Agriculture for Food Security

Textbook for Class X

Department of Curriculum and Professional Development
Ministry of Education
Thimphu

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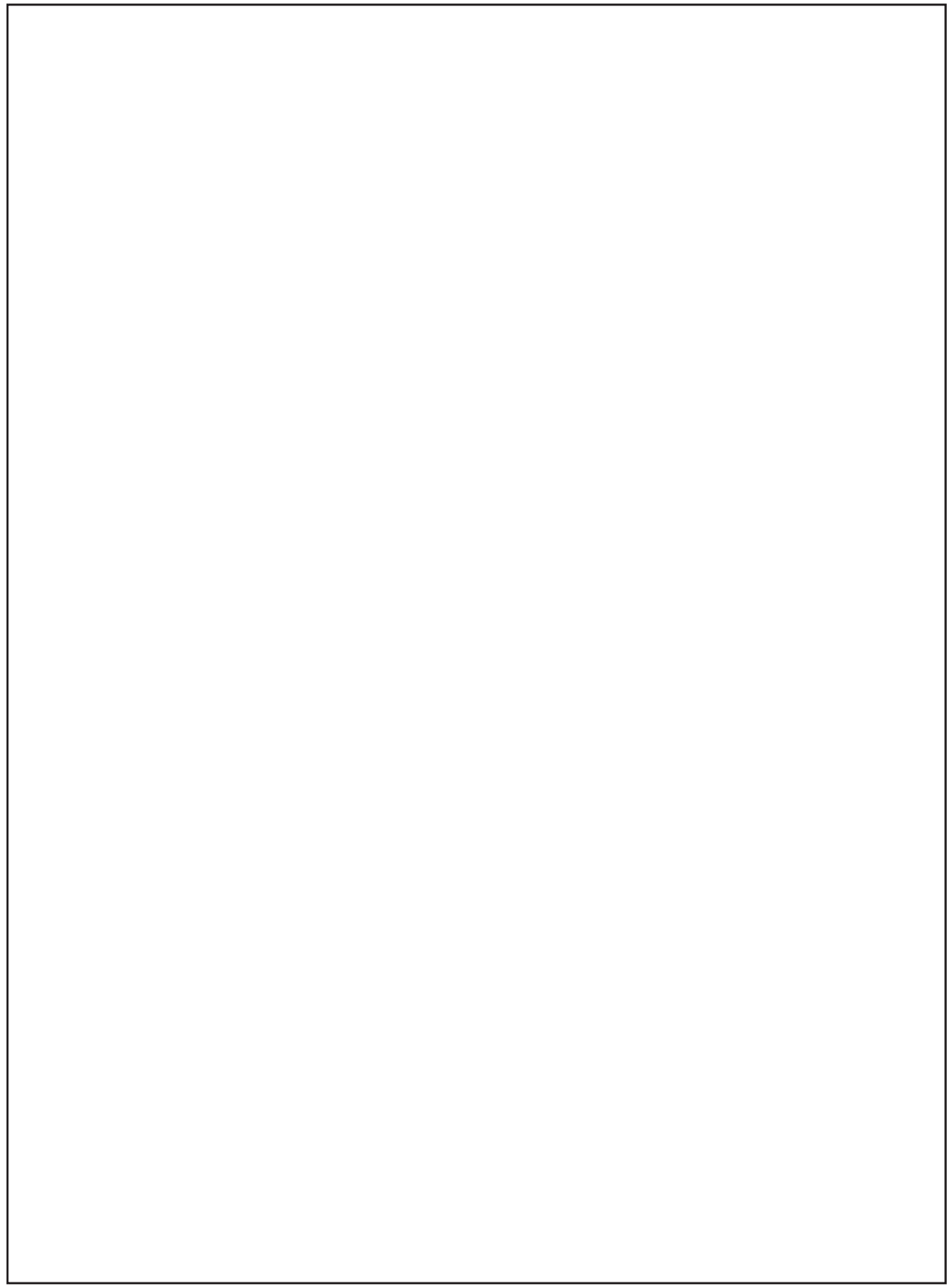

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We would like to sincerely acknowledge the retrieval and use of ideas and pictures from various sources. We reaffirm that this book is purely for educational purposes.

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We are confident that with this modest effort of the two ministries "agriculture education" will progress in a more dynamic manner.

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Preface

Understanding the AgFS Curriculum Design

The AgFS Curriculum for classes IX to XII have been designed to fulfil thee aspiration of the Ministry of Education, Royal Government of Bhutan, in its attempt to improve the relevance of Secondary Education through curriculum diversification of 9th Five Year Plan. The curriculum design and development of AgFS was closely guided and monitored annually by the Curriculum Board of the MoE from 2008 to 2011 and approved for implementation by the 26th Curriculum Board meeting in 2012. Accordingly AgFSC was implemented in schools gradually preparing teachers, consolidating text materials developed suitable for the learners from classes IX to XII and its implementation guides for teachers, professionally trained but with little subject knowledge.

The AgFS is designed as a vocational curriculum with strong academic standard. The technical concepts, values and attitudes, and skills of AgFS require students to apply their Scientific and Geography knowledge and skills learned in their lower classes to understand AgFS and strengthen its application in their life outside school. The AgFS curriculum not only provides opportunity to use their prior knowledge but an opportunity to understand Agriculture that generates self-employment entrepreneurship especially when Bhutan is being faced with growing unemployment of the literate youth.

The AgFS as a vocational curriculum is designed to equip students for self-employment for which the learners are to be provided with all the information required to be literate in agriculture. The textbooks are designed to provide all that the learners of AgFS need know, understand and critically practice the 'package of practices' in agriculture and generate innovations, rather than wasting time looking for information and 'reinventing the wheel'.

Aims of AgFSC:

The AgFS Curriculum aims to educate Bhutanese youth on the country's favourable climatic conditions for growing food, vegetables, medicinal herbs, fruits, ornamental horticulture and rearing livestock that provides ample opportunities of self-employment and employment of others in addressing unemployment of literate youth. The AgFSC aspires to educate on reducing Bhutan's import of huge quantities of agriculture produce from its neighbouring countries threatening the nation's food sovereignty and depletion

of its small economy. This curriculum advocates vocational pathways of Bhutanese youth to contribute to the nation's development and feeding Bhutan's small population.

Educational Experiences /Content of AgFS

The AgFS book of class X is a continuation of AgFS IX. It starts with the 'Introduction to Ornamental Horticulture' a new idea and an avenue for entrepreneurship in our growing urban centres in chapter one, but connects to what Bhutan has been known for in the past and present by the theme of chapter two – Medicinal and Aromatic Plans and Spices (MAPS). Bhutan is a home numerous MAPS gaining popularity globally which the literate Bhutanese youth can capitalise and do well economically.

Chapter three introduces the ideas of 'postharvest handling and technology' which is important aspects of agriculture industry. Much of agriculture produce is lost due to lack of understanding how agriculture produce after harvest behave and handling technology required to keep the produce fresh before reaching consumers or being consumed. The ideas and skills of post-harvest are to be applied and practice subsequent Chapters, especially while 'growing vegetables and fruits' under Chapter four and five. 'Starting a Dairy Farm' in Chapter six provides basic ideas and procedures of farming, importance of livestock in a mixed farming system, supporting farmers to be successful and provides some insight on dairy production with special emphasis on quality breeding and different breeds yielding high quantity of milk and dairy product. This is yet another lucrative and blooming business picking nearby growing urban centres of our country.

The AgFS X ends with 'Farm Management' which provides broad understanding of how a farm or business enterprise needs to perceived, set goals, planned, implemented, monitored, reviewed and evaluated for sustenance and prosperity.

The AgFS books from a collective efforts of Ministry of Agriculture and Forests (MoAF) and its agencies, College of Natural Resources (CNR) of University of Bhutan (RUB), Department of School Education (DSE), Ministry of Education and Royal Education.

Implementation of AgFS

AgFS is a technical subject and what students learn in theory is expected to practice in schools or observe what others do in their fields. Therefore, AgFS is not expected to be taught like the academic subjects. Both the teachers and the students – teaching or learning AgFS *need to read independently, understand and discuss in the class or at the site on the concepts and procedural skills of AgFS, share experiences of Agriculture* – growing

and caring of vegetables, fruits, livestock, forestry and their management critically for betterment of future with changing climate and environment. The ideas from the book are to be taken as a starting point for discussions and not as absolute knowledge and skills procedures. Future modern farmers need to experiment and do things that will work better.

Considering that the AgFS is a vocational subject, need to practice theory learned within the school campus. If practical work cannot be done in the school, teachers need to organise *field trips* to the farm nearby where vegetables, fruits, livestock and forestry activities are being carried out, learn through field trips, and write how such activities are being carried out individually or in small group.

It is also envisaged that students will be provided with ample opportunities to visit RNR Research and Development Centres and interact with researchers. It is recommended that RNR staff of the 'gewog', dzongkhag and regional ARDC of Ministry of Agriculture and Forests are consulted for their technical expertise and seek support of their services, especially in practical work.

Although this book provides production and management recommendations for whole range of vegetables, fruits and livestock, it is expected that subject teacher be selective of the most relevant crop/livestock that is suitably grown/raised in the locality. This will also allow students to relate their studies with the farms around.

Mode of Assessment

The assessment of student's performance in AgFS theory and practical work is to be based on the principle of (a) 'assessment as learning', (b) 'assessment for learning' and (c) 'assessment of learning'. The tools design for different aspects of teaching and learning processes are to be used for objective assessment of student's performance.

Resources required for AgFS curriculum implementation in schools

The School Agriculture Programme (SAP) exists in most of our schools with gardening as an important school activity. However, AgFS as a school curriculum is a recent idea. For the AgFSC to be offered to the students by a school as per the implementation guidance suggested above requiring:

a) Advocate on the awareness of AgFS as a vocational/technical subject available for students from Classes IX to XII, which provides employment for the literate youth and enhance food security for the sovereignty of the GNH nation.

b) Encourage teachers to teach AgFS, reduce work load of teaching other academic subject (s) and school administrative work.

c) Offer AgFS subject to the students who are interested in the subject.

d) Establish institutional linkage with ARDC, Gewog RNR centres, School Agriculture Programme (SAP) unit of Department of School Education, Ministry of Education, and the SAP focal department of Department of Agriculture, MoAF, Dzongkhag Livestock Officer, and Dzongkhag Agriculture Officer for collaboration to implement AgFSC in schools.

e) Budget to implement AgFSC in schools.

f) include space for gardening, space for constructing shed for livestock and horticulture, proper fence.

g) Agriculture Tools for different agriculture activities such as:

    i) Spades, pick axes, crowbars, racks, weeding hoe, shovel, sickle, knives, water pipe, watering can, knapsack, wheel barrow, and any other tools required for AgFS students proportionately.

    ii) Horticulture – pruning and grafting tool sets

h) Facilitate AgFS Class to use the services of Agriculture experts available in the locality through field trips and guest speakers.

Foreword

For the children of a predominantly agricultural land that our country is, there ought to be a natural link between their hands and the soil. Thankfully, this is largely the case especially in our more rural areas. In the more urban parts though, the human-nature bond is coming under increasing pressure owing to the onslaught of modernisation. The humanising influence of working with the hand is, therefore, getting weaker with the passage of time.

Our seats of learning have had a long tradition of school agriculture that has provided excellent opportunities for our students to work the land, raise garden, grow fruits and vegetables and generally tend the surroundings under the auspices of the Socially Useful and Productive Work programme and . With the initiation of a more structured School Agriculture Programme as a joint effort between the Ministry of Education and the Ministry of Agriculture & Forests, we have witnessed a visible improvement both in the process as well as the outcome of students' work.

The launch of the all-out educational reform initiative through the nurturing of Green School concept is expected to restore, among others, the vital link between human beings and the natural environment both as a science and as an art. We expect our students to experience the joy of sowing the seeds, see them germinate and emerge above the soil, follow the changes in shape and size, fruit and flower, mature and complete the cycle. We want our children and youth to feel the soil, understand the effect of sun and rain on plants as well as notice the impact of wind and drought.

A happy consequence of this engagement with the soil will be the production of much-needed food items, organic and nutritious, satisfying because self-produced, nurtured through love and care. The otherwise dreary-looking bare land dons multiple colours as seasons change and beautify the campus and elevate it as a seat of learning. The different sights, sounds and smells that a rich campus produces sharpen and sensitise our senses and awaken us to our full sensibilities.

These multiple benefits of keeping ourselves close to the life-affirming soil have inspired us to introduce School Agriculture as one of the optional subjects for

classes nine and above from the 2013 academic session. We commend the excellent work done by our colleagues in the Royal Education Council (REC) , Ministry of Education (MoE), and the Department of Agriculture (DoA) , Ministry of Agriculture and Forests (MoAF), and all other contributors for their inputs in the production of this document.

We trust that our students will find the contents as appealing and educative as our educators and instructors bring to our schools the joy of farming both as a hobby and as an occupation and help in building a healthy and food-secure Bhutan of Gross National Happiness.

Tashi Delek!

Dr. Pema Gyamtsho,
Minister,
Ministry of Agriculture and Forests.
Year 2013

Thakur S Powdyel,
Minister,
Ministry of Education.
Year 2013

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1 Chapter

Introduction to Landscaping and Ornamental Horticulture

'Making ourselves useful in terms of doing things for food, clothes, shelter and medicines are not only the primary reasons of education. We live for greater values – values that live beyond our lives, values that humans appreciate, like and uphold, values which people of all walks of life appreciate and have attachment in their lives. These values also become business or life earning industry. One such industry is the ornamental horticulture.

Most Bhutanese consider themselves fortunate to have been born in a country that has landscape with breath-taking scenic beauty – snow-capped high mountains, forests with wide range of different species of trees, bushes, shrubs and grasses, valleys with fast flowing rivers, slopes and plains dotted with houses of scattered human settlement, livestock and crops. It is indeed a beautiful country with natural scenic beauty to marvel at. However, there is a preference of human made environment rather than living in harmony with nature. Living in urban colonies is beneficial as it has its own problems. Landscaping and planting trees, bushes, flowers, making lawn and maintaining them have become part of human made urban environment. It is a new idea in Bhutan but it is gaining popularity rapidly as the urban centres expand with the rural population migrating to urban centres.

This chapter introduces the concept of Ornamental Horticulture comprising landscape designing, plantation of ornamental trees, bushes, flower and the art of lawn making. The landscape designing, floriculture and lawn making are beautiful arts with their unique concepts and principles. This chapter also explores the immense opportunity of business entrepreneurship in landscape designing, floriculture and lawn making in the urban as well rural communities. It is a new to Bhutan but is gaining popularity.

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A lot of ideas on landscape design and lawn making, especially pictures pertaining to horticulture and literature have used online resources. Teachers teaching AgFS and students are encouraged to use online resources for more information on landscape design and lawn making.

1.1 Ornamental Horticulture

Horticulture has been defined as the culture of plants for food, comfort and beauty. The cultivation of ornamental plants forms a major branch of horticulture. Ornamental horticulture consists of floriculture and landscape design. It is a booming industry across the globe.

a) Landscape

It refers to the visible features of an area of land, often considered in terms of their aesthetic appeal. Landscape may be natural but in the urban landscape is often human made that adds to the aesthetic appeal to the urban environment.

Figure 1.1 Landscape

A landscape includes the physical elements of defined geophysical landforms such as (ice-capped) mountains, hills, water bodies such as rivers, lakes, ponds, and the sea, living elements of land cover including indigenous vegetation, human elements including different forms of land use, buildings, and structures, and transitory elements such as lighting and weather conditions.

Figure 1.2 Landscaping

Landscaping is a profession that includes designing, installing, and maintaining the outdoor human environment. In Bhutan it is an emerging area. There are only few floriculture nurseries in the country that are operating at a small scale. Proper landscape design by the professionals is almost non-existent. There is a good opportunity for young entrepreneurs to start floriculture industry in the country.

i. Landscape design

Figure 1.3 Landscape design

Landscape design is an art and its effectiveness depends on the creativity of a designer, however, the elements and principles of designs serve as guidelines for design process and development. The elements of design are line, form, texture, and colour. A designer uses these elements to generate a design. The principles of design are focalization, proportion and scale, balance, order and unity, repetition, rhythm and sequence, and interconnection. Most artists incorporate the principles of design into their projects whether it is in landscape design, floral design or rock garden design.

ii. Elements of designs

Figure 1.4 Elements of design - Line

Line plays an important role in a landscape. This design element causes physical and/or visual movement. Line leads the viewer's eyes through the landscaped space. It defines and delineates space. As a designer, incorporate line into a landscape by using contrasting plant material and by forming patterns with similar plant materials. Pattern is line organized in a repetitive sequence. Examples of lines created in a landscape include ground patterns, edges of contrasting plant materials, and tree tops meeting the sky. Straight lines are used to represent formality or a contemporary concept. Intersecting straight lines suggest change of view or direction, or a pause. Meandering or curved lines suggest a more relaxed and slower movement. These lines are used to create a casual and informal concept.

Form is the outline of an object, plant, or space. It is easiest to see it in an individual plant or object. Form can also be the total mass of plants when they are grouped together. Some of the more common forms of landscape plants include round,

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conical, oval, weeping, horizontal, and upright. Most deciduous trees and shrubs have a rounded form. A conical form is characteristic of many evergreen trees. Evergreen shrubs have more of horizontal form. The uses of forms are usually dictated by the concept or theme for a landscape. Formal concepts suggest the use of modified forms of plant material and ground beds. Such a formal landscape would include very straight, crisp, and precise planting beds; topiaries; and other visually clean-lined plants.

Figure 1.5 Elements of design - Form

Informal or woodland concepts use much more irregular or natural forms. Casual curving ground beds and loosely branched trees and vines are used in this concept. Vertical forms are used to create strong accents and for adding height. Horizontal or spreading forms add visual width to tall structures. Incorporate weeping or drooping forms to create soft lines and to provide a transition to the ground plane. Rounded plant forms create large masses and are effective as borders and enclosures.

Texture is the surface quality of any plant material or structure in the landscape. Texture of a plant may refer to the foliage or branching and is classified as fine, medium or coarse. However, texture is relative and must be seen as a comparison. In addition to being a physical feeling like rough or soft, texture also describes how one perceives a visual difference. For example, the leaves of one plant are rough and coarse when compared to the smaller leaves of a second plant. However, when compared to the larger leaves of a third plant, the smaller leaves of the first plant appear smooth and fine. Another example, considered is coarse-grade gravel. Next to fine sand, the gravel has a coarse texture. When compared to granite or marble chips, the coarse-grade pea gravel has a finer texture. Coarse texture has a more dominant quality than fine texture and can be used to accent an area. It

Figure 1.6 Elements of design - Texture

also makes the space feel smaller and can be used to make wide open spaces feel more enclosed. Fine texture is often used as a unifying effect and creates a larger open feeling. So this can be used in small spaces such as courtyard as it makes the area seem larger and expanded.

Colour in landscape can be introduced from several parts of a plant. Most common colour comes by way of flowers, but colour can also be added from foliage, fruits and branching. Colour has impact on human emotion. Warm colours (red, orange and yellow) create excitement while cool colours (blue, green, purple) have a calming effect. There are many shades of green that foliage can display: light green, silver green, blue green, and dark green. Together a nice variety of green colours can create visual interest and contrasts. Although foliage is commonly green there are selections that maintain foliage of other colours such as shades of purple, green and yellow. Variegated foliage is a popular selection because it is unique in colour and pattern. It is often a good selection to create a focal accent because it attracts attention. In choosing flowers for colour consider the length of bloom, normally annuals bloom all season, while perennials range from a week to several weeks. Another consideration when selecting flower colour is timing. Select plants so there is a sequence of flowering throughout the growing season. This creates a movement of change and interest throughout the entire season. Another way to introduce colour in the landscape is fruit. It is often a great way to get colour late in the growing season when few things are blooming. Colourful trunks of the tree also add colour, especially exfoliating varieties. Lighting has effect on the colour of plants therefore try different types of bulbs available for lighting. Therefore as a designer, consider all these factors concerning the influences of colour in a landscape design.

Figure 1.7 Elements of design -Colour

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b) The principles of designing landscape

They serve as guidelines that govern the organization of the design elements and materials in accordance with the laws of nature. Landscape design principles include balance, proportion and scale, order and unity, accent/focalization, repetition, rhythm and sequence, and interconnection. Landscape designers use these principles of design to create landscape designs that are both functional and aesthetically pleasing.

Balance is a sense of equality. It is the equalization of visual weight from one area of a landscape composition to another. There are two general forms of balance in landscape design: symmetrical and asymmetrical. Symmetrical balance is a mirror image of both sides. If a line is drawn in the middle, a symmetrical design would have the exact same placement and selection of plants and material on both sides.

Figure 1.8 Designing landscape -Balance

Symmetrical balance is rather structured and has a formal nature and is normally seen in formal gardens where the hedges are tightly sheared. It is considered much easier to achieve because it only has to be repeated on both sides. Asymmetrical balance is an informal balance. It does not repeat the same plant material in the same quantity or in the same relative position on either side of the centre axis. An asymmetrically balanced design implies equal weights on either side of the centre axis. However, it does not have the "sameness" on each side. Although the objects are different on either side it is still balanced. While viewing an asymmetrically balanced landscape, the viewer feels a sense of stability. Since it is unstructured it appeals to a loose, natural sense of balance.

Proportion describes the relationship between the components of the landscape and the landscape as a whole. For example plant tall trees near a tall, narrow house or building. A small house surrounded by large trees appears smaller than it actually is. A large house surrounded by small trees appears larger than it actually is. A design is in proper proportion and scale when a pleasing relationship exists

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among and between each component and the design as a whole.

Figure 1.9 Designing landscape -Proportion

Order and unity are emotional and visual reactions to the overall structure and organization of the design elements. Order is the overall organization and structure of a design. It is the basic scheme or "skeleton" of the design. Order is created and carried out through the composition. Examples of order in a design may be symmetrical versus asymmetrical balance or a formal versus naturalistic arrangement.

Figure 1.10 Designing landscape -Order and unity

Unity is the harmonious relationship among all elements and characteristics of a design. A unified design is homogeneous and congruous. A design lacking unity appears disorderly and haphazard. Too many components and materials and the complex use of the elements create competitiveness and a lack of integration within a design. To establish unity in a design, stay simple and minimize differences. Limit the complexity of the design elements incorporated into the design. Group the elements in groups of three or uneven numbers. Always remember to simplify diversity and reduce the number of differences between the components in the landscape.

Accent: Interest can be stirred by elements of accent. This can be achieved with focalized accent or interesting effects such as contrasting textures. Focalized accents are objects or plants that would directly attract an observer's attention. An

Figure 1.11 Designing landscape -Accent

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example would be a sculpture, water feature or a specimen plant. Specimen plants are those having unique characteristics such as unique form or colour, texture etc.

As a designer, create an accent or focal point that is strong and effective. Do not incorporate too many focal points into the landscape. Otherwise, their effect will be lost. Use the design elements (line, form, texture, and colour) to move the viewer's eyes through the landscape to the place of the focal point. Most landscapes usually contain visual focal points such as plants and structures. However, running water and rustling leaves are effective as focal points, capturing the sense of sound. If colour is the element to be used as the focal point on a site with great depth, use blues or whites as minor focal points. Advance these minor focal points to a dominant red, orange, or strong yellow focal point.

Repetition involves repeating or using an element more than once throughout a design. It helps establish and add order and unity to a design. Repetition provides a common feature throughout the design that pulls the design together. Repetition can be in the form of texture, colour or form.

Figure 1.12 Designing landscape -Repetition

Rhythm and sequence describe the dynamic unity or the related, orderly movement that implies continuity. They are the apparent flow of lines, textures, and colours that express a feeling of motion rather than confusion. Order and repetition help establish rhythm and sequence in a design. Rhythm and sequence characterize continuity and connection from one part of the design to another part. They group the components together, drawing the design together. This keeps the viewer's eyes busy and allows them to follow easier through the design. As a designer, accomplish rhythm and sequence in a design by repeating one or more of the

Figure 1.13 Designing landscape - Interconnection

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elements such as line (creating a pattern), form, texture, and colour.

Interconnection is a design principle for producing unity in the design. Various components in the design are physically linked together. Repetition helps in establishing interconnection. A designer may incorporate interconnection into the entire design or into only a small space within the design.

1.2 Floriculture

Flower farming is known as floriculture. Floriculture is concerned with growing and marketing of flowering and foliage plants which includes cut flowers, potted plants, annual bedding plants, and floral design products. It is a discipline of horticulture concerned with the cultivation of flowering and ornamental plants for gardens and for floristry, comprising the floral industry. The development of plant breeding of new varieties is a major occupation of floriculturists.

Figure 1.14 Flowers grown in a green house

Nursery structure is very important for floriculture. It could be simple raised beds with thatched roofs to elaborate greenhouses/glass houses with controlled atmospheres, depending upon the size and scale of business. Nurseries could be wholesale, retail, corporate and/or specialized.

Whatever the nursery size or whether you are into cut flower, potted plants, bedding plants business, follow these guidelines each year to plan production schedule. The floral industry is one of the major industries in many developing countries. Netherlands, for example, remains the centre of production for the European floral market, as well as a major international supplier to other continents.

There are several thousand different species of flowers and foliage plants that are grown as commercial crops. Flowers include such crops as carnation, gladiolus, roses, hydrangea, lily, tulips, anthurium, gerbera, heliconia etc.

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a) Carnation

Carnations are popular flower, considered as the 'flower of gods' in Greek. They belong to family 'Dianthus' and are available in many different colours and shades.

Figure 1.15 Carnation

i. Planting Considerations

Carnations can be grown indoor as well as outside. Carnations need well-draining soil without mulch, for good air circulation, will be much easier if you saw seeds.

ii. Planting carnation Indoor

Start carnation seeds in nursery indoors six to eight weeks before your area will be frost-free, or sow carnation seeds outdoors by sowing them in 1/8-inch deep soil that will drain well, if the place is warm enough.

1. Choose a container with drainage holes in it, filling the container within an inch or two from the top with potting soil.
2. Sprinkle the seeds across the top of the soil and cover them lightly.
3. Water until the soil is most and then wrap the container in a clear plastic bag to create a greenhouse effect.
4. Carnation seeds should germinate in two to three days.
5. Transplant seedlings into smaller pots or outdoors (if your area is free of frost) once they attained a height of 4 to 5 inches
6. Keep the soil of container moist at the growing stage and water once a week after that.
7. Add manure to support carnation growing and bloom flowers.
8. Cut off the stem to the ground level when flowering season is over.

Figure 1.16 Planting Carnations

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iii. Planting Carnation Seeds Outdoors

Sawing seeds, transplanting and caring of carnations in an outdoor garden is similar to growing carnations indoors. However, carnation plants may not bloom in the first year when the seeds are sown outdoors. Begin carnation outdoors gardening by:

- preparing the soil of the garden,
- sowing them in 1/8-inch deep soil that will drain well.
- keep the soil in your garden moist while seedlings are growing.
- thin the small plants to 10 inches to 12 inches apart, once the seedlings are thriving.

iv. Care for Carnations

- Water the growing carnations once each week, and
- Add manure to encourage strong carnation garden plants.
- Pinch off the flowers as they become spent to encourage additional blooming.
- Cut off carnation stems to ground level at the end of the flowering season,.

b) Gladiolus

Gladiolus is a perennial flower and grows between 2 to 5 feet in height. Gladiolus are available in different varieties and in a multitude of colours. The taller varieties, which should be staked, are often placed in the back of a garden to beautifully complement shorter plants.

Gladiolus are summer flowers, have corms and multiplies from corms, bloom, and which dormant in winters.

Figure 1.17 Gladiolus

Gladiolus can be planted about two weeks before the last expected spring frost. It will take 70 to 90 days from planting until flowering. For a continual harvest of flower spikes, plant a few corms every two weeks until early summer.

i. Procedures of Planting Gladiolus

1. Plant gladiolus corms in spring after the frost when the soil is warmer, in well-drained soil with plenty of sunshine.

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2. Prepare garden to loosen the soil to about 12 to 15 inches deep.
3. Mix a layer of compost or FYM.
4. Place the corms of gladiolus flower in rows for easier tending the plants and to harvest the flowers.
5. Set the corm in the hole about 4 inches deep upright.
6. Space the corms 6 to 8 inches apart.
7. Cover with soil and press firmly.
8. Water the corms thoroughly.

Figure 1.18 Gladiolus corms

9. If you're planting tall varieties, be sure to stake them at planting time. Be careful not to damage the corms with the stakes.
10. It takes about 60 days from the time gladioli are planted for the corms to root, grow, bloom and go dormant in colder season.

ii. Care for the Plant

- Put a 2- to 4-inch layer of mulch around your gladioli to keep your soil moist and to help prevent weeds growing.
- Water your plants regularly throughout the summer in case rainfall is less /water them moderately to keep the soil moist at the growing stage.
- Remove the faded/dead flowers to ensure continuous blooms.
- Cut the stalk off at about 2 to 3 inches above the soil, once all the flowers on a stalk are gone.
- Leave the plant intact to mature and rejuvenate the corms for the next season.

Figure 1.19 Caring Gladiolus

- Cover the garden with a layer of hay or straw for winter protection, in case the place is not very cold.
- Dig out corms before the first fall frost if winters are too cold /get frost.

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b) Rose

Figure 1.20 Roses

Rose is a flowering shrub. Its name comes from the Latin word Rosa and belongs to the family of plants called Rosaceae.

The flowers of the rose grow in many different colours, from the well-known red rose or yellow roses and sometimes white or purple roses.

i. Tips for growing rose flower

Roses need sunlight, at least six hours a day is ideal, require rich and well drained soils with 2 to 3 inches of coarse organic mulch around roses. Need water, regular inspection and prune timely.

Roses are popular and beautiful flowering shrubs and growing roses isn't a stressful task. Rose is propagated from its stem cuttings. With proper planting and a little care, one can have a successful rose garden.

Figure 1.21 Growing roses

ii. Procedures of growing rose

1. Select a place where the rose shrubs will receive sun shine.
2. Prepare that the soil can be drained well, add manure to make the soil fertile and support growing rose plants.

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3. Plant dormant roses in early spring. Potted plants can be planted any time between spring and autumn, but spring is preferable.
4. Soak the bare root roses in water for at least 24 hours prior to placing them in the ground (if you're planting bare root roses).
5. Both bare root and potted rose bushes need to be planted about 2 feet deep, with the hole large enough to accommodate the roots.
6. Backfill the hole with top soil, adding some well-rotted manure in with it and water thoroughly.
7. Mound up additional soil around the base of the plant. Note that this is not necessary for actively growing roses.
8. Care of rose bushes is important for the health and vigour.
9. Water rose weekly throughout their growing season. Rose bushes are very susceptible to fungal diseases, such as black spot and powdery mildew, especially when their foliage is kept too wet.,
10. Add fertilizer or well-rotted manure for roses in spring.
11. Mulch your rose bush to retain moisture and also from winter protection.
12. Prune rose bushes when leaf buds appear in spring. Cut about 1/4 inch above the bud eyes and prune out any twiggy or unhealthy branches.
13. Starting a rose garden and knowing how to take care of roses shouldn't be intimidating.

iii. Propagating Roses from Cuttings

1. Choose rose stems that are healthy.
2. Take cuttings from the upper part of the plant and from the side.
3. Select a stem that is four to six inches long and has at least two or three leaves attached. Leaves produce sugars from photosynthesis and hormones that promote rooting.
4. Take a sharp knife.
5. Make a clean slice at a 45 degree angle, below a leaf node, to maximize the rooting area.
6. Remove flowers or buds and lower leaves from the cutting.

Figure 1.22 Cutting roses

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7. Cut the remaining leaves in half to reduce moisture loss through transpiration and maximize the amount of energy the cutting can expand on developing roots.
8. Quickly dip the bottom two inches of the cutting into rooting hormone, which may not be always necessary but will greatly improve your success rate.
9. Make a small hole in the growing medium for the stem to fit into and gently place the cutting into hole.
10. Cover with a plastic bag to create a greenhouse effect and maintain high humidity levels.
11. Set them in a window exposed to sunlight and provide bottom warmth.
12. Keep the growing media moist and wait until roots appear.
13. "Harden off" plants slowly before transplanting outside.

c) *Hydrangea*

There are three main types of big leaf hydrangeas: Mop head hydrangeas are the most recognizable and popular hydrangea due to their large puffy flower heads. Their flowers can be purple, blue, or pink.

Figure 1.23 Hydrangea

Hydrangea is a plant with medicinal benefits. The root and underground stem are used to make medicine. Hydrangea is used for urinary tract problems such as infections of the bladder, urethra and prostate; enlarged prostate; and kidney stones. It is also used for hay fever.

i. *Growing hydrangea*

1. Most hydrangeas thrive in rich, porous, somewhat moist soils. They prefer full sun in the morning, with some afternoon shade; however, many will grow and bloom in partial shade.
2. Plant in spring or autumn.
3. Dig a hole as deep as the root ball and 2 to 3 times as wide.

Figure 1.24 Growing Hydrangea

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4. Place it in the hole and backfill it with soil with well decomposed manure.
5. Water it well as it requires a lot of water in the beginning to establish the root system.
6. Cut the shrubs all the way back to the ground or prune hard annually, in late winter or earlier spring for larger bloom or
7. Keep some stems to reduce flopping and for smaller bloom

d) Lily

Lily flower (Lilium spp.) is a trumpet shape and comes in many colours that include pink, orange, yellow and white. Some popular types of lilies include Asiatic lilies. They are very easy to grow and grow almost anywhere.

Figure 1.25 Asiatic lilies

Rubrum lilies resembles the tiger lily, although the colours range from white to deep pink and have a sweet scent.

Figure 1.26 Rubrum lilies

Oriental lilies are the classic "late bloomer." Flowering bulbs bloom after Asiatic lilies, continuing the lily parade in the landscape well into the season. Growing

oriental lily plants is fairly easy provided you have a well prepared site for bulbs, plenty of sun and good drainage. Some of the most magnificent flowers in the lily family are in this large group of species and cultivars.


Figure 1.27 Oriental lilies

Martagon lilies have whorled leaves and turkscap flowers. They are also called turk's cap lilies, with as many as 20 blooms on one stem. They are of many colours and have often freckled with flecks of colour. Martagons do not grow well in hot climates.



Figure 1.28 Martagon lilies

Tiger lilies are some of the species of oriental lilies. Their flowers are curved and freckled. They multiply in clumps and produce more than a dozen flowers on each stem. Its colours range from a golden yellow into a deep red.

Trumpet lilies are known for their trumpet-like flowers and are very fragrant. They can grow up to 5 feet high. Their large, trumpet-shaped flowers atop tall flowering stems bloom in early or midsummer.

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Figure 1.29 Tiger lilies

Figure 1.30 Trumpet lilies

i. Growing of lilies

1. Prepare garden for the lilies where the plants can get proper sunshine.
2. Dig to loosen the soil and ensure the bed has good drainage.
3. Mix the soil with matured compost thoroughly.
4. Make a hole of about 6 inches deep and place the bulb inside with the flat part down and the pointed end up.
5. Space the bulbs about 8 inches apart.
6. Fill each hole with the soil and press it gently down.
7. Water the ground thoroughly.
8. Water the plants frequently during active growing period.
9. Remove dead lily flowers, keeping more than a third of the stem.
10. Divide the lily bulbs and replant them when the lilies bulbs go dormant in the autumn/winter.
11. Plant fresh bulbs each year, if you are growing lilies for indoor.

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e) Petunia

Figure 1.31 Petunia

Petunias are prolific bloomers and are one of the most popular garden flowers. Most petunia varieties will bloom throughout the summer and they are in about every colour – blue, white pink, red, and yellow and so on.

Petunias have wide trumpet-shaped flowers and branching foliage that is hairy and somewhat sticky. There is great variety of petunias within the family – single and double blooms, ruffled or smooth petals, striped, veined or solid colours, mounding and cascading habits and even some with fragrance.

Petunias are tropical perennials, though hybrids are usually grown as annuals. Petunias like cool weather but they are not frost-tolerant. Petunias repeat bloom throughout the summer.

i. Growing of Petunias

Figure 1.32 Growing petunia

1. Plant petunias outdoors in a light, fertile soil that is slightly acidic with good drainage.
2. Plant petunias in spring. They grow easily when you transplant them to the garden in the spring.
3. Remove dead flowers from the stem for continues flowering.
4. Prune stem to continue setting flower buds. Extreme heat can cause petunia plants to stop setting flowers until the temperature drops.
5. Cut the branches of petunias when they become long to refresh the plant fresh buds.
6. Add decomposed manures or foliage to give petunia the energy to bloom.
7. Water petunias judiciously and ensure the soil is well drained. Daily watering may be required for spreading and container-grown petunias.

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8. Most petunia varieties prefer full sun, but in the heat of summer, partial shade will keep them refreshed and blooming better.
9. Growing petunias from seeds:
10. Grow petunia seeds in a warm temperature for germination and remove them to grow on in cooler temperatures.
11. Petunia seeds are tiny and fine but they need light to germinate.
12. Don't cover the seed with soil but rather sprinkle the seeds on top of the soil and pat lightly, for good contact.

ii. Tips to care for petunia (if grown in containers):

- Place petunias in the sun for at least 6 hours.
- Watering is essential.
- Provide right soil.
- Fertilize for prolific blooms.
- Removing dead flowers from the stems.
- Look for pest.

f) Begonias

Begonia is a genus of perennial flowering plants in the family Begoniaceae. The genus contains more than 1,800 different plant species. The Begonias are native to moist subtropical and tropical climates. Some species are commonly grown indoors as ornamental houseplants in cooler climates.

