in 1961, the very year DoA was established.

One of our foremost efforts has been on institutional restructuring starting from the initiation of the model farms in the 1960s to the current National Seed Centre. The main emphasis of the institutional realignment is to establish a robust seed system where in all the demands for improved varieties of agriculture crops are met. Besides the government supported formal seed system, DoA also liaise closely with private nursery entrepreneurs in an effort to complement the growing demand of improved seeds and planting materials. We need to continue developing the seed industry to match to the technological advancement and developments in the agriculture sector.

Towards this, it gives me immense pleasure to publish this manual which was an outcome of a past meeting that focussed on seed related issues deliberated on the seed production and supply system between the Agriculture Research and Development Centre's (ARDC) and the National Seed Centre (NSC). Let me congratulate and commend the colleagues of the Department for successfully publishing the manual on breeder and foundation seeds production system for field crops and horticulture crops. I am confident that the manual will assist in establishing a robust seed production system and guide our technical staff in production quality seeds as per the prescribed protocols. These are the building blocks to be improved by the agriculture sector in rendering our services to transfer the benefits of strong seed sector to the farming community.

Once again, I would like to commend the work of the Specialists of the Department and the Commodity Coordinators led by Agriculture Research and Extension Division for coordinating and successfully publishing this manual.

Tashi Delek

Kinlay Tshering (Ms.)
Director

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Introduction

Agriculture plays a vital role in the Bhutanese economy providing livelihood to majority of the country's population. Bhutanese agriculture has made significant growth over the years transitioning from subsistence farming to semi commercial and commercial farming. This accelerated growth and development in the agriculture can be attributed to research and development support by the Royal Government of Bhutan. The government focussed on the seed system development right from the start of the 1st Five Year Plan in 1961 recognizing the critical role that improved seeds and plants play in increasing agriculture productivity. The agriculture input supply system over the years has undergone several institutional restructuring and is now better placed with improved facilities and more support from the growing private sector. The Community Based Seed Production (CBSP) also supplements the formal seed sector to meet the needs of the farmer and is a sustainable seed production model. CBSP can mainly benefit small holder farmers who do not have access to quality seeds.

Good quality seed is the most basic input essential for improvement of agriculture crops. In order to ensure seed self-sufficiency, the production and supply of the improved open pollinated seed varieties and planting materials is continued through the formal seed system. The National Seed Centre, Regional Seed Centres, agricultural farms and Agriculture Research and Development Centres are key agencies involved in seeds research and development. The Department of Agriculture continues to streamline the seeds services considering the agriculture transformation over the years.

The breeder and foundation seed production manual was developed primarily to improving the existing seed production system. The guideline clearly outlines the breeder and foundation seed production system in the Agriculture Research and Development Centres(s) and the National Seed Centre. This guideline can be used by seed certification officer as a monitoring guide. The guideline also establishes the seed classes of cereals, vegetables, fruits and nuts and plantation crop that will be commonly used under Bhutanese context. This manual highlights the seed production schemes that will guide the formal seed sector. The following are the seed classes:

1. **Classes of seed for orthodox seeds (Three generation model)**
    a. **Breeder seed**

        It is the initial handful of seeds obtained from the selection of individual plants or through breeding of two parents of the variety which is available with the original breeders or the variety developing agencies (Government Institutes or Private Institutes). Breeder seed should be produced and maintained by the original breeder or variety releasing agency whoever is involved in developing the varieties. The genetic purity of the breeder seed should be 100% as the varietal purity of subsequently multiplied foundation, and certified seed largely depend upon the quality of the breeder's seed.

b. Foundation seed

It is the progeny of breeder seed and National Seed Centre shall be responsible for production and maintenance of foundation seeds. It should be produced under the close supervision of original breeder or qualified plant breeders or technical officers. The genetic purity of the foundation seed should be maintained at 99.5% level.

c. Certified Seed

It is the progeny of foundation seed and its production is supervised and approved by National Seed Centre and Seed Certifying Agency. It can be produced by National Seed Centre, Private seed companies and community seed producers under the close supervision of the National Seed Centre and Seed Certifying Agency. This is the commercial seed which is available for the growers and the genetic purity should be 99%.

2. Classification in Fruits and nuts

In fruit and nuts, different system of seedling production categories is followed. In our case the following classification is adopted in order to be consistent with cereals and other horticultural crops in the country. The seedlings category includes foundation stock, mother stock and multiplication stock.

a. Foundation stock

Plants that is genetically pure and maintained under strict conditions at all times to ensure free incidence of insect, pests and diseases. These plants which are limited in numbers are maintained for the purpose of producing high quality scion or bud sticks following specified management techniques. These stocks are maintained by national repository centre or research centres with proper record of their pedigree.

b. Mother stock

Plants derived from foundation stock which are true to type and free of pests and diseases. Good numbers of plants are maintained by agencies mainly National Seed Centre for further propagation and distribution.

c. Multiplication stock

Plants derived from mother stock, true to type and certified for sale. These are produced by nurseries under National Seed Centre or registered private nursery growers

I. FIELD CROPS SEED PRODUCTION

A. Rice seed production

1.0 Background

Rice belongs to the genus *Oryza* of the Poaceae or grass family. Cultivated rice belongs to two species, *O. sativa* and *O. glaberrima*. Rice cultivated in Bhutan or in Asia is *O. sativa*. Within *O. sativa,* three main eco-types or geographical races, namely, Indica, Japonica and Javanica are found. In Bhutan, Japonica varieties (bold grain) are predominant in the high-altitude regions, while Indica types (slender grain) are found in the lower foothills. Intermediate types (combination of Japonica and Indica) are found in the mid altitude regions. Rice plant usually takes 3 - 6 months from germination to maturity. It takes about 35 days for reproductive phase and about 30 days for ripening phase. The difference in growth duration is due to time taken during vegetative stage. The three growth phases of the rice plant are: Vegetative phase (germination to panicle initiation), Reproductive phase (panicle initiation to flowering) and Ripening phase (flowering to mature grain). Rice is basically a self-pollinated crop but cross-pollination does occur to the extent of 0 – 4 %. Hence, seed producers have to be mindful of this fact.

Since 1988, a total of 26 rice varieties have been released by different research centres (Table 1). These varieties are recommended for different agro-climatic and altitudinal zones. Of the total, 3 varieties have been denotified by VRC. These denotified varieties are Milyang 54, BW 293 and Barket. No seed production is required for these varieties.

Table 1: Released rice varieties in Bhutan

Variety	Year released	Releasing centre	Yield (t/acre)	Recommended altitude (m)
IR 64	1988	ARDC Bajo	2.0-3.2	600-1500
IR 20913	1989	ARDC Bajo	1.6-2.4	600-1500
No 11	1989	ARDC Bajo	1.6-2.4	Above 1500
BR 153	1989	ARDC Bhur	1.2-1.6	Up to 600
Khangma Maap	1999	ARDC Wengkhar	1.6-2.4	Above 1500
Bajo Maap 1	1999	ARDC Bajo	2.0-3.2	600-1500
Bajo Maap 2	1999	ARDC Bajo	2.0-3.0	600-1500
Bajo Kaap 1	1999	ARDC Bajo	2.0-3.4	600-1500
Bajo Kaap 2	1999	ARDC Bajo	2.0-3.4	600-1500
Yusi Ray Maap 1	2002	RDC OA Yusipang	2.5-3.5	Above 1800
Yusi Ray Kaap 1	2002	RDC OA Yusipang	2.5-3.5	Above 1800
Wengkhar Rey Kaap 2	2002	ARDC Wengkhar	2.0-3.0	600-1500
Wengkhar Rey Kaap-6	2006	ARDC Wengkhar	2.0-3.0	600-1500
Jakar Rey Naab	2006	RC Jakar	1.5-2.0	>2000 m
Yusi Raykaap 2	2010	RDC OA Yusipang	2.0-3.0	>1800 m

Yusi Raymaap 2	2010	RDC OA Yusipang	2.0-3.0	>1800 m
Wengkhar Raykaap 10	2010	ARDC Wengkhar	1.0-2.0	<700 m
Bhur Raykaap-1	2010	ARDC Bhur	2.0-3.0	<700 m
Bhur Raykaap 2	2010	ARDC Bhur	1.0-2.0	<700 m
Bhur Kambja 1	2010	ARDC Bhur	1.0-1.5	<700 m
Bhur Kambja 2	2010	ARDC Bhur	1.0-1.5	<700 m
YusireyKaap 3	2018	ARDC Yusipang	2.2-3.0	>1800
Yusirey Kathra-Mathra	2018	ARDC Yusipang	2.0-3.0	>1800

2.0 National seed production scheme

The three seed production stages are Breeder seed, Foundation seed and Certified seed. While the ARDCs releasing new varieties are responsible for maintaining and supply of breeder seeds, NSC has the responsibility of producing foundation and certified seeds. Even though rice is a self-pollinated crop, there is cross-pollination to the extent of 4 %, hence the crop should be raised in isolation and seeds set by open-pollination. To maintain the varietal purity an isolation distance of 3 m should be maintained in all stages of seed production. If isolation by space is not possible, use time isolation of 21 days. Barrier isolation with polythene sheets of 2 m height or barrier crops such as sesbania or sugarcane covering a distance of 3 m can also be used.

Variety-wise breeder seed production responsibility is assigned amongst the ARDCs (Table 2)

Table 2: Seed production schemes in rice

Altitude zone	Varieties	Responsibility
High (>1800 m)	Khangma Maap, No 11, Yusi Ray Maap 1, Yusi Ray Kaap 1, Jakar Rey Naab, Yusi Raykaap 2, Yusi Raymaap 2, YusireyKaap 3, Yusirey Kathra-Mathra	ARDC Yusipang
Mid (800-1800m) (West)	IR 64, IR20913, Bajo Maap 1, Bajo Maap 2, Bajo Kaap 1, Bajo Kaap 2,	ARDC Bajo
Mid (800-1800m) (East)	Wengkhar Rey Kaap 2, Wengkhar Rey Kaap 6, Wengkhar Raykaap 10	ARDC Wengkhar
Low (<800 m)	BR 153, Bhur Raykaap-1, Bhur Raykaap-2, Bhur Kambja 1, Bhur Kambja 2	ARDC Samtenling

3.0 Specific methods for breeder seed production

- Sampling of the variety to obtain breeder seed from good panicles: select about 200 panicles that are true-to-type and disease-free
- Table examination of samples: About 200 panicles of each sample should be threshed separately and the seed should be examined on the table
- Discard any sample appearing off-type, diseased or otherwise unacceptable

- Sow the seeds of 200 samples in nursery, which is clean and fertile
- Transplant single seedling at a spacing of 30 x 30 cm
- Inspection of two-row plots and removal of off types: Throughout the season of growth, from the seedling stage until maturity, the plot should be examined critically and any off-types removed immediately
- Harvesting and threshing: Each plot should be harvested individually with a sickle and tied in a bundle
- The total bundles should be labelled and stored properly until the next planting season
- Later the seed should be cleaned by hand, and seeds must be examined for uniformity
- Uniform seeds are then bulked and labelled as Breeder Seed

4.0 Specific methods for foundation seed production

- Under the supervision of a breeder, the seed stock is handled to maintain specific identity and genetic purity (100%), which may be distributed and produced under careful supervision of an agricultural experiment station, or a certified Seed Centre.
- The technical procedure for production of foundation seed is similar to that of breeder seeds
- Use sufficient amount of breeder seed to raise seedlings in clean nurseries
- Transplant single seedling at a spacing of 20 x 20 cm
- Apply recommended amount of fertilizers and weed management methods
- Carry out timely roguing/removal of off-types and diseased plants
- Harvest, thresh, clean and store seeds properly.

5.0 Specific methods for certified seed production

The method of seed production for certified seeds is similar to foundation seeds. There is a slight difference in the field and seed standards between the foundation and certified seeds as shown in table (3 & 4).

Table 3: Field standards for foundation and certified seeds

Contaminants	**Isolation distance**	
	Foundation	**Certified**
Fields of other varieties	3 m	3 m
Fields of same variety not conforming to purity	3 m	3 m
Off-types	0.05%	0.20%
Objectionable weeds*	0.01%	0.02%
Plants infected by seed borne diseases (Max. % of infected plants)	5	10

* objectionable weeds include wild rice and *Echinocloa* species

Table 4: Seed standards for foundation and certified seeds

Parameters	Foundation	Certified
Germination (minimum)	85%	80%
Pure seed (minimum)	98%	97%
Inert matter (maximum)	2%	3%
Other crop seeds (max)	10 per kg	20 per kg
Other variety seeds (max)	10/kg	20/kg
Weed seeds (max)	10/kg	20/kg
Objectionable weed seeds* (max)	2/kg	5/kg
Seed moisture	12%	13%

6.0 Agronomic principles of seed production

6.1 Field selection

- The land selected should not be cultivated with the same crop in the previous season
- This standard requirement is applicable for both nursery and main field
- Land should be free of volunteer plants
- Land should be fertile with good irrigation and drainage facilities
- Homogeneous plot with good exposition to sun for synchronous flowering and seed maturation

6.2 Seed selection and sowing

- Seeds should be healthy with good germination percentage
- Quality seeds can be separated from unviable seeds by soaking in water
- The unviable and damaged seeds that float on the water surface should be removed and the good quality seeds that sink should be used for cultivation
- If there is excess of chaffy seeds in the selected seed lot, take some water in a container (bucket) and drop an egg in it and keep adding salt till the egg reaches surface
- Then add seeds to the water and remove the chaffy unviable seeds that float on the surface of the water
- Then wash the selected seeds in water for 2-3 times to remove the salt completely

6.3 Land preparation: Nursery bed and field

A proper land preparation is necessary to minimize competition with weeds in nursery bed as well as in transplanted fields. Depending upon the season, location and type of variety, the seed beds and fields should be prepared before the onset of rains. The nursery bed should be

- smooth as fine as the seeds
- well leveled with good drainage and should not be waterlogged
- raised above the ground and free from weeds and diseases

- Dry or wet depending on the traditional practice of allocation or the type of variety

Observe the following in transplanting:

- remove the roots, debris, stumps, and field wastes
- plough and harrow well and make a good tilth
- construct the bunds in sloppy land to hold the rainwater and good drainage
- level the field for uniform water depth for a good seedling establishment and translocation of nutrients

6.4 Isolation requirement

Rice is a self-pollinated crop which is ensured by the mechanism of cleistogamy within the same flower but cross pollination up to 4% can occur. In certification system, the seed fields should have following isolation distance for pure seed production reducing the contaminations of the foreign pollens of other variety, admixtures, other cereal crop seeds, and seed-borne diseases (blast).

- 3 meters of stripe isolation distance be maintained surrounding the seed plot by planting non-cereal crop or left un-cropped
- 5 meters of isolation distance be maintained between the seed plots of same variety if the varietal purity of one of the plots is doubtful

6.5 Seed rate

The recommended seed rate is 24 kg per acre. The seed rate for a seed crop is determined by the seed size, seed purity and seed germination capability. It could be calculated based on:

- Seed germination
- Recommended seed rate (100% pure seed with 100% germination)
- Area to be planted
- Seed amount required for the area
- Seedling transplantation spacing

6.6 Seedling production

Two types of nurseries can be used: wet-bed nursery and semi dry-bed nursery depending upon the location and situation.

6.6.1 *Wet-bed nursery*

The raising of rice seedlings in wet-bed method is carried out on raised beds. The beds should be approximately one meter (1m) wide with an arrow strip around it. The relatively narrow width ensures that any area within the bed can easily be reached from either sides, spaced approximately 40 cm between the beds for use later as irrigation channels and raised 10cm above the original surface of the plot. The surface of the bed is prepared smooth using a board or any flattened hard object.

Seeds are soaked overnight and pre-germinated seeds are broadcasted on the beds in a way to achieve an even distribution preventing dense spacing. After sowing, seeds are covered with a thin layer of soil to protect against heavy rain or birds. The sown seeds beds could also be covered with banana leaves, grass, or paddy straw and moistened from the top or irrigated through the channel to be kept moist all the time.

The seedlings in wet seedbed grow very fast and become ready for transplanting from14 days onwards. However, it depends on the variety and the nursery bed conditions. Younger seedlings are always preferable, as they establish themselves more quickly. The "fourth leaf" stage is generally regarded as optimal age of seedling for transplanting.

6.6.2 *Semi dry-bed nursery*

It is same as the wet bed nursery but the bed is dry. Dry seeds are broadcasted on the bed and covered completely with a thin layer of soil or mulched with leaves. The beds should be watered thoroughly immediately after planting and twice every day thereafter. The bed can be watered along the channels or splashed onto the beds otherwise. Seedlings growing, on dry bed surface are totally dependent on rain or irrigation/ hand splashing water from top. Dry bed seedlings will not grow as fast as wet bed seedlings. Seedlings from the dry bed become ready for transplanting from 21 days onwards. These beds should be saturated with water before uprooting the seedlings, making soil moist and loose.

6.7 Method of planting

For seed production purpose, transplanting is recommended. The main advantages of transplanting are a good and uniform plant stand, easier crop and water management, and good control of weeds and other pests. Increased labour input for transplanting is a major disadvantage. Transplanting can be done manually, and if enough labour is available it is always advisable to transplant in straight rows or lines. Otherwise, random transplanting is fine for certified seed production, keeping in mind the following points:

- Random method of transplanting can be adopted if the weed pressure is expected to be low and if herbicide such as Butachlor is intended to be used for weed control.
- Avoid wide spacing in random transplanting. A plant density of 25-35 hills per squared 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.
- In line planting, use ropes, guides or markers to attain straight rows. Plant seedlings on spots indicated by ropes or markers.
- 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.

- There is no single spacing recommended for all varieties – it will depend on the variety, soil fertility and planting season.

The time of rice transplanting basically depends on the altitude of a locality. Use the following guide for different rice growing zones.

- High altitudes (above 1600 m): May - early June
- Mid altitudes (700-1600 m): June- early July
- Low altitude (below 700 m): Late June - end July

6.8 Irrigation

There are generally two types of irrigation and water management practices commonly followed in rice seed production, depending on water availability:

- *Continuous flooding* with standing water: It is practised where there is abundant and assured irrigation water, maintaining standing water in the field at depths of 3 - 4 cm.
- *Intermittent irrigation or AWD* (alternate wetting and drying): 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. Intermittent irrigation helps to reduce shochum pressure.
- 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.
- 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.

6.9 Weed management

Weeds compete with rice for sunlight, nutrients and water, cause economic loss through increased cost of production and reduction in the yield and quality of rice. Direct seeded (especially dry direct seeding) and upland rice are often exposed to greater pressure of weeds than the traditional transplanted rice. Therefore, timely control of weeds is critical for high yield and quality of rice. Hand weeding, mulching, crop rotation, and herbicides applications are used to control the weed infestation in rice.

- Start hand weeding at 2 weeks after sowing or even earlier, depending on the level of weed infestation,
- Second weeding at 4 – 5 weeks
- Third weeding at 7 – 8 weeks, depending on the duration of maturity of the rice crop and the level of weed infestation.
- Use mulching of direct sown rice fields and dry nursery beds with moist straws that will reduce the growth of weeds and hand-weed after emergence of seedlings.
- Apply recommended dose of pre-planting (application before crop is planted), pre-emergence (application after planting, but prior to emergence of weeds) or post emergence (application after emergence of weeds) herbicides at right time depending upon the infestation of weeds using correctly calibrated sprayer.

6.10 Field inspection and field standards

A seed crop needs to be inspected and certified by the field inspectors for genetic purity under the scientific seed production system. The seed crop needs regular inspections and examination of plant population from the emergence in nursery and in field after transplantation for plant growth, weed infestation, diseases, and insect pest attacks and off-types to be removed. Field inspection is carried out at least twice at following stages:

- At vegetative stage
- After panicle emergence and during flowering when seed has started to develop
- Later at maturity stage when panicles get complete dry and seeds have low moisture content
- The seed inspector checks the standing crop following the pathway for meeting the minimum field standards for off-types, other plants, weeds, and diseased plants.

6.11 Roguing

Weed plants, diseased plants, insect damaged plants, and off-types not meeting the standards should be rogued out and the seed field should be cleaned before undertaking the field inspection from certification agency. In general, roguing could be carried at any stage of the plant. But in certification, 3 - 4 roguing are normally recommended to be done in seed crop of rice to avoid mixing with other crop and contaminants. First roguing at heading but before flowering stage to rogue out the obvious off-types at this stage, second roguing after completion of flowering and third roguing at maturity but before harvesting.

In roguing, obvious off-types plants like different in panicle colour and shape, plants susceptible to diseases (blast), tall plants, plants with false smut balls, early heading plants, and volunteer plants from previous crop should be removed. In roguing the plants infected with blast and false smut should be collected properly and buried or burned far away from the seed plot.

6.12 Harvesting and threshing

Timeliness and proper technology and practices of harvesting are important in rice crop for yield and quality of the seed. It is often seen that irrigated rice tend to ripen irregularly. Therefore, the seed crop should be allowed to mature completely on stand and soon after the harvest maturity, it has to be harvested to avoid the losses due to shattering, sprouting on standing crops because of the rainy and stormy weather on delayed harvest. As the harvest time approaches, following actions should be taken to harvest a good seed crop of rice:

Inspect the plants daily most particularly the panicles on mature tillers and note the exact duration of maturity that plants reached from days to heading.

- 85 % of panicles and grains have changed colour from green to straw
- Drain the water off and leave the standing crop to complete ripening leading to drying of the grains at hard dough stage
- Normally, 21 - 24 % of seed moisture is suitable.

Harvest the crop by cutting the bunch of plant in the field for few days to further dry the panicles. Rice stalks in bundle are threshed out using thresher), or manually beating on stone and farmer's fields. Care is taken in handling the seed during mechanical damages and admixtures.

6.13 Drying, processing and cleaning

Delayed drying may result in non-enzymatic browning (stack-burning), microbial growth, and mycotoxin production. Harvested grain are sun-dried over tarpaulin for 2 - 3 days and constantly turned for uniform drying and seeds are brought to 13 % moisture content for safe storage.

In humid environment, the modern novel technology of seed drying using zeolite drying beads could be used for efficient drying and dried seeds should be stored in sealed pack at 8 - 9 % MC.

Check whether it is dried enough or remains wet following the local method:

- Take a glass jar with screw lid,
- Put a handful of dried grains and add a spoonful of salt, and seal the jar and left for 24 hours
- Examine the salt whether it is in clump or remain dispersed
- If salt is in clump, the seeds are wet and needs drying or if remains dispersed, seeds are well dried
- Dry seeds are cleaned by winnowing during threshing in open air
- Further processed using air screen cleaner, length separator, gravity separator to remove the empty hulls, dust particles, pieces of stalks/awns, broken seeds, weevil infested seeds, weed seeds, and other crop seeds.
- Seeds are graded for uniform size and dried once again if necessary.
- The recommended moisture content for storage of rice seed in ambient condition is 13 %.

6.14 Bagging, tagging and storage

- After cleaning and drying, seeds are bagged in recommended seed containers and size with proper labelling.
- The size of bag for rice seed is normally 30-35 kg and proper kind of seed containers recommended by certification are 200 gauze lined jute bag, Super Grain-Pro bags, PICs bags and improved metal bins.
- Seed is treated with Bavistin to protect the seeds in storage.
- For certification and tagging, seeds are required to be tested in seed testing laboratory for minimum standards as follows and use the respective tags.

7.0 Seed multiplication ratio

Seed multiplication ratio means the number of seeds to be produced from a single seed when it is sown and harvested. In rice the seed multiplication ratio is 1:70. Depending on the quantity of seeds to be produced for different categories, seed planning can be done using this ratio.

B. Wheat seed production

1.0 Background

Wheat belongs to the grass family (Poaceae) and is widely cultivated for its seed, a cereal grain which is a worldwide staple food. The many species of wheat together make up the genus *Triticum*; the most widely grown is common wheat (*T. aestivum*). The wheat plant has long, slender leaves, stems are hollow in most types of wheat plants and heads have many flowers ranging from 20 to 100. The flowers are grouped together in spikelets. Each spikelet has two to six flowers. In most spikelets, two or three of the flowers become fertilized, thus producing grains.

Since 1988, a total of 6 wheat varieties have been released by different research centres (Table 5). These varieties are recommended for different agro-climatic and altitudinal zones. Of the total number of varieties, Sonalika has been denotified by VRC. The denotified variety is conserved in the gene bank and no seed production is required.

Table 5: Wheat varieties released in Bhutan

Variety	Year release	Releasing Agency	Recommended agro-ecology	
Bajoka 1	1991	RC Bajo	Up to 1800	Spring crop
Bajoka 2	1994	RC Bajo	Up to 1800	Spring crop
Gumasokha ka	2014	RC Bajo	Up to 1800	Spring crop
Bajosokha ka	2014	RC Bajo	Up to 1800	Spring crop
Bumthang ka drupchu	2015	RC Bajo	Above 1800	Winter crop

2.0 National seed production scheme

The three seed production stages are Breeder seed, Foundation seed and Certified seed. While the ARDCs releasing new varieties are responsible for maintaining and supply of breeder seeds, NSC has the responsibility of producing foundation and certified seeds. Even though wheat is a self-pollinated crop, there is cross-pollination to the extent of 0–4%. The crop should be raised in isolation and seeds are allowed to set by open-pollination. To maintain the varietal purity an isolation distance of 3m is maintained in both certified and foundation stages of seed production.

Variety-wise breeder seed production responsibility is distributed among the ARDCs in given in the table 6.

Table 6: Breeder seed production responsibility

Altitude zone	Varieties	Responsibility
High (>1800 m)	Bumthang Ka Drupchu	ARDC Yusipang
Mid and Low (<1800m	Bajoka 1, Bajoka 2, Gumasokha ka, Bajosokha ka	ARDC Bajo

3.0 Specific methods for breeder seed production

- Sampling of the variety to obtain breeder seed from good ear: select about 200 ears that are true-to-type and disease-free
- Table examination of samples: each ear should be threshed separately and the seed should be examined on the table
- Discard any sample appearing off-type, diseased or otherwise unacceptable
- Sow the seeds of 200 ears in an ear-row nursery at a row spacing of 25-30 cm
- Inspection and removal of off-type: throughout the season of growth, from the seedling stage until maturity, the plot should be examined critically and any off-types removed immediately
- Harvesting and threshing: each plant should be harvested individually with a sickle and tied in a bundle
- The total bundles should be labelled and stored properly until the next planting season
- Later the seed should be cleaned by hand, and seeds must be examined for uniformity
- Uniform seeds are then bulked and labelled as breeder seed

4.0 Specific methods for foundation seed production

- Under the supervision of a breeder, the seed stock is handled to maintain specific identity and genetic purity (100%) which may be distributed and produced at the National Seed Centre currently.
- The technical procedure for production of foundation seed is similar to that of breeder seeds
- Use sufficient amount of breeder seed to produce foundation seeds
- Sow the seeds in well prepared fields at a row spacing of 25 - 30 cm
- Apply recommended amount of fertilizers and weed management methods
- Carry out timely roguing/removal of off-types and diseased plants
- Harvest, thresh, clean and store seeds properly.

5.0 Specific methods for certified seed production

The method of seed production for certified seeds is similar to foundation seeds. There is a slight difference in the field and seed standards between the foundation and certified seeds as shown in the table 7 and 8.

Table 7: Field standards of foundation and certified seeds

Contaminants	Isolation distance	
	Foundation	Certified
Fields of other varieties	3 m	3 m
Fields of same variety not conforming to purity	3 m	3 m
Fields of wheat, triticale or rye with loose smut infection	150 m	150 m
Off-types	0.05%	0.20%
Inseparable other crops*	0.01%	0.05%
Plants affected by seed-borne diseases	0.10%	0.50%

*include barley, oat, triticale

Table 8: Seed standard of foundation and certified seeds of wheat

Parameters	Foundation	Certified
Germination (minimum)	90%	85%
Pure seed (minimum)	98%	97%
Inert matter (maximum)	2%	3%
Other crop seeds (max)	10 per kg	20 per kg
Other variety seeds (max)	10/kg	20/kg
Weed seeds (max)	10/kg	20/kg
Objectionable weed seeds* (max)	2/kg	5/kg
Seed moisture	12%	12%

6.0 Agronomic principles of seed production

6.1 Field selection

The land selected for wheat seed production should be:

- Free from volunteer plants
- Free from contaminants: weeds, noxious weeds and soil borne diseases transmitted through seeds
- All soil types with well drainage and productive with neither too acidic and nor too alkaline pH
- Long interval of crop rotation
- The field where no wheat crop was grown in previous year
- A two years crop rotation for loose smut contamination reduction

6.2 Isolation requirement

Wheat is a self-pollinated crop and about one to four percent of cross-pollination occurs. Wheat

seed fields should be isolated accordingly to reduce contaminations from other variety seeds, other cereal crop seeds, and diseases (loose smut).

- 3m of stripe isolation distance be maintained surrounding the seed plot by planting non-cereal crop or left uncropped
- 5m of isolation distance be maintained between the seed plots of same variety if the varietal purity of one of the plots is doubtful
- 150 m of isolation distance be maintained between two wheat seed plots to avoid the contamination of loose smut if the variety is susceptible

6.3 Seed rate

The recommended seed rate of wheat is 40 kg per acre across the growing environment. Too dense or too sparse plant population is not desirable for seed production. Seed rate for a seed crop is determined by the seed size, seed purity and seed germination capability. It could be calculated using:

- Seed germination capability
- Recommended seed rate (supposed of 100% pure seed and 100% germination)
- Area to be planted
- Seed amount required for the area

6.4 Seed treatment

The seed should be treated with systematic fungicide Bavistin for controlling loose smut and other contamination from soil borne diseases before sowing.

