SUSTAINABLE AGRICULTURE IN SMALL STATES
The paper-based version of an “Introduction to Agriculture in Small States” has been adapted from the Moodle version published on the Virtual University of the Small States of the Commonwealth (VUSSC) web site. (www.vussc-learning.org)

The assignments, activities and discussions have been modified to support either a blended learning approach or a classroom delivered course. All of the activities can be completed as small group or as individual exercises. Discussions can be chaired by the instructor either in the class or if available via an online discussion board. Guidance on how to complete the activities will be provided by your instructor.

Access to the Internet is not required to complete this course, although the instructor is encouraged to create a course web site to support student to student communications and information sharing when not engaged in classroom work. YouTube videos have been used in the Moodle course to illustrate some of the concepts and best practices used in the agri-industry. Links to videos and other supplementary learning resources has been embedded in this paper based study guide. You are encouraged to view these videos and resources from an Internet ready computer.

The content of this study guide may be modified by your instructor or hosting institution to reflect the unique requirements within your region or within your institution.
# Table of Contents

## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Overview</td>
<td>1</td>
</tr>
<tr>
<td>Course Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Course Goals and Objectives</td>
<td>1</td>
</tr>
<tr>
<td>Course Approach</td>
<td>1</td>
</tr>
<tr>
<td>Course Schedule</td>
<td>2</td>
</tr>
<tr>
<td>Course Assignments</td>
<td>2</td>
</tr>
<tr>
<td>Course Grading</td>
<td>3</td>
</tr>
<tr>
<td>Common Definitions</td>
<td>4</td>
</tr>
<tr>
<td>Instructor Expectations</td>
<td>8</td>
</tr>
<tr>
<td>Unit 1 – Best Practices in Crop Management</td>
<td>10</td>
</tr>
<tr>
<td>Overview</td>
<td>10</td>
</tr>
<tr>
<td>Goals and Objectives</td>
<td>10</td>
</tr>
<tr>
<td>Lesson 1.1 – Introduction to Crop Production</td>
<td>11</td>
</tr>
<tr>
<td>Overview</td>
<td>11</td>
</tr>
<tr>
<td>Objectives</td>
<td>11</td>
</tr>
<tr>
<td>Crop Taxonomy</td>
<td>11</td>
</tr>
<tr>
<td>Pulses</td>
<td>12</td>
</tr>
<tr>
<td>Plant Families</td>
<td>13</td>
</tr>
<tr>
<td>Environmental Factors Impacting Crop Growth</td>
<td>14</td>
</tr>
<tr>
<td>Abiotic Factors</td>
<td>14</td>
</tr>
<tr>
<td>Biotic Factors</td>
<td>16</td>
</tr>
<tr>
<td>Selection of Crops</td>
<td>17</td>
</tr>
<tr>
<td>Summary</td>
<td>20</td>
</tr>
<tr>
<td>Lesson 1.2 – Crop Production Best Practices</td>
<td>21</td>
</tr>
<tr>
<td>Overview</td>
<td>21</td>
</tr>
<tr>
<td>Objectives</td>
<td>21</td>
</tr>
<tr>
<td>Crop Production Site Selection</td>
<td>21</td>
</tr>
<tr>
<td>Farm Layout</td>
<td>22</td>
</tr>
</tbody>
</table>
Land Preparation .................................................................................................................. 24
Cultivar Selection .................................................................................................................. 25
Tillage .................................................................................................................................... 26
Vegetative Propagation ........................................................................................................ 27
Air Layering .......................................................................................................................... 27
Cuttings .................................................................................................................................. 27
Rooting Media for Cuttings .................................................................................................... 28
Grafting .................................................................................................................................... 29
Considerations When Grafting ............................................................................................. 30
Seed Production ....................................................................................................................... 31
Seedling Production ............................................................................................................... 32
Transplanting .......................................................................................................................... 35
Planting Methods .................................................................................................................... 36
Principles of Planting ............................................................................................................ 38
LESSON ASSIGNMENT ......................................................................................................... 39
Summary .................................................................................................................................. 39
LESSON 1.3 – WATER MANAGEMENT .................................................................................. 40
Overview ................................................................................................................................. 40
Objectives ............................................................................................................................... 40
Symptoms of Water Stress ..................................................................................................... 40
Irrigation ................................................................................................................................... 41
Surface Systems ...................................................................................................................... 42
Manual Systems ...................................................................................................................... 42
Sprinkler Systems .................................................................................................................. 42
Drip Systems .......................................................................................................................... 44
Factors To Consider ............................................................................................................... 44
Responsible Irrigation ............................................................................................................ 45
LESSON DISCUSSION ........................................................................................................... 46
Summary .................................................................................................................................. 46
LESSON 1.4 – CROP NUTRITION ......................................................................................... 47
Overview ................................................................................................................................. 47
Objectives ............................................................................................................................... 47
Fruit Tree Planting .......................................................... 72
Summary ........................................................................... 75
UNIT 1 – ASSIGNMENT ....................................................... 76
UNIT 1 – SUMMARY ............................................................ 77
UNIT 2 – BEST PRACTICES IN LIVESTOCK MANAGEMENT .......... 79
OVERVIEW .......................................................................... 79
GOALS AND OBJECTIVES .................................................. 79
LESSON 2.1 – ANIMAL ANATOMY AND PHYSIOLOGY ................ 80
Overview ........................................................................... 80
Objectives .......................................................................... 80
Digestive Systems ............................................................. 80
Ruminant Digestive Systems .................................................. 80
Non Ruminant Digestive Systems ............................................ 82
Avian Digestive Systems ....................................................... 83
Skeletal System ................................................................... 84
Parts of the Skeleton ........................................................... 85
Cow Skeleton ....................................................................... 85
Pig Skeleton ......................................................................... 86
Chicken Skeleton ................................................................. 87
The Heart ............................................................................. 88
Blood .................................................................................... 89
Reproductive Systems .......................................................... 91
Chicken Reproduction .......................................................... 92
Cow Reproduction System ..................................................... 93
Pig Reproduction System ....................................................... 93
Fertility Problems ................................................................. 95
Endocrine System ................................................................. 95
Use of Hormones .................................................................. 97
Immune System ................................................................. 97
Innate Defence System ........................................................ 98
Acquired Immune System ..................................................... 98
Objectives .................................................................................................................. 123
General Husbandry Practices.................................................................................... 123
Sheep Husbandry Practices...................................................................................... 127
Cattle Husbandry Practices...................................................................................... 128
Castration.................................................................................................................. 131
Dehorning .................................................................................................................. 134
Pig Husbandry Practices......................................................................................... 137
Poultry Husbandry Practices..................................................................................... 141
Summary .................................................................................................................... 145
LESSON 2.6 – ANIMAL HEALTH .............................................................................. 146
Overview .................................................................................................................... 146
Objectives .................................................................................................................. 146
Disease Causes .......................................................................................................... 146
Types of Disease ........................................................................................................ 147
Methods of Infection ................................................................................................. 148
Recognizing Diseases ............................................................................................... 149
Health Management ................................................................................................. 149
Records Keeping ........................................................................................................ 150
Example of Farm Records ....................................................................................... 150
Summary ..................................................................................................................... 151
UNIT DISCUSSION .................................................................................................... 152
UNIT ASSIGNMENT .................................................................................................. 152
UNIT Two SUMMARY ............................................................................................... 153
UNIT THREE - BEST PRACTICES IN HARVEST MGMT, POST MGMT & AGRO PROCESSING .......................................................................................... 155
OVERVIEW .............................................................................................................. 155
GOALS AND OBJECTIVES ..................................................................................... 155
LESSON 3.1 – HARVEST MANAGEMENT ................................................................ 156
Overview .................................................................................................................... 156
Objectives .................................................................................................................. 156
Crop Maturity ............................................................................................................ 156
Maturity Indices ......................................................................................................... 157
Example Maturity Indices ......................................................................................... 161
Factors Affecting Storage Life ................................................................. 200
Storage Methods ................................................................................... 200
Storage Compatibility ........................................................................... 203
Summary ............................................................................................... 207
LESSON 3.4 – QUALITY AND SAFETY DURING AGRO-PROCESSING ... 208
Overview ............................................................................................. 208
Objectives ............................................................................................ 208
Processing in Small States .................................................................. 208
Processing & Preservation Methods .................................................... 211
Production Control, Quality & Safety ................................................ 216
Other Safety & QA Guidelines ............................................................ 219
Summary ............................................................................................... 219
UNIT THREE DISCUSSION ................................................................. 220
UNIT THREE ASSIGNMENT ............................................................... 220
UNIT THREE SUMMARY ....................................................................... 221
UNIT FOUR – AGRIBUSINESS MANAGEMENT .................................. 222
OVERVIEW .......................................................................................... 222
GOALS AND OBJECTIVES .................................................................. 222
LESSON 4.1 – APPLIED AGRICULTURAL ECONOMICS .................. 223
Overview ............................................................................................. 223
Objectives ............................................................................................ 223
Demand and Supply ............................................................................ 223
Production Function ............................................................................ 224
Law of Diminishing Returns .............................................................. 226
Relationship of Production, APP & MPP .......................................... 228
How to Produce .................................................................................. 230
What to Produce? ................................................................................ 232
Cost Concepts ...................................................................................... 233
Summary ............................................................................................... 235
LESSON 4.2 – AGRIBUSINESS MANAGEMENT .................................. 236
Overview ............................................................................................. 236
Objectives ............................................................................................ 236

Sustainable Agriculture in Small States
COURSE OVERVIEW

COURSE INTRODUCTION

Many small states are facing the challenges of being competitive on the global agricultural markets. Therefore a common scenario being observed is that the new generation from small states is more and more reluctant to go into agriculture preferring other employment opportunities. The relevance of this course to small states is to stimulate and encourage people from the small states to remain and develop a sustainable agriculture sector focusing on the development of viable agro industrial sector.

This course builds upon the Introduction to Agriculture course. This course will introduce to best practices in the agriculture sector in small states and thus better prepare you to succeed in this industry.

COURSE GOALS AND OBJECTIVES

Upon completion of the Sustainable Agriculture for Small States Course you will be able to:

1. Employ the best practices in crop management and livestock management.
2. Describe the anatomy and physiology of farm animals.
3. Employ appropriate nutritional practices supporting your livestock.
4. Identify animal health and wellness issues.
5. Examine the need for food security.
6. Employ appropriate pest management strategies.
7. Employ appropriate record management practices.
8. Explain the harvest management process.
9. Appropriately manage a small farm operation.
10. How to effectively use agriculture value chains and cooperatives.

COURSE APPROACH

This course was developed and will be delivered as a fully online course supported by an instructor/facilitator. The course content was extracted from the paper-based Sustainable Agriculture course developed by COL and VUSSC partners.

Course participants will be required to actively engage their peers in discussion exploring a variety issues that impact the tourism industry in general and tour guiding specifically. Learners will be required to complete a number of different activities and assignments. Some activities are reflective in nature and learners will only be asked to review the materials and reflect upon how they would answer the questions presented. Other activities and assignments will require that you formulate a reply or
solution to the case study or question and submit it to your instructor for feedback and grading.

Finally you will be required to complete a major project that will help you synthesize and apply the knowledge and skills you learn throughout the course.

**COURSE SCHEDULE**

The course is divided into three week segments, one for each Unit. The proposed schedule for the course is below.

<table>
<thead>
<tr>
<th>Week</th>
<th>Activity</th>
</tr>
</thead>
</table>
| 1    | • Review course information.  
      | • Participate in class introductions discussion.  
      | • Read Lesson 1.1 and 1.2. |
| 2    | • Complete Lesson 1.2 Assignment.  
      | • Read Lesson 1.3 and 1.4.  
      | • Participate in Lesson 1.3 discussion.  
      | • Begin Unit 1 Assignment. |
| 3    | • Read Lesson 1.5 and 1.6.  
      | • Participate in Lesson 1.5 discussion.  
      | • Complete Unit 1 Assignment. |
| 4    | • Read Lesson 2.1 and 2.2. |
| 5    | • Read Lesson 2.3 and 2.4.  
      | • Begin Unit 2 Assignment. |
| 6    | • Read Lesson 2.5 and 2.6.  
      | • Participate in Unit 2 Discussion.  
      | • Complete Unit 2 Assignment. |
| 7    | • Read Lesson 3.1 and 3.2. |
| 8    | • Read Lesson 3.3 and 3.4.  
      | • Begin Unit 3 Assignment. |
| 9    | • Participate in Unit 3 Discussion.  
      | • Complete Unit 3 Assignment. |
| 10   | • Read Lesson 4.1 and 4.2. |
| 11   | • Read Lesson 4.3 and 4.4.  
      | • Begin Unit 4 Assignment. |
| 12   | • Participate in Unit 4 Discussion.  
      | • Complete Unit 4 Assignment.  
      | • Participate in Lessons Learned Discussion.  
      | • Complete Course Evaluation Forum. |

**COURSE ASSIGNMENTS**

There is one lesson and four unit assignments scattered throughout the course. All of the assignments build upon the information contained in the lessons and the recommended
readings listed in each lesson. The assignments require the learners to review a specific problem or address specific issues in the operation of a farm. The specific instructions for each assignment are available in the assignment section in each unit or at the end of the study guide. It is recommended you review them all before proceeding to begin the course.

The assignments will be submitted to your instructor and feedback provided by way of either email or by paper feedback. The timing for submission of each assignment is reflected in the course schedule. Additional timings will be provided by the instructor.

**COURSE GRADING**

Each classroom discussion and assignment is awarded points based on the table below. The five assignments represent 230 points or 76% of the grade. The remainder of the grade (24%) is based on your active participation in the classroom discussions and activities.

<table>
<thead>
<tr>
<th>Unit/Lesson Activity</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Introduction Discussion</td>
<td>5</td>
</tr>
<tr>
<td>Lesson 1.2 Assignment</td>
<td>30</td>
</tr>
<tr>
<td>Lesson 1.3 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Lesson 1.5 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Unit 1 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Unit 1 Major Assignment</td>
<td>50</td>
</tr>
<tr>
<td>Unit 2 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Unit 2 Major Assignment</td>
<td>50</td>
</tr>
<tr>
<td>Unit 3 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Unit 3 Major Assignment</td>
<td>50</td>
</tr>
<tr>
<td>Unit 4 Discussion</td>
<td>10</td>
</tr>
<tr>
<td>Unit 4 Major Assignment</td>
<td>50</td>
</tr>
<tr>
<td>Lessons Learned Discussion</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>300</strong></td>
</tr>
</tbody>
</table>
### COMMON DEFINITIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy</td>
<td>The bodily structure of a plant or an animal or of any of its parts.</td>
</tr>
<tr>
<td>Annual Crop</td>
<td>Crops that grow and produce within a period of one year.</td>
</tr>
<tr>
<td>Artificial Insemination (AI)</td>
<td>The impregnation of a female animal by artificially injecting semen into the vagina, uterus rather than by mating.</td>
</tr>
<tr>
<td>Avian</td>
<td>Of, relating to, or characteristic of birds.</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Variation of life forms in a given ecosystem.</td>
</tr>
<tr>
<td>Bioposticides</td>
<td>Microbial biological pest control agents.</td>
</tr>
<tr>
<td>Burdizzo</td>
<td>A tool used for close castration.</td>
</tr>
<tr>
<td>Caudal</td>
<td>Relating to or near the tail or hind parts of an animal.</td>
</tr>
<tr>
<td>Cellular Respiration</td>
<td>The process organisms undergo that convert glucose to energy, usually using oxygen and glucose to produce ATP, carbon dioxide and water.</td>
</tr>
<tr>
<td>Circulatory System</td>
<td>The circulatory system consists of the heart which is a four chamber suction and pressure pump that moves blood through two separate systems, one to and from the lungs and the other around the body.</td>
</tr>
<tr>
<td>Climacterism</td>
<td>The phenomenon in plants whereby ripening in fruits is accomplished by an increase in the rate of respiration.</td>
</tr>
<tr>
<td>Crop Taxonomy</td>
<td>Science of grouping crops into different categories according to their similarities.</td>
</tr>
<tr>
<td>Cultivar</td>
<td>A cultivated variety of a plant that has been deliberately selected for specific desirable characteristics.</td>
</tr>
<tr>
<td>Dehorning</td>
<td>Removal or cutting horns.</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Any of the organs of the body, such as the pituitary gland or the ovaries, which produce and release hormones into the blood to be carried around the body.</td>
</tr>
<tr>
<td>Farrowing</td>
<td>Act of giving birth in pigs.</td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>A small cone shape structure it protects downward, ending in the pituitary.</td>
</tr>
<tr>
<td>Interferon System</td>
<td>An antiviral protein produced by cells that have been invaded by a virus.</td>
</tr>
<tr>
<td>Dry Cows</td>
<td>The cows which are not lactating, (not producing milk).</td>
</tr>
<tr>
<td>Fungicides</td>
<td>Chemicals used to control fungi.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Gizzard</td>
<td>The word &quot;gizzard&quot; comes from the Middle English <em>giserdd</em>, meaning cooked entrails of poultry.</td>
</tr>
<tr>
<td>Herbicides</td>
<td>chemicals used to control weeds</td>
</tr>
<tr>
<td>Hybrid</td>
<td>an offspring resulted from the crossbreed between different varieties</td>
</tr>
<tr>
<td>Maturity</td>
<td>Maturity is the stage at which a commodity has completed all phases of growth and development such that after harvesting its quality will at least be at the minimum acceptable to the consumer.</td>
</tr>
<tr>
<td>Macro-Nutrient</td>
<td>nutrients that are required in large quantities</td>
</tr>
<tr>
<td>Marginal Cost (MC)</td>
<td>The additional cost incurred from producing an additional unit of output</td>
</tr>
<tr>
<td>Marginal</td>
<td>Economists' term for 'extra' or 'added'</td>
</tr>
<tr>
<td>Marginal Input Cost</td>
<td>The additional cost incurred by using an additional unit of input</td>
</tr>
<tr>
<td>Marginal Return</td>
<td>(a) The return from one extra unit of output. (b) The addition to gross return from using one extra unit of input. If the marginal return of an input exceeds its marginal cost, additional profit may be made by adding units of the input until its marginal return and marginal cost are equalized.</td>
</tr>
<tr>
<td>Marginal Revenue (MR)</td>
<td>The additional income received from selling one additional unit of output.</td>
</tr>
<tr>
<td>Marginal Physical Product (MPP)</td>
<td>The additional physical product resulting from the use of an additional unit of input</td>
</tr>
<tr>
<td>Marginal Cost (MC)</td>
<td>The additional cost incurred from producing an additional unit of output</td>
</tr>
<tr>
<td>Marketing</td>
<td>As defined by <a href="http://www.dictionary.reference.com">www.dictionary.reference.com</a> is &quot;the total of activities involved in the transfer of goods from the producer or seller to the consumer or buyer, including advertising, shipping, storing, and selling.&quot;</td>
</tr>
<tr>
<td>Market Opportunity</td>
<td>Is an area of buyer need in which a company can perform profitable, such as making a buying process more efficient or providing more advice and information.</td>
</tr>
<tr>
<td>Micro-Nutrient</td>
<td>Nutrients that are required in small quantities</td>
</tr>
<tr>
<td>Niche Market</td>
<td>Is the subset of the market on which a specific product is focusing; therefore the market niche defines the specific product features aimed at satisfying specific market needs, as well as the price range, production quality and the demographics that is intended to impact.</td>
</tr>
<tr>
<td>Omasum</td>
<td>The third compartment of the stomach in ruminants</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>The esophagus or oesophagus sometimes known as the gullet, is</td>
</tr>
</tbody>
</table>
an organ in vertebrates which consists of a muscular tube through which food passes from the pharynx to the stomach.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Oviduct</td>
<td>A tube inside an animal that an egg passes through as it leaves the ovary (= organ that produces eggs); in a woman, either of the fallopian tubes</td>
</tr>
<tr>
<td>Pancreas</td>
<td>The pancreas is a gland organ in the digestive and endocrine system of vertebrates. It also produces digestive enzymes that pass into the small intestine. These enzymes help in the further breakdown of the daquin mayes.</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Chemicals used to control pests</td>
</tr>
<tr>
<td>Perennial Crop</td>
<td>Crops that grow and produce for a period longer than one year</td>
</tr>
<tr>
<td>Phagocy Cells</td>
<td>That are the cell to engulf foreign bodies</td>
</tr>
<tr>
<td>Physiology</td>
<td>The biological study of the functions of living organisms and their parts.</td>
</tr>
<tr>
<td>Pituitary Gland</td>
<td>A small organ at the base of the brain which controls the growth and activity of the body by producing hormones</td>
</tr>
<tr>
<td>Postharvest Handling</td>
<td>All activities associated with extending the life of fresh produce items after they have been harvested until they reach the final consumer.</td>
</tr>
<tr>
<td>Postharvest Loss</td>
<td>The condition of harvested fresh produce items which is manifested by a reduction in quality or quantity which makes them unfit for human consumption.</td>
</tr>
<tr>
<td>Postharvest Management</td>
<td>The control of all aspects of the physiology of the harvested commodities. It acknowledges that fresh produce items are diverse in nature and, therefore, have specific needs in order to maintain their quality and maximise their shelf life.</td>
</tr>
<tr>
<td>Postharvest Technology</td>
<td>Postharvest technology applies scientific approaches and methods to harvested fresh produce items in order to improve their quality, extend their shelf life and meet consumers’ requirements through packaging storage, processing, distribution and marketing.</td>
</tr>
<tr>
<td>Product Development</td>
<td>Means offering new or improved products for present market. By knowing what the present markets needs, an entrepreneur or farmer may see ways to add or modify product features, e.g. through improved best practices, create several quality levels, or add more types or sizes to better satisfy customers while seeking, also, to expand.</td>
</tr>
<tr>
<td>Reticulorumen</td>
<td>The reticulorumen represents the first chamber in the alimentary canal of ruminant animals.</td>
</tr>
<tr>
<td>Ruminant</td>
<td>Characterized by the chewing of cud</td>
</tr>
<tr>
<td>Rumen</td>
<td>The first division of the stomach of a ruminant animal, in which</td>
</tr>
</tbody>
</table>
most food collects immediately after being swallowed and from which it is later returned to the mouth as cud for thorough chewing. Also called paunch

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scapula</td>
<td>The scapula forms the posterior (back) located part of the shoulder girdle.</td>
</tr>
<tr>
<td>Secondary Metabolite</td>
<td>Chemical compounds produced in plants which do not play a role in the primary functions such as photosynthesis and respiration</td>
</tr>
<tr>
<td>Testes</td>
<td>The male sex gland</td>
</tr>
<tr>
<td>Utility</td>
<td>The American Heritage Dictionary defines utility as &quot;the quality or condition of being useful&quot;. Utility is further defined as any quality and/or status that provide a product with the capability to satisfy the consumer's wants and needs. Marketing is responsible for creating most of a product's inherent utility.</td>
</tr>
<tr>
<td>Weaner</td>
<td>An animal that has been recently weaned.</td>
</tr>
</tbody>
</table>
INSTRUCTOR EXPECTATIONS

MY EXPECTATIONS
As an instructor or a student participating in a distance education course we must make commitments to each other to ensure that everyone has a positive and supportive learning experience. To ensure we all start the course with the same level of commitment I would ask you to review the list below.

In distance education the instructor and student often enter with unwritten expectations of each other. If these expectations are not shared early in the course, then both parties may eventually be disappointed when individuals do not live up to the unstated expectations. Therefore we must recognize my commitment to you as the instructor and you must understand what expectations the instructor has of you, the distance learner. Below are my expectations.

MY COMMITMENT TO YOU

Instructor Commitment 1: I will respond to your email messages or online queries within 48 hours of being sent.

Instructor Commitment 2: Where appropriate I will provide constructive feedback and input during classroom and blended learning activities and discussions.

Instructor Commitment 3: Your course assignments and other graded activities will be marked and returned to you within ten calendar days after the published due date or after the date you submitted to me for grading.

Instructor Commitment 4: I will ensure I am available to you for individual discussions, consultation and support and I will keep you informed when I will not be available due to personal or professional commitments.

MY EXPECTATION OF YOU, THE STUDENT
To exercise my commitment to you I need the cooperation and commitment of all participating students. As a student engaged in my course you must commit to the following:

Student Commitment 1: As a student in this course I understand that I am ultimately responsible for my own learning and my own eventual academic success.
**Student Commitment 2**: As a student in this course I promise to commit the time, effort and energy required to succeed in my academic studies.

**Student Commitment 3**: As a student in this course I promise to regularly attend classes, complete all readings, activities and assignments, and meet all course deadlines and schedules. I will submit all of my assignments on the published due date.

**Student Commitment 4**: As a student in this course I will communicate with my peers in a timely, professional, non-threatening and constructive manner.

**Student Commitment 5**: As a student in this course I promise to review all Rubrics before submitting assignments for grading to ensure that my submission meets 100% of the assignment criteria.

I hope all parties can live up to these expectations. Thanks in advance .....
UNIT 1 – BEST PRACTICES IN CROP MANAGEMENT

OVERVIEW
Food as the main source of energy is required for the existence of man. This should be available in both quantity and quality for the proper and healthy growth of individuals and collectively as a nation. Moreover, it should be accessible to all at all time. Crop production which is the art of cultivating crops should incorporate all categories of food types namely cereals, vegetables and fruits to provide the basic proportion of individual food values viz. carbohydrate, protein, minerals salts, vitamins and some other essential nutrients. Each of the food types require basic environmental factors for their proper cultivation. As discussed in the Introduction to Agriculture course the most common environmental (agro-climatic) factors influencing crop production are climate, soil and biotic factor such as pest and diseases. These factors intricately interplay on the standing crops that may influence their yields in one way or the other. Good agronomic practices from site selection to post harvest should be improved upon to be more sustainable and hence realize good yield. This unit aims to dwell upon the concept of food security and good agronomic practices as a direction for healthy and sustainable growth of a nation.

GOALS AND OBJECTIVES
Upon completion of this unit, you will be able to:

1. Explain the significance of different types of crops in providing food security in small states.
2. Describe factors to consider when selecting a site for crop production.
3. Explain the importance of sustainable land preparation methods in crop production.
4. Design a simple farm layout for a small scale crop production suitable for your area (project).
5. Describe methods employed in the cultivation of a local grown crop and recommend sustainable practices where appropriate to improve the existing practices (assignment).
6. Design a record keeping tool useful for a small-scale farmer in your local state (Final project).
7. Assess the implications of existing crop production practices on food safety in your state.
OVERVIEW

In achieving the aim of food security, all categories of crops containing the respective proportion of food elements should be integrated to provide a balance diet. In crop production therefore there should be a strong emphasis on the production of crops rich in carbohydrate, protein, mineral salts, vitamins and some other essential elements in small states where most of the farmers practice subsistence farming. In small states, farmers should be encouraged to grow different categories of food to meet their basic nutritional requirement. The practice of mixed farming would be a way forward to small states’ farmers.

Different crops require different physical and environmental conditions to maintain a proper and healthy growth. The environmental conditions that are of significance in crop production are soil, climate and to some extent the biotic factor. These conditions are always at interplay exerting forces on the growth and performance of standing crops. The role of temperature and rainfall are important climatic elements that influence the growth of crops. Certain crops require high amount of rainfall while others are adapted to drier conditions. To realize the full potential yield of crops, the amount of water required for each crop should be adjusted. In the dry season where rainfall is significantly low, the crop water requirement is supplemented by irrigation. This can facilitate the production of crops all year round. This could be a strategic way to maintain the availability of food by farmers in small states. Global warming as result of deforestation has been identified to impact the production of crops most particularly in tropical regions where crops are climate dependent.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Describe the different types of crops.
2. Explain the impact of the environment on plant growth.
3. Select crops appropriate for the environment.

CROP TAXONOMY

In the Small States of the Commonwealth, there are varieties of crops which are grown which best suit the environment in which the countries are located. Crops grown are also in accordance to what people prefer and their nutritional needs.
Crops can be categorized into various groups according to their structures and functions. Some crops are put into similar groups because they have similar plant structures, functions and characteristics.

For the purpose of this course, crops have been classified under following categories:

**Crop Cycle:** One way to classify crops is by their growing cycle. The three types of crop cycles include:

1. **Annuals:** In this category, we are referring to crops that have a short cycle with a crop duration from 1-12 months. Examples are greens with crop cycle of 2-3 months, bean 2-3 months, tomato 5 months, maize 5 months, etc.
2. **Short Term Perennial:** This refers to crops that have a crop cycle of 1-3 years. Examples are banana about 5 years, Pawpaw about 2 years. After this duration, crops are renewed.
3. **Long term Perennials:** Here we are referring to crops that have a crop cycle of a longer duration, above 3 years. Crops under this category would be mainly fruit trees. Examples are mangoes, coconut, etc.

**Physical Characteristics:** Crops can also be classified based on their physical structures.

1. **Leafy Crop:** These are grown for their leaves. Examples are lettuce, greens, spinach, Chinese cabbage
2. **Root Crop:** These are grown for their tubers which are found underground. Examples are, potato, cassava, sweet potato, taro.
3. **‘Fruit’ Crop:** These are grown for their ‘fruits/pods/cobs’. Examples are tomato, eggplant, chilly, maize, bean. The latter can also be categorized as a legume crop (see Leguminosae family).

Legume plants are notable for their ability to fix atmospheric nitrogen. This occurs as a result of symbiotic relationship with bacteria (rhizobium bacteria) found in root nodules of these plants. The ability to form this symbiosis reduces fertilizer costs for farmers who grow legumes, and allows legumes to be used in a crop rotation to replenish soil that has been depleted of nitrogen. The nitrogen fixation ability of legumes is enhanced by the availability of calcium in the soil and reduced by the presence of ample nitrogen.

Legume seed and foliage have a comparatively higher protein content than non-legume plant, probably due to the additional nitrogen that legumes receive through nitrogen-fixation symbiosis. The high protein content makes them desirable crops in agriculture.

**PULSES**

One important category of crops is pulses. A pulse is an annual leguminous crop yielding from one to twelve grains or seeds of variable size, shape, and color within a pod. Pulses
are used for food and animal feed. The term "pulse", as used by the Food and Agricultural Organization (FAO), is reserved for crops harvested solely for the dry grain. This excludes green beans and green peas, which are considered vegetable crops. Pulses are important food crops due to their high protein and essential amino acid content. Like many leguminous crops, pulses play a key role in crop rotation due to their ability to fix nitrogen. Pulses are 20 to 25% protein by weight, which is double the protein content of wheat and three times that of rice. For this reason, pulses are called "vegetarian's meat". Examples are dry bean, chick pea etc.

Another categorization of crops would be in terms of seasonality. Thus, there would be winter and summer crops.

Examples of winter crops are; peas, potatoes, cabbage. Summer crops are creepers, egg plant. However with research, winter crops can be grown in summer with the development of summer variety.

**Supplementary Readings:** To learn more about pulses go to:

Wikipedia. (nd.). Pulses [http://en.wikipedia.org/wiki/Pulse_(legume)]

**PLANT FAMILIES**

Another way of classifying plants is by plant families. This classification is based on common plant parts such as seeds, flowers, fruits etc.

The table below shows the main families commonly grown in the small states.

<table>
<thead>
<tr>
<th>Family</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Solanaceae</em></td>
<td>eggplant, tomato, chilly</td>
</tr>
<tr>
<td><em>Brasicas</em></td>
<td>crucifers ex. cabbage, Chinese cabbage,</td>
</tr>
<tr>
<td></td>
<td>cauliflower</td>
</tr>
<tr>
<td><em>Cucurbitaceae</em></td>
<td>cucurbits ex. cucumber, pumpkins,</td>
</tr>
<tr>
<td></td>
<td>watermelons, squash, gourds</td>
</tr>
<tr>
<td><em>Leguminosae (also called Fabaceae)</em></td>
<td>legumes: bean, pea, soybean, peanut</td>
</tr>
<tr>
<td><em>Aliaceae</em></td>
<td>onion, garlic</td>
</tr>
<tr>
<td><em>Musaceae</em></td>
<td>banana</td>
</tr>
<tr>
<td><em>Asteraceae</em></td>
<td>lettuce</td>
</tr>
<tr>
<td><strong>Family</strong></td>
<td><strong>Crops</strong></td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td><em>Convolvulaceae</em></td>
<td>sweet potato</td>
</tr>
<tr>
<td><em>Annonaceae</em></td>
<td>pawpaw, custard apple, sour sop</td>
</tr>
<tr>
<td><em>Annacardiaceae</em></td>
<td>mango</td>
</tr>
<tr>
<td><em>Aracaceae</em></td>
<td>coconut, palms</td>
</tr>
<tr>
<td><em>Araceae</em></td>
<td>eddoes or taro</td>
</tr>
</tbody>
</table>

**Supplementary Readings:** To learn more about plant families it is recommended you read the following:


The SeedSite.com. (nd.). Plant Families. ([http://www.theseedsite.co.uk/families.html](http://www.theseedsite.co.uk/families.html))

**ENVIRONMENTAL FACTORS IMPACTING CROP GROWTH**

Local environmental conditions are important parameters that impact the growth and development of plants. The physical environmental conditions or abiotic factors include temperature, light, water, soil fertility. Biotic factors include animals, insects, and diseases.

Each plant has certain environmental requirements to attain the highest potential yields. To realise this objective a crop must be grown in an environment that meets these requirements. Some crops are grown in an environment that provides all their environmental requirements however; a crop can also be grown with some adaptation under unfavourable agro-climatic conditions. However, plants would produce a lower yield as a result of stress. The environment can be artificially modified such as in the greenhouse that emulates the actual environmental conditions that favour a good yield.

Let's investigate each factor in some detail.

**ABIOTIC FACTORS**

**Air Temperature**

Each crop grows and develops most rapidly at the optimum air temperature range which occurs mostly between 55 and 75°F (12 and 24°C). Most crops (and especially vegetables) can be classified according to the temperature requirements of their optimum air temperature range. However they are generally grouped into whether
they require low or high air temperatures for growth. Temperature requirements are usually based on night temperature. Those that grow and develop below 65ºF (18ºC) are the cool season crops, and those that perform above 65ºF are the warm season crops. Crops that originated in temperate climates usually require lower temperature, while those that originate in the tropical climates require warmer temperature.

**Soil Temperature**

Microbial growth and development, organic matter decay, seed germination, root development, and water and nutrient absorption by roots are much dependent on soil temperature, and this may have dramatic effects on the growth of plants. Generally, these processes occur faster at higher temperatures. Soil temperature also has significant influence on the size, quality, and shape of storage organs. Dark-coloured soils absorb more solar energy than light coloured soils.

Below freezing point, when temperatures are significantly low most crops are injured. This is quite evident in tropical or subtropical plants that are cultivated at a very higher temperature. This latter type of injury is called chilling injury. Susceptibility to cold damage varies with different species and there may be differences among varieties of the same species. The susceptibility of plants to damage as a result to cold temperature varies with the stage of plant development.

Too high temperatures may result in destruction of the protoplast which results in cell death. This mostly occurs at temperatures of 113-122ºF (45-55ºC).

**Light**

Photosynthesis is much dependent on light intensity. The amount of light received by plants in a particular region is affected by the intensity of the incident (incoming) light and the length of the day. Elevation and latitude influence the intensity of light. The amount of sunlight also varies with the season of the year and time of day, as well as, other factors, such as clouds, dust, smoke or fog.

Plants have varying preferences for light intensity. The light saturation point of the plant determines the relative light requirement of plant. The light saturation point is the point above which an increase in light intensity does not result in an increase in photosynthetic rate. Crops such as corn, cucurbits, legumes, potato, and sweet potato require a relatively high level of light for proper plant growth while onions, asparagus, carrot, celery, lettuce and spinach can grow satisfactorily with lower light intensity. Some plants flower when exposed to a specific day length. Short day plants flower rapidly when the days get shorter and long-day plants flower faster when days get longer. Plants that are not affected by day length are called day-neutral plants. These plants can flower under any light period.
Water

Water is essential to photosynthesis and plays an essential role in transpiration. Moreover, it regulates the stomata, and thus is crucial to growth and leaf expansion of plants. A steady active plant growth is mostly favourable when water is in balance (the supply is equal to the need). Stress in plants occurred when there is imbalance of water supply within the tissue. This occurs as a result when transpiration exceeds photosynthesis or the transpiration of water through the stomata exceeds the plant’s capacity to compensate for the internal loss.

Most crops have different critical growth periods, and if water stress occurs during critical stages of growth, yield is directly affected. When moisture requirements are not met during this critical phase, irreparable damage usually is the result. The plant quality is diminished, or the plant yield is reduced.

Drought is defined as a period without significant rainfall or moisture. Plant stress as a result of droughts would impair the growth and yield of plants. The plant may adjust to short-term water stress by closing the stomata and thereby reducing water loss through the leaves. When the stomata are closed, the plant wilts, carbon dioxide (CO2) from the atmosphere cannot enter the leaf; as a result photosynthesis is reduced or stopped. Growth will be slowed if such conditions are not corrected.

In a waterlogged condition, the pores in the soil are saturated with water so the oxygen supply is almost completely deprived. As a result, the availability of oxygen to plant roots is quite scanty and these can minimise the respiration process in the plants. Plants weakened by lack of oxygen are much more susceptible to diseases caused by soil-borne pathogens. Plant absorbs their nutrients in the form of solution, and waterlogging due to lack of oxygen in the soil causes death of root hairs, reduces absorption of nutrients and water, increases formation of compounds toxic to plant growth, and finally retards growth of the plant.

BIOTIC FACTORS

Biotic factors include soil organisms, pests, parasites, diseases, weeds.