Figure 1.33 Begonias

Tuberous Begonias will remain in bloom for several months in the summer, producing large clusters of single or double flowers in almost every colour except for blue, with proper care. Some varieties are upright plants, growing up to 2 feet tall, but the majority of tuberous Begonias grown are multi-stemmed, pendulous hanging plants.

i. Planting and care

Begonias grow well in shade and in slightly sandy soil rich in compost. They can be planted directly in the garden in late spring, or started indoors in early spring.

1. Prepare the planting area to a depth of six inches, adding sand and matured

compost.

2. Space the Begonia tubers 12 inches apart, with the hollow side up.
3. Cover with about one inch of fine soil.
4. Keep the soil evenly moist and provide manure or fertilizer once new growth begins to show.
5. Stop feeding in late summer and allow the plants to slowly die back in autumn.

Figure 1.34 Growing begonias

6. Dig up the tubers before the first frost and store them in dry peat moss in a cool, dry place until spring.
7. To start indoor gardening tubers indoors, for planting outdoors:
   i. use well decomposed compost and sand in equal proportion, in a pots or containers.
   ii. set the tubers and cover them with half inch soil and keep in a place warmer than the room temperature until new growth is established, then reduce to room temperatures until it is time to plant them in the garden.
8. Tuberous Begonias can also be grown as house plants by:
   i. Keeping the plants in a place where they will receive bright but indirect sunlight, such as an unobstructed east facing window.
   ii. Allowing the soil to dry slightly between watering, and water thoroughly.
   iii. Providing additional humidity by misting tuberous Begonias daily.
   iv. Maintaining growing temperatures for Begonias grown indoors are 65° to 70° F. during the day and 50° to 65° at night and avoiding hot and cold drafts.
   v. Cutting it back to within 3 inches of the crown, when blooming decline after Begonia has flowered for several months.
   vi. Giving plant a fresh start by placing it in a cool location with moderate light.
   vii. Keeping the Begonia dry but not allowing the soil to dry completely.
   viii. Replacing by a larger size pot for the Begonia plant, when new growth begins to emerge.
   ix. Moving the plant back to brighter light and resume moderate watering and light fertilization.

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ii. Growing Tuberous Begonias from Seeds

1. Begonia seeds need light for germination.
2. Do not cover these tiny seeds.
3. Sow seeds indoors 12-16 weeks before planting time in the garden.
4. Maintain a temperature in the growing medium of 65°-75°F.
5. Germination takes 15-20 days

Figure 1.35 Growing tuberous begonias

Wax begonia is a hardy perennial that blooms almost all the year round with more than 1,000 species. Wax begonia comes in many shapes, colours, and sizes. They are easy to grow. They even grow well indoors. Depending on the species, this plant can grow anywhere from six inches tall up to two feet. Flowers are red, white, yellow, and pink, and have variegated leaves.

iii. Growing from seeds and caring of Wax begonia

Begonia seeds are very tiny enclosed in small seed pods. The seed pod may have several million seeds that have potential to develop into several million seedling. Wax begonias grow best in:

Figure 1.36 Growing wax begonias

- an area where there is plenty of Sun but some shade will be required in the tropical areas.
- at least about 60 degrees Fahrenheit temperature and will bloom better up to 75 °F
- a relatively humid environment. A small humidifier may be useful for indoor plants to maintain humidity above 50 percent.
- in the moist soil, but not dripping wet.
- in any light, well-draining soil.
- in the subtract with fairly less fertilizer.

iv. Growing in Containers

Wax begonias make lovely indoor houseplants, especially if you live in an area where the plant does not thrive all year long.

- Plant wax begonia in a large pot /container to last your wax begonia about four to five years.
- Ensure your large pot has adequate drainage holes to avoid over soaking the roots of wax begonia.

Figure 1.37 Begonias in containers

g) Azaleas

Azaleas are flowering shrubs with multiple of colours. Azaleas bloom in the spring and their flowers last several weeks. They grow better near or under trees, also require well-drained, acidic soil. Test the soil pH using a soil testing kit.

Figure 1.38 Azaleas

i. Tips for Growing an Azalea Houseplant

1. *Harvest azalea seed* pods after they begin to brown in autumn,
2. Store them in paper envelopes to complete the drying process.
3. Prepare a pot for the seeds in late fall of the same year,
4. Fill it to within 1 inch of its top with a damp mix of 1 part peat moss and 1 part sand.

Figure 1.39 Growing azaleas

ii. Azaleas propagation by stem cuttings.

1. Fill a container with pre-moistened peat moss.
2. Remove a piece of your established azalea with a sharp knife.
3. Take three or four cuttings from a healthy azalea in the morning when the shrub is well-hydrated
4. Remove the leaves on the bottom half of the stem cutting.

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5. Use clean pruners to cut each stem just below a leaf or bud, making each cutting about 3 inches long. The best cuttings for rooting are flexible but not too thin and firm enough to snap when sharply bent.
6. Dip the bottom end of your cutting into water, place the cutting end into the hormone powder or gel and then shake off the excess.

Figure 1.40 Azaleas stem propagation

7. Push the stem cutting of Azaleas gently in the moist substrate in the container.
8. Place pot with azalea cutting in the warm room.
9. Transfer the azalea into larger pot for their healthy growth and better flowering.
10. Azaleas can be transplanted outdoor from pots.

1.3 Lawn

An area of soil-covered land planted with grasses and other durable plants such as clover which are maintained at a short height with a lawnmower used for aesthetic and recreational purposes.

Figure 1.41 Lawn

Turf grasses are among the oldest plants used for landscaping. Most turf grass used in landscapes is perennial. Nearly all species can be reproduced from seed. They are mainly classified as cool season grasses and warm season grasses. Tall fescue and rye grasses are cool season grasses. Bermuda grass, carpet and kikuyu are warm season grasses so suitable for warm areas.

Grass texture is a way of describing the width of the grass leaf blade. The wider the blade, the coarser is the texture. Fine textured grasses are more attractive than coarse textured grass. Fine texture is more expensive. Colour varies from pastel

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green to dark bluish tones. Density refers to the number of leaf shoots that a single plant can produce. It is either sparse to thick. Lawns can be of mixture, blends or single species. It is either sparse to thick. Lawns can be of mixture, blends or single species.

A mixture combines two or more species of grass: A blend combines two or more cultivated varieties of a single species. Mixtures are more common in temperate zone landscapes and single species are more common in subtropical and tropical landscapes. Blends offers uniform colours and texture, resistance to damage and pest and the varieties in blends will have similar maintenance needs

i. Art of Lawn making

It refers to growing of grass or turf, mowing to maintain a desired height of grass or turf on a landscape designed around a house for aesthetic beauty. It can also be in the gardens, around trees/ plants or flowers /bushes.

Figure 1.42 Lawn making

Four methods of lawn installation are Seeding, Sodding, Plugging, Sprigging and Stolonizing methods. Selection will depend upon: species of grass, type of landscape and how quickly the turf must be established. Seeding is the most common and cheap. Seeds can be applied by hand or with spreader. When a lawn is needed immediately, Sodding is used. Sod is an established turf which are grown in one place and sold or moved to landscaping areas. A sod cutter is used to cut the sod into strips. These are then lifted, rolled up and placed onto pallets for transport. It is expensive but provides instant landscaping. The soil should be moist before installation of sod. Sod should be installed soon after it has been installed. Individual strips are laid into place. Sod should not be stretched to fit as it will shrink later, leaving gaps in lawn. Each strip should be fitted tightly against each other. Use flat roller to make sure all the strips are touching the soil.

ii. Tips for successful lawn making:

1. Prepare soil and level the ground,
2. Condition the soil properly,

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3. Provide proper drainage and gradient (slope),
4. Plant grass at proper time of year,
5. Apply fresh, good quality seed, sod, plugs or sprigs,
6. Provide adequate moisture to promote rapid establishment of the lawn and
7. Timely mowing for maintenance.

Student Activity

Schools are the best places to learn about floriculture and related activities since they have flower gardens, lawns and ornamental plants maintained by the school management for creating suitable environment conducive for learning.

Different groups of students carrying out projects on improving the school campus provide an excellent opportunity of developing the ideas of ornamental horticulture industry entrepreneurship in students. Landscape designing, flower gardens, ornamental plants of different species and lawn making and maintenance can make schools educative in making aesthetic values, respect and care for the plants. The objective of the practical activity is to improve the aesthetic beauty of the school campus based on the theory learned from this chapter.

Activity

1. Divide the class into group of manageable size.
2. Assign group task to design landscape, grow flowers and ornamental plants, and lawn making and its maintenance.
3. Collectively study the campus and discuss what different groups can do to improve the aesthetic beauty of the campus.
4. Propose to the school leadership of the class project and support required to carry out the campus beautification project of designing landscape, plant flowers, foliage, bush and trees.
5. Start the project and upon completion assign a small group to maintain this project.
6. Assess the students' performance using assessment tool provided in the curriculum guide.

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2 CHAPTER

Medicinal, Aromatic Plants and Spices

Historically Bhutan was known for its medicinal and aromatic plants. There are more than 600 plants with medicinal properties in Bhutan, of which 300 species are used in traditional medicines. Considering the high demand for traditional medicines, there is a need to introduce sustainable management system for the natural resources. In an effort to ensure sustainability, a systematic package of production for seven species (*Ruta, Manu, Goned, Gurgum, Tiyangku, Somaradza*, and *Chirata*) of medicinal plants has been introduced. These 7 species are promoted in farmers' field for commercial production.

This chapter provides basic information and package of practices on the nine medicinal species and two spices. Readers will be exposed to different medicinal plants and get to know their uses. The information in the chapter can be used by students to cultivate medicinal plants commercially and generate income.

2.1 Medicinal and Aromatic Plants in Bhutan

Bhutan has a rich diversity of medicinal plants and is known as '*Menjong Gyalkhab*' meaning the land of medicinal plants. There are 7000 plant species of which 600 have medicinal properties. Medicinal plants collected from Bhutan's temperate and lower zones are known under the traditional broad classification as '*Khrog-sman*' while plants from the country's alpine zone are known as '*Sngo-sman*'. As of now 227 species of *Sngo-sman* and 93 species of *Khrog-sman* are used in traditional medicine in Bhutan. There is a growing demand of medicinal plants by ITMS as popular alternative medicine with the setting up of indigenous unit in each of the district hospitals. The demand is expected to further increase with the corporatization of Traditional Medicine Company in the year 2017 by the Government. However, most of the raw materials used are from wild collection and many are imported from India.

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In this section, package of practices for seven(Ruta, Manu, Goned, Gurgum, Tiyangku, Somaradza, and Chirata) of the cultivated medicinal plants which are currently promoted in the farmers field are described in detail. Some of the medicinal plants adopted by farmers for cultivation are enlisted below:

a) Ruta: Saussurealappa

Ruta is a very important and critically endangered medicinal plant in Bhutan. It is widely used in the Bhutanese traditional medicine and nearly wiped out from Bhutan had it not been for the single plant rescued from Kola Goempa in Bumthang in the late 90s. The cultivation program for the Ruta, since then was very successful.

Figure 2.1 Ruta plants

It is a tall, stout herb with annual stem and perennial roots growing at an altitude ranging 2500-4000 metres above sea level. Flowering heads of bluish/purple colour are born in the top of the stem in July-August. Leaves are heart shaped and fruits are achenes. Roots are 20 to 50 cm long weighing between 150 to 200g when fresh. The roots have a pungent taste and a characteristic fragrant aromatic odor.

Figure 2.2 Ruta roots

Ruta has been used as tonic and aphrodisiac, for the treatment of asthma, bronchitis, cholera and acute stomach ulcer. Farmers apply extracts of Ruta as pesticide. The highly aromatic roots are used for incense making.

i. Cultivation

1. Nursery preparation

Well drained deep sandy to loamy soil is considered best since the plant develops long and thick roots. The plant requires moisture for development but is susceptible to water-logging. So, the site selection must be done with

this consideration.

Ruta is a biennial crop. In the month of March to April, prepare the nursery by ploughing/digging the plot several times and crushing the clods into fine texture. Add sufficient FYM (minimum 8 tons/acre) prior to sowing. Prepare a nursery bed to 20 cm in height, 1.5m in with and 5m in length. Make furrows of 3-5cm deep at a spacing of 30 cm each(in 1.5m bed there will be 5 furrows of 30 cm apart) Sow Ruta seeds thinly in the furrows and gently cover the seeds with fine soil. The seeds take 4 to 5 week to germinate and another 4 -6 weeks for transplanting stage. The seed requirement for an acre plantation is about 1.5 kg.

2. *Transplanting*

When plantlets are sufficiently developed (4-5 leave stage), it should be gently up rooted and transplanted in a well-prepared field. The transplanting should be done on a moist day or when it is raining. This improves the survival rate. Transplant into the main field in raised beds of 1.5 m breadth and length as permitted by the field at a spacing of 50 x 50 cm or 16,000 plants per acre. Transplanting is recommended in June – July when there is rain. Watering is recommended for the first 6 to 7 days. For the purpose of reducing the cultivation cost, it was found that direct sowing and thinning of the seedlings to the recommended spacing of 50cm plant to plant and row to row is also possible.

3. *Manuring*

Apply FYM twice (8 t/acre), once prior to transplanting during the first year and another in the second year when the plants begin to sprout again.

4. *Weeding*

Ruta is very sensitive to weed competition during its early development. Therefore, keep the plantation weed free by weeding as and when required. In general, weed the plants until they are large enough to shade out the weeds.

The Ruta plantation will remain thus in the first year with the addition of several leaves and senescing thereafter (October/November). In the spring of the following year (March/April), leaves will sprout and the plant

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stump will shoot out bearing flowers by August/September. By October/ November, seeds will mature and the seeds must be harvested by cutting the inflorescence at the base and drying them in containers. Seed must be thrashed and kept for future plantations.

ii. Harvest and post harvest

In the month of November/December of the second growing season, Ruta will be ready for harvest. A brisk irrigation is given to moist the soil 2 to 3 days prior to harvest. Grovel and pick axe is used to dig the soil around the Ruta root, Effort must be given to dig out the entire root and as far as possible intact. Wash the roots to remove soil. Chop to 1-2cm slices and spread it on a tarpaulin and dry under the shade. After drying to 10 to 15 % moisture content, they are packed in clean air tight plastic bags. All the harvest and post-harvest operations are carried out in the best hygienic practices.

iii. Expected income

Depending on soil type, care and the climatic conditions, yields can go up to 4 tons of dried roots/acre. The present price paid by Department of Traditional Medicine (DTMS) is Nu. 400/kg of dried root & Nu.1000/kg of dried seed. Prices are subject to change/revision.

b) Manu: Inula Racemosa

Manu is a very important medicinal plant in Bhutan. It is widely used in the Bhutanese traditional medicine and cultivated in Bumthang and Haa. It is a deciduous perennial that grows to 2.0 metres (6.6 feet) high by 2.0 metres (6.6 feet) wide and prefers many types of soil with a pH ranging from acid to alkaline and full sun with moderate moisture. This plant is self-fertile and has hermaphrodite flowers and is pollinated by bees, flies, self. It is vigorous plant, grows at an elevation of 3000 to 4000 metres above sea level.

Figure 2.3 Manu plant

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It is used for lowering cholesterol, curing asthma, bronchial disease,chronic bronchitis, for cardiac complications and for cough. The highly aromatic roots are used for incense making.

i. Cultivation:

1. Nursery preparation

Well drained sandy to loamy soil is considered best since the plant develops long and thick roots. The plant requires moisture for development but is susceptible to water-logging. So, the site selection must be done with these considerations.

Manu is a biennial crop. It does well in moist well-drained soil in sun or partial shade. In the month of March –April, prepare the nursery by ploughing/digging the plot several times and crushing the clods into fine texture. Add sufficient FYM (minimum 8 tons/acre) prior to sowing. Prepare nursery bed of 20 cm in height, 1.5m in with and 5m in length. Make furrows of 1-2cm deep at a spacing of 30 cm each (in 1.5m bed there will be 5 furrows of 30 cm apart). Sow Manu seeds thinly in the furrows and gently cover the seeds with fine soil. The seeds take 4 to 5 weeks to germinate and another 4 -6 weeks for transplanting stage. The seed requirement for an acre plantation is about 0.5 kg.

2. Transplanting

When plantlets are sufficiently developed (4-5 leave stage), gently up root and transplant in a well-prepared field. The transplanting should be done on a moist day or when it is raining. This improves the survival rate. Transplant into the main field in raised beds of 1.5 m breadth and length as permitted by the field at a spacing of 50 x 50 cm or 16,000 plants per acre. Transplanting is recommended in June – July and watering is recommended for the first 6 to 7 days

3. Manuring

Apply FYM twice (8 t/acre each), once prior to transplanting during the first year and another in the second year when the plants begin to sprout in spring.

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4. Weeding

Manu is very sensitive to weed competition during its early development. Therefore, keep the plantation weed free by weeding as and when required. In general, weed the plants until they are large enough to shade out the weeds.

The Manu plantation will remain in field during first year with the addition of several leaves and senescing thereafter (October/November). In the spring of the following year (March/April), leaves will sprout and the plant stump will shoot out bearing flowers by August/ September. By October / November, seeds will mature and the seeds must be harvested by cutting the inflorescence at the base and drying them in containers. Seed must be thrashed and kept for future plantations. The cost of Manu seeds is Nu 2000/kg.

ii. Harvest and post harvest

In the month of November/ December of the second growing season, Manu will be ready for harvest. A brisk irrigation is given to moist the soil 2 to 3 days prior to harvesting. Grovel and pick axe is used to dig the soil around the Manu root. Effort must be put into dig out the entire root and as far as possible in intact form. Wash the roots to remove the soils. Chop to 1-2cm slices and spread it on a tarpaulin and dry under the shade. After drying to 10 to 15 % moisture content, they are packed in clean air tight plastic bags. All the harvest and post-harvest operations are to be carried out with the best hygienic practices.

iii. Expected income

Depending on the soil type, care and the climatic conditions, yields can go up to 4 tons of dried roots/acre. The present price paid by Department of Traditional Medicine (DTMS) is Nu. 400/kg of dried root & Nu.2000/kg of dried seed. Prices are subject to change/revision.

c) Goned: Carumcarvi

Goned is found scattered here and there in Ligshi Dungkhag, Haa and Paro. It is an aromatic plant, characterized by carminative (calming) properties. It has been grown for its seeds as well as oil for thousands of years. In Bhutan, Goned is cultivated in Lingshi, Haa, Paro and Bumthang Dzongkhags.

It is an erect, biennial herb with thick tuberous root stocks, growing to 80 cm in height with narrow finely grooved leafy stems. During the first year, goned produces a rosette of dark green, finely cut, feathery leaves. The crop requires cold temperatures during winter months to initiate the production of flowering stems in the second year. It flowers in late spring and seed is produced 30-35 days after flowering.

Figure 2.4 Goned plant

It is used for flavoring children's medicines, meat & confectionery products; as an antidote to flatulence and aid to digestion; helps in respiratory, eye & urinary problems, also used in mouthwash and gargle preparations as well as in the perfume industry; also used as condiment and spice.

i. Cultivation

1. Nursery preparation: Prepare fine nursery bed by adding well-matured leaf compost or FYM in the month of April/May. Sow seed thinly in lines 1.5 to 2 cm deep and 20 cm apart into moist soil @ 10-20 g of seed/10 sqm. Do regular weeding and irrigation during dry periods.
2. Transplanting: Transplanting of healthy plantlets in June- July into a well-prepared field at 15 x 35 cm between plants.
3. Manuring: When plants are about 10 cm tall, apply well matured leaf compost or FYM as a side dressing after a round of weeding.
4. Weeding and care: Do the weeding as and when required depending upon the weed pressure. Good fencing is required to avoid domestic and wild animals damaging the plantations.
5. Harvest & Post harvest; Harvest when seed turns brownish (May - June). Special care is required to avoid seed losses – seed falls out easily. We recommend cutting the entire plant at the base early in the morning when dew is still present. Put up in bundles and begin threshing after the seed is dry. Store goned seed in thin layers assuring air ventilation during storage in order to avoid fungus contamination. Water content of seed must not exceed 12%.

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ii. Expected income

Depending on the variety, care and the climatic conditions, yields vary from 160 to 400 kg of seed/acre. At the present rate of Nu. 325 per kg of seed paid by the ITMS, farmers can expect incomes from Nu. 52,000to 130,000per acre.

d) Gurgum: Carthamustinctotius

Figure 2.5 Gurgum plant

Safflower was originally cultivated for petals used in making dyes for various purposes. Presently the crop is grown particularly for oil and petals. Safflower is adapted to both dry land and irrigated cropping systems. Areas with rainfall above 1000 mm are not recommended since the crop is susceptible to increased humidity or prolonged water-logged conditions.

It is an erect biennial thistle like herb, branched towards the apex with a strong central stem, up to 1.5 m tall. Leaves are spiny, oblong or ovate-lanceolate, glabrous and alternate, minutely spinose-toothed with the upper ones being clasping. Flowers are borne on heads or capitula arising from the top of branches (1-5 heads/plant), with yellow, orange, and red or white corollas surrounded by cluster of leafy spiny bracts. Fruits or seeds (achenes) are white, 6-7 mm long, shiny and almost four-sided in shape. Flowers in June- July.

Gurgum is used as a laxative; cures liver diseases, builds blood and improves the general health. It is also used as a diuretic and an aid to digestion & weight loss besides being used to treat post child birth pains & internal bleeding.

Tender shoots are reported to be taken as salad and potherb. Seed are also eaten roasted or fried, and are used in chutney preparations.

Safflower petals are the chief ingredient used in the formulation of Tsheringma Herbal Tea of the ITMS in Bhutan, It is also used as a substitute for dre-zang (saffron). It is also cultivated for its seed oil which is claimed best for cooking because of the very low cholesterol content. The seed husk or cake is used as a very nutritious cattle feed.

i. Cultivation

1. Planting and Land Preparation

Light well-drained soil with a pH of about 7 is found best. The plant requires moisture for development but is susceptible to water-logging. Prepare field by ploughing once or twice and crushing the clods into fine texture. Add sufficient FYM. Raise the beds at a breadth of a metre keeping the length as permitted by the field. Irrigate the field prior to sowing if it is dry.

Sowing is recommended in the month of February -March for summer crop and in Sept – Oct if cultivated as winter crop in the lower altitudes. Sowing should be adjusted so as to avoid rainfall during bloom. Sow seeds directly at 2.5 cm depth (2 seeds/hole) with a spacing of 20 cm x 20 cm; or sow thinly in furrows 20 cm apart and 2.5 cm deep. Under optimal soil moisture, the seeds will germinate between 8-15 days after sowing. Thinning out of crowed seedlings is important for a good yield. Plants should be thinned out to a spacing of 20 cm x 20 cm when they are at 4-5 leaved stage.

2. Manuring

Apply FYM when the plants start to form buds to increase flower production.

3. Weeding

Safflower is very sensitive to weed competition during its rosette stage and therefore keep the plants weed free by weeding at least twice after germination and after 4-leaved stage. In general, weed the plants until they are large enough to shade out the weeds.

ii. Harvest and post harvest:

When the petals have fully bloomed and before it starts to scenes they are harvested. The petals are cut with the help of scissors at their base and collected in a basket and dried. The harvesting operation is repeated after every 3 days so that maximum petal quantity is obtained. Petal are dried in a clean net/tarpaulin under shade. The dried petals are packed in a clean air tight and supplied to DTMS. Since this method of petal harvesting is tedious and time consuming, and as an alternative, we can let the petals dry on the seed inflorescence, and when the seeds are mature and the crop harvested for seed, the dried petals can gently be removed from the seed capsule and collected in a clean container.

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e) Ti-yangkhu: Dracocephalum tanguticum

Figure 2.6 Ti-yangkhu plant

The plant is not found in Bhutan and is usually imported from Tibet for medicine production. Since 1999, the plant is being cultivated in Soe and Lingshi Thimphu, Haa and Bumthang. It is glabrous erect perennial herb, 1-1.5 ft tall, blue flowers, root with tubers, bearing narrow, ovate and aromatic leaves, 2 – 8 cm long. It is said to grow naturally, in the wheat field, trail sides, gardens in the Tibet and Himalayan region at an altitude of 3000-4200 m above sea level. It is used for stomach ache, liver and lung ailments, improves blood, heals wounds, dries up watery pus. It is also used for flavouring meat curries.

i. Cultivation

1. Nursery preparation

The raised bed with very fine soil should be prepared. Seeds are fine and tiny, because of which they are sown 1-1.5 cm deep in rows in the month of Feb – March. They will germinate in 15 to 20 days' time. Though seed can be sown by broadcasting method, raising nursery and transplanting is the best method to save labour and seed

2. Transplanting

When the plants are 5 – 6 leaf stage in the month of May and June, transplanting can be done. Transplant the 5 – 6 leaf seedlings at a distance of 20 cm row to row and 20 cm plant to plant. Watering the transplanted plants for a week is very essential if there are no rains.

3. Manuring

Farm yard manure(FYM) and forest compost is used to improve the crop yield and performance, no chemical fertilizers are used in the cultivation of MAPS(thumb rule)

4. Weeding

As and when weeds grow, weeding and hoeing must be done to promote vegetative growth and to keep the field clean.

ii. Harvest and post-Harvest

Harvesting time will differ according to altitude climate of the place. In June or July when the plants are in 50 % in bloom or just before they begin to dis-colour, the whole aerial parts (i.e. shoot, branches, leaves and flowers) are harvested by cutting 4 – 5 cm above the ground taking care not to contaminate with soil and other weeds. The harvested plants are then bundled at the base with a string and hung dry under roof. Alternatively, it can be dried in shade by spreading thinly on a tarpaulin. Dry in a cool and shady place (not in sun, smoke, heat). When it is dry it is very brittle, so pack them up in a good packing bags so that small pieces are not lost.

After harvest, earth up soil and add FYM @ 2 kg per plant base. Under optimum condition of moisture and soil fertility, there can be a second harvest(in much reduced qty) in October – November. If there is sufficient moisture over the winter, the harvested stumps will regenerate shoots the following spring and the harvesting procedure can be repeated annually. The dried plant material is then sold to ITMS at their prevailing rates.

Being perennial in nature, plants will sprout in April and May. Earth up, apply FYM @ 2 kg per plant and irrigate. This will hasten vegetative growth. By the month of June and July, plants will flower. Harvest, dry and pack as in year one.

iii. Expected income

Based on the yield obtained from a cultivated plot, it has been estimated that a total of 580 kg dry Tiyangkucan be obtained from an acre of land. Because of the fact that the plant is not found in Bhutan and that it has to be imported from Tibet prior to 1990s, the local market is good. DTMS will now absorb any quantity produced in the farmers filed. Also, the local and private Drungthos and Lams are after the plant for making their medicinal pills (Dashelrueps). The DTMS pay Nu 256 per kg of dried plant material.

f) Cordyceps: Cordycepssinensis ('Yartsa-guenbub')

Cordycepssinensis is commonly known as cordyceps mushroom or caterpillar fungus. It is locally known Yartsa Guenbub which can be translated into English as 'winter-worm, summer-grass'. The whole parts are used for the medicinal purposes. It is good for reinforcing the lung and kidneys, arresting bleeding and restoring

energy and also anti-aging. It acts as anti-oxidant, anti-tumor effect, anti-fatigue and stress. It also has tonic and aphrodisiac properties.

Figure 2.7 Cordyceps

Cordyceps grows in the cold, grassy alpine meadows of mountainous regions. It is found growing in Tibet and it is reported to occur in Japan, Australia, New Zealand, Canada, United States, Mexico, Russia, India and Bhutan. In Bhutan, it is distributed in alpine areas of Lunana, Laya, Lingshi, Soe, Naro, Sephu, Baylangda, in some places of Bumthang, TashiYangtse and Haa dzongkhags.

Cordyceps is unique black, bladed-shape fungus. The stroma appears above the ground in summer as a dark brownish-black blade (3-6 cm long and 0.4-0.7 cm thick). The larva looks like a silk worm, 3-5 cm in length, and 0.3-0.8 cm in diameter. The body surface is deep yellow or yellowish-brown and the head is reddish-brown. It has 8 pairs of legs, the middle 4 pairs being the most prominent. The stroma, slightly longer than the larva's corpse, is rod-like and twisted growing from the

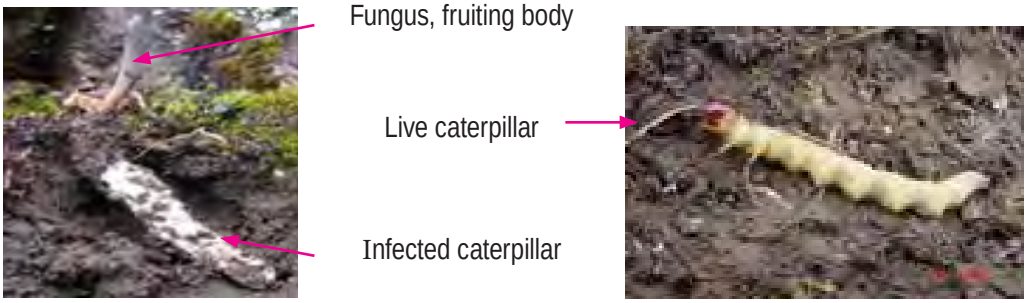

Figure 2.8 Cordyceps larve

head of the larva. In Bhutan (Lingshi condition) immature Cordycepsdevelops by April- May, from May - June the Cordyceps starts maturing (spore developing stage), June-July the Cordyceps matures (spores are discharged) and some of these spores lands on the host (caterpillar) and by July-November Cordyceps fungus develops within the host (before killing the host). From November-April host insect over winters and the life cycle continuous.

iv. Harvesting

Matured cordyceps are harvested during mid-May to mid-June. After harvest it should be cleaned thoroughly and properly dried. Always check and keep it in air-tight container, and handle with care as it is brittle when dry.

g) Lemon grass (Cymbopogon species) - Humcu-tsa/Chi-tsa

Lemon grass belongs to family Gramineae. Lemongrass is used in herbal teas and other non-alcoholic beverages, baked goods, and confectioneries. Lemongrass oil is used in perfume, soap and cosmetics industries. Lemongrass forms the starting material in the manufacture of synthetic Vitamin A. It is also used in pharmaceutical preparations, such as pain balm, disinfectants, and mosquito-repellent creams.

Figure 2.9 Lemon grass

In Bhutan lemongrass is found growing as under growths in Chirpine forests up to 1600masl in Mongar district. Lemongrass is widely adapted to a range of soils and performs well on sandy to clay loam soils with a pH range of 5 to 8.4 and good drainage. It grows well at a temperature range of 10 to 33°C, and needs enough sunshine for the development of oil in the plant. The grass is sensitive to cold weather and cannot withstand frost. The favourable rainfall for dry land growing of lemongrass should range from 700 to 3000 mm uniformly distributed throughout the year.

Lemon grass oil is extracted by steam distillation. Grass is either distilled afresh or is allowed to wilt for 24 hours under shade. Wilting reduces the moisture content and allows a larger quantity of grass to be packed in kettle thereby saving on fuel. Chopping grasses to 5-10cm size increases the recovery of oil because of exposure of oil-bearing glands and also facilitates even packing. The grasses should be packed firmly to prevent the formation of steam channels. As the distillation proceeds, the distillate collects on the separator and oil being lighter than water and insoluble floats on the top of the separator and is continuously drawn off. The oil is then decanted and filtered.

On an average 30-35 tons of lemon grass yield 100-120 kg oil/ha/annum. Quality of oil is judged by citral content. In world market the standard required is 75% citral content.

h) Ginger: Zingiberofficinale (Sa-ga)

Ginger is an herbaceous perennial belonging to the Zingiberaceae family. Ginger is associated with many health benefits and used in ayurvedic preparations. The rhizomes are mainly used as spices. It is also used in the preparation of pickles, beverages, medicines and confectionaries, but in Bhutan it is used mainly for fresh consumption. Processing of fresh ginger into dried ginger powder, ginger tea sachets and ginger pickles are some of the value added products explored & processed.

Figure 2.30 Ginger

i. Cultivation

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

India is the major market for ginger from Bhutan as the domestic consumption is low. About 80% of the ginger production in Bhutan is sold to India while Minimal quantities are also auctioned via the auction markets. Small quantities are sold in the weekend markets. According to the Bhutan RNR statistics 2016, about 2904.96 MT of Ginger has been exported to India, valued at Nu. 69.7 Million.

Ginger thrives best in well drained soils like sandy loam, clay loam, red loam or lateritic loam. A friable loam with a pH of 6.0 to 6.5 rich in humus is ideal. However, being an exhaustive crop, it is not desirable to grow ginger in the same

soil year after year. Ginger grown in red soil is considered better quality in the auction yard (Dorji, 2017).The crop cannot withstand water logging and hence soils with good drainage are preferred for its cultivation.

1. *Field preparation*

The land is to be ploughed 4 to 5 times or dug thoroughly with receipt of early summer showers to bring the soil to fine tilth. Beds of about 1 m width, 30 cm height and of convenient length are prepared with an inter-space of 50 cm in between beds. In the case of irrigated crop, ridges are formed 40 cm apart. In areas prone to rhizome rot disease and nematode infestations, soil solarization of beds for 40 days using transparent polythene sheets is recommended (Jayashree E, 2015).

2. *Recommended seed/ seedling rate*

The seed rate varies from region to region and with the method of cultivation adopted. The seed rate is 1,500-1,800 kg per acre in Bhutan (UNDP, 2016). At higher altitudes the seed rate may vary from 2000 to 2500 kg/ha.

3. *Planting time*

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

4. *Irrigation*

Ginger is cultivated as rain fed crop in high rainfall areas (uniform distribution for 5 to 7 months) and irrigated crop in less rainfall areas where distribution is not uniform. Ginger requires 1300-1500 mm of water during its crop cycle. The critical stages for irrigation are during germination, rhizome initiation (90 DAP) and rhizome development stages (135 DAP). The first irrigation should be done immediately after planting and subsequent irrigations are given at intervals of 7 to 10 days in conventional irrigation (based on prevailing weather and soil type). Sprinklers and drip system can also be employed for better water use efficiency and enhanced yield.

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5. *Planting*

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

6. *Transplanting*

Though transplanting in ginger is not conventional, it is found profitable. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on planting material (Jayashree E, 2015).

7. *Weed management*

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

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.

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.

10. Removal of mother rhizome

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

This practice is believed to give proper space to the developing rhizome and although the quality of rhizome is inferior, farmers get income due to off-season price advantage. Fifteen days after mau extraction, FYM is applied once again and earthed up (Rahman k, 2009).

11. Nutrient Management

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

As the soil fertility will be varying with the soil type, agro ecological conditions or management systems, site specific nutrient management based on the soil test results for major nutrient is advocated. The fertilizers are to be applied in 2 to 3 split doses. Full dose of phosphorous is applied as basal dose at the time of Planting. Equal split doses of N and K is top dressed at 45, 90& 120 Days after planting.

12. Plant Protection against diseases

i. Soft rot

Soft rot is the most destructive disease of ginger which results in total loss of affected clumps. The disease is soil-borne and is caused by Pythiumspp, among which, P. aphanidermatum and P. myriotylum are widely distributed

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in India. The fungus multiplies with build-up of soil moisture with the onset of south west monsoon. The infection starts at the collar region of the pseudo-stem and progresses upwards as well as downwards. The collar region of the affected pseudo-stem becomes water-soaked and the rotting spreads to the rhizome resulting in soft rot with characteristic foul smell. At a later stage root infection is also noticed. Foliar symptoms appear as light yellowing of the leaf margins of lower leaves which gradually spreads to the leaf lamina. In early stages of the disease, the middle portion of the leaves remain green while the margins become yellow. The yellowing spreads to all leaves of the plant from the lower region upwards and is followed by drooping, withering and drying of pseudo-stems.

Control Measures:

- Seed rhizomes are to be selected from disease free gardens, since the disease is also seed borne.
- Treatment of seed rhizomes with mancozeb0.3% or metalaxylmancozeb 0.125% for 30 minutes before storage, and once again before planting and drenching at 30 and 60 days after planting reduces the incidence of the disease.
- Cultural practices such as selection of well drained soils for planting is important, since stagnation of water predisposes the plant to infection.
- The soil may be solarized before planting by covering the moist soil with a transparent polythene film for 45-50 days.
- Application of Trichodermaharzianum along with neem cake @ 1 kg/ bed helps in reducing the incidence of the disease.
- Once the disease is located in the field, removal of affected clumps and drenching the affected and surrounding beds with mancozeb 0.3% or metalaxylmancozeb 0.125% or copper oxychloride 0.2% checks the spread of the disease.

ii. Bacterial wilt

Bacterial wilt caused by Ralstoniasolanacearum Biovar-3 is a soil and seed borne disease that occurs during south west monsoon. Water soaked spots appear at the collar region of the pseudo-stem and progresses upwards and downwards. The first conspicuous symptom is mild drooping and curling of leaf margins of the lower leaves which spread upwards. In the advanced stage, the plants exhibit severe yellowing and wilting symptoms.

The vascular tissues of the affected pseudo-stems show dark streaks. The affected pseudo-stem and rhizome when pressed gently extrudes milky ooze from the vascular strands. Ultimately rhizomes rot emitting a foul smell.

Control measures

- The cultural practices and seed rhizome treatment adopted for managing soft rot are also to be adopted for bacterial wilt. Seed rhizomes must be taken from disease free fields for planting.
- It is not advisable to plant ginger consecutively in the same field every year. Fields used for growing potato, or other solanaceous crops are to be avoided.

iii. Leaf spot

Leaf spot is caused by Phyllostictazingiberi. The disease starts as water-soaked spot and later turns as a white spot surrounded by dark brown margins and yellow halo. The lesions enlarge and adjacent lesions coalesce to form necrotic areas. The disease spreads through rain splashes during intermittent showers. The incidence of the disease is severe in ginger grown under exposed conditions.