6.5 Method of seed sowing

There are conservation technologies and cropping pattern developed in wheat. Zero tillage, surface seeding, wheat-maize cropping pattern, intercropping with soybean are some effective technologies. But for seed production, following operations should be performed:

- Seed crop should be sown in rows with seed drill or behind the plough furrows
- Depth of seeding should be 5 cm
- Seed drill should completely be cleaned and checked for other contaminations before using the other variety to avoid mixing
- Row distance should be 20-25cm to facilitate roguing off-types and diseased plants

6.6 Nutrient management

Use existing recommendation of chemical fertilizers. However, it could be managed according to the soil composition, soil moisture, nutrient contents of soil and agro-ecological zones. Besides the essential elements of NPK, there are other elements such as zinc, copper, iron, manganese boron could be applied based on the soil nutrient analysis for good seed yield.

6.7 Irrigation

In wheat, four to six irrigations at different growth stages are required for a seed crop. However, it depends on the soil type. For example, for light soils, extra irrigation is required. Wheat is very sensitive to moisture stress at crown root initiation and heading stages.

- First irrigation at crown root initiation stage about 30 – 35 days after sowing
- Other irrigations at late tillering, late jointing, heading/flowering, milk, and dough stages

6.8 Weed management

Timely and periodic weeding is essential to keep the field free from weeds for good seed production. First weeding should be done after 30 - 40 days after sowing. This helps in controlling the weeds and helps in minimizing the yield loss. In general, the weed control in wheat is done using herbicides.

6.9 Roguing

The inspector on inspection if find weed plants, diseased plants, off-types not meeting the standards suggests the directives to carry roguing and clean the seed crop. In general, 3 - 4 roguing are normally practiced in wheat to bring the seed crop to seed certification standards.

- First roguing at heading or flowering stage to rogue out the obvious off-types at this stage
- Second roguing after completion of flowering and start of development of the colour in ears
- Third roguing on complete maturity and development of ear colour

In roguing, obvious off-types plants like different in colour, plants susceptible to diseases, tall plants, plants with smut galls, early heading plants, and ear-heads with variations in plot should be removed. In roguing, the smutted ear-heads should be collected in paper bag and buried or burned far away from the wheat plot.

6.10 Field inspection

A minimum of 2 field inspections should be done between flowering and harvesting stages. During inspection parameters such as isolation requirement, off-types, volunteer plants, diseased plants etc. are checked.

6.11 Harvesting

Harvest is done soon after the maturity of the seeds that turns from green to straw yellow. Ear-heads should be harvested when the seeds attain maximum physiological maturity. Following tips are suggested for right timing of harvest:

- When peduncle of ear-heads turns golden yellow
- Grains thresh out easily when the dried ear-heads are rubbed in between palms.
- The suitable moisture content at harvest should be 20 %

6.12 Threshing and processing

Harvested plants should be stacked on a clean floor of the threshing yard free from other varieties. Harvested plants with a moisture content of 15% should be threshed manually or with threshers. This level of moisture content is safe for threshing without any mechanical injury to the seeds. Threshed grains are winnowed and cleaned. Cleaned seeds are dried to attain a safe moisture content of 12–13% and graded using a suitable sieve to remove chaffy, under and oversized seeds.

6.13 Drying and storage

The cleaned and graded seeds are dried to attain 12-13% of moisture content. Normally the seeds can be stored for one year under ambient storage conditions without losing much of the germination potential.

6.14 Seed standards

The percentage of minimum physical purity of the certified and foundation seeds should be 98%, a minimum of 80% of germination capacity and 8-13% of moisture content. The presence of inert and husk less seeds should not exceed 2.0%.

7.0 Seed multiplication ratio

Seed multiplication ratio means the number of seeds to be produced from a single seed when it is sown and harvested. In wheat the seed multiplication ratio is 1:20. Depending on the quantity of seeds to be produced for different categories, seed planning can be done using this ratio.

C. Maize seed production

1.0 Background

Maize (*Zea mays*) is one of the most widely cultivated food crops in Bhutan. More than 69% of the rural households grow maize. Maize is grown from lesser than 300 to approximately 3000 meter above sea level (masl) under rainfall and irrigated conditions in cool and very hot climates with growing cycles ranging from 3 - 10 months.

Maize is a tall annual plant growing to a height of 2 - 3 m. It belongs to family poaceae (graminae). The maize plant possesses a simple stem of nodes and internodes. The leaves are broad and single leaf arranged in two vertical rows on the opposite sides of an axis. A pair of large leaves extend off each internode leaving a total of 8 - 21 leaves per plant. The leaves are linear or lanceolate (lance-like) with an obvious midrib (primary vein) and can grow from 30 to 100 cm in length. The male and female inflorescences are positioned separately on the plant. The male inflorescence is known as the 'tassel' while the female inflorescence is the 'ear'. The ear of the maize is a modified spike and there may be 1 - 3 per plant. The maize grains, or 'kernels', are encased in husks and total 30 - 1000 per ear. The kernels can be white, yellow, red, purple or black. Usually maize plants take 140 - 160 days to harvest after sowing with 50 - 55 days under vegetative stage and 55 - 160 under reproductive stage. Maize is a monoceious plant and thus it is cross pollinated.

There are six improved varieties as highlighted in table 9.

Table 9: Released varieties of maize in Bhutan

Variety	Year of Release	Yield Potential (t/ac)	Recommended AEZ	
			Altitude (masl)	Cropping suitability
Yangtsepa	1992	1.2-1.6	Upto 1800	Main Single
Khangma Ashom 1	1999	1.5-2.0	Upto 1800	Main Single
Khangma Ashom 2	1999	1.6-2.0	Upto 1800	Main Single
Chaskarpa	2012	1.6-1.9	1200-2100	Main Single/GLS Tolerant
Shaphangma Ashom (QPM)	2012	1.6-1.9	1200-2100	Main Single/GLS Tolerant
Bhur Ashom	2015	1.5-1.8	600-2100	Early Variety/Double cropping

(Source: National Maize Program, ARDC Wengkhar)

2.0 National seed production scheme

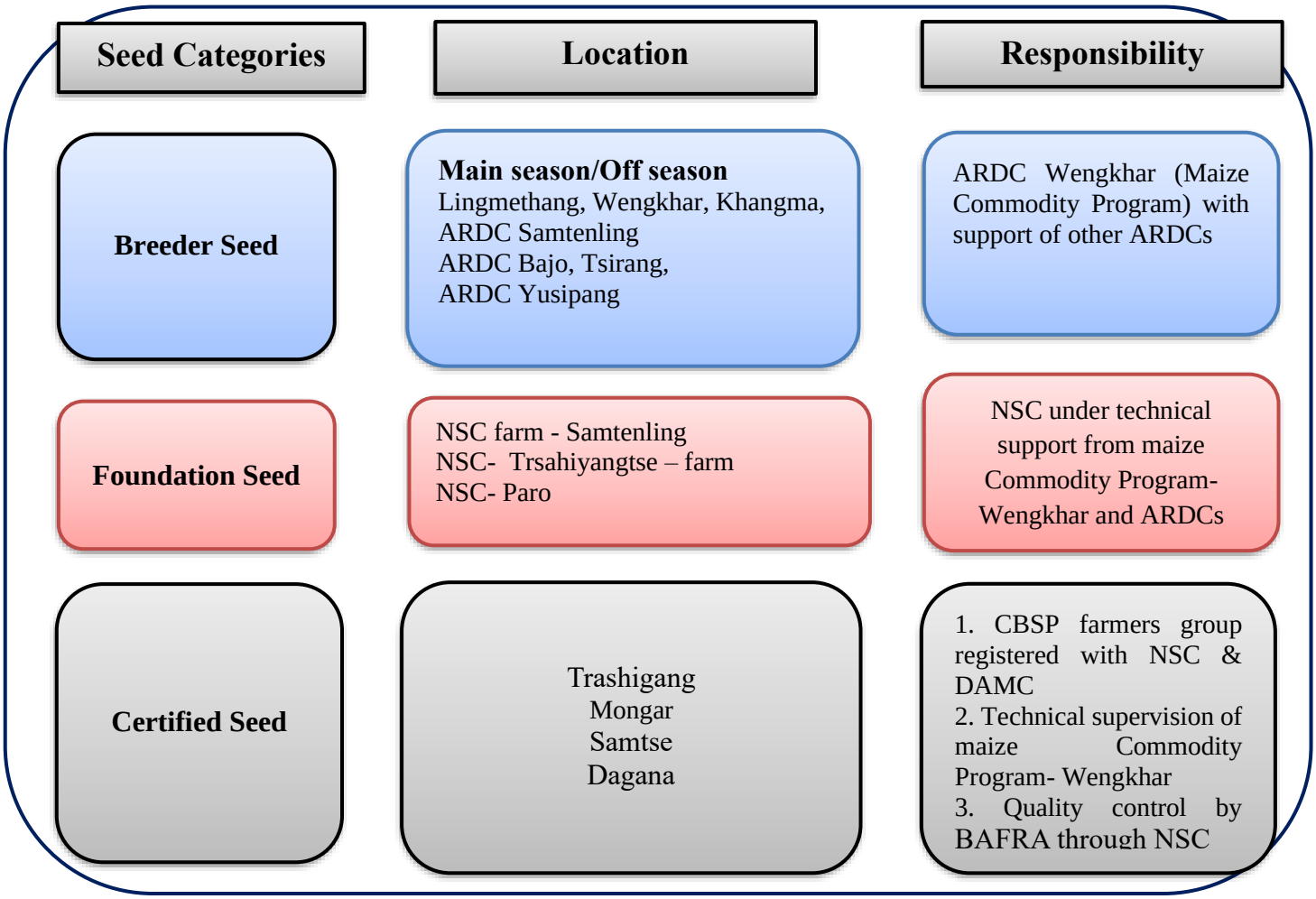

Figure 1: National seed production scheme of maize

3.0 Specific methods for breeder seed production

- ARDC Wengkhar, the coordinating centre for maize commodity program will produce the breeder seed.
- The quantity of breeder seed to be produced should be 30 kg for each variety.
- Plant bulk seed to obtain at least 5000 plants. Planting has to be done in rows with adequate isolation (either distance or time isolation has to be followed)
- At flowering time convert into half sib crossing block
- This can be done by designating male and female rows
- The ratio of female to male has to be kept at 2:1 and additional 2 male rows on each side (see figure 2)

Maize sowing pattern																	
Male	Male	Female	Female	Male	Female	Female	Male	Female	Female	Male	Female	Female	Male	Female	Female	Male	Male

Figure 2: Male to female ratio in half sib crossing block

- De-tassel all the designated female rows as early as the tassel appear
- Also from the designated male and female rows remove, diseased and any recognizable off type plants
- At harvest divide the field into several grids or consider about 16 plants per grid depending on grid size
- At harvest select 300 ears with acceptable characteristics of a variety from the female rows
- The selected ears are shelled and bulks are made. Balance bulk is supplied to NSC as basic seed for the production of Foundation seed. Balanced bulk is also kept for subsequent cycle for maintenance and basic seed production.
- Selected ears with acceptable traits can be also harvested from male rows and can be used as foundation seeds but not as the progenitors of breeder seeds.
- Isolation distance for breeders seed production is 300 m or at the least 25 days
- The seeds obtained should be dried to moisture content of 13 % or lower.

4.0 Specific methods for foundation seed production

- The foundation seed production will be carried out at National Seed Centre.
- The ARDC will supply the breeders seed to NSC in limited quantity
- Plant the seeds received from ARDC in isolated plot
- Rogue out up to 10 - 15% of the off-type plants before flowering
- Rough out all off-type and diseased plants
- The isolation distance for foundation seed is 200 m or time isolation of at least 25 days
- Shell and bulk to supply as Foundation seed for production of certified seed

5.0 Specific method for certified seed production

It is the last stage of the commercial production. The standards for certification vary from country to country. Depending on the certification standards, adequate steps have to be followed. For Bhutan, Registered Seed Growers (Community Based Seed Production groups) produce the certified seed under the supervision of NSC, ARDCs and is certified by BAFRA.

The general steps are:

- The foundation seed shall be the source of seed
- NSC should supply Foundation seed annually to the RSGs.
- Identify suitable area for seed production
- Maintain proper isolation either through distance or time
- Natural barriers like a strip of forest can help to compromise for isolation
- If possible, select a small isolated field/block for certified seed production (damage by wild animals could be a problem if far away field are selected)
- Ask farmers to plant foundation seeds supplied by NSC in a slightly lower than recommended density
- Exercise strict roguing and follow procedures that meet certification standards
- Carry out field selection considering traits that are acceptable or the original traits of a particular variety
- Harvest selected plants and bulk the seeds
- Carry out required seed treatments and pack it adequately

6.0 Agronomics principle of seed production

6.1 Ecological requirement

Maize is grown under diverse physical condition. It is one of the most widely cultivated crop and grown in both tropical and warm temperate zones. The important ecological requirement is as indicated in table 10.

Table 10: Maize growing environment

Agro-eco-zones	Altitude (masl)
Sub-tropical Maize production	<1200
Mid altitude Maize Production	1200-1800
Highland Maize Production	>1800

6.1.1 *Temperature*

Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19^{o}C. The response to temperature varies with the stage of the crop. Optimum temperature for germination is around 18^{o}C and at temperature below 13^{o}C germination is slowed down. Temperature range of 21 - 27^{o}C is suitable for better growth of maize plant. Maize is sensitive to frost at all growth stages and a frost free period of 120 - 140 days is required to prevent damage.

6.1.2 *Soil*

Maize can grow on number of soil types, however it does best in rich moist soil. The ideal soil for growing maize is well-drained, preferably sandy loam with high organic matter content. It prefers soil with pH within 5.8 - 6.8. Maize does not tolerate water logging thus a good drainage is necessary for quality seed production.

6.2 Water requirement

Maize is sensitive to both moisture stress and excessive moisture. For quality seed production, soil must have adequate moisture until 40 - 45 days from sowing. The moisture requirement varies with the crop growth stage, weather and soil condition. Soil moisture is critical during tasselling and kernel development stage and thus should be maintained through irrigation. Irrigation is necessary after the first weeding and during the tassel stage.

6.3 Field preparation and nutrient management

The field preparation should be done two weeks prior to seed sowing or planting. Any crop residues from previous year's crop should be removed from the field. Sufficient application of well decomposed farm yard manure (FYM) should be applied before the ploughing. In general, an application of 15 MT of well decomposed FYM is recommended for one hectare. An application of NPK at the rate of 60:30:30 kg/ha is also applied before sowing. The 50% of nitrogen is used as basal dose during the plantation.

6.4 Seed sowing and rate

The recommended sowing method for maize is through line sowing as it requires less seed and facilitates easy weed control. Fields need to have adequate moisture during the sowing for faster germination. For line sowing, 2 - 3 maize seeds should be sown in each spot at 3 - 5 cm depth. The seeds should be sown at a spacing of 20 - 25 cm (seed to seed) and 60 - 70 cm (row to row).
The seed rate depends upon the sowing method and the spacing of the plants. For normal crop the seed rate is 10 - 15 kg per acre. For seed production the seed rate is 10 – 15 % led to ensure good seed set and development. It will also allow better or full expression of the plant characters type which helps in identification of desirable plants and to eliminate off-types. Usually for line sowing 10 kg seed is recommended for one acre. However, in Bhutan where broadcasting method is popularly practiced the recommended seed rate is 15 kg per acre.

The following sowing time (table 11) is recommended for seed production in different agro-ecological zone.

Table 11: Sowing time for maize

Agro-ecological zones	Altitude (masl)	Sowing/Planting
Highland Maize Production Zone	>1800	March
Subtropical Mid-altitude Zone	1200-1800	March
Subtropical Low Altitude Zone	<1200	February

6.5 Intercultural practices

6.5.1 *Thinning*

Thinning in maize seed production refers to the practice of keeping only one healthy seedling and removing another seedling from each spot. This practice helps to control competition for nutrition, water and sunlight among the plants. Thinning should be done after 25 - 30 days of sowing or at 4 - 5 leaf stage. It should be done just after the first weeding at the same time.

6.5.2 *Weed Management*

Minimum of two weeding is necessary for seed production. First weeding should be done at 20-25 days after crop emergence while the second weeding is recommended at 40-45 days after the crop emergence.

6.5.3 *Pest and disease management*

Gray leaf spot (GLS) and Turcicum Leaf Blight (TLB) are the two major diseases in maize growing areas. The details of the diseases can be found in the extension materials on major diseases of maize published by NPPC.

6.6 Harvesting

Maturity of the maize depend on the variety. Complete drying of silks, leaves, stems and brownish colouration of the cobs indicate maturity. Maize should be harvested when the husk becomes dry or dark brownish colour. In maize, the physiological maturity is indicated by formation of black or brown layer on the bottom of the seed. Harvesting should be done during dry days.
Consideration for selection of plants and cobs during harvesting

- The plants should be selected from the centre of the field for seed purposes due to less chance of out-crossing.
- Always select medium sized plant that is neither short nor tall
- The stalk should be healthy and not infested with any pests and diseases.
- The cobs which are slightly bent (bend forming 45^{o} angle) in plant should be selected.
- Select cobs of equal size with thick husks.
- Remove rotten cobs, and the cobs which are not completely covered with husk.

- Always select the cobs with kernels of uniform size.
- Remove the top and bottom part of a cob for selecting uniform kernel.

6.7 Seed storage

The seeds should be stored properly in a cool and dry place following traditional methods -hanging in attics or in the ground floor. Seeds should be stored below 10^{o}C at 13 % MC and relative humidity between 45 – 55 % to maintain the seed quality. Seeds are stored in silos to prevent damages.

7.0 Seed multiplication ratio

Seed multiplication ratio is the amount of seed a crop can produce. This is based on the productivity of the crop and the volume of seed. In general, it is the number of seeds to be produced from a single seed when it is sown and harvested.

Table 12: Seed multiplication ratio of maize

Classes of seed	Seed rate (kg/ac)	Production (kg/ac)	Ratio	SMR
Breeder seed	10 kg	1700	170	1:170
Foundation Seed	10 kg	1700	170	1:170
Certified seed	15	1500	150	1:150
Average	**12.5**	**1600**	**128**	**1:128**

D. Rapeseed and Mustard seed production

1.0 Background

Oilseed is a generic term referred to a group of crops valued for oil content. It is one of the basic commodities for agriculture trade and is transacted as vegetable oils, natural food, nutritional products and premium snacks. Rapeseed & Mustard, Soybean (*Glycine max*), Groundnut (*Arachis hypogea*), Sunflower (*Helianthus annuus*) and Niger (*Guizotic abyssinica*) constitute oilseeds in Bhutan. However, rapeseed & mustard particularly *Brassica campestris* var toria (*Tori* or *Peka*) is predominantly grown and is the traditional oil crop in the country. It is the main oil crop from which oil is extracted in Bhutan. Soybean is also an important crop in eastern Bhutan where it is intercropped with maize. However, in absence of processing unit soybean is consumed as a grain and sometimes feed to livestock.

In addition, there are a number of perennial oil-bearing trees from where seeds can be harvested to extract oil. These include Pangtsi (*Symplocus paniculata*),Yika (*Maduca butyretica*), Karshing or Kadam (*Jatropa curcas*) and Shingshe (*Neolitsea* sp). These trees exist on field bunds as a part of agroforestry system and are minor oil crops of Bhutan.

Rapeseed-Mustard is a group of crops having different kinds of breeding behaviour. On one hand it includes self-compatible (self-pollinated) crops like yellow sarson (*Brassica rapa* var yellow sarson), gobhi sarson (*Brassica napus*) and Ethiopian mustard (*Brassica carinata*) while on the other hand self - incompatible (cross pollinated) crops including toria (*Brassica rapa* var toria), brown sarson (*Brassica rapa* var brown sarson) and taramira (*Eruca sativa*) are existing. In India, mustard (*B. juncea*) is the major crop of the group and has cross-pollination ranging from 5 - 15%.

Varieties of rapeseed and mustard

There are six improved varieties released in the country.

Table 13: Released varieties of rapeseed and mustard in Bhutan

Sl. No.	Name of the variety	Origin	Year of Release	Releasing agency	Yield potential (t ha^{-1})	Maturity days after sowing	Remarks
1	Type 9	India	1989	RDC Bajo	0.4	90-95	<2000 m
2	M 27	India	1989	RDC Bajo	0.4	85-90	<2000 m
3	Bajo Peka 1 (BSA)	Pakistan	1994	RDC Bajo	0.5	145-155	<2000 m
4	Bajo Peka 2 (PT 30)	India	1994	RDC Bajo	0.4	120-130	<2000 m

5	Yusi Peka 1	Nepal	2017	RDC Yusipang	1.0	90-95	Rainfed dryland
6	Yusi Peka 2	Bangladesh	2017	RDC Yusipang	1.0	90-95	Terraced wetland

2.0 National seed production scheme

Table 14: National seed production scheme of mustard

Sl.no.	Categories	Responsibility	Location
1	Breeder seeds	ARDCs	Wengkhar, Bajo, Yusipang, Samtenling
2	Foundation seeds	National Seed Centre	NSC farms
3	Certified seeds	Registered seed growers	Registered Seed Grower Villages

3.0 Specific methods for breeder seed production

An isolation distance of 400 m is recommended for production of breeder seed of self-incompatible (cross pollinated) crops, including *B. rapa var. toria*; *B. rapa* var brown sarson and *E. sativa* (taramira) and 200 m for self-compatible (self-pollinated) crops, including *B. juncea* (Indian mustard), *B. rapa* var yellow sarson and *B. carinata* (Karan rai). Approximately 500 true-to-the type plants are selected from the basic bulked or multiplication plot for breeder seed production of self-pollinated crops while 2500 or more plants are selected in cross pollinated crops to prevent the narrowing of genetic base of these crops. Five border rows of the same variety (true to type) should be planted around the plot.

Selected plants are harvested and threshed separately. The seed lot from each selected plant should be examined critically for seed characters such as shape, colour etc. Off-type seed lots (or plants) are discarded and only the true to type lots (plants) are maintained separately for raising nucleus seed plot.

Sowing for breeder seed plot is done from the selected individual nucleus plants in plant to progeny rows. Each progeny row is examined critically at different growth stages for diagnostic characteristics. If any progeny row shows any variation the entire progeny row should be uprooted before flowering.

In case off-types are found after flowering, the surrounding rows should also be uprooted to avoid contamination. Single plants (about 500 in self-pollinated and about 2500 in cross pollinated crops) are harvested and their seed is kept separately for raising the next cycle of nucleus progeny rows next year.

The removal of off type plants should be carried out at 3 stages. First, the off-type plants distinguishable on the basis of morphological characteristics should be removed before flowering. Second, the off-type plants, which are identified at flowering, should be removed before pod-formation. Third, the off-type plants should be removed on the basis of siliqua and seed characteristics and also on the basis of maturity duration. Disease infected plants should also be removed. The field should be kept free from all kinds of weeds particularly from *Argemone maxicana* (Satyanashi) which should be uprooted altogether, before it flowers.

4.0 Specific methods of foundation seed production

- The foundation seeds will be produced by the National Seed Centre.
- The releasing institute (ARDC) will supply the breeder seed to NSC.
- Plant the seeds received from ARDC in isolated plot
- The isolation distance maintained between the varieties is 50 m for self-compatible and 100 m for self-incompatible types for foundation seed production
- The isolation distance maintained between the varieties not conforming to the varietal purity requirements for certification is 200 m for self-compatible and 100 m for self-incompatible types

5.0 Specific methods of certified seed production

It is the last stage of the seed production. The standards for certification vary from country to country. Depending on the certification standards, adequate steps have to be followed. The Registered Seed Growers (Community Based Seed Production groups) produce the certified seed under the supervision of NSC, ARDCs and is certified by BAFRA.

- The foundation seed shall be the source of seed
- NSC should supply foundation seed annually to the RSGs.
- The isolation distance maintained between the varieties is 25 m for self-compatible and 50 m for self-incompatible types.
- The isolation distance maintained between the varieties not conforming to the varietal purity requirements for certification is 50 metres for both self-compatible and self-incompatible types.

Table 15: Seed standards of foundation and certified seeds

Factor	**Class of seed**	
	Foundation Seeds	**Certified seeds**
Pure seed (minimum)	97.0%	97.0%
Inert matter (maximum)	3.0 %	3.0 %
Other crop seeds (Maximum)	10/ Kg	20/ Kg
Other distinguishable varieties (maximum)	10/ Kg	20/ Kg
Total weed seeds (maximum)	10/ Kg	20/ Kg

Objectionable weed seeds (maximum)	5/ Kg	10/ Kg
Germination (minimum)	85.0%	85.0%
Moisture (maximum)	8.0%	8.0%
For vapour proof container (maximum)		
Mustard	5.0%	5.0%
Rapeseed	7.0%	7.0%

Table 16: Field standards of foundation and certified seeds of mustard

Parameters	Foundation seed	Certified seed
Isolation distance	200m	100m
Off types	0.10%	0.50%
Objectionable weed seed	0.05%	0.10%

6.0 Agronomic principles of seed production

6.1 Land selection

The land selected should be fertile and free from volunteer plants. It should not be cultivated with the same crop in the previous season. The land should be tilled twice to make the soil fine.

6.2 Seed selection and sowing

Good quality certified seeds should be sourced from an authorized dealer. Seeds should be healthy with a good germination percentage. Seed rate is 4 - 5 kg per acre. Selected seeds should be treated with bio-control agents like *Trichoderma viride* @ 4 gm per kg of seeds. Mix *Trichoderma* in rice gruel and mix the solution with seeds. Dry the seeds in shade for 30 minutes before sowing. This will help in the control of root rot and wilt disease.

Treated seeds should be sown in ridges and furrows at 4 – 5 cm depth. The spacing maintained is 45 x 15 cm. After sowing, planking is done to cover the seeds.

6.3 Nutrient management

FYM or compost @ 4 tonnes per acre or vermi-compost @ 1.6 – 2 tonnes per acre should be applied and thoroughly incorporated into the soil before the last tilling. This will help to improve the texture as well as the nutrient content of the soil. Green manure crops like *Sun hemp* or *Sesbania* are grown in the field and ploughed into the soil after 40 – 50 days of sowing. This enhances the nitrogen, phosphorous and other nutrients in the soil.

Trichoderma viride @ 1.5 kg per acre is mixed with 300 kg compost and kept as such for a week and then applied to the field as top dressing. It will protect the crop from root rot and pathogens like *Pythium* and *Phytophthora*.

6.4 Weed management

In summer crop harrowing is done 25 – 30 days after sowing. The first weeding is done 45 – 50 days after sowing. Weeding is repeated before flower bud initiation stage followed by harrowing.

6.5 Pest and disease management

Mustard aphid, painted bug, sawfly, *Alternaria* blight and white rust are some of the common pests and diseases affecting mustard crop. The NPPC should be contacted for IPM technologies.

6.6 Irrigation

Irrigation should be done once in 15 days. It is critical during flowering and pod filling stages.

6.7 Roguing

Roguing should be done from the vegetative to harvesting phase. Off-types are removed based on the branching type, capsule size and colour and colour of the seeds. Maximum percentage of off-types permitted is 0.10% for foundation seed production and 0.50% for certified seed production.

6.8 Field inspection

A minimum of three field inspections should be done from pre-flowering to maturity stage by the Seed Certification Officer. First inspection is done before flowering followed by second inspection during flowering. The third inspection is scheduled at maturity stage prior to harvesting.

6.9 Harvesting, threshing, drying and storage

Harvesting should be done when 75% of the pods become golden yellow in colour. The moisture content of the seeds will be 25% in this stage. Delaying harvest may result in yield loss. The crop is harvested at the level of lowest pods.

The harvested plants are heaped and dried under the sun for 4 – 5 days to attain 12 – 13% of moisture level for uniform maturation of seeds. This is called swathing. During swathing the immature pods with green seeds mature. Threshing is done after 10 – 12 days by hand using stick. Threshed seeds are cleaned by winnowing and sieving using suitable size of sieve.

Seeds are dried under the sun to attain 8% of moisture content. This is safe for mustard seeds and can be stored in gunny or cotton bags up to one year under open storage conditions. The minimum percentage of purity of foundation and certified seeds should be 97% with 85% of minimum germination capacity and 8% of maximum moisture content. Presence of other distinguishable variety in foundation seed should be 0.10% and that of certified seed should be 0.50%.

E. Quinoa seed production

1.0 Background

Quinoa (*Chenopodium quinoa* Willd) was introduced to Bhutan from Peru in 2015 by DoA. It is rapidly being promoted in different agro-ecological zones as nutrient dense and climate resilient crop. Quinoa is locally called as Royal Quinoa in English, *Ashi Heychum* in Dzongkha, *Ashi Mo* in *Sharchop* and *Rani Bethu* in *Lhotsham*. Quinoa is known as a pseudo-cereal because its characteristics are very different from those of the true cereals like rice, wheat and maize. Quinoa does not contain gluten, which most typical cereals do.