Soil organisms which include bacteria, fungi, earthworm, nematodes and termites can cause damage to the crops and some of them are beneficial to crops. For example, the bacteria (Rhizobium bacteria) which live in the root nodules of legumes can fix nitrogen in the soil. On the other hand, other bacteria can cause diseases to crops.

Pests such as insects, rodents and birds can cause damage to crops which lowers their yields.
Parasites such as nematodes can cause a lot of damage to crops and as a result reduce their yield. Nematodes are slender, worm-like animals, typically less than 2.5 millimetres (0.10 in) long that infect plant roots, causing the development of root-knot galls that drain the plant’s photosynthate and nutrients. Infection of young plants may be lethal, (e.g. root knot nematodes).

Diseases which are caused by bacteria, virus and fungi can affect the growth and development of crops and therefore can reduce their yields.

Weeds also affect growth and development of crops because they can compete for sunlight, water, space and nutrients.

**SELECTION OF CROPS**

When selecting crops for food production in small states one must consider the following criteria:

**Adaptability of the crop to the local climate**: Crops produce high yield when they are well adapted to the environment.

**The consumer preferences**: Culture, religion and other factors can influence the choice and preferences of consumers for specific crops.

**Crop uses**: Some crops can be used for different purposes, foods, drinks, fodder, decorations etc.

**Import substitution**: Such crops when grown locally would also help to reduce foreign exchange drain.

**Nutritional value**: The nutritional value for the end client and the environmental requirements to grow the products needs to be considered. Examples are provided in the table below.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Scientific Name</th>
<th>Description</th>
<th>Nutritional Value</th>
<th>Environmental Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potatoes</td>
<td>Ipomoea batatas</td>
<td>Root tuber, annual</td>
<td>Carbohydrates</td>
<td>High light, potassium for lateral growth, dry weather for harvesting</td>
</tr>
<tr>
<td>Cassava</td>
<td>Manihot esculenta</td>
<td>Root tuber, annual</td>
<td>Carbohydrates</td>
<td>High light, moderate nutrients and moderate water,</td>
</tr>
<tr>
<td>Taro</td>
<td>Colocasia</td>
<td>Stem tuber,</td>
<td>Carbohydrates</td>
<td>Tropical, wet</td>
</tr>
<tr>
<td>Crop</td>
<td>Scientific Name</td>
<td>Description</td>
<td>Nutritional Value</td>
<td>Environmental Requirements</td>
</tr>
<tr>
<td>----------</td>
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<td>-------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Maize</td>
<td><em>Zea mays</em></td>
<td>Cereal, annual</td>
<td>Carbohydrates</td>
<td>High light, moisture, high N demand</td>
</tr>
<tr>
<td>Rice</td>
<td><em>Oryza sativa</em></td>
<td>Cereal, annual</td>
<td>Carbohydrates</td>
<td>High light, high moisture, low moisture at harvesting</td>
</tr>
<tr>
<td>Beans</td>
<td><em>Phaseolus vulgaris</em></td>
<td>Legume, annual crop</td>
<td>Protein</td>
<td>High moisture during growth, dry weather at maturity</td>
</tr>
<tr>
<td>Lettuce</td>
<td><em>Lactuca sativa</em></td>
<td>Leafy vegetable, annual</td>
<td>Vitamins and Minerals</td>
<td>High light, high nitrogen</td>
</tr>
<tr>
<td>Spinach</td>
<td><em>Spinacia oleracea</em></td>
<td>Leafy vegetable, annual</td>
<td>Protein, Vitamins and Minerals</td>
<td>High light and nitrogen</td>
</tr>
<tr>
<td>Tomatoes</td>
<td><em>Solanum lycopersicum</em></td>
<td>Fruit, salad, annual</td>
<td>Vitamins and Minerals</td>
<td>High light, calcium</td>
</tr>
<tr>
<td>Banana</td>
<td><em>Musa spp</em></td>
<td>Starchy fruit</td>
<td>Carbohydrates and Potassium</td>
<td>Tropical, high moisture throughout</td>
</tr>
<tr>
<td>Mango</td>
<td><em>Mangifera indica</em></td>
<td>Fruit, perennial</td>
<td>Contains Vit A, C and E</td>
<td>Frost-free, warm dry tropical climate, dry temp. For flowering</td>
</tr>
<tr>
<td>Pawpaw</td>
<td><em>Carica papaya</em></td>
<td>Papaya, deciduous</td>
<td>Contains Vit A, C, Laxative</td>
<td>Requires warm, humid, tropical weather, frost tolerant</td>
</tr>
<tr>
<td>Coconut</td>
<td><em>Cocos nucifera</em></td>
<td>Palm family, oil crop, perennial fruit</td>
<td>Oil, Dietary Fibre, Vitamins and Minerals</td>
<td>Warm temperature, high humidity, high rainfall</td>
</tr>
<tr>
<td>Bread fruit</td>
<td><em>Artocarpus altilis</em></td>
<td>Starchy fruit, evergreen</td>
<td>Carbohydrates</td>
<td>Tropical, wet, light shade when young, full light at</td>
</tr>
<tr>
<td>Crop</td>
<td>Scientific Name</td>
<td>Description</td>
<td>Nutritional Value</td>
<td>Environmental Requirements</td>
</tr>
<tr>
<td>------</td>
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<td>-------------</td>
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<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td>deciduous</td>
<td>maturity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY

This lesson has prepared you to select crops to cultivate based on environmental and biotic factors. The next lesson will build upon the lessons learned and guide you through the implementation of best practices for crop production.
LESSON 1.2 – CROP PRODUCTION BEST PRACTICES

OVERVIEW

Over the years there has been a marked development with rising standard of living and new consumer expectation for food standards and environment friendly production practices. The agricultural sector has lagged behind in terms of modernising its production practices to meet these new expectations due to several inherent constraints. Producers and their employees, as professionals in the agricultural industry need to respond to these exigencies.

This can only be achieved through the adoption of Good Agricultural Practices (GAP).

Its overall guiding principle is on the improvement of the quality and safety of the produce grown at each step in the production/supply chain while ensuring sustainability of production through the rational and judicious use of resources and also care of employees. Good Agricultural Practices are collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability.

OBJECTIVES

Upon completion of this lesson you will be able to:

1. Describe the criteria for selection of a site for crop production.
2. Examine the best practices in farm layout.
3. Discuss best practices in land preparation and sustainability.
4. Describe how to select plants based on farm location.
5. Examine the best practices employed in growing crops.

CROP PRODUCTION SITE SELECTION

Site selection for crop production is one of the most important parameters that should be critically analyzed before cultivation of any crop. Growing site provides all the basic necessities that facilitate the performance of crops from planting to harvest, but there is always variation among crops for the need of these elements. The most important factors in site selection are:

**Soil Type:** Soils vary in both physical and chemical properties and this can significantly influence the growth of crops. There are crops that are more adapted to clayey soils than sandy soil and vice versa. Sandy soil has poor water retention property and can be easily drained, is less suitable for the growth of crops that have adventitious type of root
system that are much more adapted to superficial growth. The better soil types are deep, well-drained, sandy loam and loamy soil. Heavy clayey soils are less suitable as they are poorly drained and easily waterlogged.

**Slope of the Land:** This is an important parameter that should be considered in site selection. In more pronounced sloppy land, there is high tendency of soil erosion, and in a very severe situation during high precipitation, some amount of landslide may occur which may eventually erode a large portion of the lands surface along with the crop. Moreover, sloppy land experiences inadequate distribution of light which is a critical requirement for the healthy plant growth.

**The Site Location:** The site should be distanced from areas that are prone to pollution activities such as waterways, aquifers, residential areas. It should be very close to water source for irrigation purpose most particularly in drier areas. The site history should be known e.g. previously industrial waste dumping sites should not be used for crop production.

**Nearness to the Market:** This is an important parameter when cultivating crops that are quite perishable, and need to be maintained or stored for a relatively shorter period. Cultivation of vegetables and fruits as classical crops should be close to the markets with a good accessibility.

**FARM LAYOUT**

A farm layout is the planning out of the farm. The farm should be arranged into different sections to identify where places in the farm are, for example to know where specific crops are to be planted. Crop farms should be designed:

- as an environment friendly enterprise that is the farming practices have minimal impacts on both on-farm and off-farm natural resources; or
- to allow for the optimum agricultural use and profitability of the site.

An on-site assessment of a farm is necessary so that a map can be drawn of the property’s topography, boundaries, soils, water resources, taking into account the cropping calendar and a farm business plan. Cropping calendar refers to sequence of crops on a farm on an annual basis.

**Factors to be Considered**

Crop Rotation: It is the practice of growing a series of different types of crops in the same area in sequential to avoid the build-up of pathogens and pests that often occurs when one crop species is continuously cultivated. Crop rotation also aims to balance the fertility demands of various crops to avoid excessive depletion of soil nutrients. An important component of crop rotation is the replenishment of nitrogen through the use of legume
crops in sequence with cereals and other crops. Crop rotation can also improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants.

**Topography:** Sloppy land is more susceptible to erosion. Cultural practices such as drainage, cover crops, terraces, contours planting should be envisaged. The steeper the slope, the higher is the risk of erosion. Perennial crops such as banana can be planted on a sloppy land.

**Boundaries:** At the initial stage, the establishment of windbreaks for protecting the crops against the impact of strong wind is to be considered.

**Soil Type:** Different crops have different soil suitability. Rice for example would grow best in a more marshy soil. Soil can be improved by incorporation of organic matter or soil amendments.

**Water Resources:** Irrigation systems should be considered where water resources are limited (see irrigation).

Field Layout - Based on Crop, Soil and Water Location
LAND PREPARATION

To ensure your farm is properly established and sustainable you need to carefully plan and implement the preparation of the land for cultivation. Some issues to consider are described below.

Land Clearing

Before planted, the land must be cleared. Land clearing involves:

- derocking;
- removal of weeds/brushing of primary or secondary bushes;
- removal of crop remains; and
- in some cases, cultivation of the land.

Land Clearing Methods

- Spraying with herbicides (type of weedcide will depend the types of weed present)
- Mechanical Control.
- Burning.
- combination of different techniques.

Mechanical Clearing

A range of mechanical operations are used to prepare and clear land of vegetation. Key factors to be considered for mechanical clearing are:

**Topography** – Consideration is made for the slope of the land. Various mechanical applications are best suited for particular site conditions.

**Foliage** – The size and species of foliage will influence the most practical mechanical means to employ.

**Availability of Skilled Labour** – The competence and attitudes of all involved will lead to a successful operation and safe practices.

**Soil Condition** – Wet clay soils may risk compaction by heavy machinery, therefore making planting difficult and affecting seedling root growth.

**Land Clearance**: The type of operations used in land clearing include:

- hand clearing,
- disking,
- root raking/Line raking,
• line dozing,
• gravity rolling,
• tractor crushing,
• towed rolling,
• ripping; and
• V-Blading.

Most of these operations involve crawler tractor units of varying capacities and capability, fitted with a cultivator.

Examples of crawler tractors used for clearance

CULTIVAR SELECTION
Crop production in various locations depends on the availability of plant varieties specifically adapted to local production conditions. Cultivar selection is very important aspect in ensuring the productivity of each cropping system. A cultivar is a specially developed type of a crop with specific characteristics to suit a particular environment.

Good cultivars are adapted to local climatic and soil conditions, provide resistance to major pests and diseases, produce acceptable yield and quality, and have appropriate agronomic characteristics that are compatible with production systems.

Hybrid Selection
Hybrids are produced when two cultivars from the same species are crossed. Hybrids are selected because they have desirable characteristics not found or inconsistently present in the parent individuals or populations. Choosing an appropriate hybrid is an essential for crop production. Each field has unique limitations, such as soil fertility, moisture intake, slope, insect and disease potential etc. And each manage has unique financial, labour, equipment resources available to address these limitations. Other production decisions also play a role on the type of hybrid to be selected. For example, an early maturing hybrid may give poor yields under full irrigation and a full season hybrid may not do well on a non-irrigated site. However, with all other things being equal, every crop producer wants the
highest yielding hybrid available. Hybrid seeds have the disadvantage of being expensive and hybridisation may results in the loss of many indigenous crop varieties if farmers use mass-produced hybrid seeds.

To preserve biodiversity for future generations, a gene bank of indigenous seeds should be kept. Local farmers should be encouraged to preserve local indigenous crops by sharing cuttings and other planting materials.

TILLAGE

Preparing a field for planting a crop entails moving soil by using tillage operations. **Primary tillage** is used to loosen the soil and incorporate organic residues. **Secondary tillage** is done in order to smoothen the top soil, break up clods and to kill weeds. The amount of tillage operations necessary depends on the soil conditions, the crop requirements, including the amount of residues on the field. In some situations (sloppy land), no-till is an option.

**Soil and Crop Assessment**

The extent of tillage should be matched to the crop and cultural practice requirements. Small-seeded crops require fine seedbeds. Rougher seedbeds can be tolerated for larger-seeded crops or transplants, saving on labour and soil structure. Wherever necessary, tillage should be reduced because tillage breaks soil aggregates and earthworm channels, thus promote compaction.

**Environmental Impact**

Crop production utilise important environmental natural resources: soil and water. The quality of these resources must be ascertained for sustainable systems. The use of heavy tillage machinery, loss of organic matter owing to soil disturbance, and adoption of chemical technologies for pest control have been causing soil degradation, pollution of ground water and increase production of green house gases. It is against that background that new tillage systems have been developed in order to maintain soil productivity and favourably affect environmental quality. In addition the type of tillage systems to be used will largely be determined by the farm size, labour availability, power sources and the technical skills of the farmer.

**Tillage Methods**

**Conservation tillage** is any tillage or planting system that maintains at least 30% of soil surface covered by residues after planting to reduce soil erosion by water. Crop residue is influenced by the type of crop that establishes the original residue and the type of tillage operations prior to planting. The use of conservation tillage varies by crop and is dependent on factors such as the soil type, top soil depth and local climatic conditions.
Conventional tillage on the other hand entails tillage operation over the field for a long period of time to prepare good seedbeds by clearing surface residue and interrupting insect, weed and disease cycles. This practice gives the crop weed-free germination condition, but leaves the soil bare for a long period of time, thus making it susceptible to erosion.

VEGETATIVE PROPAGATION

Plants have two ways of reproduction, sexually by means of seeds, and asexually or propagation by means of vegetative tissue. Both ways occur in living plants in nature. Some plants reproduce mainly by propagation while others rely almost totally on sexual reproduction. For the crop grower it is desirable to be able to manipulate sexual and vegetative reproduction to fit into the crop improvement programme. Genetically the two ways of reproduction differ. Seeds contain genes from the female and the male parent. Vegetative material is genetically identical to the mother plant from which it is collected.

There are several ways of vegetative propagation. The three main types in crop propagation are grafting, air-layering and the use of cuttings. The three types are referred to as macro propagation, as alternative to micro propagation or tissue culture. Propagation by cuttings is the most convenient and cheapest method and usually preferred where possible. Air-layering is a variation of propagation by stem cuttings in which root formation is initiated before the plant part is separated from the mother tree. In grafting, the shoot (scion) of the desired tree is joined with a root (stock or root stock) of different genetic origin. The methods of propagation to be used in a particular situation are a matter of experience with the individual crop species plus the purpose and conditions of the propagation.

AIR LAYERING

In air layering (or marcotting), the target region (bark) is removed and then surrounded with soil which is further surrounded in a moisture barrier such as polyethylene film. Rooting hormone is often applied to encourage the wounded region to grow roots. When sufficient roots have grown from the wound, the stem from the parent plant is removed and planted.

If you have an Internet connection and want to learn more about air layering watch the video at the following URL:

http://www.youtube.com/watch?v=eozrB950FFc&feature=player_embedded

CUTTINGS

Cuttings are parts of plants that are cut and separated from the mother crop and propagated to form roots and/or shoots and eventually develop into entire plants. Cuttings can be formed from roots, leaves or stems. The age of the tree and branch from where cuttings are collected has a very strong effect on rooting. Cuttings taken from young trees
usually have a much better rooting than cuttings from older material. Cuttings should be rooted under shade. The requirements and tolerances in terms of light and temperature etc. vary according to species.

Cuttings are easiest rooted under tunnel or greenhouse conditions, since several factors can be manipulated and controlled under these conditions. Most crucial factor is the water stress since the cuttings may easily desiccate until they have formed water-absorbing roots.

If you have an Internet connection and want to learn more about cuttings watch the video at the following URL:

http://www.youtube.com/watch?v=yFL-jEkWSV8&feature=player_embedded

ROOTING MEDIA FOR CUTTINGS

The following are common rooting media for cuttings:

**Water:** Can be used for easily rooting species. Its great disadvantage is the lack of aeration. Artificial aeration promotes rooting and impedes decaying.

**Sand:** The sand used should be fine enough to retain some moisture around the cutting and coarse enough to allow free draining. The sand should be washed and sterilized before use.

Seashore sand has a high salt concentration which may be toxic to some plants.

**Soil:** Well aerated sandy loam is preferable. Due to the possible presence of root-borne disease, soil may need to be sterilized or treated with pesticides eg. Seedlings.

**Peat Moss:** Used together with other materials in order to increase the water holding capacity.

**Coconut Husks:** Widely used in humid tropical environments where it has the same use as peat moss.

One or more of the following conditions may lead to failure of cutting materials to establish.

- The cutting material has flower buds but no or few vegetative buds.
- The cutting material was taken from too old plant parts.
- The cuttings were not taken from the trees at the appropriate time.
- The cuttings dried out before rooting was initiated or during the rooting process.
- The rooting medium is unsuited for the root formation.
- The cuttings were rooted with the distal end in the rooting medium.
- The cuttings were attacked by the fungi.
**GRAFTING**

In grafting, a scion from the genotype is united with a stock (root stock) from another plant (e.g. trees, roses). The scion contains the desired genes to be duplicated in future production by the stock/scion plant.

For a good grafting the root stock as well as the scion has to be in good conditions/right stage, and the two parts should be compatible.

The best time of grafting is 1–2 months before leaf flushing when the scions have dormant vegetative buds, i.e. the dry season just before the onset of the wet season; or in cool climates the cool season just before the onset of the warm season (spring). At that time the buds are just about to sprout and the level of the plant hormone auxin is high.

Grafting can be done in the nursery in which case the stock is growing in a container. For some species grafting can take place under field conditions, provided the graft union is well protected after the grafting.

**Securing the Graft:** Using the stretching tape avoids girdling. Adhesive tape is more convenient than non-adhesive tape since it does not need tying. The adhesive material should not be non-water soluble. Waxed string is convenient since it will adhere to itself and the plant part without tying. It should be strong enough to hold the grafted parts together, yet weak enough to be broken by hands. No stretching wrapping material needs to be removed in order to avoid girdling. Strips of plastic polyethylene or PVC about 30 cm long and 10–15 mm broad can be home made and be used as non-adhesive tape. These materials are lightly elastic but must be eventually removed.

**Additional Guidelines:** The following are general guidelines for grafting:

- Scions should be taken from the upper part of the tree.
- Scions should be taken from vigorously growing branches.
- Scion length should be about 15–25 cm.
- Scion diameter should be according to the size of the stock, i.e. 6–12 mm in diameter.
- Scions should be without flower buds.
- Scions should have well developed vegetative buds in a dormant stage.
CONSIDERATIONS WHEN GRAFTING

Grafting can be done either in the nursery or in the field. Some advantages and disadvantages of the two methods are listed in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nursery Grafting</strong></td>
<td>• Grafting procedure quick (short distance between root stocks).</td>
<td>• Problems with fungal diseases.</td>
</tr>
<tr>
<td></td>
<td>• Easy control of identity of the scion.</td>
<td>• Problems with restricted root development of container plants.</td>
</tr>
<tr>
<td></td>
<td>• Grafting can be done under any weather condition.</td>
<td>• Labor intensive care of container plants.</td>
</tr>
<tr>
<td></td>
<td>• Easy to protect grafting material during grafting</td>
<td>• Relatively slow growth and late flowering.</td>
</tr>
<tr>
<td></td>
<td>• Easy to manipulate climate optimal for the grafted plants.</td>
<td></td>
</tr>
<tr>
<td><strong>Field Grafting</strong></td>
<td>• Few problems with fungal diseases.</td>
<td>• Grafting procedure slow (distance between root stocks).</td>
</tr>
<tr>
<td></td>
<td>• No problems with restricted root development of the stock</td>
<td>• Difficult in keeping control of the identity of the scions.</td>
</tr>
<tr>
<td></td>
<td>• Care of field stock rarely necessary.</td>
<td>• Grafting restricted under adverse weather conditions.</td>
</tr>
<tr>
<td></td>
<td>• Relatively fast growth and early flowering</td>
<td>• Difficult to protect grafting material from desiccation during the field work.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Special requirement for the protection of the grafted plants in the field.</td>
</tr>
</tbody>
</table>

Consider the following when grafting.

- The two parts may not unite and the plant will die due to:
  - incompatibility of the root stock and scion/bud.
  - lack of sufficient cambial contact due to in-proper cuts or/and unfit joint.
  - desiccation of the graft union.
  - water or infection is entering the joint.
- the plants dry out due to lack of watering or too dry an atmosphere due to:
bad timing of the grafting, i.e. in-proper stage of development of the scion/bud.
- the scion/bud has dried out before grafting.
- the root stock is in a bad condition.
- damage or loss of the bud(s).

**Care of Grafted Plants**

1. Grafted plants are susceptible to evaporation from the cut until callus has been formed to close the wound. Therefore it should be kept in a humid atmosphere until the two parts have grown together. In the nursery they can be kept in a humid atmosphere in a mist house. In the field, the grafted plant can be covered by a plastic bag.
2. After the parts have united, the wrapping material should be removed and the plants still be kept in the nursery for some time to harden.
3. Normal nursery practices of watering, root-pruning etc. should be carried out until the plants are planted out.
4. Shoots and branches that grow out from the root stock, i.e. below the grafting point should be removed. In order to help in identifying the graft union for a long time, the place of union may be painted.
5. If flowers occur in the first year or before the vegetative parts have been sufficiently developed, they should be removed.

**SEED PRODUCTION**

Seed is a farmer’s most valuable input more so in a context of small island/state agriculture with limited financial resources. Seed of low quality would not contribute towards food security and would impact on farmers’ yield and income. In order to ensure availability of good quality seeds (seed security) there are a number of principles to be considered. Since 1987, the FAO has developed the Quality Declared Seeds (QDS) scheme.

Quality Declared Seed is seed produced by a registered seed producer, which conforms to the minimum standards for the crop species concerned and which has been subject to the quality control measures outlined in the guidelines. The Farmer Guarantees the Seed Quality.

The QDS scheme helps to encourage local seed (open pollinated) production in countries where the adoption of a fully certified scheme for seed production is difficult or where a seed certification scheme is absent.

- It is less technical than a full seed certification scheme.
- It is less demanding in terms of resources.
- It is easy to adopt.
• It provides reasonable safeguards that the seed produced and offered for sale is of standard suitable for crop production.
• It promotes efficient production and distribution of quality seed among local farmers and traders.

The QDS system needs a regulatory framework to operate, namely:

• for inspection of fields and seed lots,
• for technical guidance in rogueing, field sanitation,
• seed processing and storage, and
• to ensure that the seed producer abides to the rules of QDS protocol, officials will check 10% of the crops in the field and 10% of the seed for sale.

Production protocols are as follows:

• Confirm site isolation.
• Confirm field status (past crops-crop rotation, weed, disease).
• Ensure standardized production practices available for specific crops (good planting material with the desired varietal characteristics, planting distance, fertilizer recommendation, pest and disease control programme).
• Conduct field inspection and rogueing at pre planting, vegetative stage & flowering stage for uniformity, plant quality.

Seed produced should be properly labelled mentioning crop and variety, varietal purity, germination percentage, moisture content, producer, origin and contact point, date packed.

**Supplementary Readings:** To learn more about the Quality Declared Seed System you should review the following online FAO web site:

[FAO. (nd.). Quality Declared Seed System.](http://www.fao.org/docrep/009/a0503e/a0503e00.htm)

**SEEDLING PRODUCTION**

Quality seeds are rare and expensive resources (especially hybrid seeds). Every effort in a sustainable production system should be made for its optimal use. Every seed should count. Farmers having recourse to direct sowing tend to use seeds irrationally with a high seed rate/hole to ensure crop establishment.

The use of quality seedlings is a key factor that ensures uniform crop stand and good yield. Quality seedling (transplants) refers to strong, vigorous, healthy planting material with excellent root stem.
Quality seedlings improve the chance of success and provides the following advantages:

- Helps to minimize seed wastage.
- Reduces transplantation shock and increase the chance of survival.
- Favours rapid plant establishment.
- Reduces crop cycle in field and favours early harvest.
- Helps farmers to save time.
- Ensures uniform crop stand and higher yield.

Vegetable seedlings can be raised on seed beds in open field conditions or under protected structure (mini tunnels) or nurseries.

![Example of mini-tunnels](image)

Tunnels and nurseries are to be sited:

- in a secure place;
- exposed to sunlight;
- protected from wind;
- away from cultivation site; and
- fenced.

Seedlings raised under open field conditions are more exposed to pests and diseases attack and adverse climatic conditions. Moreover, at transplanting stage, the bare-rooted seedlings suffer from transplanting shock often resulting in high mortality, poor crop stand and low yield.

Transplants ensure a uniform and complete stand of plants. Transplant production requires approximately 4-5 weeks. They are raised in seed trays, jiffy pellets, plastic bags and are ideal because they allow field planting without disturbing the root system.

Seed/plug trays or containers are filled with a sowing medium such as commercial potting soil, or a potting mix prepared from a combination of top soil, compost, sand and fertilizers.
(N, P, K). In case of adverse climatic conditions seed trays can easily be transported to a secure place.

Examples of seed trays

Seeds may also be sown (broadcast or in lines (10 apart) in seed beds (add dry sand for small seeds for proper disposal). The seedbeds (1m wide and 20-25 cm high, length varies) should be fertile and well drained. Incorporate a thin layer of compost and some fertilizers in the bed. After sowing, cover with a thin layer of soil and water regularly. After seeds have germinated, there is a need to thin out some of them for optimal plant density for plant growth. Thin seedlings at the first true leaf stage.
New seedbed.

TRANSPLANTING

The ideal transplant is a seedling with 3-4 true leaves, stocky and disease-free, and without flower buds. Transplanting can be done manually or by machine.

- Begin hardening plants 6-9 days before transplanting.
- Slightly withhold water.
- Expose seedlings to stronger sunlight.
- Thoroughly water seedlings 12-14 hours before transplanting to the field.
- Select the healthiest and strongest ones.
- Transplant to holes with care so as not to damage the root system. Seedlings in jiffy pellets are transplanted directly while those in containers need to be removed from them.
- Transplanting should be done in the late afternoon or on a cloudy day in order to minimize transplanting shock.
Sustainable Agriculture in Small States

PLANTING METHODS

Giving crops a healthy start begins with proper planting. Problems showing up on established crops can often be traced back to poor planting. Traditional planting methods are often passed down through the generations. While some of the old ways are still recommended today, many planting practices are changing to reflect current research and technology.

There are many different methods that can be used for planting crops. The key with getting seeds to germinate is to have good "seed/soil" contact, which means that soil is in direct contact to the surface of the seeds. Ideally the best seed/soil contact is where the seeds are completely surrounded by soil.

Planting methods applied are:

- manual planting
- broadcasting
- aerial seeding

Manual Planting

The seed is placed in the furrow or hole by hand and covered with soil by closing the furrow/hole. With this system the planting depth and planting distance may be irregular.

Aerial Seeding

Aerial seeding is a method whereby an airplane or helicopter drops a high rate of seed onto the soil surface through the canopy of an already established summer crop. Depending on the weather during stand establishments, yields from aerial seeding can be very high or the crop can be a complete failure. Small-seeded crops such as wheat can be planted by aerial seeding.
Broadcasting

The seed is broadcast on the soil surface with a fertilizer spreader and incorporated into the soil with light tillage (usually disk or field cultivator).
Seed broadcasting with tractor

PRINCIPLES OF PLANTING

To ensure proper germination of seeds, the following factors should be considered:

1. The seeds must be planted (covered by a thin layer of soil) at the correct depth.
2. There should be good seed/soil contact and the soil should allow moisture to enter the seeds.
3. The temperatures (and season) must be right for the particular type of seeds planted. Depending on the soil type, watering may be required for multiple times daily in order to keep the soil moist for the seeds and seedlings to grow.

The time of planting is another factor that the farmer must make. The time of planting in an area will be determined by:

1. The temperature and the climatic conditions of the area.
2. The occurrence of the first rain and the distribution thereafter to store sufficient moisture in the soil of the plant at the time it has the largest requirement. This would not apply with the availability of an irrigation system.
3. The type of crop to be planted (e.g. summer or winter crops).
4. The cropping system used.
LESSON ASSIGNMENT

Task: Develop an annual cropping calendar that would provide the three main sources of nutrients. i.e. carbohydrates, proteins and vitamins/minerals. You are to take into account crop seasonality and give explanations on selection and timing of crops.

Instructions: The calendar and explanation should be no more than two page. Submit your final paper to your instructor for review, feedback and grading. The instructor should provide a due date and additional guidance.

SUMMARY

This lesson discussed some of the best practices guiding crop production. Farmers must consider the type of crop, the selection of seeds vs. seedlings, the creation of seedlings and the location of planting. We also examined how to prepare the land for planting and how to plant the crop.

The next lesson will explore the issue of water management and how to ensure that your plan
LESSON 1.3 – WATER MANAGEMENT

OVERVIEW
Water is vital to crop growth. Water constitutes about 80% of the dry weight of a crop. It transports all nutritive elements to the plant as well as those produce by the plants. Optimal crop production cannot be envisaged without irrigation. It is to be stressed that water is a rare and vital resource and every effort should be made for its optimal use for a sustainable agricultural production.

In situation where rainfall is erratic or scantily distributed in a field plot, this does not favour a good development of the plant resulting in lower yield and at times crop failure (severe drought).

OBJECTIVES
Upon completion of this lesson you will be able to:

1. Discuss the issues related to agricultural water management.
2. Describe different irrigation methods.
3. Identify the guidelines governing responsible water management.

SYMPTOMS OF WATER STRESS
Plants are like any other living entity; they require water and exhibit specific signs when they do not get enough water. Some of the symptoms of plant water stress include:

- Wilting of plants particularly during high temperature at mid-day.
- Discoloration of the leaves (bluish and reddish color).
- Early or late flowering.
- Flower and fruit drop.
- Empty pods and small fruits.
Timely irrigation helps avoid water stress. Irrigation systems allow the farmer to:

1. Bridge rainfall deficit in the dry period of the year by provision of collected rainfall water.
2. Cultivate a variety of crops including high yielding ones (hybrids) which has a higher crop water requirement.
3. Spread out the cropping calendar thus avoiding production based on rainfall availability.
4. And finally to have better quality crops through its proper scheduling.

Generally the stages of germination, flowering, and fruiting are the critical times for crop development and the need for irrigation. Excessive irrigation does not help plant growth and in fact is a waste of water and could have an adverse affect on the plants. Essentially irrigation aims to provide water through different methods at critical stages and at the right place.

**IRRIGATION**

Various irrigation methods can be used to supply irrigation water to the plants. Each one has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local context. Four methods of irrigation include:

1. Manual - Via can or hose.
2. Surface Systems.

Let's examine each one.
SURFACE SYSTEMS

Surface irrigation systems essentially applies water on the surface of the field by gravity flow. Water is fed into small channels or along field borders. It is a wasteful system of irrigation as much water is lost between crop rows. It is suitable for row crops and trees.

[Image of crops being irrigated]

View this online video to see how surface irrigation systems very wasteful and should not be used unless no other alternative is available.

http://www.youtube.com/watch?v=E2lm1uyaeMI&feature=player_embedded

MANUAL SYSTEMS

This is the simplest method whereby water is collected from a water source (well, canals, reservoirs) and brought to the plant using a watering can or by a hose. It’s cheap but labour intensive and time consuming. It’s well adapted to small plots.

[Image of manual irrigation]

SPRINKLER SYSTEMS

The system comprises a network of pipes or hose with water being pumped and then sprayed onto the crops through rotating sprinkler heads. Water is spread more homogenously in a circle though it is susceptible to wind drift. Discharge varies with
different types of sprinklers. This system requires a power source a fair amount of maintenance (leakage, clogs).

There are some losses as water falls on the leaves and is not applied directly to the root zone (watered inter-row would favour weeds) and through evaporation (could be high in high temperature and dry conditions) of the fine water droplets.

Sprinkler irrigation is adapted for most types of crops. There are two major types of sprinkler systems:

- Static systems that must be installed in the field.
- Mobile systems that automatically move across the field.
DRIP SYSTEMS

A drip system is the most efficient irrigation method as water is judiciously used. Water is supplied under pressure through a pipe system to the crop, where it drips slowly onto the soil through emitters or drippers which are located close to the plants. Irrigation is localized and continuous (can be controlled via the irrigation pump controller) with only the immediate root zone of each plant being wetted (wet bulbs). It is a low pressure system as compared to the sprinkler system which requires a higher one. Water loss by evaporation and infiltration is limited. It also has the advantage of enabling application of fertilisers in the irrigation water.

The system is costly in terms of hardware/running cost and requires a fair amount of maintenance in terms of leaks, clogging of drippers and filters, insect damage and replacement of buried pipes.

FACTORS TO CONSIDER

Whatever irrigation method is chosen, its proper design, irrigation practice and maintenance are of utmost importance.

Some of the factors affecting irrigation are as follows:

- Crop water requirement of the plant (varies with crops and crop stage).
- Soil type (structure and texture, ex. sandy soils drains faster).
- Depth of soil to be irrigated.
- Water deficit calculated from rainfall and evapotranspiration*.
- Efficiency of the irrigation system.
* Evapotranspiration (ET) is a term used to account for water evaporation (by sun and wind) from the soil surface and plant transpiration to the atmosphere. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves.

Evapotranspiration = Transpiration + Evaporation

Evapotranspiration - Energy Balance from Media Innovation Team on Vimeo.

Go to: http://vimeo.com/2981941 to view video.

RESPONSIBLE IRRIGATION

Pumping large amount of water is detrimental to water table and can even result in the seepage of seawater into the water table in coastal regions. This contaminated water is not good for irrigation. As stated there is no advantage in over-irrigating. It can favour pests and diseases development (ex. excessive irrigation would favour damping off in nurseries, leaching of fertilisers, soil compaction).

Water should be applied until the soil at a depth of 10-20 cm is thoroughly wet. A tensiometer can also be used to determine irrigation schedule. It is a devise for measuring soil moisture tension.

Different tensiometers

Water should be applied when the upper layers of the soil are dry and plants are showing signs of water stress. Irrigate in the afternoon or early evening to minimize evaporation.
LESSON DISCUSSION

After completing this lesson your instructor should organize small group discussions to explore the following questions.

Consider the process used for water management in your local community.

1. What, if any, water management strategies exist?
2. What is the impact of these strategies?
3. How can you improve the water management approach in your local community or farm?

Discuss the above with your peers and collectively draw your own conclusions.

SUMMARY

Irrigation is the life blood of any farm. Effective irrigation systems with appropriate crop selection will increase production and ideally reduce the cost of production.
LESSON 1.4 – CROP NUTRITION

OVERVIEW
Crops depend much on nutrients which are naturally produced in the soil or supplemented into the soil to improve it. There are 20 essential nutrients which consist of macro- and micro-nutrients which are very essential for the growth and development of crops. Macro-nutrients are needed in large quantities while micro-nutrients are needed in smaller quantities by crops.

OBJECTIVES
Upon completion of this lesson you should be able to:

1. Identify what nutrients are essential to support crop growth.
2. Select the most appropriate fertilizers to support crop nutrition.
3. Examine alternatives to chemical fertilization.

ESSENTIAL CROP NUTRIENTS
The following are essential nutrients for crops’ growth and development:

1. Carbon (C), Hydrogen (H) and Oxygen (O) are beneficial elements for plant growth and they come from air and water.
2. Macro-nutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca) and Magnesium (Mg).
3. Micro-nutrients: Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Boron (B), Chlorine (Cl), Molybdenum (Mo), Cobalt (Co), Nickel (Ni), Silicon (Si) and Sodium (Na).

When crops don’t get enough of the essential nutrients from the soil they will not grow well therefore, showing deficiency symptoms for the nutrient which is deficient in the soil.

Supplementary Readings: To learn more about the nutrients that are essential to your crops you are asked to review the following web site.


Note: You need to review the four links: Major Nutrients; Secondary Nutrients; Micronutrients; and Crop Needs.
NUTRIENTS JOB AID - DEFICIENCY SYMPTOMS

The table below describes a number of symptoms of inappropriate or deficient nutrients.