Control measures

- The disease can be managed by spraying of Bordeaux mixture 1% or mancozeb 0.2% or carbendazim0.2%, with the appearance of disease symptoms.

iv. Nematode pests

Root knot (Meloidogyne spp.), burrowing (Radopholussimilis) and lesion (Pratylenchus spp.) nematodes are important nematode pests of ginger. Stunting, chlorosis, poor tillering and necrosis of leaves are the common aerial symptoms. Characteristic root galls and lesions that lead to rotting are generally seen in roots. The infested rhizomes have brown, water-soaked areas in the outer tissues. Nematode infestation aggravates rhizome rot disease.

Control measures

- The nematodes can be controlled by treating infested rhizomes with hot water (50°C) for 10 minutes,
- Using nematode free seed rhizomes and solarizing ginger beds for 40 days.

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13. Insects and pest

i. Shoot borer

The shoot borer (Conogethespunctiferalis) is the most serious insect pest of ginger. The larvae bore into pseudostems and feed on internal tissues resulting in yellowing and drying of leaves of infested pseudostems. The presence of a bore-hole on the pseudostem through which frass is extruded and the withered and yellow central shoot is a characteristic symptom of pest infestation. The adult is a medium sized moth with a wingspan of about 20 mm; the wings are orange-yellow with minute black spots. Fully-grown larvae are light brown with sparse hairs. The pest population is higher in the field during September-October.

Control measures

- The shoot borer can be managed by spraying malathion (0.1%) at 21-day intervals during July to October. The spraying is to be initiated when the first symptom of pest attack is seen on the top most leaf in the form of feeding marks on the margins on the pseudostem.
- An integrated strategy involving pruning and destroying freshly infested pseudostems during July-August (at fortnightly intervals) and spraying malathion(0.1%) during September-October (at monthly intervals) is also effective against the pest.

ii. Rhizome scale

The rhizome scale (Aspidiellahartii) infests rhizomes in the field (at later stages) and in storage. Adult (female) scales are circular (about 1 mm diameter) and light brown to grey and appear as encrustations on the rhizomes. They feed on sap and when the rhizomes are severely infested, they become shrivelled and desiccated affecting its germination.

Control measures

- The rhizome scale can be managed by timely harvest, discarding severely infested rhizomes, and treating the seed rhizomes with quinalphos (0.075%) (For 20-30 minutes) before storage and also before sowing in case the infestation persists.
- The seed rhizome may be stored in sawdust + Strychnosnuxvomica leaves (dried) after seed treatment.

iii. Root grubs (Holotrichia spp.)

Occasionally feed on tender rhizomes, roots and base of pseudostems causing yellowing and wilting of shoots.

Control measures

- The pest can be controlled by drenching the soil around the rhizomes with chloropyriphos (0.075%).

ii. Harvesting

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

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

1. Yield

The average productivity recorded in Bhutan is about 2,063 kg per Acre with the highest average yield recorded from Samtse dzongkhag (3,235 kg/acre) and lowest average yield was recorded from Punakha Dzongkhag (220 kg/acre) (Agriculture Statistics, 2017)

2. Post-Harvest Management

i. Processing

Processing of ginger to produce dry ginger basically involves two stages: peeling of the ginger rhizomes to remove the outer skin and sun drying to a safe moisture level (Plotto A, 2002).

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ii. Peeling

Peeling serves to remove the scaly epidermis and facilitate drying. Peeling of fully matured rhizomes is done by scrapping the outer skin with bamboo splits having pointed ends and this accelerates the drying process. Deep scraping with knifes should be avoided to prevent the damage of oil bearing cells which are present just below the outer skin. Excessive peeling will result in the reduction of essential oil content of the dried produce. The peeled rhizomes are washed before drying. The dry ginger so obtained is valued for its aroma, flavour and pungency.

The rhizomes are peeled only on the flat sides and much of the skin in between the fingers remains intact. The dry ginger so produced is known as the rough peeled or unbleached ginger

iii. Drying

The moisture content of fresh ginger at harvest is about 80-82% which is brought down up to 10% for its safe storage. Generally, ginger is sun dried in a single layer in open yard which takes about 8 to 10 days for complete drying. The sun-dried ginger is brown in colour with irregular wrinkled surface. The yield of dry ginger is about 19-25% of fresh ginger depending on the variety and climatic zone.

iv. Polishing, cleaning and grading

Polishing of dried ginger is done to remove the dry skin and the wrinkles developed on the surface during drying process. It is generally done by rubbing against hard surface. Cleaning of dry ginger is done manually to remove the extraneous matter and the light pieces. Once the ginger is cleaned and it is graded manually based on size of the rhizome, its colour, shape and the extent of residual lime (in the case of bleached ginger).

v. Packaging/ storage

Dry ginger, packaged in gunny bags are highly susceptible to infestation by insects like Lasiodermaserricone (cigarette beetle) during storage. Fully dried rhizomes can be stored in airtight containers such as high-density polyethylene or similar packaging materials. Long term storage for more than two years would result in deterioration of its aroma, flavour and pungency.

3. *Seed maintenance*

i. Seed selection

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

ii. Storage

There are three traditional methods of seed rhizome storage.

1. Storage in soil pits: In pit storage, either a circular or rectangular pit (1-2 m depth) is dug. A thin layer of straw is spread over the bottom of pit and rhizomes are placed into this in layers just below ground level. Again a thin layer of straw covers the rhizomes. The final covering is done with the soil little above the ground level (as roof). The pits are opened at the time of next year sowing. In this method, the rhizomes get spoiled in two ways, i.e., around 25-30% rhizomes rot in the pit itself and about 10-15% rhizomes sprout in the pit and are rendered useless for sowing. Some farmers in Meghalaya opined that ginger stored in pits along with sand protect the ginger from rotting.
2. Storage in a dry and shaded place: Storage in dry, shaded places is economic for the larger growers but there is a problem of rhizome drying. The seed rhizomes are stored along with the leaves of local neem.
3. In situ storage: By in situ storage (delayed harvest), farmers harvest the rhizome according to market demand and allow the rest of rhizomes remain unearthed in the field. This method is prone for rhizome rot, rhizomes start sprouting in course of time and harbour insect pests.

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i) Large Cardamom (Cardamomumsubulatum) (Alenchi)

Large cardamom (Amomumsabulatum Roxb.) belongs to Zingiberaceae family & is native to moist deciduous and evergreen forest of Sub-Himalayan tracts and it is one of the main cash crops cultivated in south-western region of Bhutan. The crop was introduced to Bhutan centuries back from Sikkim and its cultivation gradually started in other parts of Bhutan covering mainly southern foothills. The present cultivation of crop is based on the inherent indigenous knowledge of the farmers which was derived and adopted from farmers in Sikkim. As a result, package of practices were developed to provide information on cultivation practices of the crop.

Figure 2.31 Cardamom

The large cardamom plant is a perennial herb with subterranean rhizomes with leafy shoots. The stem is a pseudo-stem which is called tiller, and its inflorescence a spike. Generally, 30-40 flowers are observed in a spike. Large cardamom flowers are yellow, bisexual, and zygomorphic which is pollinated by bumble bees. There are three petals with a labellum which is mainly for attracting insects for pollination. Stamen possesses filament and anthers. Anthesis occurs in the morning hours. Ovary is inferior with ovules in axile placentation and the stigma is funnel shaped. The fruit is called capsule which is achinated, and maroon in colour with seeds that are whitish during immature stage and dark brown to black at matured stage.

Cardamom plantations in Bhutan covered an area of about 13,880 acres with an annual production of 2,245 MT in 2017. Samtse, Chukha, Dagana, Tsirang, Sarpang and Trongsa are the major large cardamom growing Dzongkhags. Large cardamom is grown only in India, Nepal and Bhutan which lie in the sub-Himalayan region in south-east Asia. Bhutan is third after Nepal and India

in production of large cardamom in the world.

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; and is also used as one of the prime ingredients in Birayani preparation. It contains 2 to 3% of essential oil and possesses high medicinal properties like carminative, stomachic, diuretic, cardiac stimulant and antiemetic.

i. Cultivation

1. Climate requirement

Large cardamom prefers humid subtropical, semi-evergreen forests on medium to steep hills of eastern sub-Himalayan region. It is a shade loving plant (Sciophyte) grown in tracts with well distributed rainfall spread around 200 days with a total of about 3000-3500 mm/year. The plants are usually grown along small springs, in moist and shady sides of mountain streams and along hilly slopes. It is grown successfully depending upon the cultivars in the altitude ranging from 600 to 2000 masl (DoA, 2018).

2. Soil requirement

Deep and well drained soils with loamy texture are best for large cardamom cultivation. The crop requires at least moderate deep (0.6m) top soil for its good performance. Large cardamom soil should be rich in organic matter and nitrogen, medium in available Phosphorus and medium to high in available potash. Soil pH should range from 4.5 to 6.0, have high exchangeable iron and aluminum. Even though the crop can be grown in undulating and steep terrains, land with moderate slope is preferred (DoA, 2018).

3. Site selection

Large cardamom grows best in forest loamy soils with gentle to medium slopes. Slopes facing north are the most favorable for its growth as they prevent direct sunlight during the day time. Luxuriant growth is observed nearby perennial water sources. However, water logged condition is detrimental to the plants' growth. It performs well under partial shade (50%). Thus, the agro-forestry based cropping system is highly recommended (DoA, 2018).

4. *Land preparation*

The land selected for planting is cleared of all under growths and weeds. Old large cardamom plants, if any may also be removed. Pits of size 30 × 30 × 30 cm are prepared on the contours at a spacing of 1.5 × 1.5 from the center of the pits. Wider spacing of 1.8 × 1.8 m is recommended for robust cultivars like Ramla, Ramsey, Sawney and Varlangey etc. while closer spacing of 1.45 × 1.45 m is advised for non-robust cultivars like Dzongugolsey, Seremna etc. Pits are left open for weathering for a fortnight and then filled with topsoil and FYM. Filling operation should be completed by the third week of April before the onset of pre-monsoon showers.

5. *Planting*

Planting of large cardamom is done in May- June when there is enough moisture in the soil. A mature tiller with 2-3 immature tillers/vegetative buds is used as planting unit. For better production, quality planting materials are to be raised in the nurseries or to be collected from BAFRA certified nurseries. Suckers/seedlings are planted by scooping a little soil from the center of the pits and planted up to collar zone. Deep planting should be avoided. Staking is needed to avoid lodging of plants from heavy rain and wind and mulching is done at the plant base.

6. *Mulching*

A soil base with gentle slope from the plant is beneficial for application of inputs to the plants viz., FYM, vermin-compost, neem cake, mustard cake, etc. If the land is not terraced, soil base may be made by removing top soil from the upper half to be placed on the lower half followed by mulching. Mulching at the plant base helps to retain moisture and the prevent erosion of topsoil. Mulching improves the soil condition and the soil fertility. Dried organic matter, leaves, weeds, etc., can be used as mulching materials.

7. *Manures and fertilizers application*

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

in plantation with high productivity, fertilizers @ 20:30:40 kg N, P and K per hectare may be applied in two splits, full P in April and half N and K in April and September (DoA, 2018).

8. *Irrigation*

Large cardamom plants cannot thrive well under water stress conditions. In the first year of planting watering is required at least once in 10 days during dry months from September to March for better growth in coming months. It is observed that the productivity is higher in plantations where irrigation is provided. Depending on availability of water source, hose or sprinkler irrigation and irrigation through small channels are advised. Water harvesting pits can be made in between four plants during rainy season can support the water requirement of the crop in the dry season to some extent.

9. *Shade management*

Large cardamom performs best under the partial shade. About 50% shade is found ideal. Uttis, himalyan alder/gamashing is the most recommended shade trees. The other trees recommended as shade tree are Panisaj, Pipli, Malito, Argeli, Asare, Bilaunce, Kharane, Siris, Faleto, Jhingani, and Chillowne/Zalashing. If the crop is cultivated in marginal lands, intercropping with fruit crops like mango, banana, citrus, andavacado can also be practiced.

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

10. *Weed management*

Weed control in the plantations is an important operation for maximum utilization of available soil moisture and nutrients by the plants. Three rounds of weeding are recommended for effective control of weed growth in initial two to three years. Weeding is generally done by using a sickle or by hand depending upon the intensity of weed growth. From around the plant base weeds are pulled out by hand and in inter-space slashing

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with sickle are practiced. Clean weeding is not advised as the crop is found to be a good colonizer. While weeding, dried shoots and other thrashed materials are used as mulch around the plant base which will help to conserve moisture in the ensuing dry months, cover the exposed roots and prevent weed growth around the plant base. During flowering period, the thrashed materials should not cover the inflorescences.

ii. Harvesting and curing

The indication of time of harvest is when the seeds of top most capsules turn brown. As soon as the said colour appears and to enhance maturity, bearing tillers are cut at a height of 30-40 cm from ground and left for another 10-15 days for full maturity. The spikes are harvested by using harvesting knives known as "Chhuri". The harvested spikes are heaped and capsules separated and dried. The cured capsules are rubbed on wire mesh for cleaning and removal of calyx.

Traditionally cardamom is cured in Bhatti, where capsules are dried by direct heating. Under this system the cardamom comes in direct contact with smoke which turns the capsules dark brown or black with smoky smell. Drying is done till moisture content of the produce is brought down to 10-12 % level and gives metallic sound while shuffling.

iii. Post-harvest Management

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

This chapter provided 'package of practices for cultivation of MAPS' with opportunities for entrepreneurship that generate self-employment and employment of others in the service of our nation, not only to gain economic self-reliance but to strengthen the glory of 'lhojong menjong'.

Student Activity

With the ideas from this chapter, students can be encouraged to explore local Medicinal and Aromatic Plants. Every community has very rich traditional herbal treatment practices of various diseases, fractures and dislocation of bones and joints that are unknown to others. They are often very effective and do not have side effects unlike the modern chemical medicines. Students can do a project on collecting information to design manual on traditional treatment.

Activity I - Discussion to explore local knowledge of MAP

1. Start open discussions with questions:
   a. What did you learn from this chapter about our country?
   b. What evidence do you have in support of our country being considered as a 'menjong'?
   c. To prove our country being known as 'menjong' carry out a project on local traditional treatment practices in the community around the school.
2. Objectives of group activity – To study local treatment practices and develop a treatment manual consisting of what kinds of treatment for what kinds of sickness or injuries, types of treatment, herbs/plants or things used as medicines, how they are made and how they are being used for how long before sickness or injuries are cured.
3. In smaller group groups;
   a. Design questionnaires to collect information on local treatment covering the objectives.
   b. Plan field visit of community to collect information through interview of elders or /and observations of how the treatment is done if possible, visit community, collect information, compile and prepare presentation.
   c. Group present to the class, collect comments for improve, improve compilation, edit write up, develop into pamphlets, exhibit to the school and share with others for practices.
   d. Assess the students as per the curriculum guide and record.

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Activity 2 - Growing of Spices (Ginger or Cardamom)

1. Assign students in small groups to grow one of the spices mentioned following the 'package of practices for cultivating spices' provided in the chapter. Different group could be assigned to grow different spices, with instructions to plan, execute plan, keeping records of development, care, harvest of produce, etc.
2. Plan a field trip to a farm where MAPS are grown and sold or processed, to learn more about MAPS, write report on the learning or experiences gained from the field trip.

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3 CHAPTER

Introduction to Post Harvest Technology

The Ministry of Agriculture and Forests improved production systems in the country through farm mechanization, distribution of improved seed materials, improving the extension services, providing road connections to almost all the production areas and initiating post-harvest technology. However, production of agriculture and horticulture produce is only the beginning. The produce in fresh or processed form has to journey through a series of handlers and sellers till it reaches the final destiny i.e. the consumer or the processor. The period after harvest and before consumption is very crucial for the produce as the supply of food and water from the mother plant are cut-off and they have to survive on their own food reserve. The utilization of reserve food material without external supply leads to deterioration in produce quality and ultimately perishes, resulting in huge loses to the producer, traders and the consumers. Most of the fruits and vegetables grown in the country are small scale production in the backyard gardens for self-consumption. There is scope for production of fruits and vegetables on commercial scale.

This chapter explores the concept of post-harvest technology, starting from the appropriate stages for harvesting, handling of produce and use of technology can prolong and safeguard the produce before they are sold to the consumers. The post-harvest technology discussed in this chapter, will enable the farmers a continued supply of fresh fruits and vegetables to the consumers of the urban centres, will greatly reduce the nation's dependence on import of agriculture produce. The post-harvest technology is expected to be practiced for all agriculture produce both by the producers as well as by the consumers to minimize waste. For the learners, the post-harvest technology is expected to be practiced while growing fruits and vegetables in the subsequent and relevant chapters. '*What is post-harvest technology and related ideas that helps post-harvest technology work?*' will be key questions that the learners need to ask in order to understand the underlying processes and practices.

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3.1 Post-Harvest Technology

The management strategies/practices adopted to maintain produce quality after harvesting through handling processes till consumption is termed as post-harvest management. It is a bridge between production and marketing of fresh or processed produce. However, it entails keeping in mind clear objectives of the use of technology to harvested fruits and vegetables are (i) to maintain quality of appearance,(ii) texture, (iv) flavour and (v) nutritive value, (vi) to protect food safety, and (vii) to reduce losses between harvest and consumption.

To achieve these purposes, farmers need to understand the developmental stages of fruits and vegetables, harvesting them at the right time, harvesting them with care, use appropriate technology to preserve the produce before they are sold to the consumers or processed. Harvesting produce at an appropriate developmental stage is very important for the consumers and the processors alike.

a) Understanding the developmental stage of fruits and vegetables

i. Maturation

The principles dictating the stage of maturity of a fruit or vegetable are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables as maturation, ripening, and senescence. *Maturation* is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. *Ripening* follows or overlaps maturation, rendering the produce edible, as indicated by taste. *Senescence* is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. Senescence ends at the death of the tissue of the fruit. It is important to understand the stages of fruits and vegetables maturity and these could help farm manager save farm produce.

Maturity is the particular stage in life of plant part or fruit at which they attain maximum growth and size. Good quality of fruits and vegetables are obtained when harvesting is done at the proper stage of maturity. It is the stage where any organ of the plant attains full growth and development. So it is the stage of fruit development beyond which no further growth take place. After maturity of any organ it starts its decline stage i.e. called as "Ripening". The maturity indices are also called as "Maturity Standards" or "Signs of Maturity". Maturity signs help

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in judging maturity of fruits and vegetables. The signs are based on experience, skill and judgment. As the market value depends upon quality of the produce, the knowledge regarding maturity indices for the right stage of harvest is very vital. Also shelf life of the produce in some fruits depends upon maturity stage of harvested produce.

Fruits harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. Similarly, vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For example, small or immature vegetables possess better texture and quality than mature or over-mature vegetables. Therefore, harvesting of fruits and vegetables at proper stage of maturity is of paramount importance for attaining desirable quality. The level of maturity actually helps in selection of storage methods, estimation of shelf life, selection of processing operations for value addition etc.

To ensure sensory quality (flavour, colour, aroma, and texture), nutritional quality and an adequate post-harvest shelf life; to facilitate scheduling of harvest, packing operations and marketing over the phone or through internet, maturity indices of vegetables and fruits are determined by:

i. *Visual method*: Observation of skin colour (apple), determining the size (carrot), drying of outer leaf (onion), drying whole plant body (potato), change in smell or flavor (Jackfruit), dropping down of ripe fruits (peach).

ii. *Physical means*: Testing the firmness of fruit with penetrometer (apple), easy of separation or abscission (chilli), determining the specific gravity (potato), weight of the fruit (apple).

iii. *Chemical analysis*: The Soluble Solid Content (SSC) also called Total Soluble Solids (TSS), can be determined in a small sample of fruit juice using hand refractometer (apple), measuring the acid content in oranges through neutralization reaction (mandarin), determining the starch content through Iodide test (apple), analyzing the reducing and non-reducing sugar (peach), etc.

iv. *Computation method*: Counting the number of days from full bloom (when 80 % of the flowers open) to maturity (apple).

v. *Physiological method*: Measuring the respiration rates especially in fruits and also the production of ethylene in the fruit (apple).

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ii. Pre-Harvest factors

These stages of fruits and vegetables are natural processes and bound to take place sooner or later, they are influenced by external factors considered as pre-harvest factors. These factors can control the stages of maturity of fruits and vegetables and can be of much advantage to the farmers as well as for the people who have business in the agriculture produce. The pre-harvest factors responsible for maturity, ripening and deterioration of fruits and vegetables are:

1. Selection of varieties

Varieties with higher yield, better keeping quality, slower ripening and longer shelf-life under ambient condition and better processing quality are developed and commercially grown. It is advisable for the farm managers to select and grow. The post-harvest quality of citrus fruits increase significantly when trifoliate orange, tangelo or Cleopatra are used as root stock.

2. Cultural operations

These help prolong shelf-life of fruits and vegetables. Pruning or thinning increase the fruit size and decrease TSS (Total Soluble Solids) and acidity. Quality of fruits is improved by the application of potassium (K), manganese (Mg) and zinc (Zn), while higher nitrogen (N) and phosphorus (P) deteriorate the quality. Excessive irrigation before harvesting decreases the shelf-life and sensory quality, while insufficient irrigation enhances the maturity of the crop. For root crops, preparation of the soil to a tilth of porous nature is necessary to avoid root forking. In onion and garlic, irrigation should be stopped 3 weeks before harvesting to ensure better keeping quality.

3. Respiration

It is the process by which plants take in oxygen and give out carbon dioxide. This reaction produces energy in the form of heat. Respiration is a basic reaction of all plant material, both in the field and after harvest. It is a continuing process in the growing plant as long as the leaves continue to make carbohydrates, and cannot be stopped without damage to the growing plant or harvested produce. Fresh produce cannot replace carbohydrates or water after harvest. Respiration uses stored starch or sugar and will stop

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when reserves of these are exhausted; aging follows and the produce dies and decays.

Respiration depends on a good air supply. Air contains about 21 percent of the oxygen essential to normal plant respiration, during which starch and sugars are converted to carbon dioxide and water vapour. When the air supply is restricted and the amount of available oxygen in the environment falls to about 2 percent or less, fermentation instead of respiration occurs. Fermentation breaks down sugars to alcohol and carbon dioxide, and the alcohol produced causes unpleasant flavours in produce and promotes premature ageing.

4. *Transpiration*

It is the loss of moisture from the surface of fruits and vegetables. Most fresh produce contains from 65 to 95 percent water when harvested. Within growing plants there is a constant flow of water. Liquid water is absorbed from the soil by the roots, then passed up through the stems and finally is lost from the aerial parts, especially leaves, as water vapour. Fresh produce continues to lose water after harvest, but unlike the growing plant it can no longer replace lost water from the soil and so must use up its water content remaining at harvest. This loss of water from fresh produce after harvest is a serious problem, causing shrinkage and loss of weight.

The loss of fresh produce due to respiration and transpiration can be controlled by addressing the factors affecting respiration and transpiration such as:

i. *Temperature*: Higher the temperature higher the rate of respiration and transpiration and vice versa.

ii. *Humidity*: Higher relative humidity indicates low transpiration and lower relative humidity results in higher transpiration from the produce.

iii. *Nature of skin:* the amount of gaseous exchange and loss of water depends on the nature of the skin. Skin of fresh produce containing large number of pores will have higher rate of respiration and transpiration than in produce containing fewer numbers.

iv. *Maturity:* Immature fruits and vegetables have higher rate of respiration and transpiration than matured produce as they are growing.

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v. *Surface area of fruits/ vegetables*: More exposed surface area is to the air more transpiration occurs in a fresh produce. Leafy vegetables have more surface area so more transpiration and short shelf life.

vi. *Nature of surface coating:* fruits have wax coating on their skin which reduces the rate of gaseous exchange and also the transpiration from the fresh produce, whereas vegetables are not protected. Therefore fruits have longer shelf life than the vegetables.

vii. *Mechanical damage* to fresh produce accelerates the rates of both respiration as well as transpiration. Mainly because the damage part needs to repair before it is too late and this requires energy. The energy is produced through respiration and higher rate will produce more water.

b) Causes of deterioration in fruits and vegetables and process of preventing loss

Owing to high moisture content and tender nature, vegetables pose significant post-harvest problem. High moisture content makes it difficult and expensive to conserve vegetables as dry products. They bruise easily and are metabolically active than the fruits. These characteristics significantly limit the storage life of vegetables.

Loss estimation is a tedious job and in perishable the estimation are not as precise as they are in the durable commodities. The losses are highly locality specific and level of loss acceptable in rural market differs greatly from that acceptable in commercial post-harvest sector. Nevertheless, expert with long experience in the field have estimated 20 to 30% losses in fruits and vegetables under Indian conditions.

In Bhutan, there is no research document recorded on loss estimation, however it will be same as that in the developing countries. Understanding the nature of loss of fresh fruits and vegetables, which may be primary or secondary as explained below, are of most important during harvesting and handling the produce.

i. Primary causes of losses

1. Physio-biochemical losses

In addition to unavoidable natural processes of senescence, the post-harvest rooting in tuber vegetables, seed germination, greening of potatoes leading

to production of harmful compounds, toughening and sponginess in green beans, sweet corn, carrot, radish that represents physiological loss though are not significant but reduce the quality of vegetables.

2. Mechanical losses

Besides causing damage, bruising and cracking make the vegetable more prone to attack by organisms and significantly increase water loss and gaseous exchange. Many a times, the mechanical damage on vegetables due to pressure thrust during transportation, though not visible, leads to rupture of inner tissues and cells. Such produce degrade faster during the natural senescence process. Processing operations such as spillage, abrasion, excessive polishing, peeling or trimming add to the loss of the commodity.

3. Microbial losses

Like any other food, fruits and vegetables are prone to microbial spoilage caused by fungi, bacteria and yeasts. A significant portion of losses of vegetables during post-harvest is attributed to disease caused by fungi and bacteria. It is estimated that 36% of the vegetable decay is caused by soft rot bacteria. Obviously, the source of infection is soil in the field, water used for cleaning and surface contact with equipment and storage environment.

4. Physical loss

Chilling injury by low but non-freezing temperature is common in tropical and sub-tropical vegetables. The fruit vegetables such as beans, cucumber, okra, pepper and tomato are affected commonly. The symptoms of chilling injury may not be evident while the vegetable is held at chilling temperature but becomes noticeable only after the vegetables is transferred to room temperature (22°C). Each vegetable has specific heat requirement during processing, improper cold, undesirable gaseous composition of controlled atmosphere storage lead to physical damage to tissue breakdown i.e. Storage disorders.

ii. Secondary causes of losses

Inadequate harvesting, transportation, storage, marketing and legislation lead to conditions favourable for primary causes of losses. But inadequate harvesting facilitates and rough handling during harvesting result in bruising and increase

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possibilities of contact of the produce with the soil that leads to contamination with organisms. A prolonged time taken for harvesting and grading leaves the produce with field heat for longer time which causes faster senescence. Besides use of improper machinery and equipment, mechanical harvesting also causes serious losses, if processing is delayed. Mechanical harvesting of tomato has been reported to result in more cracking (33%) than hand picking (10%). Harvesting of vegetables during or immediately after rains creates condition favourable for decay organism. Harvesting during hotter part of the day leaves higher field heat in the produce that result in faster senescence, shriveling and wilting of the vegetables as compared to those harvested in the early morning or late afternoon.

Harvesting is one of the important operations that decide the quality as well as storage life of produce and helps in preventing huge losses of fruits. Harvesting of fruits should be done at optimum stage of maturity. During harvesting operation, a high standard of field hygiene should be maintained. Produce should be handled with care to minimize mechanical damage and avoid undue losses of fresh produce. Some fruits and vegetables are more durable than others, but all should be treated with the same gentle handling. The harvesting operation includes;

- Identification and judging the maturity of fruits.
- Selection of mature fruits.
- Detaching or separating of the fruits from tree, and
- Collection of matured fruits.

c) *Harvesting of fruits and vegetables with appropriate technology*

Different kinds of fruits and vegetables require different methods of harvesting. The methods of harvesting are broadly divided into – Manual Harvesting and Mechanical Harvesting.

i. Manual Harvesting

Harvesting by one's own hand is called manual harvesting. Almost all the fruits and vegetables in Bhutan are harvested manually except potato with some degree of mechanization. This is because of small scale production, difficult and steep terrains and small land holdings. Manual harvesting is must when produce is harvested for fresh markets. Although it is a slow process, manual harvesting can provide intended care to the produce thereby reducing post-harvest losses.

Delicate crops like leafy vegetables, root crops like radish, carrot and crops like chili, eggplant, beans and peas do not require harvesting tools. The harvester can pull the crop to uproot, catch the fruit or pods and pull at the stalk end. Vegetables like cabbages, asparagus and broccoli are harvested using knife. Potato and other tubers are dug out from the soil with digging tools. Harvesting containers and bags are used to hold the produce and unloaded into bigger container when filled.

Figure 3.1 Manual harvesting

Comparatively fruits are difficult to harvest as they are borne on the twigs, high above the ground. Equipment like ladder and pole harvesters are used. Apple is harvested in Bhutan by shaking the tree, since manual harvesting takes longer time. However such practices are not encouraged for fresh marketing since it damages the fruits and reduces market value. Oranges can be harvest with clippers and reduce pressure damage while harvesting, however it is easy to harvest with hand.

ii. Mechanical harvesting

Figure 3.2 Mechanical harvesting

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Large scale commercial cultivation of fruits and vegetables in developed countries are for processing and value addition which are harvested mechanically or using machines. In such commercial farms manual harvesting will extend the harvesting period, besides the stage of maturity will differ with time. Thus machines are employed to speed up harvesting and to maintain uniform maturity. Mechanical harvesting utilizes numerous mechanical devices for harvesting huge quantity of produce in short period of time. However it inflicts mechanical injuries to the produce and leads to losses if not processed and value added immediately.

iii. Field transportation

It is the transportation of fruits and vegetables from the production site to temporary or factory pack-house. It is important to keep the harvested produce cool and protected from sun and rain. Commercial scale production or large scale producers will have a temporary pack house in the field to protect the produce from environmental hazards of heat and light and to prepare for shipment to pack-houses. In Bhutan field transportation of fruits and vegetables differ slightly depending on the road connectivity, tradition and economy of the area.

Figure 3.3 Transportation of harvest

Apple is transported manually in bamboo baskets for short distances and in open trucks for long distances. The damage due to splinters and sharp edges of bamboo baskets can be avoided by lining the bamboo basket with jute bag or any thick cushioning materials. Rigid plastic crates with proper ventilation are introduced to farmers and exporters for motor transports. Such plastic crates are available for purchase as well as for hire during the season at subsidized rates at NPHC and IFPPs.

Unlike apple, oranges are transported through different modes such as horseback, manually in bamboo baskets and motor transport systems. Since orange production sites are far from towns, field transportation takes days together to reach pack-house located near the market. This causes damage to fruits due to pressure and heat build-up and resulting in losses. Road connectivity to the production sites will reduce the damage and time of travel to pack-houses.

For crops like potato, onion and garlic temporary pack houses are made in the field at the site of production with tarpaulin sheets as shading material. Freshly harvested produce are dried to remove soil and foreign materials from the surface, sort out wounded and graded into different sizes. Tubers will remain in the field pack-house for few days. During this period avoid wetting of the produce. Thereafter tubers are packed in 50 kilo gram jute bags and transported to market.

Other vegetables are produced in small quantities in the North and Western part of the country. In these regions produce are harvested towards afternoon and processed (sorted, washed and packed/bundled) for local markets. Few vegetables like cabbage, chili and pea are targeted for bigger markets in Thimphu and Phuntsholing. Such vegetables are immediately processed and marketed to destined markets to reduce loss and maintain quality.

Southern foothills experience subtropical climatic conditions congenial for producing vegetables almost throughout the year. As such vegetables are produced on semi-commercial scale to be marketed to other parts of the country. The field transportation to pack-house is effective in collecting produce in bulk, sorting and preparing for distant markets throughout the country.

d) Pack-house facility and pack-house operations

The agriculture produce from a farm is transported usually to a pack house. A pack-house is a designated facility where fresh produce is pooled and prepared in order to meet the requirements of a target market. In this context, market preparation operations or pack-house operations are needed. The pack-house is the site where post-harvest treatments are applied and quality standards are monitored.

The pack-house system integrates components (raw materials, utilities, technologies, equipment and personnel) that function together to prepare produce for the market. Each component, therefore, has a significant effect on the final quality

of fresh produce. Within the larger system of the post-harvest handling chain, the pack-house also serves as a control point where quality management can be applied to assure a reliable supply of produce of good quality to consumers. With increasing consumer concerns and requirements for food safety and quality, it is important that the pack-house serve as a suitable site for the implementation of effective strategies to eliminate or minimize microbial, chemical and physical contamination.

A pack-house facility also serves as:

a. An accumulation or collection point – the produce is grouped into homogenous quantities according to the demands of specific markets.

b. A temporary holding area prior to distribution – during holding, the produce is protected from contamination and maintained at an appropriate temperature to minimize deterioration.

c. A dispatch point of produce to different destinations – if the facility services several markets, produce is segregated into distinct groups prior to loading.

A pack-house facility must have adequate protection from sun and rain. Direct sunlight increases commodity respiration hence increasing the rate of deterioration. Rain, on the other hand, can promote disease development especially under high temperature conditions. The floor of the pack house must be firm, smooth and level coated concrete or tiled floor allowing unhampered movement of materials and personnel. It must have good ventilation. Adequate air movement removes heat, ethylene and moisture produced during respiration and transpiration of a commodity. It also improves the comfort of personnel working inside a pack-house. The pack house must have good lighting. Adequate lighting is required to ensure that each item of produce can be inspected closely to allow removal of produce with physical, physiological or pathological defects. It will also improve staff effectiveness.

Pack-house operations involve:

i. *Receiving* the fresh produce from the field or field packing-sheds for further processing and handling operations. The pack-house should have a receiving area depending on the quantity of produce it receives at any time of the year. It allows preparation of fresh produce for subsequent operations and also for inspecting the quality of incoming produce. The

produce can be inspected for damage, insect or rodent infestation, decay, foreign materials and visible chemical residues.

ii. *Maturity assessment:* Depending on the intended market or requirements of the target market, maturity must be checked. Mature fruits can be processed for fresh consumption whereas ripe fruits should be prepared for preservation and value addition.

iii. *Trimming or removal* of unwanted plant parts or those likely to be rejected by consumers or those parts that can contribute to deterioration. Specific trimming procedures for some commodities are described in Table 3.1. The dried flower remnants at the tip of the fingers of bananas are removed because these parts can harbour decay-causing organisms that can be a potential source of inoculum besides making the bunch of bananas unsightly. Workers should wear clean gloves during removal of dried flower remnants.

Table 3.1 Specific trimming procedures for some commodities – Adapted from Bautista and Esguerra (2007)

Commodity	Procedure	Description
Banana	Dehanding Deflowering	Separation of hands from the stalk Removal of dried floral parts from the individual fingers
Cabbage		Removal of wrapper leaves
Carrot	Topping	Trimming of tops and vegetative parts
Garlic	Topping	Trimming of tops and vegetative parts
Lettuce		Removal of wrapper leaves
Onion (bulbs)	Topping	Trimming of tops and vegetative parts
Radish	Topping	Trimming of tops and vegetative parts
Roses	Dethorning	Removal of thorns from stems
Sweet corn, baby corn	Dehusking	Removal of husks
	Desilking	Removal of silk
Pineapple	Detopping	Removal of crown

iv. *Sorting* or removing product or portions of product that may detract or pose a risk for shortened shelf life and/or contamination by a microorganism. Field sorting can help to reduce the volume of produce to

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be handled at a packing facility. It also lessens the chances of introducing contaminants into the packing facility. Tents or mobile packing sheds can be used as working areas for preliminary sorting of freshly harvested produce. Sorting for mechanical damage, pest damage, presence of decay or misshapen produce can easily be done in the field.

v. *Grading* or classifying produce into groups according to set criteria of quality and size recognized or accepted by governments and the industry. Each group of produce bears an accepted name and size grouping, such as Extra Class, Class I or Class II in the case of the Codex Alimentarius Commission (CAC) standards for fresh produce.

vi. *Washing/Cleaning:* Provide customers with product that is attractive and clean with minimal risk of microbial contamination. Washing and cleaning removes latex, dirt, chemical residues, reduces the microbial load, insects such as mealy bug and aphids and other extraneous materials from the surface of the produce. Produce with a clean appearance is appealing to the consumer and can be easily sold. Soil adhering to produce can cause abrasion damage during transport and serve as a source of contamination. Harvesters should, therefore, remove as much soil as possible prior to hauling produce to the packing facility. Physical damage must be minimized during the cleaning process.

vii. *Wiping:* Some commodities are wiped with a wet or moist cloth. Alternatively fruits must be sprayed with water on a sorting table and then wiped with a clean piece of cloth.

viii. *Dry brushing:* It is applicable for water-sensitive commodities. Ginger is, for example, brushed without using water to remove clods of soil. Small brushes are used to remove adhering dirt and insects on Jack fruit.

ix. *Forced air cleaning* is applicable for water-sensitive commodities. Jackfruit is subjected to pressurized air to remove dirt and insects. Silk in baby corn can also be removed using forced air. Periodic cleaning and sanitizing of equipment will reduce the potential for cross-contamination.

e) Use of antimicrobials or sanitizers

Depending on its source, water can be contaminated; hence the ability to ensure water quality is essential. Antimicrobials or sanitizers are generally added to potable water to ensure that it is of the highest microbiological quality. Antimicrobials reduce the microbial population in water and on the surface of produce by 10 to 100 fold. Commonly used antimicrobials include:

i. Chlorine

It is a commonly used sanitizer in most pack-houses. It is added to water at 50-200 ppm total chlorine at pH 6.0-7.5 for a contact time of 1-2 minutes. Chlorine when dissolved in water generates hypochlorous acid (HOCl), the active compound that kills microorganisms.

ii. Hydrogen peroxide

It is classified by the United States Food and Drug Administration (FDA) as a 'Generally Regarded as Safe' (GRAS) compound. The recommended level of usage is 0.27-0.54 percent.

iii. Peroxyacetic acid

It is a strong oxidant formed from hydrogen peroxide and acetic acid. It is highly soluble in water and leaves no known toxic breakdown residues or products.

iv. Ozone

It is a water-soluble gas, very strong oxidizing agent and sanitizer and has the ability to diffuse through biological cell membranes. It is legal for food contact applications. Concentrations of 0.5-2.0 ppm are effective against pathogens. Ozone readily decomposes in water with a half-life of 15-20 minutes.

v. Curing

Bulb crops such as onions must undergo a curing process to prevent the entry of microorganisms. This process allows closing of the neck and drying of the outer scales. Freshly harvested citrus fruits must also be cured in order to prevent oleocellosis.

vi. Waxing

This process is intended to replace natural waxes that may be lost during harvesting and handling, as well as to improve gloss, reduce moisture loss and decelerate ripening. Waxes impregnated with antifungal compounds may also be used for disease control. Appropriate coatings should impart gloss; be transparent, odourless and tasteless; biodegradable; impermeable to water, and semi-permeable to O_2 and CO_2. Commodities that are generally waxed include citrus fruits such as mandarins, oranges, pomelos, apples and pineapples.

vii. Ripening and De-greening

In the context of market preparation operations, ripening is the process of artificially accelerating the transition of a fruit or fruit-type vegetable like tomato from its initial mature-green stage to a semi- or fully-ripe stage. At this stage, the commodity has fully developed all of the aesthetic and sensory characteristics desired by consumers. Many commodities are harvested at the green stage because they are more durable during transport, market life is longer (because of comparatively slower disease development, less time for moisture loss to occur), colour development is controlled and ripening provides flexibility for retailing. The hormone responsible for initiating ripening is ethylene (C2H4). A commonly used analogue to ethylene is acetylene (C2H2) that is used in artificial ripening. The main drawback to early harvesting at the mature-green stage is that the produce will not have acquired maximum dry matter accumulation, and thus may not attain optimum taste and flavour than eaten ripe. De-greening is a process used to destroy the green pigment that produces the desired peel colour of the fruit, such as yellow for banana, lemon and orange for Valencia orange, ponkan and mandarin fruits.