Quinoa is an annual herbaceous plant that belongs to the family Amaranthaceae. It is a dicotyledonous plant usually erect, with a height ranging from 100–300 cm. The plant height depends on environmental conditions and variety. Leaves are generally lobed, pubescent, powdery, rarely smooth, and alternatively inserted on a woody central stem. The plant may be branched or unbranched, depending on variety and sowing density. Stem colour may be green, red, or purple. The leafy flower cluster arises predominantly from the top of the plant and may also arise from the leaf axil on the stem. Flowers are sessile, of the same colour as the sepals, and may be hermaphrodite, pistillate, or male sterile. The stamens have short filaments bearing basifixed anthers; the style has two or three feathery stigma. The fruit of Quinoa is a seed. The seeds are of different shapes depending on variety and measure 1–2.6 mm. Quinoa seeds are of different colours: white, yellow, red, purple, brown, and blacks. The vegetative period of varies between 120 and 240 days and is related to photoperiod sensitivity. Quinoa is predominantly autogamous or self-pollinated. It is also partially allogamous or cross-pollinated species with 10-15% cross pollination.

Released Varieties

There are four released varieties recommended for cultivation in Bhutan, Table 17.

Table 17: Released varieties of quinoa in Bhutan

Variety	Local Name	Maturity (Days)	Grain Colour	Potential Yield (Kg acre^{-1})
Amarilla Marangani	Ashi Heychum- AM	173	Yellow	750
Amarilla Saccaca	Ashi Heychum- AS	170	Yellow	900
Ivory 123	Ashi Heychum- 123	150	Brownish	900
DoA-1-PMB-2015	Ashi Heychum- TW	140	Brownish	750

2.0 National seed production scheme

Being an annual crop and that the sowing time differs for different agro-ecological zones and altitudes a very simple seed production scheme is recommended for Quinoa.

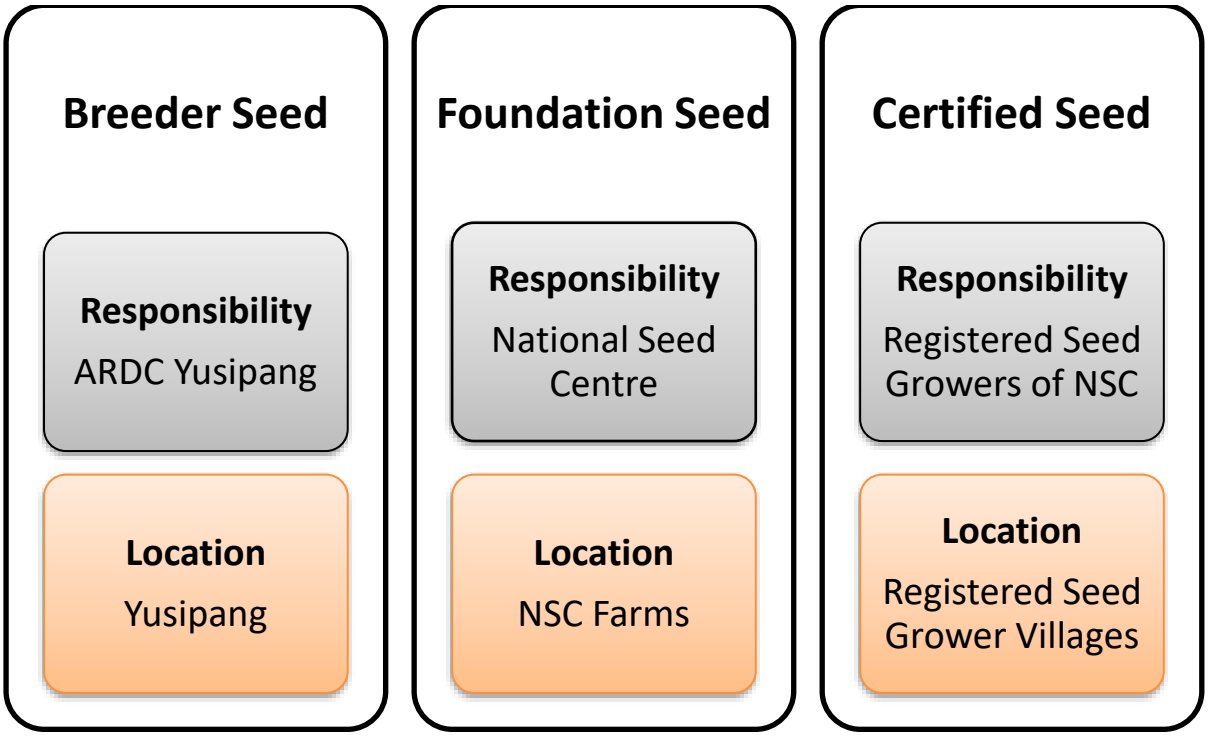

Figure 3: National seed production scheme of quinoa

3.0 Specific methods of breeder seed production

- ARDC Yusipang which is the coordinating centre for Quinoa commodity program will produce the breeder seed.
- The quantity of breeder seed to be produced should be 5 kg for each variety.
- Breeder seed must be cultivated on land which in the previous year did not cultivate Quinoa.
- The minimum isolation required for the production of breeder seed is 200 m or 30 days.
- Breeder seed will be produced through a rigorous selection of 200-300 healthy plants.
- Wild Chenopodium *or* Lambsquarters *(Chenopodium album)* weeds in and around breeder seed production field should be thoroughly weeded out before it flowers to avoid seed contamination through cross pollination.
- As Quinoa has an asynchronous flowering and maturity, the plants maturing early should be selected.
- The panicles from the harvested plant should be dried, cured and threshed separately.
- The threshed grain should be cleaned and dried separately.

- The seed obtained should be dried to moisture content of less than 10%.
- The seed germination percentage should be above 90%.
- Breeder seed should be supplied to NSC annually.

4.0 Specific methods of foundation seed production

- The National Seed Centre (NSC) will produce the foundation seed.
- Breeder seed shall be the source for foundation seed.
- The quantity of foundation seed quantity to be produced should be 50 kg for each variety.
- All ARDCs can also produce the foundation seed to meet their demand for research and outreach programs.
- Foundation seed of the same variety could be sown for two consecutive years on the same land.
- The minimum isolation distance required for the production of foundation seed is 200 m or 30 days.
- Wild Chenopodium *or* Lambsquarters *(Chenopodium album)* weeds in and around foundation seed production field should be thoroughly weeded out before it flowers to avoid seed contamination through cross pollination.
- Foundation seed will be produced through a rigorous selection of 700-1000 healthy plants or by bulking the most uniform plants.
- As quinoa has an asynchronous flowering and maturity, the plants maturing early should be selected or bulked.
- The panicles from the harvested plant should be dried, cured and threshed separately.
- The threshed grain should be cleaned and dried separately.
- The seed obtained should be dried to moisture content of less than 10%.
- The seed germination percentage should be above 80%.
- Foundation seed should be supplied to RSGs annually.

5.0 Specific foundation for certified seed production

- The Registered Seed Growers (RSG) registered with the National Seed Centre (NSC) will produce the foundation seed under the supervision of NSC
- Foundation seed shall be the source for certified seed.
- NSC should supply foundation seed annually to the RSGs.
- NSC in collaboration with regional ARDCs should identify, develop and train RSG for quinoa is the most suitable locations.
- One RSG should be given the responsibility to produce certified seed of single variety.
- The minimum isolation required for the production of certified seed is 100 m.

- To avoid contamination through cross pollination RSG members should be advised not to plant other *Chenopodium* species at least 300 m close to the certified seed production field.
- RSG farmers should be trained to identify and weed out all wild Chenopodium *or* Lambsquarters *(Chenopodium album)* weeds before flowering to avoid seed contamination through cross pollination.
- Certified seed of the same variety may be sown on the same land for unlimited consecutive years provided adequate soil fertility is maintained.
- For certified seed all the off types should be rogued.
- As quinoa has an asynchronous flowering and maturity, the uniform plants maturing early should be harvested as bulk.
- The late maturing plants should be harvested separately and should not be mixed with certified seed.
- Adequate drying and curing should be done before threshing.
- Threshing and cleaning should be done separately to avoid mixtures of other grains.
- The seed obtained should be dried to moisture content of less than 10%.
- The certified seed should meet all the prescribed national seed standards.

6.0 Agronomic principles of seed production

Important considerations for seed production of quinoa

- Asynchronous flowering and maturity- flowering and ripening of grains in quinoa are not synchronous which does not allow harvesting of all the crops together from the field at one time. This characteristic is considered a natural defense for adaptation to adverse climatic impacts. Harvesting often has to be repeated depending on maturity of plants in a field.
- Flowering and grain filling are critical stages where irrigation should be considered when there are frequent dry spells in the growing season.
- Harvesting time- It is crucial to know when the quinoa crop is ready for harvest. Usually, the leaves turn yellow or red, depending on the variety. The appearance of grains on the panicle is an indication of physiological maturity. Another way to test if the plant is ready for harvest is to tap the panicle with the hand. If the grains fall out, harvesting can begin.
- Physiological maturity - The physiological maturity of quinoa is indicated by hard and dry grains and the moisture content at this stage will be about 15%.
- Quinoa seeds lose viability more rapidly than cereals because of the porosity in the integument, which allows a seed to easily gain or lose moisture. It may initiate germination in the panicle or pre-harvest seed germination.
- Pre-harvest seed germination – Seeds germinate on the panicle when wetted by rain hence time of harvesting is very important. This condition is also called vivipary and quinoa seed are highly viviparous.

- The moisture content for safe storage of quinoa grain is less than 10%.

6.1 Ecological requirement

Quinoa is cultivated in dry-land as a rain-fed crop. However, provision of irrigation gives higher grain yield. To obtain good quality seed, provision of one to two irrigations when the soil conditions are very dry is important. The critical stages of water requirement in Quinoa are at flowering and grain filling where irrigation should be considered. Quinoa requires short day lengths and cool temperatures for good growth.

Temperature

In general, the adequate mean temperature for quinoa growth is 15–20◦C, but it can grow at mean temperatures ranging from 10-25◦C. Extremely high temperatures can cause flower abortion and no grain formation. It is very important to plan the sowing date to avoid air temperatures higher above 32°C during the flowering stage that can cause poor seed setting. Apart from drought, frost is one of the major growth limiting factors in high altitude areas. Frost tolerance in Quinoa depends on the duration of the frost, the quinoa variety, the phenological stage of the plant when frost occurs. We have observed that Quinoa is susceptible to frost at seedling stage and until grain setting.

Soil

Quinoa grows best in loam soil with good drainage and high organic matter content, 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). Quinoa does not tolerate water logging conditions. Soil mulching with rice straw after seed sowing has been found useful for weed control and moisture conditions.

6.2 Land requirements for seed production

- Choice of land is important to obtain high quality of quinoa seed and to avoid off types and mixtures mainly from volunteer plants.
- The land requirement specified above for breeder, foundation and certified seeds should be strictly followed.
- Quinoa crop does not tolerate water logging.

6.3 Field preparation and nutrient management

The field preparation method for quinoa is similar to that for mustard and wheat. Quinoa requires a leveled field, well-drained seedbed in order to avoid water logging. When power-tiller is used, first ploughing followed by soil pulverization with rotovator is sufficient. Application of sufficient quantity of Farm Yard Manure (FYM) ensures higher grain yield. It is recommended that application of about 3 -5 MT of well rotten FYM per acre gives good seed yield.

6.4 Seed Rate and sowing time

The recommended seed rate is 2 kg per acre. Seed sowing is critical for the success or failure of the crop. Emergence of seedlings, plant density and final yield depends on the correct seed sowing. Quinoa seeds are sown at different times, depending on the place to be sown, the varietal traits, and soil moisture. Sowing depth should be 1-3 cm. For seed crop line sowing is recommended with a line to line spacing of 0.60 m and plant to plant space should be maintained at 0.20 cm. Shallow sowing poses the risk of seed dehydration or burning by solar radiation as well as seed picking by birds. Deep sowing can prevent germination due to restricted growth.

For seed production the following sowing time is recommended for different agro-ecological zones.

Table 18: Sowing time for quinoa

Sl. No.	Altitude Range	Agro-Ecosystem	Sowing Time for Seed Crop
1	1800 -2600 m asl	Warm Temperate	May
2	1200 -1800 m asl	Dry Subtropical	Mid July- Mid August
3	Below 1200 m asl	Warm Subtropical, Dry Subtropical Humid Subtropical	Mid October- first week of November

6.5 Harvesting, drying, curing and threshing

6.5.1 *Harvesting*

The maturity of the crop depends on variety and location. It is crucial to know when the quinoa crop is ready for harvest. Usually, the leaves turn yellow or red, depending on the variety. The appearance of grains on the panicle is an indication of physiological maturity. Another way to test if the plant is ready for harvest is to tap the panicle with the hand. If the grains fall out, harvesting can begin. The physiological maturity of quinoa is indicated by hard and dry grains and the moisture content at this stage will be about 15%. 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 by rain it leads to pre-harvest seed germination on the panicles or vivipary.

6.5.2 *Drying and Curing*

Immediately after harvest, the crop should be sundried or made into bundles and hanged for drying and curing. The harvested crop can be hanged in the shed or on the ceiling of store. 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.

6.5.3 *Threshing and Winnowing*

Threshing involves the separation of the grains from the panicles. 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. Each variety should be threshed separately to avoid seed contamination. Winnowing is done to separate and clean the grains from the bran and other unwanted materials. Winnowing is done manually using locally made winnowers.

6.5.4 *Seed Storage*

After winnowing clean quinoa grains are obtained. The grains should be properly dried without exposing to direct sunlight in order to maintain the product quality. Quinoa seed must remain dry during storage. Grains should be stored in clean and dry environment. quinoa seeds should be stored in air tight moisture proof bags at low temperature and relative humidity. When stored in bags, the filled grain bags should be stacked properly on wooden planks to avoid seeds coming in contact with the cement floor. The safe moisture content for storage is less than 10%. It is important to properly label the bags and containers before storage.

F. Grain legumes seed production

1.0 Background

Legumes are flowering plants that belong to the family Leguminosae which is characterized by podded fruits. Leguminosae is one of the largest flowering plants that constitute approximately 19780 species. The edible legumes mostly belong to sub family papilionoideae which includes soybean, chickpea, lentil, beans, pea, peanut. Based on the consumption and uses they can be classified as pulses or grain legumes, vegetable legumes, legumes for oil extraction and animal feed. Legume species when harvested solely for dry grains are called pulses (dry beans, chick peas, lentils etc). Legume species when used for vegetable (e.g. green pea, green beans) or for oil extraction (e.g. soybean, groundnut) are not considered grain legumes or pulses.

Legumes are an important component of the Bhutanese farming systems and it grows in diverse agro-ecological zones in various cropping systems as relay and mixed cropping with maize. There are about 16 species grown in the country, but the most widely grown species are *Glycine max, Phaseolus vulgaris, Pisum sativum* and *Vigna* spp. Other species include: *Arachis hypogea, Cajanus cajan, and Lens culinaris.* Legumes flowers are hermaphrodite and self-pollinated crops.

Mung and Urd Bean

- It is classified into two types based on the colour of grains: Green Gram (*Vigna radiata* L.) and Black Gram (*Vigna mungo* H.)
- The corolla of *Vigna mungo* is bright yellow while that of *Vigna radiata* is pale yellow; mung bean pods are pendulous (hanging) whereas they are erect in black gram.
- Mung bean is slightly less hairy than black gram.

Soybean (*Gycine max* L.)

- The plant grows up to a height of 1.5m depending upon the varieties. The stems are erect and hairy.
- The self-pollinated stalkless flowers are borne on the axil of the leaves. Flowers are either yellow or purple in colour.
- The pods are hairy and bears in cluster of 3-5 in numbers

Lentil (*Lens culinaris Medik*)

- Leaves are pinnate which are ovate to lanceolate in shape
- Flowers are usually double or 1-4 raceme which are white to pale or purple to dark purple in colour.
- The flowers blooms in sequence from lower branches and proceed upwards.
- Flowers pollinate before opening

Common bean (*Phaseolus vulgaris*)

- Rajma beans is also known as Rajma beans, French bean, kidney bean, garden bean, snap bean.
- Flowers are cleistogamy, self-pollinated with some chances of cross pollination up to 1.1%
- They are classified into dwarf and climbing types depending on the growing habits.
- The distinguishing features of the *Phaseolus* species from other leguminous is that the keel petal terminates in coil in one to two turns

Garden pea (*Pisum sativum*)

- Garden pea is the cool season annual vine legumes with greenish waxy appearance
- The plants grow up to height of 2 m but many modern varieties have short vine, about half meter.
- Flowers are born on the axil of the leaves, and consist of racemes with 1-4 flowers

Varieties released in Bhutan (Table 19)

Table 19: Released varieties of legumes in Bhutan

Crops	Variety released	Year of release	Releasing Agency
Mung Bean	Lingmithang Mung 1	2002	ARDC Wengkhar
Mung Bean	Lingmithang Mung 2	2002	ARDC Wengkhar
Soybean	One Daughter	1994	NSC
Soybean	KhangmaLibi 2	2002	ARDC Wengkhar
Soybean	Brag	2002	ARDC Wengkhar
Soybean	KhangmaLibi 1	1999	ARDC Wengkhar
Common Bean	Borloto	1990	ARDC Bajo
Common Bean	Pusa Parvati	1990	ARDC Bajo
Common Bean	Top Crop	1990	ARDC Bajo
Common Bean	Rajma	1994	ARDC Bajo
Common Bean	Green Arrow	1999	ARDC Bajo
Common Bean	White No. 1	1999	ARDC Bajo
Common Bean	Selection 9	2004	ARDC Bajo
Common Bean	Selection 9	2004	ARDC Bajo
Garden Pea	Arkel	2002	NSC
Garden Pea	Usui	2002	NSC

2.0 National seed production schemes

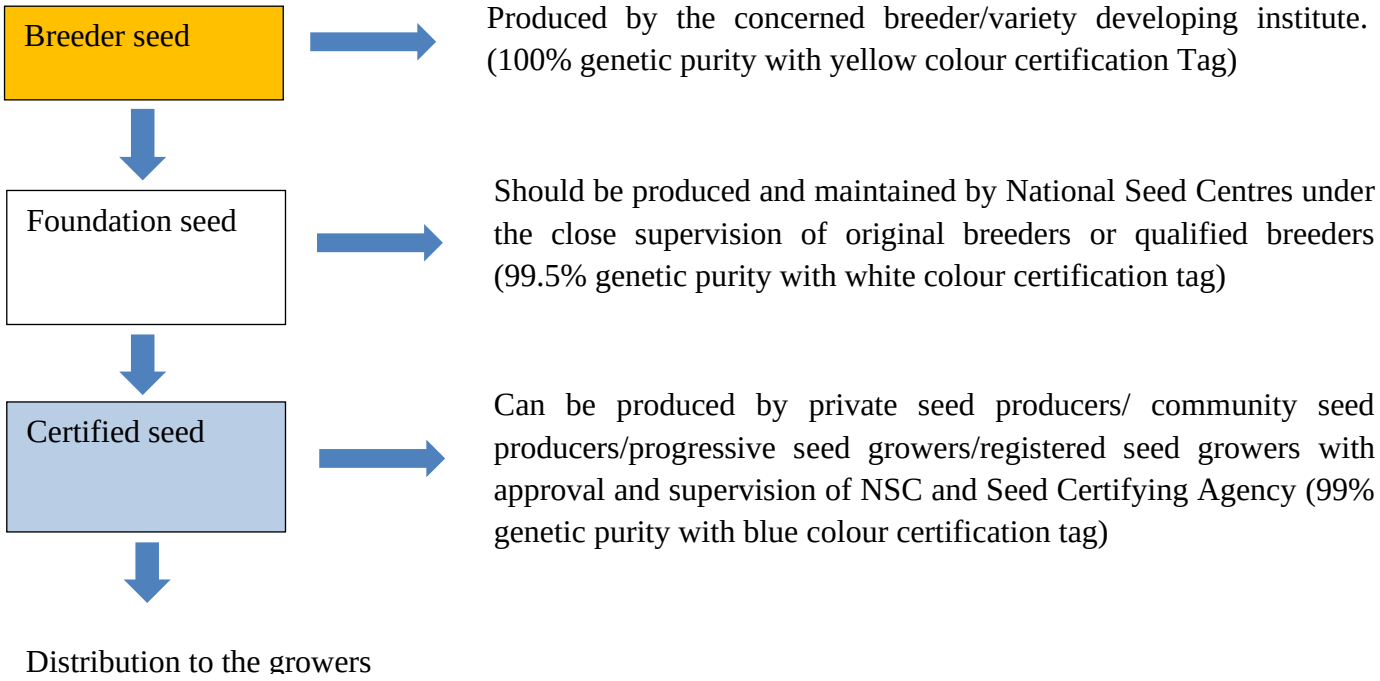

Figure 4: National seed production scheme of legumes

3.0 Specific methods of breeder seed production

- Breeder seed is required to be grown in a minimum area of 200 m^2 area for base population for selecting true to the type single plants. The field should be uniform in terms of topography, moisture availability and soil fertility. The recommended inter and intra row spacing at 30 cm and 10 cm for lentil and pea, 45 cm and 10 cm for mung bean and urd bean, should be maintained. Weed free conditions should be maintained for quality seed production. Standard agronomic practices must be followed to raise the basic population.
- Select 1000-1200 true-to-type plants before flowering for lentil, pea, rajma, mung bean and urd bean. The selected plants should be tagged and observed throughout the growing period and any plant showing variation should be rejected and uprooted before flowering.
- The selected tagged plants should be harvested separately. The seeds of individual plant should be table examined and if the seed of any plant does not confirm to the seed characters of the variety, it should also be rejected
- Seed should be properly dried, treated with insecticide before storage
- In the next cropping season, the individual plant progenies should be grown in rows following recommended inter and intra row spacing in a well prepared, homogeneous and disease-free field having no water logging and salinity problems. An isolation distance of 5 m and leaving 1.5 m space after each bed for self-pollinated crops in seed

production fields for a regular visit by the breeder and the monitoring team is desired for maintaining varietal purity

- The individual plant progenies should be regularly visited and observed by concerned breeder right from germination to different growth stages. Any plant progeny deviating from the characters of the original variety or showing disease incidence in the field should be completely removed.
- The true to type single plant progenies should be harvested and threshed separately. Due care should be taken at the time of harvesting and threshing to avoid any kind of physical mixture of progenies.
- The seed lot of individual progeny should be examined with reference to seed size, shape and colour etc. Any progeny showing deviation from the varietal seed characteristics should be rejected
- The seed should be dried to 10% moisture level and stored after treating with insecticide to avoid losses during storage.

Table 20: Field and seed standards for breeder seeds of legumes

Standards	**Soybean**	**Common bean**	**Garden pea**
A. Field Standards			
Isolation distance (m)	10	25	50
Max. Off-type (% per 100 plants)	0	0	0
B. Seed Standards			
Purity (% per weight)	98	99.5	98
Minimum Germination (%)	75	80	80
Max. Inert matter (%)	0	2	
Max. Moisture content (%)	14	15	12
Max. Other crop seeds (% per 1000 numbers)	0	0	0
Max. Other varietal seeds (% per weight)	0	0	0
Max. Weed seed (% per weight)	0	0	0
Noxious weeds		0	0

Table 21: Additional field standard for diseases

Crops	**Diseases**	**Tolerance**
Beans	Halo blight (*Pseudomonas phaseolicola*) Anthracnose (*Collectotricum lindemuthianum*) Bean common mosaic virus Common blight (*Xanthomonas phaseoli*)	
Peas	Leaf spots (*Ascochyta spp*) Pod spots (*Mycosphae rellapinodes*) Bacterial blight (*Xanthomonas vignicola*)	

Soybeans	Bacterial blight (*Pseudomonas* spp) Bacterial pustule (*Xanthomonas phaseoli*)	None during final inspection

(Source: FAO. (1991). Seeds and Plant Varieties (Seeds) Regulations, FAO/Germany Cooperative Program. (2012). Seed Production and Training manual)

4.0 Specific methods for foundation seed production

- National Seed Centre is responsible for the production of foundation seed of any released varieties.
- Foundation seed production should be done under guidance of original breeders or qualified breeder.
- Field should be well prepared following recommended isolation distance with recommended package of practice.
- Frequent roguing should be done to remove off types.
- Field and seed should conform to the standards as mentioned in the Table 22

Table 22: Field and seed standards for foundation seeds of legumes

Standards	**Mung Bean**	**Soybean**	**Lentil**	**Common bean**	**Garden pea**
A. Field Standard					
Isolation distance (Fields of other varieties	10	3	10	10	10
Isolation distance (Fields of the same variety)	10	3	10	10	10
Max. Off type (%)	0.10	0.10	0.10	0.10	0.10
Plants affected by seed borne disease (%)	0.10			0.10	
A. Seed standards					
Min. Pure seeds (%)	98.0	98.0	98.0	98	98.0
Max. Inert Matter (%)	2.0	2.0	2.0	2.0	2.0
Max. Other crop seeds (Nos. per kg)	5	0	5	0	0
Max. Weed seeds (Nos. per kg)	5	5	10	0	0
Max. Other distinguishable varieties (Nos. per kg)	10	10	10	5	5
Min. germination (%)	75	70	75	75	75
Max. Moisture (%)	9.0	12.0	9.0	9.0	9.0
Moisture for vapour proof container	8.0	7.0	8.0	7.0	8.0

Additional field standards for weeds

- Spotted beans and heat damaged beans: maximum 0.5% allowed
- Rejects (insect-damaged beans, off-coloured seeds, beans with cracked skin, broken beans, too small seeds, etc.- maximum 3 allowed.

5.0 Specific methods of certified seed production

- Certified seeds can be produced by any Private Seed Produces, Community Seed Producers, Registered Seed Growers, and Progressive Seed Growers
- Certified seed production is done with approval and supervision of NSC and Seed Certifying Agency
- Field should be prepared maintaining recommended isolation distance for the crops and conforming to the field standards as mentioned in the Table 5.
- Timely field inspection and roguing should be carried at flowering and pod stage
- Harvesting should be done at right maturity of the seeds
- Cleaning and drying of seed should be done maintaining 9-10 moisture level

Table 23: Field and seed standard for certified seeds of legumes

Standards	Mung Bean	Soybean	Lentil	Common bean	Garden pea
A. Field Standard					
Isolation distance (Fields of other varieties	5	3	5	5	5
Isolation distance (Fields of the same variety)	5	3	5	5	5
Max. Off type (%)	0.20	0.150	0.20	0.20	0.20
Plants affected by seed borne disease (%)	0.20			0.20	
A. Seed standards					
Min. Pure seeds (%)	98.0	98.0	98.0	98	98.0
Max. Inert Matter (%)	2.0	2.0	2.0	2.0	2.0
Max. Other crop seeds (Nos. per kg)	10	10	10	0	5
Max. Weed seeds (Nos. per kg)	10	10	20	10	0
Max. Other distinguishable varieties (Nos. per kg)	20	40	20	10	10
Min. germination (%)	75	70	75	75	75
Max. Moisture (%)	9.0	12.0	9.0	9.0	9.0
Moisture for vapour proof container	8.0	7.0	8.0	7.0	8.0

6.0 Agronomic principles of seed production

6.1 Land requirement

- To avoid any mixture with the volunteer plants from the previous season's crop, it is essential to avoid the field that was planted with the same crop in the previous year particularly for lentil.
- The field which are infected with any designated diseases should be rejected as some diseases in case of rajma beans and mung bean are seed borne. Quality seed production should be done in disease free plots
- Since most of the pulse crops are self-pollinated with few percentages of natural cross pollination, isolation distance between the two cultivars helps to maintain varietal purity (Isolation distance mentioned in the Tables 20, 22 & 23)

6.2 Seed Treatment

- It is recommended to treat the seeds with 3 gm Captan (50 WP) or 1 gm Carbendazim (50 WP) per kg of seeds before sowing to avoid seed and soil borne fungal diseases.
- Treatment of seed with phosphorus solubilizing bacteria (PSB) improves the availability of phosphorus to the plants.
- If the particular crop is being grown for the first time, it is recommended to inoculate the seeds with Rhizobium culture. Seed should be first treated with fungicides followed by PSB or Rhizobium and should be dried in the shade.
- If the seed is to be treated with insecticides, application of insecticides should be done first followed by fungicides and PSB or Rhizobium

6.3 Spacing

Table 24: Spacing of legumes

Crops	Mung bean	Soybean	Lentil	Common bean	Garden Pea
Spacing (RR in cm x PP in cm)	30x5-10	30x5	30x3-4	30x15 (bed sowing) 45x30 (ridge sowing)	45x10
Seed rate (kg/acre)	8	25-30	12-16	30 for hills 20 for plains	40

6.4 Irrigation

- Irrigate immediately after sowing
- Three to four irrigation required for legumes
- Flowering, pod setting and pod filling are the critical stage for irrigation

6.5 Nutrient management

Table 25: Nutrient management in legumes

Crops	Mung bean	Soybean	Lentil	Common bean	Garden Pea
Recommended dose of fertilizer: NPK (kg/acre)	5:10:5(Rain fed) 10:20:10 (Irrigated)	8:32:16	8:16:16	36:50:0	24:32:28
FYM (MT/acre)	5	4		10	8

6.6 Field inspection

- Minimum of 2 inspections should be done at flowering and during pod stage. Additional inspection can be done when there are particular problems
- During field inspection, the inspector should confirm that the particular variety of the crops conform to the characteristics of variety
- The field inspection should also examine the boundary of the field to confirm the isolation distance is satisfied
- Field should be than inspected and estimate for weeds and diseases presents. During this, the inspector will observe 30 numbers of plants randomly each from five separate places within the seed production field.
- Number of plants not conforming to the characteristics of the variety (off-types) and number of plants of other legumes species are counted separately.
- If number of off-types or the number of other legume species exceeds three, the field should be rejected.
- After field inspection, inspection report will be completed and decision has to be made either to accept or reject the field or to recommend further remedial action

6.7 Roguing

Any off-types, objectionable weed plants, seed borne diseases noticed during field inspection should be removed. Roguing should be done to meet the following standards

Varietal purity: At least 98 percent of the pulses must conform to the characteristics of the variety

Species purity: There shall not be more than two percent of other crop species with similar seed size.