<table>
<thead>
<tr>
<th>Plant Nutrients</th>
<th>Function</th>
<th>Deficiency Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Essential component of all protein</td>
<td>Light green to yellow appearance of leaves, especially older leaves; stunted growth; poor growth.</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Converts light energy to chemical energy (ATP) during photosynthesis.</td>
<td>Leaves may develop purple coloration; stunted plant growth and delay in plant development.</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Reduces water loss from the leaves and increases drought tolerance</td>
<td>Older leaves turn yellow initially around margins and die; irregular fruit development.</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Essential in manufacturing chloroplasts.</td>
<td>Initial yellowing of young leaves spreading to whole plant; similar symptoms to nitrogen deficiency but occurs on new growth.</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Regulates transport of other nutrients into the plant and also activates certain plant enzymes.</td>
<td>Reduced growth or death of growing tips; blossom-end rot of tomato; poor fruit development and appearance.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>An important part of chlorophyll and important in photosynthesis. It is important in the production of ATP through its role as an enzyme cofactor.</td>
<td>Initial yellowing of older leaves between leaf veins spreading to younger leaves; poor fruit development and production.</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>Deposited in cell walls and contributes to its mechanical properties.</td>
<td>Susceptible to lodging; reduces the number of panicles m² and the number of filled spikelets per panicle (in rice).</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Required in a large number of enzymes and plays an essential role in DNA transcription.</td>
<td>Inter-venal yellowing on young leaves; reduced leaf size.</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Involved in many enzyme processes. Necessary for proper photosynthesis. Involved in the manufacture of lignin and grain production.</td>
<td>Causes die back of the shoot tips, and terminal leaves develop brown spots.</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Necessary for photosynthesis and is present as an enzyme cofactor in plants.</td>
<td>Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue.</td>
</tr>
<tr>
<td>Plant Nutrients</td>
<td>Function</td>
<td>Deficiency Symptoms</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Necessary for building the chloroplasts.</td>
<td>Inter-veinal yellowing or mottling of young leaves.</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Important in sugar transport, cell division, and synthesizing certain enzymes.</td>
<td>Death of growing points and deformation of leaves with areas of discoloration.</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>Necessary for osmosis and ionic balance; it also plays a role in photosynthesis.</td>
<td>Leaves are small and yellowish with spotty necrosis. The chlorosis occurs on smooth flat depressions in between leaf blade and in more advanced cases bronzing on the upper side of the mature leaves.</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>A cofactor to enzymes important in building amino acids.</td>
<td>Have pale green leaves with rolled or cupped margins.</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>Required for iron absorption.</td>
<td>Plants may fail to produce viable seeds.</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Involved in osmotic (water movement) and ionic balance in plants.</td>
<td></td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>Required for nitrogen fixation in legumes and in root nodules of non-legumes.</td>
<td>Deficient levels could result in nitrogen deficiency symptoms.</td>
</tr>
</tbody>
</table>

**TYPES OF FERTILIZERS**

As the essential plant nutrients are produced in the soil, they can be depleted if the land is cultivated year after year. In some soils they become infertile and these nutrients need to be put back into the soil in order for it to meet the needs of the crops.

Deficiency symptoms provide information on the types of fertilisers to be used. Fertilizers can be categorized into two groups namely: Organic fertilizers and Inorganic fertilizers.

**Organic fertilizers:** Organic fertilizers are derived from animal wastes or plant residues; or minerals naturally occurring.

**Inorganic fertilizers:** Inorganic fertilizers are produced synthetically by man or they are manufactured in industries by man using the Haber - Bosch process.

Let’s explore both types of fertilizers.

**COMPOSTING**

Organic fertilizers are derived from animal wastes or plant residues; or minerals naturally occurring. Examples of organic fertilizers are farmyard manure, green manure, compost, worm castings, seaweed, saltpetre and guano. Organic fertilizers improve the soil structure
and they are slow releasing fertilizers. In the long term they are available for plants to take up.

Compost can be made on the farm at very low cost as most of its ingredients can be easily found around the farm.

Composting is the purposeful biodegradation of organic matter, such as farm yard manure and food waste. The decomposition is performed by micro-organisms, mostly bacteria, but also yeasts and fungi. Composting converts organic waste into an extremely useful humus-like, soil end product, permitting the return of vital organic matter, nutrients, and particularly bacteria that is vital to plant nutrition to the soil.

The composting process happens due to the activity of micro-organisms (bacteria) and other larger organisms like worms and insects. These need certain conditions to live and be able to ‘work’ optimally. Conditions required for optimal composting are:

- Type of organic material.
- Air.
- Moisture.
- Temperature.

A good composting process passes through 3 consecutive phases, these are as follows:

**Heating Phase** - During the first stage of composting, the compost heap starts to heat up considerably and it results in the breaking down of the complex and tough fibrous material of the organic matter.

**Cooling Down Phase** - The fermentation phase gradually changes into a cooling down phase. Decomposition occurs without much generation of heat and the temperature drops slowly. During this period new types of micro-organisms convert the organic components into humus.

**Maturation Phase** - In this end phase of decomposition, the temperature drops to soil temperature, depending on the climate, 15-250 C. Apart from the micro-organisms mentioned, the large soil fauna (worms, termites, and insects) are active at this stage too. The compost is ready for use if it feels crumbly and looks like good brown/black organic soil.

To learn more about composting for sustainable agriculture view the following video:

http://www.youtube.com/watch?v=5NFhkO6MsmM&feature=player_embedded

**ORGANIC MATERIAL**

In general, any type of organic material of plants and animals can be used. It is essential to mix old and tough materials, which are difficult to decompose (crop residues, small twigs),
with young and sappy materials, which are easily decomposable (fruit, vegetable skins, young leaves). This is because different types of organic matter contain different proportions of carbon (C) and nitrogen (N). The micro-organisms who decompose the organic matter need both carbon and nitrogen to function well. In general, young, living material that decomposes fast contains low levels of carbon but high levels of nitrogen. Tough, dead material decomposes slowly and contains large amounts of carbon but low amounts of nitrogen. Too little nitrogen-rich material means the composting process will be slow, too much of it will result in the heap becoming acid and smelly. The ideal ratio of carbon and nitrogen for starting a compost pile is a C:N ratio = 25-30 :1.

Examples of nitrogen-rich materials are: young leaves, all types of manures, fish meal, fish waste, urine, leguminous plants.

Examples of carbon-rich materials are: dry leaves, crop residues of maize, sugarcane, rice, etc., twigs, wood-shavings, carton, etc.

Plant parts sprayed with chemical pesticides can have an adverse effect on the decomposition and the quality of the compost. Diseased material with rusts and viruses for example, should be kept to a minimum.

REQUIREMENTS

All composts require three ingredients: micro-organisms; air; and moisture. Let's look at all three.

Micro-Organisms

The first condition for composting is the presence of the composting organisms. Adding these organisms to the heap can be done by mixing ready-made compost with the organic materials. If there is no compost the soil can be added. Collect this soil preferably from a shady and humid place, e.g. from below trees.

Soil that contains moisture contains micro-organisms. Soil that has been dried out by the sun usually does not contain many living organisms.

Air

The micro-organisms in the heap require oxygen to survive and to do their work converting the organic material. The carbon dioxide which is produced by the micro-organisms as a result of their activity needs to be blown out by a flow of air. If there is not enough air in the heap, the useful micro-organisms will not survive. Other micro-organisms that do not need oxygen will thrive and decomposition of the organic material will slow down. In order to get enough air in the heap do not put the compost heap right up against a wall. When building up the heap put a layer of rough material (twigs) at the bottom, so air can enter the heap.
Moisture

The micro-organisms need moisture to live and to spread through the heap. The activity of the organisms will slow down if the heap is too dry. But if the heap becomes too wet, then there will not be enough air and the composting organisms will die. This will cause the heap to ferment rather than compost. Judging the right amount of water requires a little experience.

PLANNING

Choosing a good place for a compost heap is important. Bear in mind the following points:

- A shady place, out of the wind, is ideal. This could be behind a building or behind a row of trees. Moisture in the heap will then evaporate less quickly, yet here will be enough air. Under wet weather conditions the heap will have to be protected against excess water.

- Choose a protected and well drained place on a higher part of the land. Putting a simple roof above the place where the compost is made protects the heap against the sun and against the rain. The protection against these climatic influences will improve the composting process. Temperature and moisture level will stay more constant.

Setting up of the Heap

The compost heap can be above ground or underground in a pit or a trench. Whichever method is used, the heap of organic material has to be set up in a special way. Decomposition is easier if the material is cut into small pieces and if easily decomposable material is mixed with material more difficult to decompose.

A useful suggestion is to start the heap by a foundation of coarse plant material such as twigs or sugar cane stalks. The outside air can easily flow in under the heap and any excess water flows away more quickly. If the heap is built up in layers, the individual layers should preferably not be thicker than 10 cm for plant material and 2 cm for manure.

Covering the Heap

In an area of heavy rain the heap will have to be protected against excess water. Preferably it can be kept dry by putting a simple roof above the heap or even simpler: covering with a layer of leaves, a cloth, jute or plastic etc. If plastic is used then only cover the top, so that the air can penetrate through the sides. Trenches around the heap facilitate the run off of excess rain water. Covering the top with the materials mentioned can also be an advantage.
in dry areas. It prevents excess evaporation of moisture from the heap and it dries out less quickly.

**INORGANIC FERTILIZERS**

Inorganic fertilizers are produced synthetically by man or they are manufactured in industries by man using the Haber - Bosch process. Inorganic fertilisers can be of simple type ex: urea (nitrogen only) or complex type (3:4:3) which contains the three essential elements NPK

Examples of inorganic fertilizers are Nitrogenous fertilizers, Phosphorus fertilizers and Potassium fertilizers. NPK is a fertilizer which contains the nutrients; nitrogen, phosphorus and potassium. These are the macro-nutrients which plants need in large amounts.

- **Nitrogenous fertilizers are**: Ammonium sulphate, Urea, Ammonium nitrate sulphate.
- **Phosphorus fertilizers are**: chloride, Calcium ammonium nitrate and Superphosphate, Dicalcium phosphate and Tricalcium phosphate.
- **Potassium fertilizers are**: Potassium chloride and Potassium sulphate.

The inorganic fertilizers release the nutrients rapidly to crops. Micro-nutrient deficiency in crops can be difficult to diagnose. If crops are suspected of deficiency, this problem can be fixed by proper amendment. Adjusting the pH of the soil can make some of the micro-nutrients available for crops to take up.

**SUSTAINABLE FERTILIZATION PROGRAMMES**

A good fertility programme should be based on the knowledge of the difference between crop nutrient needs and the ability of the soil organic residues to supply nutrients. The following are steps to follow when implementing an effective, sustainable fertilization program:

- The nutrient needs of the crop as well as the nutrient status of the soil should be known. This can be achieved by regular soil tests.
- Determine the amount of nutrients supplied by non-fertilizers such as, animal manure, green manure, compost and soil organic matter.
- Apply the fertilizer to each crop at the time of its maximum nutrient uptake period.
- Use cover crops. Leguminous green manure provide nitrogen to the soil. Cover crops also add organic matter to the soil and improve soil structure.

**Soil pH correction**

Liming: Soils become acidic as a result of organic matter decomposition or by the addition of nitrogen fertilizers. The hydrogen ions produced by these processes displace calcium, magnesium, and potassium from the surfaces of the soil particles. These free salts are then
leached from the upper regions of the soil profile by water moving downward through the soil.

Decreasing soil pH diminishes activity of the bacteria and other beneficial fungi. Lower soil pH will also suppress the activity of nitrogen-fixing bacteria living in symbiosis with legumes.

The addition of lime to soil lessens the acidity. Lime adds calcium, a needed nutrient to reduce the concentrations of hydrogen ions which is the cause of low soil pH. Nutrients such as potassium and molybdenum become available when lime is added to the soil. Lime increases the rates of breakdown of soil organic matter, thus releasing available nitrogen into the plant root zone. Lime also reduces the need to fertilize.

Soil test, should be done to determine the soil acidity from which the amount of lime needed to neutralise it is be calculated.

**Supplementary Readings:** To learn more about sustainable agriculture and supporting fertilization programmes it is recommended your review the following online article:


**SUMMARY**

The use of appropriate organic or inorganic fertilizers will help enhance your farm output. But you must also determine what the impact is on your soil and on the ability of your farm to sustain the use of different types of fertilizers. You need to become familiar with what works in your environment and embrace the best practices in crop nutrition.
LESSON 1.5 – PEST MANAGEMENT

OVERVIEW

Pests and diseases are responsible for important crop losses (quantitatively and qualitatively). Pests include insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms), and microbes that destroy property, spread disease or are a vector for disease or cause a nuisance.

This lesson will examine methods of protecting your crops from various pests and the effective use of pesticides.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Describe the insects, pests and diseases that threaten your crops.
2. Explain the life-cycle of insects.
3. Describe the effective use of pesticides.
4. Explain the protective clothing required to apply pesticides.
5. Explain how the integrated pest management approach works.

INSECT THREATS

Insects damage plants when feeding on leaves, fruit and tubers. Type of damage can be chewing, sucking or mines. Insect populations have different life-cycles, but in general they go through either a three or four stage process as illustrated below.
Usually it is the larva which causes the most crop damage. Common insect pests are leaf miners, fruit borers, fruit worms, aphids, mites, leaf eating caterpillars, thrips, scales and whiteflies.

Below are some examples of insect damage.

<table>
<thead>
<tr>
<th>Aphids</th>
<th>Whiteflies</th>
<th>Caterpillars</th>
</tr>
</thead>
</table>

**CROP DISEASES**

Diseases are caused by pathogens (infectious diseases). Causative organisms are fungi, bacteria, viruses and nematodes. They are spread by spores over long distances by air or water, or they may be soil borne. Symptoms are leaf spots, leaf yellowing, leaf malformation, rusts, mildew and rot.

Below are some examples of different diseases on plants.
It is recommended you view the video produced by IGNOU. It describes the various threats to your crops and discusses means of fighting the various insects, diseases, etc. The video is about thirty minutes long, but worth watching.

http://www.youtube.com/watch?v=7WJxXWboYX0&feature=player_embedded

PESTICIDES

With the intensification and development of agricultural production, agro chemical industries have developed a range of pesticides for pest control. A pesticide is any substance or mixture of substance intended for preventing, destroying, repelling or mitigating any pest. A pesticide may be a chemical substance, biological agent (such as a virus or bacterium), antimicrobial, disinfectant used against any pest.

Herbicides are also considered as pesticides are used for killing invasive weeds, to clear roadside weeds, trees and brush.

Yet one has to bear in mind that pesticides are not only toxic (poison) to pests but also to humans (accumulation of toxic chemicals along the food chain or accidental ingestion). As such pesticides are meant to be used based on recommended protocols from regulatory agencies to decrease these associated risks to acceptable level for the user’s safety and the consumer as well as the environment.

CLASSIFICATION

Over the years different types of pesticides have been developed. These can be classified as follows:

According to the target pest

<table>
<thead>
<tr>
<th>Target organism</th>
<th>Examples</th>
<th>Category of pesticide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungi</td>
<td>Powdery mildew</td>
<td>Fungicide</td>
</tr>
<tr>
<td>Insects</td>
<td>Aphids, Fruit flies, leaf miners</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Mites</td>
<td>Red spider mites</td>
<td>Acaricides</td>
</tr>
<tr>
<td>Mollusc</td>
<td>Snail</td>
<td>Molluscide</td>
</tr>
<tr>
<td>Nematodes</td>
<td>Root knot nematode</td>
<td>Nematicide</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Leaf spot by Xanthomonas campestris</td>
<td>Bactericide</td>
</tr>
<tr>
<td>Virus</td>
<td>Tobacco mosaic virus</td>
<td>Virucide</td>
</tr>
</tbody>
</table>

According to their mode of action

1. **By contact:** The pest is killed when it is in direct contact with the pesticide.
2. **By ingestion:** The pest is killed when it eats a lethal dose of the pesticide which is applied to the surface of the plant.
3. **Systemic**: The pesticide is absorbed and dispersed in the plant. The targeted pest is killed when it eats or sucks a lethal dose.

4. **Growth regulators**: The pest is killed when it is changing to another growth stage.

5. **By repulsion**: In this case the product has a repulsive effect on the pests.

Pesticides can also be grouped into chemical families. Prominent insecticide families include:

- organochlorines,
- organophosphates,
- carbamates,
- pyrethroids, and
- biopesticides.

**Biopesticides** are the latest generation of pesticide and are microbial biological pest control agents (bacteria or fungi). They are considered more environmentally friendly than synthetic pesticides (ex. is Bacillus thuringiensis a bacterial based product).

Biopesticides, are considered as a key component of integrated pest management (IPM) programs and are receiving much practical attention as a means to reduce the load of synthetic chemical products being used to control plant diseases. They should not necessarily be viewed as replacements for chemical control of plant diseases, but rather as an important supplement in sustainable pest control strategy.

**Organic pesticides** are products developed natural plant materials. A common one is neem extract obtained from the neem tree (Azadirachta indica) and effective against flies, beetle and caterpillars or chilly extract, effective against ants, aphids and caterpillars.

**REGULATION AND TOXICITY**

Based on acute toxicity, pesticides are assigned to a Toxicity Class. This refer to a classification system where pesticide are assigned a toxicity Class based typically on results of acute toxicity studies in animal experiments, notably rodents, via oral, or sometimes inhaled, or external application. The system is based on LD50 determination in rats, thus an oral solid agent with an LD50 at 5mg or less/kg bodyweight is Class I-a, at 5-50 mg/kg Class I-b, at 50-500 mg/kg Class II, and at more than 500 mg/kg Class III.

The lower the LD 50, the higher is its toxicity!

The World Health Organization names four toxicity classes as follows:

- Class 1 – a: extremely hazardous;
- Class 1 – b: highly hazardous;
- Class 2: moderately hazardous;
- Class 3: slightly hazardous
After developing a pesticide list, the user should obtain labels of all products under consideration so that their strengths and weaknesses can be analyzed. Labels generally are available locally from retail outlets or their suppliers. These provide critical information to the user on product features and on risks relating to product use, together with correct measures to take in the case of an emergency. These should be read and understood before use. If you cannot understand the label then have it read and explained to you.

Pesticide labels are colour coded. See the toxicity table below.

<table>
<thead>
<tr>
<th>Depiction</th>
<th>Colour of lower triangle</th>
<th>Toxicity class</th>
<th>Oral LD₅₀ value (mg/kg)</th>
<th>Signal words (Upper half)</th>
<th>Warning words (Outside the diamond)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POISON</td>
<td>Bright red</td>
<td>Extremely toxic</td>
<td>&lt;50</td>
<td>POISON (In red)</td>
<td>Keep out of reach of children. If swallowed or symptoms of poisoning occur, call doctor.</td>
</tr>
<tr>
<td>POISON</td>
<td>Bright yellow</td>
<td>Highly toxic</td>
<td>51-500</td>
<td>POISON (In red)</td>
<td>Keep out of the reach of children.</td>
</tr>
<tr>
<td>DANGER</td>
<td>Bright blue</td>
<td>Moderately toxic</td>
<td>501-5000</td>
<td>DANGER</td>
<td>Keep out of the reach of children.</td>
</tr>
<tr>
<td>CAUTION</td>
<td>Bright green</td>
<td>Slightly toxic</td>
<td>&gt;5000</td>
<td>CAUTION</td>
<td>----</td>
</tr>
</tbody>
</table>

**PRECAUTIONS HANDLING PESTICIDES**

As stated the pesticide user is also at risk if he is applying it indiscriminately. Precautions to be taken are listed herewith:

Wear protective clothing. These comprises long sleeve shirt (cotton), long pants, an overall (plastic or PVC) and a hat.

Wear protective equipment viz. gloves, face shield, respirator/eye mask where required and boots (to be inside the pants’ end). Check that the equipment is in good condition before use.
Some general advice on the safe use of pesticides - Exercise caution at all times. Now let's examine the guidelines for handling pesticides.

**Before Application**

**Note**: Handling of concentrated product is more hazardous that diluted one. When working with pesticides consider the following:

1. Handle and transport products with caution.
2. Transport crop protection products separately from foodstuff or animals.
4. Always follow the label instructions for use. Applying more does not imply a better control. In fact it is costlier and could be phytotoxic to the plant and be a source of development of resistance to the product among the target pest.
5. Always wear protective gear.
6. Do not mix products ('cocktails'). It could be a cause of phytotoxicity or be incompatible and thus nullify its effectiveness.
7. Use suitable equipment for measuring and mixing. Do not scoop or stir with bare hand.
8. When preparing the dilution, prepare a paste in a container first before its incorporation in the sprayer. Or else it could cause clogging problem in the sprayer.
9. Evaluate drift risk (residential areas).
10. Inform the neighbourhood of your activity. Children are to be kept away.
During Application

During application of a pesticide consider the following guidelines.

1. Ensure that your sprayer is in good condition.
2. Use the right nozzle for corresponding treatment.
3. Do not spray during the hottest part of the day, windy period or when it is raining.
4. Avoid spraying at flowering stage as it could affect pollinators (or when they are not active).
5. Ensure that the wind is in your back when applying.
6. Do not eat, smoke or drink whilst handling, working with or applying crop protection chemicals.
7. Do not blow in clogged nozzles. Better use a thin wooden stick (no metal pin as it could damage the nozzle).
8. Always wash hands and face before drinking and eating.
9. Wash any chemical splashes immediately from skin or eyes. In case of accidental poisoning, take container/label to doctor/hospital.

Below are some examples of different application methods.

After Application

Some of the guidelines you should consider after applying pesticides to your crops include:

1. Avoid re-entering the field during the next 24 hours.
2. Place warning signs in the field.
3. Apply any spray mix left over on wild vegetation in the surrounding.
4. Abide to pre harvest interval of the product.
5. Always triple rinse emptied product containers and dispose by following local best practice.
6. Take a shower and wash your clothes after working with chemicals (wash spray clothes separately from the domestic washing).
INTEGRATED PEST MANAGEMENT

With the development of intensive agriculture, there has been a shift to heavy reliance on use of pesticides. As a result it did not take long for problems associated with chemical pest controls to be observed, among which:

- Imbalance in the fauna- Insects, formerly under natural control by predators and parasites, began to cause significant damage.
- Loss of beneficiaries/pollinators (bees).
- Build up of resistance among the pest to chemicals applied.
- Related illness among agricultural workers.
- Pollution of the environment (fishes/rivers-foodchain).
- Residues on harvest.

Consumers (export market but also local) also now want safe and affordable supply of ‘chemical free’ food products and are environment sensitive. As a consequence the concept of Integrated Pest Management (IPM) has been developed.

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on an array of complementary control methods/strategies. It is an integral part of recommended Good Agricultural Practices adopted worldwide by professional responsible farmers.
IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. IPM aims to minimize pest damage by the most economical means, and with the least possible hazard to people and the environment.

**IPM STRATEGIES**

IPM controls methods/strategies rely on:

**Strategy 1: Action Thresholds**

Before taking any pest control action, IPM first sets an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. Sighting a single pest does not always mean control is required. Periodic scouting to ascertain pest density are carried out and upon establishment of given densities chemical treatment is started, i.e. thresholds, example in cabbage it is 5 looper larvae per 10 plants at any plant stage. It is in fact the opposite of systematic recourse. e.g. in tomato, fruit worm control starts as from 6 larvae/6 plants. It is in fact the opposite of systematic recourse to preventive chemical application.

**Strategy 2: Monitor and Identify Pests**

Not all insects/weeds require control. Many organisms are even beneficial. IPM programs work to monitor for pests (scouting) and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.

**Strategy 3: Prevention**

As the first line of pest control, IPM programs work to manage the crop to prevent pests from becoming a threat. The next section will explore different control methods.

**PEST CONTROL METHODS**

IPM believes that more effective and less risky pest controls should be considered before applying pesticides. This would include:

**Natural Crop Management Methods**

Employing appropriate natural crop management methods can be very effective and cost-efficient and present little to no risk to people or the environment. These include:

- Rotation of crops into different fields/plots.
- Selecting pest-resistant varieties of plants.
- Land preparation: Ploughing to expose pests.
- Using pest-free planting material.
- Decrease plant density and increase pruning.
**Mechanical Control Methods**

Use of mechanical methods to protect your crops could include:

- Trapping (ex. yellow sticky traps against leaf miners).
- Nets over the crops.
- Mulching.
- Hand picking.

**Physical Control Methods**

Some of the ways of reducing pests includes:

- Hot water treatment of seeds.
- Use of natural repellents (planting marigold, coleus and lemon grass can drive away insects).

**Biological Control Methods**

Biological methods include the use of natural predators are used to control the targeted pests. An example of a biological control is the use of ladybugs to prey on aphids and scale insects.

Another method is the use of sterile insects who are repeatedly released into the field. The released insects are normally male as it is the female that causes the damage, usually by laying eggs in the crop. Eg. is the control of fruit flies, most particularly the Medfly (Ceratitis capitata). Sterile males will prevent the fertilization of the eggs.

**Chemical Control Methods**

Once a decision is reached to have recourse to a pesticide as a last resort, IPM programs would have recourse to a selective exercise of chemicals for effectiveness and risk. Bio pesticides would here be the first option to be considered then evaluate the proper chemical control method both.

**Summary**

The health of your products often depend on how the type of pest and disease management programs you employ. The health and safety of your customer is also contingent on the effective and safe application of pesticides. The ideal is to use natural or non-chemical methods that flow from the Integrated Pest Management approach.
LESSON DISCUSSION

After completing this lesson your instructor should organize small group discussions to explore the following:

Before the participating in the discussion each student should investigate the type of pests and diseases that impact on the local crops.

During the discussion be prepared to discuss:

1. Determine the type of pest and disease management strategies used by the local farmers.
2. Determine if these are the appropriate strategies?
3. If yes, why; if no what strategies and methods should be considered?

Explore the response to your investigations with your peers.

SUMMARY

The health of your products often depends on how the type of pest and disease management programs you employ. The health and safety of your customer is also contingent on the effective and safe application of pesticides. The ideal is to use natural or non-chemical methods that flow from the Integrated Pest Management approach.
LESSON 1.6 – PLANTING BEST PRACTICES

OVERVIEW
Agriculture's cultural practices are rooted in past tradition and historical best practices. Farmers have learned what works and what does not and they pass it down from generation to generation. This lesson will explore a number of cultural practices that support the effective management and growth of your agricultural crops.

OBJECTIVES
Upon completion of this lesson you should be able to:

1. Discuss the application of fertilizer.
2. Employ weed control strategies.
3. Examine soil management techniques to support plant growth.
4. Employ trellises and other tools to support your crop during growth.
5. Explore the best practices of pruning and dwarfing.

SOIL MANAGEMENT CULTURE PRACTICES
Soil management strategies have developed over time and experience. This includes how we prepare the soil and planting the crops.

Tillage
This practice aims at loosening the soil for improved aeration and water infiltration. It is done by turning the soil lightly in the crop interrow. The picture below illustrates a tractor tilling the soil.
Earthing Up

It is the technique of putting soil up around the base of a plant. It stabilises and encourages the development of the plant and also protects tubers from being exposed to sunlight (ex ‘green’ potato caused by solanine). It can be done manually (usually using a hoe) or mechanically. The picture below illustrates earthed-up potato plants.

Planting Methods

Crops can be raised through several methods among which in holes, furrows, ridges or in beds. The choice of planting method will depend on the crop. Sizes, depth/ height and
Spacing will also depend on the crop and soil type. Beds usually have a width of 1 meter for ease of work.

Supplementary Readings: To learn more about planting and beds it is recommended you read the following online articles:


FERTILIZER APPLICATION

Fertilizers are applied as basal (in the hole/furrows), top dressed that is after crop establishment (in band or circle). When applied in holes and furrows it need to be covered with a layer of soil to avoid contact with the seed while top-dressed fertilizers need to be covered to avoid volatilization (nitrogen loss by evaporation) and risk of ‘burning’ to young plants. Potash and phosphate fertilizers are applied as basal while nitrogenous based are applied as top dressing. In cases of micronutrients deficiency, these are sprayed as foliar fertilizer. In hydroponics system, fertilizers are applied as a nutrient solution (see hydroponics).

Supplementary Readings: To learn more about fertilizer application it is recommended you read the following online article:
Methods of Application of Fertilizer
(http://www.icrisat.org/vasat/learning_resources/OrganicFAQs/appli_fertilizer.htm)

Weed Control

Weeds compete with the crops for light, air, water and soil nutrients. They are also a ‘reservoir’ of pest and disease whereby they would be a continuous source of infestation. Failure to have a weed control strategy will result in poor crop development and economic cost for its control.

WEEDS CONTROL STRATEGY

You should adopt a proactive strategy aiming at preventing invasion of weeds. Following are recommended:

- Potential sources of weeds are tools, equipment, livestock manure, seeds which are moved from one farm to another. These need to be cleaned.
- Tillage to expose weed seeds to birds and other predators
- Band application of fertilisers is preferred to broadcast where the weeds are also fertilized.
- Crop rotation strategy which limit built up of weed population. Different crops have different cultural practices and as such make it difficult for the weed to develop. Creepers are good for ‘smothering’ the weeds. Legumes are good cover crops for orchards.
- Mulching which involves covering the soil with grasses, straw or plastic. The first two would also be a source of organic matter.
- Remove and eliminate (deep burying) weeds before they flower. Seeds produced will be more weeds for the next season. Weeding can be manual or chemical. Chemical weed control can be pre and post emergent i.e. before or after the emergence of the weeds.
- Intercropping where short cycle crops are grown in the interrow of long cycle ones whose canopy take some time to ‘close’. Ex. bean cultivation in the interrow of sugarcane plantation.
- Soil sterilization which involves the sterilisation of the soil to be cultivated either chemically (use of fumigants) or physically (solarisation).

THINNING

Thinning is the selective removal of excess seedlings, primarily undertaken to allow space for other seedlings to have a proper growth rate. It is usually carried out in crops where seeds are broadcasted ex carrots. Seedlings are removed by cutting or uprooting them.
Sucker management is a form of thinning. This usually refers to the removal of excess suckers in plants such as banana. It enables sustained yield when plant density is managed and their bearing spaced.

**TRELLISING**

A trellis is a structure, usually made from interwoven pieces of wood or bamboo with wires or string to support climbing plants (eg. creepers or cucurbits). It has the advantage of optimizing limited space and limiting fruit soil contamination. It is a common practice in hydroponic production where crops are grown ‘vertically’.

Different trellising methods are illustrated below.
FRUIT TREE PLANTING

Planting fruit trees requires some special considerations. Some of the guidelines are provided below.

**Staking**

It is a technique whereby a stake (sturdy stick) is placed near the axis of a transplanted plant and the plant tied to it. The stake acts as a support to the young plant. A more formal method of staking is described in the diagram below.
Windbreaks

Some areas and fruit trees are more exposed to strong winds. These winds cause soil erosion, increased rainfall, a reduction in the foliation area of plants, flattening of crops, drying of flowers, and damage to fruit trees. A windbreak reduces the wind substantially by providing effective protection for crops and helps to mitigate the adverse effects of strong winds. They should be permeable enough to allow a certain amount of wind to blow through. Windbreaks are established alongside fields depending on wind direction. Because the windbreak occupies a productive land area, it is important that it produces additional income to compensate for the loss in crops. The species selected should be suitable for lumber, firewood, and poles. They should be maintained and pruned regularly.
Pruning / Dwarfing

Pruning is a practice involving the selective removal of parts of a plant. This practice usually entails removal of diseased, damaged, dead, non-productive, or otherwise unwanted tissue from a plant, such as branches, buds, or roots. Reasons to prune plants include deadwood removal, shaping (by controlling or directing growth), improving or maintaining health, reducing risk from falling branches and both harvesting and increasing the yield or quality of flowers and fruits. Specific tools are used this purpose, such as pruning shears, pruning knives, loppers and chainsaw.

Topping is a very severe form of pruning which involves removing all branches and growths down to a few large branches or to the trunk of the tree. In orchards, fruit trees are often lopped to encourage re-growth and to maintain a smaller tree for ease of picking fruit.

Bagging

This practice involves covering the fruit bunch with a polythene bag which protects the fruits from damage caused by insects and disease.
Flower Induction

This is a technique whereby flowering is induced artificially using chemicals (ethylene) so as to have even flowering and harvest or avoiding biennial/alternate bearing (used in pineapple and some fruit trees).

SUMMARY

This lesson provided a number of best practices that have proven successful when planting crops and fruit trees.
UNIT 1 – ASSIGNMENT

Now that you have completed the first unit, you should complete this assignment before proceeding.

Task: Find a farm or tract of land and interview the farmer. Explore the following questions with the farmer.

1. What type of crops do you grow? Do you grow them from seeds or seedlings? Explain.
2. Do you practice any form of crop rotation? What form of tillage and planting methods do you use?
3. What is your water management approach and strategy to ensure a healthy crop?
4. What type of fertilizers or other forms of crop and soil nutrition do you use?
5. What threats exist to your crop?
6. What type of pest management and disease management strategies do you employ on your farm?

Deliverable: Upon completion of the interview and tour of the farm you are to produce a report. The report should address the questions and should include supporting data or diagrams to illustrate your answers.

Once you have produced your report submit it to your instructor for review, feedback and grading.
UNIT 1 - SUMMARY

In this unit you learned that in the Small States of the Commonwealth, there are varieties of crops which are grown which best suit the environment in which the countries are located. Crops grown are also in accordance to what people prefer and their nutritional needs.

Crops can be categorized into various groups according to their structures and functions. Some crops are put into similar groups because they have similar structures, functions and characteristics.

The physical environmental conditions are important parameters that favour the growth and development of plants. The physical conditions or abiotic factors include temperature, light, water, plant fertility, soil medium and biotic factors include animals, insects, and diseases.

It is important to consider the following factors when selecting crops for food security: adaptability of the crop to the local climate, consumer preferences and the use of the crop.

Good Agricultural Practices are a collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food agricultural products, while taking into account economical, social and environmental sustainability.

Site selection for crop production is one of the most important parameters that should be critically analyzed before cultivation of any crop type. Growing site provides all the basic necessities that facilitate the performance of crops from planting to harvest, but there is always variation among crops for the need of these elements.

Crop farms should be designed to protect the environment, allow for the optimum agricultural use and profitability of the site, and make sure that the farming practices have minimal impacts on both on-farm and off-farm natural resources.

Land preparation is one of the most important aspects in crop production. Preparing a field for planting a crop entails moving soil by using tillage operations. The amount of tillage operations necessary depends on the soil conditions, the crop requirements, including the amount of residues on the field.

Crop production in various locations depends on the availability of plant varieties specifically adapted to local production conditions. Cultivar selection is very important aspect in ensuring the quality of each cropping system. A cultivar is a specially developed type of a crop with specific characteristics to suit a particular environment.

Good cultivars are adapted to local climatic and soil conditions, provide resistance to major pests and diseases, produce acceptable yield and quality, and have appropriate agronomic characteristics that are compatible with production systems.
Plants have two ways of reproduction, sexually by means of seeds, and asexually or vegetatively by means of vegetative tissue. Both ways occur in living plants in nature. In nature, some plants reproduce mainly vegetatively while others rely almost totally on sexual reproduction.

Giving crops a healthy start begins with proper planting. Problems showing up on established crops can often be traced back to poor planting. Traditional planting methods are often passed down through the generations. While some of the old ways are still recommended today, many planting practices are changing to reflect current research and technology.

There are many different methods that can be used for planting crops. The key with getting seeds to germinate is to have good "seed/soil" contact which means that soil is in direct contact to the surface of the seeds. Ideally the best seed/soil contact is where the seeds are completely surrounded by soil.

Water is vital to crop growth. It transports all nutritive elements to the plant as well as those produce by the plants. Optimal crop production cannot be envisaged without irrigation. It is to be stressed that water is a rare and vital resource and every effort should be made for its optimal use for a sustainable agricultural production.

Crops depend much on nutrients which are naturally produced in the soil or are put into the soil to improve it. There are 20 essential nutrients which consist of macro- and micro-nutrients which are very essential for the growth and development of crops. Macro-nutrients are needed in large quantities by crops and micro-nutrients are needed in small quantities by crops.

Composting is the purposeful biodegradation of organic matter, such as farm yard manure and food waste. Composting converts organic waste into an extremely useful humus-like, soil end product, permitting the return of vital organic matter, nutrients, and particularly bacteria, that are vital to plant nutrition to the soil.

Pests and diseases are responsible for important crop losses (quantitatively and qualitatively). Pests include insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms), and microbes that destroy property, spread disease or are a vector for disease or cause a nuisance.

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on an array of complementary control methods/strategies. It is an integral part of recommended Good Agricultural Practices adopted worldwide by professional responsible farmers.
UNIT 2 – BEST PRACTICES IN LIVESTOCK MANAGEMENT

OVERVIEW

Livestock production varies in scale from systems of production and management in different states of the Commonwealth. Good Agriculture Practices (GAPs) will also be introduced in this section with particular reference with production of livestock.

The three systems of production in livestock are as follows: intensive, semi-intensive and extensive. These systems need to be understood by any farmer or entrepreneur. By comprehending these systems the farmer would assist in the development of their environmental, social and economic well-being. This type of sustainable development ensures that other living organisms are not adversely affected while maximizing economic and social profit for the farmers.

One of the main objectives is for the students to understand sustainable systems these systems encompass a variety of issues some of them include: the anatomy and physiology of farm animals from three classifications; ruminant, non-ruminant and avian. In this unit the students will also be able to study and research the anatomy and physiology of farm animals, breeding and selection, sustainable animal production systems, housing, nutrition, animal husbandry, animal health, and record keeping.

The student will develop a basic understanding in animal science and also hands on experience in the workplace as the activities given are practical and theoretical combined with on the job training at the end of this unit.

GOALS AND OBJECTIVES

Upon completion of this unit you should be able to:

1. Explain the contribution of livestock pieces to food security in your country.
2. Distinguish three categories of animals in terms of their housing, breeding, husbandry, nutrition, and health in relation to good agricultural practices.
3. Describe how livestock animals and good agricultural practices can be enhanced through record keeping.
4. Identify your role in animal husbandry.
5. Explain the best practices for the care and breeding of farm animals.
6. Describe the diseases that impact the health of your animals.
7. Explain how to counteract disease and poor health.
LESSON 2.1 – ANIMAL ANATOMY AND PHYSIOLOGY

OVERVIEW

In this lesson the student will have an opportunity to learn and research about the anatomy and physiology of three categories of farm animals.

Farm animals are classified as ruminant, non-ruminant and avian. This classification is based on different digestive systems of these groups of farm animals.