Ripening and de-greening are achieved by exposing mature and good quality produce to ethylene or its chemical analogue, acetylene, at an optimum ripening temperature with sufficient air circulation. Bananas, mangoes, papayas and tomatoes are common artificially ripened fruits. Citrus fruit such as pomelos and mandarins undergo de-greening.

1.2 Storage of fruits and vegetables

If produce is to be stored, it is important to begin with a high quality product. The batch of produce must not contain damaged or diseased units, containers must be well ventilated and strong enough to withstand stacking. In general proper storage practices include temperature control, humidity control, air circulation and maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes.

Cold storage of fruits and vegetables was used extensively by our ancestors to keep food after the harvest season. In modern times, the year round availability of fresh produce in the supermarket has reduced the use of home storage. However, even today there are benefits of home storage, which make it a good alternative to buying

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produce from the store. Most importantly, home gardeners often have excess fruits and vegetables that cannot be consumed immediately but would store well. Even those without gardens can buy food 'in season' when it is fresh and inexpensive and then store it at home until a later date. Both these options are cheaper than buying food in the winter when it is often quite expensive. In addition, stored food harvested at peak maturity from the garden usually has better flavour and a higher nutritional value.

The marketable life of most fresh fruits and vegetables can be extended by prompt storage in an environment that maintains product quality. The desired environment can be obtained in facilities where temperature, air circulation, relative humidity and sometimes atmosphere composition can be controlled. Storage rooms can be grouped accordingly as those requiring refrigeration and those that do not. Storage rooms and methods not requiring refrigeration include: in situ, sand/coir, pits, clamps, windbreaks, cellars, barns, evaporative cooling, and night ventilation:

a) Conventional storage methods of fruits and vegetables

In situ. This method of storing fruits and vegetables involves delaying the harvest until the crop is required. It can be used in some cases with root crops, such as cassava. It means that the land on which the crop was grown will remain occupied and a new crop cannot be planted. In colder climates, the crop may be exposed to freezing and chilling injury.

i. Sand or coir

This storage technique is used in countries like India to store potatoes for longer periods of time, which involves covering the commodity underground with sand.

ii. Pits or trenches

These are dug at the edges of the field where the crop has been grown. Usually pits are placed at the highest point in the field, especially in regions of high rainfall. The pit or trench is lined with straw or other organic material and filled with the crop being stored, then covered with a layer of organic material followed by a layer of soil. Holes are created with straw at the top to allow for air ventilation, as lack of ventilation may cause problems with rotting of the crop.

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iii. Cellars

These underground or partly underground rooms are often beneath a house. This location has good insulation, providing cooling in warm ambient conditions and protection from excessively low temperatures in cold climates. Cellars have traditionally been used at domestic scale in Britain to store apples, cabbages, onions, and potatoes during winter and oranges in China (Figure 3.4).

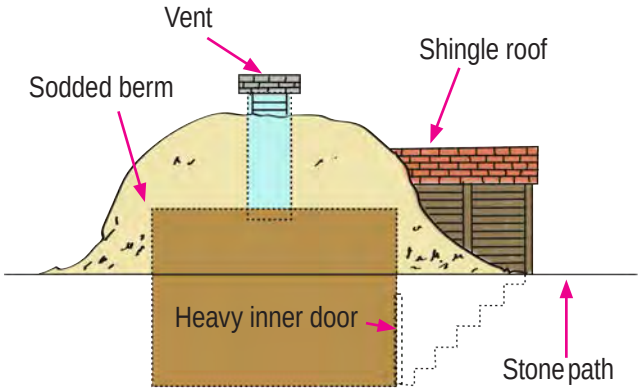

Figure 3.4 Cellar for storing fruits and vegetables
Source FAO

iv. Barns

A barn is a farm building for sheltering, processing, and storing agricultural products, animals, and implements. Although there is no precise scale or measure for the type or size of the building, the term barn is usually reserved for the largest or most important structure on any particular farm. Smaller or minor agricultural buildings are often labelled sheds or outbuildings and are normally used to house smaller implements or activities.

v. Evaporative cooling

When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage.

vi. Night ventilation

In hot climates, the variation between day and night temperatures can be used

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to keep stores cool. The storage room should be well insulated when the crop is placed inside. A fan is built into the store room, which is switched on when the outside temperature at night becomes lower than the temperature within. The fan switches off when the temperatures equalize. The fan is controlled by a differential thermostat, which constantly compares the outside air temperature with the internal storage temperature. This method is used to store bulk onions.

b) High investment storage methods for fruits and vegetables

The shelf life of fruits and vegetables stored in conventional stores are very short and face many challenges to maintain the required environmental conditions such as temperature, relative humidity and atmospheric composition. Besides, nothing much can be done to stop microorganisms from spreading diseases in the conventional stores. Therefore more efficient systems of storage facilities were developed. These storage technologies are capital intensive but very efficient in preserving the produce fresh and maintaining their quality for longer duration.

i. Pre-cooling of fruits and vegetables

Pre-cooling is done to remove the field heat of the harvested produce, which is detrimental to keeping quality of fruits and vegetables and it is done to retard ripening and senescence processes. Prompt pre-cooling conserves the weight and extends the storage life in tomato. Physiological Weight Loss (PWL) of fruits and vegetables in storage can be reduced from 6 to 2.5% by employing pre-cooling treatments. The process also reduces pressure on the machines in the main cold store as the produce is already cooled to pre-requisite temperature.

ii. Methods of pre-cooling

Several effective methods for rapid removal of heat from produce are in commercial use. The choice of method depends largely on the perishability and refrigeration equipment of the produce, its adaptability to a specific method and the availability of facilities. Some of the methods of pre-cooling are:

i. *Hydro cooling:* Cooling with cold water is a rapid and effective method used for cooling a wide range of fruits and vegetable in bulk before packing. Its use is limited for packed commodities because of the difficulty of achieving sufficient water flow through the containers. Flooding, spraying or immersion accomplishes hydro cooling. A properly designed flood system is more efficient than either the spray or immersion system because it combines a great volume

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of water with rapid movement of cooling medium over the product. When cooling is completed, the product must be moved to a cold room. Hydro-cooling applied with refrigerated $CaCl_2$ solution (21°C for 10 minutes) would prevent storage disorders.

ii. *Air-cooling or room cooling:* The use of refrigerated air as pre-cooling medium is widely used for pre-cooling packed fruit, but the system is not widely used for vegetables. Pre-cooling with air can be accomplished in a conventional cold storage room, a special pre-cooling, a funnel cooler, or a forced air cooler. Cooling with air requires a longer time than cooling with water or vacuum.

iii. *Vacuum cooling:* Leafy vegetables are commonly cooled by reducing atmospheric pressure in artificial hermetically sealed chambers. Reducing the atmosphere pressure also reduces the pressure on water vapour in the chamber and thus cooling is affected. The outstanding advantages of vacuum cooling are the speed and uniformity of cooling of adapted commodities. Leafy vegetables, particularly lettuce is difficult to cool with water or air, but they can be field packed and then cooled quickly and uniformly by vacuum. Commodities like tomatoes (with epidermis which is resistant to water movement) are not adapted to vacuum cooling.

iv. *Refrigerated cold store:* It maintains temperature of the storage room as per the requirement of stored produce. The cold stores are made of air tight chambers with insulated walls, ceiling and floor. Refrigeration consists of compressor, evaporator and condensing unit. The compressor and condenser units are placed outside the cold room while evaporator is placed inside the room. These units are connected with copper pipes through which a refrigerant circulates (Refrigerant: is a chemical used in a cooling mechanism, such as an air conditioner or refrigerator, as the heat carrier which changes from gas to liquid and back to gas in the refrigeration cycle).

These refrigerants have very low boiling point. When the compressor starts running, it forces the liquid refrigerant through copper pipes into the evaporating unit at one end. The evaporating unit consists of long copper tube coiled into a small area with a fan in front. The refrigerant in the evaporator is exposed to warm air inside the store, because of produce respiration. It picks up heat from the air in the store and vapourizes. As the compressor operates it pulls the heated gas refrigerant into the condenser and release cool liquid refrigerant into the evaporator simultaneously. In the condenser heated gas / refrigerant is condensed into liquid phase through loss of heat to conductors such as cool air or water, blowing over or running down the condenser (Figure 3.5)

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This cycle continues until the minimum required temperature in the store is achieved. At that temperature the sensor will automatically stop the compressor and the flow of refrigerant. However the fans in the evaporator continue to run removing heat from the produce and mixing with the cool air inside. Due to respiration of the produce the heat builds up in the store, when temperature reaches the maximum set limit compressor will start again and the same cycle repeats as described. To obtain required humidity inside the store additional humidifiers need to be installed.

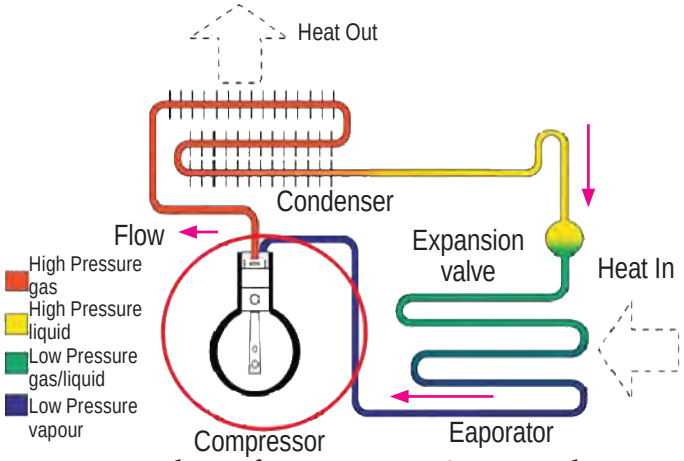

Figure 3.5 Working of a compressor. Source: Hilton, 2010.

iii. Modified Atmosphere (MA) storage

Refrigerated cold stores can control only temperature however the rate of respiration also depends on other factors such as the composition of air, production of ripening hormones etc. Modified storage such as packing of fruits and vegetables in Low Density Polyethylene (LDPE) bags could modify the micro environment for better storage. The packing material should be permeable to gas and impermeable to water. Therefore water loss from the produce can be avoided. In this method the movement of air in and out is slow through the polyethylene sheet however there is no control on the composition of the air.

Controlled Atmosphere (CA) Storage: Normal atmospheric air consists of 78 % Nitrogen (N_2), 21 % Oxygen (O_2) and 0.03 % Carbon dioxide (CO_2). Oxygen is the key element required for respiration, increase or decrease in the quantity affects the rate of respiration. Control of air composition in the store is to reduce the amount of oxygen and the condition can be achieved only through use of sophisticated equipment. The volume of oxygen in the CA store can be checked either by removing oxygen or increasing the volume of nitrogen and carbon dioxide in the store. To regulate each component of air a set of sensor, monitor, injector and scrubber are required. The room or compartment for CA store should

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be 100 per cent air tight. In a cold store there can be many compartments of CA stores of different fruits and vegetables, however such establishments are very costly. They are increasingly used for storing fruits on commercial scale. Depending on the species and variety of produce, various blends of O_2, CO_2, and N_2 are required. Low content O_2 atmospheres (0.8 to 1.5%) called ULO (Ultra -Low Oxygen) atmospheres are used for fruits with long storage lives (e.g., apples). MA and CA compliment the refrigerated cold store and they are not the substitute.

1.3 Packaging of Fruits and Vegetables

Figure 3.6 Packaging

Packaging is an important consideration in fruit and vegetable market. The use of properly designed containers for transporting and marketing of vegetables can significantly reduce their losses and maintain their freshness, succulence and quality for longer period. Packaging also provides protection from mechanical damage and undesirable physiological changes and pathological deterioration during storage, transportation and marketing. Many vegetables are transported in gunny bags or bamboo baskets. Packaging material such as polyethylene films, paper boards and boxes lined with polyethylene and other materials can effectively prolong the shelf life of vegetables. By using plastic films vegetables can be protected from dry air. Polyethylene packaging provides modified atmosphere and consequently reduces decay, softening and loss of appearance of the produce. The thickness and permeability to CO_2, O_2 and water vapour of films needs to be standardized for each vegetable.

In Bhutan potato, cabbage and chili are packed in jute bags for transportation and marketing. 100 kg jute bags were used to accommodate huge quantities, being heavy damage occurs at every stage of handling. Later 50 kg jute bags are introduced to ease handling and to reduce damage to the produce. Apples packed in wooden boxes shows 85 to 95 percent compression damage. The use of Corrugated Fiber Board (CFB) boxes with molded paper trays could reduce handling damages to 5 to 10 per cent during packaging and transport to market. Wide variety of containers such as wooden boxes, baskets woven from bamboo

and wood, Jute sack/bags, earthen pots and Corrugated Fiber Board (CFB) boxes are important packaging materials used in the transportation and distribution of fruits in most of the developing countries. All the packaging materials must have some amount of ventilation in order to prevent physiological break down.

i. *Wooden boxes:* they have good stacking strength but they are heavy in weight. However they can be made into desired shapes and sizes. The major problem is sprinters and nails that may puncture the produce besides it also absorbs moisture and is prone to fungal and mold growth. Mostly used for packing apple for export to Bangladesh.

ii. *Plastic crates:* plastic crates are available in many shapes and sizes (nest-able and stackable plastic crates with lid) depending on their requirement. They are used for field to pack-house transportation as well as for storing fruits in the cold store. They are costly but can be used repeatedly over a period of 5 to 10 years. The crates should be well ventilated for air to move through the produce.

iii. *Jute bags:* Jute bags are used for packing potato, cabbage, carrot, radish, peas etc. Jute bags for packing fruits and vegetables should not accommodate more than 50 kg, otherwise there would be compression and handling damages to the produce. Now-a-days netted polypropylene bags are also used for packing potato and cabbage due to produce visibility and excellent ventilation.

iv. *Polyethylene bags:* Both Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) bags are used for unit packing/ packing small quantities of produce for retail marketing. These bags are able to modify the atmosphere inside supporting the produce to extend shelf life by few days.

v. *Corrugated Fiber Board boxes:* They are made from the craft paper which can easily be manufactured from Bamboo, grasses and various types of agricultural residues as well as by recycling the used cardboards or papers. They are light, provide cushion to the produce, easy to handle, can be printed and improves the produce image. However being week cannot withstand high pressure on top, wax should be applied to protect the boxes from water besides they cannot be used for storing produce in refrigerated cold store. Corrugated Fiber Board boxes with molded paper trays are very good packaging materials for delicate crops such as apple, peach, kiwi, mango, plum etc. Being expensive it is difficult to replace the wooden boxes nevertheless handling damages can be reduced to almost 5 to 10 per cent.

Packaging is the vital component in post-harvest management of fruits and vegetables. It helps in minimizing deterioration during handling and marketing of

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fruits and vegetables. Adequate packaging protects the produce from physiological, pathological and physical deterioration and retains their attractiveness. In Bhutan, packaging of fruits and vegetables is not done properly and hence, it acts as major cause of post-harvest losses. In big package as well as packing large fruits such as watermelon, papaya, muskmelon etc. the cushioning material like paddy straw, hay, paper shavings, tissue and Expanded Polyethylene (EPE) nets are used to avoid bruising of fruits and vegetables during transportation and marketing.

1.4 Transport and distribution of fruits and vegetables

Transportation and distribution of fruits and vegetables are important. Fast transportation with minimum damage during shipment is very important in successful marketing of perishable commodities. For the local market manual transportation in bamboo baskets, power-tillers, boleros, DCM truck and trucks are used and for a distant market transportation is mainly done through motor road and by air. Maximum quantity of produce are being transported by road and only high value low volume, highly perishable crops are transported by air transport. Although they are slower, railway and shipping are much cheaper as they can carry huge volume of produce unfortunately they are not available in Bhutan. For long distance road transportation trucks should have a special system of ventilation and arrangement to reduce the temperature and maintain proper humidity inside. This can successfully be done by adopting the technique of evaporative cooling without using high cost mechanical refrigeration.

The losses in transportation occur due to physical and mechanical injuries under uncontrolled transportation. Injuries and losses under controlled conditions of transportation mainly occur from temperature and relative humidity. To overcome this difficulty the produce should be transported in well ventilated carriages. Efficient transport system can go a long way not only in reducing the post-harvest loss of horticultural produce but also in stabilizing the price fluctuation of the same commodity available in different corners of the country.

1.5 Management of postharvest pests and diseases

Losses caused by postharvest pests and diseases are greater than generally realized because the value of fresh fruits and vegetables increases several-fold while passing from the field to the consumer. Postharvest losses are estimated to range from 10 to 30% per year despite the use of modern storage facilities and techniques.

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When estimating post-harvest pest and disease losses, it is important to consider reductions in fruit quantity and quality, as some diseases may not render produce unsaleable yet reduce product value. For example, blemished fruit may not be sold as fresh fruit but may still be suitable for processing, in which case, it brings a lower price.

Postharvest pests and diseases affect a wide variety of crops, particularly in developing countries that lack sophisticated postharvest storage facilities. Fungi are more commonly found attacking fruit, whereas bacteria are more common as postharvest pathogens of vegetables. Aside from direct economic considerations, diseased produce poses a potential health risk. A number of fungal genera such as *Penicillium, Alternarta* and *Fusarium* are known to produce mycotoxins under favourable conditions.

i. Post-harvest diseases

Infection by fungi and bacteria may occur during the growing season; at harvest time; during handling, storage, transport and marketing; or even after purchase by the consumer. Postharvest diseases are often classified according to how infection is initiated. The so-called 'quiescent' or 'latent' infections are those where the pathogen initiates infection of the host at some point in time (usually before harvest), but then enters a period of inactivity or dormancy until the physiological status of the host tissue changes in such a way that infection can proceed. The dramatic physiological changes which occur during fruit ripening are often the trigger for reactivation of quiescent infections. Anthracnose of mango caused by *Colletotrichum spp.* and grey mould of strawberry caused by *Botrytis cinerea* are good examples of 'latent' infection.

The other major group of postharvest diseases are those which arise from infections initiated during and after harvest. Often these infections occur through surface wounds created by mechanical or insect injury. Wounds need not be large for infection to take place and in many cases may be microscopic in size. A good example is the blue and green mould of citrus caused by *Penicillium spp.*

ii. Post-harvest pests

Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious. Insect damage is usually caused by insect larvae burrowing through produce, e.g. fruit

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fly, sweet potato weevil, potato tuber moth. Infestation usually occurs before harvest. Post-harvest spread is a problem where produce is held in store or is exposed to lengthy periods of transport. Rats, mice and other animal pests again are sometimes a problem when produce is stored on the farm.

a) Factors that influence postharvest pests and diseases

i. Weather

Weather is the climatic condition over a short period of time. The amount of rainfall and sunshine affects many factors related to plant pests and diseases. Wet and humid weather provides congenial environment for harmful pathogens to invade produce and cause diseases. It also influences the amount of inoculum that overwinters successfully to the amount of pesticide residue that remains on the crop at harvest.

ii. Physiological Condition

Condition of produce at harvest determines how long the crop can be safely stored. For example, apples harvested slightly immature to ensure that they can be stored safely for several months. The onset of ripening and senescence in various fruits and vegetables renders them more susceptible to infection by pathogens.

iii. Fungicide Sprays

Certain pre-harvest sprays are known to reduce decay in storage. Several studies done on the effectiveness of pre-harvest ziram fungicide application on pome fruit showed an average reduction in decay of about 25 to 50% with a single spray.

iv. Packing Sanitation

It is important to maintain hygienic condition at all stages during production and postharvest handling to minimize sources of inoculum for postharvest pests and diseases. Organic matter (culls, extraneous plant parts, and soil) can act as substrates for decay-causing pathogens. Chlorine readily kills microorganisms when used as sanitizer for cleaning equipment, receiving tanks and storage areas if the amount of available chlorine is adequate. A level of 50 to 100 ppm of active chlorine provides excellent fungicidal activity.

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b) Integrated management of post-harvest pests and diseases

The entire crop production and handling system should be considered (production, harvest, postharvest and marketing) when developing integrated pests and diseases management strategies.

i. Pre-harvest

Production begins with selection of cultivars offering some natural resistance to the pests and diseases you expect to deal with in your region. Plant or use only good quality, clean seed or stocks. Use appropriate cultural practices during production to assist the produce to avoid and/or resist pest attack (proper planting density, fertilization, irrigation, pH modification, weeding, pruning, thinning, and ventilation/air movement through the canopy). Monitor fields/orchards to determine actual pests and diseases levels before implementing pests and diseases control. Use a combination of appropriate pests and diseases control methods (biological control, chemical pesticides, protectants, sanitation practices). Keep fields and orchards free of debris and discarded produce. Eradicate produce infested/infected with pests and diseases.

ii. Harvest

Avoid damage during harvest by handling produce gently. Harvest at proper maturity of produce to have the maximum resistance against pests and diseases. Use sharp, clean tools for harvest and trimming processes.

iii. Curing

Cure root, tuber and bulb crops to heal harvest wounds and increase resistance to pests and diseases.

iv. Pack-house

Sort to remove any damaged, decayed, over-mature or under-ripe produce. Wash or clean produce to remove soil and debris and to reduce the amount of innoculum on surfaces. Trim senescent leaves from vegetables and remove dried flower parts from fruits. Use appropriate postharvest treatments to manage pest and disease problems (chemicals, heat, hot water, pesticides).

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v. Packing

Avoid over-use of liners that constrict air flow in the package and contribute to condensation (free moisture) and poor cooling efficiency. Use ventilated plastic bags as liners for produce highly susceptible to water loss.

vi. Storage

Avoid ethylene damage to sensitive commodities by using ethylene scrubbers and avoiding mixed lots of produce in storage. Keep produce at its lowest safe temperature for maximum pests and diseases management. Avoid freezing and chilling injury by keeping sensitive commodities at appropriate moderate temperatures. Keep leafy vegetables, carrots, and cool season vegetables at very high relative humidity (98-100%) to reduce incidence of decay. Store onions and garlic at low humidity to reduce decay (60-70% RH).

Student Activity

Post-harvest technology (PHT) is one of the most important aspect of managing Agriculture produce (fruits, vegetables and cereal, etc.). With the understanding of the theory behind PHT, a farmer can improve farming activities such as selecting appropriate seeds and seedling, care of crops, harvest at an appropriate time, harvest with appropriate tools and technology, carefully, transporting to the store, ensuring the store has appropriate temperature and humidity, etc. to prolong the shelf life of the produce before the produce is sold or consumed. However, it will be too expensive to experiment on the produce to check on the accuracy of the theory behind PHT. The practical activities are to be designed to study the use of PHT by the retailer or consumers, their understanding of PHT, educate them to understand and use the PHT to prolong the shelf-life of Agriculture produce. Therefore, the students need to thoroughly read the chapter, understand and frame questions through which the whole sale dealers, retailers and consumers are made aware of the theories, their applications and the ideas that they would try in future to do better in their business.

Activity 1 – preparing for education campaign

1. Divide students into smaller groups of about 3 to 4 members each and ask them to choose common vegetables such as chilli, potatoes, tomatoes, sag, peas, beans, etc. and fruits such as banana, mango, apple, pear, orange, grape, etc.
2. Instruct them that they are to visit market/shops to study the conditions of vegetables and fruits and help the shopkeepers to get ideas of prolonging the shelf life of the vegetables and fruits. Discuss in group to
    a. Come up with ideas of how the group would approach the shopkeeper and win over some time to observe the conditions of fruits and vegetables and spend some time asking some questions about the vegetables and fruits.
    b. Frame the questions that the group would like to ask to find more about vegetables and fruits such as the conditions, why so and what could be done to prolong the shelf life of vegetables and fruits (based on the theory learned from the chapter).
    c. What responsibility each member of the group would carry out in the education campaign such as taking the lead role talking to the shop keeper, asking questions, recording the answers, writing reports, and so on.
    d. Present to the class for comments and approval.

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Activity 2 – presentation of the group work, improvement and approval

1. Instruct the group to present starting from group one and record comments for improvement from other groups.
2. Teacher moderate the discussions and support improvement.
3. Approve group work for educational survey.

Activity3 – planning survey/education campaign of Sunday Market, vegetable market or a vegetable shop and carrying out

1. Select appropriate season for the educational survey, get approval from the school management and fix one Saturday/Sunday.
2. Brief the students to be careful and cautious of approaching, briefing the shopkeeper(s) and asking questions.
3. Carrying out the educational survey, compiling, writing report and setting a date for submission of reports.
4. Assess the educational survey reports as per the guide and record the performance of the students

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4 Chapter

Growing of Vegetables II

The "Bhutan Vision 2020" envisages that while the country's economic future will be rooted in and driven by hydro-power based investments, the economy will also be well-balanced and sufficiently diversified by a thriving horticulture and organic based high-value agriculture sector. It is an indication of the paramount importance that agriculture and associated sectors are placed in. Horticulture is one of the most important sub-sectors of agriculture which provides greater prospects to realize the vision and goal of the nation's food and nutrition security as discussed in IX. Vegetables play a major role in increasing household income, improving the nutritional standards and in providing employment to many Bhutanese to help realize the vision of food self-sufficiency and food security.

Bhutan has a wide range of Agro-Ecological Zones with suitable climatic conditions. Vegetables of different kinds can be grown in different part parts of Bhutan all the year round and can be a steady source of income for Bhutanese farmers. This opportunity remains untapped till today, but the scenario is expected to change as the unemployment of literate youth rises.

Growing of vegetables I continues as Growing of Vegetables II of this chapter which adds to the pool of knowledge, values and skills required to be of better service to the nation. The AgFS students of class X, will learn concepts of growing different varieties of vegetables and experience the joy of preparing the land, growing different vegetables, caring them, seeing the vegetables develop and cultivating them using the ideas and practices of the post-harvest technology. This can greatly enhance agriculture enterprise, to supply quality fresh vegetables to the traders and the consumers, for which the learners need to learn:

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4.1 Tomato (Lycopersicon esculentum)

Dzongkha name: Lam benda

The tomato fruit is consumed in diverse ways, including raw, as an ingredient in many dishes and sauces, and in drinks. While it is botanically a fruit, it is considered a vegetable for culinary purposes. The fruit is rich in lycopene, which may have beneficial health effects. Tomato is not frost tolerant and so a three month frost free period is required with optimum temperature of 20-24°C. Fruiting will be poor under very hot conditions at the same time pollination is reduced if the night time temperature falls below 13o C. It grows best on rich, free draining soils with a good structure with pH 5.5-6.8. Loams are ideal but avoid very heavy soils. Avoid growing other Solanaceae, including potato with tomato. Intercrop with root crops and legumes to avoid diseases.

Figure 4.1 Tomatoes

i. Varieties

Roma, Nozomi, Bajo lambenda and *Ratan*

ii. Planting times

- Upper hills: March – July
- Mid hills: December – July
- Lower hills: October – December

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iii. Field preparation

Choose a sunny place. Soil needs to be well dug and finely prepared. Nursery needs to be prepared well adding well decomposed FYM/compost to give a fine seedbed. Sow seed at 1 g/10 m^2 at 0.5 to 1cm deep with spacing of R-R = 15 cm and P-P = 3-5 cm can be used. Transplant when seedlings are 7.5-15 cm tall, normally 30-40 days after sowing, with spacing of R-R = 60-75 cm and P-P = 45-60 cm. This depends on the variety and its growth habit, while staking varieties requiring wider spacing.

iv. Manures and Fertilizer

Tomato has a high requirement for nutrients. Use 20-25 kg FYM/compost /10m2 and N P K: 40: 90:90 kg/ha basal dressing and 40 kg/ha top dressing after 4 weeks. This amounts to urea =90 g/10 m^2 ; SSP= 560 g/10 m^2 ; MoP =70 g/10 m^2 as basal dose plus urea 90 g/10 m^2 as the top dressing.

v. Crop management

Irrigation is given whenever needed but do not flood the crop. Shallow weeding is necessary. Staking is needed for cherry and indeterminate varieties of tomatoes. Pruning is only necessary in staking types, which are trained on a single stem. Remove side shoots or suckers, yellow or decaying leaves below the first truss. Removal of unnecessary parts like dead and decaying parts not only help to prevent pest and disease incidence but also result in better fruit. Stop the plant growing after the 4th truss by removing the growing point. This will give better fruit production. Dwarf types will only need pruning to remove large numbers of small fruits.

Apply the principles of post-harvest technology to harvest and care for the produce.
For long distance transport tomatoes are best harvested when green. Pick by twisting rather than pulling. Tomato can yield 20-30 kg/10 m^2 depending on varieties. Hybrids can yield even higher. Length of storage depends on the harvest stage. Mature green fruits can be stored for up to 30 days at cool temperatures (10°C). Hang up the whole plant. Ripe fruits will keep for about 10 days.

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4.2 Chilli (Capsicum annum)

Dzongkha name : Ema

Figure 4.2 Chillies

There is a wide range of varieties with different shapes and sizes of fruits. Chilli is grown generally in the same way as tomato. Chilli is an excellent source of vitamin C and good sources of vitamin A and riboflavin. Sweet peppers are an excellent source of vitamin C but contain lesser vitamin A. The hotness of chilli is due to a chemical called capsaicin, which can be used as an insecticide.

Chilli grows best on rich well drained soils like loams with pH 5.5-6.8. Optimum temperature should be 20-25°C. Water logging causes leaf drop.

i. Varieties

Varieties of chilli grown in Bhutan are *Sha ema, Yangtse ema, Californian wonder* and *Super Solo*

ii. Field preparation

Field /nursery preparation is as for tomato with a seed rate of 1-2 g/ 10 m^2, and Spacing R-R= 45-60 cm and P-P = 30-45 cm. For Sweet Pepper R R= 55 cm and P-P= 45 cm.

iii. Manures and Fertilizer

Management of Manures/Fertilizer is as in tomato. Raising the beds is very effective in controlling some common diseases. Mulching with organic matter like Artemisia leaves is recommended to suppress weed growth, prevent moisture loss, and improve soil and plant health as well as act as an organic manure.

Remember the objectives of post-harvest technology, and its principles and practices. Always harvest with stalks attached. Leave on the plant if you want them to turn red for storage. It yields 5-12 kg/10 m^2 fresh fruit and 0.5-1 kg/10 m^2 dried fruit.

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4.3 Brinjal/Eggplant (*Solanum melongena*)

Dzongkha name: Dolom

This is an erect, many branched annual grown for its large oblong or egg shaped fruits. Although grown in a similar way to tomato, the main difference is that it requires a longer growing season. Since this period must be frost free it can be difficult to grow in higher areas. Brinjal is a good source of riboflavin, iron, niacin, thiamine and vitamin C.

i. Varieties

Varieties grown in Bhutan are *Paro local, Big round* and *Pusa purple long.*

ii. Planting times

The planting times of Bringal

- Upper hills: March-April
- Mid hills: February-June
- Low hills: February-June

Figure 4.3 Brinjal

iii. Plant Spacing

R-R=50- 75 cm and P-P = 50-60 cm. Weeding is very important in the early stage as the crop is slow. Stake and tie plants to stake growing for support.

iv. Management

Raising bed and mulching recommended as in Chili. Do not allow the soil to dry out. Mulching is advisable. Add manures N P K – 50: 80: 40 kg/ha basal dose, 50 kg/ha urea for top dressing with splits at 4 and 8 weeks. This amounts to urea = 110 g/10 m^2 ; SSP = 500 g/10 m^2 ; MoP = 70 g/10 m^2 as the basal dose plus 55 g/10m2 urea at each 4 and 8 weeks.

Harvest when the fruits reach a good size and the skin is still bright and glossy. Fruits are edible from 1/4 size up to full size. Fruits left too long become much tougher. Cut off the stalk when harvesting. Good crop can yield 10-25 kg/10 m^2 .

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4.4 Cucumber (Cucumis sativus)

Dzongkha name: Geun

A strong climbing or creeping trailing annual vine bearing long or round green fruit with crisp white flesh. Cucumber comprise a group called cucurbits which include melons, gourds and pumpkin. All are grown in similar ways and suffer from the same pests and diseases. It is a good source of vitamin C. Cucumbers require warm and wet conditions to grow. They are not frost tolerant. Optimum temperature =20-27° C. Cucumber needs continuous supply of moisture and plenty of humus. Cucumber will grow well on any soils which provide these. Loamy soils with pH = 5.5-6.8 are probably best.

Figure 4.4 Cucumber

i. Varieties

Varieties grown in Bhutan are *Shaba genchu* and *Santou No 1*

ii. Planting times

- Upper hills: March-May
- Mid hills: January-February
- Low hills: February-March

iii. Field preparation

Mostly cucumbers are grown in small numbers around the edge of a vegetable garden. The best method of doing this is to dig individual holes. Dig holes 25 cm deep, and 25 cm diameter. Fill the hole with a mixture of well-rotted compost plus soil.

Plant three seeds 25 cm deep in each hole. When the first leaves appear, then thin out to leave just the single strongest seedling. In case of large scale plantation, grow on ridges or individual mounds. Give a standard land preparation and make ridges. Plant the seeds on one side of the ridge only. Spacing depends on whether the plant is supported or not. If staked use R-R=1-1.5metres and P-P = 40-60 cm. If not supported maintain R-R= 1 .5-2.5 m and P-P= 60-90 cm.

iv. Manures and Fertilizer

FYM/compost = 10-20 kg/10 metre square, N P K =45: 35: 25 kg/ha basal dose

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and 30 kg/ha top dressing after 4-6 weeks. This amounts to urea = 99g/10 m^2; SSP= 220 g/10 m^2 ; MoP= 41 g/10 m^2 as the basal dose plus urea 65 g/10 m^2 as the top dressing.

v. Management

Irrigate the crop and mulch immediately. The soil needs to be kept moist at all times. Pinching out the growing tips when the plant has 6- 7 leaves will encourage side branches. Weeding is necessary as cucumber is shallow rooted, so care is needed.

vi. Harvest

Sequentially harvest at 2-4 day intervals. Cut off the fruits, do not tear them off. Do not leave on the plant too long as quality deteriorates. Cucumber can yield up to 10-20 kg/10 m^2

4.5 Pumpkin (Cucurbita muschata)

Dzongkha name: Kaku ru

Grown for its green yellow or orange large round fruit, it is a trailing, annual plant. The fruit is very good source of vitamin A and a good source of iron, thiamine, niacin and vitamin C.

Figure 4.5 Pumpkin

i. Varieties

- *Aonthang brumsh*a
- *Tetsu kabuto*
- *Japanese red*

ii. Planting times

- Upper hills: April-May
- Mid hills and low hills: February-March

Grow as cucumbers except leave to trail on the ground, do not support. The spacing varies depending on the variety and growing method with spacing of R-R=1-3 metres and P-P = 0.5-2 m. Yield can be around 15-30 kg/10 m^2

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4.6 Bitter gourd (*Momordica charantia*)

Dzongkha name: Khag tim

Bitter gourd can be grown in low and mid hills. It is sown during February-April. Prior to sowing, seed can be soaked in water for 6-8 hours. Follow the practices as cucumber, with Spacing R-R = 1.6 m and P-P = 1 m. It can be harvested after 90 days when fruits are young and tender. It can yield 6 to 8 kg/10 m^2 depending on the fruit size.

Figure 4.6 Bitter gourd

4.7 Carrot (*Daucus carota*)

Dzongkha name: Laphu marp

i. Varieties

There are two general types of carrot. *Asian* or *desi* carrots which are not frost hardy but are more heat tolerant. These produce short roots with poor colour. European types are better for temperate climates as they are frost hardy. Early Nantes is the only European type variety that grows well in temperature range of 5-20°C. Carrots are an excellent source of vitamin A and a good source of niacin and vitamin C.

Carrot grows best on lighter soils which allow better root development. Deep loams or sands give best results.