Weeds general: The seed field should be free from weed growth in such a way that it shall not obstruct valid inspection of the crops.

Weeds specific: There shall not be more than the specified number of weed plants per unit area as per the seed and field standards

Seed borne diseases: The seed field should be free from any designated seed borne diseases.

Other diseases: The seed field should be reasonably free from other diseases in such a way that the amount of diseases should not be such as to prevent the valid assessment of the characteristics of the variety

6.8 Pest management

Table 26: Major pest of legumes

Pest	Damaging Symptoms	Control Measure
Gram Pod borer (*Helicoverpa armigera*)	-Defoliation of leaves, Head of larvae bore inside the pods with half of body exposed outside, Pods with bored holes	-Removal of infested parts -Pheromone traps (4.8 nos per acre) -Spray Azadiractin (0.3%) @ 5/7ml/L at 10 to 15 days interval depending on the severity Spray Dimethoate (30EC) @ 494.8ml/acre
Bean Aphid (*Aphis craccivora*)	-Leaves, inflorescence and pods covered with black coloured aphids -Honey dew secretion	- Spray Azadiractin (0.3%) @ 5/7ml/L at 10 to 15 days interval depending on the severity Spray Dimethoate (30EC) @ 494.8ml/acre
Spiny pod borer (*Etiella zinckenella)*	-Dropping of flowers and young pods, pods with brown coloured holes	-Pheromone traps at distance 50m (2 traps per acre) -Manual collection and destruction of larvae
White Fly (*Bemisia tabaci*)	-Yellow and curled leaves - Insect spread mosaic virus	-Spray Dimethoate (30EC) @ 2ml/L at 35-40DAS and repeat after 15 days if required

6.9 Harvesting, seed extraction, cleaning, drying, curing and storage

- Time of harvesting is crucial to maintain the quality of seeds.
- Legumes seeds are usually harvested when plants start to senesce, 80% of leaves and pods turn yellow.
- Seeds harden making rattling sound at harvesting stage.
- After harvesting, plants are dried in the sun for few days so that seed is dried well maintaining the standard moisture content of the seeds
- After ensuring full drying of pods and seeds, manual threshing is done to extract seeds from pods. Mechanical threshing can also be done.
- The seeds are then cleaned by winnowing to remove undesirable mechanical mixtures, shrivelled and damaged seeds
- For cleaning: air cleaners, aspirators, indented separators, disc separators, gravity separators, spiral separators and drum separators can be used.

- After thorough cleaning, seed is once again dried. The ideal moisture level for the pulses ranges from 10-12% and can be stored up to 8 months from the date of packaging.
- After thorough cleaning and drying, seed is stored in polythene lined gunny bags or any safe storage structures such as air tight polythene plastic sheet, metal bins or plastic bins.
- Bruchids (*Callosobruchus* spp.) is one of the most serious storage pests of pulses. The adult lay eggs on the seed and emerging larva bore inside making holes from which adults emerge. Those seeds are unfit for sowing.
- The tradition practice of storing pulse is mixing with ash, dried neem leaves or wheat straw.
- For commercial seed storage, the storage room or storage bins can be fumigated with any commercially available fumigants such as ethylene dibromide or phosphine.

7.0 Seed multiplication ratio

Table 27: Seed multiplication ratio of legumes

SI. No.	Crops	Seed Multiplication Ratio
1	Mung Bean	1:40
2	Soybean	1:16
3	Lentil	1:20
4	Common Bean	1:9
5	Garden Pea	1:19

II. VEGETABLE SEED PRODUCTION

A. Potato

1.0 Background

Potato originated from the highlands of South America, particularly in Colombia, Ecuador, Peru, Bolivia, and Chile. Potato is an annual herbaceous plant of the nightshade family, *Solanaceae*, thus closely related to the tomato, eggplant, tobacco, and chili. The main potato species cultivated, *Solanum tuberosum L.*, is subdivided into two subspecies: *Solanum tuberosum ssp. tuberosum* (adapted to long days) and *Solanum tuberosum ssp. andigena* (adapted to short days).

Potato is one of the widely produced, consumed and traded horticultural crops in Bhutan. It has capabilities to provide more nutritious food from less land in less time than other crops such as 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 m asl and is the most important crop for the farmers in the altitude above 2500 m asl. It is grown by more than 34,000 households in all 20 districts of Bhutan.

Varieties released in Bhutan

There are four main potato varieties released and grown in Bhutan for different agro-ecologies with varying yield potentials as indicated in table 28.

Table 28: Potato varieties released in Bhutan

Sl. No.	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, DoA	15-23	160-180	All agro-ecologies
4	Yusi Maap	2017	National Potato Program, DoA	12-17	120-140	Mid and high altitudes

2.0 National seed production scheme

The three seed production stages are Breeder seed, Foundation seed and Certified seed. While the National Potato Program or ARDCs releasing new varieties are responsible for maintaining and supply of breeder seeds, NSC has the responsibility of producing foundation and certified seeds.

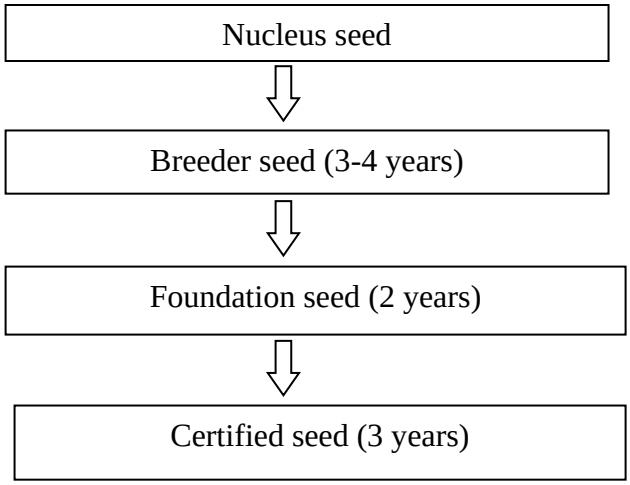

Figure 5: National seed production scheme of potato

3.0 Specific methods for breeder seed production

Breeder seeds are the initial small quantity seeds in the form of miro-tubers obtained from tissue culture laboratory or the mini-tubers from aeroponics of the National Seed Centre in Paro. The breeder's seed of potato is generated from sprouts of selected individual tubers of a particular variety (nucleus) for the purposes purifying and maintaining that variety. However, new genotypes are imported from germ-bank of the International Potato Centre, Lima. The initial small quantity of miro-tubers or mini-tubers seed multiplied by National Potato Program, ARDC Yusipang under supervision of a qualified breeder to produce breeder seed. The varietal purity of subsequently multiplied foundation and certified seed largely depend upon the quality of the breeder seed. That is why the breeder seed should be pure to begin with.

- Sampling of the variety to obtain nucleus seed from good tubers of a known plant: select about 20 tubers that are true-to-type and disease-free
- Sampling plants of the variety to obtain nucleus seed should be indexed and properly marked.
- Selected plants should be free from identifiable diseases like late blight or leaf roll virus
- Discard any tubers appearing to be off-type, diseased or otherwise unacceptable
- In vitro multiplication of meri-clones: that is meristem tips of apical buds collected and micro-multiplied in tissue culture lab. Micro-plants can produce disease-free micro-tuber and mini-tubers from tissue culture and aeroponics, respectively.
- Keep micro-tubers for 2-3 months before planting to break the dormancy.
- Harvested mini-tubers or micro-tubers should be cold stored and used as seed in the following season.
- Altitude should be 2000 m above sea level or more to avoid disease pressure

- Micro-tubers should be planted in vermiculite (not in soil) under greenhouse to produce mini-tubers or could obtain mini-tubers from aeroponics.
- Mini-tuber can be produced from micro-tubers under high density planting on nursery beds made of vermiculite.
- Mini-tubers should be planted at 60 x 15 cm spacing in a shallow depth which becomes the generation I of the crop.
- From generation II the crop can be planted in ridges of 50-70 cm as the tuber sizes then will be of commercial seed size.
- Potato tubers are generally planted with a distance of 15-20 cm between the plants and ridge-to-ridge distance of 50-70 cm.
- Generally planting depth of 7-8 cm is recommended and increase in plant depth can cause difficulty in crop establishment.
- In case of new, scarce and insufficient seed, all seed sizes may be used to for multiplication
- Crop rotation is important to avoid volunteers from previous season from contaminating the purity – at least 2 years gap should be maintained
- Inspect the plots and remove of off types: Throughout the season of growth, from the seedling stage until maturity, the plot should be examined critically and any off-types or diseased-planted should be removed immediately
- Apply recommended amount of fertilizers and weed management methods applicable to potato
- Breeder plot may be sprayed twice for the control of late blight using Metalaxyl 8% + Mancozeb 64 % at 200 - 400 litres per acres and the concentration should 2 g/litre of water as an insurance purposes
- At maturity harvest carefully with bruising the tubers, cure them in shade for two weeks before packing and labelling as breeder seed.
- Curing process should facilitate hardening of skin at temperatures of 15 - 18 ^{o}C.

4.0 Specific methods for foundation seed production

- Under the supervision of a breeder, the seed stock is handled to maintain specific identity and genetic purity (100%), which may be distributed and produced under careful supervision of an agricultural experiment station, or a certified Seed Centre.
- The technical procedure for production of foundation seed is similar to that of breeder seeds except that it starts production from seed size tubers and not from micro-tubers or mini-tubers
- The seed used for production of foundation seed should be breeder seed and avoid mixing with old generation of same variety for maintaining seed vigor and degeneration
- Crop rotation is important to avoid volunteers from previous season from contaminating the purity – at least 2 years gap should be maintained

- Never cut tubers into pieces for planting to avoid contamination of seed with diseases
- Apply recommended amount of fertilizers and weed management methods applicable to potato
- Carry out timely roguing/removal of off-types and diseased plants – this can be best performed in flowering stages as off-types can be easily identifiable then
- Harvest, cure, clean and store seeds properly.

5.0 Specific methods of certified seed production

The method of seed production for certified seeds is similar to foundation seeds. There is a slight difference in the field and seed standards between the foundation and certified seeds as shown in table 29 & 30.

Table 29: Field standard for foundation and certified seed production of potato

Isolation distance	***Foundation***	***Certified***
Field of other crops	5 m	5 m
Fields of other potato varieties	5 m	5 m
Fields of same variety not conforming to purity	5 m	5 m
Contaminants		
Off-types	0.2 %	2%
Leaf roll and severe mosaic	0.02%	1%
Total virus diseases	0.7%	1.5%

Table 30: Seed standards for foundation and certified seeds of potato

Parameters	***Foundation***	***Certified***
Seed tuber weight	35 to 65 g/tuber	35 to 65 g/tuber
Seed tuber sizes	30 to 60 mm	30 to 60 mm
Tuber not confirming to above weight and size ranges (maximum)	3%	5%
Varietal Purity of seed (minimum)	99%	98%
Inert matter (maximum)	2%	3%
Cuts and bruises, cracks and other mechanical damage (maximum)	2%	3%

6.0 Agronomic principles of seed production

6.1 Land preparation

Potato requires a deep, loose, friable and well-aerated soil. Potato is shallow rooted plant and loose soil is required for stolons to penetrate through the soil and for ease of tuber enlargement during bulking. That is why well suited to light soils with high organic matter content is needed. 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. The land should be tilled at least twice; large clods should be broken by harrowing or manually.

6.2 Seed rates

The seed rate of potato is 800 to 1000 kg per acre. Seed tubers of 35 – 65 gm each or tuber diameter of 30 - 50 mm should be selected as the seed potatoes. Soil is prepared into raised ridges (rows) with the distance of 50-70 cm between the ridges before planting.

6.3 Planting and harvesting season

Table 31: Planting and harvesting of potato

Agroecology	Planting	Harvesting	Example dzongkhags
High altitude	February/March	July to September	Bumthang and Haa
Mid altitude	December/January	June to July	Trashigang and Chukha
Low altitude	Late October to November	January and February	Samtse and Sarpang

6.4 Nutrient management

Well-decomposed FYM/compost should be applied at 6-8 MT per acre. For mineral fertilizers, the recommended rate from National Soil Services Centre (NSSC) is provided in Table 32. If a particular dzongkhag does not feature in Table 2, one is recommended to use values from a nearby dzongkhag in a similar agro-ecological zone.

Table 32: Fertilizer recommendation in potato

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)

6.5 Irrigation

Potato should be irrigated time to time depending on field conditions. Foliar irrigation should be avoided to prevent late blight infestation. While irrigating, the ridge should be wet and should be done in the middle of two ridges so that water is available in the rooting zone.

6.6 Weeding and earthing up

Weeds should be removed manually by weeding at one and half months after planting. During the first weeding earthing up should be done to reinforce ridges. The earthing up operation should be done carefully to avoid disturbing the stolons and roots. Earthing up improves soil aeration, reduces weed pressure and increases stem density. Second weeding can be done depending on weed pressure. However, earthing up should be avoided once the plants approaches flowering stage to prevent disturbance to the stolons or tuber formation. Pre- or post- emergence herbicide (Metribuzin 70 WP) should be applied at 200 to 400 litres per acres (1 gm per litre of water) to manage weeds.

6.7 Plant protection measures

Potato late blight is the most destructive disease in potato. Late blight can be treated using Metalaxyl 8% + Mancozeb 64 % at 200 to 400 litres per acre (2 gm per litre of water). Early blight can be also treated in the same way.

6.8 Harvesting, curing and storage

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. Minimizing the damage at harvesting and handling should be main objective. It is recommended to harvest the crop during sunny and dry weather.

6.9 Curing

For curing, the potatoes need to be placed ventilated shady area devoid of wind to avoid excessive evaporation of moisture which might otherwise lead to tuber shrinkage. Best curing takes place at 15-18^{o}C. For good curing, it takes 10-15 days depending on the temperature of the place.

6.10 Sorting and Grading

After properly curing the tubers, they should be sorted, graded, packed and stored in a cool store. The potatoes should be graded into tubers of 35 to 65gm per tuber or tuber diameter of 25 mm to 50 mm into *seed category* which is saved or sold as seed potato.

6.11 Storage

It is better to store them in a dark, cool place (2 to 10^{o}C) in order to keep the glycoalkaloid content low. The store room should be cleaned before the storage to prevent of and disease infestation.

B. Cole crops seed production

1.0 Background

Cole crops are cultivated species of *Brassica oleracea* that includes Broccoli (*Brassica oleracea var italica*), Brussel Sprouts (*Brassica oleracea var gemmifera*), Cabbage (*Brassica oleracea var capitata*) and Cauliflower (*Brassica oleracea var botrytis*), among others and belongs to Brassicaceae (Cruciferae). These are cool season crops and are usually grown in winter. They prefer mean temperature of 7 to 13^{o}C for optimal growth and development. Cole crops are cross-pollinated and easily cross among the same species like broccoli, brussel sprouts, cabbage and cauliflower. However, they do not cross with turnips, mustard and Chinese cabbage which are of different species. Cole crops are self-infertile and must be grown in groups, at least 10 to 15 plants to maintain gene base and seed viability.

i. **Broccoli:** It is cross-pollinated and similar to cauliflower in its curd (flower mass) formation. It is more heat tolerant than cauliflower, but at higher temperature, seed yield tends to decrease. Inflorescence does not exhibit polarity and hence number of secondary curds sprout from the axil of the leaves even if the curd is removed.

ii. **Cabbage:** Among the cole crops, cabbage requires the lowest temperature for seed production. Hence, thermo-period is the most critical factor for its flower induction. Flowers are borne on terminal racemes which develop on main stem and branches and are perfect flowers. It is a cross-pollinated crop and pollination occurs mainly through bees.

iii. **Cauliflower:** The floral parts are formed from curd. The inflorescence is dwarf and umbrella shaped. There is no central main stem above where branching begins, and no leaves develop on the flower branches. Pollination is similar to that of cabbage. One of the unique characteristics of cauliflower is inflorescence exhibits polarity, and thus if the curd is removed, no flower stalks will re-sprout from axils below the curd.

Varieties

Total of 17 varieties have been released/notified and recommended for cultivation in the country (Table 33).

Table 33: Released varieties of different cole crops in Bhutan

Crop	Variety	Potential yield (t/acres)	Maturity (days)	Remarks
Broccoli	Dessico	0.8-1	100-110	
Cabbage	Copenhagen Market	9-10	75-85	

	Golden Acre	5-6	70-80	
	Green Coronet (Hybrid)	12-13	80-90	
	Gianty (Hybrid)	11-12	70-80	
	T1-163 (Hybrid)	10-11	65-75	
	Bondey Cross (Hybrid)	10-11	90-110	
	Lucky Ball (Hybrid)	9-10	80-100	
	Asha (Hybrid)	7.6	66	Heat tolerant
	Bengal king (Hybrid)	11.4	68	Heat tolerant
Cauliflower	White Top	10-15	100	
	White Summer	10-12	90-100	
	19905	3-4	120	
	Wengkhar Metokopi I	7-8	90	
	Wengkhar Metokopi II	10-12	120	
	White Express 50 (Hybrid)	3.3	41-63	Heat tolerant
	Pragati 40 (Hybrid)	2.5	41-59	Heat tolerant

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by ARDCs, foundation seeds maintained by NSC and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs).

Table 34: National seed production scheme for cole crops

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

Breeder seeds will be maintained by the releasing agencies like ARDCs. Seeds should be genetically pure or true to type: for this purpose, following practices are recommended;

- Do not grow other cole crops of the same species and/or different varieties of the same crop within the isolation distance of 1600 m
- Time isolation of at least 20 days must be followed

- Caging of plants or cultivation under protected condition with occasional opening for pollination by insects (or hand pollination) must be practiced
- Plant at least 10 - 15 plants to maintain genetic base and seed viability
- Moisture content should be 7 %
- Purity of seeds should be more than 98 %
- Germination percent should be more than 90 %

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by National Seed Centre
- Maintain isolation distance of 1600 m or follow time isolation of at least 15 days or produce under net house
- Plant in groups to maintain genetic base and seed viability
- Moisture content should be less than 8%
- Purity of seeds should be 98%
- Germination percentage should be at least 70%
- ARDCs will also produce some amount of foundation seeds for demonstration of technologies

5.0 Specific methods for certified seed production

- Foundation seeds shall be the source of certified seeds
- Foundation seeds shall be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 1000 m or follow time isolation of 15 days or produce under protected structures
- Plant in groups to maintain genetic base and seed viability
- Moisture content shall be less than 8%
- Purity of seeds shall be 98%
- Germination percentage shall be at least 70%

6.0 Agronomic principles of seed production

6.1 Climate

Cole crops are cool season crops. Among the cole crops, broccoli is more heat tolerant and seed production can be done in the elevation range of 1400 - 1900 m asl. Cabbage is very sensitive to temperature for seed production. In Bhutan, cabbage seed production is suitable between 1900 - 2500 m asl. Cauliflower also requires vernalization for flower induction and 1600 - 2300 m asl is suitable for seed production.

6.2 Land requirement

Well drained loamy soil is ideal for seed production. Soil pH should be in the range of 5 to 7 and should not be acidic. Good drainage of the field is pre-requisite and it is advisable to grow on raised beds. The seedlings should be planted on raised beds of 15-20 cm high and 1 m wide. Cole crops are shallow rooted and therefore field should be thoroughly prepared.

6.3 Seed rate

Though it depends on spacing, normally 100 - 150 grams is enough for an acre of land.

6.4 Spacing

Seedlings are transplanted when they are one month old or when seedlings attain 6 - 7 true leaves stage. Spacing of 60 x 45 cm is commonly practiced. The season for transplanting depends on the locations but ideally August to September is recommended.

6.5 Irrigation

Irrigation should be provided regularly and ensure that soil is neither dry nor muddy. Irrigation is critical especially during bolting and pod formation stage. Lack of irrigation during these stages severely affects seed yield.

6.6 Nutrient management

Nutrient management depends on the soil conditions. In general, 6 MT FYM, 20 kg nitrogen and 30 kg phosphorus are recommended for an acre of land.

6.7 Methods of seed production

Broccoli: Seed production is done through seed to seed method. Once flower stalks have emerged, retain healthy ones for seed production.

Cabbage: Seed production can be done either through seed to seed or head to seed methods. To facilitate easier emergence of flower stalks, usually three types of incisions are practiced: cross cut, top cut and complete removal of head. However, cross cut method is usually recommended.

Cauliflower: Seed production is done through seed to seed method. To facilitate stalk emergence, central portion of the curd is scooped out and healthy flowering stalks are maintained.

6.8 Field inspection

Minimum of three inspections should be made: before marketable stage, at the marketable stage and flowering stage.

6.9 Roguing

Remove off types whenever they are observed, and it is particularly critical during:
Curd/head maturity stage: retain only those plants that conform to standard size, shape and maturity.
Flowering stage: retain plants that are healthy and have uniform flowering. Percentage of off types and seed borne diseases should not exceed 10% and 20% respectively for foundation and certified seeds.

6.10 Pest management

Some of the common and important pest and diseases are discussed here:
Aphids: attacks leaves, flowers, pods and suck the juice. They can be mechanically removed or sprayed with Malathion/ Diazinon 50 EC @ 2 ml per liter of water.

Caterpillars: feed on leaves during the vegetative production and feeds on branches, pods, and twigs during the pod formation stages. Caterpillars can be hand-picked or controlled by spraying Malathion/ Diazinon 50 EC @ 2 ml per liter of water.

Sclerotina rot: appears from the beginning of flowering on the main stem and branches. The symptoms are firstly a grey irregular oval blotch appears at the dividing places of branches, secondly becomes blackish rot and blights withering whole upper parts of the plant. This is most serious disease in cabbage seed production and also an important pathogen in seed quarantine.
Spray wettable copper or copper-based fungicides such as copper oxychloride.

6.11 Harvesting and seed extraction

Seeds should be harvested before pods split but should be fully matured since seeds do not ripe after harvest. Seeds are usually ripe when 60 to 70% of the pods turn brown. If need be, selective harvesting of seeds should be done. Seeds are extracted by threshing with sticks or using machine in advance countries.

6.12 Cleaning, drying, curing and storage

Once extracted, seeds should be properly cleaned and the seed lot should not contain more than 2% inert material. For better viability seeds are dried under shade, cooled, treated with 1.5g of Thiram per kg of seeds, packaged in plastic pouch and store in refrigerators. If properly stored, cole crops seeds remain viable up to 5 years.

6.13 Seed multiplication ratio

One gram of broccoli contains approximately 215 seeds, cabbage 210 and cauliflower 300 seeds. One acre of cold crops yields about 190 kg of seeds.

C. Root crops seed production

1.0 Background

Carrot (*Daucus carota* L.) belongs to Apiaceae and radish (*Raphanus sativus* L.) belongs to Brassicaceae. They are two of the most important root crops in Bhutan. The other members of the group are turnip (*Brassica rapa* L.) and beet (*Beta vulgaris* L.).

i. Carrot: Carrot is grown in wide range of elevation barring very hot places. However, for ideal growth and development temperature range of 15 - 18^{o}C is required. Carrot has compound umbel comprising primary, secondary, tertiary and quaternary umbels. Flowers are borne mainly by primary umbel. Carrots are usually self-sterile and cross pollinated. For seed production, the area should be free of wild carrot Queen Anne's lace as they easily cross-pollinate. Carrot like radish is insect pollinated.

ii. Radish: Radish is of mainly two types, annual and biennial. Annuals are of tropical in origin and do not require chilling for flowering. Biennial which is common in Bhutan are temperate in nature and require chilling for flowering and seed production. Inflorescence is typical terminal raceme, and flowers are white. Radish fruits differ from other crucifers in that it is not siliqua but pod. It is highly cross-pollinated crop. However, it crosses only among the radishes and not with turnip.

Varieties

Total of 8 varieties have been released and recommended for commercial cultivation in the country (Table 35).

Table 35: Released varieties of carrot and radish in Bhutan

Crop	Variety	Potential yield (t/acres)	Maturity (days)
Carrot	Early Nantes	4-6	80-90
	Nisa	4-6	90-100
	Wengkhar Lhapu Maap	14	105
	New Khuruda	8-9	100-110
	All Seasons Cross (Hybrid)	8.9-10	110-120
	Spring Tokinashi	8-10	50-80
Radish	Minowase	9-10	50-60
	Bajo laphu 1 (Hongkong White)	12-20	45
	Spring Tokinashi 35 days	9-10	50-60

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs)

Table 36: National seed production scheme of root crops

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs)
- Seeds should be genetically pure or true to type: for this purpose, follow either of these practices: Do not grow plants of different varieties of the same species within the isolation distance of 1600 m for carrot and 600 m for radish or time isolation of at least 15 days must be followed
- Caging of plants or cultivation under protected condition with occasional opening for pollination by insects must be practiced
- Moisture content should be 6% for radish and 8% for carrot
- Purity of seeds should be 95% for carrot and 98% for radish
- Germination percent should be more than 80% for carrot and 90% for radish
- ARDCs will provide 0.5 kgs of carrot and 2 kgs of radish seeds to NSC after release of new variety and every after 3 years for carrot and 5 years for radish if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by National Seed Centre
- Maintain isolation distance of 1000 m for carrot and 1600 m for radish. Alternatively, follow time isolation of at least 15 days or produce under net house condition with occasional removal of nets for insect pollination
- Moisture content should be 6% for radish and 8% for carrot
- Purity of seeds should be 95% for carrot and 98% for radish

- Germination percentage should be at least 60% for carrot and 70% for radish
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 800 m for carrot and 1000 m for radish. Alternatively, follow time isolation of 10 days or produce under net house with occasional removal of nets for insect pollination
- Moisture content should be 6% for radish and 8% for carrot
- Purity of seeds should be 95% for carrot and 98% for radish
- Germination percentage should be at least 60% for carrot and 70% for radish

6.0 Agronomic principles of seed production

6.1 Climate

Carrot has wide range of adaptability. However, best growth and development can be achieved when mean temperature is 15 - 18^{o}C. Radish is a low temperature long day plant, therefore, needs to go through vernalization and photoperiodism in order to produce flowers and seeds. For flower induction, it requires low temperature (vernalization) and for its flower and seed development it requires some extent of long day length (photoperiodism). Temperature above 32^{o}C often leads to drying of pollen and failure in germination.

6.2 Land requirement

Root crops require well drained soil free of clods for proper root development. Excess nitrogen leads to branching, and development of hairy and fibrous roots. Clay soils are not suitable for root development. Preferably, soil pH should be in the range of 6.5 - 7.5.

6.3 Seed rate

Though it depends on spacing, normally 470 gm for carrot and 2.8 kg for radish are recommended per acre of land.

6.4 Spacing

Carrot and radish are directly seeded and should not be transplanted. Spacing of 30 x 7 cm and 30 x 15 cm is commonly practiced for carrot and radish respectively. Though the sowing time is site specific, it is usually done from mid-August to September.

6.5 Irrigation

Irrigation depends on the condition of the soil. However, soil should not be dry and it is critical to provide irrigation during flowering and seed development stages.

6.6 Nutrient management

It depends on the nature of the soil. However, in general, for one acre of land, 8 kg of N, 4 kg of P and 44 kg of K are applied in addition to 3 MT of FYM for carrot. For radish, 20 kg each of NPK and 5 MT of FYM are applied. FYM should be properly decomposed. Undecomposed organic materials often lead to forking or deformed roots.

6.7 Method of seed production

In root crops, both seed to seed and root to seed methods of seed production are followed. Ideally, root to seed method of seed production is recommended since roots of required standard can be selected. In carrot and radish, selection of root is critical as it determines the quality and yield of the crop in *root to seed production* method. Root selection should be done 40 - 45 days after sowing when 60 - 70% of root development has occurred and general quality features of the roots have expressed. Roots should conform to the given parameter of a variety such as colour, shape and size among others. Select the desired roots and give slant cut (about 50% of the size) and plant them vertically.

Carrot: In European types, root should be cylindrical and orange in colour, and in Japanese type, root should be conical and deep orange. Roots should not be forked or with thick absorbing roots.

Radish: Roots should be preferably white, conical in shape and of desired size or in conformity with the given standard of the variety. It should not be branched or have thick roots.

6.8 Field inspection

Field inspection should be done at least four times after 20 - 30 days of sowing to remove off types, at the time of lifting the roots to select roots, during flowering time to remove off types and at maturity select quality and uniform seeds for harvest.

6.9 Roguing

Growing stage: In about a month after sowing, remove off types that do not conform to the growth habit of the given variety and those that are weak and diseased.
Flowering stage: In case of carrot, only 3 - 4 main branches are retained and rest are removed.

6.10 Pest management

Aphids: attacks leaves, flowers and pods in radish. They can be mechanically removed or sprayed with Malathion / Diazinon 50 EC @ 2 ml/ liter of water.

Caterpillars: feed on leaves during the vegetative production and feeds on branches and twigs. Caterpillars can be hand-picked or controlled by spraying Malathion/ Diazinon 50 EC @ 2 ml/ liter of water.