1. Ruminant are animals that chew their food and their digestive system consist of two or more stomachs. An example is a cow.
2. Non ruminants also chewed food but have only one stomach. An example is a pig.
3. Avians swallow their food whole and have one stomach to digest the food. An example is a chicken.

We will explore all three during this lesson.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Describe the similarities and differences of ruminant vs. non-ruminant vs. avian anatomy and physiology.
2. Identify the different organs and supporting systems and their functions of ruminant, non-ruminant and avian farm animals.
3. Examine the skeletal systems of the three categories of farm animals.

DIGESTIVE SYSTEMS

All digestive systems take the food we eat and break down into different nutrients absorbed by the body. Most foods must be broken down before this absorption can take place. This is achieved by chemical and physical actions in our digestive system. Most animals (including humans) have some form of a digestive system. Let's explore the different types in our three categories of farm animals: ruminant, non-ruminant and avian.

RUMINANT DIGESTIVE SYSTEMS

Cattle, sheep and goats belong to a class of animals called ruminants. Ruminants have a digestive system which allows them to utilize roughages (e.g. hay, grass) as a major source of nutrients. These animals have a large (capacity up to 50 gal. or more)

All have a fluid filled digestive organ at the beginning of the digestive tract called the rumen. See the diagram of a cow and goat digestive system below.
In the ruminant's digestive system the different organs perform the following functions:

<table>
<thead>
<tr>
<th>Organ</th>
<th>Function</th>
</tr>
</thead>
</table>
| Rumen            | Largest of the four parts  
Filled with bacteria  
Connects to large amounts roughage to amino acids.  
Capacity in Cow = 160 litres  
Capacity in Goat = 50 litres |
| Reticulorumen    | Compartment where liquid goes  
Honey comb in the structure |
| Omasum           | Grinds and squeezes  
Removes some liquids |
| Abomaum          | True stomach  
Enzymes and acids |
| Small Intestine  | Partially digestion  
Bile  
Pancreatic juice  
Intestine  
Captures most of the food nutrients villi or papillae |
| Large Intestine  | Main function is to absorb water  
Add mucus to undigested food |
Acids Present in Ruminant's Digestive System

Three major volatile fatty acids are absorbed from the stomach to support distinctive metabolic phases in the digestion process.

**Acetic acid** is utilized minimally in the liver, and is oxidized throughout most of the body to generate ATP. Another important use of acetate is as the major source of acetyl CoA for synthesis of lipids.

**Proprionic acid** is almost completely removed from portal blood by the liver. Within the liver, propionate serves as a major substrate for gluconeogenesis, which is absolutely critical to the ruminant because almost no glucose reaches the small intestine for absorption.

**Butyric acid**, most of which comes out of the rumen as the ketone beta-hydroxybutyric acid, is oxidized in many tissues for energy production.

NON RUMINANT DIGESTIVE SYSTEMS

Non ruminant or mongastric digestive systems consist of a single stomach and supporting organs for the digestion of food. Humans, horses, pigs and rabbits all have a single or simple stomach to process high fibre content diets.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Mouth, oesophagus, stomach | • Enzyme acts on food  
|                     | • Food mixes                                  |
| Abomasum            | • True stomach  
|                     | • Enzymes and acids                           |

Non-ruminant animals and their mongastric digestive systems are much simpler than those in ruminant animals and consist of the following organs.
### Avian Digestive Systems

Avians include most domestic birds including chickens, turkeys, geese and ducks. Their diet consists mainly of seeds and other organic materials that they can swallow whole. Their digestion system requires them to swallow and retain small pebbles, gravel and grit to assist in the grinding and digestion of the food. It is important to ensure that their feeding area has sufficient materials to support the digestive process.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Small Intestine  | ￭ Partially digestion  
  ￭ Bile  
  ￭ Pancreatic juice  
  ￭ Intestine  
  ￭ Absorbs most of the food nutrients villi or papillae |
| Large Intestine  | ￭ Main function is to absorb water  
  ￭ Add mucus to undigested food |

An Avain's digestive system consists of the following major organs.

<table>
<thead>
<tr>
<th>Organs</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth, Beak</td>
<td>￭ Cannot chew food</td>
</tr>
<tr>
<td>Organs</td>
<td>Role</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>• Connect mouth to crop</td>
</tr>
<tr>
<td>Crop</td>
<td>• Stores food</td>
</tr>
<tr>
<td>Gizzard</td>
<td>• Crushes food&lt;br&gt;• Contains grit and gravel&lt;br&gt;• Mixes food with digestive juice</td>
</tr>
<tr>
<td>Small Intestine</td>
<td>• Partially digestion&lt;br&gt;• Bile&lt;br&gt;• Pancreatic juice&lt;br&gt;• Intestine&lt;br&gt;• Absorbs most of the food nutrients villi or papillae</td>
</tr>
<tr>
<td>Large Intestine</td>
<td>• Main function is to absorb water&lt;br&gt;• Add mucus to undigested food</td>
</tr>
</tbody>
</table>

**SKELETAL SYSTEM**

Most living organisms have some form of skeleton. There are three major types of skeletons: hydrostatic skeletons; exoskeletons; and endoskeletons.

Hydrostatic skeletons are found in organisms like worms and other entities which are viewed to not have a spine. A hydrostatic skeleton consists of series of fluid filled chambers that are able to expand and contract and thus support movement.

Exoskeletons exist on the outside of the body and are found primarily in insects. Exoskeletons are hard outer organisms that protect the inner muscles and organs. They do not grow with the insect and thus must be shed on a regular basis if the organism grows.

Humans and all other mammals have endoskeletons; skeletons that exist inside the body and are manipulated by muscles and ligaments. The endoskeleton serves a number of purposes that include:

- Providing support for the body;
- Protecting internal organs;
- Support blood formation and mineral homeostasis; and
- Support storage of fat cells and minerals.

Let's explore the skeletal systems of a cow, a pig and a chicken so that you can identify the similarities and differences.
PARTS OF THE SKELETON

Each animal's skeleton has different shapes and sizes depending on whether the animal is a biped (like a bird), quadruped (like cows and pigs) and whether it spends most of its time on land or in the water. But no matter the shape and size of the animal each skeleton has two common regions: The Axial Skeleton; and the Appendicular Skeleton.

Axial Skeleton

This region of the skeleton consists of four major parts:

1. Skull.
3. Ribs.
4. Sternum.

Appendicular Skeleton

This region of the skeleton consists of the following parts:

1. The Girdle (Pectoral and Pelvic).
2. The Limbs (Forelimbs and Hind Limbs).

COW SKELETON

![Cow Skeleton Diagram]
PIG SKELETON
Circulatory System

The circulatory system is the means of transporting blood throughout the body. The blood carries nutrients and oxygen to every cell in the body and at the same time helps cool the body. Blood, which consists of white and red blood cells also helps fight infection and supports the healing process.

The circulatory system of all mammals is similar. It consists of the heart which pumps the blood throughout the body and a system of arteries, veins and capillaries that carry the blood to and from the heart. It includes the lungs which feed the blood oxygen and the liver and kidneys which cleanse the blood as it circulates.

Below is a diagram of a pig’s circulatory system.
Now let’s explore more about farm animal circulation systems.

THE HEART

The heart of all mammals consists of four chambers that regulates suction and pressure pump in the body. The chambers each serve a different function with the right auricle receiving deoxygenated blood from the body, the contraction of the right auricle then enables the flow into the right ventricles. From here the blood then moves into the lungs which in turn oxygenated the blood. After being oxygenated the blood circulates into the left auricle. Then it is pumped to the left ventricle and finally out through the vein artery, the aorta, to be distributed throughout the body.
BLOOD

Blood is another major component of any circulatory system. The blood is a liquid that consists of plasma, red cells, white cells and platelets.

Plasma is the transportation system that moves the red and white blood cells throughout the body. It also transports different nutrients throughout the body to different organs where they are used or stored. Plasma consists of:

- 91% water,
- proteins,
- sugar,
- fats,
- antibodies,
- waste products, and
- hormones.

Red blood cells (erythrocytes) are of a disc like shape which contains the substance haemoglobin whose main function is to transport oxygen around the body. The erythrocytes live about 120 days and are continuously made in the bone marrow.
White blood cells (leucocytes) do not have haemoglobin but do contain a nucleus and unlike red blood cells are far less in the body. Leucocytes are then divided into two other groups based on their nucleus.

White Blood Cell Attacking Bacteria

The first type of white blood cells are granulocytes or polymorphonuclear leucocytes (“polymorphs” or “polys”) have granules in the cytoplasm and a purple lobed nucleus. “The most common (neutrophils) can squeeze out of capillaries and are involved in engulfing and destroying foreign invaders like bacteria. Some (eosinophils) combat allergies and increase in numbers during parasitic worm infections. Others (basophils) produce heparin that prevents the blood from clotting”.

The second type of white blood cells are agranulocytes or monomorphonuclear leucocytes have a large unlobed nucleus and no granules in the cytoplasm. “There are two types of agranulocytes. The most numerous are lymphocytes that are concerned with immune responses. The second type is the monocyte that is the largest blood cell and is involved in engulfing bacteria etc. by phagocytosis”.

Platelets are the really small fragments of cells which are linked to the clotting mechanisms of the blood.
REPRODUCTIVE SYSTEMS

The main reproductive organ of a male is testes which produces male gametes (spermatozoa) and male sex hormones. The testes regulation is due to gonadotropic of hormones and androgens.

The ovaries are the primary reproductive organ of the female. The ovum (the female sex gametes) and female sex hormones estrogen and progesterone.

Animals such as a mare or ewe are considered to be monotocous giving birth to one young per gestation period so produce one ovum in each cycle. In comparison to polytous reproductive cycles, like the pig that can produce 10 to 25 ova per cycle and giving birth to several piglets. The size and shape of the ovaries vary in different animals.

Gestation periods will vary by animal. The average time between fertilization of the egg and birthing for different farm animals is reflected below:

- Cow - 9 Months
- Horse - 11 Months
- Sheep and Goat - 5 Months
- Pig - 4 Months
- Chicken - 21 Days
- Duck - 28 Days
**Supplementary Readings:** To learn more about the animal reproduction process and cycle it is recommended your review the following online article:

SUNY. (nd.). Animal reproduction.  
([http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/bio%20102/bio%20102%20lectures/Animal%20Reproduction/animal.htm](http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/bio%20102/bio%20102%20lectures/Animal%20Reproduction/animal.htm))

**CHICKEN REPRODUCTION**

**Male Reproductive Organs & Urinary Tract**

The male possesses two testes, along the back, near the anterior ends of the kidneys. They are elliptical shaped and light yellow in color.

Each ductus deferens opens into a small bump, or papilla, which is on the dorsal wall of the cloaca. The papilla serve as the copulatory organ.

The incorrectly named, "**rudimentary copulatory organ**" is located on the medial ventral portion of the cloaca and is used to classify the sex of baby chicks.
Reproductive organs of the female bird

Although bird embryos possess two ovaries and oviducts, only the left one normally develops and becomes functional with age. The ovaries appear like a bunch of grapes and in an adult will contain five to six developing egg yolks. The oviduct is usually along the left side of the abdomen and is divided into five regions: funnel or infundibulum, magnum where albumen is secreted, isthmus which secretes the shell membranes, uterus or shell gland, and the vagina which connects to the cloaca. Chicken eggs are incubated about 21 days before hatching. Turkey eggs are incubated for 27 days.

Extracted from: MSU IACUC Poultry Module

COW REPRODUCTION SYSTEM

To learn the details of a cow’s reproductive system you need to read the following article:


PIG REPRODUCTION SYSTEM
To learn about the details of boar and sow reproduction systems you need to read this article:

FERTILITY PROBLEMS

Factors that affect the fertility of farm animals includes:

- Heredity/Genetics of the animal.
- Nutrition.
- Age.
- Climate of the local environment.
- Diseases that impact farm animals.
- Management of the environment and the animal by the farmer.

Supplementary Readings: To learn more about each issue it is recommended you read the following online article:

HSC Online. (nd.). Factors that affect animal fertility. Charles Stewart University, Australia. (http://www.hsc.csu.edu.au/agriculture/production/animal_fertility/anfert.htm)

ENDOCRINE SYSTEM

The nervous and endocrine system enables an animal to adapt to changing environmental conditions. The nervous system is the communications medium that signals the endocrine system when hormones need to be excreted.

Endocrine glands secrete chemicals and hormones but have no ducts. The hormones are excreted into the blood stream to support the physiological processes of organs and tissue within the body. Some of the most important endocrine glands include the pineal gland, the hypothalamus, the pituitary gland, the thyroid, the ovaries and the testes. Each of these glands works in a number of unique ways in specific areas of the body.

The diagram below illustrates the endocrine system of a cow. The table below describes the location and functions of each gland.

<table>
<thead>
<tr>
<th>Glands</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
</table>
| Pituitary Gland and Hypothalamus | underside of the cerebrum of the brain | • It is also known as master gland.  
• Controls other endocrine gland activities.  
• A link between the endocrine and endocrine systems.  
• Divided into two parts  
• Anterior secretion such as growth hormones, prolactin, for milk production initiations. Follicle stimulating hormones (FSH) that stimulates ovaries production and |
<table>
<thead>
<tr>
<th>Glands</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineal Gland</td>
<td>deep within the brain</td>
<td>Produces the melatonin hormone that controls the development of sexuality maturity. The seasons of breeding and hibernation.</td>
</tr>
<tr>
<td>Thyroid Gland</td>
<td>in the neck, just in front of the trachea</td>
<td>Produces thyroxin hormones that control animal growth and development speed. The rate of developmental re in the body is mature animals. Contain 60% thyroxine hormone if little in the duct can come goitre (enlargement of the thyroid gland)</td>
</tr>
<tr>
<td>Parathyroid Gland</td>
<td>in the neck just behind the thyroid glands</td>
<td>Adjust the amount of calcium in the blood and excretion of phosphates in urine.</td>
</tr>
<tr>
<td>Adrenal Gland</td>
<td>on the cranial surface of the kidneys</td>
<td>Contain two parts which is the center cortex and inner medulla Adrenal cortex produces aldosterone, cortisone and hydrocortisone and male and female sex hormones.</td>
</tr>
<tr>
<td>Pancreas</td>
<td>in the first bend of the small intestine</td>
<td>Secrete the hormone insulin that adjust glucose amount in the blood.</td>
</tr>
<tr>
<td>Ovaries</td>
<td></td>
<td>Produces two important sex hormones. Estrogen-stimulating sexual characteristics and thickening the lining of the uterus. Progesterone- provides pregnancy and prevention of uterus contraction.</td>
</tr>
<tr>
<td>Testes</td>
<td></td>
<td>Produces testosterone hormones that stimulate male sexual characteristics and growth of male reproductive system</td>
</tr>
</tbody>
</table>
USE OF HORMONES

The use of hormones is being used more and more by farmers to enhance their animal population. Today there is some concern by the public and government about the impact of hormones on human health. Farmers need to explore this option carefully and consider the impact of hormone therapies on the safety of their product.

Supplementary Readings: To learn more about the impact of hormones read the following online article:


IMMUNE SYSTEM

Immunity is the ability of an animal to resist disease. The immune system consists of a variety of specialized cells enzymes and other serum proteins found throughout the blood and tissue of the body. The specialized cells are found to be concentrated within the spleen, thymus, lymph nodes, bone marrow, blood and other organs and glands.
INNATE DEFENCE SYSTEM

The Innate(native) defence system is the first line of defence that occurs naturally in animals. This defence system already existed in a healthy animal, and vaccination is not needed to introduce the system into the animal body. Components of the Innate defence system are as follow:

**Natural Defence System:** Certain livestock species have immunity against certain diseases which is naturally functioned, e.g. black leg affect cattle but pigs are immune to black leg.

**Phagocytic Cells:** These cells engulf, kill and digest invading bacteria. They also have a role in controlling viral diseases.

**Complement System:** This is made up of at least 20 serum proteins. The serum proteins increase blood flow to an injured area that has been invaded by an infectious agent. This component system reaction produces cleanotactic substance which attracts phagocytes.

**Interferon System:** Interferon is a minute protein that is secreted by cells once they are invaded by infectious agents. Interferon inhibits production of viral protein in the infected cells. They send signals to other body cells to initiate defence against replication of viruses in case they are attached.

Interferon works against different viruses since they are not viral specific. Interferon levels secreted by invaded cells can reach protective levels within short period of time. Interferon also functions in an active immune system.

ACQUIRED IMMUNE SYSTEM

An Acquired (adaptive) immune system is a system that protects previously susceptible animals. This can happen in two ways.

**Active Immunity**

Active immunity is required to stimulate protection against high levels of disease challenges. This involve vaccinate animals with disease antigens derived from an infectious agents to stimulate specific immune responses to achieve resistance to the disease. Different diseases would require different types of active immunity to stimulate protection in animals.

Specialized macrophage cells called antigens presenting cells ream the animals’ body seeking out, ingesting and digesting foreign (disease) materials.
Passive Immunity

In this case, passive immunity allows the animal to receive another animal’s antibodies and other cellular factors. The most common example is the transfer of the maternal antibodies to the newborn calf in colostrums. High levels of antigen specific antibodies are secreted into the down colostrums during days of parturition in cows. A calf should buckle within 12 hours, post-partum in order to get protective anti-bodies into its blood stream.

The other example is utilization of antiserum and antitoxin in livestock. Antiserums and antitoxins being produced by other animals are given to the animals in a form of injection. This antiserums and antitoxin are administered once the animal has been exposed to a disease environment, e.g. (sick animal, newborn that did not receive colostrums).

Summary

All farmers should have an understanding of the anatomy and physiology of their animals. This knowledge will help farmers better understand and become engaged in the effective management of the health and well-being of their farm animals. It will help farmers better communicate their concerns to other professionals like veterinarians and others.
LESSON 2.2 – BREEDING AND SELECTION

OVERVIEW
Effective selection and breeding of animals will depend on how the animal is going to be used once it matures. For example, one can choose to produce chickens for meat and sell them to the local market or they can be breed for home consumption in the backyard. They may also be breed as egg layers. The desired purpose of the animal would determine what type of chickens you need and what breed of chickens you need to fulfil your plan.

The principles and practices of livestock breeding will help guide you to the proper selection of a breed of animal that will suit your desired outcomes. There are reasons behind animal breeding, why it is important and what type that would serve your need. This lesson will explore this process.

OBJECTIVES
Upon completion of this lesson you will be able to discuss:

1. The principles of animal breeding.
2. Different mating methods for chickens, cows and pigs.
3. The implication of selection and breeding on food safety.

Before you start this lesson you should review the reproductive systems of the cow, pig and chicken presented in Lesson 2.1.

PRINCIPLES OF BREEDING
The fundamental principles of scientific breeding are as follows:

1. Breeding should be done on purpose and the breeder should know the purpose of the breeding and the standard to which the animals are to be bred. It can be for size, weight, egg production, meat quality or combination of these factors. For example, poorly bred or desi hens are often voracious feeders, but because they are not bred for egg production, they do not lay correspondingly large number of eggs. The efficiency of conversion of feed into the eggs is an inherited trait and can only be reproduced in the succeeding generations by careful selection and breeding.

2. Breeding should be done from parents who conform as closely as possible to the required standard.
3. In selection and mating, all the birds which fail to possess the desired standards should be discarded or culled.

4. The parents selected for breeding should also be of pure breeds.

5. For a successful breeding, selection must be practiced continuously and carefully, from the hatching to maturity.

6. Environment plays an important part in breeding. So a favourable condition should be created in respect of housing, feeding, sanitation and general care.

7. Pedigree breeding is an important practice wherein efficiency of mating can be measured and the selection and mating operations modified to ensure improvement but this is possible only in well-established farms, requiring lot of technical expertise, and accurate mating and breeding rewards.

Supplementary Readings: To learn more about breeding principles you should read the following online articles:


POULTRY MATING METHODS

Mating is an act of joining a male animal with a female animal to enable them to reproduce to result in a progeny. Take for example, chickens in this case, where hens may produce fertile eggs for hatching and multiplication. The number of female birds allowed to be mated by a male bird depends upon the factors like breed, body weight, virility, season, age and physical condition of the male. For example, more females may be allowed for each male in the Leghorns (light breeds) than in the heavier breeds such as the Rhode Island Reds. Similarly a young cockerel (young male) can be given more pullets than an old cock. More females can be allowed in the mating pen during spring than during winter (where the winters are very cold). In summer, mating should be suspended as fertility will be very poor and the birds get exhausted.

Mating may occur in several kinds (1) Pen mating, (2) flock mating, (3) stud mating, (4) alternating males, (5) artificial insemination.
Artificial insemination may not be a feasible proposal for the village level poultry, as the villagers may not have the necessary infrastructure or expertise in this field.

**Pen mating:** In this type of mating, ten hens are kept in a breeding pen and one cock is permitted to mate and live with them freely. Eggs collected, a week after letting in the cock, will normally be fertile.

**Flock mating:** The large flock of hens is kept with a number of cocks in the proportion of one cock for every ten hens. But under confined conditions, the males develop a tendency to fight each other and generally one male becomes the aggressor preventing the others from mating. This may affect the fertility seriously. The eggs also cannot be traced to the cock concerned and so pedigree breeding is not possible. On the other hand, on a free range, there will not be much scope for fighting and the birds are free to run about. Flock mating is preferred where ordinary farm conditions are prevalent and no pedigree breeding is undertaken. It also permits housing for a large number of fowls as one unit and thereby reduces the overhead costs.

**Stud mating:** Stud mating consists of keeping the cocks and hen in separate pens or confining the males in separate coops in the pen of the females. The hens are let into the male's pen one by one at intervals, and after mating they are removed to their own pen.

**Alternate males:** In this method two males are used for mating, but only one is allowed to serve the hens at a time for one full day, while the other is confined to the coop. The following day the male that had been employed is removed to the coop, and the second one is let in with the flock. In this method, too, the paternity of the off-spring cannot be determined.

Similarly, bigger animals like Pigs, Cattle, horse etc. They have heat signs where the female animal old enough to reproduce, shows signs that it can be mated. The farmer should be aware and be familiar with animal heat signs and age of animals if he/she has to allow them to be mated. Selection of which breed to use for breeding depends on which trait the farmer wish his/her animals to become for his purpose.

**PIG MATING METHODS**

Domesticated pigs have been bred for many years using several different methods. Each method has its advantages as well as its disadvantages. These methods are hand-mating, pen-mating, pasture-mating, artificial insemination (A.I.) and embryo transplant. All of these methods can be used when a gilt, a young female pig, is at least 10 months old or on a sow, an older female pig, and have to be in heat before any of these methods have the desired outcome of offspring. Male pigs or boars are mature at 8 to 12 months old and can be used in all the methods as well.
**Hand-mating:** Pigs occurs when one sow or gilt is mated or bred to one boar. The advantages to this method of breeding pigs are that it allows the breeder the opportunity of choosing which pigs are bred and eliminates any social competition. This method also allows plenty of time before the boar is to breed the next sow or gilt which is important to the boar’s fertility rate. The disadvantage to this method of breeding pigs is that it requires quite a bit of the person’s time and effort.

**Pen-mating:** This occurs when several sows are brought to the boar’s pen to be bred. The advantages to this method of breeding pigs are that it does not require as much time from the person handling the situation as other methods does and often times the sows are more stimulated by being moved to the boar’s pen than the opposite. The disadvantage of pen-mating pigs is that it is not the most efficient use of the boar as sows may be bred after they have already conceived and there is a larger chance of loss of pregnancy due to “social competition.”

**Pasture-mating:** Pigs is just as the name assumes, it is when pigs, both sows and boars, are allowed to roam freely in pasture situations and let nature take over. This is the least controlled method of breeding pigs and is not the most widely practiced, especially in smaller operations.

**Artificial insemination (A.I.):** occurs when the sow or gilt is bred using semen collected from a boar. The boar is not involved in the mating in any way other than donating his sperm. The handler or breeder of the pigs will have to be aware of the techniques related to performing A.I. on a gilt or sow. This method is one of the most controlled methods available. The only uncontrolled step in this method is the date of the gilt or sow coming in heat. Advantages other than control include the breeder having the opportunity of upgrading their herd without actually purchasing a boar. The disadvantage would be the cost that can be associated and that the breeder will have to learn the technique required to accomplish this method.

**Embryo transplant:** occurs when the sow or gilt has a viable embryo transplanted into its uterus. The technique for this method requires the breeder to be knowledgeable in embryo transplant, but luckily it can be done without any surgery.

**RECORDS KEEPING**

Record keeping in livestock production plays a major role when considering selection and mating of animals because one cannot accept accidental mating in animals that would spoil the genetic makeup of the stock. Therefore proper and sound record keeping of breeding animals should be kept up to date to accurately breed the desired animals to produce the output that one wants.

Animal identification usually go side by side of controlled breeding program in that the farmer needs to keep a record of which animals have been mated to which by recording
their details. This method is also popular with indoor or intensive piggery because the animals’ breeding programs are usually monitored closely in order for the farmer to know the animals’ heat periods, date of service, date of farrowing, date of weaning and some other management practices needed to care for them during their production cycles.

**CATTLE MATING METHODS**

Cattle mating methods are similar to those used when mating pigs. Some of the issues to consider when attempting to breed cattle includes:

1. The timing of the fertilization is essential. Cows usually produce a single ovum and there is only a period five to ten hours when the animal is fertile.
2. The age and health of the animal will impact the success or failure of the mating process.
3. The number of pregnancies already experienced by the female.

To learn more about cattle breeding and management practices to improve breeding efficiency it is recommended your review the following article:


**FOOD SECURITY & BREEDING**

Almost all small states have local breeds of chicken, pigs, goats, and cattle. These local breeds are genetically resistant to many diseases and pests, and are generally low maintenance. But some local breeds may produce less meat, eggs or milk production. These limitations can be improved through proper management and a good breeding program.
SUMMARY

This lesson provided an introduction to the principles and methods of effective breeding and selection. The process is a complex one that often takes time and in some cases
money. It may take several generations to achieve the results you desire therefore the planning and effective management of a long term breeding programme are required if you are to succeed in increasing production.
LESSON 2.3 – LIVESTOCK HOUSING

OVERVIEW

Animal housing is a critical element in the livestock production process. There are a number of factors to be considered in the planning of housing facilities. However, it is important that the design must take cognizance of the comfort of both the animal and the person that will be accessing the facility. Housing must reduce the stress factors on the animals especially if they spend a major period of time confined to these environmental surroundings. On the other hand good housing conditions are important to the stockman since if he is not comfortable he will not spend much time in the housing facility and ultimately may miss signs and symptoms of negating factors of animal production that may need to be remedied.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Describe the factors related to livestock housing.
2. Explain the housing requirements for cattle, swine, sheep, goats and chickens.

FACTORS AFFECTING LIVESTOCK HOUSING NEEDS

When planning and building livestock housing the main focus is on the physical environment, in particular the temperature, ventilation and support, but all other factors should also be considered in order to create a good layout, where healthy, high yielding animals can be provided with correct feeding, can be easily handled and can produce without stress or suffering physical harm.

Some the factors that must be considered when defining livestock housing needs are:

- Ventilation.
- Odour.
- Fly control.
- Rodent control.
- Disease control.
- Temperature control.
- Lighting.
- Orientation (To sun and to other buildings) Consider things like location upwind and scent.
- Access (like in and out).
- Drainage.
• Support services (electricity, water, heating).
• Proximity to storage like for feed.
• Comfort for the animals and the workers should be considered.
• Safety (fire, confined spaces, etc.).
• Security of animals and equipment.

While all these are important only some of the factors will be explored in this lesson.

**HOUSE/BARN TEMPERATURE**

When considering the temperature for livestock housing you must consider their average body temperature and the in-barn temperature that they will most thrive at.

<table>
<thead>
<tr>
<th>Animals</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Dairy Cow</td>
<td>38.6</td>
</tr>
<tr>
<td>Beef Cow</td>
<td>38.3</td>
</tr>
<tr>
<td>Pig</td>
<td>39.2</td>
</tr>
<tr>
<td>Sheep</td>
<td>39.1</td>
</tr>
<tr>
<td>Goat</td>
<td></td>
</tr>
<tr>
<td>Horse</td>
<td>37.9</td>
</tr>
<tr>
<td>Chicken</td>
<td>41.7</td>
</tr>
</tbody>
</table>

**Average Body Temperatures**

[Dairysite.com](http://www.dairysite.com) notes that "dairy cows are comfortable at lower temperatures and show very small declines in milk production if properly fed, protected from wind, precipitation, and provided a comfortable, dry place to rest. Note that lower temperatures do not normally impact milk production. The site recommends that the temperature of a cow barn can range from just above 0 degrees to about 25 degrees Centigrade.

Sows will thrive and grow faster at moderate temperatures well below their average body temperature. It is recommended that pig barns be kept at a temperature of between 24 and 27 degrees. [Vetsweb.com](http://www.vetsweb.com) reports that "sows farrowing a litter spread a lot of warmth to their surroundings -- and usually find it difficult to get rid of their body warmth in a pen. It was also claimed that high temperatures in farrowing sows could decrease their food intake, affecting indirectly both current piglet growth and the size of future litters". When farrowing it is recommended that the temperature be kept lower.

A poultry barn will require different temperatures depending on the age of the chicken. [BCCChickens.ca](http://www.bccchickens.ca) reports that when "chicks are placed in the barn, it is heated to 29° - 32°C (84° - 90°F) and the temperature is slowly reduced to 21° - 23°C (70° - 75°F) by the time the birds are shipped".
Thus, depending on the type of livestock you are raising you will need different types of housing that allows the farmer to control the temperature of the barn.

VENTILATION OF HOUSING/BARNS

The most problematic environmental factor affecting the physiological functions of livestock in the African Caribbean and Pacific (ACP) countries is temperature. For the majority of farm animals a mean daily temperature in the range 50 to 68°F (10 to 20°C) is commonly referred to as the normal body temperature range. Therefore ensuring that the housing facility is adequately ventilated is an important issue having proper ventilation will assist in heat loss by evaporation and by conduction/ convection as long as the air temperature is lower than the skin temperature.

While other farm animals have the ability to regulate their temperature through homeostasis poultry lacks this ability because they do not have sweat glands. All heat loss therefore originates from these animals respiratory tract. Other livestock species have varying abilities to sweat and in ascending order they are as follows: Pig, sheep, goat, cattle, donkey and horse.

Pigs require a change in ambient temperature as they age and grow; there is a decreased feed intake when under heat stress. Piglets develop optimally at 86-89.6°F (30-32°C) feeder pigs (30 to 65 kg) prefer temperature in the range of 50-77°F (10-25°C). The optimal ambient temperature for pigs weighing 75 to 120 kg is 59°F (15°C).

Sheep can endure an extensive range of temperatures but should be protected from wind and rain. An extended period of high ambient temperatures inhibits reproduction. Heat stress also reduces lambing percentage, decreases the incidence of twinning, and decreases the birth weight of lambs.

Goats are affected by temperature, rain and humidity. When housed in hot climates, goats need shelter from intense heat during the day whereas in humid areas they need protection from heavy rains.

The environmental requirements for poultry similarly to swine vary with age. Chicks should be started at 95°F (35°C) but after one week the temperature is reduced gradually to 75.2°F (24°C) by week five. Broilers at normal temperatures below 64.4°F (18°C) are heavier than similar stock reared within the 64.4-95°F (18-35°C). Laying birds produce the greatest number of eggs and the largest sized eggs at 55.4-75.2°F (13-24°C).

Supplementary Readings: To learn more about ventilation of barns and livestock housing you should read the following online articles:

CATTLE HOUSING

Cattle are more efficient in the production of milk and in reproduction if they are protected from extreme heat and particularly from direct sunshine. Thus in ACP climates shade becomes an important factor. If these livestock are kept in a confined area, there should no mud or manure in order to reduce hoof infection to a minimum. The best flooring option would be to have concrete floors or pavements. Another flooring option that is practical if ample space is available is an earth yard, properly sloped for good drainage.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Age Months</th>
<th>Weight kg</th>
<th>Bedded Shed Area per Animal (m²)</th>
<th>Free Stalls Dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young stock</td>
<td>1.5 - 3</td>
<td>70 - 100</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Young stock</td>
<td>3 - 6</td>
<td>100-175</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Young stock</td>
<td>6 - 12</td>
<td>175 - 250</td>
<td>2.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Young stock</td>
<td>12 - 18</td>
<td>250 - 350</td>
<td>3.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Bred heifers &amp; small milking cows</td>
<td>400 - 500</td>
<td>3.5</td>
<td>2.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Milking cows</td>
<td>500 - 600</td>
<td>4.0</td>
<td>3.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Large milking cows</td>
<td>&gt; 600</td>
<td>5.0</td>
<td>3.5</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Space Requirements
In a deep-bedded system, straw, sawdust, shavings or other bedding substance is periodically placed in the resting area so that a combination of bedding and manure builds up in a thick layer. Although this augments the bulk of manure, it may be easier to handle than wet manure alone. This system is most practical when bedding is plentiful and cheap. By designing the building to be partially enclosed on the east and west, the shading characteristics can be improved. In as much as a well drained earth floor is quite adequate, such a building will compare in cost with a shaded area which is paved.

“Although simple yard and a shade or yard and bedded shed systems are entirely satisfactory in warm climates, a loose housing yard and shed with free stalls will satisfy this need. Less bedding will be required and less manure will have to be removed. Free stalls must be of the right size in order to keep the animals clean and to reduce injuries to a minimum.” (Bengtson et al, 1998).

**SWINE HOUSING**

Before considering swine housing several factors should be addressed: easy access to a good all-weather road; well drained ground; and sufficient distance from residential areas to avoid creating a nuisance from odour and flies. An east-west orientation is usually preferable to minimize exposure to the sun. Ground cover, such as bushes and grass, can reduce reflected heat considerably, and the building should be located where it can most benefit from surrounding vegetation. A fairly light well drained soil is preferable, and usually the highest part of the site should be selected for construction.

Pig houses should be simple, open sided structures as maximum ventilation is needed. A building for open confine merit is therefore essentially a roof carried on poles.
<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Stocking density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>A. Farrowing/suckling pen.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting area, if weaner pens are not used</td>
<td>m²</td>
<td>10.0</td>
</tr>
<tr>
<td>Resting area, if weaner pens are used</td>
<td>m²</td>
<td>8.0</td>
</tr>
<tr>
<td>Manure alley width</td>
<td>m</td>
<td>1.7</td>
</tr>
<tr>
<td>Farrowing pen (System IV)</td>
<td>m</td>
<td>-</td>
</tr>
<tr>
<td>Farrowing crate, length excl. trough</td>
<td>m²</td>
<td>2.0</td>
</tr>
<tr>
<td>Width depending on size of sow</td>
<td>m</td>
<td>0.65 - 0.72</td>
</tr>
<tr>
<td>Free space behind the crate</td>
<td>m</td>
<td>0.4</td>
</tr>
<tr>
<td>Piglet creep (incl. in resting area)</td>
<td>m²</td>
<td>2.0</td>
</tr>
<tr>
<td>B. Boar pen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Pen with yard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting area (shaded)</td>
<td>m²</td>
<td>6</td>
</tr>
<tr>
<td>Yard area (paved)</td>
<td>m²</td>
<td>12</td>
</tr>
<tr>
<td>2. Pen without yard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting area (shaded)</td>
<td>m²</td>
<td>9</td>
</tr>
<tr>
<td>C. Gestating sow pens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Loose in groups of 5 - 10 sows</td>
<td>m²</td>
<td>2.0</td>
</tr>
<tr>
<td>Yard area (paved)</td>
<td>m²</td>
<td>5.5</td>
</tr>
<tr>
<td>Feeding stalls, depth x width</td>
<td>m</td>
<td>2.0 × 0.6</td>
</tr>
<tr>
<td>2. Individual stalls with access to manure alley, length of stalls excl. trough</td>
<td>m</td>
<td>2.2</td>
</tr>
<tr>
<td>Width of stalls</td>
<td>m</td>
<td>0.65 - 0.72</td>
</tr>
<tr>
<td>Width of manure alley</td>
<td>m</td>
<td>1.5</td>
</tr>
<tr>
<td>3. Confined in individual stalls</td>
<td>m</td>
<td>2.2 × 0.70</td>
</tr>
<tr>
<td>Length x width of stalls</td>
<td>m²</td>
<td>2.0</td>
</tr>
<tr>
<td>D. Weaner pen (to 25 kg or 12 wks)</td>
<td>m²/pig</td>
<td>0.35</td>
</tr>
<tr>
<td>Manure alley width</td>
<td>m</td>
<td>1.0</td>
</tr>
<tr>
<td>E. Growing pen (to 40 kg or 17 wks)</td>
<td>m²/pig</td>
<td>0.3</td>
</tr>
<tr>
<td>Manure alley width</td>
<td>m</td>
<td>1.1</td>
</tr>
<tr>
<td>F. Finishing pen, resting area excl. trough</td>
<td>m²/pig</td>
<td>2.0</td>
</tr>
<tr>
<td>Manure alley width</td>
<td>m</td>
<td>1.2 - 1.4</td>
</tr>
</tbody>
</table>

**Recommended Dimensions**
POULTRY HOUSING

The term poultry includes several avian animals namely: chickens, turkeys, ducks and geese. This section however will focus on chickens only. Chickens offers one of the best sources of animal protein, both meat and eggs, at a cost most people can afford. When considering housing for chickens it has to be realized that no single system of housing is best for all circumstances or situation. Source: May Pitakere et al., 2009

Proper planning of housing facilities for a flock of laying hens requires knowledge of management and environmental needs in the various stages of the life of the chicken. Before constructing the poultry house finding a suitable site is necessary and the best site is one that is well-drained, elevated but fairly level, and has an adequate supply of drinking water nearby.