- Avoid heavy soils. pH = 5.5-6.8.
- Avoid soils with fresh FYM.
- Growing carrot alongside onion and garlic reduces the risk of carrot fly.

Figure 4.7 Carrots

ii. Planting times

- Upper hills: March-May.
- Mid hills: October-January.
- Low hills: October-November

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Dig the land to a depth of at least 30 cm. Do not add fresh FYM. Carrot are always directly sown. Mixing the seeds with sand improves the accuracy of sowing. Maintain spacing of R-R =15 cm and P-P =2-3 cm. Use seed rate of 8-10 g/10 m^2 and sow seed 1 cm deep. Carrot is a slow germinating crop taking 2-4 weeks to emerge.

iii. Manures and Fertilizer

The main requirement is potassium for root development. Use N P K = 20: 10: 60 kg/ha as a basal dose. It amounts to urea = 40 g/10 m^2; SSP = 60 g/10 m^2; MoP= 100 g/10 m^2. This may be too much potassium as most soils here seem to have reasonable potassium content. FYM/compost should have been added to the soil before the previous crop.

iv. Management

Carrots should be watered before any wilting occurs but water requirements are low after the seedling stage. Thin the crop to 10 cm apart and weed as and when necessary. Earth up any exposed roots otherwise exposed roots will turn green.

v. Plant protection

The major problem is carrot fly. The larvae tunnel into the roots. Other symptoms are leaves turning red, wilting and later yellowing of leaves. As carrots are not grown on a large scale here the importance of the problem is not really understood.

vi. Control measures

Sow carrots maintaining proper spacing so that thinning is not required. If thinned, destroy or dispose all seedlings. The smell of thinned or pulled seedlings attract the pest. Sow early to reduce pest problem, inter crop with garlic and onions to avoid pests.

vii. Harvest

Carrot will mature in 112 days. Either pull up the whole roots or dig them up. Keep foliage attached for fresh sale, but remove for storage. A good crop of carrot can yield 10-20 kg/10 m^2.

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4.8 Radish (Rhaphanus sativus)

Dzongkha name: Laphu

Figure 4.8 Radish

Radish is an annual or biennial crucifer grown for its roots. There are two basic types; Japanese types with large cylindrical white roots and European types with small round red roots. Roots are rich in calcium and a good source of thiamine and niacin. Leaves are a good source of vitamin A and C.

Radish can be grown throughout the country provided the correct variety is chosen. Some are suitable for the southern regions while others are adapted to the higher areas. If the wrong variety is sown at the wrong time then they tend to bolt and flower early rather than producing roots.

Radish grows best on light friable soils which are reasonably fertile and contain plenty of well decomposed organic matter. pH = 6-6.8.

- Avoid heavy clay soils as root formation will be poor.
- Avoid other root crops and brassica in crop rotation. Radish can give yield of 15-30 kg/10 m^2 (Japanese types) and 8-10 kg/10 m^2(European types).

4.9 Onion (Allium cepa)

Dzongkha name: Gop

Onion is an erect usually biennial herb grown for its bulb. Bulbs are a good source of vitamin C, iron and calcium. Leaves are a good source of vitamins A and C, thiamine, riboflavin and niacin.

Onions are a cool season crop. However different conditions are required for vegetative (leaf) growth and for bulb formation. Leaf growth occurs best under cool conditions with an adequate supply of moisture. Bulb formation requires warmer, drier conditions. The switch from leaf growth to bulb formation is largely controlled by light (the photoperiod), with onions generally being long day plants. This means that long days (11-16 hours of light) are required for bulb formation. Onions are generally frost hardy.

Onions can be grown on any soils containing plenty of organic matter. Bulb formation may not be so good on very heavy soils and under very wet conditions, under such conditions rotting of bulbs can be a problem. The best soils will be light rich soils with adequate drainage. Optimum pH = 5.8-6.5 Onions are very sensitive to the toxic effect of aluminium. Intercropping onions can be used to reduce pest attacks on other vegetables as the smell repels some pests e.g. carrot fly of carrots. However, onions tend to flower when grown in the shade.

i. Varieties

- *Red cross*
- *Red globe*
- *Bombay red*
- *Nasik red*
- *Senshu red*

Figure 4.9 Onion

ii. Planting times

Because of the more complicated requirements in terms of temperature, light and water, onion is more sensitive to planting time than other vegetables.

- High hills: February-June (Feb under plastic, best Mar-April).
- Mid hills: October-December.
- Low hills: October-November.

Consult extension agents and research people to find the optimum planting time and variety to grow. Varieties imported from abroad must be fully tested under a wide range of conditions prior to release.

iii. Management

Onions are shallow-rooted crop and need water regularly. During dry condition crop has to be irrigated regularly to keep top 7.5 cm of soil moist. However, excessive irrigation will increase the risk of rotting. Dry conditions cause the outer scales to crack.

Weeding is very important due to slow early growth but care must be taken not to damage roots. Mulching is recommended to conserve moisture and keep weeds down. Carefully loosen the soil once plants are established then mulch between the rows. Thinning of direct-sown plots will be necessary until plant spacing is 10 cm. Thinned onions can be used as salad onions.

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iv. Harvest

Stop irrigating when tips of leaves start to dry. Harvest when leaves have completely withered. This can be speeded up by bending the green leaves over once they start dying. After digging up the bulbs they need to be cured prior to storage. Leave in the sun for up to five days. Onion can yield 15-25 kg/10 m^2. Hang up in bunches after curing, allowing free air circulation.

4.10 Garlic (Allium sativum)

Dzongkha name: Cha Goop

Garlic is a bulbous biennial herb with numerous small bulblets or cloves. Each clove is surrounded by a thin papery sheath. Since it is only used in small amounts as a flavouring agent, garlic is unlikely to be a major source of vitamins. Garlic has a number of medicinal properties and is recommended as herbal medicine. It can be grown as onion. It prefers richer soils than onion, as additional FYM will benefit the crop. Intercropping garlic with other crops repels some pests and protects other vegetables.

i. Planting times

- Upper hills: March-May
- Mid hills: October-December
- Low hills: October-November

Figure 4.10 Garlic

ii. Field preparation

Prepare land similar to onion. Separate cloves from the main bulb and plant at a depth of 2-4cm. Spacing can be R-R=15-25 cm and P-P = 10-15 cm. In 10 m^2, 350 cloves will be required. Apply 20 kg/10 m^2 FYM or compost and N P K = 40 – 60: 80: 40 kg/ha basal dose. Crop needs to be top dressed with 40 kg/ha top dressing after 6-8 weeks. This amounts to urea = 85 g/10 m^2; SSP =500 g/10 m^2; MoP = 70 g/10 m^2 plus basal dose Urea= 85 g/10 m^2top dressing.

iii. Management

Weeding is essential as garlic is shallow-rooted crop. Provide shallow irrigation during dry periods.

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iv. Harvesting

Garlic can be harvested when the leaves turn yellow and dry. Dig up the plants, cut off the stems and dry. It can yield 4-10 kg/10 m^2. Sun dry prior to storage.

4.11 Asparagus (Asparagus officinalis)

Dzongkha name: Nya Khachu

Asparagus is a perennial herbaceous plant whose shoots are used as a vegetable. Rooted seedlings are known as crowns, and the shoots as spears. Spears are rich in vitamins A, B and C. Asparagus can be grown under a wide range of conditions from sub-tropical through .to temperate conditions. The variety available in Bhutan is for mid and high hills, up to 2600 masl. Choose a sunny spot sheltered from strong winds. It grows best on deeply cultivated soils, rich in organic matter, with a loose texture. Soils should be well drained with a pH of 6-7.

Figure 4.11 Asparagus

i. Varieties

Variety of Asparagus grown in Bhutan is *Mary Washington*.

ii. Raising crowns in nurseries

Make well-prepared beds incorporating plenty of FYM/compost. Seeds are sown in February-April at a spacing of R-R = 35 cm and P-P = 4 cm and depth=3-5 cm. It is advisable to soak the seeds for 24 hours prior to sowing. Seed rate required is 5- 7 g/10 m^2. The seedlings should be thinned to a spacing of 15 cm when they are 7.5 cm tall.

iii. Planting times

The field needs to be ploughed as deep as possible. It is very important to control any perennial weeds thoroughly at this stage as future control will be difficult. Asparagus crowns are planted in trenches which are gradually filled up with soil as the crowns grow, so that the crown is always kept covered. There are two ways of doing this.

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Double-row systems in which each trench contains 2 rows. A double-row system makes better use of available space. Spacing of trench-trench-1.5 m, R-R within the trench=30 cm and P-P = 45 cm. For single-row system, spacing may be R-R=1.5 m and P-P =45 cm

iv. Field preparation

Trench of 60 cm depth should be dug. Fill half of the trench with FYM/ compost and then add a 10cm layer of soil on top. The crowns are then planted on here and covered with soil until totally hidden. As the crowns grow, more soil is added until the bed is level, ensuring the crown is always kept covered.

v. Transplanting time

Asparagus is normally planted during March-May, provided irrigation facilities are available. If not delay planting until the rains start. The crowns need three months growth in the first year before dormancy sets in. Keep the crowns moist when transporting them by covering them with damp sacking. Crowns grown from seed should be one year old when transplanted.

Manures and Fertilizers require to add to the trench at the time of transplantation is FYM/compost (25-30 kg/10 m^2), N P K: 50 90 40 kg/ha, Urea =110g/10m2; SSP= 60 g/10 m^2; and MoP=70 g/10 m^2.

Apply fertilizer from the second year onwards: N P K: 150: 100: 200 kg/ha, Urea =330 g/10 m^2; SSP= 630 g/10 m^2; and MoP= 330 g/10 m^2.

Asparagus has a high nutrient demand. Generally nitrogen promotes fern growth, Phosphorous increases spear size and potassium spear numbers. Timing of application of fertilizers: add half of the N and K in January-February and the rest after the last harvest. All of the P should be added after the last harvest. FYM can be added as mulch from the 3rd year onwards.

Watering is usually required in the first month after transplanting when the root system is not fully developed. Hand weeding is done as necessary

vi. Harvest

It is important to allow some spears to develop into ferns (leaves) to keep the plant growing. Normally the first spears will appear in the first year after transplanting.

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Do not harvest these. In the second year after transplanting, spears can be cut from March -mid July by cutting them off under the soil surface with a sharp knife when they are 10-12 cm high. Taller spears have less flavour. Do not harvest after mid-July but allow any spears to develop into ferns. These will then turn pale in November indicating dormancy. They should then be cut off and burned to reduce potential disease problems. Good crop can yield 2.5-4 kg/10 m^2.

Vegetables is a big business in Bhutan and vegetables are imported all the year round. Why not grow our own and stop importing to stop money flowing out?

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Student Activity

Provide similar activity that the students have experienced in IX but with different vegetables and research /experiment based work in nature

Activity 1-Growing of vegetables in school

1. Divide the students into groups depending on the vegetable that can be grown in the school campus.
2. Instruct each group to grow different vegetables discussed in this chapter as per the cultivation guidelines.
3. Maintain records of hours spent on work, record types of work involved, observe development stages and care required till harvest and provide opportunity to share after certain interval, so that all will learn to grow different vegetables.
4. Record quantity and quality of produce.
5. Prepare and present their reports at the end of the season.
6. Assess the student's practical work using the assessment tools.

Activity 2-Field trips to learn growing of vegetables which cannot be grown in the school campus.

1. Plan field trips on the academic calendar at the planning period and seek permission from the school leadership.
2. Write to the agency /inform the farm of intended visit with clear objectives.
3. Prepare field trip plans as per the guide provided in the curriculum guide.
4. Arranged filed trips objectively, assign task of write up on the project.
5. Assess the project (field trip write up) as per the guide.

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5 Chapter

Growing of Fruits II

Bhutan's geographical landscape and its climatic conditions provide environment suitable to grow subtropical fruits in many interior parts of the country such as Punakha, Wangdi, Trongsa, Zemgang, Mongar, Tashigang, Tashi Yangtse, Lhuntshe and Pemagatshel, in addition to the Southern Dzongkhag such as Samdrup Jongkhar, Sarpang, Chukha and Samtse. This chapter provides opportunity to learn to grow and sell some popular subtropical fruits and business entrepreneurship which could create employment for young Bhutanese. Such an entrepreneurship could bring economic development for self-reliance to this GNH nation.

5.1 Citrus (Citrus spp.)

Dzongkha name: Tshelu

Figure 5.1 Citrus

Citrus are members of the *Rutaceae* family and the Himalayan regions and south China are places of origin for most of the citrus species. Fruits are mostly consumed as fresh fruit, particularly those citrus from the sweet orange, mandarin, pummelo and grapefruit group. It is used for preparation of squashes, cordials, juices and juice concentrates and marmalade jam. Limes and lemon are mostly used for flavouring vegetable dishes, and preparing refreshing drinks, squashes and cordials. They are rich in vitamin C, acids and volatile oils. The essential oils and perfumes produce from citrus flowers, leaves and fruits are in big demand in international market. In Bhutan, mandarin orange is by far the most important and principal cash crop in sub-tropical belt.

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a) Species and cultivar

The primary species of cultivated citrus are sweet orange (Citrus sinensis), lemon (Citrus limon), lime (*Citrus aurantifolia*), citron (*Citrus medica*), pummelo (*Citrus maxima*), grape fruit (*Citrus paradisi*), and the loose skin orange group: mandarin orange (Citrus reticulata), satsuma mandarin (*Citrus unshiu*), cleopatra mandarin (*Citrus rashni*), and tangerine (*Citrus tangerine*).In Bhutan local mandarin is the only cultivar grown commercially.

(a) Mandarin

(b) Sweet orange

(c) Lime

(d) Lemon

Figure 5.2 Species of citrus

b) Conditions for growth

i. Climate

Productivity of citrus depends upon variety of factors: climate, soil and management. The optimum temperature for citrus fruit growth is around 23°C with a minimum threshold of 8°C. Temperatures above 30°C are not favourable for fruit size, quality and yield. Below 12°C colour development is a problem. Water requirement of citrus species differ and range from 750 mm to 1200 mm rainfall

per year. Water during fruiting and marble size is critical for fruit size and yield. Rainfall and irrigation during these critical stages increase yield even if the trees have been under stress in previous seasons.

ii. Soil

Citrus grows in any soil that is well drained, sufficiently aerated and that allows the tap root system to penetrate to desired depth. It prefers a soil with pH range of 6-7.

c) Procedures of growing

i. Nursery

Citrus can be propagated through seeds or through budding, grafting, air layering and micro-propagation. The advantage of using seeds is that the tree is vigorous and the viral diseases are usually not transmitted, however the disadvantages are that the plants may neither be true-to-type nor produce fruit until the seventh or ninth year. Other disadvantages are like upright tree structure with thorns which make harvesting and management operations difficult. Further plants grown from seed tend to be susceptible to several soil related diseases link *Phythophthora spp*. However, vegetative propagation will produce plants that are identical to the parent, will produce fruit in two to three years, be of a more manageable size, give uniform and high quality fruit and have resistance to certain diseases. In Bhutan the local citrus is favoured as a seedling because of its natural adaptation to the environment, vigorous growth habit, and its disease and drought hardness.

ii. Seed production

1. Seeds should be selected from mother plants that are 10-15 years old, regular bearing and high yielding, free from diseases.
2. Extract seeds from mature fruit, wash and rinse the seeds thoroughly in water.
3. Plant seeds at a depth of 6mm to 12 mm in planting pots or seed-beds. While using seedbeds mulch the bed before germination and remove as the seeds germinate.
4. Under ideal conditions seeds should begin germinating between 7-10 days after planting.
5. Once seedlings are 20-60 cm high (6 months to 1 year) they should be lifted and transplanted either to individual rows in a secondary nursery, or to individual

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containers.

6. The soil must be moist thereby allowing for the easy lifting of plants with little damage to the roots.
7. Because citrus is a poly-embryonic crop, roguing of seedlings should be carried out at transplanting.
8. Markedly larger or smaller seedlings with defects in leaf and petiole shape should be rogued out as they are probably off type seedlings.
9. Those uniform seedlings selected for nursery rows or individual containers are referred to as liners. Liners are planted at 1-1.5 m apart with plants 30 cm apart in rows. The liners are grown in nursery for 24-30 months.

iii. Seedling selection

Vigorous growing, 24 to 30 months old. Select seedlings that have a single stem, many side shoots or branches, ball-shaped having lush dark green leaves are selected.

iv. Orchard layout

The land must be flat or gently sloping and where slope grades are more than 10%, terracing is necessary to secure moisture penetration without erosion. Triangular, hexagonal, rectangular and contour system of planting depending upon the land topography.

Spacing for mandarin is recommended to be about 6 m x 6 m. Spacing for lemon and lime ranges from 3-4.5 m and grapefruits are planted at 7-7.5 m. However, it is to be kept in mind that the distance between plants and rows is determined by the soil conditions, variety, rootstock, moisture supply and means of cultivation.

Pit size of 0.5 m x 0.5 m x 0.5 m should be dug and filled with top soil, farmyard manure and compost 3-4 weeks prior to planting. The pit should be watered after filling so that the soil mixture settles down. If the soil is not fertile and if there is hardpan below, size of 1m x 1m x 1m is recommended to facilitate better root penetration.

Planting can be done at any time of the year if there is an irrigation facility available, if not, plant during rainy season. The seedling must be set in the pit at the same depth as it was in the pots or in nursery bed. Do not plant deep in the

pit. In the case of budded or grafted plants, the joint should be above the ground level otherwise roots will develop from the scion portion.

v. Manures & Fertilizers

Ideally, one should undertake either a soil or leaf analysis to determine the present fertility status of the soil, or the availability of nutrients to the plant. For a leaf analysis the sample should be taken from the first leaf below the terminal fruit. National Soil Service Centre at Simtokha, Thimphu, under the Ministry of Agriculture and Forest has all the facilities to carry out the analysis.

The following are fertilizer recommendations only and are subject to change due to soil type and results of soil and leaf analysis. A mixture can be formulated by using the ratios as given to the left of table one.

Table 5.1 Age of tree and corresponding ratio of fertilizer

Age of the tree	Grams of mixture/tree	Manure	Ratio of fertilizer
2-3	100-200	5	0.2 part Muriate of Potash (60%K_2O) 0.3 part Urea (46%N) 0.5 part Superphosphate (16%P_2O_5)
4-6	300-400	10	
7-9	500-900	20	
10 years and over	1000	20	

Basal dressing of NPK should be applied after harvest, before the spring flush. Another critical period for fertilizer application is in spring during the spring flush when the tree is undergoing blooming and early fruit development. Manures and fertilizers should be spread evenly under the area covered by the canopy of the tree and extending out about 50 cm from the canopy. It is not advisable to dig a trench around the edge of the tree or to scrape soil from under the tree to cover the applied manures and fertilizers. This practice damage the feeder roots of citrus which are shallow and found in the top 5 cm of the soil under the canopy. Feeder roots are responsible for tree growth and nutrient absorption.

vi. Pruning

Water shoots which are long, thorny, rapid growing shoots are pruned or rubbed off as well as the unwanted shots/branches. The distance from the ground to the

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first branch should be maintained. The centre of tree should be kept open and upright branches occupying this area should be removed. Diseased/ dying or borer infested branches should also be removed.

vii. Weeding

In Bhutan farmers do not follow any standard management practices. Weeding is normally done once a year.

d) Harvest

Harvest season in Bhutan spreads over a period of three months, from November to early February since cultivation is over a range of altitudes. Fruits are harvested when they have attained full maturity and colour. Ideally the fruits are harvested with citrus clippers, snipping the stem at the base of the calyx. Long stem can puncture skins of neighbouring fruits in the baskets or packing cases. The pickers must be careful not to pull the calyx end or "button" out of the fruit when fruits are pulled or picked. Damaged skins are easily infested by post-harvest diseases like "blue mould". Yield of mandarin in Bhutan is estimated to be low at 6.86 t/ha due to poor management practices. This does not compare with mandarin yield in other countries such as Brazil (14.9 t/ha), Australia (14.4 t/ha), Japan (18.2 t/ha and India (13.3 t/ha).

e) Post-harvest handling

Fruits should be graded and kept as cool as possible until consumed or sold. Grading is based on the size of the fruits or the defect on the fruits, all of which are controlled by the Bhutan Food and Agriculture Regulatory Authority. Local materials for packing used are wooden boxes that are light and well ventilated with straw to cushion and protect fruit while in transit.

5.2 Mango (Mangifera indica L.)

Dzongkha name (Aam chu ku li)

Mango belongs to family *anacardiaceae* and is native to the Indian subcontinent, the Indo-Burma region. It is called the king of fruits. Ripe fruits are used for table purpose and processed into squashes, juices, syrups, jams and jellies. Canned mango slices and pulps are also popular. Mango is a very good source of vitamins A and C. Raw fruits are used for the extraction of tannin and other astringent

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products as well as for the preparation of chutneys, curries and pickles. Besides its use for propagation, stones can be served as a good stock feed for cattle.

Figure 5.3 Mangoes

a) Varieties

There are many varieties grown, popular ones that grow in India also are grown in Bhutan such as *Langra* and *Dusehari.*

Langra is the main variety grown in Bhutan with tall and spreading trees. Fruits ripen in first fortnight of July. The pulp is moderately firm, juicy, creamy and fibreless, except for the irregular bearing habit, this variety ranks as one of the best.

Dusehari is the leading variety of India with small to medium sized trees. It is a mid-season cultivar which ripens in July. Fruits are small to medium, with an elongated shape. The pulp is sweet, firm and fibreless. Fruits have a high keeping quality and this variety trees bear fruits regularly year after year.

b) Conditions for growth

i. Climate

Mangoes are grown at altitudes from sea level to 1200 m in the tropics, but they do best below 600 m. The optimum temperature is 24-30°C. Temperatures above 46oC and falling below freezing are not suitable and severe frost can both damage and kill young trees. Mango is drought tolerant and will survive on as little as 300mm of rain per year, but for commercial production a minimum of 635mm is recommended. In areas with two wet seasons, flowering and fruit production may occur twice each year, but in most areas one crop per year is produced.

ii. Soil

Mangoes grow in most soils provided they are not too waterlogged, too alkaline or too rocky. A pH of 5.5-7.5 is preferred.

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c) Procedures of growing

i. Nursery

Mangoes can be propagated by seed, grafting and budding. Propagation through seed is the cheapest, easiest and the oldest method. However, seedlings grown from seeds seldom come true to type. Approach (Figure 1), side, tongue and stone grafting are the common methods of propagation, however, other methods like cutting, chip budding and air layering are also employed, though on a limited scale. Vegetative propagation requires skill and is expensive, however commercial orchards uses vegetatively propagated seedlings mainly for uniformity.

Figure 5.4 Side grafting in mango

ii. Orchard Layout

Square, hexagonal and quincunx system of layout are usually used. The square system is most commonly followed. This system is easy to execute and permits intercultural operations cross-wise.

iii. Spacing

Dig pit size of 3 feet x 3 feet with space of about 10.5m for seedling mangoes and 9 m for grafted seedling is adequate.

iv. Planting

Rainy season is the best time to plant. A hole slightly bigger than the seedling's earth ball should be dug. The packing material around the earth ball of the seedling should be removed – taking care that the ball is not injured. The plant along with its ball is placed in the hole of the pit and with the help of the planting board the position is set. Moist top soil is used in refilling the vacant space and the earth around the plant should be firmly pressed. As soon as the planting is completed, watering should be done. Do not plant seedlings either too deep or too high. The graft union should be approximately 23cm above the level of earth in the pit.

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v. Orchard Management

Mango trees are highly susceptible to frost injury. Young plants especially in the localities which are subject to frost should always be covered with thatches. Smudging (burning heaps of dry matter at several places in the orchard), also helps control effect of frost. In areas where the summer heat is intense protect young plants either by planting quick growing plants, or by white washing the trunks to protect against sunburn injury. Weeding and irrigation should be carried out when necessary.

vi. Manures and Fertilizers

Apply manures and fertilizers at the rates given below:

Table 5.2 Fertilizer rates

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

vii. Training and Pruning

Normally mango trees require less or no pruning. An ideal aim for pruning should be a dome-shaped top that is be neither too near to the ground nor too high as this avoids exposure to the trunk from sunburn. Removal of dead wood and thinning of overcrowded branches are necessary.

d) Harvesting and Yield

Mangoes usually begin to bear 3-4 years after planting in the case of budded or grafted trees, or 5-6 years after planting in the case of seedlings. Bearing normally continues for 40 or more years. Fruit takes about five to six months to mature. Yield varies according to the varieties. A grafted tree can yield 300-500 fruits in the tenth year, 2000 to 5000 in the 20th year onwards.

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e) Postharvest handling and storage

There are many methods to jode maturity index such as fruit colour and fullness of cheeks. Mangoes are harvested when mature and then ripened. Maximum storage life will be obtained if fruits are quickly cooled to between 7°C-10°C, although there is some variation in the optimum storage temperature among different cultivars. Relative humidity should be maintained at 90-95%. Mango is susceptible to chilling injury therefore temperature should be maintained.

5.3 Guava (*Psidium guajava L.*)

Dzongkha name: Belp-sew

Guava belongs to the family *Myrtaceae* and is native to Tropical America. Fruit is very high in vitamin C and is also a rich source of vitamin A and B2 (riboflavin) and minerals like calcium, phosphorus and iron. The vitamin C content of guava is four to five times higher than that of citrus. The Guava fruits are used for making jam, jellies, and various culinary purposes. The fruits can be canned in sugar syrup.

Figure 5.5 Guava

a) Varieties

There are many white and red fleshed local varieties but their identity is not known. One of the imported varieties from India is Allahabad safeda. The fruit is medium, roundish in shape and slightly depressed at ends, the surface is smooth, glossy and has a skin colour that is straw yellow. Fruit quality is excellent and keeping quality is medium. It bears heavily and withstands drought condition.

b) Conditions for growing

i. Climate

Guava gives optimum production in tropical regions below 1300 masl in elevation. The optimum temperature for production is between 23-28°C. An annual rainfall of about 100 cm is sufficient during the rainy season and rains during harvesting deteriorate the fruit quality. Young plants are susceptible to drought and cool

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temperature. But the established trees can withstand prolonged drought, heat and waterlogged soils.

ii. Soil

It is a hardy tree and can be grown in a wide range of soils including marginal soil. It can tolerate a soil pH range of 4.5 to 8.2.

c) Procedures of growing

i. Nursery

Vegetative propagation is difficult in guava than any other plant. Air layering is commonly practiced and the best time is in February to March and again in July to August. Layers form roots within 3-5 weeks. When the roots grow through the ball of moss the stem is cut below the rooted portion and then potted and kept in shade until new leaves appear. When new flushes are produced the plant is then hardened in sunlight and then transplanted in the field.

Propagation through seeds can be done. Seeds should be taken only from plants, which are known to produce good-quality fruit. Seed germinate in 2-3 weeks. Seedlings are susceptible to damping off, so sterilized soil should be used and careful watering practiced. Under good conditions, a seedling will grow to 30cm tall in 6 months and can be planted into the field.

ii. Orchard layout

Planting can be done in a layout that is appropriate to land topography. Hexagonal, square or contour system of layout is followed. Dig pit size of 1 m x 1 m and filled up with topsoil and manures and then let it settle for a month. Plants are spaced 6 m x 6 m apart in the square system. Planting is done in June-July or the onset of monsoon. Guava can be grown as intercrop in arecanut plantation in southern Bhutan.

iii. Manures and Fertilizers

Farm yard manure (FYM) and fertiliser may be applied as recommended in the table below.

Table 5.3 FYM application according to age of tree

Age of the tree	FYM (kg/ plant)	Urea (g/plant)	SSP (kg/ Plant)	MOP (g/ plant)
1-3	10-20	150-200	0.5-1.5	100-400
4-6	25-40	300-600	1.5-2	600-1000
7-10	40-50	750-1000	2-2.5	1100-1500
10 and above	50	1000	2.5	1500

FYM should be applied in May and half of the inorganic fertiliser should be applied in May -June and the remaining half in September-October. Pruning is confined to the removal of low branches, which touch the ground, and of diseased or crossed branches. Weeds are removed by shallow cultivation. Guava is mostly grown under rain fed conditions and whenever irrigation facilities are available, they are rarely practiced.

d) Harvesting and Yield

Plants bear fruit 3-4 years after planting and attain full bearing capacity at the age of 8-10 years and continue to bear for 30 or more years. Fruits are harvested selectively by hand along with stalk and leaves. The yield of a plant depends on its age, cropping pattern and cultural practices. About 500-800 fruits per tree per year can be obtained from a 10 year old tree.

e) Postharvest handling and storage

The skin of the guava is very delicate, so fruits must be handled with care. Fruits for local markets should be kept as cool as possible until sold. Fruits intended to be sold at a distant market are harvested when it is firm and light yellow. Guava can be stored for 2-3 weeks at 7-10°C.

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5.4 Banana (*Musa spp.*)

Dzongkha name: Ngangla

Banana belongs to the family *Musaceae* and is native to South East Asia. In Bhutan it is mainly grown in the subtropical areas of the south however there is no large scale commercial farms.

Figure 5.6 Banana

It is a good source of vitamin A and a fair source of Vitamin C, and B2. Banana fruits are also rich source of minerals like magnesium, sodium, potassium and phosphorus and fair source of Ca and Fe. Ripe fruits are used for table purpose. The immature fruits are used as vegetable. The end of the inflorescence called pendant is also used as vegetable. Many products are made from banana like banana chips, soft drinks, flour and jam. Ripe fruits taken with tamarind and salt are said to control dysentery. Beer is made out of banana in Africa. Starch is manufactured from the pseudo-stem. The sheaths and leaves are used for making crude ropes.

a) Varieties

Banana varieties are broadly divided into two groups such as table and culinary. In Bhutan only the table varieties such as Chini champa, Dhusrey and Jhaji are grown.

b) Conditions for growing

i. Climate

Bananas will grow in most of the humid subtropics and semi-arid subtropics. Growth is retarded at temperatures below 20°C and higher than 35°C. Yields are generally high when grown in areas with temperatures above 24°C. Banana grown under humid subtropical conditions have better quality fruits as they develop better aroma and crisp pulp. Hot winds blowing in high speed during summer months shred and desiccate leaves. The best production occurs where rainfall is abundant and is fairly evenly distributed throughout the year.

ii. Soil

Banana will grow in a wide range of soil types, provided there is moderate to good drainage. Optimum production will occur in soils which are high in organic matter,

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retain moisture well and contain abundant amounts of nitrogen and potassium. A pH between 6.0 and 7.5 is normally required for commercial production.

c) Procedures of growing

i. Field preparation

Bananas are propagated vegetatively, usually by lifting and replanting a sucker and its attached rhizome. Square, rectangular or hexagonal layout is followed. Dig pit of size 60 cm x 60 cm x 60 cm with spacing of 3m x 3m for tall varieties and 2 m x 2 m for dwarf varieties, fill it with soil and manure or other decomposed organic matter. Plant suckers in the centre of the pit and compact with soil and manure. Time of planting is determined by the availability of irrigation facilities, therefore normally planted during the onset of monsoon.

ii. Management of Banana plantation

Banana being heavy feeders requires very large quantity of nutrients for growth and high yields. This accounts for 20-30% of the total cost of production. Choice and quantity of fertilizers, time and mode of application and frequency of application vary depending upon cultivars, production system and agro-climatic conditions. Nitrogen (N) and potassium (K) requirements is high and the phosphorus (P) requirement is comparatively low. However in Bhutan there is no recommendation available for banana plantation.

iii. Water requirement

Water requirement of banana varies from 1800 mm to 2200 mm. Furrow, basin and flood irrigation are being practiced. Spading is commonly used to control weeds, though using integrated weed management by including cover crops, intercropping and hand weeding wherever necessary will contribute to increased production. First six month of growth, are critical for weed growth and plantation has to be kept completely free of weeds. After planting, banana will begin to form suckers from the base. The removal of surplus suckers is an important operation. Ideally, a clump of bananas should have only three suckers at any one time, one which is fruiting, one that is flowering, and one which has not yet flowered. If a plant is allowed to develop into a large clump without thinning, yield will be reduced.

iv. Bunch propping

It is essential for tall cultivars where strong wind is a routine menace. Propping involves the supporting the pseudo-stem with a bamboo stem. A banana will flower and produce fruit within 6-18 months after planting. The fruit is harvested when they are still green but after the ridges have begun to become rounded and the topmost hands have become light green. A good management can yield 12000 to 24000 kg/acre.

d) Postharvest handling and storage

Banana can be ripened by many methods. As with most fruits, ripening occurs in response to ethylene production and applying ethylene will enhance ripening. Smoking the fruit is often practiced to ripen fruits. The ethylene in the smoke and the warmth enhance both the speed and uniformity of ripening. Green bananas are shipped at 13-14°Cto delay ripening. Banana is sensitive to chilling injury so lower temperatures will lead to chilling injury

5.5 Papaya (Carica papaya L.)

Dzongkha name: Manduphala/Chugoen

The papaya belongs to family *Caricaceae* and is believed to be native to southern Mexico and neighbouring Central America. It is now present in every tropical and subtropical country. In Bhutan it is grown in kitchen gardens for home consumption. Papaya contains vitamins A, B1, B2 and C. It also contains low amount of sodium. Papaya is a common dessert and is used as salads. A variety of products such as jam, jelly, nectars, ice-cream, yogurt and dry slices may be made from the ripe fruit. Unripe fruit can be candied, fermented or cooked as a substitute for apple sauce. Papain is used as meat tenderizer and for medicinal and industrial purposes. Carpaine an alkaloid found in papaya leaves has been used for medicinal purposes. They can also be cooked to make desserts. In the West Indies, young leaves are cooked and eaten like spinach.

Figure 5.7 Papaya

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a) Varieties

Most of the varieties grown in Bhutan are not identified. There are some Indian varieties which will also do well in Bhutan. These varieties are:

Honey dew: The plant is of medium height and bears fruit quite heavily high on the trunk. The proportion of male plants is low. The fruit is large, elongated and contains few seeds. The flesh is extra fine and sweet with a pleasant flavour. This variety is also known as Madhu Bindu. The keeping quality of fruit is medium.

Coorg Honey Dew: This is a selection from Honey dew. The plant is tall and bears fruits heavily, low on the trunk. Most of the plants are hermaphordite, but a few occasionally produce pistillate flowers. The fruit is large, of variable shape and contains few seeds. Its flesh is appreciably thicker, but slightly less sweet than that of honey dew.

b) Conditions for growing

i. Climate

Papaya grows well up to an altitude of 1068 masl and is suitably grown in warm and humid conditions. Optimum temperature for growth is between 21°C and 33°C. Papaya is extremely sensitive to frost and if the temperature falls below 12-14°C for several hours at night, growth and production are severely affected. Cool temperatures will also alter fruit flavour. Successful production depends upon the availability of supplemental irrigation during dry period. Drought frequently leads to the rapid shedding of the older leaves and poor fruit set. Papaya trees are delicate and require protection from strong winds.

ii. Soil

Papayas are grown in a variety of soil types, with the most essential requirement being drainage. Poor drainage leads to the development of root rots. A porous loam or sandy loam soil is preferred. Papaya grows well at a soil pH between 5 to7.

c) Procedures of growing

i. Nursery

Papayas are normally propagated by seed. Growers select trees with desirable

characteristics, from which seeds generally open pollinated from hermaphroditic fruit are saved. This seed produces a uniform progenies if they are collected from a single cultivar. Fresh seeds are washed and air dried in the shade. Seeds germinate with higher percentage if the sarcotesta (gelatinous material covering the seed) is removed during seed washing. Seeds kept at 7-10°C and 50% RH are viable for several years. Seeds may be sown in trays filled with a suitable medium, or in polythene bags or directly in the field. Germination occurs in 12-20 days. Saplings are transplanted from poly pots at the two leaf stage. Saplings grown in containers should be hardened gradually in the sunlight and field transplanted around 1.5 to 2 months after germination at about 20 cm high.

ii. Orchard layout

Layout systems such as square, rectangular, hexagonal or contour is chosen depending upon land topography and convenience. Dig pit measuring 0.5 mx0.5 m is recommended in hard soils with a general spacing of 2.5 m x 3 m depending on the variety. Plant 3 seedlings per pit (10-15 cm apart) and lightly irrigate the seedling. Planting can be done from February-March or June-September, however monsoon planting is preferred.

iii. Removing unwanted male plants

After flowering, which usually takes place within 5-6 months only one female or hermaphrodite plant per pit is retained. Most of the male plants are removed. The male plant can be identified with its pendulous flower stalk, whereas female flowers are sessile. However, well scattered male plants at a ratio of 1:15 (male: female) have to be retained for pollination.

(a) Male flower *(b) Female flower*

Figure 5.8 Papaya plants

iv. Manures and fertilizers

Twice a year at 6 months intervals NPK fertilizer is added at a rate of 200 g per pit. Spread evenly around the basin and incorporate it into the soil without disturbing the roots and then water immediately.

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v. Weeding and Hoeing

Light digging is recommended after each time you irrigate, but keep this shallow as the root are located at a depth of 45 cm.

vi. Thinning of fruits

Remove few fruits from the cluster in order to obtain both good shape and quality fruit.

d) Harvesting and Yield

The first crop of papaya matures within 12 months after transplanting in orchard. Harvesting can be done at 5 day intervals. Papaya is ready to harvest when most of the skin is yellow green and ripen at room temperature. Papaya yields 23-75 fruit/tree, with fruit weights varying from a 0.5 kg to 3 kg each, giving a total output of 30-60 tons/ha.

e) Postharvest handling and storage

Mature fruit can be stored at 7°C for about 3 weeks. Pack in a shallow basket in single layers padded with straw for transportation or export.