6.11 Harvesting and seed extraction

In carrot, optimum time for harvesting is when the seeds on the umbel turn bright yellowish to brown. Ripened umbels look swollen in the centre filled tightly with large seeds while umbels that are not filled properly shows curving inward. Never collect seed umbels from dried or diseased plants. The ripened umbels are harvested from the plants cutting each umbel one by one keeping 10-15 cm of their stem. Seeds are extracted by threshing the umbels. In radish, seed can be allowed to mature fully on the plants since there is no natural dehiscence or harvest when 70% of the plants turn yellow. Plants are cut and brought to the threshing place to dry for 7 - 10 days, and then seeds are extracted by beating with sticks.

6.12 Cleaning, drying, curing and storage

Once seeds have been extracted, they are cleaned (never winnow in carrot since seeds are very light), dried and stored. Impurity should not be more than 2 - 5% and seeds should be dried below 8% moisture content. If properly stored, carrot seeds can be stored up to 3 years and radish for 4 - 5 years.

7.0 Seed multiplication ratio

One-gram of carrot seeds contains approximately 640 seeds and 50 seeds in radish. One acre of carrot yields approximately 240 kg and radish 300 kg of seeds.

D. Bulb crops seed production

1.0 Background

Bulb crops mainly comprises bulb onion, green onions, welsh onion, garlic, leek and shallot. Among these, bulb onion and garlic are two of the widely grown bulb crops. Thus, in this manual only bulb onion and garlic seed production methods are discussed:

i. Onion

Onion is one of the most economically important crops under bulb crops. The common onion, *Allium cepa* L can grow from tropical to temperate zones. Bulb onion is normally grown for consumption of basal portion of the leaves that thicken to form bulb, though upper portion of the leaves can also be consumed at tender stage. In terms of photoperiodism, onion varieties can be classified as long day (> 14 hours), intermediate (10 - 12 hours) and short-day (8 - 10 hours). Flowers are borne in simple umbels at the apex of floral stem. It is a cross pollinated crop and mainly pollinated by honey bees. Onion is a biennial crop in that it takes almost two years to produce seeds: bulb formation takes place in the first year and seeds in the second year. Seeds are small, black and irregularly shaped.

Varieties

Total of 4 varieties have been released/ notified for commercial cultivation as described in Table 37.

Table 37: Released varieties of onion in Bhutan

Variety	Potential yield (t/acre)	Maturity (days)
Bajogop 1 (Red Creole)	7–8	120-140
Bombay Red	4-6	110-160
Senshu Red	7	120-170
White Creole	5-7	120 - 160
Pune red	4-6	110-120

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs)

Table 38: National seed production scheme of bulb crops

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs)
- Seeds should be genetically pure or true to type: for this purpose, follow either of these practices: Onion is cross pollinated and should maintain more than 1000 m isolation from different varieties of the same crop or time isolation of at least 20 days must be followed
- Bulb to seed method is preferred over seed to seed
- Caging of plants or cultivation under protected condition with occasional opening for pollination by insects (or hand pollination) may be practiced
- Moisture content should be less than 10 %
- Purity of seeds should be 99 %
- Germination percent should be more than 90%
- ARDCs will provide 1.5 kgs of seeds to NSC after release of new variety and every after 2 years if required by NSC

4.0 Specific methods for foundation seed

- Breeder seeds should be the source of foundation seeds and will be maintained by NSC
- Maintain isolation distance of 1000 m or follow time isolation of at least 15 days or produce under net house
- Moisture content should be maximum of 10 %
- Purity of seeds should be 99 %
- Germination percentage should be at least 70 %
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 500 m or follow time isolation of 15 days or may produce under net house
- Moisture content should be maximum of 10 %
- Purity of seeds should be 99 %
- Germination percentage should be at least 70 %

6.0 Agronomic principles of seed production

6.1 Climate

Onion has wide range of adaptability and thus can be grown from tropical to temperate zones. However, for flower differentiation, cool temperature is required. Mean temperature of 12 - 15^{o}C promotes seeds stalk initiation and thus normally short-day condition favours seed production. On the contrary, mean temperature of 20 - 22^{o}C favours vegetative growth. However, sudden rise in temperature could lead to early maturity leading to formation of small sized bulbs.

6.2 Land requirement

Onion can grow on wide range of soils. However, sandy loam, silty loam and deep friable soils that can retain enough moisture are ideal. Heavy soil with waterlogged conditions is not suitable and pH of 6 - 7 is preferred.

6.3 Seed rate

Though it depends on spacing, normally 1 - 2 kg is more than enough for an acre of land.

6.4 Spacing

Seeds are sown at 1 cm depth in rows about 10 cm apart on the nursery bed. When the seedlings are 4 - 5 weeks old with 3 - 5 well-formed leaves, transplant them. Seedling should not be transplanted deeper than 2.5 cm. Seedlings are transplanted at a spacing of 45 x 30 cm. The transplanting season depends on the site and variety but generally September - October is the recommended time.

6.5 Irrigation

Uniform irrigation is required throughout the season. However, most critical stage to provide irrigation is right after transplanting and during bulb formation. At bulb maturity, irrigation may be withheld for better postharvest quality.

6.6 Nutrient management

It depends on the nature of the soil. However, in general, for one acre of land, 8 MT of FYM, 20 kg of N, 30 kg of K and 30 kg of P are recommended.

6.7 Method of seed production

Two methods of seed production are practiced: bulb to seed and seed to seed.

6.7.1 *Bulb to seed*

In this method, bulbs are produced in the first year. Bulbs are selected as per the desired horticultural traits (size, uniformity and no bolting) and then stored in properly ventilated place. In the following year, the selected bulbs are planted in the field to produce high quality seeds. The method is recommended for production of high-quality basic seeds. Bulbs are ready to be harvested when there are 75 % neck falls. Irrigation should be stopped at least 2 weeks before the bulb harvest. Bulbs are harvested with neck attached and kept under shade for 3 - 4 days for curing, and then necks are cut about 2 cm above the bulb. Bulb with typical colour with medium size (4-5 cm) are selected and stored in well ventilated room for seed production.

6.7.2 *Seed to seed*

This is also one of the common methods to produce seeds. In this method, plants are left in the field to produce flower stalks and seed formation. Plants that are healthy and show uniformity in flowering are tagged and seeds harvested. However, in this method unlike in bulb to seed method, selection of plant with desired bulb characteristics is not possible.

6.8 Field inspection

Minimum of three inspections should be made: before flowering, flowering stage and then at maturity.

6.9 Roguing

Usually, three rounds of roguing are practiced: once to remove volunteer and off type plants especially those that bolts too early, second at the time of flowering to remove off types and retain only those that are healthy and uniform in flowering, and finally at maturity stage to select plant with desired bulbs characteristics.

6.10 Pest management

Purple Blotch and Rust

It is one of the most common problems in onion and garlic. Spray with fungicide Mancozeb at the rate of 2 gm per litre of water. The infected crop residue is reported to be source of infection. Therefore, farmers should remove all the crop residues after harvest. Alternatively, crop rotation also minimizes the occurrence of the disease.

6.11 Harvesting and seed extraction

Plants do not mature at the same time. Hence 2 - 3 times of harvest may be required. Seeds are easily shattered and thus must be harvested before shattering. Seeds are usually harvested when 50 % of the black seeds are exposed on the umbels. Umbels are dried and seeds extracted by threshing.

6.12 Cleaning, drying, curing and storage

Once extracted, seeds are soaked in water for 2 - 3 minutes in a bucket. Heavy and healthy seeds settle to the bottom and inert materials and unhealthy seeds float which should be discarded. Then, seeds are dried, preferably in shade up to 10 % moisture content and stored in porous materials like cloth or paper bags in well aerated place. Impurity should not be more than 1 %.

7.0 Seed multiplication ratio

One gram of onion contains approximately 460 numbers of seeds. One acre of onion can yield about 260 kg of seeds.

ii. Garlic

1.0 Background

Garlic, *Allium sativum* L is hardy plant and requires cool and moist condition for growth and relatively dry period during bulb formation. Garlic has higher nutritive value than other bulb crops. It is rich in proteins, phosphorus, potassium, calcium, magnesium and carbohydrates. It also contains ascorbic acid. It is exclusively propagated through cloves or bulbils.

Varieties

Till date, there is only one local selection for garlic (table 39)

Table 39: Variety of garlic

Variety	Potential yield (t/acre)	Maturity (days)
Local selection	4 – 6	230-250

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs)

Table 40: Seed class and responsibility

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs)
- Bulb size of 8 - 10 cm in diameter is preferred
- Isolation distance of at least 5 m must be maintained
- Bulbs characteristics that do not conform to required standard should not be more than 0.1%
- ARDCs will provide 150 kgs of bulbs to NSC after release of new variety and every after 5 years if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by NSC

- Maintain isolation distance of about 5 m
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of up to 5 m

6.0 Agronomic principles of seed production

6.1 Climate

Garlic is a hardy crop and requires cool and moist condition during vegetative growth and relatively dry condition during bulb formation. Longer days with high temperature favours bulb formation and critical day length is about 12 hours.

6.2 Land requirement

Garlic can grow on wide range of soils but does well in fertile, well drained loamy soil. Ideal pH ranges from 6 - 7.

6.3 Seed rate

The bigger cloves from outside the bulb are usually selected. Though it depends on the spacing, normally 280 kg of cloves are recommended for one acre of land.

6.4 Spacing

Spacing of 30 x 15 cm is maintained, and usually planted from March - April though like onion, it can also be planted from September - October.

6.5 Irrigation

Garlic requires irrigation at regular interval and especially during vegetative and early stages of maturity. However, irrigation after long spell of dryness results in splitting of bulbs and excessive irrigation may lead to sprouting of bulbs. Irrigation should be withheld few weeks before the harvest.

6.6 Nutrient management

It depends on the nature of the soil. However, in general, for one acre of land, 10 MT of FYM, 40 kg of N, 20 kg of K and 20 kg of P are recommended.

6.7 Method of seed production

Though plants flower in some cases, seed production does not happen. Hence, cloves are exclusively used as seeds. Healthy and compact bulbs with uniform shape and size are selected. Then, cloves with diameter of 8 - 10 cm are selected as seeds since they give better yield and quality. Selected cloves are sown at a spacing of 30 x 15 cm.

6.8 Field inspection

Minimum of three inspections should be made at: vegetative growth, bulb formation and maturity stage.

6.9 Roguing

In the early stages diseased, weak and off types are rogued off and at maturity stages those plants with uniform growth and desired bulb characteristics are maintained.

6.10 Pest management

Purple Blotch and Rust

It is one of the most common problems in onion and garlic. Spray with fungicide Mancozeb at the rate of 2 gm per litre of water. The infected crop residue is reported to be source of infection. Therefore, farmers should remove all the crop residues after harvest. Alternatively, crop rotation also minimizes the occurrence of the disease.

6.11 Harvesting

Plants are ready to harvest when the tops turn yellow to brownish and plants have fallen over. Bulbs are usually harvested along with tops.

6.12 Cleaning, drying, curing and storage

Once harvested, bulbs are properly dried to remove excess moisture, and then must be cured for 7 - 10 days in the shade to further remove moisture and enhance compactness of bulbs. Curing is done either with 2.5 cm of the tops retained above the bulb or by retaining full tops. Properly cured bulbs are stored in well ventilated rooms or stored by hanging with dried tops in a well-ventilated room.

7.0 Seed multiplication ratio

Though it depends on variety and method of cultivation, usually one kilogram of garlic contains approximately 500 cloves, and from one acre of land, 3 MT of garlic can be produced.

E. Leafy vegetable seed production

Leafy vegetables grown in our country include mustard green, pak choi, chinese cabbage, lettuce, spinach, leafy beet, etc.

i. Mustard Green (Local name: Saag, Hoentshe, Momshabu)

1.0 Background

Mustard green (*Brassica juncea*) belongs to the family Brassicaceae, the same family as that of cole crops. The economic plant part is the leaves, which is used for culinary purpose. Most of introduced and released varieties available in Bhutan have broad leaves and thicker mid veins while the local lines are less broad with thinner mid veins. The inflorescence is an elongated raceme, borne terminally on the main stem and branches. The flowers are usually bright yellow, though colours may vary from orange to pale yellow depending on variety.

Varieties

The varieties available for cultivation in our country are all open pollinated. The varieties released and available for cultivation are enlisted in Table 41.

Table 41: Released varieties of mustard green in Bhutan

Variety name	Release name	Year of release	Releasing agency	Recommended agro-ecology
Him Beauty	Him Beauty	1990	NASEPP/NSC	1200-2600
Takana Red	Takana Red	1990	NASEPP/NSC	1200-2600
Taisai	Taisai	1990	NASEPP/NSC	1500-2600
Neguna	Neguna	1990	NASEPP/NSC	1200-2600
Mayuri Green	Wengkhar Peytshe 1	2004	ARDC-Wengkhar	600-2600
Red Rayo	Wengkhar Peytshe 2	2004	ARDC-Wengkhar	600-2600

2.0 National seed production scheme

The Seed production scheme will consist of breeder seeds maintenance by the respective Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and or Registered Seed Growers (RSGs).

Table 42: National seed production scheme of mustard green

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

Breeder seeds will be maintained by the releasing agencies ARDCs. Seeds should be genetically pure or true to type. For this purpose, follow either of these practices: do not grow other leafy vegetables or crops of the same species and/or different varieties of the same crop within the isolation distance of 400 m for mustard green and 1000 m for spinach to avoid small amount of natural cross pollination that can occur in the range of 1- 6% or time isolation of at least 20 days must be followed

- Cultivation under protected condition with occasional opening for pollination by insects (or hand pollination) must be practiced
- Moisture content should be 7- 8 %
- Purity of seeds should be more than 98 %
- Germination percent should be more than 85 %
- ARDCs will provide 0.4 kg of seeds to NSC after release of new variety and every after 5 years if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by the NSC
- Maintain isolation distance of 400 m (mustard green) and 1000 m (spinach) or follow time isolation of at least 20 days or produce under net house.
- Moisture content should be less than 8 %
- Purity of seeds should be 98 %
- Germination percentage should be at least 70 %
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds will act as the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies

- Maintain isolation distance of 200 m (mustard green) or 800 m (spinach) or follow time isolation of 15 days or may produce under net house
- Moisture content should be less than 8 %
- Purity of seeds should be 98 %
- Germination percentage should be at least 70%

6.0 Agronomic Principle of Seed Production

6.1 Climate

Seed production of mustard green is easy compared to other vegetables due to its short duration. An ideal situation for seed production would be a place with warm winters and less rains at harvesting time. It grows well in mean annual temperature of 6 - 27˚C and mean annual rainfall of 500 - 4200 mm.

6.2 Soil

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. It can tolerate a pH of 4.3 - 8.3.

6.3 Seed Rate and Spacing

Seed rate is 250 - 500 gm per acre and plant spacing of 40 x 60 cm is optimum.

6.4 Methods of seed production

The seed production of mustard green can be done through two types of methods viz., direct sowing and transplanting methods.

6.4.1 *Direct Sowing method*

The normal sowing time of mustard green in Bhutan for seed production at an altitude of 1400-2000 m asl is coinciding with the winter vegetable production season. The sowing time starts from August - September depending on the elevation of the seed production sites. Earlier sowing is done in the cooler areas while later in the warmer areas. However, the seed production calendar is different for the areas situated at an elevation above 2000 m asl. The seed production for cooler region is carried out in summer due to extreme winters.

The land preparation is as similar to that of other vegetable crops with an addition of adequate FYM. Sow the seeds maintaining a row to row spacing of 80 - 90 cm and plant to plant distance

of 20-30cm. About 4-5 seeds per spot can be sown. Linear sowing in lines can also be done but it becomes laborious during thinning process. Then cover the seeds thinly by soil.

6.4.2 *Transplanting method*

It is recommended to follow the transplanting method for seed production due to;

- Strict management of discarding of off-types at the time of transplanting.
- Convenience of rotation in the field.
- Production of uniformly good seeds due to better management.

The only drawback of this method is that it is more labour-intensive than the direct sowing method as it requires extra labour for raising seedlings and transplanting. This is the reason why many farmers opt for the direct sowing method.

6.5 Irrigation

Vegetative and pod formation are the most critical stages for irrigation.

6.6 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, It is advised to apply dolomite powder @ 1.5 Mt per acre.

6.7 Intercultural Operations

The intercultural operations similar to that of the normal vegetable production such as weeding, irrigation and fertilization, etc, should be followed. In addition, some of the most important cultural operations that are necessary or critical for seed production of mustard green are as follows:

i. **Thinning of seedlings**: The first thinning of the crops should be carried out when the crop attends 6-7 true leaves. Subsequent thinning shall be done as and when required including the thinning done at the beginning of the spring.
ii. **Staking**: For seed production staking of plants is also recommended.
iii. **Earthing up**: It is recommended to keep the base of the plant warm. Earthing up should be carried out at least twice. The first earthing up should be done during the time of first weeding and the second after the plants have sufficiently bolted in order to avoid lodging.
iv. **Heading back of main flowering branch:** Prune off the terminal growth of main flowering branch down to just above lateral branch by a sharp knife or secateurs. The practice is done mainly to remove apical dominance. This will encourage the growth of side shoots and accordingly result in the production of more flowers and seeds.
v. **Roguing**: The removal of off-types is mandatory and should be done while thinning. Care should be taken to inspect the surrounding fields for other plants that can cross-pollinate with the crop especially at bolting time. Such plants should be removed instantly.

6.8 Major Pests and Diseases management

The most common pests are aphids and leaf eating caterpillars. Powdery mildew is also common disease with the onset of the cool dry season. The pest should be managed using IPM technologies.

6.9 Harvesting, threshing and storage

Seed matures when siliqua dries and turns light brown colour. Seed shattering is common. However, the best time to harvest the plants for seeds is when 80 % of the pods turn yellowish in colour.

Harvest by cutting the plants from the bottom with the seed stalks intact. It is then bundled into 2 - 3 plants and hung on the drying pole for several days in shade. It is not recommended to dry the cut plants on the ground as it may absorb moisture and deteriorate the quality of the seeds. Such seeds are also prone to disease infection and in case of rainfall may lead to germination in pods.

Threshing

Threshing of the seed pods is done after about a week when all the pods are completely dried. There are several methods to thresh seeds. Small harvests can be threshed by rubbing pods between your hands or against a surface to break open. For larger harvests, place whole plants in large tubs or on plastic sheets and thresh with legs. Discard stalks after seeds have been extracted. The threshed seeds are then dried in shade and cleaned by winnowing.

Seed Storage

Sun drying is the best and most common method of drying seeds in the farmer's field. Maintain seed moisture content to about 7- 8% for storage. The dried seeds should be stored in clean airtight containers in cool and shady dry place. For long term use, the seeds can also be stored in refrigerator. However, most of the vegetable seeds can be stored at a temperature below 15^{o} C. When stored in cool dry conditions, seeds can remain viable for six years.

ii. Lettuce

1.0 Background

Lettuce (*Lactuca sativa*), king of salads can be grown easily in the cool climate. It is a nutritious leafy vegetable, rich in mineral and a source of vitamin. Lettuce are ideal plants to produce seeds as they do not cross pollinate, thus, producing true to type plants.

Varieties

There are five released varieties:

- Hogay petshey Thigthra (Flashy trout)
- Hogay petshey Leedo (Biscia Rosa)
- Hogay petshey Hyme (Green Oak Leaf)
- Great Lake
- Hogay petshey Oro (Blushed butter oak)

2.0 National seed production scheme

The Seed production scheme will consist of basic seeds maintenance by the respective Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by nurseries under NSC, and Private Seed Companies (PSCs) and or Registered Seed Growers (RSGs).

Table 43: National seed production scheme

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Agronomic Principle of Seed Production

3.1 Climate

It is a cool weather crop. lettuce germinates at a temperature range of between 15 - 20ºC. Germination may be compromised at temperatures above 25ºC. The ideal temperature range for growth is between 15 - 20ºC. It is more challenging to grow lettuce in summer, as the disease pressure is higher than in winter and the hot conditions may induce bolting in certain cultivars.

3.2 Soil requirement

It requires well drained loamy soil with a pH range of 6 - 6.8

3.3 Nursery

- Prepare well pulverized raised beds measuring 1 m width with convenient length
- Sow seeds during the first week of March
- Sow seeds thinly in lines of 3 on raised beds and irrigate carefully (lettuce seeds are very light and can be easily washed away while irrigating)
- Approximately 250 gm of seeds is sufficient to cover an acre

3.4 Field preparation and transplanting

- Plough fields a week before planting and incorporate well decomposed FYM @ 6 - 8 MT per acre.
- Prepare raised beds of 1m width with convenient length.
- Transplant seedlings in April when it has attained 4-5 leaves.
- Planting space should be maintained at 40 cm between plants and 30 cm between rows (three rows per bed).
- Place the seedlings firmly in the soil and irrigate immediately

3.5 Intercultural operation

Lettuce is a short duration crop and one of the easiest crops to grow. Hoe and weed at least 1-2 times. Lettuce is a high water demanding crop therefore frequent irrigation during spring will optimize the production. Critical stage of irrigation for lettuce is during head development.

3.6 Nutrient management

Fertilizer requirement depends on the soil fertility status. However, 22.67 kg of N, 90 kg of K and 136 kg of P per acre is generally recommended.

3.7 Pest and disease management

Some of the pest and diseases include downy mildew, cottony rot, aphids and greenhouse white fly. These pests should be managed using IPM technologies.

3.8 Harvesting, processing and storage

Harvesting for seeds can be done when two-thirds of the flowers on the stalk has turned fluffy white, approximately about 2 - 3 weeks after flowering. Immature seeds are usually greenish and flatter than fully matured ones. It is best to collect the heads when the seeds have matured but the heads have not fully dried. The seed can be harvested from a single plant by shaking their heads

into a bag. This should be done in 2 - 3 days or you can harvest the whole plant and put it on mat in shade. Seed will continue to ripen and shatter.

Seed Processing

After drying seeds for 2 – 3 days in shade, stripping and crushing the plant is essential. It can be done by rubbing the seeds with hands to extract seeds and to separate from chaff. Separate again by winnowing.

Storage

Lettuce seeds remain viable up to 3 years under ideal condition. Store seeds in jars, cloth or mesh bags or foil envelopes. Protect from direct sun. Refrigerate the seeds below 15^{o}C to prolong the seed viability.

F. Solanaceous vegetable seed production

i. Chilli (Hot pepper- *Capsicum frutescens* L.) & Capsicum (Sweet pepper-*Capsicum annuum* L.)

1.0 Background

Capsicum and Chilli (*Capsicum annuum* and *Capsicum frutescens*) commonly known as sweet pepper and hot pepper are commercially important crops of the family Solanaceae. Capsicum and chilli are often self-pollinated crops, but cross-pollination occurs to the extent of 7 – 36 % mainly through insects. Seeds should be allowed to set by self-pollination. The flower is protogynous. Anther dehisces only ½ - 5½ hours after stigma becomes receptive. Anthesis in chilli occurs between 6.00 - 9.00 hr. Flower remains open for 2 - 3 days, receptivity of stigma is the highest on the day of flower anthesis. Optimum temperature required for pollination is about 20 – 25ºC.

Table 44: Released variety of chilli in Bhutan

Sl.No.	Crop (Variety)	Variety/Breeding Line (s)	Year of release	Releasing Agency
1	California Wonder	California Wonder	1990	ARDC-Bajo
2	Sha Ema	Paro Local	1990	NSC
3	Super Solo	Big Round	2004	ARDC-Wengkhar
4	Yangtse Ayema		2007	ARDC-Wengkhar

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by registered nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs).

Table 45: National seed production scheme of chilli

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs). Seeds should be genetically pure or true to type

- Land to be planted with chili shall be free of volunteer plants.
- Do not grow other crops of the same species or different varieties of the same crop within the isolation distance of 500 m
- Cultivation under protected condition (green house/white net house) with occasional opening for pollination by insects (or hand pollination) must be practiced
- Moisture content should be 6 - 8 %
- Purity of seeds should be more than 98 %
- Germination percent should be more than 80 %
- ARDCs will provide 0.4 kg of seeds to NSC after release of new variety and every after 5 years if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by NSC
- Maintain isolation distance of 500 m in open condition or produce under greenhouse/net house
- Moisture content should be less than 6 – 8 %
- Purity of seeds should be 98 %
- Germination percentage should be at least 60 %
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 250 m or follow time isolation of 15 days or may produce under net house
- Moisture content should be less than 6 - 8 %
- Purity of seeds should be 98%
- Germination percentage should be at least 60 %

6.0 Agronomic principles of seed production

6.1 Climate

Chilli requires warm and humid climate with temperature range of 20 – 25^{o}C. It requires sufficient moisture in the soil during flowering and fruit formation. Dry soil condition leads to flower and fruit drop. Too much moisture in the soil will cause root rot. Under rain-fed condition it requires about 600 - 700 mm annual rainfall.

6.2 Land requirement

The land should be free from volunteer plants and weeds. There should be at least 2 years interval between the related crops cultivated in the selected land. The soil should be fertile, free from soil borne diseases with good drainage.

6.3 Isolation distance

Under open field conditions, minimum isolation distance of 500 m for foundation/hybrid seed and 250 m for certified seed production are necessary. It is highly recommended to grow in green house and net house to avoid cross-pollination.

6.4 Seed selection and sowing

Seeds should be healthy and free from disease and pest infection. Remove broken, coloured seeds and use uniformly graded seeds. Selected seeds should be treated appropriately to protect the crop from seed borne diseases. Treat seeds with laundry bleach (4 - 5%). Seeds can also be coated with ash and ash water. Seeds are also sterilized by dipping seeds in warm water (50^{o}C) for 10 minutes before sowing.

6.5 Seed rate

Seed rate is 400 gm per acre.

6.6 Nursery 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. Prepare the beds of 20-25 cm high with 1 m 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

6.7 Field Preparation

There are different ways to prepare the field.
The main field should be ploughed thoroughly for 4 - 5 times to get proper tilth before transplanting.

Bed preparation and transplanting (rainy season)

Prepare raised bed of 25-30 cm high with 1m 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 1m width and convenient length depending upon the size of the field.

6.8 Transplanting

The seedlings of 35 - 40 days old are ready for transplanting. The seedling should be approximately 20 – 25 cm tall and have 3 - 4 leaves on the main stem. Transplanting may be done on the ridges in the evening. The treated seedlings should be transplanted to the main field. The spacing followed is 60 x 45 cm for hot pepper and 45 x 30 cm for sweet pepper.

6.9 Weeding

Weeding is most important during the early stages of the crop. Manual weeding is most preferred. The crop should be hoed twice at 15 days interval starting from 30 days after transplanting. Weeding should be done after 20 and 45 days following transplantation.

6.10 Irrigation

First irrigation is done immediately after sowing. After transplanting keep the soil wet at least for 3 days. Subsequent irrigation should be done once a week or 10 days depending on the soil moisture. Irrigation during flowering and fruit setting stages are very crucial.

6.11 Nutrient

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.

6.12 Roguing

Roguing should be done from early vegetative phase up to fruiting stage. Diseased plants and off-types should be rogued off periodically. Maintain about 10 - 20 fruits per plant.

6.13 Field inspection

A minimum of 3 field inspections should be done from flowering to harvesting stages. The first inspection is done before flowering in order to verify isolation, volunteer plants, and other relevant factors; second during flowering stage to check off-types and other relevant factors. The third

inspection is carried out at maturity stage or prior to harvesting to verify true nature of plant and other relevant factors.

Table 46: Field standards of foundation and certified seeds

Parameters	Foundation seed	Certified seed
Isolation distance (max)	500m	250m
Off types (max)	0.10%	0.20%
Plants affected by seed borne diseases (max)	0.10%	0.50%

Table 47: Seed standards for foundation and certified seeds of chili

Factors		Classes of seeds	
		Foundation seeds	Certified seeds
Pure seed (min)		98	98
Inert matter (Max)		2	2
Other crop seeds (Max)		.05	.1
Weed seeds		.05	.1
Germination (min)		60	60
Moisture content (max)			
i)	Ordinary container	8	8
ii)	Vapor proof container	6	6

6.14 Pest and disease management

Capsicum and chilli are commonly affected by pests and diseases like damping off, fruit rot, aphids, whitefly, hoppers, mites, thrips, etc., during different growth stages of the crop.

Thrips and aphids can be controlled by spraying Dimecron (systemic pesticide), pod borer can be controlled by spraying Nuvacron and the mites can be controlled by spraying Kelthane. The major diseases affecting the plants are die-back or fruit end rot, powdery mildew and bacterial leaf spot. Spray Dithane M-45 for control of die back, Karathane for powdery mildew and Agromycin for leaf spot disease control.

6.15 Harvesting, processing, seed extraction, drying and storage

Harvesting is done once the fruits are physiologically mature and turns from green colour to red. The matured fruits are harvested by hand picking.

Harvesting should be done in different pickings. The well ripened fruits with deep red colour should be collected in each picking. After harvest, fruit rot infected fruits are to be discarded. The

harvested pods are dried under shade for 1 - 2 days and then under sun for another 2 or 3 days. Before drying, pods are to be selected for true to type and graded for seed extraction. The seeds are extracted from graded dried pods. The pods are taken in gunny bag and beaten with pliable bamboo sticks. The seeds are cleaned by winnowing and dried to 10 % moisture content on tarpaulin.

Drying and storage

The extracted seeds should be dried in the shade for a few days before storage to attain a moisture level of 8 %. The dried seeds should be packed in cloth bags or moisture proof containers and stored in a dry and cool place (0 to 8^{o}C). When the seeds are kept under the cold, dark and dry storage conditions, they will remain viable for up to five years.