Issues of ventilation need to be addressed and how to reduce the spread of odour has to be considered so making sure the site is located downwind is essential. Adequate spacing between houses is another factor and separation from one type of chicken to the other also taken into consideration. Another important factor that has to be considered is the safety of the birds the housing should offer protection from predators and theft as well as the exclusion of rodents and other pests.

Lightening is a major factor that should be considered when it comes to addressing chicken housing, having a properly maintenance of the lighting schedule, since any sudden change
in the length of the photo-period is likely to result in a significant drop in production. Chickens should have fourteen hours of light throughout the laying period.

There are five major systems used in housing of layers: Semi-intensive; deep litter; slatted or wire floor; a combination of slatted floor and deep litter; and cage or battery system and each should be considered depending on the stage of the bird.

Source: May Pitakere et al., 2009 and Bengtson et al, 1998

SHEEP & GOAT HOUSING
According to Sheepandgoat.com the housing and shelter needs for sheep and goats are very similar vary by climate, geographic region, season, production system, and personal preferences of the shepherd. Even if livestock spend most or all of their time outside, some type of facilities is usually needed to store feed and equipment and handle, isolate, and quarantine animals.
**Recommended Housing Requirements**

Within the ACP regions housing should be kept to a minimum except for the more intensive systems of production. A simple thatched shelter should be providing so that there should be shade and protection from excessive rain.

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Floor Space</th>
<th></th>
<th>Trough Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
<td>m²/animal</td>
<td>m²/animal</td>
<td>m²/animal</td>
</tr>
<tr>
<td>Ewe/ Doe</td>
<td>35</td>
<td>0.8</td>
<td>0.7</td>
<td>2</td>
</tr>
<tr>
<td>Ewe/ Doe</td>
<td>50</td>
<td>1.1</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Ewe/ Doe</td>
<td>70</td>
<td>1.4</td>
<td>1.1</td>
<td>3</td>
</tr>
<tr>
<td>Kid</td>
<td></td>
<td>0.4 - 0.5</td>
<td>0.3 - 0.4</td>
<td>-</td>
</tr>
<tr>
<td>Buck</td>
<td></td>
<td>3.0</td>
<td>2.5</td>
<td>-</td>
</tr>
</tbody>
</table>

**SUMMARY**

Farmers must realize that one size does not fit all farm animals. Each breed requires different housing requirements. Even within a breed the age of the chick, calf or sow may impact the space, temperature and ventilation requirements. This lesson provided an overview of the ideal housing requirements for each type of livestock. When growing your farm or introducing new livestock onto your farm you must take the housing requirements of the animals into consideration.
LESSON 2.4 – LIVESTOCK NUTRITION

OVERVIEW
One of the most expensive components of maintaining livestock is meeting their nutritional requirements. Feeds account for 60% or more of the total production costs. Nutrients required for maintenance and production are provided by various plants and plant derived feeds along with small amounts from non-plant sources. The major constituents are proteins, fat, carbohydrates, minerals, vitamin and water. Each nutrient fulfills specific roles in growth, production or metabolism. Nutrients classes are defined by their chemical structure or by their function in metabolism.

OBJECTIVES
Upon completion of this lesson you will be able to:

1. Discuss the nutritional requirements of your livestock.
2. Plan the water needs of your farm animals.

NUTRITION BASICS
All animals require some form of food to support their growth and well being. Without food an animal dies. Without the proper food or nutrition we leave our animals open to disease, physical ailments, stunted growth, infertility and other issues that impact the productivity of our farm animals.

Nutrients can be classified into four different types. Each type is required by farm animals in different amounts and at different times of their growth cycle. These include:

Energy: Nutrients are converted to energy which allows the body and its cells to do work. Energy or lack of it impacts lactation, reproduction, maturation, movement and digestion. The primary source of energy will vary with the different animals. This will be discussed later.

Proteins: Nutrients provide proteins which act as the building blocks of the animal's body. Like energy, proteins are essential for maturation, lactation and reproduction.

Minerals: Nutrients that supply minerals to the body are required to support bone growth and a variety of other bodily functions.

Vitamins: Vitamins are also essential to animal growth, to assist in muscle development, fight disease, reproduction and the operation of various organs.
The four basic types of nutrients are summarized below:

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>Main building block of the body. Measured as % crude protein (CP)</td>
<td>Implement for growth, lactation, reproduction, laying and maintenance.</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>It is expressed as total digestible nutrients (TDN). It is the most needed and expensive nutrients in a diet.</td>
<td>Implement in growth, lactation reproduction, laying movement and food digestion.</td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
<td>They are required in both large amount (macro-minerals and very small amount (micro-minerals). Macro-minerals include copper, zinc. Manganese, iron, iodine, selenium and sulphur. Mineral content is affected by the type and quality of food stuff.</td>
<td>Growth, bone formation, reproduction.</td>
</tr>
</tbody>
</table>
| **Vitamins** | Biological compounds that is active in small amounts. These are fat soluble and water soluble vitamins examples of fat soluble vitamins include vitamin A,D,E,K. Water soluble vitamin include B vitamin, e.g. biotin, Riboflavin, etc. | Vitamin A is important for growth, reproduction and maintenance. 
Vitamin D is required for development of bones. 
Vitamin E and Selenium are for muscle tissue development. |

**SOURCES OF NUTRIENTS**

Nutrients for livestock can be grown by the local farmer, purchased from other farmers or procured from a feed company. Some sources of nutrients include:

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Sources</th>
</tr>
</thead>
</table>
| **Protein** | The sources of protein will include: soya bean meal, canola meal, cotton seed meal, meat meal, fish meal, Lucerne and other legume grasses. 
Grains also have moderate protein contents, e.g. corn, barley, oats etc. |
| **Energy** | The sources of energy include fat and oils, cellulose and semi, cellulose farm roughage and starches from grains. The grain will include corn, soya bean, meal wheat, burley, etc. |
Nutrients | Sources
---|---
Minerals | This will include things seen as mineral mix, legume hay, clover, lespedeza, alfalfa, etc.
Vitamin | The good sources of vitamins are fresh forages, well preserved hay. Silage and grains also contain vitamins but their vitamin content is relatively low.

**NUTRIENT DEFICIENCIES**

The lack of proper nutrition will result in a number of physical disabilities. The list below describes some of the more common symptoms.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Deficiency symptoms</th>
</tr>
</thead>
</table>
| Protein | • Poor growth  
• Late maturity  
• Poor production |
| Minerals (calcium) | • Poor growth  
• Weak bones |
| Phosphorus | • Poor growth  
• Craving for need, hair bail  
• Poor conception rates. |
| Sodium | • Poor growth  
• Lacking of mood |
| Selenium | • Weakness  
• Inability to stand |
| Vitamins (A) | • Lowered fertility |
| Vitamins (D) | • Rickets  
• Weak and easily fractured bones |
| Vitamins (E) | • Nutritional muscular dystrophy |

**WATER REQUIREMENTS**

Although it varies by species, about 60% of an animal's total body weight is made up of water and about 80% of our blood is water. In addition, water is essential to digestion, absorption of nutrients and body waste removal.

The daily water requirements for different animals vary widely. Some of the factors that impact the amount of water required by farm animals include:
1. Animal size.
2. Stage of animal production, e.g. lactation, gestation, laying etc.
3. Environmental factors e.g. temperature relative humanity etc.
4. Quality of water.
5. Water content in animal feeds.

The follow on sections illustrate the recommended daily intake of water for different farm animals.

**Cattle Water Intake**

The cattle milk is composed of about 87% water. The cow’s water requirement is related to its milk production. The cow’s peak water intake is positively correlated within food intake.

<table>
<thead>
<tr>
<th>Dairy cattle type</th>
<th>Average water requirements (litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy calves (1-4 metres)</td>
<td>9</td>
</tr>
<tr>
<td>Heifers (5-24 metres)</td>
<td>25</td>
</tr>
<tr>
<td>Milking Cows</td>
<td>115</td>
</tr>
<tr>
<td>Dry cows</td>
<td>41</td>
</tr>
<tr>
<td>Food let cattle (beef)</td>
<td>41</td>
</tr>
<tr>
<td>Lactating cows within calves (beef)</td>
<td>55</td>
</tr>
<tr>
<td>Dry Cows, bread heifer and bulls</td>
<td>38</td>
</tr>
</tbody>
</table>

**Pig Water Intake**

<table>
<thead>
<tr>
<th>Pig type</th>
<th>Average water intake (litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaner</td>
<td>2.0</td>
</tr>
<tr>
<td>Feeder Pig</td>
<td>7.0</td>
</tr>
<tr>
<td>Gestating sow</td>
<td>15</td>
</tr>
<tr>
<td>Boer</td>
<td>15</td>
</tr>
<tr>
<td>Lactating sow</td>
<td>20</td>
</tr>
</tbody>
</table>

**Horse Water Intake**

<table>
<thead>
<tr>
<th>Horse type</th>
<th>Average water intake (litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>16.5</td>
</tr>
<tr>
<td>Medium</td>
<td>32.5</td>
</tr>
<tr>
<td>Large</td>
<td>49</td>
</tr>
</tbody>
</table>
Sheep Water Intake

<table>
<thead>
<tr>
<th>Animal Type</th>
<th>Average water requirement (litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeder lamb</td>
<td>4.5</td>
</tr>
<tr>
<td>Gestating ewe</td>
<td>5.75</td>
</tr>
<tr>
<td>Ram</td>
<td>5.25</td>
</tr>
<tr>
<td>Lactating ewe</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Chicken Water Intake

<table>
<thead>
<tr>
<th>Chicken age by weeks</th>
<th>Average water requirement (litres/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broilers:</td>
<td></td>
</tr>
<tr>
<td>1-4</td>
<td>50-415 litres/1000 birds</td>
</tr>
<tr>
<td>5-8</td>
<td>550-770 litres/1000 birds</td>
</tr>
<tr>
<td>Layers:</td>
<td></td>
</tr>
<tr>
<td>Laying hens</td>
<td>250 litres/1000 birds</td>
</tr>
<tr>
<td>Pullets</td>
<td>105 litres/1000 birds</td>
</tr>
<tr>
<td>Broiler breeders</td>
<td>250 litres/1000 birds</td>
</tr>
</tbody>
</table>

WATER QUALITY

Water is vulnerable to a number of different environmental factors that may impact the quality of the water. The quality of the water will depend on its source and how it is distributed to the livestock.

Different sources of farm water will include:

- Well water.
- Water from lakes or rivers.
- Runoff water collected in a collection pond/pool.

The quality of the water will depend on:

- The mineral count and salinity of the source water.
- The type of distribution system used.
- The location of the water source (i.e. close to grazing/growing fields).
- The type of fertilizers used to grow crops.
- The method of manure disposal/storage.
To protect the quality of your farm water you should ideally:

- Isolate the source of the water from potential contaminants.
- Regularly test the water.
- Regularly treat the water if contamination is suspected.

**SUMMARY**

Water and water access is an important part of any farm. Water is not only needed to support the livestock, it is required to grow the crops and support the day to day operation of the farm.

Accurate estimates of the water needs of the farm are necessary as a farmer grows his livestock. This lesson provided some tools to estimate the quantity of water needed by the farm.

Not only is quantity essential, the quality of the water source and delivery methods must also be considered and monitored.
LESSON 2.5 – HUSBANDRY PRACTICES

OVERVIEW

The implementation of effective animal husbandry practices should result in lowering the cost of production while at the same time increasing production output. Healthy animals should result in higher quality products and thus allow the farmer to maximize revenue potential.

Good animal husbandry practices should satisfy animal welfare concerns and ensure the health of the food chain. Several of the issues impacting effective animal husbandry have been addressed Unit 3 - The Best Practices in Livestock Production. This lesson will provide additional information to guide the effective implementation of animal husbandry practices.

OBJECTIVES

Upon completion of this lesson you should be able to explain specific animal husbandry practices for sheep, cows, pigs and chickens.

GENERAL HUSBANDRY PRACTICES

The next few pages describe husbandry practices that apply to a number of different farm animals. These are presented in no particular order and animal specific practices will be presented later.

Identification

Animal identification can be done by tattooing, tagging, ear notching or hole punching the ear. Electronic identification such as micro-chip is also acceptable. In horned sheep, the horn may be horn branded. The ear marking instrument should be sharp and the operator should avoid tearing of the ear when ear tagging.
Tail Docking

Tail docking is recommended when there is a problem of faecal and urine contamination and fly-strike. In such condition if tail docking is not done it leads to poor animal hygiene and welfare. Tail docking can be done in early as 2 weeks and it is encouraged that it should not be done later than 12 weeks. Aesthetic will be required for animals that are older than 6 months.

Acceptable methods of tail docking includes surgical, rubber ring, and use of gas flame heated scoring iron. The docked tailed should be
long enough to cover the vulva and the same length applies to males.

Sheep Docking Procedure

Handling & Movement

It is essential that farm animals are handled gently in order to reduce stress to individual animals and the others around them. Farmers must know about animal behaviour to effectively handle the animals. You must have a specific purpose for handling farm animals. Some of these will include milking, shearing, hoof trimming and others. Each may require different methods and different tools.

When moving animals from one location to another you must be aware of the herd instincts of each breed. Sheep tend to group together when being herded while horses and cows wish to scatter. Although popular in many locations it is recommended the use of dogs for handling sheep not be considered.

Humane Destruction

When animals need to be put down farmers must employ effective and humane methods that result in a quick and painless death should be practiced. Some of the methods include:

A sustainable firearm for euthanasia (22 calibre rifle humane killer pistol) should be used at short range but should not be put directly on the head.
A captive-bolt penetrating stunner which uses blank cartridges colour coded can be an alternative. The stunner should be placed firmly against the skull before firing. Stunning should be followed immediately by bleeding out.

Use of a drug, usually administered by a vet, to stop the heart.

You need to consider a method of disposing of the carcass depending on the reason for putting the animal down. If it is put down for meat it should be butchered in accordance with the safe practices dictated by your local regulations.

If the animal was diseased it should be removed quickly from the site and carcass disposed of in a safe manner that will not expose other animals to the disease. This usually means cremation or burial.

**Environmental Requirements**

Animals should not be kept in an area that is free from dust or noxious chemicals that would be dangerous to their welfare. As noted in an earlier lesson animal housing should have natural effective ventilation. The design of the house should be in such a way that it removes excessive heat, moisture, Carbon dioxide, dust, noxious gases and infectious organisms from the environment.

Overcrowding of animals should be avoided. A standard space allowance for different systems of production in different animals should be followed. See the earlier lesson for specific dimensions.

**Feeding & Water**

Fresh drinkable water should be provided to all animals at ad libitum. The water troughs should always be clean. The water requirement s for different classes of animals should be observed. The water source should be monitored and clean.

When feeding, adequate trough space should be provided for all animals. For example a minimum of 2 cm of trough space per sheep is appropriate where ad libitum feeding is practiced. A 20 cm trough space would be recommended for controlled feeding.

Close monitoring of animals during feeding and watering should remain one of the managers concerns. Feeding routines should be logged.
SHEEP HUSBANDRY PRACTICES

In addition to the general husbandry practices discussed earlier some of the specific practices that relate to sheep are described below.

**Shearing:** in most cases shearing is done once in a year. Crutching, winging and ringing can be done as the need arise in order to avoid a risk of fly strikes, impaired vision and stained wool. When shearing, cuts need to be treated. When shearing exposure to adverse weather should be avoided and sheep should be returned to their feed.

**Dips:** Dips should be maintained and to operate in such a way that injury, disease and stress are minimized.

**Hoof trimming:** sheep reared on soft grounds grow hooves rapidly and that way hooves need to be trimmed, as well as poor hoof conformation. When trimming a sharp instrument should minimum in order to avoid sleet or server lameness.

**Horn trimming:** The house of rams need to be cut back to avoid injury from an in growing horn. Horn trimming would also allow tree movement in handling races as well as preventing a ram from hurting other sheep and care-taker.
When cutting a horn, damage to soft horn tissue should be avoided, as well as bleeding.

Permanent dehorning should only be done under anaesthesia.

**Lambing and orphan lambs:** Ewe flocks lambing under grazing conditions should be little disturbed. Lambing ewes should have access to shelter. Orphan should grow colostrums of other ewes. Warmth and shelter should be provided. Weak lambs with very chances of survival should be humanely destroyed.

**Castration:** it is normally not recommended if lambs are to be marked before they reach puberty (3-6 months). Acceptable castration method includes:

- Knife Method: the lamb should be properly restrained and the knife should be kept clean and sharp.
- Use of rubber-ring: it is recommended that castration be done before 12 weeks.

**Teeth grounding/Trimming:** Corrective dental procedures on individual sheep may be under taken to alleviate a specific dental problem if it would be beneficial to its health and well-being.

**Feeding:** Sheep being introduced to an intensive feeding system, particularly high starch diets should be given time to adjust both to the new dietary regime and the troughing.

**Watering:** One drinking nipple should be provided for every 15-30 sheep with a minimum of two per pen. One watering bowl is required for a maximum of 60 sheep. A minimum trough length of 30 cm is recommended for a mob of up to 500.

**CATTLE HUSBANDRY PRACTICES**

This section will cover three husbandry practices in detail and for other practices that are related to cattle but not covered in this section is because they are already discussed under other livestock species.

Castration, dehorning and branding produce wounds on cattle and hence why they are called surgical procedures. Each will be discussed separately.

**Branding**

Branding is the placing of permanent identifying mark on the hide of an animal. This will destroy the hair follicles as well as altering hair regrowth.

**Methods of Branding**

a) **Hot branding:** Fire branding is not preferred method of identification, but it is permanent and may be the only practical system in some situations. It is usually incorporated with other husbandry procedures, such as castration and dehorning.
Branding is best done when animal is young. Young animals are easier to handle and restrain. This reduces stress on the animal and decreases the risk of workplace accidents.

When branding the animal's welfare should always be considered. The discomfort to the animal can be minimised as follows:

- Ensure that the animal is properly restrained.
- Check that irons are at the correct temperature (the iron should be blue hot, not black or red hot).
- Do not brand hot animals.
- Do not brand weak or emaciated animals.
- Brand animals that are between 2 to 6 months old.
- Never brand an animal on the cheek.

Electric Branding and Ear Marking

 Freeze Branding: Freeze branding uses ultra-low temperature to destroy the skin hair cells that produce pigmentation. A freeze brand appears as a white hair growing on the branded area.

- Freeze branding causes little pain but the process takes longer time, and thus causing stress.
- Freeze brand is clearly visible from a distance in dark coated animals.
- The dry ice and liquid nitrogen used in freeze branding are expensive.
• The results of freeze branding vary with the thickness of the skin of the animal and the coat colour.
• The brand is not normally visible on light coated animals.

Freeze Branding
CASTRATION

Castration is the removal of the testicles from the male animals.

Benefits of Castration

- Castrated animals are less aggressive.
- Castrated animals are easier and safer to handle.
- They are less likely to fight, and thus reducing injuries to other cattle and human beings.
- Prevention of unwanted mating.

When to Castrate

Cattle should be castrated at young age since castration at early age significantly reduces the following;

- Pain and discomfort for all the animals.
- Risk of bleeding and infection.
- Recovery time after castration.
- Difficulty of restraining the calves and procedure performance.
- Risk to the operator and the amount of labour needed.

Issues to Consider

When castrating the following welfare issues should be considered:

- Castrating without local or general anaesthesia should be confirmed to calves preferably under the age of 6 months.
- Castration of older bulls be performed by and animal health expert.
- Castration with rubber rings is only recommended for calves of 2 weeks of age or younger.
- Castration with burdizzo should be performed as young as possible.
- The scalpel blades used should be sharper, sterile until opened, easier to sterilize and the blades should be replaced after every 15-20 calves.
- Before starting and in between castration of animals the instruments should be disinfected.
- Hands should be clean and be disinfected with effective antiseptic solution before each castration.
- The antiseptic solution should be changed every 15-20 calves to avoid them being contaminated.
• Do not castrate calves if they are wet or to avoid the risk of infection ad fly-strike (avoid rain and dust).

Problems related to surgical castration:

• Swelling
• Infection
• Bleeding
• Fly-strike

Methods of Castration

1. Surgical Castration Method

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Visual certainty that castration is done.</td>
<td>• More bleeding resulting in blood loss.</td>
</tr>
<tr>
<td>• Development of cod. Enhances appearance and price.</td>
<td>• Likely risk of infection from open wound.</td>
</tr>
<tr>
<td></td>
<td>• Needs higher work place safety because of sharp bleeds.</td>
</tr>
<tr>
<td></td>
<td>• Need experienced technician.</td>
</tr>
</tbody>
</table>

Surgical Castration
2. Rubber Rings Method

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Calves can be castrated and easily as two weeks old age.</td>
<td>• Higher risk of tetanus.</td>
</tr>
<tr>
<td>• Bleed less due to no open wound.</td>
<td>• Limited to calves younger than two weeks.</td>
</tr>
<tr>
<td>• Rings and applicator are not expensive.</td>
<td>• No development of scrotal cod.</td>
</tr>
</tbody>
</table>

Rubber Ring Tools
### 3. Burdizzo Method

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Older calves can be castrated with reduced stress.</td>
<td></td>
</tr>
<tr>
<td>- Bloodless without open wound.</td>
<td></td>
</tr>
<tr>
<td>- Appears to have less pain compared surgical castration.</td>
<td></td>
</tr>
<tr>
<td>- Needs an experienced person.</td>
<td></td>
</tr>
<tr>
<td>- The equipment used is an expensive.</td>
<td></td>
</tr>
<tr>
<td>- A person cannot visually confirm the success of the operation/ procedure.</td>
<td></td>
</tr>
</tbody>
</table>

**Burdizzo Castration Tools and Method**

**DEHORNING**

Dehorning is the removal of horns from cattle. It is labour intensive and needs skilled technicians. Dehorning has animal welfare implications. Dehorning can be avoided by breeding polled cattle.

Reasons for dehorning:

- The risk of hurting other cattle and human beings is reduced.
- Cattle with horns are more aggressive towards other cattle.
- It is easier to handle dehorned cattle.
- Cattle with horns would require more space per animal during transport and will increase transport costs.
- Cattle with horns will require more space in feedlots (trough space).
- Dehorned cattle attract better prices.
Dehorning of old animals reduces growth.

Young calves should be dehorned since they suffer less pain and stress, have less risk of infection and better growth rates. They are also easier to handle.

The best time to dehorn is before the horn bud attaches to the skull (about 2 years old).

If the dehorning cannot be done before the horn bud attaches there will be more bleeding and the wound will be large. Dehorning can be done even if a calf is 6 years provided the good dehorning procedures are followed.

Dry and cool conditions are best for dehorning.

**Animal Welfare Requirements**

Animals should be dehorned as young as possible preferable before weaning. Dehorning animals without local anaesthesia should be limited to animals under 6 months. Older animals can have their horns be tipped (removal of sharp ends) without anaesthesia. Dehorning cattle above 12 months of age is not recommended.

After dehorning animals should be inspected regularly for the first 10 days and any infected wound be treated. A suitable fly repellent should be applied at the time of dehorning.

**Methods of Dehorning**

The recommended methods of dehorning calves are by scoop dehorners and heat cautery which are done as soon as horn buds are detectable.

Cattle must not be dehorned with corrosive chemicals. Inward growing horns are likely to penetrate or contact facial features should be trimmed appropriately.

If the treated horn bud continues to grow due to improper dehorning, do not attempt to dehorn the animal for the second time as to avoid excessive bleeding.

**Dehorning Knife:** The knife has a sharp curved blade to ensure 1cm of skin around the horn bud is removed. It is suitable for calves up to 2 to 3 months old. It is only appropriate if the horn bud is still mobile and is not yet attached to the skull.
Dehorning Knife

**Scoop Dehorner:** Suitable for calves that are between 2-6 months old. Scoop dehorners before the horn bud can get attached to the skull.

![Scope Dehorner](image1)

**Cup Dehorner:** This is used in a situation that the horn is too big or solid for the scoop dehorner. Cup dehorners are best for calves up to six months where horn bud is already firmly attached.

![Cup Dehorner](image2)

**Guillotine Dehorner,** surgical wire, horn saw and tipper: These can be used to dehorn older cattle. They are accompanied with anaesthetic during dehorning.

![Guillotine Dehorner](image3)
Guillotine Dehorner

PIG HUSBANDRY PRACTICES

Below are a number of issues you must consider when raising pigs for commercial purposes.

Food and Water

- Food provided should be fresh, palatable and free from anything known to cause harm to animals.
- Boars and pregnant sows should be given some bulky or lighter fibre feed to satisfy appetite. The feeds should not cause the sow to become over-fat.
- Medicated water should only be used under professional advice.
- The temperature of water should not inhibit drinking.
- The water requirements of different classes of pigs should be met and the drunker designs should allow pigs to have access to water.

Housing

- Pigs grouped in pens require sufficient space for each to sleep, defecate and access feed and water.
- Sucking piglets that are under three months and weaners should be provided bedding and supplementary heating that protects against cold.
- During hot weather adult pigs may suffer from heat stress and steps should be taken to alleviate distress and avoid death. Pigs should not be loaded for transportation in hot conditions (35 Celsius or more).
- Lactating and gestating sows should be inspected regularly for signs of heat stroke and affected animals to be cooled.
- Provide access water for wallowing or mist sprays for outdoor pigs.
- Access to shelters in cold weather and shade in hot weather must be provided to all outdoor pigs.
- Feed and watering points must be provided so that all pigs can gain access and obtain their physiological requirements.
- Outdoor pigs should not be raised on land that is contaminated with toxins or any disease causing organisms at levels known to cause harm.
- Faeces and urine should not be permitted to accumulate to the stage where there is no clean area for pigs to lie down.

Commercial breeds of pigs developed for intensive systems may not be suitable for all outdoor conditions (the breeds that are more suitable would include large black Tamworth, Berkshire or hybrids of such breeds).
Inspection

- Pigs should be inspected at least once a day by a competent stock person.
- Personnel in charge should be to recognise early signs of distress or disease.
- More frequent and thorough inspections should be undertaken where there is an increased risk to the welfare, (e.g. hot weather, out breeds of disease, forming, when pigs have been recently mixed).
- When pigs are housed in large groups it is difficult to visualize all pigs so inspection can be done by moving away the livestock.

Health

- Wearing must be many, to minimise any negative impact on the health and welfare of the sow and piglets.
- Dead pigs must be removed as soon as possible.
- Pigs with incurable sickness must be humanely euthanased.
- Pig producers must have a herd health program in place to manage the risk of disease.
- Vaccination and other health treatments must be administered to pigs only by person must be administered to pigs only by person competent for such procedures.

Farrowing and Weaning

- All piglets must be checked within 24 hours of birth to see that they are feeding and also if they are not sucking they should be provided with appropriate substitute.
- The piglets need to be fostered in case a sow dies prior to weaning.
- A sow should be placed in farrowing ram before the litter is due, to allow her to become accustomed to their surroundings.

Boar Management

- Aggressive adult boars should be housed individually to prevent fighting or be put in compatible groups.
- The floor of the boars’ house should be well maintained and not slippery.
- Mating should be close under supervision of a competent person.
- Housing system that provides boars with more freedom of movement are encouraged.

Moving Pigs

- Pigs should be moved quietly by using non-injuries objects.
• Design of pig housing and loading facilities should be based on expert advice. It should minimise stress on animals and facilitate ease of pig movement.

• **Castration**
  - It should be performed by trained and competent operators.
  - Surgical castration of male pig older than 21 days of age must be performed under anaesthesia.
  - Surgical castration requires use of sterile sharp knife or surgical scalpel.
  - Good post-operative drainage of the surgical wound is essential.
  - Piglets should be castrated between 2-7 days.
  - At 8-21 days of age pigs will need appropriate and effective restraint when castrating.

**Tail Docking**

• It should be practised as a preventive measure
• It should be done before pigs are 7 days old.
• Where tail biting is not a problem there is no need of tail docking.
• The management factors such as feeding environment etc should be investigated wherever there is a problem of tail biting, and if the problem continues tail docking can be done.

**Teeth Clipping**

• This procedure is done if there is aggression between litter mates or damage to the bow.
• Only the tips of the teeth should be removed.

**Nose Ringing**

• Nose ringing should be avoided
• It should only be done as a last resort to prevent adverse effects to the environment.
• Nose rings should be placed through the cartilage of the top of the snout or the tissue separating the nostrils.
• Provision of adequate pasture to clear can deter pigs from rooting up groomed.

**Identification**

• Where necessary the pig ear may be tattooed, tagged, notched or punched.
• Micro-chip can also be used in pigs.
• Ear notching should be avoid if possible, and if done it should be before piglets are seven days of age.

**Back fat Measurement and Pregnancy Diagnosis**
Use of ultrasonic is the recommended method for pregnancy testing and back fat measurement.
Tusk Trimming

- This is done where injury to human or other animals by boar is possible.
- It should be done by using embryotomy wire.
- The boar should be properly restrained and anaesthesia is not required as the tusk lacks sensory nerves.
- The tusks should be cleared above the level of gums without causing damage to other tissues.

POULTRY HUSBANDRY PRACTICES

This is intended to advice people responsible for the welfare and husbandry of poultry. It recognises that the basic requirements for welfare of poultry. It recognises that the basic requirements for welfare of poultry are a husbandry system appropriate to their physiological and behavioural needs.

The basic needs of poultry are as follows:

- Readily accessible feeds and water.
- Freedom to move, stand, turn around, stretch, sit and lie down.
- Visual contact with other birds.
- Housing which protects them from adverse weather conditions.
- Prevention of disease, injury and vice and their rapid treatment should they occur.

Housing Methods

Cage System

- The floor must be constructed to ensure support for each forward pointing toe and the slope of the floor should not exceed 8 degrees.
- Multi-deck cages should be in such a way that birds in lower tiers are protected from the excrete of birds on top tiers.
- The feed trough should be at least 10cm.
- The cages must allow birds to stand normal height and that means the cages should be higher than the height of a standing bird.
- The design of the cage should in such a way that the entry and removal of the bird into the cage will not cause injury or unnecessary suffering.

Non-Cage Systems

- The floor should consist of litter material or slatted flooring or wire flooring or any combination of these.
- The litter material provision is encouraged for birds to dusk bath and forage.
- The design of the slats should be that the slats adequately support the birds. The gaps between the slats should not exceed 25 mm.
• Provision of adequate perching space recommended.
• If perches are provided all birds should have an opportunity too roost if that is their preference.
• The horizontal distance between the perches should be at least 30 cm but not more than one metre.
• Laying hens must be provided with laying nests with the ratio of 1 nest: 7 hens, or at least 1m2 of nest per 120 hens.
• The nests should have bedding that encourages nesting behaviour.
• The nest boxes should be easily accessible.
• Nest litter should be kept clean, dry and be moisture absorbent.

Free Range System

• Poultry should not be kept on land which is contaminated to an extent which could seriously prejudice the health of poultry.
• All birds when fully feathered must have access through opening to the outdoor range during the day for a minimum of 8 hours.
• Birds on the range should have access to shaded areas and shelter from rain.
• Birds should be provided with protection from predators at all times.

Equipment

• All equipment to which poultry have access must be designed and maintained to avoid injury or pain to the birds.
• All automated hatchery and environmental control equipment must have adequate back-up system or alarms in case of equipment failure.
• Young birds require light and food and water during the rainy period.
• Avoid sudden increases in light intensity since it may cause flight reaction in some birds.
• More poultry do not have access to daylight they should be given lightening over a total period of at least 8 hours per day.

Ventilation

• Ventilation is required at all times to provide fresh air.
• Poultry should be protected from extreme weather condition including stormy draughts is cold weather.
• The presence of ammonia is usually a reliable indicator of the build up of noxious gas. High levels of ammonia will cause eye and nasal irritation is humans.
• Mechanically ventilated sheds must have a back-up power supply or alternative equipment ventilation system.
Temperature and Humidity

- Newly hatched birds have a poor ability to central body temperature, so they require supplementary heat.
- The behaviour of the birds is the best indicator of discomfort if insufficient or excessive heat is being provided.
- In hot weather provision of adequate cool water and ventilation is essential and birds must have access to shade.
- Temperature control systems in layer sheds should prevent ambient temperature at bird level exceeding 33 degree Celsius.
- The construction and positioning of most boxes should be in such a way that they do not trap heat.

Feeding

- Poultry must have access to food at least once in each 24 hour period.
- Newly hatched birds must be provided with good within 60 hours of hatching.
- A poultry diet must well balance and must meet the poultry requirements.
- Avoid force fed except for therapeutic reasons.
- Adequate feed must be supplied in the feeding systems free range shade.
- Avoid given diets to birds that do not want eat.
- Never use electric pulse wires to control feeding.
- Never use method of moult inducement to control feeding and water for birds.

Water

- Birds must have access to sufficient water to meet their physiological requirements.
- Ensure that birds are not deprived from water more than 24 hours.
- Clean and right temperature of water supply should always be given to birds.
- Each bird must have access to at least two independent drinking points.

Health

- Care must take always exercise to detect signs of ill health or distress in a flock.
- Vaccination and other treatments should be applied by skilled people.
- Any outbreak of feather picking or cannibalism occur management practices should be adjusted, e.g. reduce stock density temperature or a high intensity etc.
- Trapped birds should be free immediately and correct management measurement should be applied to avoid recurring.
- Always follow manufacture instruction when given medication.
- Diseased birds should remove from the flock immediately and humanely destroyed as soon as possible.
• Avoid dislocation as a method of destruction in birds.
• Ensure proper hygienic procedures should be taken when cleaning and restocking a flock for disease prevention measures.
• Keep out predators that can be carriers of diseases into poultry farm.

Artificial Insemination (AI)

The processes should only be carried out by competent and trained personnel. High standards of hygienic should always be kept during this process (AI).

Beak Trimming (BT)

Removal of the tip of the beak to avoid feather backing and cannibalism. The process should only be carried out by an accredit operator or under good supervision.

Toe Removal (TR)

Male breeding birds should remove its inward pointing toe to reduce entry to hen during mating time. This process always is carried when chick is three days after hatching to trimming.

Toe Trimming

Should always be limited to the nail of toe to prevent adult males injuring other birds during fight.

Blinkers

Blinker and other vision in paired should always be used under the supervision of a veterinary. Avoid the use of contact lenses that may cause eye irritation and infection as well as abnormal behaviour.

Flight Restriction

Feather clipping can be done to avoid birds from flying around building

Identification

Use proper branding methods such as wing colouring etc, for bird identification. Regularly check on these branding to avoid injury of birds.

Hatchery management

• Proper disposal of all hatchery waste such as unfertilized embryos should be done immediately.
• Hatching should be brooded within 48 hours.
• Weak and deformed birds should be culled and destroyed humanely.
Poultry Transport

Always ensure that birds are not in a stress condition during transportation and unloading.

Sale of Poultry

- Avoid sale yards of poultry that may cause stress to the birds.
- Birds should be sold in cages and pen with access to water, feed and shelter.
- Keep birds below the temperature of 33 degree Celsius when transporting in a vehicle.

SUMMARY

This lesson provided best practices and tips in how to effectively manage the health and well-being of your animals. These practices should be considered and applied when caring for your livestock.
LESSON 2.6 – ANIMAL HEALTH

OVERVIEW
The success of any type of livestock operation is closely related to the level of the animal’s health. Losses related to diseases happen in dependent ways such as death, medication costs and condemnation of meat at slaughtering process as well as poor growth, reduced yield and poor feed conversion.

This lesson will cover the basic facts of the diseases, how they spread and the ways to minimize the disease and losses related to them.

OBJECTIVES
Upon completion of this lesson you should be able to:

1. Identify the types and causes of disease that could affect your farm animals’ health.
2. Employ good farm health management practices.
3. Keep appropriate animal health records.

DISEASE CAUSES
Disease is an alteration of the body or body organs which interrupts or disturbs the body’s function. A disease often results from combination of two or more causes.

Indirect Factors
This includes chilling, poor ventilation, overcrowding, inadequate feeding and improper medication. These are the causes that are more related to stress.

Direct Factors
These are more related to disease causing micro-organisms which include bacteria, viruses, parasites, fungi, nutritional deficiencies, chemical poisons as well as unknown causes.

Supplementary Readings
To learn more about the causes of disease in animals it is recommended you read the following online article.

TYPES OF DISEASE

Infectious

They are caused by bacteria, viruses, and fungi, when living organism like bacteria, enter the body and multiply they disturb the body processes and thus causing a disease. These diseases are produced by living organisms.

To learn more about infectious diseases you should review the CDC article: Diseases from Farm Animals (http://www.cdc.gov/healthypets/animals/farm_animals.htm).

Contagious Diseases

All contagious diseases are infectious but not all infectious diseases are contagious. These diseases are passed from one animal to another through contacts.

You should review the following New Zealand Ministry of Agriculture web site to learn more about infectious and contagious diseases: Diseases of Sheep, Cattle and Deer. Concentrate on the following links:


Non-Infectious Diseases

These are the diseases that are not caused by a pathogen and cannot be shared from one animal to another. Non-infectious diseases are mainly caused by environmental, nutritional deficiencies or genetic inheritances.

Favourable Conditions for Disease

The ability of an organism to cause disease in a host is known as its virulence or pathogenicity.

An organism should enter the body of the susceptible host; e.g. infectious bronchitis virus will cause disease only in chicken. Salmonella organism will cause disease in most domestic animals (poultry, pig, sheep, goats, and cattle).

The ability of an organism to produce chemical toxins or invades body tissues is.

Supplementary Readings
An excellent source for exploring the diseases that impact each major system is the following manual. You are not required to read it, but you should review the table of contents to become familiar with the different diseases it describes and how to prevent or treat different livestock diseases.