5.6 Arecanut (*Areca catechu L.*)

Dzongkha name: Doma

Arecanut or commonly known as betel nut is a tropical palm belonging to *Palmacea* family. Although the exact origin of Arecanut is unknown, it most probably originated from Central Malaysia. In Bhutan arecanut could have been introduced a long time ago from India. It is grown in the sub-tropical southern dzongkhag of Sarpang, Samchi and Samdrup Jongkhar. It is one of the main cash crops providing high income with relatively low investment.

Figure 5.9 Arecanut

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The nuts or the hard dried endosperm of ripe and unripe seeds are chewed as a masticatory by about 400 million people around the world from Zanzibar to India and the Central Pacific. The plant is tall with slender erect, unarmed and solitary stems living for 60-100 years. The popular practice is to wrap small slices of the nut in a fresh leaf of betel-pepper (Piper betel L.) which is added with a dab of slaked lime. Other ingredients such as cardamom, tobacco, clove may also be added to the betel quid. It is also commonly chewed in Bhutan and is customary in celebrations and ceremonies. Chewing is said to increase the production of saliva and gastric juices and thus aid digestion. It also has astringent and tonic properties. Chewing has also been linked by the World Health Organization (WHO), with the increase in oral cancers. The other ill effects of chewing this nut are lesions of the mouth and gums, abrasions of the teeth and mouth and throat cancer.

a) Varieties

So far there are no known varieties in Bhutan; however palms are identified by the shape of the nuts, notability oblong and round nuts. In India, varieties and types like Sumangala, Mangala, Sreemangala and Mohitnagar, are popular. In Bhutan, the most widely grown palm is believed to be the variety Mohitnagar due to its origin and proximity to the Indian border.

Mohitnagar variety has a high level of uniformity in performance, bunches are well placed and nuts are loosely arranged on spikes for uniform development, early stabilization of production, consistent higher yield with an average yield of 3.67 kg per palm.

b) Conditions for growing

i. Climate

Arecanut prefers a tropical climate from sea level to 900 masl with ample supply of soil moisture and plentiful rainfall throughout the year. Arecanut can grow in areas with a minimum of 14oC and a maximum 36°C and an average rainfall of 1500 to 5000 mm. Arecanut is very sensitive to drought therefore irrigation is necessary in areas with less than 1250 mm rainfall per annum.

ii. Soil

Arecanut can grow on a variety of soils, but clay loam is preferred, while heavy clay soils should be avoided.

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c) Procedures of growing

i. Nursery

Arecanut is propagated entirely by seed. Seed nuts are collected from high yielding palms which bear fruit early. Fully ripe nuts of good quality are selected. Seeds should be sown 15 cm apart immediately after harvest in shady areas, their stalk ends pointing upwards. Soil moisture should be maintained. Germination commences in about 40 days after sowing. The seedlings are then transplanted to the second nursery when they are about three months old. A spacing of 30 cmx30 cm is maintained. Seedlings will be ready for transplanting to the main field when they are 12 to 18 months old.

ii. Field preparation

A triangular, square, rectangular, hexagonal system of layout is used. Dig pit of 60 cm x60 cm are normally used for planting arecanut with Spacing of 2.5 mx2.5 m between plants. Plants are usually planted in May to June and again in September to October depending upon the intensity of rainfall. Arecanut is intercropped with betel pepper, banana, cassava, black pepper, pineapple, turmeric and ginger.

Fertilizer recommendation of 100 g of Nitrogen, 40g of P_2O_5 and 140 g of K_2O with 12-15 kg of compost can be applied per palm per year. Apply all fertilizer within the circumference of the edge of the leaf canopy. Weeding is done as and when there is high weed pressure.

d) Harvesting and yield

Arecanut start bearing fruits when it is 7-9 years old and reaches optimum production at 10-15 years. Economical bearing will continue until approximately the 40th year. Nuts are harvested during March to April. A palm produces 2-6 bunches of nuts per year each with 50-400 nuts. Nuts may be harvested either green, or as mature fruits as per the market demand. Average yield in Bhutan is 7 pons per tree, (1 pon = 80 nuts).

e) Post-harvest handling and storage

Nuts are air dried at room temperature. Keep dried nuts in a cool, shaded area. Arecanut can be stored using storage pits. Pits are dug and the sides are lined with banana leaves or plastic to avoid soil contact. Nuts are then dumped in the

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pit, covered with plastic/banana leaves, and finally with soil. It can be stored for 6 to 7 months.

5.7 Passion Fruit (*Passiflora spp.*)

Dzongkha name:Jagachup

Purple passion fruit *Passiflora edulis* belongs to Passifloraceae family and is considered native to Southern Brazil. It is widely distributed around the world during the nineteenth century. The origin of the yellow passion-fruit *Passiflora flavicarpa* is unknown. It may have originated from Australia as a mutated form of *P.edulis,* or seeds may have been obtained from tropical America. It is eaten as fruit. The rich juice, which has been called a natural concentrate, can be sweetened and diluted with water or other juices (especially orange or pineapple) to make cold drinks. In South Africa, passion-fruit juice is blended with milk; in Australia the pulp is added to yogurt. Passion-fruit juice can be boiled down to a syrup which is used in making sauce, gelatine desserts, candy, ice cream, cake icing, cake filling, cold fruit soup, and in cocktails. In Bhutan passion fruit cultivation is increasing and the passion fruit juice is available in the market.

Figure 5.10 Passion fruit

a) Varieties

There is no identified variety in Bhutan; however it has been grown for many years in kitchen garden for home consumption.

b) Conditions for growing

i. Climate

Climate preference ranges from tropical climates in the lowlands for *P. flavicarpa* to the highlands with cool climates for *P. edulis*. The economic life of purple passion fruit at elevations of 800m is 3-4 years, while elevations of 1200 to 1500 m can produce reasonable crop for up to 8 years. Purple passion fruit both thrive and yield well at night temperatures of between 4.5°C -13°C and day time temperatures of 18-30°C. Mature vines withstand light frost but are injured at 1°C to 2°C below

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freezing. For yellow passion fruit temperatures below 15°C during the day and 10°C during the night reduces vegetative growth and potential yields, while high temperatures of 30°C during the day and 25°C at night can prevent flower production. Yellow passion fruit grows well at elevations of 600 m or higher. Well distributed rainfall is required, especially where there is no supplementary irrigation.

ii. Soil

Passion fruit can tolerate a wide range of soil types although the vines are highly susceptible to poor drainage and water logging. Soil pH can range from 6.5- 7.5.

c) Procedures of growing

i. Nursery

This fruit can be propagated easily by seeds, cuttings or air layering, or grafting upon a seedling rootstock. Where the yellow passion-fruit is favoured, plants are produced from seed both for commercial production and rootstock production. Yellow passion fruit makes a superior rootstock due to its resistance to nematodes, stem, root rots, and its vigorous growth habit. Purple passion fruit is in turn often grafted onto yellow stock due to its self-incompatibility. For the yellow passion fruit seeds are washed to remove pulp, dried in the shade and sown immediately, or stored at 10-13°C for future use. Seeds stored at room temperature for 3 months give better than 85% germination. Seeds germinate in about 2 weeks, although germination can extend over 2-3 months, due to seed coat dormancy. However, propagation through cutting is the easiest with good rootings.

ii. Transplanting

Seedlings at the 2-4 leaf stage are transplanted into individual plastic bags. They are then grown in the semi-shade for 1-2 months and gradually given more sun. After being hardened off in the full sunlight for 1-2 months and having obtained a height of 25-50 cm seedlings can then be transferred into the field. For grafted vines, the scion should have reached about 25cm and been hardened off for two months in full sunlight before being planted into the field.

iii. Trellis design

There are a number of trellis types. The three most commonly used are the Fence, 'A' frame Pergola, and the 'T' or 'cross' trellis. For the fence trellis one to several wires are strung parallel, one below the other on upright posts.

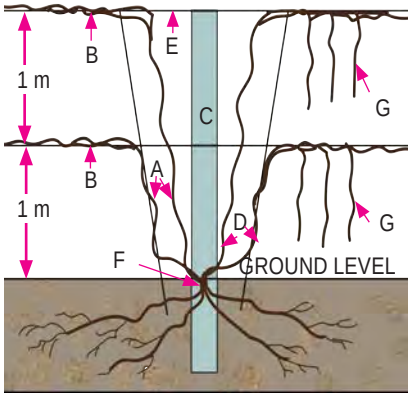

Figure 5.11 Trellis

iv. Spacing

In cooler subtropical climates using the purple passion-fruit or its hybrids, plants may be spaced 2.5-3 m apart. A row spacing of 5m apart may be used if there is vigorous growth. For the yellow passion fruit in warm areas, plants can initially be spaced at 2.5 m and after the first harvest year every other vine is thinned to provide a permanent spacing of 4.8 m (694 plants per ha).

v. Training

Plant holes are made 0.6-1.0 m away from the posts. One or two lateral shoots are trained to grow in one direction and the remaining shoots in the other. These shoots are tied to stakes and placed in the right position. All other trailing branches are removed.

vi. Pruning

Passion fruit flowers on a current season's shoot, and practices that encourage new lateral growth increases flowering. Pruning also allows sunlight and air movement into the vine, minimizes disease conditions. If vines are not pruned the plant becomes a tangled mess with only the new outside growth bearing fruit. Light, selective pruning, particularly at the end of a production cycle, enchases new growth and maintains high yields for the following year.

d) Harvesting and yield

Fruit is allowed to ripen on the vine and abscise. Fallen fruit is gathered once or twice a week, depending on the quantity. During rainy periods, fruit are gathered more frequently and, if sunburn is a problem, fruit may need to be gathered daily.

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e) Post-harvest handling and storage

Purple passion fruit store for up to 4-5 weeks with little loss of mass at 5°C and 80-90% humidity. The yellow passion fruit can only be stored for about 1 week at 5-7.5°C.

5.8 Grapes (*Vitis vinifera*)

Dzongkha name: Goen duem

Grapes belong to family Vitaceae and the species *Vitis vinifera* is the European species from which originated all the fruiting varieties grown in the world for fruit or wine. Grapes are highly digestible and have a number of therapeutic properties. They are laxative and diuretic. As well as being eaten fresh, grapes are used to prepare various desserts, jams, gelatines and wine.

Figure 5.12 Grapes

a) Varieties

Perlette: seedless, muskat taste and flavour. *Thompson seedless* is light green colour, oblong berries, sweet and juicy, and largely used for dried grape. *Muskat* is one of the most popular varieties of table grapes in the world due to its appearance and flavour, as well as its hardiness in withstanding handling and shipping. Italian grapes have large, consistent fruit with a lovely golden-yellow colour, and a delicate, pleasant musky flavour.

b) Conditions for growing

i. Climate

Grapes are grown under wide range of climatic conditions, ranging from warm temperate climates to sub-tropical climates. Well-distributed rains broken by frequent spells of dry periods are more suitable. Climate having short sharp winter and long dry summers are useful and helps in the continuous growth of vines throughout the year. During resting periods in winter vines can tolerate frost – 1°C at early bud burst and – 0.5°C at bloom and fruiting. Warm dry conditions improve pollination and fruit set. Grapes cannot tolerate high humidity. Water

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need is at its highest in the beginning of the vegetation process (budding); then it decreases at the beginning of blossoming and remains at its minimum during the blossoming stage and becomes highest during the berry development stage; it diminishes again with the beginning of the berry ripening.

ii. Soil

Grapes tolerate many soil types, provided it is deep and well drained. Generally light soils are preferred and those with lower fertility can make canopy management easier. High fertility induces excessive growth that leads to disease problems and additional summer pruning. Dig pit of size 45 cm x 45 cm x 4 cm and fill with well-rotted FYM or leaf mould, keeping spacing of 3m apart. Grapes cuttings are planted during dormant season (January-March).

c) Procedures of growing

i. Nursery

In Bhutan propagation is done by hard wood cuttings though grafting is practised in other countries. Grape is very easy to root. Cuttings are prepared during December-January. Cuttings of 20-30 cm long are prepared from one season old, mature canes that are taken after pruning i.e. during the dormant seasons. They are tied in bundles and stored in moist sand for about a month for callusing. Cuttings are planted in a slanting position in beds with the lower end just below a node. They root in about 3-4 months.

ii. Grape trellis construction

A trellis for vine support is designed and constructed to be strong and long-lived and to require low maintenance. It is a major long-term vineyard investment and should last 20 years or more.

Figure 5.13 A grape vine trellis

a. A single curtain cordon trellis usually consists of two tightly stretched wires, one above the other, about 1m and 1.8 m above the soil surface.
b. Line posts should not be more than 7 m apart in order to provide vertical support.

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c. Line posts should be 2.5 cm to 10cm in diameter and 2.4 m to 2.7 m long, with 0.6 m below ground and 1.8 m above ground.

d. End posts that support and position the wire tensioning must be larger (3 to 3.3 m with 0.9 m to 1.2 m below ground) and a minimum diameter of 10 to 15 cm.

v. Training and pruning

As the growth begins, only one shoot is allowed to grow which is lightly tied to a stake or grown up to a string to the first wire. Once the decision is made on how many trunks you are to use, the grower has to then decide on how the fruiting arms are to be positioned. There are many systems used such as cordon system, four cane-kniffen system, fan systems and the Guyot system. Guyot is the name of the French grape grower who improved the management of grape. This system is largely used throughout the world; especially in steep slopes.

d) Harvesting and yield

Birds and other predators can be a serious problem at harvest time. Netting is the best way to prevent fruit loss. Table grapes are harvested when they taste good. Sugar content varies from variety to variety. Many varieties are harvested when the sugar level is above 16%, while others require over 20% for top quality. The rooms for storage has to be relatively dry, not too dry, with very little external light entering, clean and as cool as possible about 5°C is considered the optimum.

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Student Activity

It is not necessary that the students have to practically grow the fruits in the school campuses. They can learn from what others who have fruits or orchard in their farm.

Depending on the location of the schools, practical work can be organised either to try grow the fruits, if possible or take the students to study how the fruits are grown, cared, monitored development, harvested and sold or consumed by the farmers who have horticulture business.

Activity 1 – growing of fruit trees in the school campuses.

1. List the fruit trees that can be grown in the campus.
2. Permit the students to choose a fruit or fruit tree from the list, ensuring that all fruits /fruit trees have more of less equal number of students.
3. Instruct them to plan and grow fruit trees – referring the topic of the chapter if the need arise.
4. Allot land areas which will be disturbed by other activities of the school, prepare the ground for plantation.
5. Procure sapling or seeds/cuttings and handover to the students with instructions to plant, care, and monitor and record the development of fruit trees. Brief the students about fruit trees, taking time to bear fruits in a season or two.
6. Invite other students and staff to the orchard or garden to witness the growing of fruit trees in the campus for 'Agriculture for Food Security' and self-employment to address unemployment in the society.
7. Assign students to record the care and observe the development of fruit trees, assess the group work as per the criteria provided in the guide.

Activity 2 – field trip to study the growing, caring, development, bearing fruits and economic returns from the fruit trees.

1. Plan and prepare for field trips to farmers growing fruit trees /horticulture business.
2. Assign students to frame questions and discuss what they intend to learn

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through the question that they would like to ask the farmers during their field trips. Questions may be targeted to make the farmers more critical about growing fruit trees for better business.

3. Organise field trip as per the guide,
4. Assign students to write report on the field trip, and
5. Assess their work as per the guide.

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6 Chapter

Starting a Dairy Farm I

Mixed farming is a common practice of farmers in Bhutan. Depending on the agro-ecological zones and topography of the region, crops and livestock play important roles for the rural farmers. Keeping dairy cattle is beneficial for the farmers since milk is produced for home consumption and surplus milk for sale or converting milk into milk products. Cattle are also kept in the farm to produce farmyard manures which improve the fertility of the field for growing crops. Emphasis had been placed on dairy development by the Ministry of Agriculture and Forests as it is recognized as one of the most important and feasible means to increase the income of the farmers and to improve their living standard.

This chapter provides basic concepts and procedures of raising animals in a dairy farm that has the capacity to support Bhutan's growing urban population with dairy products as well as generating employment for Bhutan's sustenance in this competitive world of 21st century.

6.1 Common cattle in Bhutan's dairy farm

Cattle population has increased over the years and accordingly the production of milk and milk products has also increased to certain extent. Improved management practices if followed by our farmers will lead to considerable increase in the milk and milk products in the country. Following are the breeds of cattle prevalent in our country.

a) Jersey

This is an exotic breed of cattle and introduced in our country for cross breeding purpose. This breed was developed in the Island of Jersey in the English Channel, off the coast of France. Jersey varies in colour from light red to black and from white spotted to solid in marking. The tuft of hairs at the end of the tail may be

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black to white. The muzzle is black with light encircling ring.

Figure 6.1 Jersey

Jersey is the smallest of the dairy breed. It is an economical milk producer. The cows have straight top line, levelled rumps and sharp withers. They have a double dish forehead. They have excellent udders. Adult cows weigh about 500 kg and males about 600 to 700 kg. The average gestation period of Jersey cows is 280 days and yield about 4000 litres of milk on average in a lactation. Under the good management system, a Jersey cow will produce about 22 litres of milk per day. The milk of a Jersey cow has the highest fat content of all the breeds.

b) Brown Swiss

This breed was developed in Switzerland, which is a rough and mountainous country. This breed is widely found in many parts of the world. Purebred Brown Swiss bulls were introduced from Indo-Swiss Project, Patiala, India for crossbreeding programme in Bhutan. The average gestation period for females is 290 days with average milk yield of 5250 litres in a lactation. Average milk production is 25 litres per day with a high fat content.

Figure 6.2 Brown Swiss

The colour of this breed varies from a light fawn to almost black. The nose, switch and horn tips are black. The animals are fairly large in size and are extremely strong.They have large heads which are usually convex. Calves are large and weigh more than 40 kg at birth. Adult males weigh about 700 to 800 kg and adult females weigh about 500 to 600 kg. The animals are quiet, docile and easily manageable and can tolerate more heat than Jersey.

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c) Holstein Friesian

Holsteins Friesian (HF) are originally from the Netherlands. This breed has big udder. Holstein Friesians are the highest milk producing dairy cows in the world. Holsteins Friesian are mostly black-and-white. Occasionally we may see a cow that will be all black with very little white on her, or be all white with very little to no black on her.

Figure 6.3 Holsteins Friesian

Pure Holsteins Friesians have the capability of producing as much as 30 litres of milk per day under good management. Holsteins are actually the largest dairy breed used in dairy operations. A mature cow can weigh around and over 680 kg and stands 58 inches tall at the shoulder. A healthy Holstein calf weighs 40 kg or more at birth.

Holstein gestation is approximately nine months. While some cows may live considerably longer, the average productive life of a Holstein is approximately four years. The genetic potential regarding the milk production is above 10,000 kg milk per lactation with 4.0 % fat and 3.4 % protein.

d) Siri or Thrabam

Animals of this breed are found in the hill tracts around Darjeeling (West Bengal, India) and in Sikkim and Bhutan. Bhutan is said to be the real home of this breed. It is distributed in various parts of Sikkim and Darjeeling. Siri has a medium body, small head, square cut, and wide and flat forehead presenting convexity. Siri cattle have sharp horns, relatively small ears, well placed hump covered with bunch of hair at the top. They have strong legs and feet, the dewlap (loose skin hanging under the neck of the cattle) is well developed, bulls have tight sheath (skin cover). The udders

Figure 6.4 Siri

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of the cows are well developed. The colour most frequently seen is black and white or extensive solid black, in colour patterns similar to that of Holstein-Friesians. Pure black or pure red is not uncommon. The animal carries a thick coat all the year round, and it is generally believed that this protects them from heavy rains and severe cold.

Bulls are eagerly sought after for draft purposes due to their size and reputed strength. They are used for agricultural work such as ploughing, cultivating, threshing, etc. Cows are poor milkers.

e) Yak

It is a grazing animal accustomed to travelling great distances in harsh environment. Most yaks are found in the mountains and plateaus of Tibet and western China.

Figure 6.5 Yak

The live weight is generally 250 to 550 kg for the males and 180 to 350 kg for the females. The yak hair is long especially on the flanks that often reaches the ground. It has a big tail with a brush of long hair coming from its roots. The horns are spread outward and upward and the head is held low.

Yaks are especially useful as riding and pack animals. Yak bulls (generally castrated) are also used for ploughing. Meat is also important in yak rearing areas. Yak milk is much richer than cow's milk. The fat percentage of yak milk ranges from 5.7% to 6.8%.

6.2 Care of lactating dairy cow

The performance, health, and welfare of the lactating cow are reflections of the quality of care received at every stage of its life. Performance depends on converting feed nutrients into milk. Over the last 20 years, milk production has increased due to improvements in genetics, nutrition, milking systems, facility design, health programmes, care, and management.

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a) Facility design

Proper facility design reduces stress and provides comfort, proper nutrition, and health of the lactating cow. Temperatures under 4°C may adversely affect lactating cows. The cow adapts to the stress of cold weather by increasing appetite and diverting energy from milk production to producing body heat. A heavier winter coat also helps the animal adapt. Rain and fog do not directly harm the cow. However, mud in corrals (enclosed area for holding animals) increases the risk of mastitis, and frozen, crusty mud may injure the teats and udder. Cows housed in mud may increase nutritional requirements for body maintenance of up to 20 to 50 percent.

Cow productivity can also be decreased by temperatures over 24°C and is worsened by high humidity. The heat-stressed cow eats less, and milk production is reduced. Signs of stress, such as panting or standing in water, are not obvious until prolonged exposure to extreme temperatures or humidity occurs. Heat stress is compounded when the temperature does not fall below 21°C at night.

b) Water

Animals need fresh, clean drinking water for normal growth and production. A dairy cow consumes about 22.5 litres of water per litre of milk produced daily. Cows are particularly sensitive to water problems because of the large volume they drink. Since milk contains about 87% water, water must be made available to the cow at all times so that whenever she feels like drinking she should have easy access to it.

c) Health Care

Cows are prone to many of the common and economically significant diseases. Common diseases include mastitis, reproductive tract infection, foot disease, and gastrointestinal problems. Prevention of disease requires a multi-disciplinary approach to management, including facility design and operation, nutrition, waste management, animal selection, and veterinary medicine.

d) Foot Care

Healthy feet are important to the productive cow. Lameness will interfere with movement to the milking facility, obtaining feed and water, exhibiting estrus, and general health. Foot rot, laminitis, hairy foot warts, etc. can cause severe

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discomfort for the dairy animal and be a source of economic loss to the dairy. The first sign of foot rot is lameness that may involve one or more feet. In acute cases, lameness is followed by swelling of the foot, spreading of the toes, and an abscess above the hoof. If not corrected, the infection will spread deeper and infect the joints, resulting in chronic arthritis (inflammation of joints).

Hoof (tip of toe of animal) should be trimmed at regular intervals to maintain proper foot conformation and prevent losses due to lameness. Management practices that help reduce hoof damage and avoid bruising will help reduce the incidence of foot disease. Proper drainage of all locations to minimize standing water also helps. Early detection and treatment will help minimize the incidence of foot disorders. Foot bath solutions such as 1% potassium permanganate solution may be used to decrease the incidence of some foot diseases.

e) Proper Milking Procedures

Proper milking procedures are important for the prevention of mastitis and for complete removal of all milk from the udder. The milking process begins with washing the udder and drying with a clean towel. Check for any abnormal milk by milking 2-3 squirts from each teat onto a disc with black surface suitable for detecting abnormal milk such as flakes in the milk. The washing of udder and drying stimulate milk let-down. Also, if mastitis is detected, treatment with a suitable antibiotic may be required. If a quarter is treated with an antibiotic for mastitis, the milk should not be used for human consumption (duration of 72 hours).

Handling of cows should be done in a gentle and quiet manner. Any disturbance causing cows to become frightened will interfere with milk let down. Oxytocin, a hormone released from the pituitary gland into the blood, is responsible for the milk let-down reflex in the mammary gland. When a cow is frightened, adrenalin is released which prevents the secretion of oxytocin and milk let-down.

f) Drying off Cows

Cows of exotic breeds and crossbred cows continue to give milk even at advanced stage of pregnancy if they are not forced to dry (stop milking). Drying a cow becomes very important aspect. A minimum of 60-70 days dry period must be practiced. When the cow is seven months pregnant it must be dried.

Why should a cow remain dry for a period before calving? Following are the reasons:

1. To rest the organs of milk secretion.
2. To permit the nutrients in the feed to be used in developing the foetus instead of producing milk.
3. To enable the cow to replenish in her body the stores of minerals which have become depleted through milk production.
4. To permit her to build up a reserve of body flesh before calving.
5. If dry period is not sufficient the growth of the calf is affected. A milking cow is thin because its nutrients have been extracted along with milk.

f) Length of dry period

Cows should always be in at least a medium state of flesh at the time of giving birth to their young ones. For this reason, thin cows should have longer dry periods than those carrying more flesh. For cows, which are well fed and are in good condition at the time of drying off, it is suggested that the dry period should be 40 - 80 days, the shorter period being for low producers. Thin cows should remain dry for longer periods.

6.3 Management of cow and calf 'during and after parturition' (birth of calf)

Success in dairying depends largely on the proper care and efficient management of the herd. All dairy operations must be planned with due regard to the comfort of the animals. Care of pregnant cows during and after calving, therefore, should receive the personal attention of the dairy farmer otherwise he/she is likely to make many costly mistakes. Few hints are given here for his guidance.

a) Caring for the Cow

Usually a dairy cow will carry her calf for a period of 280 days. However, they may range from 270 - 290 days after conception. Advanced pregnant cows must be taken care to prevent them from being injured by slipping on the floor or by crowding through doorways. Symptoms that an animal is about to calve include swelling of the udder, swelling of the vulva and dropping away ligaments around the tail head.

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Birth usually takes in one or two hours. At the first sign of calving, the front feet of the calf should appear first, then nose. After calving the exterior of the genitalia, the flanks and tail should be washed with an antiseptic solution. Keep the cow warm to prevent her from chill and it is desirable to give her warm water to drink just after parturition.

High producing cows will develop milk fever and mastitis. To avoid milk fever, it is best not to draw all the milk from the udder for a day or two after calving. To avoid mastitis, regular tests should be made by a veterinarian.

b) Care of Calf after Parturition

Soon after calving, the naval cord of the calf should be snipped off at about 2" away from the body with the help of a pair of sterilized scissors and painted with Tr. of Iodine and dusted with boric acid powder. Make sure the calf gets first milk within 24 hours after calving. The antibodies present in colostrum protect the calf against diseases and the colostrum has a laxative effect.

The rate of colostrum milk feeding should be about 10% of the calf's body weight per day, up to a maximum of 5 - 6 litres per day. If the calf suffers from diarrhoea, the milk allowance should be reduced to half or less until the calf recovers. Take the body weight of the calf if possible and identify the calf by giving identification marks. Colostrum provides to the calf with an immediate source of energy, a passive immunity to disease through antibodies and immunoglobulin and a reserve of vitamins and minerals.

The ability of the calf to absorb antibodies and immunoglobulin, which are proteins, into its system decreases after it is eight hours old (sometimes sooner) and has virtually ceased when it is 24 hours old. If the calf gets immunoglobulin from 0-24 hours, resistance to diseases develops. Therefore, it is vitally important to the future health of the calf that it suckles within a few hours of birth.

Colostrum Substitute

Whipped egg + 0.31 parts water + 0.61 parts whole milk + half teaspoonful of castor oil.

i. Calf scours

Calf scours is the most common symptom of illness in young calves and can

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be caused by several different viruses, bacteria and organisms. Most often it is a problem in the first month of life. Viruses like the rotavirus (most common) and bacteria like salmonella and Escherichia coli, or E. coli for short, as well as coccidia and other internal parasites can cause scours. Symptoms of scours are watery stools and dehydration similar to diarrhoea in humans.

ii. Prevention of Scours

The most important method of prevention is to provide adequate colostrum in the first few hours after birth. Only in the first few hours or so can a calf absorb the antibodies from the colostrum it drinks to give it immunity to many infections present in the herd.

A calf needs about two litres of colostrum milk. Remember that heifer cows that do not mix with the herd may not have enough antibodies in their milk to provide suitable protection to their calves. To overcome this, and problems with sick cows or cows dying at calving, a store of frozen colostrum should be kept if a freezer is available. Provide adequate housing or shelter from the weather to reduce stress. Stress is important in allowing scours to develop. Maintain a suitable management and feeding system. Overfeeding and sudden changes of diet can cause further stress.

iii. Treatment of Scours

The most important thing to do is to replace the lost body water and salts. This is done by using electrolytes in their correct concentration. The earlier this is done, the better the response. Antibiotics can be used if necessary. A treatment regime could to replace all the milk with electrolytes, use antibiotic if necessary and gradually replace electrolyte with milk over several days.

If calves are severely affected and do not drink, it will be necessary to give intravenous fluids. Force feeding usually results in pneumonia, because very sick calves cannot swallow properly. Make sure affected calves are warm and dry. Exposure to the weather when sick will make things worse.

6.4 Dairy Housing

An efficient management of cattle will be incomplete without a well-planned and adequate housing of cattle. The pictures taken from the internet provide ideas

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of how cattle housing can be constructed. Improper planning in the arrangement of animal housing may result in additional labour charges and thus curtail the profit of the owner. During construction of a house for dairy cattle, care should be taken to provide comfortable accommodation for individual cattle. The points, which should be considered for dairy housing are:

Figure 6.6 Dairy housing at Samrang megafarm

1. ***Topography and drainage:*** A dairy building should be at a higher elevation than the surrounding ground to offer a good slope for rainfall and drainage for the wastes of the dairy to avoid stagnation within.
2. ***Exposure to the sun and protection from wind:*** A dairy building should be located to a maximum exposure to the sun. Buildings should allow direct sunlight to reach the platforms, gutters and mangers in the cattle shed.
3. ***Accessibility***: Easy accessibility to the buildings is always desirable. Situation of a cattle shed by the side of the main road preferably at a distance of about 100 metres should be aimed at.
4. ***Water supply:*** Abundant supply of fresh, clean and soft water should be available at a cheap rate.
5. ***Labour:*** Honest, economic and regular supply of labour is available.
6. ***Marketing:*** Dairy buildings should only be in those areas from where the owner can sell his products profitably and regularly. He should be in a position to satisfy the needs of the farm within no time and at a reasonable price.
7. ***Electricity:*** Electricity is the most important sanitary method of lighting a dairy. Since a modern dairy always handles electric equipment, which is also economical, it is desirable to have an adequate supply of electricity.
8. ***Floor:*** The inside floor of the barn should be of some impervious material which can be easily kept clean and dry and is not slippery.
9. ***Walls:*** The inside of the walls should have a smooth hard finish of cement,which will not allow any accumulation of dust and moisture. Corners should be round.

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10. ***Roof:*** Roof of the barn may be of bamboo mats, singles, slates or even banana leaves.
11. ***Manger (feeding trough or bowl like structure):*** It can be made out of log which is commonly seen in the villages. It must be easy to clean whether it is made of wood or cement concrete.
12. ***Gutter:*** It should be wide enough to hold all dung without getting blocked and be easy to clean. Suitable dimensions are 2/ width with a cross-fall of 1// away from standing. The gutter should have a gradient of 1// for every 10/ length. This will permit a free flow of liquid excreta.
13. ***Manure management: It*** frequently becomes a problem as more and more animals are concentrated on a small acreage. The estimated amount of manure produced by dairy animals varies with the rate of feeding and type of ration. As an example, various estimates have shown that a 450 kg cow produces from 27 to 40 kg of wet manure daily (Table 4.1).

Manure contains excellent organic matter and is frequently added to gardens, flower beds, crops, and pastures. While it is limiting in nutrients as a fertilizer, it is excellent for soil aeration, increases soil organic matter and promotes growth of microorganisms that are beneficial to plants. In contrast, too much manure added to the soil could release nutrients such as nitrogen and phosphorus that may pollute the water supply. Also, manure may be harmful to some types of plants. Manure management becomes important as more animals are housed on the ranch. By starting early, the problem of flies and mud can be avoided. A manure pit must be dug for manure storage so that it can be composted in a storage area until needed.

6.5 Common Infectious Diseases of livestock

Dairy cattle are prone to many types of diseases such as infectious diseases, contagious diseases, ectoparasitic diseases, endoparasistic diseases, skin diseases, etc.

a) Anthrax

It is an acute septicaemic disease caused by bacteria called Bacillus anthracis. It can affect all types of animals. The route of infection is by ingestion, wound infection, inhalation and biting flies. Oozing of black coloured blood from the natural orifices (ears and nose) and elevated temperature are the symptoms of anthrax.

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Control

Anthrax can be controlled by Penicillin injection 40 – 48 lakh I.U. intra-muscularly and repeating at 6 hourly interval for 5-7 days. Annual vaccination with anthrax spore vaccine – 1 ml subcutaneous. Vaccination is to be done only in endemic areas. The carcass of dead animals should not be opened but buried deep.

b) Black Quarter (BQ)

It is an acute disease caused by bacteria. Animals of 6 months to 2 years of age are affected. The animals get infected by ingestion and through wound. Lameness and swelling of quarters (hind legs) occurs. Quarter becomes hot and crepitates (make crackling sound) on pressing are symptoms.

Control

Administer crystalline Penicillin 48 lakh I.U. intra-muscularly at 6 hourly intervals for five to six days. Vaccinate with Alum precipitate vaccine 5 ml sub-cutaneous and burying the carcass deep in the ground is a prophylactic measure to stop Black Quarter.

c) Foot and Mouth Disease

It is highly contagious and viral disease of cloven footed animals. There is rise in temperature by two to three degrees followed by inflammation of the oral cavity and there is formation of vesicle. The mucosa of the lips, gums, dental pad and the tongue get eroded. Vesicles also erupt in inter digital space causing severe pain and lameness. Often udder gets swollen and teat canal gets blocked. The lesions may also develop in udder and teats. Because of the lesions on the gum, tongue and the dental pad, the animal cannot eat feed and fodder.

Control

There is no treatment to control this disease. Bi-annual vaccination against bi-annually (vaccinate after every six months) can prevent it. Affected animal's foot and mouth should be washed with alum solution and 2% potassium permanganate solution. In severe cases, intra-muscular injection of Dicrysticine 2.5 g should be given for five days. To control the spread of disease, movement of livestock and livestock products from the infected areas should be restricted.

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d) Haemorrhagic Septicaemia (HS)

It is an acute bacterial disease occurring early in monsoon. The animal affected will have swollen neck, throat and brisket (chest) region and will have respiratory distress, salivation and protrusion of tongue. These are the symptoms of Haemorrhagic Septicaemia.

Control

The animal affected should be treated with Sulphamezathine 33.3% solution at 3 ml per 5 kg body weight intra-venous. The dose should be repeated after 24 hours. For prophylactic measure, vaccinate the animals with alum precipitate HS vaccine at 5 ml subcutaneous and it should be done before the onset of monsoon.

e) Mastitis

It is a bacterial disease affecting the udder. The udder becomes hard, swollen, hot and painful. The milk becomes water or bloody.

Control

Isolate the animal suffering from mastitis from the healthy herd. Treat the affected quarter with intra-mammary preparation for at least 3 consecutive days. Milking the affected cow after the healthy cow can stop spreading Mastitis.

f) Ecto-parasitic disease

Ticks are blood sucking ectoparasites and they transmit diseases like Babesiosis, Theilariosis, anaplasmasis, etc. Spray the animals with solution of 2 ml deltamethrin liquid diluted in 1 litre of water. Spraying can be done at 12 -15 days interval can control and eliminate the ticks.

To support farmers keeping their farm animals well and productive, trained staff are appointed in every 'gewog'. Avail their technical support to enhance your livestock welfare and productivity.

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Student Activity

Many boarding schools have livestock in their campus providing opportunities for the students to be with the animals, see how they behave, develop and learn to care for them. However, many schools also cannot afford to keep livestock in the campus for many reasons. Nevertheless, most farmers do keep animals in their farms and students do have opportunities to learn about livestock, especially the milking cows. Practical work therefore can be arranged accordingly.

Activity - studying milking cows and calf, feeding practice, caring, monitoring and recording the management of milking cow and calf.

1. Assign students with different aspects caring for the milking cow in the campus such as

   i. cow shed,

   ii. feeds and feeding,

   iii. veterinary care,

   iv. milking practices and milk yield,

   v. sale or consumption of the milk and milk products.

2. Review (i) to (v) against ideas learned from the chapter and plan and improve (i) to (v).

3. Study the management of cows and calf, record and report to the school management.

4. Assign students to write review report, improvement and impact report, assess and provide feedback as per the guide.

7 CHAPTER

Managing an Agriculture Farm

To recapitulate, you have learned the concept of 'Food and Nutrition Security' essential for individuals in different stages of life, and the food sovereignty of a nation – the reason for taking 'AgFSC in IX and X'. In the past, Bhutan's Agro-Ecological-Zones (AEZ) gave rise to different agriculture practices supporting the food security of people living in different AEZ, bringing unity amongst people. The same AEZ of Bhutan, has the capacity to address the unemployment problems of 21st century Bhutan, rearing livestock and growing sufficient food, vegetables, fruits, medicine required for urban Bhutanese population all the year round. The AgFSC is not only to regain food sovereignty of the our GNH nation, with more educated youth taking up entrepreneurship in Agriculture – growing of vegetables, fruits and medicinal herbs, rearing animals (cows, pigs, fish and poultry) and the art of landscape and lawn design, floriculture, to make Bhutanese economy more sustainable. The last chapter of AgFS IX provided ideas of how one may start a farm business. It is appropriate here to introduce the ideas of how one may go about managing a farm in Bhutan. Various ideas of growing crops, vegetables, fruits and medicinal, aromatic plants, agro-forestry and rearing animals in a farm need to manage well.