7.0 Seed multiplication ratio

One gram of chilli seed contains approximately 200 seeds. The seed multiplication ratio is 1:240.

ii. Tomato (Solanum lycopersicum)

1.0 Background

Tomato (*Solanum lycopersicum*) belongs to the genus Lycopersicon under Solanaceae family. Tomato is one of the most highly consumed vegetables and is used for soup, salad, pickles, ketchup, puree, sauces, etc., Tomato can be grown in a variety of geographical zones in open fields or greenhouses. Tomato plants can be indeterminate or determinate in their growth habits. Tomato flowers are yellow in colour and are perfect, regular and hypogynous and are borne on inflorescences that may be either determinate (cymose) or indeterminate (racemose), depending on the species.

Varieties

There are 3 released varieties of tomato in Bhutan as shown in table 48.

Table 48: Varieties of tomato released in Bhutan

Sl. No.	Crop (Variety)	Variety/Breeding Line (s)	Year of release	Description	Releasing Agency
1	Roma	Roma	1990	Determinate, dwarf with oval fruit	ARDC-Bajo
3	Cherry tomato	CHT160	1999	Indeterminate with round fruit	ARDC-Bajo
4	Bajo Lambenda 1	Rattan	2002	Determinate with round fruit	ARDC-Bajo

2.0 National seed production scheme

Seeds production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by registered nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs).

Table 49: National seed production scheme of tomato

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods of breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs). Seeds should be genetically pure or true to type
- Land to be planted with tomato shall be free of volunteer plants
- Do not grow other crops of the same species or different varieties of the same crop within the isolation distance of 50 m
- Cultivation under protected condition (green house/white net house) with occasional opening for pollination by insects (or hand pollination) must be practiced
- Moisture content should be 6 - 8%
- Purity of seeds should be more than 98 %
- Germination percent should be more than 85 %
- ARDCs will provide 0.4 kg of seeds to NSC after release of new variety and every after 5 years if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by NSC
- Maintain isolation distance of 50 m in open field or produce under greenhouse/net house
- Moisture content should be less than 6 - 8%
- Purity of seeds should be 98 %
- Germination percentage should be at least 70%
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 25 m or follow time isolation of 15 days or may produce under net house
- Moisture content should be less than 6 -8 %
- Purity of seeds should be 97 %
- Germination percentage should be at least 70 %

6.0 Agronomic Principles of seed production

6.1 Climate

Tomato requires a long and warm growing season and is sensitive to either very hot or cold growing temperatures. The ideal temperature required for tomato is between 15^{o} - 25^{o}C for fruit

setting. It can be grown at elevation from 300 masl up to 2200 masl. In areas below 1000 masl tomato are grown as winter crop (September- December). In areas between 1000 - 1500 masl it is grown as summer crop (March to June). In areas above 1500 masl it is grown from April - September. Tomato is mainly grown as winter crop in the lower foothill. However, in the inner Himalayas it can be grown as a summer crop.

6.2 Land requirement

Selection of suitable land is important especially for seed production where previous crop grown should not be of the same family (chilli, egg plant, potato etc.) to avoid cross-pollination from volunteer plants. The land should be tilled twice to make the soil fine.

6.3 Isolation requirement

Tomatoes are 50% self-pollinating and 50% insect pollinated crop. Therefore, under open field conditions, varieties require minimum isolation distance of 50 m for foundation seed and 25 m for certified seed. For hybrid seed production, it requires minimum of 200 m for foundation and 100 m for certified seeds. It is highly recommended to produce seed in green house and net house to avoid cross-pollination.

6.4 Seed selection and sowing

Seeds should be healthy and free from disease and pest infection. Remove the broken, coloured seeds and use uniformly graded seeds. Selected seeds should be treated appropriately to protect the crop from seed borne diseases. Treat seeds with bleach (4 - 5%). Seeds can also be coated with ash and ash water. Seeds are also sterilized by dipping seeds in warm water (50^oC) for 10 minutes before sowing.

6.5 Seed rate

Seed rate is 150 – 200 gm per acre. Sow nursery in 50 m^2 to transplant one acre.

6.6 Nursery preparation

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.

6.7 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.

6.8 Transplanting

The seedlings of 40 - 45 days old are ready for transplanting. Select seedlings with short internodes having 6 - 7 leaves on the main stem. Transplanting may be done on the ridges. Transplant the seedlings on the raised beds with the row to row distance of 50 cm and plant to plant 40 cm. Use either plastic mulch or paddy straw.

6.9 Weeding

Keep away weeds both in the nursery as well as in the main field. Frequently weed the field to keep it free from unwanted plants that will compete for water, air, light and nutrients. Avoid disturbance of plant roots during weeding.

6.10 Irrigation

Irrigation frequency will depend on factors such as; weather, soil type and method of irrigation. It is important to keep the soil moderately moist after transplanting to encourage vegetative growth. Irrigation is given immediately after transplanting and continued for 2 - 3 days. Subsequent irrigation may be given after 6 - 7 days during summer and 4 - 5 days during dry season. Generally, 14 - 15 times irrigation is necessary throughout its growing stages. After the fruit set, maintain uniform soil moisture to avoid blossom end rot and fruit cracking. Light irrigation is required towards the time of harvest to avoid diseases. It is important to maintain proper drainage to avoid standing water around the root area. Avoid showering on leaves.
Using paddy straw or saw dust mulch improves yield, soil health and conserves soil moistures.

6.11 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.

6.12 Branch and fruit control

All indeterminate varieties are trained with wires, strings or stakes to prevent lodging and loss of fruits by coming in contact with soil. It is done by providing individual stake or by stretching jute ropes on 2 - 2.5 m long bamboo poles erected on either side of ridges. 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. Removal of unwanted shoots enhances plant vigour. Remove first flower. Maintain about 5 - 10 fruits per plant.

6.13 Roguing

Roguing is done from the seedling stage until harvest. Off-types and plants affected by early blight, leaf spot and mosaic diseases should be removed from the seed production field.

6.14 Field inspection

A minimum of three field inspections should be made: First at vegetative phase, second at flowering and fruiting stage, and third before harvesting of fruits.

Table 50: Field standard for foundation and certified seed

Parameters	Foundation seed	Certified seed
Isolation distance (max)	50m	25m
Off types (max)	0.1%	0.2%
Plants affected by seed borne diseases (max)	0.1%	0.5%

Table 51: Seed standard for foundation and certified seed

Factors	Classes of seeds	
	Foundation seeds	Certified seeds
Pure seed (min)	98	97
Inert matter (Max)	2	2
Other crop seeds (Max)	.05	.1
Weed seeds	None	None
Germination (min)	70	70
Moisture content (max)		
i) Ordinary container	8	8
ii) Vapor proof container	6	6

6.15 Harvesting, seed extraction, drying and storage

Tomato fruits are harvested after full maturity. The fruit from first harvest and last harvest is not recommended for seed extraction since they have better vigour and viability. For seed purpose fruit from 6 - 7 harvest lots is kept for seed extraction. Fruits harvested for seed extraction should be graded for true to type and medium to large size fruits for higher recovery of quality seeds.

Seed extraction

The extraction of seeds from ripe fruits is done by fermentation method and acid method. In fermentation method, the crushed fruits are allowed to ferment for 1-2 days and then put in water where the pulp and skin float and the seeds settle down at bottom.

In acid method, the fruits are crushed into pulps in a plastic bucket (do not use zinc and iron container). Then add 100 ml of hydrochloric acid per 14 kg of crushed tomato fruits. 1 – 2 times stirring is necessary in between. This will facilitate the separation of seed and pulp. After 30 minutes, the seed separated out from the pulp settle down at the bottom of the bucket and then the floating fraction is removed. The settled seeds should be washed with water for 3 - 4 times. The washed seeds are dried in a partial sun light

Drying and storage

After proper drying, the seeds should be processed to maintain high vigor and viability by removing immature and small seeds. Remove broken, immature, diseased seeds and other inert matters. The seeds should be dried to bring the moisture content up to 8% before storage. The seeds may be treated with Captan or Thiram @ 3gm per kg of seeds. Place seeds in vapor proof jars, zip lock plastic bags, plastic containers (pet bottles). Seeds should be stored in a cool, shady and dry place. Place the seeds in a refrigerator (below 15^{o}C is ideal) for long term storage.

7.0 Seed Multiplication Ratio

One gram of tomato seed contains approximately 250 - 380 seeds. The seed multiplication ratio is 1: 400.

iii. Brinjal or Eggplant *(Solanum melongena*)

1.0 Background

Brinjal or Eggplant *(Solanum melongena*) belongs to Solanaceae family grown for its edible fruits botanically classified as berry. It is versatile crop adapted to wide agro-climatic regions. The eggplant is delicate tropical perennial plant often cultivated as tender or half hardy annual in temperate climates. It grows up to 40- 150 cm tall with large coarsely lobed leaves that are 10- 20 cm. The stem is often spiny; flowers are white to purple in colour with five-lobed corolla and yellow stamens.

Varieties

The most popular cultivated brinjal varieties in Bhutan are;

Table 52: Varieties of brinjal in Bhutan

Sl. No.	Variety/Breeding Line (s)	Year of release	Releasing Agency
1	Pusa Purple Long	1990	ARDC-Bajo
2	Paro Local	1990	NASEPP
3	Big Round	1990	NASEPP

2.0 National seed production scheme

Seed production scheme will consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by registered nurseries under NSC, and Private Seed Companies (PSCs) and Registered Seed Growers (RSGs).

Table 53: National seed production scheme

Sl. No	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

- Breeder seeds will be maintained by the releasing agencies (ARDCs). Seeds should be genetically pure or true to type: for this purpose
- Land to be planted with eggplant shall be free of volunteer plants.

- Do not grow other crops of the same species and/or different varieties of the same crop within the isolation distance of 200 m
- Cultivation under protected condition (green house/white net house) with occasional opening for pollination by insects (or hand pollination) must be practiced
- Moisture content should be 6 - 8%
- Purity of seeds should be more than 98%
- Germination percent should be more than 90%
- ARDCs will provide 0.4 kg of seeds to NSC after release of new variety and every after 5 years if required by NSC

4.0 Specific methods for foundation seed production

- Breeder seeds should be the source of foundation seeds and will be maintained by NSC
- Maintain isolation distance of 200 m in open field or produce under greenhouse/net house
- Moisture content should be less than 6 - 8%
- Purity of seeds should be 98%
- Germination percentage should be at least 70%
- ARDCs will also produce some amount of foundation seeds for demonstration and dissemination of technologies

5.0 Specific methods for certified seed production

- Foundation seeds should be the source of certified seeds
- Foundation seeds will be produced under supervision of NSC or other relevant agencies
- Maintain isolation distance of 100m or follow time isolation of 15 days or may produce under net house
- Moisture content should be less than 6 - 8%
- Purity of seeds should be 97%
- Germination percentage should be at least 70%

6.0 Agronomic principles of seed production

6.1 Climate

Eggplant requires long growing season with high average day and night temperatures. Suitable temperature is between 21- 32^{o}C with maximum of 35^{0}C and minimum of 18^{0}C. Young seedlings are sensitive to frost. For seed germination optimum temperature is 25 to 32^{0}C. In altitude below 1000 masl seed sowing is done in mid-February, potting and transplanting at the end of March. Mid hill: seed sowing at the end of February and planting in mid-April. Since the temperature is low at the time of seed sowing and potting, it is important to cover with plastic to increase the

temperature. Under Bajo condition, additional plastic tunnel is used inside the poly house to meet the required temperature.

6.2 Land requirement

Selection of suitable land is important especially for seed production where previous crop should not be the same crop to avoid cross-pollination from volunteer plants. The land should be tilled twice to make the soil fine.

It is a hardy crop, which can tolerate drought and heavy rainfall. However, well drained loamy soils are preferred for better production. An eggplant does not like weeds and weeding has to be done carefully around them.

6.3 Isolation requirement

Eggplants are highly self-pollinated crop, but are immune to cross-pollination since the stigma projects beyond the anther. Therefore, under open field conditions varieties require minimum 200m for foundation seed and 100 m for certified seed. It is recommended to grow in green house and net house to avoid cross-pollination.

6.4 Seed selection and sowing

Select good quality certified seeds from the authorized dealer. Seeds should be healthy and free from disease and pest infection. Remove the broken, coloured seeds and use uniformly graded seeds. Selected seeds should be treated appropriately to prevent the crop from seed borne diseases. Seeds should be soaked in a solution of fresh cow's urine (1 part cow's urine + 5 parts of water) for 30 minutes prior to the sowing. This will inhibit the seed borne diseases like fruit rot and die back. Treat seeds with laundry bleach (0.01 - 0.02%). Seeds can also be coated with ash and ash water. Dip seeds in warm water (20 - 25^{o}C) before sowing.

6.5 Seed rate

Seed rate is 350 - 500 gm per acre. Sow nursery in 50m^2 to transplant one acre.

6.6 Nursery preparation

The nursery should be fertile with addition of well decomposed FYM and ash. About 10 numbers of nursery beds of 2-2.5 m long and 1.25 m wide will be sufficient to transplant one acre. The bed should be raised 15-20 cm height from the ground level. Treated seeds should be sown in the nursery beds in rows at 2 cm depth with 3 – 4 cm spacing. Soon after sowing irrigate the beds and cover the beds using paddy straw.

6.7 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.

6.8 Transplanting

Seedlings should be ready for transplant after 30-35 days after sowing or when the seedlings have developed 5-6 true leaves. Do not remove the soil adhering to the roots to minimize root injury and promote faster recovery. Transplant during cloudy day or preferably at evening. Spacing between seedlings varies with varieties from 50 x 30cm - 50 x 45cm. replant missing hills or wilted plants within 3-4 days after transplanting. Water the newly transplanted seedlings immediately. Mulching materials such as; rice straw, rice husk, saw dust and dry grasses should be used to cover the soil (both bed and foot paths).

6.9 Weeding

It is important that crops grown for seed production are given the optimum conditions for growth and reproduction to ensure that good seed quality and high overall seed yield will be attended. Keep away weeds both in the nursery as well as in the main field. Frequently weed the field to keep it free from unwanted plants that will compete with water, air, light and nutrients. Avoid disturbance of plant roots during weeding.

6.10 Irrigation

Irrigation frequency will depend on the many factors such as; weather, climate, soil type and method of irrigation. It is important to keep the soil moderately moist after transplanting to encourage vegetative growth. The mulched eggplant requires lesser frequency of irrigation water. Reduce the irrigation frequency 1-2 days after transplanting to encourage flowering and fruiting. After the fruit set, maintain uniform soil moisture to avoid blossom end rod and fruit cracking. Light irrigation is required towards the time of harvest to avoid diseases. It is important to keep proper drainage to avoid standing water around the root area. Avoid showering on leaves.

6.11 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.

6.12 Branch control

Pruning is necessary for plant growth and fruit development. Remove the lateral branches below the split (Y branch), except the branch near to the split to allow the air to move freely on the base of the plants and to minimize occurrence of fungal and bacterial diseases. Prune unnecessary leave to reduce competition of in nutrient absorption. Maintain about 3-5 fruits per plant.

6.13 Roguing

To effectively rouge; seed growers should have good knowledge with the characteristics of the varieties. Leaf and stem characters can easily be identified at seedling stage. Roguing can be done based on fruit size, shape and colour, and other plant characters. Off-types and plants infected with virus diseases of other seed borne diseases should be rogued out. A minimum of three roguings is necessary; before flowering, at flowering, and at fruiting stages.

6.14 Field inspection

A minimum of three field inspections should be made: First at vegetative phase, second at flowering and fruiting stage and third before harvesting of fruits by the Seed Certification Officer.

Table 54: Field standard for foundation and certified seeds

Parameters	Foundation seed	Certified seed
Isolation distance (max)	200m	100m
Off types (max)	0.1%	0.2%
Plants affected by seed borne diseases (max)	0.1%	0.5%

Table 55: Seed standard for foundation and certified seeds

Factors	Classes of seeds	
	Foundation seeds	Certified seeds
Pure seed (min)	98	97
Inert matter (Max)	2	2
Other crop seeds (Max)	.05	.1
Weed seeds	None	None
Germination (min)	70	70
Moisture content (max)		
i) Ordinary container	8	8
ii) Vapor proof container	6	6

6.15 Pest and disease management

Some of the common pests and diseases affecting eggplant crop are; fruit borer (*Helicoverpa armigera* and *Spodoptera litura*), serpentine leaf miner, aphids, mites, nematode, damping off (nursery), leaf spot, powdery mildew, leaf curl and fruit rot.

6.16 Harvesting, processing, seed extraction, drying and storage

Eggplant fruits are allowed to ripen fully to ensure complete seed development and maturity. The fully matured eggplant fruit colour turns to yellow from the normal. Harvest only the ripe yellow fruits. The harvested fruits are stored for three to four days until they become soft. This allows the seeds to mature fully. The top one-third of the fruit is removed since it contains almost no seeds. Before seed extraction, fruits are to be graded for true to type and selection of medium to large size fruits for getting higher recovery of quality seeds.

Seed extraction

The extraction of seeds from ripe fruits is done by fermentation and acid method. In fermentation method the fruits are cut vertically into equal half and then separate the seeds with the pulp. These are then allowed to stand overnight for fermentation. In this condition the seeds are easily separated from the pulp. After separation, the seeds are washed two to three times until all the pulp pieces are removed. Keep seeds in a bowl of water for about 10 minutes, all good seeds will settle down at the bottom of the bucket and then the floating fraction is removed. The washed seeds are dried in a cool, dry place for two to three days. Stir the seeds with hand 2-3 three times a day, turning them over to dry uniformly. Seeds sticking together should be disaggregated.

In acid method, the pulp containing seeds are separated from the skin and put in a plastic bucket (do not use zinc and iron container). And then add 100ml of Hydrochloric acid per 14kg of pulp containing seeds. One to two times staring is necessary in between this time. This will facilitate the separation of seed and pulp. After 30 minutes, the seed is separated out from the pulp settle down at the bottom of the bucket and then the floating fraction is removed. The settled seeds should be washed with water for three to four times. The washed seeds are dried in a partial sun light

Drying and storage

After proper drying, the seeds should be processed to maintaining high vigour and viability by removing immature and small seeds. The seeds should be dried to bring the moisture content up to 8% before storing. The seeds may be treated with Captan or Thiram @ 4 gm per kg of seeds. Place seeds in jars, zip lock plastic bags, plastic containers. The packing material should be air tight such as sealed glasses jar. Seeds should be stored in in a cool, shady and dry place. Place the seeds in a refrigerator (below 15^{o}C is ideal) for long term storage.

6.17 Seed Yield

About 250–300 kg seeds can be obtained from a hectare of brinjal crop.

7.0 Seed Multiplication Ratio

One gram of eggplant seed contains approximately 200-250 seeds.

III. FRUITS AND NUTS SEEDLINGS PRODUCTION

A. Standard Fruits and Nuts Seedlings Production

1.0 Background

Fruits and Nuts include large number of crops. However, in this manual, only common fruits (other than citrus) found in the country is described. Depending on the climatic adaptability, fruits and nuts in Bhutan are classified as:

Temperate fruits: Fruits that can tolerate wide fluctuation of both diurnal and seasonal temperatures. Fruits need distinct cold winter or exposure to specific chilling temperature for certain period, without which they do not flower. Generally, trees are deciduous and can stand frosts like apple, apricot, cherry, hazelnut, kiwi, peach, pear, persimmon, plum and walnut depending on the varieties. For optimal fruitfulness, cross-pollination is important in these crops. Crops such as hazelnut, kiwi and walnut have specific requirement for pollination. Most of the kiwi varieties are functionally dioecious and need pollinizer (one male for 9 - 10 female plants), and nuts have dichogamy and thus require pollinizer (Hazelnut) or more than two varieties (Walnut) in an orchard for better pollination and fruit set.

Sub-tropical fruits: These fruit trees can withstand low temperature but not necessarily frost. Some fruit trees require chilling for bud differentiation. They are either deciduous or evergreen trees such as avocado, banana, guava, jackfruit, litchi, loquat, mango, papaya, pecan nut and pomegranate. Crops such as banana, mango and papaya do well under less fluctuation of diurnal temperature, light and darkness and require moist warm climate. Usually, avocado exhibits protogynous dichogamy and thus categorized into two types: **A type** open as female in the morning and **B type** opens as female in the afternoon. Hence, for better pollination and fruit set, an orchard should have both A and B types. Pecan nut like any other nuts should be planted with more than one variety for fruitfulness.

Varieties

There are 82 varieties of 23 different fruit crops released and recommended for commercial cultivation in Bhutan as mentioned in table 56.

Table 56: Varieties of different fruits and nuts released in Bhutan

Crop	Variety	Yield Potential (t/acres)	Recommended Elevation
Apple	Red Delicious	7.0	2000-2800
	Royal Delicious	7.0	2000-2800
	Golden Delicious	3.7	2000-2800
	Jonathan	5.0	2000-2800

	Rich-a-Red	3.5	2000-2800
	Lobo	3.2	2000-2800
	Red chief	2.0-3.0	2000-2500
	Red Free	3.8	2000-2500
	Bajo Apple	2.5	1000-1500
	Fuji	5.0-7.0	2000-2500
	Mutsu	5.0-7.0	2000-2500
	Root stock		
	MM-106	Rootstock	>2000
	MM9	Rootstock	>2000
	MM 11	Rootstock	>1200
Apricot	Bajo Khamchung 1	2.5-4.8	1200-2000
	Shakarpara	3.0-4.0	<1800
Almond	Texas	0.12 kg/tree	1300-2500
	Drake	0.45 kg/tree	1300-2500
	Dhebhar Badhan	2.5 kg/tree	1300-2500
	Kagzi	1.6 kg/tree	1300-2500
Avocado	Bajo Gule-1 (Bacon)	1.3	1200 - 2500
	Bajo Gule 2 (Haas)	0.57	1200 - 2500
Banana	Jaji	5.0-7.0	<1500
	Gheukola	5.0-7.0	<1500
	Chinichampa	3.0-5.0	<1500
Cherry	Jabouney	4.50-5.50	1500-2500
	Royal Ann	5.0 - 5.50	1500-2500
	Seneca	6.0-6.50	1500-2500
	Seokham Drukchu	1-1.02	1600-2600
Dragon fruit	Gyalwaringa 1	20kg/plant	300-1500
Gooseberry	Bajo Amla		400-1500
Grapes	Muscat of Alexandria	3	500-1800
	Perlette	1	500-1800
Guava	Bebsew shakha	15 -20 kg/tree	400 - 1500
	Bajo- Bebsew	10 - 15 kg/tree	250 - 1300
Kiwi	Zhimpey kotong Sep	40 kg/tree	1500-1900
	Zhimpey kotong Jangkhu	35 kg/tree	1500-2000
	Zhimpey kotong Phoshing		1200-2100
	Enza Red		1500-2100
	Hayward		1500-2100
Litchi	Bhur selection-1	9.0-10.0	<1200
	Shahi	10.0-12.0	<1200

	Early Bedana	8.0-9.0	<1200
	Tsatpusey	85 kg/tree	200 - 700
	Namsokha	80 kg/tree	200 - 700
Mango	Langra	5.0-7.0	<1500
	Chausa	4.0-6.0	<1500
	Dashehari	3.0-4.0	<1500
	Amrapali	3.0 - 4.0	< 1000
	Samtelling Amchukuli I	81kg/tree	150-1200
	Samtelling Amchukuli II	69kg/tree	150-1200
	Samtelling Amchukuli III	25kg/tree	150-1200
	Samtelling Amchukuli IV	60kg/tree	150-1200
Passion fruit	Local	1.0-2.0	<1500
Peach	Nunomewase	5.9-8.0	>1500
	Bajokham 1	3.0-4.0	1000-2000
	Bajokham 2	2.9-3.7	1200-2500
	Bathpala Super	4.0-6.0	2000-2600
Pear	Hosui	6.0-7.0	1500-2200
	Kosui	5.0-6.0	1500-2000
	Bajo Lhee 1	2.0-3.0	1300-2500
	Zhey Lhee	4.8-5.5	<2000
	Wengkhar Lhee 1	70-80 kg/tree	1500 - 2000
	Shinko	70-80 kg/tree	1500 - 2200
Pecan nut	Bajo Thasa Tago 1	8kg/tree	900-1700
	Bajo Thasa Tago 2	10kg/tree	900-1700
Persimmon	Fuyu	3.0-4.0	1000-1650
	Jiro	3.0-4.0	1000-1650
	Wengkhar anday 1	25-30 kg/tree	1500-2300
Pineapple	Kiew		150-1000
Plum	Santa Rosa	3.0-5.0	>1700
	Oishiwase	5.0-6.0	>1700
	Jambay Lhakhang Chuli	4.0-5.0	2000-2600
	Soldum	60-70 kg/tree	1600 - 2500
Pomegranate	Bedana	2.5-4.0	<1500
	Bajoseindu-1	27 kg/tree	400 - 1500
Strawberry	Yusi sagong 1	0.7	1500-2500
	Pangtsalu Ngarm	1.37	1800-2600
	Pangtsalu Maap	0.63	1800-2600
Walnut	Kanthel	1.0-1.5	1400-2800
	Yusipang 2	0.5-1.0	1400-2800

	Kagzi	0.5-1.5	1400-2800

2.0 National seedling production scheme

Seedling production scheme will comprise of maintenance of foundation stock by Agriculture Research and Development Centres (ARDCs); maintenance of mother stock by National Seed Centre (NSC) and multiplication stock by nurseries under NSC, Private Seed Companies (PSC) and Registered Private Nursery Growers (RPNG).

Table 57: National seedling production scheme of fruits and nuts

Sl. No	Class	Responsible agency
1	Foundation stock	ARDCs
2	Mother stock	NSC
3	Multiplication stock	NSC/PSCs/RPRGs

1.0 Specific methods for foundation stock seedling production

- will be maintained by the releasing agency
- should be genetically pure
- should be maintained free of pests and diseases and preferably maintained in protected or isolated area
- will comprise up to 10 plants
- will be specifically maintained to generate high quality buds/scion sticks through heavy pruning
- will not be used for fruit production
- ARDCs will provide 15 - 20 foundation stock to NSC after variety has been approved for release

2.0 Specific method for mother stock seedling production

- will be maintained by NSC
- foundation stock will be the source of mother stock
- should be true to type
- should be free of pest and diseases
- will be specifically maintained to generate high quality buds/scion sticks
- ARDCs will also produce mother stock to carry out outreach programs or establish demonstration orchards for dissemination of technologies
- NSC will provide 15 - 20 mother stock to PSC and RPNG after variety has been approved for release

3.0 Specific method for multiplication stock seedling production

- will be maintained by nurseries of NSC, PSC and RPNG
- mother stock will be the source of multiplication stock
- will be produced under the supervision of NSCs/other relevant agencies
- will be true to type and free of major pests and diseases

4.0 Agronomic principles of seedling production

4.1 Nursery preparation

The nursery site will depend on the nature of crops (temperate or subtropical fruits). However, at an elevation of 1300 - 1500 m, both temperate and subtropical fruits nursery can be established. Soil should not have hard pan beneath and should be free of diseases. Soil should be fumigated or solarized to make free of pests and diseases. The ideal soil pH should be 5.5 - 7.5. Site should not be prone to water logging. To prepare nursery bed, mix FYM with sandy loam soil uniformly; in areas with clay soil, fine sand should be added. Prepare fine soil with repeated ploughing and make seedbed of about 15 cm high, 1 m wide and of convenient length.

4.2 Rootstock preparation

4.2.1 *Seed collection and extraction*

Always collect mature seeds from a healthy plant. Fruits are picked either from the tree itself or once the fruits have dropped to the ground (should not be diseased or infected). Seeds are extracted either by letting them ferment in a container or by cutting open the fruits. Seeds should be washed to remove the mucilaginous substances covering the seeds if any. Those seeds that float on water, called floaters, should be discarded as they are usually not viable. For ensuring better viability, dry seeds in a cool shade. Once dried, seeds should be stored at low temperature with moisture content not more than 8 - 10% (**applies only to orthodox type seeds**) in air tight container/pouch.

Table 58: Common rootstocks used for fruits and nuts in Bhutan.

Sl. No.	Fruit crop	Rootstocks
1	Apple	M111, M9
2	Pear	Local pear (both large and small fruited pears), Quince C
3	Persimmon	Local persimmon, Japanese Local, Nepal Local
4	Peach	Local peach, St Julian
5	Apricot	Preferably apricot, St. Julian
6	Plum	Local peach, plum, St. Julian
7	Kiwi	Wild Kiwi or same variety
8	Walnut	Local walnut
9	Pecan	Preferably pecan

4.2.2 *Seed treatment*

This applies mainly to temperate fruits. To facilitate proper and easier germination, seeds are usually subjected to two types of treatments before they are sown in the nursery.

Scarification: it is a physical cracking or chemical treatment to soften the hard seed coat to facilitate easier and faster seed germination. Scarification can be achieved by treating seeds in chemicals like Sulphuric acid (H_2SO_4) or Hydrochloric acid (HCl) for a short duration or by rubbing in the sand, using file or hammer. But care must be taken to see that seeds are not damaged. It is usually practised in seeds with very hard coats like apricot, peach, plum and walnut.

Stratification: It is a process of keeping seeds under low temperature (chilling) and moist condition to aid germination. Stratification breaks the physiological dormancy in seeds when subjected to low temperature thereby triggering germination. Thus, a pit is dug in a cool moist area and seeds are placed in alternate layers of sand. The pit must be kept always cool and moist by sprinkling water. Especially seeds of apricot, peach, persimmon, plum and walnut are required to be subjected to stratification else it takes at least two years to germinate.