METHODS OF INFECTION

Diseases can be introduced into your livestock in a variety of ways. Several of the transmission methods described below are preventable with proper husbandry practices and farm management.

- Introduction of diseased animals to healthy animals.
- Introduction of healthy animals that are carriers or can still transmit the disease to other animals.
- Contact with other objects that are contaminated with disease organism e.g. feeders, drinkers, transporting, trucks etc.
- Contact with carcasses that have not been disposed /burned properly.
- Unclean water.
- Rodents and flies.
- Mosquitoes.
- Overalls and shoes of people who move between different farms.
- Contaminated food and food bags.
- Contaminated soil, bedding, etc.
- Airborne organisms on overcrowded livestock areas.

How does body defend against disease?

There are two types of protective mechanism in animals.

Preventing Invasions of an Organism

This includes the intact skin and mucus membranes which create a direct barrier. Mucus secretions tend to dilute and flush away invading organism. Hair-like structures on some membranes move foreign material out of such structure as the trachea (wind-pipe).

Combating Agents Which Invade the Body

The mechanism that combat agents invading the body include white body blood cells and circulating antibodies.

NB. For details please refer to immune system sub topic under anatomy and physiology.
RECOGNIZING DISEASES

The following articles and videos describe some of the basic considerations when caring for livestock and controlling diseases.

To understand some of the diseases that cattle can be exposed to you should read the following article: Common Diseases in Cattle (http://www.merckvetmanual.com/mvm/index.jsp).

It is recommended you view the following YouTube Videos:

Sheep Diseases: http://www.youtube.com/watch?v=DTqfLTEO448&feature=player_embedded

Chicken Diseases: http://www.youtube.com/watch?v=8ksQ0nY3ZFg&feature=player_embedded

HEALTH MANAGEMENT

A standard disease prevention program that applies on all farms does not exist, however there are general practices that help in prevention.

1. An animal health expert should be consulted when planning a health program.
2. New stock of animals should be bought from the reliable source, one that supply healthy stock, inherently vigorous and developed for a specific purpose.
3. Separate animals according to the source and age groups.
4. Follow an all in and out programme.
5. Buy animal feeds from a reliable food suppliers but in case of mixing own feeds, mix carefully according to dependable program.
6. Supply animals with good quality water.
7. Follow a practical vaccination schedule and work out the vaccination program with the relevant authorities in your area.
8. Discourage visitors into your farm
9. Always look for signs of any disease and if you suspect anything consult veterinarian.
10. Dispose all dead animal properly, e.g. burning disposal pit, etc.
11. Maintain good records in relation to animal health which should include vaccination history, disease problem and medication.

Supplementary Readings: Another good reference that you should review is the web site produced by the UK Department for International Development and available at: Livestock Health (http://www.smallstock.info/info/health.htm).
RECORDS KEEPING

Keeping records of all farm operations is very important, especially when it comes to food safety. With today's complex food system, fresh products rarely move directly from the farmer to the consumer, but often is handled many times before it reaches the market or is consumed. When food borne illness outbreaks occur, attempts are made to trace the contamination back to the point of origin. Therefore as a farmer, keeping good records by documenting any manure use, water test results, and worker training programs may provide important data that indicates the contamination did not occur on your farm. Good records facilitate ease of auditing by buyers and regulatory agencies, and help prevent the need for formal regulations. Documentation also highlights a farmer’s commitment to reducing microbial risks on their farms.

There are several items that should be taken into consideration for record keeping this is not an exhaustive list but given to provide you with a guideline of why record keeping is important.

Supplementary Readings: To learn how to create and maintain farm records you should read the following.

Developing and Improving Your Farm Records. (http://extension.umd.edu/publications/pdfs/fs542.pdf)


EXAMPLE OF FARM RECORDS

Below are some examples that should of record keeping on in livestock production:

- Farm Diary
- Financial Records
- Breeding Records
- Birthing Dates
- Veterinary Visits (Animal sickness, drug treatments)
- Feeding Information (Feed Formula)
- Culling and Selection
- Furrowing records
- Sales records
Farmers have to consider their farms as a business and as a business it is necessary to document what is happening, keeping records is essential to the smooth operation of any organization. While there are noted advantages of record keeping especially if it is kept simple, and easy it does take some time and effort on the part of the farmer. By following the simple diagram below farmers can start a simple recordkeeping system.

<table>
<thead>
<tr>
<th>Recording receipts &amp; expenses</th>
<th>Record Livestock Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Diary</td>
<td></td>
</tr>
<tr>
<td>Keeping/Using Inventories</td>
<td>Analyzing the farm business</td>
</tr>
</tbody>
</table>

By implementing a record keeping system the farmer then has a cost effective management tool. Couple this with well-organized records can help ensure proper maintenance of facilities and equipment on your farm and provide you with a proper means of monitoring the entire farm. By ensuring that you regularly update your records and keep them readily accessible, you can track all changes on your farm. Record keeping allows the farmer to know where their business is going and what changes they should consider to ensure that a profit is made. Without proper understanding of record keeping and its current and future implications, the farm operator can make informed decisions about management.

Overall record keeping is a sound business practice and is important not only for financial reason but for efficient and effective farm management. The use of computer systems to keep records is advisable but while the use of computers can ease the burden of manual record keeping, a hard copy is always necessary in case of system errors. While farmers in ACP countries tend not to keep records a shift in this direction will go a long way in determining the weakest link on your farm.

While the use of computers can ease the burden of manual record keeping, a hard copy is always necessary.

**SUMMARY**

A farm is a business and thus needs effective records keeping and administrative practices. The farm manager must understand budgeting, bookkeeping, file management and scheduling. The manager must ideally understand how to use a computer and various online software to support the management of their farms.
UNIT DISCUSSION

Under the guidance of your instructor complete initial investigation, then discuss the results of your investigation with your peers.

*Investigate the major diseases or health threats to your local livestock populations. Be prepared to discuss the health threats and how to manage these threats to your livestock.* What can you do to prevent these threats?

UNIT ASSIGNMENT

**Task:** As directed by your instructor, you are required to study the livestock animals that exist in your local community or small nation state. Select any area, field or a farm to complete the project; you have to spend minimum of five hours in the field over a period of three weeks or more. In addition you need to interview the farmer/farm manager.

During your field experience and interviews with the farmer, you are to maintain a journal that documents the type of livestock animals that are on the farm, their classifications and housing patterns, methods of husbandry, diets and nutrition, and their health related issues. While doing this you need to have a record of all the activities for each week separately. Finally you need to discuss the finding in relation to livestock production and good agricultural practices in your country with the farmer/farm manager and note the major issues raised during the interview.

**Timeline:** The instructor will provide a timeline by which you must complete this activity.

**Guidance:** As you complete this activity ensure you consider all of the information that was covered in Units 2. Make sure you reference the supplementary readings that would support your summary. You will end up producing two documents: the journal with your field notes; and a summary paper that discusses what you observed and what you discovered in your discussion with the farmer.

**Submission:** Once you have completed the activity, you must submit your journal and supporting summary paper to your instructor for feedback and grading.
UNIT TWO SUMMARY

In this unit you learned most small states of the common wealth depend on livestock production for source of protein, traditional obligations and other bi animal products for exports. The importance of this sector to agriculture development of these small states in a sustainable way will support people’s livelihood and improving state’s economy. In doing so, practicing and future farmers of these states should be trained in this area to ensure that livestock production can be improved in all levels.

In this Unit anatomy and physiology of farm animals would serve as a basic science for understanding of the various systems that control animal body of ruminants, non ruminants and avian.

In breeding and selection of farm animals there are factors to be considered for a successful program in maintaining and developing the productive livestock breeds for different environmental conditions. The hardy breeds or sometimes called local or native breeds of animals such as chicken, pigs and goats existed for a long time in your state are ideal breeds of animals to improve on their performances since their genetic characteristics that they inherited are more resistance to many diseases and pests and are suitable for your local conditions. In order for the genes to pass from one animal to another there should be a union of male and female gametes. In farm animals this union can be through mating. There are different methods of mating for various types of animals.

In Sustainable livestock production there are three systems of keeping animals being intensive, semi intensive and extensive. The practices of these methods will determine the sustainability of a system used. So, factors given needed to be considered if one has to apply a system for a local situation.

Animals need good housing to cater for different processes that go through. The systems used will determine the type of house that an animal need. The purpose and the product that needed to be obtained influenced the decision of housing that has to be provided. However, most small states have traditional animal housings that are also sustainable and environmental friendly and low cost can be also considered.

Farm animals like human, need balance diet and clean water for survival. Different diets and feeding systems used depending on the farmer’s purpose for an animal. Amount of feed also are determined to ensure maximum output from whatever animal farm type. Animal health is important and diseases that may endanger them are studied.

Record keeping is vital to raising animals. Different types of records are kept for various types of animals depending on the process that they go through. These records are regularly updated to ensure information of a flock; a herd and an animal are correctly entered and kept. Most small states farmers do not keep any animal records, so this
practice needed to be practiced will help in further farm development, sourcing funds from loan institutions and ensuring that proper procedures are done for raising any animal.
UNIT THREE - BEST PRACTICES IN HARVEST MANAGEMENT, POST MANAGEMENT & AGRO PROCESSING

OVERVIEW

Appropriate harvesting methods and post-harvest activities ensure enhanced value of food and agricultural products. The application of the best practices described in this unit helps reduce losses and increase efficiency of all processes linked to harvesting and post production management.

The value of fruits and vegetables can be increased from the point of harvest until they reach the plate of final consumers. The aim of post-harvest management is to maximize this value addition process. Post harvest practices are beneficial to small states as they can contribute to increase export earnings from produce or extend the availability of the produce all year round.

Effective harvesting and post-harvest management determines food quality and safety, competitiveness in the market and the revenue obtained by producers. In Small States post-harvest management helps improve efficiency in handling and transportation; technologies for storage, processing and packaging; streamlining of the process and improving the infrastructure. This unit starts by focusing on the harvesting of field crops and the physiology of fruits and vegetables to understand the processes that contribute to post harvest deterioration. The changes that cause losses are then addressed which are followed by post harvest handling procedures including packaging and storage to improve produce marketability.

GOALS AND OBJECTIVES

Upon completion of this unit you will be able to:

1. Describe harvesting best practices.
2. Explain the internal and external factors that promote the deterioration of fresh agricultural commodities.
3. Recommend appropriate handling practices and technologies to extend shelf life and to preserve quality of fresh agricultural produce.
4. Recommend the appropriate processing techniques for creating safe value added products from agricultural commodities.
5. Explain the importance of market specification on packaging and labelling.
LESSON 3.1 – HARVEST MANAGEMENT

OVERVIEW

In agriculture, harvesting is the processes of gathering mature crops from the fields. *Reaping* is the cutting of grain or pulse for harvest, typically using a sickle or reaper. The harvest marks the end of the growing season, or the growing cycle for a particular crop. On smaller farms with minimal mechanization, harvesting is the most labor-intensive activity of the growing season. On large, mechanized farms, harvesting utilizes the most expensive and sophisticated farm machinery, like the combine harvester.

In crop production, harvest timing is a critical decision that balances the likely weather conditions with the degree of crop maturity. Weather conditions such as rain, and unseasonably warm or cold periods can affect yield and quality. An earlier harvest date may avoid damaging conditions, but result in poorer yield and quality. Delaying harvest may result in a better harvest, but increases the risk of weather problems.

OBJECTIVES

Upon completion of this lesson you will be able to describe the best practices and records keeping process in harvest management.

CROP MATURITY

Maturity at harvest is an important factor that determines post-harvest life and final quality (appearance, flavour and nutritive value). Three stages in the life span of fruits and vegetables are distinguished: 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.

Maturity determination also depends on the type the part of the plant that is being harvested. Some are harvested before full maturity while for others full maturity must be reached. The diagram on the next page examines some of the concepts of maturity. These will be explored in later lessons.
Maturity indices have been determined for many fresh produce items. The following section deals with maturity indices and the determination of time to harvest. Produce harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or overripe. Some typical maturity indices are:

**Commercial Maturity**

- **Sprout**
  - Asparagus, celery, lettuce, cabbage
- **Inflorescence**
  - Artichoke, broccoli, cauliflower
- **Partially Developed Fruit**
  - Cucumber, green bean, okra, sweet corn
- **Fully Developed Fruit**
  - Apple, pear, citrus, tomato
- **Roots & Tubers**
  - Carrot, onion, potato
- **Seeds**
  - Dry bean
Skin Colour

Skin colour is commonly used for fruits as skin colour changes as fruit ripens. Assessment of colour depends on the judgement of the harvester, however colour charts are available for commodities such as tomatoes and bananas.

Degree of ripening in tomato (from left to right): 1) Mature green; 2) Breaker; 3) Turning; 4) Pink; 5) Light red and 6) Red. Due to its climacteric ripening characteristics, the tomato fruit reaches stage 6 even when harvested at maturity stage 1.

Optical Methods

Light transmission properties can be used to measure the degree of maturity of fruits. These methods are based on the chlorophyll content of the fruit, which is reduced during maturation. The fruit is exposed to a bright light, which is then switched off so that the fruit is in total darkness. Next, a sensor measures the amount of light emitted from the fruit, which is proportional to its chlorophyll content and thus its maturity.
Optical Method

Shape

The shape of fruit can change during maturation and can be used as a characteristic to determine harvest maturity. For instance, a banana becomes more rounded in cross-sections and less angular as it develops on the plant. Mangoes also change shape during maturation.

Maturing Bananas

Size

Changes in the size of a crop while growing are frequently used to determine the time of harvest. For example, for bananas, the width of individual fingers can be used to determine harvest maturity. Usually a finger is placed midway along the bunch and its maximum width is measured with callipers; this is referred to as the calliper grade.

Aroma

Most fruits synthesize volatile chemicals as they ripen. Such chemicals give fruit its characteristic odour and can be used to determine whether it is ripe or not. These odours may only be detectable by humans when a fruit is completely ripe, which therefore, means that the commodity will have a short post-harvest life.

Fruit Opening
Some fruits may develop toxic compounds during ripening, such as ackee tree fruit, which contains toxic levels of hypoglycine. The fruit splits when it is fully mature, and at this stage, contains minimal amounts of hypoglycine or none at all. This creates a problem in marketing because the fruit is so mature, it will have a very short post-harvest life.

Ackee Tree Ripened Fruit

Leaf Changes

Leaf quality can determine when some fruits and vegetables should be harvested. For example, if potatoes are to be stored, then the optimum harvest time is soon after the leaves and stems have died. If harvested earlier, the skins will be less resistant to harvesting and handling damage and more prone to storage diseases.

Abscission

As part of the natural development of a fruit an abscission layer is formed in the pedicel. For example, in cantaloupe melons, the abscission layer should be fully developed at the time of harvest.

Firmness

Fruits may change in texture during maturation, especially during ripening when they become softer. Excessive loss of moisture may also affect the texture of crops. These
textural changes are detected by touch, and the harvester may simply be able to gently squeeze the fruit and judge whether the crop can be harvested.

Mechanical Means

There is, however, modern equipment like pressure testers that can be used to give a more accurate determination of harvest maturity.

The following list allows for a more objective method of maturity determination as they do not rely on the judgment of the harvester. However, these methods are destructive and as such sampling is used.

- Juice content
- Oil content
- Moisture content
- Sugars
- Starch content
- Acidity

A range of equipment is available for use with these methods of maturity determination.

**EXAMPLE MATURITY INDICES**

The following table, from Reid (in Kader, 2002) provides some examples of maturity indices.

<table>
<thead>
<tr>
<th>Index</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed days from full bloom to harvest</td>
<td>Mangoes</td>
</tr>
<tr>
<td>Development of abscission layer</td>
<td>Some melons</td>
</tr>
<tr>
<td>Surface morphology and structure</td>
<td>Netting of some melons</td>
</tr>
<tr>
<td></td>
<td>Gloss of some fruits (development of wax)</td>
</tr>
<tr>
<td>Size</td>
<td>All fruits and many vegetables</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Watermelons, potatoes</td>
</tr>
<tr>
<td>Shape</td>
<td>Angularity of banana fingers</td>
</tr>
<tr>
<td></td>
<td>Full cheeks of mangos</td>
</tr>
<tr>
<td></td>
<td>Compactness of broccoli and cauliflower</td>
</tr>
<tr>
<td>Solidity</td>
<td>Lettuce, cabbage</td>
</tr>
<tr>
<td><strong>Textural properties</strong></td>
<td></td>
</tr>
<tr>
<td>Firmness</td>
<td>Stone fruits</td>
</tr>
<tr>
<td>Tenderness</td>
<td>Peas, beans</td>
</tr>
<tr>
<td>Colour, external</td>
<td>All fruits and most vegetables</td>
</tr>
<tr>
<td>Internal colour and structure</td>
<td>Formation of jelly-like material in tomato fruits</td>
</tr>
<tr>
<td></td>
<td>Flesh colour of some fruits</td>
</tr>
<tr>
<td><strong>Compositional factors</strong></td>
<td></td>
</tr>
<tr>
<td>Starch content</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Index</td>
<td>Examples</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Sugar content</td>
<td>Mangoes</td>
</tr>
<tr>
<td>Acid content, sugar/acid ratio</td>
<td>Pomegranates, citrus, papaya, melons, kiwifruit</td>
</tr>
<tr>
<td>Juice content</td>
<td>Citrus fruits</td>
</tr>
<tr>
<td>Oil content</td>
<td>Avocados</td>
</tr>
<tr>
<td>Astringency (tannin content)</td>
<td>Persimmons, dates</td>
</tr>
<tr>
<td>Internal ethylene concentration</td>
<td>Apples, pears</td>
</tr>
</tbody>
</table>


Vegetables are harvested over a wide range of maturities, depending on the part of the plant used as food. The following table provides some examples of maturity indices of vegetable crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Root, bulb and tuber crops</strong></td>
<td></td>
</tr>
<tr>
<td>Radish and carrot</td>
<td>Large enough and crispy (over mature if pithy)</td>
</tr>
<tr>
<td>Potato, onion, and garlic</td>
<td>Tops beginning to dry out and topple down</td>
</tr>
<tr>
<td>Yam bean and ginger</td>
<td>Large enough (over mature if tough and fibrous)</td>
</tr>
<tr>
<td>Green onion</td>
<td>Leaves at their broadest and longest</td>
</tr>
<tr>
<td><strong>Fruit vegetables</strong></td>
<td></td>
</tr>
<tr>
<td>Cowpea, yard-long bean, snap bean, sweet pea, and winged bean</td>
<td>Well-filled pods that snap readily</td>
</tr>
<tr>
<td>Lima bean and pigeon pea</td>
<td>Well-filled pods that are beginning to lose their greenness</td>
</tr>
<tr>
<td>Okra</td>
<td>Desirable size reached and the tips of which can be snapped readily</td>
</tr>
<tr>
<td>Snake gourd, and dishrag gourd</td>
<td>Desirable size reached and thumbnail can still penetrate flesh readily (over mature if thumbnail cannot penetrate flesh readily)</td>
</tr>
<tr>
<td>Eggplant, bitter gourd, chayote or slicing cucumber</td>
<td>Desirable size reached but still tender (over mature if colour dulls or changes and seeds are tough)</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>Exudes milky sap when thumbnail penetrates kernel</td>
</tr>
<tr>
<td>Tomato</td>
<td>Seeds slipping when fruit is cut, or green colour turning pink</td>
</tr>
<tr>
<td>Sweet pepper</td>
<td>Deep green colour turning dull or red</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>Easily separated from vine with a slight twist leaving clean cavity</td>
</tr>
<tr>
<td>Honeydew melon</td>
<td>Change in fruit colour from a slight greenish white to cream; aroma noticeable</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Colour of lower part turning creamy yellow, dull hollow sound when thumped</td>
</tr>
<tr>
<td><strong>Flower vegetables</strong></td>
<td></td>
</tr>
<tr>
<td>Crop</td>
<td>Index</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Curd compact (over mature if flower cluster elongates and become loose)</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Bud cluster compact (over mature if loose)</td>
</tr>
<tr>
<td><strong>Leafy vegetables</strong></td>
<td></td>
</tr>
<tr>
<td>Lettuce</td>
<td>Big enough before flowering</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Head compact (over mature if head cracks)</td>
</tr>
<tr>
<td>Celery</td>
<td>Big enough before it becomes pithy</td>
</tr>
</tbody>
</table>


**HARVESTING METHODS**

Harvesting methods differ according to the part of the plant to be used. As regards forage crops, the whole plant is cut, but for underground crops (e.g., groundnuts, roots and tubers), the crop is lifted while the soil sticking to it is removed. With cereals, the crop is first cut either as a whole or partially (ears), and then threshed and cleaned to separate the grain from the ears and straw.

Harvesting can be done by manual labour, by a machine or a combination of both. Manual labour is often used in picking fruit trees and low growing fruit that cannot be picked by a machine. Vegetables like potatoes, carrots and tomatoes can be picked either by hand or by a machine.

Hand-harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time. For example in tomatoes, apples, and other vine grown crops. Machine-harvesting is usually viable only when an entire crop is harvested at one time, such as potatoes and grains.

Harvesting practices should cause as little mechanical damage to produce as possible. Gentle digging, picking and handling will help reduce crop losses.

**Combine and Threshing Methods**

Combine-harvesters, as the name implies, combine the actions of reaping and threshing. Either the 'through-flow' or the 'hold-on' principle of threshing may be employed, but the reaping action is basically the same. According to the type of machine used, and especially to their working width, capacities range from 2 to 15 hours per hectare. Such machines are being increasingly used in some tropical countries.
Harvesting grain

Grain Cleaning

Threshing operations leave all kinds of trash mixed with the grain; they comprise both vegetable (e.g. foreign seeds or kernels, chaff, stalk, empty grains, etc.) and mineral materials (e.g. earth, stones, sand, metal particles, etc.), and can adversely affect subsequent storage and processing conditions. The cleaning operation aims at removing as much trash as possible from the threshed grain.

The simplest traditional cleaning method is winnowing, which uses the wind to remove light elements from the grain.
HARVESTING GRAINS

Cropping Conditions - Grain

Crop maturity and type of product directly affects the type of mechanization and vice versa. The introduction of mechanized technology has reduced the tendency to plant mixed varieties of grain: single variety crops ripen uniformly thus making it easier to harvest or thresh them mechanically. With crops which do not mature at one time, the choice of the date for performing the harvesting operation will determine the results. For paddy an earlier harvest will generally result in low yields and high percentage of unripe grain; on the other hand, delayed harvesting will lead to shattering losses, higher percentage of broken grain at the processing level, etc. In addition, the weed infestation level will affect the use of machines and also the cleanliness of the harvested and threshed materials.

Social and Labour Constraints

Harvesting is a labour-intensive operation but is less arduous than threshing. The skills and experience of farmers, and the interests of traditional systems, must necessarily be taken into account when mechanizing certain operations. It will be easier to extend the use of harvesting machines where farmers are already employing other powered equipment such as tractors, motor pumps or processing units. The availability of workers skilled in the operation, maintenance and repair of engine-powered equipment favours the adoption of new machines.

Economic Constraints

Economic constraints are a drawback to the purchase of farm machinery. The high costs involved, above individual farmers' resources, allow the acquisition of such equipment only if credit and the possibility of farmers grouping together exist. Alternatively, if private individuals are interested in equipping themselves, they can hire out their services to the rest of the community.

To justify and encourage the purchase of machines, technical versatility can be an incentive even if the equipment proves less efficient with certain crops than a specific single-purpose one. In such a case, the choice of the equipment should be made according to the crop which is mechanized first.

Training

Training is a key element in the successful adoption of engine-powered machines by farmers. In Sierra Leone the National Agricultural Training Center, Njala University trains in the use of some common harvesters that are commonly used in small state countries.

Some of the topics that should be mastered by farmers overseeing harvest operations include:
- Credit schemes available to purchase equipment.
- The ideal conditions suitable for harvesting and threshing which will reduce the costs of these operations and improve the quality of the product obtained.
- Training on the management of equipment, while operators and mechanics need to learn about the maintenance and running of equipment;
- Training in work organization, projecting running costs, and maintaining operational accounts.

**HARVESTING FRUITS**

The method of removing the item from the parent plant varies depending the type of commodity:

Many ripe fruits and some immature seed-bearing structures such as legume pods have a natural break-point of the fruit stalk, which leaves the stalk attached to the fruit. These can be easily broken at harvest. Others like tomatoes and passion fruit which fall in this category are best removed by a “lift, twist and pull” series of movements.

Fruit and other-seed bearing structures harvested in the immature or unripe green state are more difficult to pick without causing damage to either the produce or the plant. These are best harvested by cutting them from the plant using clippers, secateurs or sharp knives.

Immature fruits with fleshy stems can be cut with a sharp knife, e.g. zucchini, okra, papaya, capsicum; these can also be harvested by breaking the stem by hand, but this method may damage the plant or fruit and the rough break will be more susceptible to decay than would a clean cut.

Mature green or ripe fruits with woody stalks which break at the junction of the fruit and the stalk are best clipped from the tree, leaving up to a centimetre of fruit stalk attached. If the stems are broken off at the fruit itself, disease may enter the stem scar and give rise to stem end rot, e.g. mango, citrus, avocado

Items with woody stems should be trimmed as close as possible to prevent fruit from damaging neighbouring fruits during transport.
HARVESTING VEGETABLES

The whole or part of the vegetative growth may be harvested by hand or by using a sharp knife.

If using a knife, the knife should be sharp and kept clean to avoid the transfer of pathogenic organisms.

Different plant parts have different methods:

1. leaves only example spinach: the stem is snapped off by hand;
2. above-ground part of the plant (cabbage, lettuce): the main stem is cut through with a heavy knife, and trimming is done in the field (the cut stem must not be placed on the soil);
3. bulbs (green onions, mature bulb onions): immature green onions can usually be pulled from the soil by hand; leeks, garlic and mature bulb onions are loosened by using a digging fork as for root crops (such as carrots) and lifted by hand; or
4. simple tractor implements are available for undermining bulbs and bringing them to the surface.

Onion Harvester

For flowering vegetables like cauliflower and broccoli they should be cut with a sharp knife and trimmed in the field.

Harvesting Roots & Tubers

Most root crops and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools, which may be wooden sticks, machetes, cutlasses, hoes or forks.
These crops may be harvested using digging tools which are pushed into the soil under the roots or tubers. The crop can then be levered upwards, loosening the soil and decreasing the possibility of damage to the crop.

The digging fork or stick (1) is pushed under the crop and downward pressure (2) on the handle loosens the soil and lifts the crop.

**HARVESTING STRATEGIES**

Employing appropriate harvesting strategies can have a positive impact on crop quality. Some of the issues you need to consider when conducting harvesting operations include:

**Harvest Time**

Quality is dependent on timing the harvest correctly for most vegetables. Size, flavour, tenderness, texture and colour can all be influenced by harvest timing. Snap beans must reach a certain sieve size, summer squash and cucumbers must be harvested within a narrow size range, melons must reach an acceptable sugar content, tomatoes to be shipped must be harvested at mature green or as "breakers" but usually not past the "pink" stage. Tomatoes for direct sales can be harvested when ripe. Sweet corn is harvested when the kernels are milky or when they are at about 75% moisture. Cabbage, winter squash, pumpkins and peppers have a wider harvest window.

**Harvest Method**

Harvest method affects quality because of its effect on the amount of injury sustained by the product during harvesting. Some fresh market vegetables can be machine harvested; snap beans, sweet corn, potatoes, sweet potatoes, onions, carrots and celery are included in this category. Quality problems involved are bruising and breakage of beans, carrots and celery petioles by the harvester. Additional damage results from the drop involved in transfer to wagons or bins. Padding at impact points or belt and chain speed adjustments may reduce damage. Sorting prior to packing is necessary to remove damaged produce.
With hand harvest, injury to the product can occur when it is thrown or otherwise inappropriately handled. Good field management is required to prevent this. The harvest crew also needs to be trained to select only marketable produce, leaving the rest in the field. Harvest aids to improve efficiency are common with melons, cabbage, sweet corn, lettuce, cauliflower and winter squash. Field packing may be associated with harvest aids. "Mule train" harvesters are common with sweet corn, cabbage, cauliflower and lettuce: in these systems produce is harvested and packaged for shipping in the field. Quality control rests with well-trained packers as the rig moves through the field.

**Harvesting and Field Handling**

The quality and condition of produce sent to market are directly affected by the care taken during harvesting and field handling. Whatever the scale of operations or the resources of labour and equipment available, the planning and carrying out of harvesting operations must observe basic principles.

The objective should be to:

- harvest a good quality crop in good condition;
- keep the harvested produce in good condition until it is consumed or sold; and
- dispose of the crop to a buyer or through a market as soon as possible after harvest.

To meet these objectives, success in harvesting and marketing must depend on planning from the earliest stages of production, particularly in regard to:

- crop selection and timing to meet expected market requirements;
- contacts with buyers so that the crop can be sold at a good price when ready for harvest;
- planning harvest operations in good time; arranging for labour, equipment and transport; and
- providing full supervision at all stages of harvesting and field handling.

When the crop is ready for harvest, labour and transport are available, and operations organized, the decision on when to start harvesting will depend largely on:

- weather conditions; and
- the state of the market.

The flexibility of the marketing date will depend on the crops. For example, root crops can be harvested and sold over a long period, or stored on the farm to await favourable prices. Others, such as soft berry fruits, must be marketed as soon as they are ready or they will spoil.
When the decision to harvest has been made, the best time of day must be considered. The aim is to dispatch the produce to market in the best possible condition, that is, as cool as possible, properly packed and free from damage.

The basic rules to observe are:

- harvest during the coolest part of the day: early morning or late afternoon;
- do not harvest produce when it is wet from dew or rain. Wet produce will overheat if not well ventilated, and it will be more likely to decay. Some produce may be more subject to damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits; and
- protect harvested produce in the field by putting it under open-sided shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot.

Produce for local markets can be harvested early in the morning. For more distant markets it may be an advantage if suitable transport can be arranged to harvest in the late afternoon and transport to market at night or early the next morning.

**HARVESTING TOOLS**

For a more efficient harvest several tools can be employed. These include knives, secateurs (pruners), machetes (cutlass) and forks. These items should be kept well sharpened and cleaned. Before each use they should be sanitised by soaking them in bleach for approximately thirty minutes to eliminate any viruses or bacteria.

Some examples of harvesting tools are shown below:

- **Shears**

- **Pole Mounted Picking Shears**
Harvest Bags

Shipping Containers

Several types of containers are used to gather the harvested commodity. They should be easy to handle by the workers. The range includes bags, baskets, buckets, boxes, picking aprons, field crates, etc. The containers should protect the commodity from damage and should provide adequate ventilation. (More on containers in a later lesson on packaging).

RECORDS KEEPING

Detailed records’ keeping is essential to effective harvest management. Detailed records can be helpful to the managers of the farm in several ways. First, such records help ensure transparency and traceability of operations and end-product/crop quality and safety. They are useful tool to identify weak operational areas which can be improved. Second, maintaining adequate documentation and records of processing operations is important if a trace back investigation of product is ever needed. Records that may be kept include the following:

Risk Assessment and Corrective Action Records describe Where, when and how, trace backs of products.

Farm Operations Records describe the following:

- Field activities e.g., inputs used (seeds, fertilizers, manure) and irrigation (source-water quality, when, where, how much, who); agro climatic data.
- Harvest/post harvest data (when, where, how much, who).
- Pest control records (what, when, where, by whom, how much).
- Produce distribution records (what, where, when, who, how).
• Employee training (who and topic- ex. pesticide, hygiene courses) records.
• Equipment monitoring and maintenance records, Calibration records (sprayers).

Financial Records describe the cost of operations and the revenues generated by the farm. More about financial management will be discussed later in the course.

SUMMARY

In agriculture, harvesting is the processes of gathering mature crops from the fields. The harvest marks the end of the growing season, or the growing cycle for a particular crop. Harvesting involves practices that may affect the food safety. On smaller farms with minimal mechanization, harvesting is the most labour-intensive activity of the growing season. On large, mechanized farms, harvesting utilizes the most expensive and sophisticated farm machinery, like the combine harvester.

It is recommended as a general practice that growers maintain records sufficient to reflect important product information and practices. Such documentation can be helpful to the stakeholders in several ways. First, such records help ensure transparency and traceability of operations and end-product quality and safety. They are useful tool to identify weak operational areas which can be improved. Second, maintaining adequate documentation and records of processing operations is important if a trace back investigation of prod
LESSON 3.2 – PHYSIOLOGY OF PRODUCE

OVERVIEW

Good post-harvest practices are important in maintaining and extending the useful life of farm produce. Invariably, farm produce is derived from living tissues which undergo biological changes to reach the point of harvest. The physiology of these changes is influenced by internal and external factors that influence the quality of the final product. It is, therefore, desirable to have an appreciable understanding of the physiology of fresh produce and of ripening in order to understand and control the factors impacting on the post-harvest quality and shelf life of fresh produce.

Post-harvest physiology addresses the physiology of living plant tissues after they have been deprived of further nutrition by picking. A knowledge of post-harvest physiology is brought to bear on post-harvest practices which apply to post-harvest handling in establishing the storage and transport conditions that best prolong shelf life.

OBJECTIVES

Upon completion of this lesson you will be able to explain the physiological processes that impact fresh produce.

CELLULAR RESPIRATION

Cellular respiration is the step-by-step breakdown of glucose and the release of energy contained in its bonds coupled with the capture of a portion of that released energy in the form of adenosine triphosphate (ATP). ATP transports chemical energy within cells to support metabolism.

\[ C_6H_{12}O_6 + O_2 = 6CO_2 + H_2O + ATP \]

Or, in other words:

Glucose + Oxygen = Carbon Dioxide + Water + Adenosine Triphosphate (ATP)

During respiration, carbon from hydrocarbons is combined with oxygen to form carbon dioxide, and hydrogen from hydrocarbons is combined with oxygen to form water.

Respiration is an energy-releasing (ATP plus Heat – as in when one exercises) process, because the hydrocarbons being broken down have greater energy value than the carbon dioxide and water molecules that are being produced.
Respiration is carried out by specific proteins, called enzymes, and it is necessary for the synthesis of essential metabolites, including carbohydrates, amino acids, and fatty acids, and for the transport of minerals and other.

In the absence of O2, as may occur in bulky plant tissues such as the potato tuber and carrot root and in submerged plants such as germinating rice seedlings, the breakdown of hexose does not go to completion. The end products are either lactic acid or ethanol.

The greatest respiratory rates are found in the more metabolically active tissues, such as those in the growing and developing regions of the plant. In general terms, the more mature plant tissues have lower respiratory rates. A major exception to this rule is climacteric fruits, in which a marked rise in respiratory rate accompanies ripening. 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 when reserves of these are exhausted; ageing follows and the produce dies and decays.

To learn more about cell respiration it is recommended you view the following YouTube video: [http://www.youtube.com/watch?v=-XGrtSA6BOs&feature=related](http://www.youtube.com/watch?v=-XGrtSA6BOs&feature=related)

**Supplementary Readings:** To better understand cellular respiration you should review the following online article:


**Effects of Air Supply on Respiration**

Respiration depends on a good air supply. Air contains about 20 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.

Poor ventilation of produce because of restricted air supply leads also to the accumulation of carbon dioxide around the produce. When the concentration of this gas rises to between 1 and 5 percent in the atmosphere, the produce will start to deteriorate by causing bad
flavours, internal breakdown, failure of fruit to ripen and other abnormal physiological conditions. Thus, the proper ventilation of produce is essential.

Supplementary Readings: To learn how to create a properly ventilated storage facility it is recommended you review the following online article.


TRANSPARATION

The surfaces of all plant parts are covered by a waxy or corky layer of skin or bark limiting water loss. Natural water loss from the plant occurs only through tiny pores, which are most numerous on the leaves. The pores (stomata) on the plant surfaces can open or close with changing atmospheric conditions to give a controlled rate of loss of water and to keep the growing parts in a firm condition.

Transpiration functions to effect the ascent of sap from the roots to the leaves (thus supplying the food-manufacturing cells with water needed for photosynthesis) and to provide the moisture necessary for the diffusion of carbon dioxide into and oxygen out of these cells. Darkness, internal water deficit, and extremes of temperature tend to close stomata and decrease transpiration; illumination, ample water supply, and optimum temperature cause stomata to open and increase transpiration. The rate is highest on a bright, dry day and lowest at night or in drought conditions. Morphological factors such as reduced leaf surfaces, a heavy cuticle (waxy) layer on the leaves, low numbers of stomata, and stomata recessed below the other epidermal cells also lower the rate.

The passage of water through the plants is called the transpiration stream. It maintains the high water content of the plant, and the pressure inside the plant helps to support it. A lack of water will cause plants to wilt and perhaps to die.

The effect of moisture content of the air on water loss

Air spaces are present inside all plants so that water and gases can pass in and out to all their parts. The air in these spaces contains water vapour, a combination of water from the transpiration stream and that produced by respiration. Water vapour inside the plant develops pressure causing it to pass out through the pores of the plant surface. The rate at which water is lost from plant parts depends on the difference between the water vapour pressure inside the plant and the pressure of water vapour in the air. To keep water loss from fresh produce as low as possible, it must be kept in a moist atmosphere.

The effect of air movement on water loss
The faster the surrounding air moves over fresh produce the quicker water is lost. Air movement through produce is essential to remove the heat of respiration, but the rate of movement must be kept as low as possible. Well-designed packaging materials and suitable stacking patterns for crates and boxes can contribute to controlled air flow through produce.