This chapter, therefore, attempts to provide some basic concepts of farm management, general elements/aspects of management, which are different from management of other business enterprise, management of different types of farming, mixed farming plans and activities with adequate resources and understanding farming as a business entity. The learners are expected to experience the Strategic Management procedures of goal setting, identifying farm activities, planning and budgeting farming activities, review plans, implementing and monitoring farming activities, care of crops, livestock and farm workers, post-harvest handling before the farm products are sold or consumed, maintain records and use records to review investment and maintenance of farming activities and production that can support farming to be sustainable and productive enterprise in Bhutan.

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7.1 Definition and Aspects of a Farm Management

Farm management is the science of optimizing the use of farm resources to the fullest so that the entire farming system that the household is engaged benefits all. The management of farm consists of making decisions of what to grow/rear livestock, where to grow/rear livestock, how much to grow/rear livestock, how to grow/rear livestock, when to grow/rear stock, what methods to use, how much resources to use, from where resources would come especially the labour to prepare the land, plant, care of crops such as irrigation, guarding against animals and pests, look for market, harvest, sell the produce, calculate expenditure and income, etc. However, the magnitude of management will differ based on the types of agriculture farm one adopts. It is utmost important for us to understand that a farm that you are going to manage is the business enterprise.

a) Types of farming

In general, Agriculture can be divided into three main types such as (a) an arable farming growing crops like rice, maize, wheat, fruits, vegetables, etc. (b) pastoral farming raising animals such as cows, yaks, goats, sheep and so on and (c) mixed farming, both arable and pastoral. Agriculture can be intensive using small areas of land with lots of expensive inputs or extensive agriculture using large areas of land with fewer inputs needed such as sheep and yak farming.

What type of farming do you think would do well in Bhutan? Arable farming, pastoral farming or a mixed farming? What about intensive or extensive agriculture? Debate to justify taking into account of the country's Agro-Ecological Zones and the prevailing farming systems.

b) Understanding a farm as a business enterprise

Farm is a business unit which consists of several crops or animal enterprises and other support items under the same management. Managing a business enterprise entails setting goals or the purposes of why an enterprise is being established for whom, what it intends to do, how and what technology to use, how much investment to make, who are to be involved, maintaining quality and so on. The management of growing crops and rearing animals like any Bhutanese farmer does will come from the topics and sub-topics that you have learned thus far. Managing a farm based on the definitions learned from the earlier paragraph with more scientifically setting objectives of the farm, planning and implementing farm

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activities of growing crops or rearing animals, caring for them, harvesting the produce at the right time with right technology, store, and transport for sale or consumption as an enterprise is what you will learn from this chapter. Therefore managing a farm entails:

c) Setting of targets or Objectives of Farm business

Every farmer has a purpose or reason for operating a farm. These are known as farming goals and objectives. Farming objectives vary from farm to farm depending on the farmers and the kind of enterprises undertaken. The objectives of the farmer may be one or a combination of the following such as:

i. to produce enough food for the family.
ii. to generate income or money for the family.
iii. to produce food and money for the family.
iv. to sustain social prestige as a producer to help others in need.
v. to engage the family members and others productively in socially useful work.
vi. for self-employment and employment of others for the sustenance of the society.
vii. to produce food or nutrition, clothes and medicine for the society.

The 'Food and Nutrition Security' is perhaps one of the most important attributes for the sovereignty of a nation. Growing crops, fruits, vegetable and rearing animals for healthy food, clothes and medicines not only provides employment for its citizens but also a sustain economy. The goals of our farming must be to produce enough food, fruits, vegetables and medicines all the year round for Bhutanese for a healthy and happy life in the GNH society, employing Bhutanese youth. It is not necessary for a patriot to join the military to protect the sovereignty of a nation. Take up Agriculture to safeguard the 'food security' of the society that can ensure 'food sovereignty' essential for the sustenance of a society. You and your family or a small group of interested literate youth could form a group and could start a farming business. The farming goals can be framed as above in the services of your country. Setting the goals or general objectives of your farm, what do you think that you could do next?

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7.2 Farm Planning

Farm planning is the next important aspect of farm management. It basically means deciding and arranging beforehand what you can do in your farm to achieve the set goals/targets or general objectives. Irrespective of the scale of farming enterprise that you intend to pursue, you need to:

a) Identifying the farming activities

Identify the farming activities that are likely to fulfil the goals /target set, taking into consideration of the your farming capacity. Farming capacity refers to farm land available that can accommodate the farming activities identified for:

1. Arable farming – growing of wheat, rice, maize, vegetables and fruits, medicinal and aromatic plants (MAP), etc.
2. Pastoral /livestock farming – rearing of cow, sheep, goats, horses, poultry, pigs, etc.
3. Mixed farming – growing of food crops, vegetable, fruits, MAP and rearing of animals in the farm.

b) Planning farming activities

Planning farming activities entails decisions on:

1. use of farm land for different farming activities as cited in (i).
2. selecting the crop enterprise with the greatest return per acre/langdo of land and animal breed for food and farm yard manure.
3. recruiting of farm workers for different farm enterprise – agriculture and livestock and prepare them for jobs.
4. use of technology /innovative ideas for different farming activities,
5. preparing the land for growing crops and infrastructure and facilities for animals.
6. buying /preparing farm yard manures /feed for livestock,
7. selecting the livestock enterprise,
8. checking the final plan with proper records at each level of decision.

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c) Budgeting the planned farming activities and review of farming plans

It is important to estimate the cost of what and how a farm enterprise is being planned. Accordingly allocate fund to implement the farming enterprise, keep record of expenditure, income generated and determine profit or loss of the enterprise. The process of budgeting should provide the planners to think and go for alternative strategies, if the plan is unrealistically over expensive or too less. It is also important to estimate the cost /expenditure of a farm business. Revisit the plans to reduce or to mobilise resources adequately. The cost may be of several kinds and could be classified as (a) fixed/overhead costs and (b) variable costs.

Fixed Costs Items or Overheads can be estimated from the:

- living expenses of the farmer and his/her family (food, medicines, school fees, etc.),
- interest for all invested capital including loans,
- depreciation of machinery (the reduction in the value of machines due to tear and wear),
- maintenance of farm buildings,
- wages and food for permanent labour,
- insurance and administrative costs, and
- taxes on land and other assets (but not income tax).

The farm business enterprise has to pay this cost irrespective of whether the business is doing well or not. Hence they are termed as fixed cost of the enterprise. On the other hand, the Variable Costs are established based on the production enterprises. Variable costs items may be the cost of:

- Seed and other planting materials,
- Fertilizers,
- Pesticides,
- Operating costs of machinery e.g. fuel, oil, etc.,
- Hiring of machinery /vehicle or animal services,
- Temporary/seasonal labour,
- Cost of livestock, feed and medicines, maintenance of infrastructure and
- Miscellaneous costs.

These variable costs are directly related to the different production activities and

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are proportional to cost increase as more of the variable inputs are used. Variable costs that are important for a farmer in determining what to produce and how much to produce and should be able to pay its variable cost in order to survive. If a farmer cannot cover the variable costs, then he should not produce at all. A farmer needs to cover all costs (to stay in business) in the long run. Therefore, a farmer needs to study the costs and receipts of the farm business for:

- the economic outcomes and effects of the farm. Decisions cannot be analysed and evaluated unless costs and receipts are considered.
- awareness, of how much it costs to operate the farm and how much benefit (income) the farm is producing or can produce.
- determining the profitability of a farm business.

Traditional farmers in Bhutan do not keep accounts of expenditure and as a result they are not able to fix the price of the farm produce. The farm produce are expensive and are often not able to sell much of the produce as many customers cannot afford to buy. Much farm produce are wasted while the customers go for imported farm produce that are cheaper. Proper accounts of cost and receipts need to be kept that can enable the farm management fix reasonable selling price of the farm produce compatible to the price of imported goods. Therefore, the farm manager needs to include the variable cost while calculating the cost of the farm produce proportionately.

It is also important for the farm management to understand different farm products considered as marketable and non-marketable products. Marketable Products are farm outputs which are normally sold at a market place. Some of these products may be used partially or fully as raw materials/supplies for another farm enterprise. Marketable products include:

- Yields of crops – seedlings, sapling for transplantation, vegetable, fruits, flowers, seeds, and by-products for sale.
- Yields of fodder crops produced for sale and for feeding livestock,
- Cereals used for animal feed and consumption of the farm workers,
- Cereal used for brewing local drinks and by-products for animal feed and
- Livestock products and by-products.
- Non-marketable Products (or self-produced supplies) include:
- Green manure and any grass weeded out of the garden adds to the 'farm yard manures' contributes to the fertility of the farm soil,

- Farm yard manure (FYM) from the livestock and organic waste of the farm,
- Straw, and other by-products of the farm produce, etc.

The marketing products of the different enterprises make up the farm receipt items, whereas, the non-marketable products constitute physical support services to be used by other production activities, which contributes to the overall productivity of the farm business. Planning to use the non-marketable farm produce of the farm economically could help budget adjustment. However, budgeting exercises need to revisit the plans of farming activities and plan farming activities more objectively.

d) Implementing the planned farming activities

You have set targets or objectives of farming, identified farming activities, farming plans have been revised based on budgeting exercises. What should you do next? Your farming activities have been planned and they are on paper only. The next step is to translate the farming plans from the paper to reality. The farming activities plans have to be implemented to give life to your farming activities. If your farming plans have been developed in group or with your family, it is important to implement them collectively. You may begin on an auspicious day and time to:

1. visit farm site with your farming plans (document) and decide the use of farm land for farming activities plan. Share reasons for allotting land areas for specific farming activities and involve other in making decisions. Collective decisions motivate co-workers to work hard more responsibly. Allot land use for:
    - growing of crops – rice, wheat, vegetables, fruit trees, etc. with fence for protection of crops.
    - development of infrastructure for livestock decided to rear in the farm, store and farm workers, etc. space for FYM and approach road /footpaths.
2. procure tools, equipment and machinery required for the farming activities.
3. recruit part time or fulltime farm workers and prepare them for farming activities on the farm.
4. prepare the land for growing crops with proper fences.
5. purchase seeds, saplings and fertilizer before FYM is ready. Refer to earlier topics or sub-topics to manage growing of crops starting with sowing

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seed, raising nursery, transplantation, and monitoring the care required for crop growing enterprise.

6. develop infrastructure and facilities for animals to be reared in the farm.
7. buy animal feed and medicines for the livestock enterprise and set daily routine for feeding and care. Refer to earlier topics /subtopics to manage livestock raising enterprise, care and monitoring their development in the farm.
8. appoint in-charges for different farming activities who have special aptitude of the activities and expertise to handle.

e) Monitoring and supporting the farming activities

It is an important aspect of management. It helps the management to understand the progress of the work as well as how the farm workers do their jobs. Observing the people at work, talking to them and their work motivate them to work harder and develop a sense of loyalty to the farm. The success of the farm will depend on the farm workers. Therefore, the management of the farm must regularly:

- ✓ visit farm workers in their work places to find out how different activities are being carried out,
- ✓ find out any problem or challenges encountered while carrying their work,
- ✓ motivate them with kind words and encouragement.
- ✓ participate in their activities just to get the feel of the work and be with the workers.
- ✓ talk about better tools, equipment, and technology that can make their work easier.
- ✓ find out if they know the job and if the management can do anything to support them.
- ✓ provide refreshment during which the farm workers and the management can have conversations and talk about big dream, etc.
- ✓ short meeting to share about farming issues or good news about productions, marketing or customers interested to buy farm produce, etc.

However, monitoring is not to be treated or taken as policing to make the worker work more. The management should not expect that the workers will work hard if you visit. On the contrary, workers may work in front of the management but not seriously work in your absence. It is important for the farm workers to feel that they are cared for and the management trust them with their farm work, since

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everybody in the farm work for the good of the farm and for themselves.

The management must also institute a monitoring system of the farm enterprises regularly as a measure for:

- ✓ detecting additional care required by the crops such as timely weeding, mulching, adding manure, watering and symptoms of diseases or pests.
- ✓ assess yield of the enterprises and timely harvest of the produce.
- ✓ determining the health of the livestock, care required, regulating feed, treatment and study the readiness of productions for marketing, etc.

f) Harvesting the produce and replenishing the farm

Harvesting the farm produce is the most delightful farming activity and can be labour-intensive in a small farm with minimum farm mechanisation. You are reaping the hard work that the farm workers and the management have invested in the farm. Therefore, post-harvest technology need to be used wisely. The shelf life of farm produce depends largely on the post-harvest technology and handling of harvested produce.

Harvesting here refers to the process of gathering a ripe crop from the field. Depending on the crops, harvesting is done at different time. For example,

- ► rice, wheat, maize, barley, bug wheat, pulses, etc. the crop would be when 85-90% seeds are matured on the panicle. The plants are cut with sickles, scythe or reaper or harvesting machines and grains are collected and stored before they are sold or consumed.
- ► some crops like vegetables such as lettuce or green 'sag' matured leaves are carefully plugged and collected from different plants by removing mature leaves without destroying the plants. The leafy vegetables continue to develop more leaves for sale throughout the season.
- ► vegetables like tomatoes, beans, cucumber, peas, etc. mature fruits are carefully plucked without destroying the plants. These plants fruit throughout the season provided adequate manure and water are provided to the plants from time to time.
- ► radish, carrot, pumpkins, garlic, etc. are uprooted and trimmed before sale or consumed.
- ► livestock are reared for milk, wool, power for ploughing field or pulling cart /transportation and above all for Farm Yard Manure.

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For some crops, the life cycles complete and therefore, replenishing the farm with growing of suitable crops, need to begin immediately on the areas where crops are harvested. Depending on the season, crops may have to be selected and farming activities begin once again. The purpose of growing crops may be for fodder as livestock need continuous feeding throughout the year.

For the sustenance of the farm, farming activities have to be continuous with proper planning for growing crops/rearing livestock, implementing the plans of growing/rearing livestock, continuous monitoring /caring the development of crops/livestock, harvesting the produce for sale or consumption. For a farm to be productive, different enterprise can be introduced based on what customers' needs. The farmers in different locations have different needs, such as:

- sapling for horticulture: apple, orange, persimmon, pear, plums, apricot, fodder trees and so on. The farm management may explore raising nursery for fruit trees, decorative plants and vegetables that could be sold to the farmers.
- seedling for vegetables such as chilli, eggplant/brinjal, tomato plants, and so on. Nursery for such crops can be a continuous earning for the farm if investment are planned and executed judiciously.

This cycle repeats all the year round and year after year and makes you a successful farmer until you decide not to continue the farming activities. There are other aspects of farm management that contribute to the success of a farm. What a farm produces need to be planned for harvesting, storing, processing such as packaging, transporting them, and selling them or consumed. Some of the aspects of management are provided as hereunder.

g) Planning for marketing the farm produce

The marketing survey conducted before the start of the farm business becomes the bases for marketing the farm produce. Depending on the consumers' tastes, choices, and demands, farm produce may be made available based on the capacity of the farm. It is important therefore to:

1. ***advertise the farm produce*** to the customers so that the customers are aware of what are available on the farm or would be available within a specific period of time. The customers here refer to not only the consumers but also the traders and middlemen, who buy and sell goods or farm produce as their business. The advertisement may be done on:

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i. boards in nearby farm with picture of farm produce available for sale.
ii. facebook/social media with notice and pictures.
iii. phone calls to hoteliers, traders, middlemen and vegetable sellers.
iv. newspaper, TV and Radio, etc.
v. announcement for auction at the auction yard involving Food Corporation of Bhutan (FCBL).

2. ***Make the farm produce available:***
   i. on demand from the farm,
   ii. at the farm gate,
   iii. in the markets.
3. ***Providing marketing services***

Markets may be local, regional, national and international. The local type market is the one which farmers and consumers are most familiar with. It is like the retail store/shop in the villages and towns to which consumers usually go to purchase their food items. The regional market is like the weekend markets where consumers, producers and other traders from different villages, Gewogs and Dzongkhags meet to sell and buy. A national market is one where buyers and sellers from all over the country meet for the purpose of selling and buying.

An international market exists when agricultural products that are produced in the country are sold to different countries outside Bhutan. Such markets are important for both the producers and the government, because to the producers they can receive high price for their produce and to the government for earning foreign exchange and revenue from the export tax.

Agricultural marketing is a process which starts with a decision to produce a saleable farm product and involves all aspects of market structure or system, both functional and institutional, based on technical and economic consideration. Agriculture marketing also involves the buying and selling of agricultural inputs such as fertilizers, seeds, chemicals, farm machineries, tools and equipment. However, be it an input or an output market, the principles of agricultural marketing are more or less the same for both markets. The Department of Agriculture Marketing and Cooperatives (DAMC), Ministry of Agriculture and Forests is mandated to look after the Agricultural Marketing activities in Bhutan.

With the help of DAMC, marketing services that your farm can obtain:

1. ***collection of small surpluses*** of different products from individual farmers. This is necessary because of the scattered nature of small but large number of farmers in remote places.
2. ***support for processing the farm produce***, changing of a produce from the form it is harvested to the form suited to consumers' needs and tastes can be regarded as processing. Some of these processing processes include canning, parboiling, steaming, smoking, drying, milling and grinding, etc.
3. ***distribution of produce***, making the products available to the consumers. Distribution may involve several activities depending on the type of product, type of consumer groups and the distance from the storage point to the market. These activities include the provision of special transport facilities, packaging, finding buyers, etc.
4. ***marketing service***s involve (i) physical handling services used in changing the form of a product and moving it to from one place to another and (ii) transfer of ownership i.e. selling from farmers to retailers or from farmers to wholesalers or from farmers to wholesalers to retailers, etc. , such as:
   - ✓ Transportation- to facilitate the movement of produce from one point to the other
   - ✓ Storage – to preserve the quality of product and also to make produce available at a later time period.
   - ✓ Sorting, Grading and Standardization – to ensure quality product in a manner desirable to the consumers and better price to the seller.
   - ✓ Packaging and presentation to the Consumers – to ensure easy handling and product quality maintenance.
   - ✓ Financing – to ensure that cash is available to pay for any marketing costs involved
   - ✓ Bringing Buyers and Sellers Together – to ensure a common and smooth transfer of product ownership
   - ✓ Risk Bearing – to get sellers to accept the consequences of marketing (i.e. profit or loss), thereby enabling them to take measures that would minimize losses.

h) Pricing of the farm produce

The cost of production calculation is used as a basis for pricing the farm product especially at the farm gate level. But for farm produces that are sold beyond the farm gate or in the market; the prices are generally determined by the forces of

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supply (producers) and demand (consumers). The farming business must supply agriculture produce in different seasons and accordingly price the farm produce considering:

- Cost of production,
- Transportation and storage charges,
- Post-harvest technology used in packaging and value addition to the produce and not take advantage of being made available in the market for the first time which disappoint the costumers. It is important that the farm produce are supplied fulfilling the demands of the consumers such as
  - ✓ consumers' taste and preferences of the produce,
  - ✓ quality and quantity,
  - ✓ affordability of the consumers and accordingly price the produce.

The price of any farm produce must be charged reasonably, considering the sustenance of the farm and the benefit of the people involved in the business of the farm. It is important for farm manager to understand and take into account the benefit of various agencies through which the farm produce has to journey from the farm producers to the final consumer.

i) Marketing Agencies

Marketing agencies may be independent individuals, partnerships, large firms, cooperatives or governmental corporations, who carry out marketing functions or provide marketing services. They are

- ► Local buyers who usually undertake the first marketing task of assembling produce from farmers or local village markets and are most close to the producers.
- ► Wholesalers, marketing intermediaries (agencies) who buy and sell produce in larger amounts than the local buyers. They buy produce from farmers or country buyers and sell to retailers, to other wholesalers within or outside the country.
- ► Commission Agents or Traders, specialize in buying and selling for potential sellers and buyers who do not make direct negotiation and bargaining with each other.
- ► Auctioneers, who offer specialized services in the negotiation of purchases and sales. Auctioneers bring buyers and sellers together at a particular time

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and place, negotiate sales quickly but in such a way that all parties present are informed of the bids and disposes of all the produce offered.

- Retailers, the closest contact with the final consumers because they sell directly to them. They get their supplies usually from the wholesalers.

7.3 Farmers Groups and Cooperatives

Countries like Nepal, India, Thailand and Japan have Farmers Groups and Cooperatives formed to support each other in the business. Small scale producers collectively produce large quantity and reduce the cost of marketing. It is because the cooperatives usually

- ✓ are not taxed on the income from the cooperative business activity.
- ✓ participate in a variety of government-sponsored or donor grant programs.
- ✓ can more easily obtain discounts on supplies and other materials and services.
- ✓ have advantage in the domestic and international markets for better negotiations and bargaining, thereby maximizing the net-surplus to its members.
- ✓ works on democratic principles and structure that makes sure its members' needs are served well. Farms registered in Groups or Cooperatives have legal assurance to its democratic organization.

To support and promote the development of farmers' groups and cooperatives in Bhutan, the Royal Government of Bhutan (RGoB) passed the Cooperative Act 2001, which was amended in 2009. One of the objectives of the Act is to facilitate the development of cooperatives as strong and sustainable pillar of the private sector that will contribute to the economic development of the Bhutanese society, especially by involving the poor. Your farm could join the farmers' groups and cooperatives to be successful.

The Department of Agricultural Marketing and Cooperatives under the Ministry of Agriculture and Forests is mandated to register and provide all kinds of technical as well as facilitating roles to the Farmers Groups and Cooperatives in the country. The department provides support in the following areas:

- » Registration of farmer groups and Cooperatives;
- » Facilitation of institutional linkages and communication;
- » Strengthen their Management skills and expertise through capacity building programs;

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- » Promote and organize FG/Cooperatives for collective agricultural marketing;
- » Promote agro tourism for groups of farmers for home stay;
- » Support negotiation on contract farming and contract marketing;
- » Facilitate Cooperative funding;
- » Advocate on their behalf for either marketing or funding etc.

As of May 2016 there are 46 Cooperatives and 323 Farmers Groups registered with the Department of Agricultural Marketing and Cooperatives (DAMC) in Bhutan. Number of cooperatives and farmers groups is bound to increase in near future as they are being benefitted and more educated young entrepreneurs take farming. Bhutan is surely on the right path towards gaining food sovereignty required for sovereign nation – a nation of Gross National Happiness.

a) Farm Business Records and Accounts

Another important aspect of farm management is to maintain farm business records and accounts. Records are essential for the farmers to know what his farm is worth at any point in time necessary for managerial decisions. It helps in planning and budgeting for farming operations.

1. Maintain farm records on how particular enterprises have performed to date, any weaknesses in the organisation of the business and actions taken to improve upon.
2. Records of whether the business's plans are implemented correctly or not, records showing the physical input and output relationships of a crop grown in a particular plot on the farm or to know the expected rate of gain from productive livestock.
3. Maintain records of the business operations and ascertain financial position, monitor profits and losses and adjust expenditures accordingly.

Basic Information record required of a farm:

- ► Farm location, size, soil types, land use and possibly past soil treatments
- ► Amount of family and non-family labour (hired/exchanged), type, sex, age and kinds of work done, number of hours spent by each category of labour, cost of hired labour, etc.
- ► Input records on seeds/seedlings, cuttings, feed/fodder, fertilisers (organic and inorganic), type, source, cost and quantities, date, field, etc.

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- Information on yield per area (crop(s) yields), types and form of yield (dried, wet, husked un-husked etc.), livestock outputs (poultry/dairy/fodder, etc.), processed or not processed etc.
- Information on work done on other farms, type of activities, duration, and wages received, etc.
- Price, Sales and Marketing Costs of Farm Products: type of products, amount, place, and revenue received. Farm gate prices of every farm produce and retail price in the local markets.

Farm must also have records of :

- Inventory – list of assets owned by the farm, farm tools and equipment inventory, crop inventory, livestock inventory, etc.
- products sold, unit price, and total value of different products.
- consumption – the product name, price per unit, total weight and value.
- the crop and livestock purchase, seller, quantity purchased, unit price and total value with dates,
- farm labour including both family and hired labour, number, type and wage rates etc.
- financial transaction on balance sheet summarizing the asset values, the liabilities, and the net worth position of the business; the income statement summarizing cash receipts, expenses, and inventory schedules; and the cash flow statement provides an overview of the business's cash flow including debt payments, family living expenses and income taxes.

There are several types of farm budgeting techniques being used in preparing farm plans and budgets. Five types of farm budgeting techniques are briefly discussed here; a) Gross Margin Analysis, b) Complete or Total Farm Budgets, c) Enterprise Budget, d) Partial Budget, and e) Cash-flow Budget. However, for a beginning farm management, cash-flow budget would serve the purpose and progressively go for other budgeting techniques.

b) A cash flow budget

A cash flow budget is a forecast of money you expect will come into the business and go out. With a properly prepared cash flow budget, you know if you understand your capacity. It does, in fact, show the financial effect of your business plan. A cash flow budget is usually prepared on a monthly basis. It starts with how much money one has with him/her or how much is in the bank. It then shows forecasted receipts and payments to arrive at the expected bank balance at the end of the

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month. Any transaction, which causes the bank balance to alter, must form part of the cash flow forecast. Later, the budget highlights the monthly differences in the cash flow of the business. This enables the business to compare what was expected and what actually happened. Such information allows the business to make necessary changes in order to derive at a positive cash flow budget.

Steps in Preparing Cash-flow Budget

Step 1. Forecasting payments and forecasting receipts are both part of preparing a cash flow budget. Table 7.1 presents a simple template (format) for preparing cash flow budget. Advertising, Depreciation, General expenses, Insurance, Interest, Postage, Printing, stationery, Rent, Repairs/maintenance, Taxation, Telephone, Vehicle running costs, Wages/drawings, etc. are some of the kinds of payments one should consider when forecasting payments.

Step 2. The Receipt Forecasts must be based on the business plan. Usually when a business is set up, its cash flow is a bit slow initially because time is spent getting established. Very few businesses have a constant cash flow throughout the year. The receipts will include cash from sales, cash from the people who will pay, sales of assets, loan money received, any money put into the business by the owners.

Step 3. The Forecasting of Payments (expenses) should also be based on the business plan. The cash flow budget should be broken down into monthly blocks starting at the beginning of the financial year. When deciding on the timing of payments, one also needs to remember to take into account seasonal influences and the timing of payments as outlined in table 7.1.

Table 7.1 An example of a template for monthly Cash Flow Budget

Details	Months												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
Receipts (Cash inflow)													
Cash sales													
Cash from credit sales													
Loans received													
Asset sales													
Cash from owners													
Refunds													

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Miscellaneous													
Total receipts (Cash inflow)													

c) Other farm budgeting techniques

i. Gross Margin Analysis:

The gross margin (GM) of a farm activity is the difference between the gross income earned and the variable costs incurred. It is probably the most commonly used measure in farm analysis and planning. For farm on which several different activities are carried out, the total gross margin is the sum of the gross margin from each activity. In any one year, total gross margins should not be less than total overheads if the farmer is to avoid extra borrowing, or the sale of some of his assets and/or use of his cash savings. Box 7.1 presents an example of a gross margin for one ha maize.

Table 7.2 A hypothetical example of an activity gross margin for one ha of maize

Details	Months												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
A) Cash outflow (Payments)													
Accounting													
Advertising													
General expenses													
Hire purchase													
Insurance													
Interest & bank charges													
Loan repayments													
Postage Print/ Stationary													
Purchases													
Rent													
Repairs/Maintenance													
Telephone													

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Vehicle													
Wages/Drawings													
B) Total Cash Outflow (Payments)													
Cash Balance (A-B)													

Income		
A) Total Sales Nu. 28000		
Variable Costs		
Seed		Nu.1000
Fertilizer		Nu.2500
Labour		Nu.4500
Repairs and maintenance of machinery		Nu. 1500
Fuel and oil		Nu. 1500
Sprays		Nu. 1100
Insurance		Nu. 700
Transport to market		Nu.2100
Selling Costs		Nu 170
B) Total Variable Costs	=	Nu 15070
Total Gross margin per hectare	= A – B or (Total Sales – Total Variable Cost)	
	= 28000 – 15070 = 12930	

Revenue	
Production (Output)	2.5 tonnes/ha
Price	Nu.1200/tonne
Gross income if all sold is 2.5 x 1200	
Disposal of crop	
Sold for cash	Nu.1200
Eaten by household	Nu.800
Extra grain stored	Nu.400
Future payment from pool	Nu.600
Total	Nu.3000

Simplified calculation of gross margin per ha of cash crop

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ii. The Total Farm Budget

The total or complete farm budget includes all the expenses and revenue of the whole farm business. It is used in a decision-making situation where the alternatives affect the use of all or most of the farm's resources. Decisions like changing the combination of farm enterprises or increasing the farm size or introducing a new practice such as irrigation, using improved seeds, etc. The main purpose of budgeting is to compare the profitability of different plans for the farm business. To see how total farm budgeting is used to develop, compare, and select farm plan, it is useful to consider the planning process.

The planning process involves answering the following questions;

- What do you want to accomplish? (Goals).
- What do you need to work with? (Resources)
- What has been done? (Analysis of past performance)
- What might be done? (Alternative plans)
- What will be done? (Decision)
- How will it be done? (Implementation)
- Is it working? (Monitoring)

Preparing the Total Farm Budget facilitates the selection of a feasible and profitable plan that is consistent with the manager's goals, abilities and available resources. The whole or complete farm budget can be developed in detail to include all the input requirements for every enterprise. Much of the information needed to prepare a whole budget is gathered during the preparation of the farm plan. At this preparation stage, the farm inventory is taken, feasible enterprises are identified, enterprise gross margins are estimated, and the farm plan developed. table 7.3 provides an example of a whole farm budget.

Table 7.3 Example of a whole or complete farm budget

Variables	Nu
Income	
Maize. Soybeans Pigs	54,000 48,000 6,000
Total Income	108,000

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Variable Cost	
Seed	9,000
Seed dressing	300
Chemicals	5,000.
Fertilizers	9,750
Labour	3,425
Machinery, fuel and oil	7,500
Marketing	5,200
Drying	3,400
Miscellaneous	1,200
Animal Feed	1,000
Feed supplement	200
Veterinary medicine	100
Repairs, fences, buildings, equipment	100
Total Variable Cost	47,125
Fixed Cost	
Depreciation	2,250
Interest	1,500
Land Charges	1,800
Total Fixed Costs	5,550
Total Costs	52,665
Net Farm Income	55,335

iii. The Enterprise Budget

It is defined as a single commodity, good or single service that is produced by a business concern. Most businesses consist of combination of several enterprises. For example, a farm may produce paddy, potatoes, vegetables, eggs, milk, mushrooms, and so forth. Each of these items constitutes an enterprise. An enterprise is an economic activity that generates income and involves expenses. An enterprise budget is an estimate of all expenses and income associated with a specific economic activity (enterprise). Each enterprise is developed on the basis of a small common unit, 1 hectare/acre for crops, 1 head for livestock, and 1 cubic metre for wood. This makes it easy to compare profits for alternative and competing enterprises. Enterprise budgets are generally organised into three sections: gross income of receipts, variable costs, and fixed costs.

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Steps in Developing an Enterprise Budget

Step 1. Estimate production and expected output price: The first step in developing an enterprise budget is to estimate the total production and the expected output price. The estimate output per unit should be average output, with adjustment for the farm's own actual use of resources.

Step 2. Estimate variable and fixed costs: The variable costs relate to those inputs that vary with the amount of production. Fixed costs are associated with the depreciation of machinery, depreciation of service animals like bulls and male pigs, interest, and land charges. The variable cost items can be further broken down into types of labour, fertilisers, chemicals, etc.

Step 3. Estimate profit: Profit per acre or per animal is gross income minus total cost. The estimated profit per hectare can be compared to the estimates for other crops. They are then used to select the most profitable crops and crop combinations to be grown each year. The enterprise budget does not contain a change for management. Therefore, another interpretation of the estimated profit is to consider it as a return to management or payment to the management input.

The Enterprise budget can be used for carrying out break-even analysis on the farm either for *Yield* or *Price* break-even analysis.

Table 7.4 An example of an enterprise budget for paddy production (1 langdo).

I) Total Output Sale of paddy grain: Sale of straw: A) Total Revenue (TR)	 - 450 drey X Nu. 20 - 150 bundles X Nu.5 	 = Nu. 9000/- = Nu. 750/- = Nu.9750/-
II a) Variable Costs Seed Fertilizer Labour Chemical Others A) Total Variable Costs (TVC) Gross Margin (A – B)	 - 5 drey X Nu. 40 - 25 kg urea X Nu.4/- - 45 person days X Nu.100/ 	 = Nu. 200/- = Nu. 100/- = Nu. 4500/- = Nu. 100/- = Nu. 150/ = Nu. 5050/- = Nu. 4700/-

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b) Fix Costs		
Taxes on land and farm, etc.		Nu.20/-
Depreciation of farm/ equipment		Nu.200/-
Interests		Nu.450/-
B) Total Fix Costs (TFC)		Nu.670/-
Total Cost (TC) = (TVC + TFC)		Nu.5720/-
III) Net Profit (TR – TC) = 9750 –5720		Nu. 4030/-

iv. Break-even Analysis

Enterprise budgets can be used to perform a break-even analysis for either yields or prices.

i. Break-even Yield

The formula for calculating the break-even yield is:

$$\text{Break - even yield} = \frac{\text{Total Cost}}{\text{Output Price}}$$

The break-even yield is the yield that is necessary to just cover all costs at a given output price. For example, in Table 7.4, the break-even yield is

$$\text{Break - even yield of maize} = \frac{5720}{20} = 286 \text{ kg per langdo}$$

Since the output price is only an estimate, the break-even yield can be calculated for a range of possible prices (Table 7.5).

Table 7.5 Possible yield for different prices

Sl. No	Price per kg of paddy (Nu)	Break-even yield (kg of paddy/langdo)
1	10	572
2	15	381
3	20	286
4	25	228
5	30	190

ii. Beak-even Price

This is the price necessary to cover all costs at a given yield level. It is calculated as follows:

$$\text{Break - even Price} = \frac{\text{Total Cost}}{\text{Expected yield}}$$

Continuing with Table 7.4, the break-even price is:

$$\text{Break - even Price of maize} = \frac{5720}{450} = \text{Nu } 12.7 \text{ per kg}$$

The break-even price is calculated for a range of possible yields as shown below.

Table 7.6 Possible break-even prices for different paddy yields

Sl.No.	Yield (kg of paddy per langdo)	Break-even Price (Nu. per kg)
1	300	19.1
2	400	14.3
3	450	12.7
4	500	11.4
5	600	9.5

Since both yield and output price in the enterprise budget are estimated, rather than actual, the estimation of break-even yields and prices is of great value to managerial decision making. It is also quite valuable to the extension agent in discussing with the farmer the various production options that are available.

iii. cost of production

The cost of production is a term that is commonly used to describe the average cost of producing one unit of output. It is equivalent to the concept of average cost in production. The estimated cost of production is found by dividing the total cost per production unit by the estimated yield. From the maize example, production cost for maize is calculated as follows:

$$\text{Cost of Production} = \frac{\text{Total Cost}}{\text{Yield}}$$

$$\text{Cost of Production of maize} = \frac{5720}{450} = \text{Nu } 12.7 \text{ per kg}$$

Notice that the cost of production is the same as the break-even price. It will change not only with the changes in estimated costs but also with changes in yield. The cost of production is a widely used concept. Whenever the current price is above the cost of production, a profit can be made. The cost of production is commonly used by Government to help set price guidelines for government programs, for marketing of products and also to provide support to the farmers.

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d) Features of successful farm management

Most common features of successful farm management are often derived by asking critical questions clarifying the purposes of farming such as:

1. Are my planning objectives clear and realistic? Why do I want to produce or increase farm production? Is it to increase income? Or is it to make ends meet? Or is it to go commercial?
2. Am I convinced that I want to improve productivity? Improving productivity can be achieved when I determine my unit costs and then find a way to decrease them. This result in decreasing the cost of production without compromising the quantity produced.
3. Have I considered the farm business's long-term survival as a top priority? Calculate the margin of safety (i.e. the money left over after paying for all the inputs and interest on loan if any) for the entire farm production. Assessing risks accurately and maintaining leeway, in case revenue is lower than expected, are two ways to ensure the business's success.
4. Have I ensured mechanism to meet consumer satisfaction? Are consumers happy with the quality of your agricultural produce? Are they happy with the pricing? Am I keeping up to the market trends? These should always be the at the back of the farm manager's mind.
5. Is there a backup plan? To have a back-up plan already thought and planned is another way to manage risks. Predict potential problems that could arise during a project, and find different alternative solutions that can address or counter the problems.
6. Am I decisive? At times of difficulties (natural calamities, disease outbreak, drastic market changes, etc.) the farm manager should have the ability to take quick and rational decisions.

Management involves decision making based on empirical research /survey data, especially to find out what the consumers wants the produce as per their tastes/ preferences. Accordingly a farmer is required to produce agriculture goods and charge cost of inputs and change in crop enterprise. Farm managers require knowledge and expertise or hire professionals who have expertise in:

- ✓ Technical – possessing knowledge on all crop production methods and techniques.
- ✓ Commercial – having adequate information on markets for farm inputs and markets for farm.