4.3 Sowing

Make furrows 1 - 1.5 cm depth at 15 - 20 cm apart. Seeds are sown in lines on a finely prepared nursery bed. Seeds should not be placed too deep into the soil. It should be placed at a depth of 3 - 4 times the size of a seed for proper and easier germination. Apply suphala (15:15:15) 100 gm /1 m wide nursery bed in a furrow and mix well with soil.

Orthodox seeds: Seeds are sown in March to 1st week of April. After the seeds are sown, beds are covered with a mulch of dry grasses to prevent moisture loss through evaporation, and to suppress weeds. Irrigate whenever necessary. Seedlings should attain graft-able size (pencil thickness) in a year's time.

Recalcitrant seeds: In case of avocado, kiwi and mango, and to certain extent persimmon, seeds should be sown immediately after extraction since drying of seeds affects germination or fruits should be kept as it is for later sowing.

4.4 Scion wood preparation

Temperate fruits: Scion woods are collected from healthy fruiting mother plants during the dormant season, ideally in January. Best scion woods are obtained from the middle portion of previous season's growth. Scion woods are waxed by dipping into molten wax at 70 - 80^{o}C (at this temperature, wax is just hot enough for smooth waxing without damaging the plant cells). Waxed scions should be packaged in a plastic bag and can be stored for 1 - 2 months in refrigerators (4 -7^{o}C) until grafting or top working. If waxing is not possible, scion woods should be immediately grafted onto the rootstocks.

Subtropical fruits: Subtropical fruits are evergreen and do not go into dormancy and thus cannot be waxed. In avocado, scion woods with at least two buds which are plump and green are collected from November - February and grafted immediately or can be kept for few days in a refrigerator (4 -7^{o}C) if wrapped in para-film. Banana is propagated through 2 - 4 months old suckers. In mango, stone grafting is usually done in July. Scion should be 4 -5 months old. Softwood grafting on to 8 - 10 months rootstock is done in July - August. Scion should be defoliated at least 10 days before. Inarching is usually done in active season, and both scion and rootstock should be at least 1 year old. In pineapple, suckers and slips are preferred over other methods of propagation. A sucker of 400 - 500 gm and a slip of 350 - 450 gm is considered ideal propagule.

4.5 Propagation

Broadly, plant propagation can be grouped into two categories:

Reproductive: Fruits can be propagated through seeds. However, plants propagated through seeds are not true to type and takes longer time to give fruiting. Propagation through seeds should be done only when alternative methods are not available as in Papaya.

Vegetative: propagation through vegetative means like grafting, budding, layering, cutting and tissue culture are recommended. It is always advisable to propagate through vegetative means. Vegetatively propagated plants have shorter gestation period, they are true to type and carry desirable characteristics of mother plants.

i. **Grafting:** There are many types of grafting methods through which a plant can be propagated. Pome fruits, stone fruits and nuts are easily propagated through side veneer grafting. Grafting is usually done during dormant/winter season (February - March). For grafting, rootstocks should attain size of pencil thickness, and diameter of scion and rootstock should be similar and graft union should be 10 - 15 cm above the ground. Only the recommended rootstocks should be used for grafting.

ii. **Budding:** It is done during the active season when it is easy to slip the barks (usually April - June). Walnut is also propagated through budding besides grafting.

iii. **Cutting:** Plants like fig is propagated easily through cuttings. Cuttings are collected in dormant season and waxed to prevent from desiccation and planted in a slanting position in the nursery in March - April. Besides grafting, grapes are also propagated through cutting.

iv. **Layering:** usually done during the active growing season when there is enough sap flow. Guava is usually propagated through air-layering though it can also be grafted. A shoot of one year old with 1 cm diameter is used.

Table 59: Common methods of grafting in fruits

Fruit crops	Propagation method		
	Grafting and budding	**Cutting, layering, suckering**	**Seed**
Temperate fruits			
Apple	Side-veneer graft	Common for rootstocks	
Pear	Side-veneer graft	Common for rootstocks	
Persimmon	Chip bud, whip graft, cleft graft, side-veneer graft		Common for rootstocks
Peach	Shield bud, side-veneer graft	Common for rootstocks; stratify for 3-4 weeks	
Plum	Side-veneer graft	Common for rootstocks	
Apricot	Side-veneer graft	Common for rootstocks	
Kiwifruit	Side-veneer graft	Stem cutting	Common for rootstocks
Grape	Green graft, Cleft graft	Hardwood cutting	Common for rootstocks
Walnut	Patch bud, whip graft, cleft graft, bark graft	Plant immediately after harvest or stratify for 8-16 weeks	
Pecan	Patch bud, whip graft, cleft graft, bark graft	Plant immediately after harvest or stratify for 8-16 weeks	
Sub-tropical and tropical fruits			
Avocado	Chip bud, side-veneer graft, cleft graft		Common for rootstocks
Loquat	Shield bud, side-veneer graft, cleft graft	Air-layering	Common for ornamentals and rootstocks
Pomegranate	Air layering		Common for rootstocks
Guava	Chip bud, side-veneer graft	Air layering	Common for rootstocks
Mango	Chip bud, side-veneer graft, Inarching		Common for rootstocks
Fig	Shield bud, patch bud, bark graft	Hardwood cutting, air-layering	Common for rootstocks
Litchi	Side-veneer graft	Air-layering	Common for rootstocks

Banana	Suckers
Papaya	Seeds
Pineapple	Suckers and slips

4.6 Aftercare

Nursery plants are tender, thus proper care and management is critical. The nursery should be properly mulched with dry grasses (not green grasses since it attracts more insects) or mulched with plastic sheet. Sprouts that arise from below the graft union or those from other than the scion wood are removed. To maintain the health/vigour, plants should not be allowed to flower or bear fruits in the nursery. Once the proper graft union has been formed, remove the plastic tape used for grafting/budding purposes since it will affect plant growth.

4.7 Irrigation

Nursery should be irrigated at regular interval of two weeks or depending on the nature of the soil. However, soil should not become muddy but should be just wet enough. Water is critical especially during dry season and at the time of sprouting.

4.8 Nutrient management

Nutrient management is essential part of nursery management. For faster growth and vigour, at least top dressing of nitrogenous fertilizer is recommended. Alternatively, foliar application of 1% urea either in the morning or late evening can also be done. Care should be taken to ensure that the entire foliage is thoroughly wet. Spraying on young leaves yield better compared to spraying on the older leaves.

4.9 Pest and disease management

In the initial phase of plants in the nursery, grasshoppers are serious pests. They completely strip grafted plants of new shoots and leaves leading to failure in graft union or death of a plant. Hence, application of insecticide is recommended. If need be, application of winter oil is essential to prevent scales and mites attack. Common diseases and their management are given below in table 60.

Table 60: Common diseases

Common Diseases	Causal Organism	Symptoms and Damage	Management
Banana			
Leaf-spot	*Colletotrichum gloeosporioides*	Regular to irregular spots on leaves with dark margins and greyish centre.	Spray Carbendazim or Calixin (2 gm/ L) in humid weather

leaf blight	*Macrophomina phaseolina*	Dark brown patches on leaves especially on the leaf lamina	Spray Carbendazim (1 gm/L) or Calixin (0.7 ml/ L) during February-March
Bunchy top	*BT Virus*	Stunting and bunching of leaves. The crown leaves are undersized, narrow and chlorotic. Broken dark green streaks on pseudostem, sheaths, midrib and secondary veins are prominent.	Rogue and remove diseased plants. Control aphid (vector) by spraying Dimethoate (50 gm and 25 gm)
Mango			
Powdery mildew	*Oidium mangiferae*	White mealy growth on leaves.	Spray Wettable sulphur (2 gm/ L) during December
Papaya			
Powdery mildew	*Oidium caricae/ Laveilulla taurica*	White mealy growth on leaves.	Spray Wettable sulphur (1 gm/ L) during September - January
Damping-off	*Complex organisms*	Drooping of seedlings which ultimately die off	Treat seed with Captaf (2 gm/ kg seeds)
Apple and pear			
Crown gall	*Agrobacterium tumefaciens*	Globular, elongated or irregular galls or tumours are formed at or near the graft-union. Plant growth is affected.	Bio-control with related species of bacterium is practiced.
Apricot, Peach, Plum			
Leaf curl disease	*Taphrina deformans*	Leaves become curled and sometimes turn red	Spray copper oxychloride 0.03%
Avocado			
Root rot	*Phytophthora spp.*	Leaves wilt, turn brown and necrotic; roots rot	Proper sanitation and application of lime or gypsum

IV. PLANTATION CROPS SEEDLING PRODUCTION

A. Tea seedling production

1.0 Background

Tea is scientifically known as *Camellia sinensis* L. and it belongs to the family Theaceae. Camellia is a large genus with various species of significant economic and scientific value. *Camellia sinensis* includes two main sub-species, viz. *Camellia sinensis* var. *sinensis* and *Camellia sinensis* var. *assamica* which are used to produce different types of tea. Tea is cross-pollinated and highly heterogeneous with broad genetic variation.

Tea plants have wide range of adaptability and it can be grown from wet sub-tropical to warm temperate region having similar agro-ecological conditions. Few tea plants are also found to be growing in Tsirang, Mongar, Trashigang, Sarpang, Zhemgang, Samdrup jongkhar, Chhukha, Dagana and Samtse Dzongkhags.

2.0 National Seedling Production Scheme

The following seedling production scheme is recommended for tea:

Table 61: National seed production scheme for tea.

Sl. No.	Class	Responsible agency
1	Foundation stock	ARDCs
2	Mother stock	NSC
3	Multiplication stock	NSC/PSCs/RPRGs

3.0 Specific methods for foundation stock seedling production

- will be maintained by the releasing agency
- should be genetically pure
- should be maintained free of pests and diseases and preferably maintained in protected or isolated area
- will comprise up to 10 plants
- will be specifically maintained to generate high quality buds/scion sticks through heavy pruning
- will not be used for fruit production
- ARDCs will provide 15 - 20 foundation stock to NSC after variety has been approved for release

4.0 Specific method for mother stock seedling production

- will be maintained by NSC
- foundation stock will be the source of mother stock

- should be true to type
- should be free of pest and diseases
- will be specifically maintained to generate high quality buds/scion sticks
- ARDCs will also produce mother stock to carry out outreach programs or establish demonstration orchards for dissemination of technologies
- NSC will provide 15 - 20 mother stock to PSC and RPNG after variety has been approved for release

5.0 Specific method for multiplication stock seedling production

- will be maintained by nurseries of NSC, PSC and RPNG
- mother stock will be the source of multiplication stock
- will be produced under the supervision of NSCs/other relevant agencies
- will be true to type and free of major pests and diseases

6.0 Agronomic principles of seedling production

6.1 Climate

Tea cultivation has been introduced in tropical and subtropical regions; it is distributed in wide range of soil and climatic conditions with altitudes ranging from 200 - 2600 masl depending on the variety. The optimum tea plants growth occurs at an annual average temperature between 18 - 25℃ and relative humidity between 75 to 85%.

6.2 Soils

It prefers acidic soil of pH between 4.5 - 5.00 with good drainage and aeration. Strong winds, frequent frost, and excessive rainfall are detrimental to the production of high quality tea.

6.3 Field selection and planting distance

Tea fields can be chosen on slopes or on flat terrain having adequate drainage. They can receive full sun, but tea is also known to thrive in foggy or misty environments. Planting should be done when the soil is well moistened in advance by irrigation or rainfall and it is very important to maintain uniform soil moisture after transplanting. The site should be prepared in advance either to establish a cover crop or apply mulch and make planting pits. Planting pits should be 45 cm by 30 cm. The suggested planting distance is 1 m between plant to plant, and 1.30 m row to row.

The recommended methods of planting are triangular, rectangular and contour planting as detailed in figure 6.

Spacing (in meter)	No. of plants per acre	No. of plants per hectare
1.0 x 1.3	3113	7783
1.0 x 1.0	4047	10118
0.5 x 0.5	16188	40470

Figure 6: Recommended spacing in tea

6.4 Method of propagation

In general, tea plants can be raised from seed, cuttings and tissue culture (micro propagation). In Bhutan, tea is commercially propagated from seeds of the elite germplasm, which facilitate easy production of seeded accessions and vegetative propagation for seedless accessions.

6.4.1 *Seeds*

Tea plants can readily be grown from seed, but the resulting seedling will vary from its parents. Tea seeds are mostly collected in winter (November-December) and sown directly within a month. Most of the seeds will germinate within 5 - 8 weeks after sowing. Pricking and potting should be done at 10-15cm height. Gradually move the plants into full sun to prepare them for transplanting (Hardening). Transplant them into the ground when the plants are about 30-45 cm tall with developed leaves.

i. Seed selection and pre-treatment

It is important to use good quality seed in planting. It is important to treat seed before it is planted, in order to improve on the level, speed and uniformity of germination. Thus, soaking seed in cold/cool water for 48 - 72 hours depending on the tree species are recommended for tea seeds before sowing. The Procedure includes:

- Soak the seeds in cold water, water should be 2 times the volume of seeds
- Remove all floating seeds
- Sow the remaining seeds in the polypots or sow directly in the field.

ii. Seed bed preparation and sowing

Nursery beds can be arranged in different ways. Potted seedlings can be raised on a flat bed of 1 m breadth, convenient length and 10 cm height. When planting seed in nursery beds, use the procedure outlined below:

- Draw lines 10 cm apart
- Furrow sowing at the spacing of 1 - 2 cm between seeds
- Cover the nursery with top soil and manure, and irrigate.

iii. Potting seedling

This is the process of transferring young and tender seedlings from seedbeds into pots. Potting should be carried out when the seedlings reach a height of 10 - 15 cm. This is usually about 2 - 3 months after sowing but depends on the species. The processes of transferring seedling are:

- Water the seed bed and pots properly before commencing the operation
- Ensure adequate shade is available
- Pull out the seedlings gently and immediately put them in a container with water.
- Note that if the roots of the seedlings are kept under sunshine they lose water and may die
- Make a hole at the centre of the pot using a stick
- Clip off the root tip if the roots are too long
- Do not hold the stem of the seedling because they are tender and weak
- Transplant the seedling in polypot
- Push the soil towards the seedling to hold it tightly
- This ensures that all the air pockets around the roots are closed

6.4.2 *Vegetative propagation*

The vegetative propagation of tea clones is done through a single-leaf cutting. Cuttings should be harvested from mother plants that are selected for propagation. The bush should be pruned to induce vigorous vegetative growth. The best rooting success is obtained from recently matured shoots containing slightly reddened bark adjacent to matured leaves with actively breaking axillary buds. All further cutting preparations should be done in the shade.

6.5 Nursery

The following factors should be considered while selecting the site:

- Good soils with pH of about 5.6 and other planting materials such as sand should be available easily
- The site should be protected from strong winds and from livestock should receive sun, and should be on a gentle slope to allow drainage

6.6 Selection of cutting

- Select cuttings from healthy and vigorous mother plants
- Prune mother plants twice a year even if the cuttings are needed only once
- Remove weak and cross branches once a year during one of the pruning
- Cuttings will be ready between 5 - 7 months after pruning
- Apply adequate manure and fertilizers immediately after pruning

6.7 Preparation and planting of cuttings

- Single-leaf cuttings are made 1 cm above the leaf node, leaving 3 - 4 cm of stem below the node
- Dip the cut end of the stem into rooting powder before inserting into a planting medium
- The leaf or the bud must never touch the soil
- In case the cuttings are bending backwards, the stems should be inserted into the soil at an angle so that leaves are clear from the soil
- The cutting should be kept moist during planting by frequent watering

6.8 Nursery maintenance

Inspect all beds at least once in a week to check for weed growth, insect pests and diseases. Maintain nursery under 50% shade.

6.9 Hardening process

Hardening is done to expose the seedlings to outside environment for survival in the field condition. Hardening should be done 2-3 weeks before planting. The hardening processes are:

- Remove the shade when the seedlings have attained the planting size.
- Reduce watering intensity (quantity) and frequency - water twice a week and later once a week
- Before planting, root pruning should be carried out frequently or re-arrangement of pots to allow more adaptation to stress

6.10 Nutrient management

In general, for one acre of tea nursery; 3-5 MT of FYM; 52 kg of N; 16 kg of K and 52 kg of P are recommended. Only 50% of nitrogen should applied during the nursery bed preparation and rest 50 % nitrogen must be split into two applications and top dressed after two months of seedling emergence and five months after transplanting into poly-pots.

6.11 Tea pruning and tipping

Tea plants are pruned to maintain size and form, stimulate vegetative growth, keep bush frames healthy and prevent reproductive growth phase (flowering - seeding) and accessibility for plucking. Pruning is done when the plucking table reach 120 - 150 cm, within 3 - 4 years but may be shorter or longer depending on plucking regime. Pruning should be done when there is adequate soil moisture and when temperature is cool (winter months). Tipping is done after prune to produce level plucking surface that facilitates efficient plucking and develop an adequate depth of foliage maintenance. Never tip with a knife.

6.12 Major pests and diseases of tea and their control measures

Sl. No.	Name of pest/disease	Symptom	Management recommendation
A	**Pest(s)**		
1	Beetle chafer grub (*Schizonycha* spp.)	Leaves wilt and surface of roots damaged just below the soil surface. Extensive callus growth (swelling) around and below the collar.	Spray Fenvelerate @ 2ml/litre of water into holes and the soil before planting.
B	**Disease(s)**		
1	Brown blight (*Colletotrichum camelliaemassee*)	Attacks nursery plants (seedlings)	Use fungicides such as Mencozeb @ 2 gm/litre of water.
2	Grey blight (*Pestalo tiatheae*)	Light to dark circular to oval brown patches with greyish centre on upper leaf surface.	Use of healthy and disease-free mother bushes. Seeds and cuttings must dip in fungicide solution @ 2-4 gram/litre of water before sowing and transplanting seedling into poly-pot.

6.13 Tea yield

Tea plants mature within 3 - 4 years after transplanting and continue yielding for over 60 years. The yields are influenced by agro-ecological zones, variety, soil-type, soil nutrition management and crop management practices. The average yield of 600 - 800 kg of processed green tea per acre per year has been harvested in the large estates and average of 200 - 280 kg under smallholder production system has been achieved.

B. Coffee seedling production

1.0 Introduction

The coffee plants originated from the mountain forests of Ethiopia. Coffee is a perennial plantation crop which belongs to genus Coffea in Rubiaceae family. It is generally grown in the tropical and subtropical areas. *Coffea arabica* L. and *Coffea canephora* P. (syn. *Coffea robusta*) are the two most important commercial species. Arabica coffee contributes over 70% of the world coffee production. Coffee is the second most traded product after oil in the world.

Varieties

There are two principal species of commercial coffee; *Coffea arabica* and *Coffea canephora* (Robusta) and two minor commercial species like *Coffea liberica* and *Coffea excelsa. Coffea arabica* is of higher quality and value grown in cooler areas at tropics and sub-tropics at 1000 m or more above sea level. *Coffea canephora* is a lower quality coffee and prices are normally 30-40% less compared to Arabica.

2.0 National seedling production scheme

Seedling production scheme will comprise of maintenance of foundation stock by Agriculture Research and Development Centres (ARDCs); maintenance of mother stock by National Seed Centre (NSC) and multiplication stock by nurseries under NSC, Private Seed Companies (PSC) and Registered Private Nursery Growers (RPNG).

Table 62: National seedling production scheme of coffee

Sl. No.	Class	Responsible agency
1	Foundation stock	ARDCs
2	Mother stock	NSC
3	Multiplication stock	NSC/PSCs/RPRGs

3.0 Specific methods for foundation stock seedling production

- will be maintained by the releasing agency
- should be genetically pure
- should be maintained free of pests and diseases and preferably maintained in protected or isolated area
- will comprise up to 10 plants
- will be specifically maintained to generate high quality buds/scion sticks through heavy pruning
- will not be used for fruit production

- ARDCs will provide 15 - 20 foundation stock to NSC after variety has been approved for release

4.0 Specific method for mother stock seedling production

- will be maintained by NSC
- foundation stock will be the source of mother stock
- should be true to type
- should be free of pest and diseases
- will be specifically maintained to generate high quality buds/scion sticks
- ARDCs will also produce mother stock to carry out outreach programs or establish demonstration orchards for dissemination of technologies
- NSC will provide 15 - 20 mother stock to PSC and RPNG after variety has been approved for release

5.0 Specific method for multiplication stock seedling production

- will be maintained by nurseries of NSC, PSC and RPNG
- mother stock will be the source of multiplication stock
- will be produced under the supervision of NSCs/other relevant agencies
- will be true to type and free of major pests and diseases

6.0 Agronomic principles of seedling production

6.1 Climate

Coffee tree is a shade loving plant but years of breeding have resulted in varieties that give good yields in full light conditions. Arabica is grown in tropical regions with an elevation of over 500 m and is best suited from 1000 - 1500 masl. The annual precipitation should be well distributed from 1200 – 2500 mm. Coffee cannot stand frost and the minimum temperature should be above 4 – 5 ℃. The ideal temperature for coffee cultivation ranges from 18 – 30 ℃. *Coffea canephora* prefers a hotter climate and is more adapted to the lowlands below 900 masl.

Both coffee species tolerate shade and they have quite similar growth requirements as other crops and forest trees, making them suitable for incorporation into agro-forestry ecosystems. Windbreaks or shelter trees are recommended in areas of frequent wind. South-east facing slope less than 15% is preferable. Steeper slopes pose major erosion risk and require terracing or special management such as contour or preferably grass strips. Normally it is best not to plant the bottom third of a slope as it will be colder and sometimes waterlogged.

6.2 Soil type

A well-drained area with adequate depth is required. Coffee prefers soil pH of 5 - 6. Good management and applications of dolomite or lime can improve pH and fertility.

6.3 Propagation and nursery practices

Propagation can be done in numerous ways. Although Coffee can also be grown from cloned plants as cuttings or tissue culture, seed and vegetative propagation are the most common propagation methods.

a. The propagation by seed uses ripe cherries from a healthy tree.
b. In vegetative propagation, a leaf or shoot of the mother tree is used.

6.3.1 *Preparation of coffee seed*

- Pick ripe and healthy fruits from the mother plants.
- De-pulp the fruits after soaking coffee fruits in water for 24 hours in a container
- Rub inside the water to remove any traces of pulp still adhering to the seeds
- Air-dry the seeds in a well-ventilated area
- Moisture content must be maintained below 10%
- Sort seeds to remove small, abnormally-shaped, infected and infested seeds
- Selected seeds are ready for raising seedlings
- The seed viability is around 3 months and should not be used unless properly stored at low temperature and high humidity.
- If coffee seeds are to be stored/ transported, treat with charcoal dust and fungicides.

6.3.2 *Preparation of coffee cuttings*

- This method produces true-to-type and uniform planting materials
- Coffee clone is used as mother plant or as source of stem cuttings
- A vertical shoot of finger size and about 1 foot-long with 3 - 4 nodes should be selected
- Leaves on the cuttings should be partially cut before transplanting in the soil medium of the nursery
- Cuttings are set in a germination nursery and insert two third deep inside the soil
- Cuttings will produce roots and shoots within 35 - 45 days
- Rooting hormones can be used to enhance the root initiation
- Rooted cuttings are then pricked into individual plastic bags with potting mixture
- After the seedlings have developed 3 - 4 pairs of leaves, about 5 - 7 months, planting in the farm can be done
- This type of planting material bear earlier than plants produced from seeds

6.4 Sowing time

Coffee seed should be planted as soon as possible after harvest. The longer it is stored, the lower the percentage of germination and the smaller the plants will be at the time of transplanting. Arabica and Robusta nurseries should begin in December and February respectively in Bhutan.

Water the seedbeds before sowing seeds. With the help of pointed stick or garden hoe, make furrows of 10 cm apart across the bed. Sow seeds at 2.5 cm apart within row and cover with top soil. Cover the beds with any straw mulch to give additional warmth and retain soil moisture. As germination time is dependent on soil temperature, it might take about 40 - 45 days to attain button or topee stage (appear shoots). At this stage, mulching materials should be carefully removed without damaging the germinated seeds.

6.5 Shade house and plastic tunnels

Select a frost and flood free area with access to a suitable water supply. Fence the area completely to keep out domestic animals. Polythene (transparent plastic) should be used to accelerate germination and plant growth because coffee seed is very slow to germinate. Sow coffee seeds either in polythene tunnel or green house to achieve faster seedling growth during cold weather. The seedlings are ready to be transplanted at heights of 15 - 25 cm.

6.6 Transplanting seedlings

Depending on temperature, coffee seedlings are ready for transplanting from the primary nursery into poly pots about 2-3 months after sowing. A mixture of well sieved fertile top soil and manure or compost can be used. Use the healthy seedlings with a straight tap root. Transplanting should be done in cool and cloudy weather. While pricking, seedlings should be planted to the same depth as they were previously planted in the seedbed. The seedlings must be transplanted into poly pots and shifted to secondary nursery. Water the seedlings immediately after transplanting.

6.7 Field management and planting trees

6.7.1 *Field management*

The area to be planted must be prepared at least one year before the small coffee trees are planted. Following activities must be carried out a year before plantation.

- Land preparation
- Plant windbreaks
- Mark out the rows
- Establish shade trees
- Irrigation

6.7.2 *Planting coffee trees*

There are four measures to follow while planting coffee trees:

- Seedling size and planting time

- Pit preparation
- Selection of plants
- Planting procedure

6.7.3 *Seedling size and planting time*

Field planting can start when the coffee plants in bags have at least 6 - 8 leaf pairs. Plants should be strong and healthy with no indication of pests or diseases. Planting out in the field should be done on cloudy days, in June through to August during the wet season. Avoid planting trees when conditions are windy, hot or dry.

6.7.4 *Pit preparation*

- Preparation of pits should be done one month before planting
- Mark the planting pits
- Dig pits of 60 cm depth and 60 cm diameter
- Pile top soil to one side of the pit and sub-soil to other side of pit
- Mix in 2 kg of well decomposed FYM
- Apply 250 gm of dolomite per pit
- Start filling the pit with top soil mixed with FYM and dolomite then complete filling the pit with sub-soil mixed with FYM and dolomite
- Re-mark the centre of the pit with a stick
- The soil should be moist at time of planting

6.7.5 *Selection of plants*

The coffee seedlings must be healthy with dark green, well-formed foliage and a minimum of 6 - 8 leaf pairs. It should have well-developed root system with a taproot that is not distorted. Harden the seedlings in sunlight before few weeks of planting.

6.7.6 *Planting procedure*

- Before planting, thoroughly water the trees in the bags
- Remove plants from plastic bags by either cutting the bag or gently sliding the plant out of the bag
- Discard plants with damaged roots or bent roots
- If plants have been in the bags for an extended time, roots may grow around in a circle inside the bag. It is important that these roots are gently teased out by hand or they will continue to grow in a circular manner when planted. Carefully straighten large roots and prune off badly twisted roots
- Ensure to remove the plastic bag
- Place the seedling upright in the pit

- Firmly press soil down with your feet. Do not stomp on the soil as this may damage the young roots. Keep the final soil level slightly heaped above the surrounding undisturbed soil as the soil will settle down after planting. Water the plants well with 1 - 2 litres of water per plant
- Mulch the newly planted coffee seedlings with rice straw or other suitable materials.

6.8 Pest management

Sl. No.	Name of pest/disease	Symptom	Management recommendation
A	**Pest(s)**		
1	White stem borer *Xylotrechus quadripes*	Wilting of leaves and dead trees or branches. Affected branches are easily broken off. When trees are first infested there maybe evidence of sawdust-like residues on the ground. The trunk may be ring barked.	Burn affected trees or branches Do not plant trees with twisted tap roots. These deformed roots result in weak trees that have been shown to have a high incidence of stem borer infestation.
2	Mealy bugs *Planococcus* spp.	White waxy colonies are usually found on the under-side of tender leaves and in soft stem areas around berries. They are found on young roots near the main root, especially where soil is loose around the trunk. They are often associated with a heavy infestation of sooty mould.	Parasitic wasps, *Leptmastix dactylopii*, are very effective. Lacewings such as *Oligochrysa lutea* are also predators of mealy bug.
B	**Diseases**		
1	Bacterial blight *Pseudomonas syringae*	Leaves become brown and necrotic with yellow halos, necrosis of shoot tips which spreads rapidly down branches. Leaves turn black and die off but remain attached to tree.	Protective sprays of copper based fungicide should be applied with the onset of rainy season.
2	Leaf spot *Cercospora coffeicola*	Brown spots on foliage which enlarge and develop gray-white centre and a red-brown margin.	Remove all crop debris from field after pruning to prevent build-up of

		Lesions may also be surrounded by a yellow halo or may have a burned appearance if lesions are numerous. Infected leaves may drop prematurely. Lesions on green berries are brown and sunken and may have a purplish halo. Infected red berries may have large black sunken areas.	inoculum. Good plant spacing and pruning to open up the canopy promotes good air circulation around foliage. It can be controlled with the use of copper fungicides.

6.9 Harvesting and processing

Careful selection of red cherries during the time of harvesting is essential for good quality coffee. To create pulping and grading easier, process only ripe and red cherries. Do not use a mixture of red over or under-ripe cherries. In Bhutan, particularly in southern regions; harvesting for *Caffea arabica* L. begins from October - November and likewise *Caffea canephora* L. starts from January - February.

The harvested cherries/fruits should be collected in clean bags or baskets to avoid contamination of fertilizers or other chemicals. Cherries should be processed in the same day without mixing with the previous stock. Equipment and sorting areas should be checked daily and maintained clean. Any fermented part of cherry from the previous day will contaminate the newly harvested cherries and result in deterioration of the entire batch. Carefully wash and sort cherries before starting the processing to remove twigs, leaves or other foreign matters.