**The Influence of the type of produce on water loss**

The rate at which water is lost varies with the type of produce. Leafy green vegetables, especially spinach, lose water quickly because they have a thin waxy skin with many pores. Others, such as potatoes, which have a thick corky skin with few pores, have a much lower rate of water loss.

The significant factor in water loss is the ratio of the surface area of the type of plant part to its volume. The greater the surface area in relation to the volume the more rapid will be the loss of water.

**Maturity & Ripening**

For the sake of post-harvest physiology and fruit development the term ‘mature’ is to be treated differently from the term ‘ripe’. Thus maturity can be termed as ‘having completed all the stages of growth and development,’ or “that stage at which a commodity has reached a sufficient stage of development that after harvesting and post-harvest handling, its quality will be at least the minimum acceptable to the ultimate consumer.”

**Hormonal influence on fruit development to maturity**

Hormones are produced by the seeds in the ovary wall of the developing fruit. Firstly, **cytokinins** are produced which initiate cell division in the ovary and cause the wall of the fruit to thicken. Next, **gibberellic acid** is produced which cause rapid cell expansion. Cell division and cell expansion both contribute to the further growth of the fruit. Very importantly, concurrent to the activity of the seeds, the parent plant produces another hormone called **abscisic acid**. This causes the embryo in the developing seeds to be made dormant so as to prevent sprouting inside of the fruit.

**Ripening**

Fleshy fruits undergo a natural stage of development known as ripening. This occurs when the fruit has ceased growing and is said to be mature. Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes, that finally leads to the development of a soft edible ripe fruit with desirable quality attributes. Excessive textural softening during ripening leads to adverse effects/spoilage upon storage.

**Major enzymes involved in fruit ripening:**
• Hydrolases: convert macromolecules to smaller aromatics
• Kinase: makes acids neutral
• Hydrolase: converts chlorophyll to anthocyanin
• Amylase: converts starch to sugar
• Pectinase: breaks down pectin (hard) to sub units (soft)

Ripeness is followed by ageing (often called senescence) and breakdown of the fruit. The fruit referred to includes those used as vegetables or salads, such as aubergine, sweet pepper, tomato, breadfruit and avocado.

There are two characteristic types of fruit ripening that show different patterns of respiration and ethylene production.

They can be classified as climacteric or non-climacteric, depending on whether or not a fruit exhibits a peak in respiration and ethylene production during ripening. Ethylene, considered to be the ripening hormone, controls ripening by coordinating the timely activation of many genes. Considerable progress has been made in the characterization of the ethylene biosynthetic pathway. The description of ethylene-dependent and -independent pathways coexisting in both climacteric and non-climacteric fruits are described below:

**Non-Climacteric Ripening**

Non-climacteric fruit ripening refers to those fruits which ripen only while still attached to the parent plant. Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase further. Respiration rate slows gradually during growth and after harvest. Maturation and ripening are a gradual process. Examples are: cherry, cucumber, grape, lemon, pineapple.

**Climacteric Ripening**

Climacteric fruit ripening refers to fruits that can be harvested when mature but before ripening has begun. These fruits may be ripened naturally or artificially. The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Examples are: apple, banana, melon, papaya, tomato.

<table>
<thead>
<tr>
<th>Non-climacteric</th>
<th>Climacteric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell pepper</td>
<td>Apple</td>
</tr>
<tr>
<td>Blackberries</td>
<td>Melons</td>
</tr>
<tr>
<td>Blueberries</td>
<td>Nectarine</td>
</tr>
<tr>
<td>Orange</td>
<td>Apricot</td>
</tr>
<tr>
<td>Pineapple</td>
<td>Avocado</td>
</tr>
<tr>
<td>Avocado</td>
<td>Papaya</td>
</tr>
</tbody>
</table>
Fleshy fruits have been classified as climacteric or non-climacteric, depending on whether or not a fruit exhibits a peak in respiration and ethylene production during ripening. Ethylene, considered to be the ripening hormone, controls ripening by coordinating the timely activation of many genes. Considerable progress has been made in the characterization of the ethylene biosynthetic pathway. The emerging picture is one of ethylene-dependent and -independent pathways coexisting in both climacteric and non-climacteric fruits.

In commercial fruit production and marketing, artificial ripening is used to control the rate of ripening, thus enabling transport and distribution to be carefully planned.

**EFFECT OF ETHYLENE**

Ethylene gas is produced in most plant tissues and is known to be an important factor in starting off the ripening of fruits. Ethylene is important in fresh produce marketing because of the following reasons:

<table>
<thead>
<tr>
<th>Non-climacteric</th>
<th>Climacteric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cacao</td>
<td>Banana</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Passion fruit</td>
</tr>
<tr>
<td>Cashew apple</td>
<td>Breadfruit</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Peach</td>
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<tr>
<td>Cherry</td>
<td>Raspberries</td>
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<tr>
<td>Cherimoya</td>
<td>Pear</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Strawberries</td>
</tr>
<tr>
<td>Feijoa</td>
<td>Persimmon</td>
</tr>
<tr>
<td>Eggplant</td>
<td>Summer squash</td>
</tr>
<tr>
<td>Fig</td>
<td>Plantain</td>
</tr>
<tr>
<td>Grape</td>
<td>Tart cherries</td>
</tr>
<tr>
<td>Guanábaná</td>
<td>Plum</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>Tree tomato</td>
</tr>
<tr>
<td>Guava</td>
<td>Quince</td>
</tr>
<tr>
<td>Lemon</td>
<td>Jackfruit</td>
</tr>
<tr>
<td>Sapodilla</td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>Kiwifruit</td>
</tr>
<tr>
<td>Sapote</td>
<td></td>
</tr>
<tr>
<td>Loquat</td>
<td>Mamey</td>
</tr>
<tr>
<td>Tomato</td>
<td></td>
</tr>
<tr>
<td>Lychee</td>
<td>Mango</td>
</tr>
<tr>
<td>Watermelon</td>
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</table>

It can be used commercially for the artificial ripening of the climacteric fruits. This has made it possible for tropical fruits such as mangoes and bananas to be harvested green and shipped to distant markets, where they are ripened under controlled conditions;

Natural ethylene production by fruits can cause problems in storage facilities. Flowers, in particular, are easily damaged by very small amounts of the gas. Ethylene destroys the green colour of plants, so lettuce and other vegetables marketed in the mature green but unripe state will be damaged if put into storage with ripening fruit;

Ethylene production is increased when fruits are injured or attacked by moulds causing decay. This can start the ripening process and result in early ripening of climacteric fruit during transport. All produce should be handled with care to avoid injuries leading to decay. Damaged or decaying produce should not be stored;

Citrus fruit grown in tropical areas remains green after becoming fully ripe on the tree. It develops full colour after harvest only if "de-greened" by the use of (manufactured) ethylene gas. The gas concentration, temperature, humidity and ventilation have to be carefully controlled in specialized rooms, so de-greening is economically viable only for high-value export or domestic markets. In most tropical countries fully ripe green citrus fruit is acceptable to local populations.

**Increases in Ethylene biosynthesis enzymes, intermediates, and ethylene release are correlated**

![Graph showing increases in ethylene biosynthesis enzymes, intermediates, and ethylene release over time.](image)

**SENESCENCE**
Senescence is a form of ageing which leads to organ/plant death. As tissues senesce they produce enzymes necessary to recycle "expensive" materials and reroute the subunits to areas for use by active growth elsewhere, in the next season, or by the next generation. In order to make the enzymes needed, respiration rates must usually increase. The senescence-specific enzymes include: proteases, nucleases, lipases, amylases, and many others. Ultimately, pectinases and cellulases complete the hydrolysis of cell components.

The vegetable and fruit industry is interested in extending the post-harvest shelf life of produce in the market. This job is difficult, because any chemical treatments used to prevent senescence must be safe for human consumption. The florist industry is greatly interested in delaying floral senescence and extending vase life.

**SUMMARY**

Understanding the physiology of produce is necessary if you wish to protect your post-harvest products. Delivering fresh produce to market may only take a day, but it may take days if not weeks. The timing of when you pick or harvest your produce depends on its physiology and ability to ripen off the vine or out of the ground. The process by which you store and transport the products needs to be considered based upon the distance to the market and the actual temperature and humidity of the environment that the products are exposed too. You need to understand the physiological process of your products to ensure quality and safety. Now let’s explore these issues.
LESSON 3.3 – PACKAGING, TRANSPORT AND STORAGE

OVERVIEW
The proper packaging and transportation of agriculture products is critical to the end quality of the produce. Losses encountered during transport can be significant; care should, therefore, be taken to keep the produce in the best possible condition during transport and the haulage of produce should be quick and efficient. To this end, produce should be properly packaged for shipping and transportation.

OBJECTIVES
Upon completion of this lesson you should be able to:

1. Describe the factors that impact the quality of your produce.
2. Explain how to properly package, transport and store fresh produce.
3. Examine different packaging and labelling alternatives to ensure quality and safety of your produce.
4. Explain the causes of post-harvest losses.
5. Examine how to minimize post-harvest losses.
6. Explore what changes occur to your produce during the post-harvest process.

STEPS IN PRODUCE DISTRIBUTION
The model below reflects the major steps and facilities involved in the fresh produce distribution process. From farm to consumer.
LOSSES DURING TRANSPORTATION

During transportation losses are usually due to mechanical damage or overheating and are as a result of:

- careless handling of packed produce during loading and unloading;
- vibration (shaking) of the vehicle, especially on bad roads;
- fast driving and poor condition of the vehicle;
- poor stowage, which allows packages in transit to sway; packages stacked too high collapsing; the movement of produce within a package increases in relation to its height in the stack; the use of closed vehicles without ventilation;
- close-stow stacking patterns blocking the movement of air between and through packages, thus hindering the dispersal of heat;
- the lack of adequate ventilation of the packages themselves; and
- exposure of the packages to the sun while awaiting transport or while trucks are queuing to unload at their destination.
Reducing Transportation Losses

Several methods are used to transport the produce to its destination. Whatever method is used, the principles of transport are the same:

- Loading and unloading should be as careful as possible.
- Transmit times should be as short as possible.
- The product should be well protected in relation to its susceptibility to physical injury.
- Jolting and movement should be reduced as much as possible.
- Overheating should be avoided.
- Water loss by the produce should be restricted.
- The required conditions of preservation should be obtained and maintained constantly, regarding in particular temperature, relative humidity and air circulation.

This YouTube video illustrates the impact of proper and improper loading. You can view it at: [http://www.youtube.com/watch?v=vHRDekjku-M&feature=player_embedded](http://www.youtube.com/watch?v=vHRDekjku-M&feature=player_embedded)

THE PACKHOUSE

Produce may be sorted and prepared for market in the field as often happens in many small states. However, as the scale of operation increases and as the market becomes more sophisticated, there may be the need for a pack house. Pack houses serve as a sheltered working site for the produce and the packers, and should create an orderly assembly and flow of produce which can be well managed and centrally supervised. They may also
provide a storage point for packing equipment and materials and, if large enough, can house office and communications facilities.

The packing house design and facilities needed depend very much on local infrastructure, types and quantities of produce, markets being served and the funds available. The various factors which have to be taken into consideration when planning a packhouse include:

- operations;
- equipment and facilities;
- location;
- design and construction materials; and
- management.

Depending on the crop or crops being handled and the market being served, some or all of the following operations will be undertaken:

- reception: off-loading, checking, recording;
- sorting;
- special treatments, if required (cleaning or washing, fungicide spraying, selection, size-grading);
- packing;
- post-packaging treatments, if required (fumigation, cooling, storage); and
- assembly and dispatch.

**Supplementary Readings:** To learn more about the impact of a packhouse operation you should review the following online case study:

Finatrac Inc. (2001). Packhouse and Cold Chain Infrastructure: “Real Results for Real People”.  
[http://www.fintrac.com/docs/honduras/cda_packhouse_program_eng.pdf](http://www.fintrac.com/docs/honduras/cda_packhouse_program_eng.pdf)

**PACKHOUSE OPERATIONS & LAYOUT**

**Packhouse Facilities**

Before considering the design features of a packhouse it is necessary to take an audit of what facilities and equipment will be needed for the packhouse, and what form and quantity of services will be needed for immediate purposes and any future expansion. The general facilities required for packing stations are described below.

1. **Water** - all packing stations require large quantities of water for washing produce, recirculation and re-utilisation may exist, but it is important that attention be given to the sanitary quality of the water that comes into contact with the produce.
2. **Electricity** - where any form of automation is employed and certainly where good lighting is needed, a source of electricity supply from mains or generator must be arranged. Even where there is mains supply, it is sensible to install reserve or emergency generators, and particularly if the packing houses has its own refrigerated store rooms.

3. **Waste Disposal** - it is important to separate waste and rejected produce from the fresh market line in order to restrict the spreading of post-harvest diseases. Waste, once separated should not be allowed to accumulate inside the packhouse or it will become a physical hindrance as well as a phytosanitary risk.

4. **Material Handling** - good handling equipment and vehicles save much time and effort and can greatly reduce the damage to produce. Provision must be made for hand trolleys and roller conveyors, and, in bigger stations, for powered conveyors and fork-lift trucks. Where pallets are used they should be compatible with box sizes to achieve close to a hundred percent fit.

5. **Produce Handling** - an immense range of equipment is available for washing, conveying, brushing, waxing, grading, and packaging specific commodities. Advice can be sought on equipment to meet specific commodity and location needs.

6. **Storage Facilities** - many packing stations include refrigerated facilities for short-term storage of highly perishable commodities. A ventilated temporary storage area may be sufficient, however, for commodities which have a reasonable post-harvest life. The possibility of future expansion of the storage facilities must also be considered.

Small-scale packing houses are likely to be handling a variety of crops at any one time and over a period of time. Where the volumes handled are relatively small, the layout of buildings and equipment should be simple and flexible.

The overall design should ensure that floor space is adequate for easy movement, doors are wide enough for passage of vehicles and pallets, storage areas are sufficient for packaging materials, all surfaces can be easily washed and drained, there is a relatively clean and quiet administration office and that the workforce have a clean area where they can wash and eat in reasonable comfort.

The following diagram shows a simple layout of a small-scale packhouse:
Throughout the entire handling system the produce is subject to activities that can lead to damage and ultimately loss in quality and value. Correct packaging can help minimise these losses. The function of packaging is to:

- Safely contain the produce.
- Protect the produce during the transportation phase.
- Communicate to the shippers, buyers and others what the produce package contains.
Now let's examine each one. The packaging must store the process in a way that is:
- an efficient handling unit, easy to be handled by one person; and
- a marketable unit. e.g. units with the same content and weight.

Packaging must help protect the produce against:
- rough handling during loading, unloading and transport;
- pressure during stacking;
- moisture or water loss with consequent weight and appearance loss;
- heat: air flow through crate or box via ventilation holes; and
- contamination during marketing.

Solid Produce Crates

Finally the packaging should be a marketing and communication tool that provides information to buyers, such as variety, weight, number of units, selection or quality grade, producer’s name, country, area of origin, etc.

On pre-packaged and consumer packages, recipes and information such as nutritional value, barcodes and any other relevant information on traceability are frequently included. It offers the seller and consumers protection. The seller is protected as his produce is easily identified from others. In the case of the consumer, he is assured that the contents of the package are safe and fit for consumption.

Information through labelling is a key component especially in the export trade where large volumes and thousands of packages are moved throughout the system.
In many small states fresh produce cross borders entering and exiting. Labelling which includes country of origin and name of exporter is an important consideration as packages which may contain non-indigenous, potentially damaging pests and diseases of plants can easily be traced to the source. This plays a key role in plant quarantine helping to prevent the entry of potentially damaging pests and diseases into a country.

PACKAGING MATERIALS

The packaging material that is utilized depends on the category of packaging. Packaging may be categorized as:

- Field and Transport packaging.
- Unit load packaging or pallet.
- Retail/Consumer units or pre-packaging.
- Let's examine each one separately.

Selecting Packaging Materials

Before deciding on what package to use, there are several factors to be considered the main ones being cost and supply. Once a decision regarding the market to be supplied is made, and the cost of the produce and the cost of transport are known, then the choice of package materials can be made. The first criterion for any form of packaging is that it must add to the value of the produce handled, sufficient to cover the additional capital outlay and operation, plus a margin for profit.
The best way to cost packaging is as a unit cost per pound or kilogram of produce, and it does not matter what the cost is as long as it can be recovered from the market. In practice this means that the packaging and the produce must be competitive with those marketed by other suppliers. Good packaging of good produce has a clear financial advantage over poor quality produce which is poorly packed and presented.

In summary factors to consider are:

- The type of produce.
- The present level of produce losses that occur during the marketing process.
- The comparative costs of the present and improved packaging.
- Expected reduction of losses if packaging is improved (based on research results).
- Expected increase in income from reduction of losses.
- Is a standard type of package available? Cost-per-unit of packages declines considerably when they are bought on a large scale; specially designed packaging is costly.
- Will there be a regular supply of the new packaging?
- Is adequate storage and assembly space available for the protection of packaging materials before use?
- Is the change in packaging acceptable to the market?

Field & Transport Packaging

There are several different types of packages in use for the containment and transport of fresh agricultural commodities. In small states a variety indigenous items are used. This is often a result of availability and cost of materials. Examples used in the field and during transport include:

**Bags (net, jute, plastic)**

The advantage of using bags is they are cheap, but you should note the following:

- They provide very little protection to the produce against compression, impact and puncture injuries.
- Bags cannot be cleaned or disinfected. They therefore represent a source of contamination of microorganisms when reused.
- Net bags are only suitable for hard produce such as coconuts and root crops (potatoes, onions, yams).
Cartons/Fibreboard Boxes

Fibreboard boxes are commonly used because:

- they are easy to handle, light weight, come in a range of sizes and shapes;
- they can come flat packed with ventilation holes and grab handles;
- the box has a low purchase cost; and
- the material can be printed on and labels can be applied with relevant market information.

Disadvantages of using fibreboard boxes include:

- Moisture and high humidity can weaken the box, therefore, washed produce should be dried before putting it into the box. (Some boxes may have a coating of wax on the inside to help strengthen them against moisture). Empty boxes should be stored in a dry place preferably flat on top of pallets
- Their low rigidity causes the stacking strength to be lower than for wooden or plastic crates. (Some boxes are corrugated which gives added strength).
- Ventilation holes may weaken the boxes.

Wooden Crates

Wooden crates may be wire bound crates, wooden trays or wooden field crates. Advantages of using wooden crates for your produce include:

- They are resistant to different weather conditions.
- They are re-usable.
- They more efficient for large fruits, such as melons
- They generally have good ventilation.
- The crates can be manufactured and repaired locally.
- Most crates have good ventilation and fast pre-cooling is possible.

Disadvantages of using wooden crates include:

- Rough surfaces and splinters can cause damage to the produce.
- They can retain undesirable odours when painted.
- Raw wood can easily become contaminated with moulds.

**Plastic Crates**

Plastic crates are usually made of polyvinyl chloride, polypropylene, or polyethylene. The advantages of using plastic crates are:

- They are durable and can last many years.
- Some are designed so that they can nest inside each other when empty to facilitate transport, and can stack one on top of the other without crushing the fruit when full.
- They are easy to clean and disinfect.
- Plastic crates are strong and weather resistant and, they can, therefore, be used in humid areas.

![Plastic Crates](image)

**Plastic field crates with stack nest design**

Disadvantages of using plastic crates include:

- Their hard surfaces can damage softer commodities; therefore, they may require the use of liners.
- Their relatively high cost may be prohibitive to small-scale producers.

**Baskets**

Baskets are used in several small states for the movement of fresh produce through the distribution system. Their major advantage is they are relatively cheap and are made from locally available and readily renewable resources. They, however, do not provide much protection to the produce and do not stack easily.
Retail Packaging

Retail packaging allows consumer to select and purchase fresh produce items in quantities and weights that permit the use of a range of package type. It also helps to slow deterioration and reduce spoilage caused by consumers selecting out of a bulk of produce.

PRE-PACKAGING

Pre-packaging refers to the convenient value-added preparation (e.g. shredded carrot and cabbage) of fresh produce that may be wrapped or packed before marketing. These products are ready to be eaten or ready to be added to fast one dish meals such as salads, stir-fry dishes or casseroles. Consequently the pre-packaged portions are prepared to meet the varying needs of consumers.

Materials normally used include:

- Moulded pulp or expanded polystyrene trays wrapped in shrinkable plastic films (shrink wrap)
- Plastic or paper bags
- Clamshells
- Mesh bags
- Plastic foam nets
- Advantages of using the above mentioned materials include:
- Plastic bags are clear, allowing for easy inspection of the contents and they may be printed.
Plastic films are available in a wide range of thicknesses and grades and may be engineered to control the environmental gases inside the bag.

The film material "breathes" at a rate necessary to maintain the correct mix of oxygen, carbon dioxide, and water vapour inside the bag.

Shrink wrapping can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels.

Clamshells are inexpensive, versatile, and provide excellent protection for the produce.

Clamshells are often used for high value produce items like small fruits, strawberries, mushrooms or items that are easily damaged by crushing.

Clamshells are used extensively with pre-cut produce and prepared salads.

Plastic foam nets provide protection for individual items like papaya and mango.

Examples of different packaging are below:
Recent focus on preserving the environment and the use of more ‘environmentally friendly’ items has led to the development of green packaging. It is more environmentally friendly as it causes less damage to the environment. There are three types of green packaging:

1. **Reusable packaging**, such as glass bottles, which can be cleaned and re-used to store the same food or something else.
2. **Recyclable packaging**, which is made of materials that can be used again, usually after processing, for packaging or some another purpose. Recyclable packaging materials include glass, metal, card and paper.
3. **Biodegradable packaging**, which will easily breakdown and disappear into the soil or the atmosphere, without causing damage.

Packaging that can be recycled should carry standard symbols that say what the product is made from and how it can be recycled. The key symbols are outlined in the diagram below:
MODULARIZATION

Produce being transported may come from a number of individual farmers and as such a variety of different size and types of containers may be packed at the same time. Where feasible, using boxes in standard sizes can greatly ease future handling. When containers are non-uniform, stacks can be unstable or heavier cartons can crush lighter ones. An unstable load is likely to fall over during transport or to collapse during storage.

The main purpose of standardizing sizes of packages is to maximize the utilization of pallet’s surface based on the standard size of 120 x 100 cm. Pallets allow for unitization and easy handling.

Packing stations can, therefore, make the job easier by using pallets which are standardized and allow for uniformity in stowage and handling.

![Mesh Bags Stacked on Pallets](image-url)
CAUSES OF DAMAGE DURING TRANSPORT

Damage to produce often happens during inappropriate handling during transportation. Some of the major causes of produce damage include:

Impact

Impact injuries may result from dropping or sudden stopping or accelerating a vehicle.

Vibration

Vibration or abrasion injuries result when produce is able to move within a container because of:

- vehicles with small wheels and bad shock-absorbers;
- weak crates;
- bad roads; and
- transmission vibration.
Compression

Compression injuries may result from:

- over packing the container;
- stacking the containers to high; and
- weak or inappropriate packaging.

Puncturing

Puncturing injuries may result from:

- nails or splinters from the crate or box;
- fingers or nails;
- other crates, fork-lifts, etc.; and
- hard and sharp stalks of fruit.

Examples of Damage

The table below provides examples of some types of typical mechanical damage and their effect on packaging containers.

<table>
<thead>
<tr>
<th>Type of damage</th>
<th>Container</th>
<th>Result</th>
<th>Important factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact damage</td>
<td>Sacks – woven and paper</td>
<td>Splitting of seams and material causing leaking and spillage loss</td>
<td>Seam strength</td>
</tr>
<tr>
<td>through dropping</td>
<td>Fibreboard boxes</td>
<td>Spilling of seams, opening of flaps causing loss of containment function. Distortion of shape reducing stacking ability</td>
<td>Bursting strength Closure method</td>
</tr>
<tr>
<td></td>
<td>Wooden cases</td>
<td>Fracture of joints, loss of containment function</td>
<td>Fastenings Wood toughness</td>
</tr>
<tr>
<td></td>
<td>Cans and drums</td>
<td>Denting, rim damage. Splitting of seams and closure causing loss of containment and spoilage of contents</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plastic bottles</td>
<td>Splitting or shattering causes loss of contents.</td>
<td>Material grade Wall thickness</td>
</tr>
<tr>
<td>Type of damage</td>
<td>Container</td>
<td>Result</td>
<td>Important factors</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Compression damage through high stacking</td>
<td>Fibreboard boxes</td>
<td>Distortion of shape, seam splitting causing loss of containment and splitting of inner cartons, bags, and foil wrappings.</td>
<td>Box compression strength</td>
</tr>
<tr>
<td></td>
<td>Plastic bottles</td>
<td>Distortion, collapse and sometimes splitting, causing loss of contents.</td>
<td>Design, material, wall thickness</td>
</tr>
<tr>
<td>Vibration</td>
<td>Corrugated fibreboard cases</td>
<td>Become compressed and lose their cushioning qualities. Contents more prone to impact damage.</td>
<td>Box compression strength</td>
</tr>
<tr>
<td>Snagging, tearing, hook damage</td>
<td>Sacks - woven and paper</td>
<td>Loss of containment function - spillage (more severe with paper sacks).</td>
<td>Tear strength</td>
</tr>
<tr>
<td></td>
<td>Tins</td>
<td>Punctured, loss of contents.</td>
<td>Metal thickness</td>
</tr>
</tbody>
</table>


**STORAGE OF PRODUCE**

The marketable life of most fresh 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.

In many small states, however, where seasonally produced plant foods are held back from sale and released gradually, storage in a controlled environment is not possible because of the cost and the lack of infrastructural development and of maintenance and managerial skills. Even in developed countries, however, there are still many people who, for their own consumption, preserve and store fresh produce by traditional methods.

Fresh produce which are most perishable cannot be stored without refrigeration, but the possibilities for extending the storage life of even the most durable fresh produce under ambient conditions are limited. Some form of storage, therefore, becomes necessary.
Storage rooms can be grouped 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.

**STORAGE LIFE**

Storage time depends on the intrinsic characteristics and perishability of the product. Shelf life ranges from short to those which naturally adapt to longer storage periods. Storage conditions also depend on specific product characteristics. For example, some commodities tolerate temperatures close to 0 °C such as leafy vegetables. Others, such as most tropical fruits cannot tolerate exposure to temperatures below 10 °C.

Some commodities have a period of dormancy after harvest before they resume growth. This period of dormancy can usually be extended to give the longest possible storage if appropriate conditions are provided. This factor is called the storage potential. Many crops such as yams, onions have this period of dormancy.

Edible reproductive parts are largely confined to the fruits or seeds of leguminous plants (peas and beans). In their fresh condition these products have a brief storage life which can only be slightly extended by refrigeration. They can also be dried, and then are called pulses. Pulses have a long storage life, provided they are kept dry, and do not present a storage problem of the sort affecting fresh produce.

Fresh fruits and vegetables include the leafy green vegetables, fleshy fruits and modified flower parts (e.g. cauliflower, pineapple). The storage potential of these is very limited under ambient conditions. They quickly deteriorate because of their fast respiration rates, which cause rapid heat build-up and the depletion of their high moisture content.

Traditional methods of preservation are sun-drying or simple domestic processing into with sugar and brine or vinegar. Most fresh fruit and vegetables have a storage life of only a few days under even the best environmental conditions.

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

**Supplementary Readings:** To learn more about the storage of produce it is recommended your review the following online article:

FAO. (nd.). Storage of fresh produce.  [http://www.fao.org/wairdocs/x5014e/X5014e0A.HTM](http://www.fao.org/wairdocs/x5014e/X5014e0A.HTM)
FACTORS AFFECTING STORAGE LIFE

The storage life of fresh produce items is affected by the following:

**Temperature** - An increase in temperature causes an increase in the rate of natural breakdown of all produce as food reserves and water content become depleted. The cooling of produce will extend its life by slowing the rate of breakdown.

**Water loss** - High temperature and injuries to produce can greatly increase the loss of water from stored produce beyond that unavoidably lost from natural causes. Maximum storage life can be achieved by storing only undamaged produce at the lowest temperature tolerable by the crop.

**Mechanical damage** - Damage caused during harvesting and subsequent handling increases the rate of deterioration of produce and renders it liable to attacks by decay organisms. Mechanical damage to root crops will cause heavy losses owing to bacterial decay. This can be remedied by healing the wounds of the roots or tubers before storage.

**Decay in storage** – Decay of fresh produce during storage is mostly caused by the infection of mechanical injuries. Also, many fruits and vegetables are attacked by decay organisms which penetrate through natural openings or even through the intact skin. These infections may be established during the growth of the plant in the field but lie dormant until after harvest, often becoming visible only during storage or ripening.

STORAGE METHODS

This section describes a number of methods and structures that can be used to store 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, but 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.

**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.

**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.

**Clamps**

This has been a traditional method for storing potatoes in some parts of the world. They are simple, inexpensive structures. A common design uses an area of land at the side of the field. The width of the clamp is about 1 to 2.5 m. The dimensions are marked out and the potatoes piled on the ground in an elongated conical heap. Sometimes straw is laid on the soil before the potatoes are placed. At the top, straw is bent over the ridge so that rain will tend to run off the structure. Straw thickness should be from 15-25 cm when compressed. After two weeks, the clamp is covered with soil to a depth of 15-20 cm, but this may vary depending on the climate. In warm climates extra straw casing may be used instead of soil in order to give added ventilation.

**Windbreaks**

Windbreaks are narrow, wire-mesh, basket-like structures about 1 m wide and 2 m high, of any convenient length, on a raised wooden base, and are used for short-term storage of dried onions in the field. The onions are covered on top with a 30 cm layer of straw, which is in turn held down by a polythene sheet fastened to the wire mesh. The windbreak is built at right angles to the prevailing wind to obtain maximum drying and ventilation.

**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.

**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.

**Night Ventilation**

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

Ventilated Storage Structures

Naturally ventilated structures can be used for the storage of produce with a long storage potential, such as roots and tubers, pumpkins and onions. They take advantage of the natural airflow around the product to remove heat and humidity generated by respiration. Buildings providing some form of protection from the external environment and with gaps for ventilation can be used. Produce can be placed in bulk, bags, boxes, bins, pallets etc.

Although simple, some key concepts need to be taken into account for the efficient operation of this system. Such stores must be designed and built specifically for each intended location. Any type of building can be used provided that it allows the free circulation of air through the structure and its contents.

When establishing a ventilated storage site the following essentials must be observed:

1. The building should be located at a site where low night temperatures occur over the required storage period.
2. It must be oriented to take maximum use of the prevailing wind for ventilation.
3. The material covering the roof and walls should provide insulation from the heat of the sun; grass thatch on a bush-pole frame can be very effective, particularly if it is wetted to provide evaporative cooling.
4. Double-skinned walls will provide better insulation, if cost allows.
5. White paint applied to surfaces of man-made materials will help to reflect the heat of the sun.
6. The structure should be built in the shade of trees if they do not interfere with the prevailing air flow; beware of bush fires and of trees falling during storms.
7. Provide ventilation spaces below the floor and between walls and roof to give good air flow.
8. If the storage facility is subject to cold night temperatures, it should be fitted with movable louvers which are adjusted to limit the flow of warm air into the store during the day.

These are the basic requirements of a ventilated storage area. Such stores may be constructed to various levels of sophistication, using, where it is economically acceptable, fan-assisted ventilation controlled by differential thermostats.

Simple open-sided, naturally ventilated structures may be used to store seed potatoes at high altitudes in warm climates. They cannot be used for table potatoes, which will turn
green, develop a bitter taste, or even become toxic if exposed to light for more than a few hours.

**Additional Cooling Methods**

**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.

**Refrigerated and Controlled-Atmosphere Storage:** For large-scale commercial operations, refrigerated storage may be used in a cold-chain operation to carry regular consignments from production areas to urban markets and retailers. This can be a highly complex operation requiring expert organization and management.

**STORAGE COMPATIBILITY**

It is often necessary to store a range of commodity in one store room. Sharing the same storage area can result in:

- differences in temperature and relative humidity conditions;
- chilling and ethylene sensitivity; and
- odour contamination and other problems affecting shelf life and quality.

Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. High ethylene producers (such as ripe bananas, tomatoes, cantaloupe) can stimulate physiological changes in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweet potatoes) leading to often undesirable colour, flavour and texture changes.

Compatibility groups have been developed as guidelines for the storage of mixed loads.

**Compatibility groups for storage of fruits and vegetables**

**Group 1:** Fruits and vegetables, 0 to 2°C (32 to 36°F), 90-95% relative humidity. Many products in this group produce ethylene.

<table>
<thead>
<tr>
<th>apples</th>
<th>grapes (without sulphur dioxide)</th>
<th>parsnips</th>
</tr>
</thead>
<tbody>
<tr>
<td>apricots</td>
<td>horseradish</td>
<td>peaches</td>
</tr>
<tr>
<td>Asian pears</td>
<td>kohlrabi</td>
<td>pears</td>
</tr>
</tbody>
</table>
Barbados cherry | leeks | persimmons
beets, topped | longan | plums
berries (except cranberries) | loquat | pomegranates
cashew apple | lychee | prunes
cherries | mushrooms | quinces
coconuts | nectarines | radishes
figs (not with apples) | oranges* (Florida and Texas) | rutabagas

*Citrus treated with biphenyl may give odours to other products

**Group 2: Fruits and vegetables, 0 to 2°C (32 to 36°F), 95-100% relative humidity. Many products in this group are sensitive to ethylene.**

Amaranth* | cherries | parsley*
anise | daikon* | parsnips*
artichokes* | endive* | peas*
asparagus | escarole* | pomegranate
bean sprouts | grapes (without sulfur dioxide) | raddichio
beets* | horseradish | radishes*
Belgian endive | Jerusalem artichoke | rhubarb
berries (except cranberries) | kiwifruit | rutabagas*
bok choy | kohlrabi* | salsify
broccoli* | leafy greens | scorzonera
brussels sprouts* | leeks’ (not with figs or grapes) | snow peas
cabbage* | lettuce | spinach*
<table>
<thead>
<tr>
<th>carrots*</th>
<th>lo bok</th>
<th>Sweet corn*</th>
</tr>
</thead>
<tbody>
<tr>
<td>cauliflower</td>
<td>mushrooms</td>
<td>turnips*</td>
</tr>
<tr>
<td>celeriac*</td>
<td>onions, green* (not with figs, grapes, mushrooms, rhubarb, or corn)</td>
<td>water chestnut</td>
</tr>
<tr>
<td>celery*</td>
<td></td>
<td>watercress*</td>
</tr>
</tbody>
</table>

*these products can be top-iced


**Group 3: Fruits and vegetables, 0 to 2°C (32 to 36°F), 65-75% relative humidity.** Moisture will damage these products.

<table>
<thead>
<tr>
<th>garlic</th>
<th>onions, dry</th>
</tr>
</thead>
</table>

**Group 4: Fruits and vegetables, 4.5°C (40°F), 90-95% relative humidity.**

<table>
<thead>
<tr>
<th>cactus leaves</th>
<th>lemons*</th>
<th>tamarillo</th>
</tr>
</thead>
<tbody>
<tr>
<td>cactus pears</td>
<td>lychees</td>
<td>tangelos*</td>
</tr>
<tr>
<td>caimito</td>
<td>kumquat</td>
<td>tangerines*</td>
</tr>
<tr>
<td>cantaloupes**</td>
<td>mandarin*</td>
<td>ugli fruit*</td>
</tr>
<tr>
<td>clementine</td>
<td>oranges ( Calif. and Arizona )</td>
<td>yucca root</td>
</tr>
<tr>
<td>cranberries</td>
<td>pepino</td>
<td></td>
</tr>
</tbody>
</table>

* citrus treated with biphenyl may give odors to other products.
** can be top-iced.

**Group 5: Fruits and vegetables, 10°C (50°F), 85-90% relative humidity.** Many of these products are sensitive to ethylene. These products also are sensitive to chilling injury.

<table>
<thead>
<tr>
<th>beans</th>
<th>kiwano</th>
<th>pummelo</th>
</tr>
</thead>
<tbody>
<tr>
<td>calamondin</td>
<td>malanga</td>
<td>squash, summer (soft shell)</td>
</tr>
<tr>
<td>chayote</td>
<td>okra</td>
<td>tamarind</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Olive</td>
<td>Taro Root</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>Eggplant</td>
<td>Peppers</td>
<td></td>
</tr>
<tr>
<td>Haricot Vert (Fine Beans)</td>
<td>Potatoes, Storage</td>
<td></td>
</tr>
</tbody>
</table>


**Group 6: Fruits and vegetables, 13 to 15°C (55 to 60°F), 85-90% relative humidity. Many of these products produce ethylene. These products also are sensitive to chilling injury.**

<table>
<thead>
<tr>
<th>Atemoya</th>
<th>Granadilla</th>
<th>Papayas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocados</td>
<td>Grapefruit</td>
<td>Passionfruit</td>
</tr>
<tr>
<td>Babaco</td>
<td>Guava</td>
<td>Pineapple</td>
</tr>
<tr>
<td>Bananas</td>
<td>Jaboticaba</td>
<td>Plantain</td>
</tr>
<tr>
<td>Bitter Melon</td>
<td>Jackfruit</td>
<td>Potatoes, New</td>
</tr>
<tr>
<td>Black Sapote</td>
<td>Langsat</td>
<td>Pumpkin</td>
</tr>
<tr>
<td>Boniato</td>
<td>Lemons*</td>
<td>Rambutan</td>
</tr>
<tr>
<td>Breadfruit</td>
<td>Limes*</td>
<td>Santol</td>
</tr>
<tr>
<td>Canistel</td>
<td>Mamey</td>
<td>Soursop</td>
</tr>
<tr>
<td>Carambola</td>
<td>Mangoes</td>
<td>Sugar Apple</td>
</tr>
<tr>
<td>Cherimoya</td>
<td>Mangosteen</td>
<td>Squash, Winter (Hard Shell)</td>
</tr>
<tr>
<td>Coconuts</td>
<td>Melons (Except Cantaloupes)</td>
<td>Tomatillos</td>
</tr>
<tr>
<td>Feijoa</td>
<td></td>
<td>Tomatoes, Ripe</td>
</tr>
<tr>
<td>Ginger Root</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Citrus treated with biphenyl may give odours to other products*
Group 7: Fruits and vegetables, 18 to 21°C (65 to 70°F), 85-90% relative humidity.