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- ✓ Financial – anticipating where spending is required and how to obtain the finance.
- ✓ Accounting – keeping record/date on all farm inputs, outputs and transaction of any kind, if the farming is to be progressive.

e) *Effciency in Agricultural Production*

Agricultural productivity is measured as a ratio of agricultural outputs to agricultural inputs. Output is usually measured as the market value of final output and input is usually measured as the market value of the purchased items. Efficiency in agricultural production is necessary to measure the efficiency of any enterprise or of the entire business to identify its strengths and weaknesses. Agricultural production efficiency can be achieved through Technical efficiency and Economic efficiency.

i. Technical efficiency

It refers to the use of knowhow in making the business productive using less inputs/ resources to produce the outputs. It is based on the comparative measurement of physical output per unit of input. For example, there are two farmers using the same amount of seed, fertilizer and labour to produce rice; they have the same type of soil and growing conditions during the season. Yet one farmer produces 2.5 MT per hectare of rice, while the other produces 3.5 MT per hectare. Clearly, the latter farmer is technically more efficient than the former.

ii. Economic Efficiency

It refers to minimize or lower costs, which might or might not require fewer inputs, while attaining a production goal. Economic efficiency is a profitability comparison and it is measured by weighing the cost of production against the returns obtained.

iii. Overall Efficiency

It is assessed by looking at the farming operation as one unit. This means that profits for each of the enterprises on the farm are summed up. When this profit is compared to the total amount of capital used (i.e. total business investment), then the returns to capital are obtained. The percentage of this return capital is a measure of the overall efficiency of the business. Thus;

Sometimes, the producer may like to use the returns to his own labour and family

as his measure of economic efficiency or overall efficiency. Thus,

Tips for Increasing Efficiency

The measurement and assessment of efficiency should encourage the farmer or the owner of a farm business to improve all the time, improving their efficiency. The "progressive farmer" refers to those farmers who always try to produce more than the previous season and improve on their general welfare through progressive improvements in their farm business operations. There are several ways in which an agricultural farm business can increase the efficiency of its operations by:

1. ***Improving Farming*** with more technically efficient ways of cultivating the soil, observation of correct plant spacing, careful control of weeds, pests and diseases, and so forth. Livestock improving involves things like careful feeding, animal disease control and for the forest products business, it involves things like better tree harvesting methods, better lumbering, etc.
2. ***Improving Business Management***, involving careful business planning and utilization of resources, especially land, capital and labour, continuously exploring ways of substituting resources to increase both output and profits, knowing more about marketing and how market helps a good agriculture or farm business regardless of the size of operation.
3. ***Intensification of Production*** in a number of ways such as: (a) more yield per animal and per unit of land will result from the raising of livestock in an intensive system such as a battery house for hens, or a feeding stall for cows; (b) supplementary feeding to a dairy cow will increase the yield of milk; (c) application of fertilizer will increase the yield per hectare of a crop.
4. ***Mechanization*** which increases the rate at which a job can be completed, and reduces the amount of labour involved. It facilitates the production of more uniform products, improving the producer's control of the acceptability of the product by the consumer.

For a progressive farmer, learning never ends and this in turn help farmers to be successful in their farming business, especially in this ever changing environment due to global warming. Be the Champion of Change is to be in the service of our GNH nation.

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Student Activity

1. Plan and prepare for a field trip to an organised farm, preferably a government farm where there is a farm manager with technical experts and regular farm workers. The aim of the field trip is to learn how a government farm functions fulfilling the objectives of a farm.

   - Frame questions with the students to learn how different aspects of farm management theory of the chapter are applied in the government farm.
   - Follow the field trip planning procedures and asking questions to the experts of the government farm, provided in the guide.
   - Assign field report to write in groups and assess their work.

Or

2. plan a field trip to a local farm practicing mixed farming. The objective of the field trip is to educate the farmer or farm worker on the farm management ideas learned from the chapter.

   - Frame questions to find out if the farm management ideas are being practiced. If not, how they manage their farms. Ask questions on different aspects of management such as setting targets for the farm, planning, etc. and working accordingly would help in them doing better farming. Choose management aspects like planning marketing, advertising for sale, price the produce for sale, etc. giving ideas of objectively managing the farm which would be of help to them. Give examples at the level of their understanding of managing a farm and find out if they are interested to learn better ways of managing a farm.
   - Follow the field trip planning procedures and asking questions to the experts of the government farm, provided in the guide.
   - Assign field report to write in groups and assess their work.

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ABREVIATION

ac	Acre
AEZ	Agro-ecological Zone
asl	Above sea level
BAFRA	Bhutan Agriculture and Food Regulatory Authority
Ca	Calcium
CAN	Calcium Ammonium Nitrate
cm	Centimetre
CNR	College of Natural Resources
CoRRB	Council for RNR Research of Bhutan
DAMC	Department of Agriculture Marketing and Cooperatives
DoA	Department of Agriculture
DOC	Day Old Chick
DoFPS	Department of Forest and Park Services
DoL	Department of Livestock
FYM	Farmyard Manure
GDP	Gross Domestic Product
GNH	Gross National Happiness
Ha	Hectare
HH	Household
IU	International Unit
K	Potassium
K_2O	Potash
mm	Millimetre
MoP	Muraite of Potash
N	Nitrogen
NPDC	National Poultry Development Centre
NSB	National Statistical Bureau
NWFP	Non Wood Forest Product
oC	Degree Centigrade
OXFAM	Oxford Famine Relief Organization
P	Phosphorus
P_2O_5	Phosphate
P-P	Plant to plant
RH	Relative humidity
RNR	Renewable Natural Resources
RNRRDC	Renewable Natural Resources Research and Development Centre
RPBC	Regional Poultry Breeding Centre
R-R	Row to row
SAP	School Agriculture Programme
SSP	Single Super Phosphate

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GLOSSARY

Acid soil	refers to any soil with a pH below 7. The lower the number the more acid the soil.
Additives	substances added to a product, usually in small quantities, in order to alter its characteristics or quality.
Aggregate Fruit	a clustered fruit composed of numerous fruitlets each with its own seed, (e.g. strawberry).
Agri-business	the group of industries dealing with agricultural produce and services to agriculture.
Agriculture	anything having to do with farming (raising crops or livestock for food, fibre or fur; or the industry which includes marketing, processing and trade in these products).
Agro ecological zones	land areas classified by their biophysical attributes, (such as rain fed soil moisture availability, temperature, length of growing period), in order to cluster land use types into homogenous units for agricultural production considerations.
Agro ecology	the design, development and management of sustainable agro ecosystems based on the application of ecological principles while considering existing social, cultural, and economic factors of farming communities.
Agro ecosystems	a system where communities of plants, microbes and animals inhabiting farmed land, pastures, grasslands or rangelands, interact with each other and their physical environment.
Agroforestry	an agroforestry system is a form of multiple land use where woody perennials (trees, shrubs, bamboos, palm trees, woody lianas) are grown on the same land management unit with crops and/or animals.
Agronomy	the science of crop production and soil management.
Alley cropping	a cropping system that involves growing crops in a wide strip, typically 6 metres in width, between lines of closely planted, fast-growing trees or shrubs. These woody species are usually leguminous and are pruned frequently to provide a mulching material and nutrients to the crop in the alley.

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Alternative farming	production methods other than energy- and chemical intensive one-crop (monoculture) farming. Alternatives include using animal and green manure rather than chemical fertilizers, integrated pest management instead of chemical pesticides, reduced tillage, crop rotation (especially with legumes to add nitrogen), alternative crops, or diversification of the farm enterprise.
Animal Welfare	the proper care of animals.
Annual	a plant that grows one season and produces seed for next year, (e.g. peas).
Aquaculture	the cultivation of aquatic animals and plants, including freshwater and marine species, for food or other purposes.
Artificial insemination	the delivery of semen into the uterus of the female animal usually by injection with a syringe-like apparatus for the purpose of achieving fertilization and sexual reproduction.
Avian	relating to birds.
Avian influenza	an Influenza A viral infection of wild birds or domestic fowl, certain strains of which cause high mortality in poultry.
Bacteria	microscopic, unicellular organisms found almost everywhere, appearing singly or in chains. Some cause disease and some are beneficial.
Baler	a machine used to compact and package roughage such as hay or straw.
Barn	a building used to shelter animals or store hay.
Basal dressing	the application of compost or fertilizer in the soil before planting in the field (or application during the land preparation).
Basin irrigation	an irrigation system in which a field or orchard is divided into basins which are filled with water.
Beta-carotene	orange pigment in plants that is a form of vitamin A
Biodiesel	a biofuel for use in diesel engines produced through the transesterfication of organically-derived oils or fats combined with alcohol (ethanol or methanol) in the presence of a catalyst. It may be used either as a replacement for or as a component of diesel fuel.
Bio-diversity	biological diversity; a measure of the variety of species of plants animals or other organisms in an ecosystem.

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Biological Control	the use of living organisms such as bacteria, fungi, or insects to control harmful weeds or insects which infest crops; this type of control excludes the use of chemical substances and relies mainly on natural sources.
Biological corridors	areas connecting separated habitats which allow movement to and access by wild species. These spaces make gene flow between isolated populations possible and may ameliorate negative effects of habitat fragmentation.
Biomass	the total amount of organic matter present in an organism, population, ecosystem or given area.
Bio pesticides	bio pesticides are certain types of pesticides derived from such natural materials as animals, plants, microorganisms, and certain minerals.
Biotechnology	the use of all or part of an organism to perform a task, function, or produce a product.
Boar	male hog or pig with intact testicles or uncastrated male pig.
Bovine	family of animals including cattle and buffalo.
Brassica	cruciferous plants with tap roots and erect branched stems, including cabbage, brussel sprouts, mustard, canola, cauliflower, and kale.
Bread	a food baked from wheat and/or other grains.
Breeding stock	Plants or animals used in breeding, selected for traits desired in producing the next generation.
Broiler	a chicken or turkey raised for meat and slaughtered at less than half mature weight.
Brood hen	a hen that is used to keep eggs warm for hatching.
Brooder	a heated house for chicks, piglets, etc.
Bull	an adult, male bovine used primarily for breeding.
Butter	a solid, yellow substance of fat, air and water made by churning milk or cream.
Calf	a baby cow or bull.
Calve	to give birth to a calf.
Canola	a crop whose seeds are used for making cooking oil; also, its meal is used as a livestock feed.
Cash Crop	any crop that is considered easily marketable, as wheat; a crop for direct sale in a market, as distinguished from a crop for use as livestock feed or for other purposes.

Castrated Animal	an animal that has had its testicles removed.
Cattle	more than one bovine animal (bulls and/or cows); general term for all sexes.
Cereal	refers to crops from the grass family grown for grain (e.g. oats, wheat, barley, rye, corn); also a processed form of breakfast food.
Chaff	the empty pods or scale-like seed covers which are separated from the grain in the threshing and cleaning operation.
Cheese	a food product made from milk solids.
Chick	a baby chicken.
Chicken	a small, domestic bird (colour varies) kept for its eggs and/or meat.
Churning	strongly stirring or agitating to combine or to separate a mixture (e.g. cream to butter).
Cleaned Seed	seed which has been screened to remove weeds, seeds and chaff.
Coat	the external covering of an animal (e.g. mammals have skin and hair for a coat).
Colostrum	the first secretion from the mammary glands after giving birth. This thick yellow milk contains antibodies that are passed on to the young to protect them from disease.
Colt	a more specific term for a male foal.
Combine	a machine which moves down the grain field removing the seeds from the stems of ripe plants of grains.
Commodity	raw materials or semi-finished goods rather than goods in general (e.g. milk, beef, vegetables, etc.).
Compost	a combination of organic matter, soil, nutrients, moisture, and lime in a state of partial decay.
Composting	the biodecomposition of organic material, such as animal wastes, plant residues or sludges, in the presence of air, by controlled methods including mechanical mixing and aerating.
Conservation	the management and preservation of natural resources for present and future uses.

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Conservation tillage	any of several farming methods that provide for seed germination, plant growth, and weed control yet maintain effective ground cover throughout the year and disturb the soil as little as possible. The aim is to reduce soil loss and energy use while maintaining crop yields and quality. No-till is the most restrictive (soil-conserving) form of conservation tillage. Other practices include ridge-till, strip-till, and mulch-till.
Contour farming	field operations such as plowing, planting, cultivating, and harvesting on the contour, or at right angles to the natural slope, to reduce soil erosion, protect soil fertility, and use water more efficiently.
Cooperatives	an organization formed for the purpose of producing and marketing goods or products owned collectively by members who share in the benefits.
Corn	a crop grown for human food, and as a livestock feed.
Corral	a fenced-in area for animals.
Cost of Production	expenses incurred by a business for production of a good or service. Production costs include raw material and labour. To find out the cost of production per unit, the total cost of production is divided by the number of units produced.
Cover crop	a crop grown to cover and protect soil from erosion by wind and water, especially in winter.
Cow	mature female bovine; some used for milk and some for meat.
Cream	the yellowish part of milk containing 18 to 20% butterfat that is usually removed from the milk during processing.
Crop	the yield of produce at harvest.
Crop acreage	acres of a specific crop planted in a cropping season by farmers.
Crop coefficient	an estimate of consumptive water use by crops based on evapotranspiration values.
Crop residues	any organic matter left in the field after the harvest of a crop, e.g. leaves, stalks, stubble, roots, hulls.
Crop rotation	system of cultivation where different crops are planted in consecutive growing seasons to maintain soil fertility.
Crop Rotation	planting different crops in fields than were there previously. Used as a crop, soil management and conservation method.

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Crop year	the year in which a crop is produced and harvested. Compare "marketing year."
Cropping systems	the pattern of crops grown on a given piece of land, or order in which the crops are cultivated over a fixed period.
Cross-pollinate	the passing of pollen from the male part of one plant to the female part of another plant of the same species.
Cud	a mouthful of previously swallowed food, regurgitated from the first stomach of ruminants. The cud is then chewed again further breaking it down for digestion.
Culling (animals)	the removal from the herd or flock of undesirable and/or inefficient breeding stock or diseased animals that will be sent to slaughter.
Cultivar	a plant variety produced by cultivation that keeps its characteristics even when reproduced.
Cultivating	preparing the land for the raising of crops.
Cultivator	an implement that digs into the soil. It is used for breaking up land and ripping out weeds.
Cultural Practices	techniques used in growing plants that include planting disease resistant varieties, rotating crops, spacing and pruning methods, providing good drainage and irrigation.
Curing	to preserve meat, fruit, or hides by salting, drying, etc.
Curing (crops)	a postharvest treatment of crops to reduce water loss and decay during storage. In root and tuber crops, curing refers to the process of wound healing with the development and suberization of new epidermal tissue called wound periderm. In bulb crops, curing refers to the process of drying of the neck tissues and of the outer leaves to form dry scales. Crops can be cured in the field or in facilities designed for the process.
Cutting	any part of a plant that can be severed from the plant and grow into an new plant.
Dairy Farm	a farm where cows or goats are kept for the production of milk.
Dam	female parent of an animal
De-blossoming	the practice of removing flowers from plants. De-blossoming is done on fruit trees in order to increase the size and quality of the fruit crop.
Desiccate	remove the moisture from anything.
Dioecious	having male and female reproductive parts on separate plants.

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Disease resistance	describing any organism which has low susceptibility or has the ability to withstand a disease caused by infectious agents (i.e., viruses, bacteria, fungi) or by parasitic nematodes, protozoa and helminths.
Disinfectants	substances used on inanimate objects that destroy harmful microorganisms or inhibit their activity.
Domestication	the process of breeding for one or more desirable characteristics in plants and animals.
Donkey	an animal similar to the horse but has much larger ears and is smaller in size. They have recently become popular as a protector of sheep against coyotes.
Double cropping	two different crops grown on the same area in one growing season.
Draft animals	animals used to supply power to pull farming implements, carts, vehicles, heavy loads, etc.
Dressed Weight	the weight of an animal after slaughter, defeathering, or skinning and evisceration.
Dry land farming	a system of producing crops in semiarid regions (usually with less than 20 inches of annual rainfall) without the use of irrigation. Frequently, part of the land will lie fallow in alternate years to conserve moisture.
Dwarfing Rootstock	a rootstock that limits the size of the plant that is grafted onto it.
Ear	the entire head of corn including the cob, husk and silks.
Ecological footprint	an ecological footprint is a measurement of the area, whether land- or water-based, required to support a certain level and/or type of consumption by an enterprise, activity, individual or population. The footprint calculation assesses the resources (e.g.the amount of water, energy, nutrients or land, [natural capital]) required for the production of what is being consumed and the resources required to assimilate the resulting waste.
Ecology	the study of relationships between the environment and organisms.
Ecoregions	physical regions which are characterized by their distinct species and communities and are also classified by their similar physical characteristics such as climate, meteorological factors, topography, elevation, soil types, etc.

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Ecosystem management	a natural resource management strategy or plan which is ecologically-based and considers all organisms and their environment with regard to the social, physical, and economic needs of humans.
Ecosystem services	benefits people and other organisms obtain from ecosystems; examples include: pure water and clean air, scenic landscapes, wildlife habitat and biodiversity.
Ecosystems	a functional system which includes the organisms of a natural community together with their environment.
Ecotourism	travel to natural settings with focus on the appreciation, conservation, preservation and sustainability of the area's natural resources and its surrounding community.
Egg	a roundish, hard-shelled body which can be used for reproduction (birds and most reptiles) or consumed as food.
Elevator	a building or terminal where grain is elevated and transferred to an alternate mode of transportation (e.g. truck to rail, rail to ship).
Embryo Transfer	the procedure where a female with desirable characteristics is induced to superovulate. The eggs are fertilized, and the resulting embryos transferred to other females.
Entomologist	a specialist in the study of the forms and behaviour of insects
Environment	the immediate surroundings of a plant or animal which influence its wellbeing.
Equipment	any material or apparatus used in farm production and operation (e.g. machines, gas tanks).
Ewe	an adult female sheep.
Factors of production	factors of production are the resources required for production of goods and services. They are generally classified into four major groups such as land, labour, capital and management (Entrepreneurship)
Family farms	an agricultural business which (1) produces agricultural commodities for sale in such quantities so as to be recognized as a farm rather than a rural residence; (2) produces enough income (including off farm employment) to pay family and farm operating expenses, to pay debts, and to maintain the property; (3) is managed by the operator; (4) has a substantial amount of labour provided by the operator and family; and (5) may use seasonal labour during peak periods and a reasonable amount of full-time hired labour.

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Farm	an establishment or plot of land, usually with a house, barn, silo, etc., where food is produced by growing crops or raising livestock.
Farm area	the area of agricultural land used for farming (crop and livestock production).
Farm enterprise	a farm enterprise is a component of a farm business. For example a farm may include crop enterprise and livestock enterprises.
Farm Gate Value	the cash value of a product when it leaves the farm.
Farm household	a farm household is a complex and dynamic decision making unit with multiple objectives where the family members manage the different farm activities.
Farm labour	people gainfully employed by a farm operator to assist with the farm work, including regular, seasonal, local, migratory, full-time or part-time employment.
Farm supplies	the different inputs (tangible and intangible) used for the production of farm outputs.
Farmer	a person who is engaged in the raising of crops, poultry or livestock.
Farmstead	an area that includes the human dwelling and other building which are often part of the farm.
Farrowing	act of giving birth in pigs
Feed Conversion Rate	the rate at which feed is converted into weight gain.
Fertile	a) of soil; capable of producing an abundance of crops, b) of animals; able to reproduce.
Fertilization	the joining of male and female to produce offspring.
Fertilizers	any organic or inorganic material of natural or synthetic origin which is added to soil to provide nutrients, including nitrogen, phosphorus, and potassium, necessary to sustain plant growth.
Fire break	a natural or constructed barrier used to stop or check fires that may occur, or to provide a control line from which to work.
Fixed costs (Ownership costs):	costs of goods that last more than one production cycle. For examples on the farm expenses incurred on machinery, equipment, land, house, etc.
Flora and Fauna	plant and animal.

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Flour	cracked or powdered grain used in baking.
Foal	a general term for a baby horse (noun); to give birth to a baby horse (verb).
Food Processing	operations which are done to prepare food for storage or sale (e.g. canning, freezing, pickling, drying, etc.).
Forage	grass and legume crops used for livestock feeds.
Fowl	any kind of bird.
Free Trade	international trade left to its natural course without tariffs, quotas, or other restrictions.
Free Trade Agreement	an agreement between countries of a particular region to allow certain goods and services to be traded among them without tariffs, quotas, or other restrictions.
Fresh	produce which has not undergone processing, such as freezing or canning.
Fructose	a simple sugar found in honey and fruits.
Fruit	the edible, mature, seed-bearing product of a plant.
Fungicide	a substance that kills fungus.
Furrow irrigation	a surface irrigation method in which water is run in small ditches or furrows, usually spaced closely together between crop rows or groups of rows.
Genetically Modified Organism (GMO)	an organism that has been developed by insertion of a gene from a source other than that species, through recombinant DNA technology. (There is increasing recognition that this term is misleading, as any organism that is modified by evolution, traditional plant breeding or mutation is "genetically modified").
Germination	the point at which a dormant seed begins to sprout, forming a new plant.
Gestation	the process of carrying in the womb during the period from conception to delivery.
Gestation period	pregnancy period
Gilt	young female that has not yet produced a litter.
Gizzard	the second part of a bird's stomach, used for grinding food.
Grafting	a method of plant propagation (reproduction) in which a piece of a desired plant (usually stems, buds or rootstock) is inserted into another plant so they unite and grow as one plant.
Grain	the edible, hard seed or kernel from cereal plants such as wheat, barley, corn, oats and rye.

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Grass	a narrow-leafed plant with seed-like grains grown for lawns and also used for pasture or grazing material for animals.
Green manure	a growing crop ploughed under and mixed with the soil to provide organic matter and fertility.
Greenhouse effect	a popular term used to describe the roles of greenhouse gases in keeping the Earth's surface warmer than it would be otherwise. These "radioactively active" gases are relatively transparent to incoming shortwave radiation, but are relatively opaque to outgoing long wave radiation, trapping it for subsequent re-radiation back to the surface, maintaining higher surface temperatures.
Greenhouse gases	those gases, such as water vapour, carbon dioxide, tropospheric ozone, nitrous oxide, and methane, that are transparent to solar radiation but opaque to long wave radiation. Their action is similar to that of glass in a greenhouse.
Gross domestic product	the value of the total final output of goods and services produced inside a country during a given year. It equals gross national product (GNP) less overseas remittances.
Gross income	the total income derived from a given unit of production. For example total revenue generated from one acre of paddy, total revenue generated from one cow in a year,
Gross national product	the value of all final goods and services produced during a year by the factors in a country. It is the sum of expenditures by consumers and governments, gross investment spending, and total merchandise exports less imports.
Growth	the development and maturing of a plant or animal.
Growth rings	the layer of wood growth put on a tree during a single growing season. In the temperate zone, the annual growth rings of many species (e.g., oaks and pines) are readily distinguished because of the differences in the cells formed during the early and late parts of the season. In some temperate zone species (e.g., black gum and sweet gum) and many tropical species, annual growth rings are not easily recognized.
Habitat	a place where the needs for food, water, and shelter of an organism are met.
Harden Off	acclimatize a plant to a change in its environment by gradually increasing exposure to the new environment.

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Hardwood	generally one of the botanical groups of trees that have vessels or pores and broad leaves, in contrast to the conifers or softwoods. The term has no reference to the actual hardness of the wood.
Harrow	an implement used for light, shallow loosening of the soil, for preparing seed beds and for killing weeds.
Harrowing	loosening the top soil to prepare it for seeds and to get rid of weeds.
Harvest index	grain weight as a percentage of total above-ground dry weight at maturity.
Harvesting	the collecting of produce from a crop.
Hatch	the emerging of the baby chick from the incubated egg.
Hatchery	a building that has specialized equipment for incubating and hatching eggs.
Hay	grasses, clover, alfalfa and other legumes, or any other leafy plant material that is cut and dried to be used for animal feeding.
Head	the portion of a plant which contains the seed (as in grain or grass).
Heat	the receptive period of the sexual cycle, especially in female animals.
Heifer	a young cow that has not borne any previous calves. She remains a heifer until her first calf is born.
Hen	a female chicken.
Herbaceous Perennial	a soft stemmed plant that lives from year to year by dying down to ground level at the end of each growing season.
Herbicide	a substance that kills plants.
Herd	a large group of cattle, sheep, goats or other animals.
Hog	generic term, usually applied to growing swine
Honey	a sweet liquid made in the hive by bees, and it can be used for human or animal feed.
Hooves	hard, horny feet on some animals (e.g. horses, cattle, goats, sheep).
Horn	a hard bony projection from the head of an animal (e.g. cattle, goats).
Horticulture	the science and art of growing fruits, vegetables, ornamental trees, shrubs and flowers.

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Hybrid	the offspring of two animals or plants of different breeds, varieties, species, or genera (especially as produced through human manipulation for specific genetic characteristics).
Hydroponics	the growing of plants in nutrient solutions with or without an inert medium to provide mechanical support.
Inbreeding	the mating of plants or non-human animals which are closely related genetically.
	an apparatus used to keep eggs warm while they are being hatched artificially.
Industrial crops	those crops that are not specifically grown for foodstuffs (such as fruit crops, vegetable crops and grain crops), but are specifically grown to yield a useful product for man or industrial processes, such as fiber, oils, rubber, chemicals, energy, waxes, or dyes.
Inoculation	using a needle to give a plant or an animal a substance which can aide in the prevention or curing of disease.
Inoculum	collective term for microorganisms or their parts (spores, mycelial fragments, etc.) which are capable of infection or symbiosis when transferred to a host. Term is also used for the symbiotic or pathogenic microorganisms that are transferred for culture.
Insecticide	a substance that kills insects.
Integrated pest management (IPM)	A pest management strategy using a systematic approach in which pest populations are monitored to determine if and when control methods are required. Integrated pest management (IPM) uses biological, chemical, physical, cultural and/or genetic control methods in order to minimize pesticide use, reduce production costs, and protect the environment.
Intensive Cereal Management (ICM)	close monitoring of cereal crops enabling application of inputs at the most critical points for optimal and economical yields.
Intensive farming	a system of raising crops and animals, usually on small parcels of land, where a comparatively large amount of production inputs or labor are used per acre. Compare extensive farming.
Intercropping	the growing of two or more different species of crops simultaneously, as in alternate rows in the same field or single tract of land.
Irrigation	application of water to soil for the purpose of plant production.

Kernels	the individual seeds from stalks of grain.
Kid	a young goat.
Lactation	the processes of milk secretion by the maternal mammary glands after parturition. The proliferation of the mammary glandular tissue, milk synthesis, and milk expulsion or let down are regulated by the interactions of several hormones including estradiol; progesterone; prolactin; and oxytocin.
Lactation Period in cows	the time from when a cow calves to the time when it is dried off to calve again; the period during which the cow is milked (approximately 305 days).
Lamb	a baby sheep (noun); to give birth to a lamb (verb).
Landraces	traditional crop cultivars or animal breeds with enough genetic integrity to be morphologically identifiable that evolved with or have been genetically improved by traditional agriculturalists.
Landscapes	the characteristics that distinguish a certain geographic area including its physical environment, biological composition, and anthropogenic activities.
Landscaping	the design and installation of plant materials (including turf) and architectural elements.
Laying Hen	a hen which is specifically raised to produce eggs. (Also layer).
Legumes	a group of plants that have pods containing seeds and the ability to fix nitrogen from the air. Used for food and forage (e.g. beans, peas, clover, alfalfa).
Lethal dose 50	the amount of a single dose of a solid or liquid substance required to kill 50% of the tested population. It is usually expressed in mg/kg (milligram of material per kilogram of body weight) and is used for all routes of exposure other than inhalation. Compare "lethal concentration 50".
Litter	a litter is the offspring at one birth of animals from the same mother and usually from one set of parents
straw, hay, wood shavings, o r other materials used for bedding animals.	
Living Modified Organism (LMO)	any organism that is the result of biotechnology and is capable of metabolizing and reproducing.

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Lodging	the condition of a plant, especially a cereal, that has been flattened in the field or damaged so that it cannot stand upright by weather conditions or because the stem is not strong enough to support the plant.
Malnutrition	a condition caused by inadequate intake or inadequate digestion of nutrients. It may result from eating an inadequate or unbalanced diet, digestive problems, absorption problems, or other medical conditions.
Mare	an adult female horse.
Marketing functions	a role that helps a company to identify and source potentially successful products for the marketplace and then promote them by differentiating them from similar products. Some of the typical marketing functions might include such as performing marketing research, developing marketing plan, and product development, as well as advertising, promotion, distribution and customers service.
Marketing services	marketing is the process of finding out what customers want and making those goods and services available at a profit. Marketing services are the methods used in the overall marketing plan of production, pricing, promotion and distribution.
Mechanization	the use and development of machines to replace hand and animal labour.
Milking Machine	an apparatus that attaches to a cow's or goat's teats and by vacuum draws the milk into a holding tank.
Mixed cropping	the growing of several crops simultaneously in the same field but not in rows.
Mulch	a layer of material (bark, hay or plastic) put over the soil surface to protect the plants from erosion, crusting, drying, freezing or weed competition.
Mule	the sterile offspring of a horse and a donkey that is usually smaller in size and makes a different sound than a horse.
Multiple cropping	the growing of more than one crop consecutively in the same field in a single year.
National parks	an area of land and/or sea usually owned and administered by a national government and is protected from human exploitation and development. The area is intended to provide environmentally and culturally sensitive scientific, educational and recreational opportunities.

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Natural resource management	the application of scientific and technical principles in the management of natural resources, such as land, water, soil, plants and animals, in order to meet ecological, economic, social and policy objectives.
Natural resources conservation	the protection, preservation, or restoration of natural resources such as forests, soil, water and wildlife.
Net income	difference between the Total Revenue and Total Costs of a given enterprise.
Organic	grown without the use of synthetic chemicals.
Organic foods	organic food is produced without: antibiotics; growth hormones; most conventional pesticides; petroleum- based fertilizers or sewage sludge-based fertilizers; bioengineering; or ionizing radiation. USDA certification is required before a product can be labeled "organic". Companies, including restaurants, that handle or process organic food must be certified also.
Oxen	adult, neutered, male bovines used for draft purposes; important in pioneer days.
Pasteurized	the process of heating to partially sterilize a food to kill bacteria.
Pastoralism	a way of life based on the raising and herding of livestock, such as sheep, goats, or horses.
Pasture	an area of grassy land where farm animals range and feed.
Pathogens	microorganisms, viruses and parasites that can cause disease.
Pathologist	a specialist who deals with the nature of disease, especially the structural and functional changes caused by disease.
Perennial	a plant that lives for more than two years.
Pesticides	manufactured chemicals, naturally occurring organisms, chemicals or devices which are used by the farmer to control plant, insect and disease pests that destroy crops or livestock. Pesticide use is carefully regulated to ensure safety to the environment, the food supply and the user.
Pet	an animal kept for the pleasure of its owner.
Pheromones	a chemical substance secreted and released by an animal for detection and response by another, especially for a member of its own species.
Photoperiodism	the physiological and behavioural response of an organism to the relative duration of light and darkness.

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Photosynthesis	the synthesis of carbohydrates from carbon dioxide and water by chlorophyll using light as energy and producing oxygen.
Physiologist	an expert who deals with the function and vital processes of living organisms.
Piglet	a baby pig.
Pod	the container for seeds on a legume plant.
Pollinate	the transfer of pollen from the male part of the flower to the female part of a flower to produce a fertilized egg that will develop into a seed.
Pome Fruit	a firm fleshed fruit in which multiple seeds are protected by a central core, e.g. apple, pear.
Poultry	a young fowl; a young turkey.
Private enterprises	organizations engaged in the production, distribution and/or sale of goods or services and owned and operated by a single or group of private persons or institutions.
Private forestry	forest operations on land owned by a private individual, group, or corporation and is not owned by a body of government.
Profit Margin	the profit remaining in a business after all expenses have been deducted.
Pullet	a hen less than one year old.
Rain fed farming	a system of producing crops without the use of irrigation.
Ram	a male sheep.
Rangelands	land on which the historic climax plant community is predominantly grasses, grasslike plants, forbs, or shrubs. Includes lands revegetated naturally or artificially when routine management of that vegetation is accomplished mainly through manipulation of grazing. Rangelands include natural grasslands, savannahs, shrub lands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows.
Ratooning	production of a subsequent crop that results from the regrowth from roots of the previous harvested crop, as in sugarcane, pineapple, and banana.
Relay cropping	the seeding of one crop into another standing crop, e.g., winter wheat into standing soybeans. A practice of starting one crop in another.
Ripening	the process of maturing in plants resulting in seeds that are fully developed and can be used to grow new plants.

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Rooster	a male chicken.
Rootstock	the underground part of a plant including a short portion of the stem onto which a scion can be grafted.
Ruminant	an animal with four stomachs. Included are cattle, goats, sheep and deer.
Rural urban migration	is the movement of people from rural areas (villages) to urban centres (cities).
Saplings	a young tree that is more mature than a seedling but is not yet seed-producing. A silvicultural tree class in which size limits vary by region but is generally accepted as 2-4 inches in diameter and 4 to 4-1/2 feet in height in the United States.
Scion	a portion of a stem used for grafting.
Seed	the reproductive portion of a plant.
Seed Drill	an implement used for planting the seeds in rows along the field.
Seeding	the process of putting seed in the ground to grow.
Sheep dog	a working dog used to herd sheep flocks.
Sheep Shears	clippers, usually electric, used to cut the wool from the sheep.
Silage	grasses, legumes and corn grown, harvested and stored as a wet roughage feed for cattle.
Silo	a storage building or pit in which green hay or high-moisture grains are fermented and stored as animal feed.
Sire	male parent of an animal
Softwood	generally, one of the botanical groups of trees that have no vessels and, in most cases, have needlelike or scale like leaves (the conifers). Also, the wood produced by such trees. The term has no reference to the actual hardness of the wood.
Soil erosion	the wearing away of the land surface by water, wind, ice, or other geologic agents.
Sow	female which has farrowed at least once
Spraying	mechanically applying a mixture containing water to prevent/ control the development of weeds, insects or diseases.
Sprout	the earliest emergence from a seed as it begins to germinate and grow.
Stalk	the straw or stem-like part of the plant that supports the seed head.
Stallion	an adult male horse used primarily for breeding.
Stem	the stalk of a plant.

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Stock	animals kept on the farm for production purposes.
Stone Fruit	a fruit with fleshy pulp that encloses a single seed in a hard shell, (e.g. peach, plum, cherry).
Strip cropping	the growing of crops in a systematic arrangement of strips or bands which serve as vegetative barriers to wind and water erosion. The strips or bands may run perpendicular to the slope of the land or to the direction of prevailing winds.
Subsistence farming	a type of farming in which most of the produce (subsistence crop) is consumed by the farmer and his family. In other words a type of farming that that is oriented towards meeting the basic needs of the farmer without surpluses for market. a farming system where the food and goods produced are predominantly consumed by the farm family and there is little surplus for sale in the market.
Supply chain	the network of firms that bring products to market, from companies that produce raw materials to retailers and others that deliver finished products to consumers. Economic value is added through the coordinated management of the flow of physical goods and associated information at each stage of the chain.
Supply Management	a distribution system in which the total quantity of a product produced in an industry is controlled, often through quotas. This maintains a level of financial return for the farmers.
Sustainable agriculture	use for the practice of agriculture which supports sustained economic profitability, sustained quality and well-being of the environment, efficient use of natural resources, and the overall quality and availability of food and fibre for mankind. the practice of agriculture that over the long term conserves or enhances environmental quality and the resource base on which agriculture and society depends.
Sustainable development	development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Sustainable technology	technologies focusing on sustainability principles: resource conservation, reuse and recycling, energy efficiency, minimizing environmental impact and pollution reduction.
Swather	an implement used to cut down grain or grass and place it into rows for the baler or the combine to pick up.

Taproot	a tapering root that grows vertically downward in which a plant stores food, (e.g. carrot, turnip).
Tariff	a tax or duty to be paid on a particular class of imports or exports.
Thinning (plants)	the practice of reducing the number of plants in an area or the quantity of vegetative or reproductive structures on individual plants.
Tissue culture	a method of maintaining or growing tissues, organ primordia, whole or parts of organs, in a manner to preserve their structure and/or function.
Top dressings	the application of compost or fertilizer on top of the soil during plant growth.
Total costs	the sum of variable costs and fixed costs for producing a particular good or service. For example on the farm, expenses incurred on the variable inputs and fixed inputs for producing an acre of paddy.
Tractor	a powerful, motor-driven machine used to pull implements and do other work on the farm
Traditional medicine	systems of medicine based on cultural beliefs and practices handed down from generation to generation. The concept includes mystical and magical rituals (spiritual therapies); phytotherapy; and other treatments which may not be explained by modern medicine.
Traditional technology	techniques that utilize indigenous, traditional methods that are often ethnic/cultural in origin. Includes methods practiced as a trade or handicraft, frequently producing in limited quantities.
Transpiration	water discharged into the atmosphere from plant surfaces.
Tropisms	movement that is inducible and takes place in a direction related to that of the stimulus, such as the movement of leaves toward light in positive phototropism or away from light in negative phototropism.
Trough	a container for drinking water or feed of farm animals.
Tuber	a fleshy food-storing swelling of an underground stem, (e.g. potato).
Vaccination	administration of vaccines to stimulate the host's immune response. This includes any preparation intended for active immunological prophylaxis.

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Variable costs (Operating Costs):	cost of goods or services that are used up in one production cycle. For example on the farm expenses incurred on seed, fertilizer, fuel, wages, rent, repairs, feed, veterinary, etc.
Vegetable	any plant whose fruit, seeds, roots, tubers, bulbs, stems, leaves or flower parts are used for food. May be eaten raw or cooked.
Vegetables	any part of a plant that is commonly eaten by humans as food, but is not considered to be a culinary fruit, nut, herb, spice or grain.
Vegetative Propagation	ways of increasing plant numbers using leaves, stems, roots or other parts by techniques such as layering, cuttings or grafting.
Vernalisation	the treatment of seeds, seedlings, bulbs, or other parts of a plant to cold conditions in order to shorten the vegetative period and promote flowering.
Veterinarian	a person who treats diseases and injuries of animals.
Watershed	the entire land surface from which water ultimately drains into a particular stream or river system.
Watersheds	the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge.
Weaning	separation of piglets from the sow
Weaning	the substitution of solid food for maternal milk or milk substitutes in the diet of a child or young mammal.
Weed	a plant that is not valued where it is growing.
Wetlands	an area that is saturated by surface or ground water with vegetation adapted for life under those soil conditions.

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