C. Areca nut seedling production

1.0 Background

Areca nut (*Areca catechu*) is a crop of tropical region belonging to Arecaceae family. It is an important cash crop grown in the southern Bhutan. Areca nut is consumed either in raw or cured (processed) form. The processed form known as Supari is mainly used in India but raw areca nut is preferred in Bhutan.

Till date, no study was conducted to identify areca nut cultivars in Bhutan. However, informally areca nut is identified into four categories based on their nut shape, viz. round (locally known as Jazi), oblong (locally known as Lamchey), small oblong and small round. Round type with thinner husk is preferred because of its larger nut size and more whitish layer inside which is reported to be less intoxicating compared to nuts with more reddish coloured endosperm. Small oblong is the least preferred nut type.

2.0 National seedling production scheme

Seedling production scheme will comprise of maintenance of foundation stock by Agriculture Research and Development Centres (ARDCs); maintenance of mother stock by National Seed Centre (NSC) and multiplication stock by nurseries under NSC, Private Seed Companies (PSC) and Registered Private Nursery Growers (RPNG).

Table 63: National seedling production scheme of fruits and nuts

Sl. No	Class	Responsible agency
1	Foundation stock	ARDCs
2	Mother stock	NSC
3	Multiplication stock	NSC/PSCs/RPRGs

3.0 Specific methods for foundation stock seedling production

- will be maintained by the releasing agency
- should be genetically pure
- should be maintained free of pests and diseases and preferably maintained in protected or isolated area
- will comprise up to 10 plants
- will be specifically maintained to generate high quality buds/scion sticks through heavy pruning
- will not be used for fruit production
- ARDCs will provide 15 - 20 foundation stock to NSC after variety has been approved for release

4.0 Specific method for mother stock seedling production

- will be maintained by NSC
- foundation stock will be the source of mother stock
- should be true to type
- should be free of pest and diseases
- will be specifically maintained to generate high quality seeds
- ARDCs will also produce mother stock to carry out outreach programs or establish demonstration orchards for dissemination of technologies
- NSC will provide 15 - 20 mother stock to PSC and RPNG after variety has been approved for release

5.0 Specific method for multiplication stock seedling production

- will be maintained by nurseries of NSC, PSC and RPNG
- mother stock will be the source of multiplication stock
- will be produced under the supervision of NSCs/other relevant agencies
- will be true to type and free of major pests and diseases

6.0 Agronomic principles of seedling production

6.1 Climatic requirements

Areca nut is cultivated in wet subtropical region receiving high rainfall. It can be grown up to an altitude of 1000 masl. Endosperm become too soft if planted in higher elevation. It can grow well in area receiving rainfall of 4500 mm annually but it can survive in area receiving rainfall above 750 mm. The mean annual temperature required is 21 – 28 ℃ but it can tolerate mean maximum temperature of 38 ℃ and mean minimum temperature of 16 ℃.

6.2 Propagation methods

Areca nut is propagated only by seeds. Seeds should be carefully selected and planted in shaded beds or pits until they germinate and then seedlings should be transplanted in a nursery for growing. The land is ploughed 2 - 3 times before sowing. Seed nuts are immediately sown after harvest or within a week after letting the husk rot.

6.2.1 *Seed collection*

The nut should be selected from a superior mother plant with a history of producing desirable nuts. Fruits are harvested when bright red or yellow to yellow orange from December- February. Fruits are harvested either by climbing the tree and cutting the fruit cluster off or by using a long bamboo pole with a sharp knife attached.

6.3 Nursery management

Since it is highly cross-pollinated, uniform selection of planting materials should be done. Selected nuts should be sown immediately or no later than 80 days after harvesting. The nut is sown on the sand bed or trenches 30 cm deep with convenient length and breadth filled with sand under partial shade. While sowing, stalk end should be pointing upward and covered with layer of sand. Spacing between nuts in the nursery is maintained at 2.5 - 5 cm. The bed may be mulched lightly with areca leaf or paddy straw. Germination starts in 30 - 40 days after sowing.

After 3 months in primary nursery, the seedlings are transplanted to secondary nursery beds of 5 cm height, 1.5 m width of convenient length. The spacing maintained in the secondary nursery is 30 cm. It can also be transplanted in the polythene bag of size (25 x 15 cm, 150 gauge) filled with potting mixture (top soil and FYM in a ratio 2:1). Proper shade should be given to the nursery plants to protect from sun by planting green manure crops or banana or covering by coconut and areca leaves. Number of leaves at the time of planting should be more than 5. It should be 12-18 months old with collar girth of 20 cm.

6.4 Field preparation

Areca nut is susceptible to sun scorching. The field should therefore have protection from exposure to south or south west sun by planting tall evergreen tree (Eg. Acacia, Kokum, Neem, Casuarina, Pongamia etc) on the south western borders. Either it can be planted in the north south direction aligning at an angle of 35° towards west. White washing can also be done on the trunk with lime slurry especially from October - January. Different system of planting can be adopted such as square system, rectangular and quincunx system.

In a well-drained soil, deep planting at a depth of 90 cm is preferred for anchorage and root development. In heavy soils with high water table, shallow planting at depth of 60 cm is recommended. The seedlings are planted with a ball of earth in the middle portion of the pit after half filling of the pit with mixture of topsoil and FYM. Proper drainage should be provided since it is sensitive to water logging. Proper drainage must be provided in every two to three rows of arecanut seedlings with 15-30 cm depth to avoid water stagnation. These drains should be joined to a common drain of 1 - 1.5 m depth.

6.5 Recommended seedling rate

Spacing of 2.7 x 2.7 m or 2.3 m x 2.7 m is recommended. Hence, an acre of land can accommodate more than 554 - 550 plants depending on the spacing.

6.6 Planting

Planting of areca nut is recommended with the onset of monsoon from May - June but it can be extended up to August - September with supplementary irrigation.

6.7 Nutrient management

In general, for each sapling; 100g, 40g P2O5 and 140 K2O are recommended. The fertilizers are to be applied in two split doses. Only 50% of fertilizers should applied during the nursery bed preparation and rest 50% must be top dressed after two months of seedling emergence.

6.8 Irrigation

Water requirement is critical especially from December - February and March - May.

6.9 Major pest and diseases of areca nut

Sl. no.	Name of pest/disease	Damaging Symptoms	Management recommendation
Pest			
1	Spindle bug (*Carvalhoria areca: Miridae, Heteroptera*).	• Dark brown necrotic lesion appears on the leaves/spindle. • Drying and shredding of infested parts with stunting of palms.	• Spraying of neem oil (10ml/L) to repel the adult. • Spraying of systemic insecticides dimethoate (1.75ml/L) or monocrotophos (1.25ml/L)
2	Arecanut root grubs *(Leucopholis burmeisteri, L. lepidophora, L. coneophora)*	• Yellowing of leaves, tapering of stem (penciling), toppling of tree, falling of nuts and reduction in the yield)	• Collection and destroying of adult beetles. • Application of phorate @ 50-20g/tree around the root twice in the year during May-June and September-October. • Application of fungal pathogen Metarrhizium anisoplae (20g/palm). • Drenching around the palm with chloropyriphos (6ml/L) around the palm.
Disease			
1	Leaf blight (Colletotrichum gloeosporioides and Phyllosticta spp.)	Small, round, brown to dark brown or black coloured spots with yellow halo are the characteristic symptoms of this disease. later, the spots coalesced to form blighted patches	• Collection and destruction of diseased plant parts helps in reduction of inoculum load of this disease. • Spraying of Mancozeb @ 2gm/litre of water results effective management for this disease.

6.10 Harvest

The seedlings can be transplanted in the permanent field only after 18 months in the nursery

V. SPICES SEEDLING PRODUCTION

A. Large cardamom seedling production

1.0 Background

Large cardamom (*Amomum subulatum* Roxb.) is one of the main cash crops grown mostly in the southern parts of Bhutan. It is a perennial crop, belongs to Zingiberaceae family and native to the eastern Himalayan region. It is cultivated mostly in the Eastern Nepal, Sikkim, Darjeeling in West Bengal, India and southwestern region of Bhutan. Large cardamom is not only used in several Ayurvedic preparations but also used as a spice to prepare premium product like masala and pan masala in India. In Bhutan cardamom is cultivated primarily for export purposes. However, small quantities are also used in tea preparations, culinary preparations and consumed fresh. It contains 2 - 3% of essential oil and possesses high medicinal properties such as carminative, stomachic, diuretic, cardiac stimulant and antiemetic. Currently, there are only two officially notified varieties (Varlangey and Golsey) in Bhutan. However, other imported varieties such as Ramla, Sawney, Seremna, ICRI Sikkim 1 and ICRI Sikkim 2 are also cultivated by farmers.

Varieties

Variety	Morphology	Tiller/Stem Color	Suitability	Release Status
Ramsey	1.2 - 2 m tall, robust with arge no. of tillers	Maroon tillers and narrow leaves	High altitude	Not released
Ramla	1.5 - 2 m tall, robust with large no. of tillers	Maroon tillers and broad and long leaves	High altitude	Not released
Sawney	1.5 - 2 m tall, robust in nature	Maroon tillers and broad and ovate leaves	Med to high altitude	Not released
Varlangey	1.5 - 2.5 m tall, robust in nature	Maroon tillers and narrow leaves with wavy margins.	Mid to high altitude	Notified
Seremna	1.5 - 2 m tall	Green tillers and drooping type leaves	Low altitude	Not released
Golsey	1 - 1.5 m tall, not robust like other cultivars	Green tillers and narrow and erect leaves	Low altitude	Notified

2.0 National seedling production scheme

In general, the scheme for planting materials production for large cardamom given in figure 7.

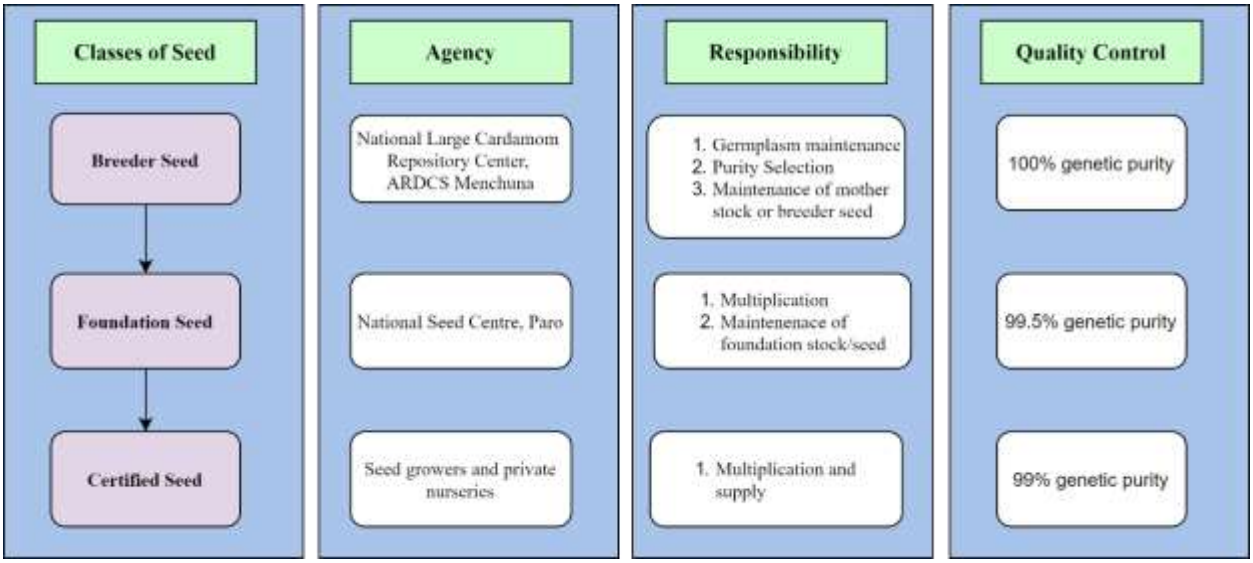

Figure 7: National seedling production scheme of large cardamom

3.0 Specific methods for breeder seed production

Following techniques shall be used to produce the breeder seeds/mother block of large cardamom

- Directly importing the released and high yielding varieties from neighbouring countries. The plant material with 100% genetically pure lines with recognised phytosanitary certificate from the donating country shall be entertained. The maintenance and propagation of breeder seed/mother stock shall be done following the guideline/agronomic principles provided in under section 6 of this chapter.
- Breeder seed/stock obtained through selection of desired cultivar from large number of selections. This process shall follow a careful and continuous selection of desired cultivars and elimination of undesired cultivars. After obvious elimination, the selections are grown over several years to permit observations of performance under different environmental conditions for making further eliminations. Finally, the selected and inbred lines are compared to existing commercial varieties in their yielding performance and other aspects of agronomic importance. The propagation material for selection can be done through either seed or the suckers.
- Breeding between released varieties. This technique shall be applied to discover and innovate new varieties using various plant breeding methods. The variety which are of desired genetic and physical traits including disease resistance and climate resilience with superior performance in comparison to existing varieties shall be proposed for release through the varietal release committee. The germplasm of the newly released variety shall then be maintained as the breeder seed or the mother stock.

Maintenance of Breeder Seed

The cardamom breeder seed/stock shall be maintained under the properly designed infrastructure with each variety separated by barrier preferably with stainless-steel woven wire mesh with wire diameter and opening width of less than 0.5 mm. All four sides of the infrastructure should be covered with the same stainless steel. The roofing of the infrastructure should be done with black agro shade net of 70% shade factor made from 100% virgin HDPE with UV treated material. Transparent normal greenhouse plastic sheet may be used during the winters to protect the plants from possible cold injury. At least 20 mother suckers/bushes shall be maintained for each variety with 100% genetic purity with plant-to-plant distance of 1.5 meters. The intercultural operation and management shall be carried out as per the general package of practice (PoP) of large cardamom. In case of severe disease incidences, recommended chemicals prescribed in the PoP and the seeds of the particular variety will be collected and maintained for future research.

4.0 Specific methods for foundation seed production

The foundation seed of large cardamom is the progeny of a released breeder seed. The cardamom repository centre shall provide at least 100 numbers of breeder seed to the National Seed Centre for multiplication of foundation stock every 5 years. The National Seed Centre in turn shall maintain the foundation seed/stock for the all the released varieties of large cardamom. The genetic purity for the foundation seeds shall be 99.5 %. The National Seed Centre shall also multiply the planting materials for supply to farmers and certified seed agencies in the country.

The foundation seed shall be maintained under monocropping system without mixing with other cardamom related varieties or cultivars. If planted under the agro-forestry based farming system, natural shade of 60% shall be maintained at all times. In case of protected propagation or maintenance, different varieties shall be maintained preferably under separate structure. However, 2-3 varieties can be maintained under single structure with proper barrier and distance between adjacent variety to prevent cross pollination and crossing. At least 50 number of clumps shall be maintained. Follow the general agronomic principle provided under section 6 of this chapter.

5.0 Specific methods for certified seed production

The certified nurseries can produce certified seed/planting material for cardamom using foundation seeds. The genetic purity standard for the certified seed shall be maintained at 99 %. The certified seed production can be done through both sexual and asexual propagation using the foundation seed following the technique provided under section 6.3.1. under this chapter.

6.0 Agronomic principles of seedling production

6.1 Site selection

The site for planting materials repository and multiplication should be preferably located at an altitude ranging from 600 - 2000 masl receiving an annual rainfall of 3000 - 3500 mm. Select the site with adequate water for irrigation and located at least 500 meters away from the main plantation to prevent disease transfer. As the crop is a shade loving plant, the nursery should be provided with artificial shade or should be grown under natural forest with optimum shade of 60 %. The site should have good road connectivity for easy transportation of inputs and planting materials.

6.2 Soil requirement

The large cardamom performs best in deep and well drained soils with loamy texture rich in organic matter and nitrogen, medium in available phosphorus and medium to high in available potash with soil pH 4.5 - 6.0. Preferably such soils should be used for multiplication of cardamom planting materials.

6.3 Cardamom propagation methods:

Propagation of large cardamom can be done through seeds and suckers. Propagation through seeds enables the production of large number viral free seedling through provision of adequate care to isolate and protect the nursery from fresh infection. Multiplication from suckers either through splitting or tissue culture technology ensures true to type and high productivity if they are collected from high yielding mother plants.

6.4 Capsule Selection and Extraction Procedure

- Collect well matured, big and disease-free capsules from basal and middle portion of healthy and productive spike of desired variety.
- The selected capsules should contain matured black seeds inside.
- The capsules from the tip of the spikes are small and mature late and are not recommended for propagation purpose.
- Remove the sticky mucilage covering seeds following any of these methods;
  - By rubbing with sand and ash mixture
  - By rubbing with jute bags
  - By dipping seeds in 25% nitric acid (25 ml nitric acid and 75 ml water) for 10 minutes and washing the treated seed thoroughly in the running water.
- Wash the extracted seeds with clean water and dry under shade for 3 to 4 days. The seed obtained after drying can be sown immediately or stored. It should be stored in a cool and dry place.

6.5 Primary nursery

Cardamom seeds should be collected and sown in September-October. Seed beds are prepared in well-drained soil dug to a depth of 30 cm. Raised beds with 15 - 25 cm height, 1 m width and convenient length are prepared. Well decomposed cattle manure is mixed with soil and the surface of the bed is brought to a fine tilth. 80-100 gm of extracted and processed seeds are sown per bed in lines spaced 10 cm apart. The seeds are then covered with fine soil and mulched with paddy straw/dry grass (10-15 cm thick). Watering is done at regular intervals to keep the surface of the bed moist. Germination of acid treated seeds commences after 25-30 days of sowing. When average germination is noticed, the mulch materials are removed. The inter space between rows is then re-mulched with chopped paddy straw. Shade structures are immediately erected by using bamboo mats/reed mats or agro-shade nets. The beds are watered regularly and weeding is done as and when required.

6.6 Secondary nursery

6.6.1 *Bed Method*

Beds of size 15 cm in height and 100 cm in width with convenient length are prepared and well-decomposed cattle manure is mixed with the soil and an even surface is formed. Seedlings with 3-4 leaves are transplanted to the beds in May-June at spacing of 15 cm between them. An overhead structure is erected for providing shade and the soil is kept moist with irrigation. When the seedlings attain a growth of 45-60 cm in height with 2-3 tillers, they are planted in the main field during June-July of the subsequent year.

6.6.2 *Poly Bag Method*

Polythene bags of 15 x 15 cm with perforations at the base are used for planting the seedlings. The bags are filled with a potting mixture of soil, sand and cow dung in the ratio of 4:1:1. The bags filled with the mixture are arranged in rows of one metre width and of convenient length under shade structures. Seedlings with 3-4 leaves are planted in the bags in April–May and watered regularly. They become ready for field planting in 10-12 months.

6.7 Sucker multiplication nursery

Suckers should be generated only in sucker multiplication nursery where adequate precautions are taken to ensure that viral diseases are not transmitted through the suckers produced. The site for such a nursery should be located at least 500 metres away from large cardamom plantations. They are established either under the shade of forest trees or under shade structures with 50% shade using black agro shade nets.

Trenches of 30 x 30 cm are prepared at convenient lengths with an inter space of 30 cm. Well decomposed cattle manure or compost is mixed with the soil and the trenches are filled to the brim.

Then the seedling or suckers with one grown up shoot with an emerging bud are planted at 30 cm apart in the trenches. The time for planting is May–June. After planting, the plant base is mulched with dried forest leaves. The multiplication rate in this method is about 1:8 in one year's time. The grown-up tillers are split into units of one tiller with an emerging bud and planted in the main field during June-July.

6.8 Micro propagation

For rapid multiplication of high yielding clones, vegetative buds from disease free high yielding mother plants are collected and plantlets are produced through the tissue culture technique. These plantlets are hardened in poly bags or in secondary nurseries and once sufficient growth is attained, they can be planted in the main field during June–July.

6.9 Mulching

To retain the soil moisture and control weed growth, mulching at the plant base should be done after application of inputs using dried organic matter, leaves, weeds, etc.

6.10 Nutrient management

Apply well-decomposed cattle manure/compost/FYM @ 2 kg per plant at least once in two years in April-May to replenish the nutrient loss through erosion and uptake.

6.11 Irrigation

Large cardamom plants cannot thrive well under water stress conditions. Watering should be frequently done during dry months from September to March for better growth in coming months. Depending on availability of water, irrigation though drip or through small channels should be provided.

6.12 Shade Management

Large cardamom performs best under the partial shade. About 50% shade is ideal. The shade for the nursery is mostly compensated using black agr0-shednets while in the agro-forestry based seedling multiplication, recommended shade trees as per the package of practices should be provided.

6.13 Weed management

Weed control in the nursey is one of the most crucial operations for maximising soil moisture and nutrients uptake by the plants. Weeding in cardamom nursery should be carried out as and when required.

6.14 Plant protection measures

The major pest and diseases of cardamom are *Colletotrichum* blight, leaf steak, wilt, leaf eating caterpillar and stem borer. Pest and diseases should be managed using IPM technologies.

Points to be considered for pest management

i. Give priority to cultural and mechanical management of pest and disease
ii. Do not apply chemicals especially in cocktails and repeatedly.
iii. Give emphasis on phytosanitation.
iv. Pest infested plants/plant parts should be destroyed immediately.

Follow pest and disease management recommendations provided in the package of practices.

B. Ginger and Turmeric Rhizome Production

1.0 Background

Ginger (*Zingiber officinale* Rosc.) and turmeric (*Cucurma longa*) are herbaceous perennial belonging to the plant family Zingiberaceae. The underground plant part, the modified stem called rhizome is used as the planting material.

2.0 National seed production scheme

Seeds production scheme for ginger and turmeric is as reflected in **Error! Reference source not found.** which consist of breeder seeds maintenance by Agriculture Research and Development Centres (ARDCs), foundation seeds maintained by National Seed Centre (NSC) and certified seeds produced by Registered Seed Growers (RSGs), and Private Seed Companies (PSCs).

Table 64: National seed production scheme

Sl. No.	Class	Responsible agency
1	Breeder seed	ARDCs
2	Foundation seed	NSC
3	Certified seed	NSC/PSCs/RSGs

3.0 Specific methods for breeder seed production

The breeder seed of ginger and turmeric are the initial small quantity of seeds in the form of rhizomes obtained through different selection and breeding methods or introduced, tested and released high yielding or climate resilient varieties by the competent agency or researcher. The breeder seed shall be directly controlled by the originating research station or institution and is responsible to provide the initial planting material to National Seed Centre (NSC) or Registered Seed Growers (RSG) for the production of foundation and certified seeds.

- The researcher shall mark the healthy and disease-free clumps in the field when the crop is 6-8 months old and still green.
- Harvest the marked plants 10-15 days before harvesting bulk rhizome.
- Select bold and healthy rhizomes from disease free plants immediately after harvest and store them in dry and shady places.
- The selected rhizomes should be true-to-type, disease-free which shows the true characteristics of the variety.
- Selected rhizome should be free from diseases especially rhizome rot disease.
- Discard any rhizomes appearing to be off-type, diseased or otherwise unacceptable
- 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.
- Follow the agronomic practices provided under section 6 of this chapter.

4.0 Specific methods for foundation seed production

Foundation seed shall be stocks of clean planting materials and it should be handled carefully to maintain specific genetic identity and purity which will be designated or distributed by ARDCs or NSC. Production of foundation seed requires careful supervision or must be approved by representatives of the ARDCs. Foundation seed shall be the source of all other certified seed. Follow the agronomic practices prescribed in section 6 of this chapter.

- Under the supervision of a breeder, the seed stock is handled to maintain specific identity and genetic purity (100%), which may be distributed and produced under careful supervision of an agricultural experiment station, or a certified Seed Centre.
- The technical procedure for production of foundation seed is similar to that of breeder seeds
- The seed used for production of foundation seed should be breeder seed and avoid mixing with old generation of same variety for maintaining seed vigour and degeneration
- Crop rotation is important to avoid volunteers from previous season, disease isolation and to get the maximum yield from unit area of land – at least 2 years gap should be maintained
- Carry out timely rouging/removal of off-types and diseased plants
- Harvest, clean and store seeds properly.

5.0 Specific methods for certified seed production

Certified seed shall be the progeny of foundation seed, registered or certified seed, should be maintained with satisfactory genetic identity and purity. In this respect, a farmer propagating certified seed should only use breeder or foundation seed for multiplication. The field standard for foundation and certified seed production is given in Table 65. The production technique is same as that of foundation seed.

Table 65: Field standards for foundation and certified seeds

Sl. No.	Particulars	Foundation seed	Certified seed
1.	Ginger (Isolation distance required)	10 m	5 m
2.	Turmeric (Isolation distance required)	10 m	5 m
3.	Off types (%) max. permitted	Nil	0.5
4.	Not conforming to varietal characteristics (should not exceed)	0.10 %	0.2%

5.	Cut, bruised, diseased, injured rhizomes or those damaged by maggots (should not exceed)	0.2% by weight	0.2% by weight

6.0 Agronomic principles of rhizome seed production

6.1 Land requirement and preparation

Ginger and turmeric thrive best in well drained loamy soils rich in humus with a pH of 6.0 - 6.5. It is recommended to follow the crop rotation with leguminous crops for better productivity and kill the disease inoculum in the old field. While light irrigation during drought condition is helpful, water logging is detrimental to both the crops.

6.2 Land preparation

The land is to be ploughed 4 to 5 times or dug thoroughly after the early summer showers and brought 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

6.3 Seed rate

The seed rate for both ginger and turmeric varies depending upon the method of cultivation and seed rhizome size.
Ginger: 600 kg per acre.
Turmeric: 1000 kg per acre

6.4 Spacing

Ginger
Beds of about 1 m width, 30 cm height and of convenient length are prepared with an interspace of 50 cm in between beds. In the case of irrigated crop, ridges are formed 40 cm apart.

Flat Beds method: Plant to plant distance of 25 x 25 cm in each direction.
Ridge and furrow method: Plant to plant distance of 40-60 x 25 cm.
In areas prone to rhizome rot disease and nematode infestations, soil solarization of beds for 40 days using transparent polythene sheets is recommended.

Turmeric

- **Flat Beds:** Used under rainfed conditions where soils are light. Flat beds of 1 m in width and of suitable length varying according to the slope of land are prepared.

- **Ridges and Furrows**: Under irrigated-conditions where the land is levelled or plain and soils are heavy, planting is done on ridges and furrows, opened at 75 cm distance and having 3-3.5 m length. Broad ridges should have 90-100 cm width and 3-6 m length depending on the slope.

6.5 Irrigation

Both crops are generally cultivated as rainfed crop in high rainfall areas and irrigated crop in less rainfall areas. Crop requires 1300-1500 mm of water in one 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 - 10 days in conventional irrigation (based on prevailing weather and soil type).

6.6 Nutrient management

At the time of planting, well decomposed cattle manure or compost @ 10-15 tonnes/acre 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 @ 800 kg per acre at the time of planting helps in reducing the incidence of rhizome rot disease/ nematode and increasing the yield.

6.7 Weed management

2-3 hand weeding is required at 45, 90 & 120 days after planting, depending on the intensity of weed growth.

6.8 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.

6.9 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.

6.10 Roughing

Removal of unwanted, off-type and diseased plants from the seed production field is known as roughing. In ginger and turmeric, roughing at harvest time for confirmation of rhizome characteristics is necessary.

6.11 Pest and disease management

Pest of ginger and turmeric include shoot borer, rhizome scale, root grubs, nematodes, soft rot, ginger wilt and bacterial wilt. The pests should be managed using IPM technologies.

6.12 Harvesting and seed extraction

The crops attain full maturity in 7-9 months after planting depending upon the variety. The crops should be harvested at full maturity for seed purpose. The healthy rhizomes (disease free) and showing good varietal phenotypic characters are selected as seed rhizomes and rest are either sold in the market for consumption or processed. Irrigation is stopped one month before harvest and the rhizome clumps are lifted carefully with a spade or digging fork. In large scale cultivations, tractor or power tiller drawn harvesters are also used.

6.13 Storage of seed rhizomes

The seed rhizomes should be stored under the shade covered with plant debris or stored in the well-drained pit dug until is it being sold or planted in the field. Constant monitoring of rot in the store is recommended.

Annexure

Annexure I: Quantity and Frequency of breeder seed supply to NSC

Sl. No.	Crop	Quantity	Frequency
I.	**Field crops**		
i.	Rice	5 kg	Annually
ii.	Wheat	5 kg	Annually
iii.	Maize	30 kg	Annually
iv.	Mustard	1 kg	Annually
v.	Quinoa	5 kg	Annually
vi.	Legumes	2 kg	Annually
II.	**Horticulture crops**		
i.	Potato	50 kg	Annually
ii.	Cole crops	1 kg	Annually
iii.	Root crops	0.5 kgs of carrot; 2 kgs of radish	Every 3 years for carrot and 5 years for radish
iv.	Bulb crops	1.5 kgs	Every 2 years
v.	Leafy vegetables	0.5 kg	Every 5 years
vi.	Solanaceous crops	0.5 kg	Every 5 years
vii.	Fruits and nuts	15-20 numbers of foundation stock	Once
III.	**Plantation crops**		
i.	Plantation crops	15-20 numbers of foundation stock	Once
IV.	**Spices**		
i.	Large cardamom	0.5 kg seed or 100 numbers of disease-free suckers	Every 3 years
ii.	Ginger and Turmeric	50 kg	Annually