<table>
<thead>
<tr>
<th>jicama</th>
<th>sweet potatoes*</th>
<th>watermelon*</th>
<th>yams*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pears (for ripening)</td>
<td>tomatoes, mature green</td>
<td>white sapote</td>
<td></td>
</tr>
</tbody>
</table>

*separate from pears and tomatoes due to ethylene sensitivity.


SUMMARY

Losses due to inappropriate packaging, transportation and storage of fresh produce will have a direct economic impact on the farmer. The proper and effective packaging, transport and storage of fresh produce will reduce losses, increase revenues and ensure the quality of the fruits and vegetables eventually delivered to the consumer. The use of proper packaging and labelling of produce packages will aid in marketing and identification of the products by the wholesale distributors and retail outlets.
OVERVIEW

Production, marketing and exports of fruits and vegetables produced in small states constitute an important source of revenue to producers. To be able to exploit this potential poses many challenges to producers from Small states. The capacity of exporters from small states to tap international markets depends upon their ability to meet stringent food safety standards imposed by developed countries. These standards are not only stringent but also increasingly demanding.

Food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or by the food processing industry. Food processing typically takes clean, harvested crops or slaughtered and butchered animal products and uses these to produce attractive, marketable and often long shelf-life food products. Similar processes are used to produce animal feed.

OBJECTIVES

Upon completion of this lesson you should be able to describe the different standards that guide the production, distribution and storage of various agricultural products.

PROCESSING IN SMALL STATES

The options for processing of agricultural commodities in Small States are subject to factors and constraints that are less relevant to the industries of larger countries. Consideration has to be given to the challenges that come with small size of states such as limitations in the availability of the factors of production, financing, and the various economies of scale. Therefore, processing methods for small States are to be chosen so as to guarantee profitability, safety, and sustainability of resource utilization and of market share.

Common Processing and Preservation Techniques for Plant and Animal Products

According to Amanor-Boadu (2003), an initiative qualifies as value-adding if it satisfies either of two conditions: (1) if one is rewarded for performing an activity that traditionally has been performed at another stage farther down the supply chain, or (2) if one is rewarded for performing an activity that has never been performed in the supply chain. In the first situation, producers might bypass processors by processing their own production, or producers might bypass wholesalers by selling directly to consumers (direct marketing).

In the second situation, agricultural producers might be able to command higher prices for commodities by adapting new varieties that yield a more uniform commodity, thus...
reducing the need for sorting at the processing level. Since the processor no longer has to incur this cost, a portion of the savings could be passed on to the grower in the form of higher commodity prices. Another example would be the transformation of a basic agricultural commodity into a processed product desired by consumers. Additionally, processing methods are applied to serve the aim of food preservation. In food preservation the food is treated to stop or severely retard deterioration due to continued physiological and biochemical processes, or the activity of micro-organisms.

For small states there is a correlation between the capacity to preserve excess food through agro processing and the attainment of sustainability in economic and technical development. The preservation role of processing mitigates against loss due to inevitable deterioration of biological systems of harvested goods.

Agro processing for sustainable agriculture must recognize and remain true to the principles of sustainability as not doing so would threaten to go counter to the efforts of the production concepts under the sustainability umbrella. The **Clean Development Mechanism of the Kyoto Protocol** is aimed at promoting sustainability in development initiatives particularly in Developing Smaller States. Since it allows for a mechanism for support for clean development initiatives, sustainably agro processing ventures are well suited to benefit.

Before proceeding you should review the following online case study:


Small States of the Commonwealth are already engaged in agro processing and preservation activities to varying degrees of technological complexity. Listed are a few of the countries and some of the products they offer for the local, regional, and international markets.

**Table showing common products from small states**

<table>
<thead>
<tr>
<th>Country</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigua</td>
<td>Jams; jellies; hot sauces.</td>
</tr>
<tr>
<td>Bahamas</td>
<td>Bottled lemonade; jams, jellies to hotels.</td>
</tr>
<tr>
<td>Country</td>
<td>Products</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Barbados</td>
<td>Prepackaged vegetables, cassava flour, bottled seasoning, milk, yogurt, ice cream, cottage cheese, margarine, vegetable oil, chicken: cut, whole, meat products, sausage, ham, smoked meat, salted pig tail.</td>
</tr>
<tr>
<td>Dominica</td>
<td>Coconut oil, soaps, bottled seasonings, essential oils, sea moss, hot sauces, plantain, banana chips, juice concentrates, jams, semi processed cocoa sticks, roasted, ground coffee.</td>
</tr>
<tr>
<td>Guyana</td>
<td>Cheese; yogurt; palm oil; coconut oil; Carambola fruit cake mix; rum; dried, smoked fish; chicken parks pre packed.</td>
</tr>
<tr>
<td>Jamaica</td>
<td>Soup mixes ‘Callalo’, pumpkin,; canned, pre packed; Irish potato pre seasoned, vacuum packed, sweet potato: blanched and vacuum packed; Akee: canned, pre packed; mango, carrot puree; canned juices; hot sauce, rum; beer, chips, Biscuits; aquaculture products: fillet, pre cooked, chilled; chicken, turkey and pork products.</td>
</tr>
<tr>
<td>Lesotho</td>
<td>Yogurt; sour milk; pasteurized milk.</td>
</tr>
<tr>
<td>Maldives</td>
<td>Virgin coconut oil; canned, dried fish; chilli paste; pickles; Roshi (pastry).</td>
</tr>
<tr>
<td>Mauritius</td>
<td>Pre packed vegetables; jams; sausages, yogurt; canned tuna.</td>
</tr>
<tr>
<td>Samoa</td>
<td>Banana, taro, plantain chips; Organic Coconut Oil; dried meat products.</td>
</tr>
<tr>
<td>Seychelles</td>
<td>Ham; Sausage; canned fish; salami; tomato sauce; jam; squash; pasteurized, condensed milk.</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>Potato chips, cassava flour.</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>Canned fish; dried fish; virgin coconut oil; bio fuel production; palm oil.</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>Jams; jellies; cassava bread; vacuum packed chicken; black pudding; smoke, frozen pork products; chips, juice concentrates.</td>
</tr>
<tr>
<td>Swaziland</td>
<td>Canned pineapple, citrus; industrial alcohol from bagasse; syrup (concentrates) sweetener; pre packed frozen chicken.</td>
</tr>
<tr>
<td>Country</td>
<td>Products</td>
</tr>
<tr>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>Tonga</td>
<td>Sun dried, salted fish; sea cucumber, sea weed dried, fermented, sun dried vanilla, Kava power, Kava drink; cassava chips.</td>
</tr>
<tr>
<td>Trinidad</td>
<td>Juices; soya oils; margarines; soaps; pasteurized, condensed, evaporated milk; bottled ‘Mauby’ bark; tomato ketchup; canned vegetables; coco bars; processed seasonings; whole, cut chicken pre packed; freeze-blasted shrimp; purees; bottled coconut water, dried, canned beef; canned fish.</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>Bacon; sausage, salted pork; smoked, dried, salted fish.</td>
</tr>
</tbody>
</table>

**PROCESSING & PRESERVATION METHODS**

The following is a short list of processing and preservation methods amenable to and practised in Small States.

**Pre Packaging**

In the Agribusiness sense, pre-packaging means to package food items in consumer size units before retail distribution or sale. This means that pre packaging can be done anywhere along the value chain before the product reaches the final customer: from the production centre to the terminal markets. Pre packaging protects the produce against deterioration from damage and excess moisture loss. Pre packaging material should be:

- Permeable (respiration dependent) enough to carbon dioxide, water vapour, and oxygen.
- Transparent.
- Possess physical properties for the type of protection needed.
Vacuum Pack

In vacuum packing suitable types of food are stored in air-tight packets or bottles from which the air has been sucked out, thus preventing the growth of microorganisms. The containers are denuded of atmospheric oxygen, so the food is protected from spoiling by the activities of aerobic bacteria or fungi. The prevention of evaporation of volatile components is also a benefit of vacuum packing. Vacuum packing is commonly used for long-term storage of dry foods such as nuts, cured meats, cheese, smoked fish, coffee, and jams.

It is also used for storage of fresh foods such as vegetables, meats; and of liquids such as soups and can extend the life of food by up to 3-5 times. Vacuum packaging products using plastic bags, canisters, bottles, or mason jars are available for home use.

Canning and Bottling

Canning (bottling) is a preservation method of hermetically sealing cooked. Here the prepared food is put in glass jars or metal cans that are hermetically sealed and immersed in a water bath or pressure canner to keep out air and then heated to a specific temperature for a specified time to destroy disease-causing microorganisms. Low-acid foods, such as meats, are heated to 240°–265°F; (116°–129°C);, while acidic foods, such as fruits, are heated to about 212°F; (100°C;). There is a wide range of products which can be canned such as; fruits and vegetables; seafood; milk; and preserves, pickles, jams, jellies, and sauces, and meat and poultry.
Examples

The table on the next page provides examples of other Agro processing and preservation methods employed in different Small States.
<table>
<thead>
<tr>
<th>Method</th>
<th>Primary Intention</th>
<th>Produce Class</th>
<th>Examples</th>
<th>Commercial example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying</td>
<td>Preservation, processing</td>
<td>FVA</td>
<td>Banana, peas, Cashew Apple, cabbage, garlic, okra</td>
<td>Dried Fish &amp; Cashew Caramel</td>
</tr>
<tr>
<td>Fermentation</td>
<td>Preservation, processing</td>
<td>FVA</td>
<td>Grape soybean milk</td>
<td>Cheddar cheese</td>
</tr>
<tr>
<td>Pre packaging</td>
<td>Preservation, processing</td>
<td>FVA</td>
<td>Pineapple cucumber potato beef</td>
<td>Sweet potato chips pre-packed</td>
</tr>
<tr>
<td>Dicing, mincing, Grinding</td>
<td>Preservation</td>
<td>FVA</td>
<td>Ground meat</td>
<td></td>
</tr>
<tr>
<td>Pickling</td>
<td>preservation</td>
<td>FV</td>
<td>Cucumber lime</td>
<td></td>
</tr>
<tr>
<td>Canning/bottling</td>
<td>preservation</td>
<td>FVA</td>
<td>Tomato carrot pineapple</td>
<td></td>
</tr>
<tr>
<td>Distillation</td>
<td>processing</td>
<td>FS</td>
<td>Ginger Bay Leaf Citronella Clove sugar cane</td>
<td>“Bug Off” insect repellant, After Shave; “BayRum”</td>
</tr>
<tr>
<td>Blanching</td>
<td>Processing, preservation</td>
<td>V</td>
<td>Peas, peanuts sweet corn</td>
<td></td>
</tr>
<tr>
<td>Pulping</td>
<td>processing</td>
<td>F</td>
<td>Mango papaya sweet tamarind</td>
<td>Alphonso mango pulp</td>
</tr>
<tr>
<td>Puree</td>
<td>processing</td>
<td>F</td>
<td>Papaya kiwi etc</td>
<td>Fruit puree</td>
</tr>
</tbody>
</table>
PRODUCTION CONTROL, QUALITY & SAFETY

Quality and safety are two very crucial attributes of food production demanded by the modern consumer. The satisfaction of these demands requires that standards be implemented. These standards have influenced the trade in agricultural produce on a global scale.

Food quality and safety include many factors and have many definitions, such as: taste, aroma, colour, texture, functionality, health, cost, environment, decent work, equity, tradition and culture. Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) are all tools for assuring product quality, and in some countries they have been made compulsory by law. Private standards, for example, EUREPGAP, are required for exporting products to certain retailers in certain markets. Organic standards and procedures, initiated by civil society, have become part of the legal and institutional framework of many countries. There are also voluntary systems for certifying quality assurance programmes, for example the International Standards Organization (ISO) standards.

The producers in the larger, more industrialized countries have the advantage of economies of scale, yet some find it troubling to stay true to the standards subscribed to because their profit margins are severely reduced by the expenses involved. One should expect then that for small states the profitability issue will be more critical. Nonetheless, to ensure that the sustainability principle is applied through to the sustainability of markets, international as well as locally accepted standards must be determined and adopted.

Food safety concerns the consumption of food containing food-hazards. Since food safety can be compromised at any stage in the food chain, it is essential that adequate control be in place. Therefore, a combined effort of all parties through the food chain is required necessitating the creation of different quality and safety assurance best practices. Let’s examine each one.

Hazard Analysis and Critical Control Point (HACCP)

HACCP stands for ‘Hazard Analysis and Critical Control Point.’ It is a systemic approach to the prevention of hazards of the chemical, physical and biological nature in food and medicine production systems. HACCP is a systemic and preventative approach to food safety where steps are designed to prevent problems before they occur and to rectify deviations upon detection are taken.

HACCP establishes Critical Control Points (CCPs), which are system check points where action can be taken (control can be applied) to reduce or prevent the risk of hazards happening. HACCP is employed at all stages of food production including processing and...
packaging. Seven distinct activities (principles) have been established as necessary to implement a HACCP plan.

**Supplementary Readings:** To learn more about HACCP you should read the following:


**HACCP Plan Principles**

The seven principles are:

**Principle 1**

**Hazard Analysis:** This involves spotting hazards and evaluating the related risks at every step in the production system. At this point possible control measures are detailed.

**Principle 2**

**Determination of Critical Control Points (CCPs):** Key actions at critical steps in the production system, which are used to effect control are known as Critical Control Points. CCPs removed, prevent, or reduce safety hazards to acceptable levels.

**Principle 3**

**Establishment of critical limits:** Critical limits associated with each CCP are established. Here points of acceptability are established with regard to the control parameters.

**Principle 4**

**Establishment of a monitoring system:** Monitoring procedures in the form of planned measurements or observations at various CCPs are done. These procedures ensure that principle No. 3 is true and that levels are kept within critical limits.

**Principle 5**

**Corrective Action:** Establishment of a procedure for corrective action as surveillance at a CCP indicates a deviation a predetermined critical limit.

**Principle 6**

**Record Keeping:** Verification procedures are established validate the efficacy of the HACCP plan. It involves such activities as auditing, reviewing of abnormalities and random sampling.

**Principle 7**

**Verification Procedures:** Documentation of procedures and record-keeping activities consistent with the application of the HACCP principles.
International Organization for Standardization (ISO)

ISO stands for ‘International Organization for Standardization.’ It is a global nongovernmental organization which develops and publishes international standards. The national standards institutes of various countries make up the ISO with the Central Coordinating Secretariat in Geneva Switzerland.

With respect to the food production and agro processing industry ISO 22000 is a standard within the ISO family which synchronizes already existing national and industry certification schemes, including HACCP. The ISO 2200 standard was outlined to serve the needs of food producers and processors and also other stakeholders participating in the food supply chain.

The standards are applied to primary food production activities as:

- Crop production
- Feed production
- Primary food processing
- Secondary food processing
- Wholesale and distribution
- Food retailing

It is also applied to other related operation as:

- Pesticide, fertilizer and veterinary pharmaceutical production
- Ingredients and additive production
- Transportation and storage
- Equipment production
- Cleaner and sanitizer production
- Packaging materials production

Supplementary Readings: To learn more about ISO standards you should review the following articles:


OTHER SAFETY & QA GUIDELINES

Most countries have their own agricultural safety and quality assurance programs to ensure the safety of the food chain. Many of the local regulations embrace various international standards and quality assurance methods. Some of the ones that impact the agricultural industry include:

SA 8000 Social Accountability Standard - Provides guidance on the working conditions and employment guidelines for labourers, including child labour.

ISO 14001 : 1996 Environmental Management Systems - Provides guidance on the effective management of the local environment, which would include your farm and other agro-processing sites.

GLOBALGAP - Is a private sector body that sets voluntary standards for the certification of production processes of agricultural (including aquaculture) products around the globe.

IFOAM - Provides voluntary standards and guidelines for the production and distribution of organic agricultural produces.

OCIA International - Is another provider of voluntary standards and guidelines for the production and distribution of organic agricultural produces.

Quality Certification Services - Provides certification for farms and agro-processing.

Click on each link to learn more about the standards or specific certification process.

SUMMARY

To ensure the safety of your food supply farmers must become familiar with and apply specific quality and safety standards. The ideal is to equal or exceed the standards that impact your portion of the industry. The aim should be to seek out and gain certification for your products. International certification will tell potential customers that you have considered their safety and that you are selling a quality product.
UNIT THREE DISCUSSION

Upon completion of this unit you should as an individual or in a small group:

Investigate and report on how your local agricultural producers ensure the safety of their locally grown produce? Are these methods adequate and would they satisfy international standards for food safety?

Under the guidance of your teacher you should form small groups and explain and discuss your findings.

UNIT THREE ASSIGNMENT

Task: You are to investigate and report on the post-harvest and agro-processing system employed in your small state or local community. Start with a medium size produce farm and identify the following post-harvest routines.

1. Describe the crops and harvesting approach.
2. Explain the amount of labour, resources and equipment used during the harvesting process.
3. Identify the post-field packaging and storage process.
4. Describe the transportation process from the farm to the wholesaler?
5. Identify how the products move from the farm to the wholesaler?
6. Explain how the quality and safety of the products are protected during the packaging, transportation and storage process?
7. Describe the wholesaler’s packhouse operation and layout?
8. Explain the agro-processing procedures employed to re-package the products for retail sale.
9. Describe the marketing and packaging process.

The second part of the assignment is to determine what standards that the various stakeholders (farmer, transporter, wholesaler, packhouse, retailer) are demonstrating during their part of the process.

Instructions: Once you have completed your detailed analysis of the agro-process you should submit a report to your instructor for review, feedback and grading.
UNIT THREE SUMMARY

In this unit you learned the relevance of the physiology and biochemistry of agricultural commodities to the harvesting, post-harvest handling, and storage of fresh produce. The internal and external factors that promote the deterioration of fresh agricultural commodities were described.

The unit also examined the principal causes of post-harvest losses in fresh produce items. It further outlines the changes in the commodities which result in losses.

The methods of reducing losses are addressed through proper harvesting procedures, transportation, packhouse operations, packing and packaging and storage.

Also outlined are step by step procedures and examples applicable to small states in an effort to assist them in improving the quality of their fresh produce and consequently to achieve sustainability.

An introduction to the different agro processing techniques and methods adapted to small states and that contribute to the sustainability of their production systems were reviewed. Quality and safety standards and practices to guarantee desired quality and safety of agro processed goods were also described.
UNIT FOUR – AGribusiness Management

OVERVIEW
This unit aims at describing the different aspects of agribusiness management as applied in small states. It starts with understanding basic economics concepts as applied to management, helping to answer the production questions of what to produce; how to produce and how much to produce. Also included in this unit is the relevance of marketing to agribusinesses in small states.

This unit also emphasizes the importance of farmers’ associations and cooperatives and the benefits of working together. This unit discusses how different forms of farmer groups can help create a strong local and national agricultural industry. A special focus is given to the concept of value chain and how farmers working together can improve the value chain.

GOALS AND OBJECTIVES
Upon completion of this unit you should be able to:

1. Understand the relevance of basic applied agricultural economics for agribusiness in small states.
2. Explain the importance of marketing to agribusiness including the marketing functions and the 5Ps.
3. Develop a marketing plan for an agribusiness.
4. Prepare a SWOT analysis for a specific agricultural enterprise.
5. Prepare a simple business proposal for an agribusiness project seeking for finance from a local banking institution.
LESSON 4.1 – APPLIED AGRICULTURAL ECONOMICS

OVERVIEW
Small farmers can benefit from understanding farming as a business and, as a result, make a good livelihood based on the application of sustainable agriculture techniques, sound farm management, and good planning and marketing decisions. Knowledge of economic principles will provide farmers in small states with a set of procedures and rules for decision making. This knowledge will be useful to help the farmer to plan and organize work on his farm. It will also guide the farmer through the steps in the decision-making process.

OBJECTIVES
Upon completion of this lesson you will be able to:

1. Explain supply and demand in the agri-industry.
2. Discuss different costing models used in the agri-industry.
3. Determine how and what to produce.

DEMAND AND SUPPLY
In all businesses, including an agriculture business, there are consumers and there are providers. The consumers purchase a service or produce and the providers produce the products or deliver the service. In agriculture the obvious products include fresh produce, meat, dairy and other related food stuffs. The amount you sell depends on the demand and the amount you can supply to your customers. This is now known as demand and supply.

The Theory of demand and supply is one of the fundamental theories of economics. It helps to understand how a market economy works, since demand and supply are crucial elements that affect resource allocation.

By definition, supply is the amount of product that a producer is willing and able to sell at a specified price, while demand is the amount of product that a buyer is willing and able to buy at a specified price. Thus, the supply and demand model shows the relationships between a product’s accessibility and the interest shown in it.

Supply and demand is an economic model of price determination in a market. It concludes that in a competitive market, price will function to equalize the quantity demanded by consumers, and the quantity supplied by producers, resulting in an economic equilibrium of price and quantity.
The price \( P \) of a product is determined by a balance between production at each price (supply \( S \)) and the desires of those with purchasing power at each price (demand \( D \)). The diagram shows a positive shift in demand from \( D_1 \) to \( D_2 \), resulting in an increase in price (\( P \)) and quantity sold (\( Q \)) of the product.

**PRODUCTION FUNCTION**

The fundamental basis for agriculture is the biological process of combining various resources to produce a useful product. The production function shows the relationship between the resources or inputs used to produce the corresponding output. A production function can be in the form of a table, graph or mathematical equation.

**Table: Input and output relationships and optimal level of input use**

<table>
<thead>
<tr>
<th>Input Variable X</th>
<th>Output or Total Physical Product (TPP)</th>
<th>Average Physical Product (APP)</th>
<th>Marginal Physical Product (MPP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>80</td>
<td>20.0</td>
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<td>6</td>
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<td>85</td>
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</tr>
</tbody>
</table>
Total Physical Product

For each level of variable input used, there is a corresponding level of output called total physical product (TPP). From the above table, at input level 1, TPP is 20. When input level is increased to 2 units, TPP is 50.

Average Physical Product

The average physical product (APP) is equal to the average amount of output produced per unit of input at each input level.

APP is calculated by the formula:

\[
APP = \frac{\text{Total Physical Product}}{\text{Input Level}}
\]

For example, when 3 units of variable input X is used, APP is equal to 70 divided by 3 which is 23.3.

Marginal Analysis

Agribusiness managers are often interested to know what will be the changes that occur when one or more of the factors of production under their control are altered. For instance, they would like to know what will be the effect on output of adding an additional unit of input.

Marginal analysis and the production function can be used to provide additional information about the relationship between the input and the TPP.

The incremental changes, increases or decreases that occur at the edge or the margin, is termed as the marginal change.

It is necessary to find the difference between the original value and the new value that resulted from a change in the controlling factor in order to calculate the marginal change.

The Greek letter delta \( \Delta \) is used as short-hand for ‘the change in’.
Marginal Physical Product

The MPP is the additional or extra TPP produced by using an additional unit of input.

\[ MPP = \Delta \text{Total Physical Product} \div \Delta \text{Input Level} \]

\( \Delta \) Represents (The Change In)

MPP can either be positive or negative. It can also be zero.

From the above table, when variable input is increased from 2 to 3 units, TPP is increased by 30 (50-20). The MPP is equal to 30 divided by 1 which is equal to 30.

**LAW OF DIMINISHING RETURNS**

The law of marginal diminishing returns is used to describe what happens to MPP when an additional unit of input is used. The law of diminishing returns states that as additional units of a variable input are used in combination with one or more fixed inputs, MPP will eventually decline.

The underlying reason behind diminishing returns is that biological processes will not respond indefinitely to increases in a given input. For example, as additional levels of fertilizer are applied to a fixed acreage of a crop, the additional output or MPP will eventually begin to decline. The MPP becomes smaller and smaller as the crop nears its biological capacity to use the input.
A Graphical Analysis - Example

From the production function (in top graph), we can observe that the TPP increases at an increasing rate as the input level is increased from zero.

As the input level is increased further, the TPP continues to increase, but at a decreasing rate, and eventually peaks and begins to decline.

From the bottom graph: MPP and APP are both increasing as long as TPP is increasing at an increasing rate.

When TPP starts to increase at a decreasing rate, MPP reaches its maximum and then continuously declines.

When TPP reaches its maximum, MPP is equal to zero.

When TPP starts to decline, MPP is negative.

APP increases over a slightly longer range than MPP before beginning to decline.

Whenever MPP is above APP, APP will be increasing and whenever MPP is below APP, APP is decreasing. The APP curve is at a maximum where the MPP crosses it.

The relationship between TPP, APP and MPP is better understood when dividing the graph into three stages.

**Stage I**: begins at the zero level and continues to the point where APP is maximum and equal to MPP

**Stage II**: begins where APP is the maximum and ends where MPP is zero (or TPP is the maximum)
Stage III: is the range of input levels where MPP is negative and TPP is declining absolutely.

RELATIONSHIP OF PRODUCTION, APP & MPP

Understanding the relationship between the production function, APP and MPP is important to determine the proper amount of input to use. With the goal of maximizing profit in mind, the farmer must select the input levels that will result in the highest profit. Any input level in stage III causes TPP to decrease and therefore is not worth considering.

In stage I, an increase in input level causes TPP to increase. A manager will want to use at least an input level that results in the greatest average physical product per unit of input. This can be achieved by using input level between Stage I and II. This point represents the greatest efficiency in the use of the variable input.

However, profit can still be increased by increasing level of input even though APP is declining along with MPP. But the exact level of input level which will maximize profit cannot be determined solely using these information. Additional information about input and output prices are required to make the right decision.

**Total Cost and Total Revenue**

Assuming that the farmer’s goal is to maximize profit, we must know what the cost of the input is and at what price the output can be sold.

<table>
<thead>
<tr>
<th>Input Variable X</th>
<th>Total Physical Product (TPP)</th>
<th>Average Physical Product (APP)</th>
<th>Marginal Physical Product (MPP)</th>
<th>Marginal Value Product</th>
<th>Marginal Input Cost</th>
<th>Total Revenue</th>
<th>Total Cost</th>
<th>Net</th>
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<td>255</td>
<td>105</td>
<td>150</td>
</tr>
</tbody>
</table>

The profit maximizing level of use of an input can be determined by analyzing the marginal or incremental change in costs and revenue as more input is added.
Marginal revenue is defined as the change in total revenue or additional income received from selling one more unit of output.

\[
\text{MR} = \frac{\Delta \text{Total Revenue}}{\Delta \text{Total Physical Product}}
\]

\(\Delta\) Represents (The Change In)

Marginal Cost is defined as the change in cost, or additional cost incurred, from producing another unit of output.

\[
\text{MC} = \frac{\Delta \text{Total Cost}}{\Delta \text{Total Physical Product}}
\]

\(\Delta\) Represents (The Change In)

**The Decision Rule**

MR and MC are used to find profit-maximizing input and output levels.

When MR > MC, an additional unit of output increases profit, because additional revenue exceeds the additional cost of producing.

If MR < MC, producing an additional unit of output will decrease profit.

Therefore profit maximizing output level is when MR = MC.

**Marginal Value Product and Marginal Input Cost**

It is sometimes more convenient to compare the added revenue and added cost measured in terms of units of input instead of output.

Marginal Value Product (MVP) is the value of revenue produced by adding one more unit of input

\[
\text{MVP} = \frac{\text{Change in revenue as a result of one unit change in input}}{\text{Units of added input}}
\]
MVP can be compared to the marginal input cost (MIC), the unit price of the input being added. MIC is similar to marginal cost, but is measured in units of input rather than units of output. Theoretically, as mentioned above, the MR=MC rule should be used to find the profit-maximizing output level, and the MVP=MIC rule should be used to find the profit-maximizing input level.

*Important Note:*

1. Always use MVP and MIC together, as both are calculated on a ‘per unit of input’ basis
2. Always use MR and MC together because both are calculated on a ‘per unit of output basis’

**HOW TO PRODUCE**

A farmer must select the combination of inputs that will produce a given amount of output or perform a task for the least cost. In other words, the farmer will determine the least-cost combination of inputs which will maximize the profit at a given level of output.

The changes in price of one or more inputs may make it worthwhile to substitute one resource for another.

*Input Substitution Ratio*

The first step in analyzing a substitution problem is to determine whether it is physically possible to make a substitution and at what rate.

The graphs below show examples of isoquants. An isoquant is a line showing the different combinations of inputs which will produce the same quantity of output.

[Graph above: Example of an isoquant map with two inputs that are perfect substitutes.]
Graph: An isoquant map where Q3 > Q2 > Q1. A typical choice of inputs would be labour for input X and capital for input Y. More of input X, input Y, or both is required to move from isoquant Q1 to Q2, or from Q2 to Q3.

Graph: Example of an isoquant map with two inputs that are perfect complements.

The input substitution ratio shows the rate at which one input will substitute for another.

\[
\text{Input substitution ratio} = \frac{\text{Amount of input replaced}}{\text{Amount of input added}}
\]

Where both the numerator and denominator are the differences or changes in the amount of inputs being used between two different points on the isoquant.
The Decision Rule

By simply identifying the type of physical substitution that exist and calculating the input substitution ratio is not sufficient to determine the least-cost input combination. The prices of inputs are also needed and the ratio of the input prices must be compared to the input substitution ratio:

\[
\text{Input price ratio} = \frac{\text{Price of input being added}}{\text{Price of input being replaced}}
\]

The least cost combination of inputs is when the input substitution ratio is equal to the input price ratio.

WHAT TO PRODUCE?

Enterprise Combination

The next question a farmer needs to answer is what to produce, or what combination of products will maximize profit. A farmer has different alternatives of enterprise to choose from.

Competitive Enterprises

It is important to understand the physical relationship among the enterprises being considered to determine the profit-maximizing enterprise combination. This will help to answer the question of what to produce when the quantity of one or more inputs is limited.

Given that resources are limited, for instance, land, capital or other input, the production from one enterprise can only be increased by decreasing production from another enterprise. This implies that there is a trade-off or substitution to be considered when changing the enterprise combination. These are called competitive enterprises as they are competing for the use of the same limited input at the same time.

It is possible to determine the most profitable combination of two competitive enterprises by comparing the output substitution ratio and the output profit ratio:

\[
\text{Output Substitution Ratio} = \frac{\text{Quantity of output lost}}{\text{Quantity of output gained}}
\]
The decision rule for finding the profit-maximizing combination of two competitive enterprises is the point where the output substitution ratio is equal to output profit ratio.

**Supplementary Enterprises**

Two enterprises are supplementary if the production from one can be increased without affecting the production level of the other.

A manager should therefore take advantage of supplementary relationships by increasing production from the supplementary enterprise. This should continue at least to the point where the enterprises become competitive.

**Complementary Enterprise**

Complementary relationship exists whenever increasing the production from one enterprise causes the production from the other to increase simultaneously.

**COST CONCEPTS**

For any small scale agribusiness enterprise, a good understanding of costs of production is important and very useful for making management decisions. Costs and be either fixed or variable. Opportunity cost is another type of cost and is of high relevance in economic analysis. This section will therefore discuss the different types of cost.

**Fixed Costs**

Fixed costs are costs associated with owning a fixed input. These costs are incurred even if the input is not used. Fixed costs do not change as the level of production changes in the short run but can change in the long run as the quantity of the fixed input changes.

Total fixed cost (TFC) is the summation of the several types of fixed costs. Fixed cost can be expressed as an average cost per unit of output.

\[
\text{Average Fixed Cost} = \frac{TFC}{\text{Output}}
\]

where output is measured in physical units.
Variable Costs

Variable costs are those over which the manager has control at a given time. Examples of variable costs are feed, fertilizer, seed and pesticides. Variable cost for each input is equal to the quantity of input purchased multiplies by its price.

Total variable cost (TVC) is the sum of all variable costs.

\[
\text{Average Variable Cost} = \frac{\text{TVC}}{\text{Output}}
\]

Total and Marginal Costs

Total cost is the sum of Total Fixed Cost and Total Variable Cost (\(TC = TFC + TVC\))

In the short run, \(TC\) will increase only as \(TVC\) increases because \(TFC\) is a constant value.

Average Total cost (\(ATC\)) is equal to Average Fixed cost plus average variable cost. It can also be calculated from the equation:

\[
\text{Average Total Cost} = \frac{\text{TC}}{\text{Output}}
\]

\(ATC\) will typically be decreasing at low output levels, because \(AFC\) is decreasing rapidly and \(AVC\) may be decreasing also. At higher output levels, \(AFC\) will be decreasing less rapidly, and \(AVC\) will eventually increase and be increasing at a rate faster than the rate of decrease in \(AFC\). This combination causes \(ATC\) to increase.

Marginal Cost (\(MC\)) is defined as the change in total cost divided by the change in output:

\[
\text{Marginal Cost} = \frac{\Delta \text{TC}}{\Delta \text{Output}} \quad \text{OR} \quad \text{Marginal Cost} = \frac{\Delta \text{TVC}}{\Delta \text{Output}}
\]

\(\Delta\) Represents (Change In)

It is also equal to the change in total variable cost divided by the change in output.

\(TC = TFC + TVC\) and \(TFC\) is constant, so that only way \(TC\) can change in from a change in \(TVC\).
Cost Curves

The relationship between the different cost concepts described above can be illustrated graphically.

Average fixed cost is always declining but at a decreasing rate. The average variable cost (AVC) curve is U-shaped, declining at first, reaching a minimum, and then increasing at higher levels of output. The average total curve (ATC) has a shape similar to that of the AVC curve.

The marginal cost (MC) curve will generally be increasing. The MC curve crosses both average curves at their minimum points. As long as the marginal cost value is below the average cost value, the average cost will be decreasing, and vice versa. For this reason, marginal cost curve will always cross the average variable and average total cost curves at their minimum points.

SUMMARY

This was a brief introduction the economic concepts important to the success of any agricultural enterprise. Farmers, wholesalers, retailers and others must master these concepts. The industry is built around demand and supply and as you produce livestock and fresh produce to meet the demand you must do so in a way that is economically successful. No business can survive if they do not cover all of the expenses and make a profit.
LESSON 4.2 – AGRIBUSINESS MANAGEMENT

OVERVIEW

An agribusiness can be viewed as a social institution in small states. Agribusiness contributes to food security at small holder level as well as at national level. Successful export-led businesses can be an important source of revenue for small states. Management plays an important role for the successful running of an agribusiness enterprise in small states. This section lays the foundation for successful agribusiness management.

Agribusiness management encompasses many aspects of the economy: agricultural producers, businesses that provide supplies and services to the producers (including cooperatives), businesses that add value to agricultural products, and those that facilitate the marketing of agricultural products to an ever-growing marketplace.

An excellent resource for this lesson is Penn State’s Agricultural Marketing Web Site. It is recommended that you spend some time reviewing it.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Explain the role of the manager in an agribusiness.
2. Define your potential market.
3. Create a strategic plan for your agribusiness.
4. Produce an annual business plan.

THE MANAGEMENT FRAMEWORK

Farmers’ jobs are more than just growing and harvesting crops or attending to their livestock; it is about the effective management of the entire agribusiness that they are engaged in. The management process requires that the agri-professional master a number of skills.

All businesses operate in accordance with certain management principles and practices. The diagram below reflects the major management roles required to ensure the successful operation of an agribusiness.
The Management Framework

Setting Objectives

An important step in managing agribusiness in small states is to start by setting objectives. Objectives have to be clearly defined and realistic. From there on, all efforts of the agribusiness should be geared to achieve the set objectives.

Objectives actually give a sense of direction to agribusinesses indicating the way to move ahead.

Planning

After setting the objectives, managers of small agribusinesses must formulate a plan. A plan can be compared to a roadmap which indicates where the agribusiness is going and how it is going to get there. The manager must identify the quantity and quality of resources required to achieve their objectives. The resources are then to be allocated among several uses. The manager must identify all the different alternatives, analyze them and select those that will come closest to meeting the objectives of the agribusiness.

Decision-Making

Successful agribusiness managers continually learn to rethink their decisions as economic, technological and environmental conditions change. Nowadays, in the globalised world in
which we are operating, it is important for small states to have good access to latest information. Such information will affect the management of businesses and help to answer the questions of what to produce; how to produce; what inputs to use; how much of each input to use; how to finance their agribusiness; and how, where and when to market their products. New information forces managers to re-think their old strategies.

The decision-making process can be broken down into the following logical steps:

1. Identify and define a problem or opportunity.
2. Identify the various alternatives.
3. Collect information.
4. Analyze the alternatives and make a decision.
5. Implement the decision.
6. Monitor and evaluate the results.
7. Accept the responsibility.

Implementation

After developing the plan, the agribusiness manager must now implement the plan. This will involve the acquisition of resources required to put the plan into action. It will also involve assigning tasks and responsibilities to people working in the agribusiness. For a business to operate efficiently, all individuals involved must know what is expected from them.

Control

The control function helps to ensure that plans are being implemented and results are being obtained. It includes monitoring performance, comparing the actual results to the expected results, and taking corrective actions when necessary. Control therefore measures progress by comparing actual performance against set objectives. Should there be any discrepancies; adjustments to plans may be required.

THE BUSINESS PLANNING PROCESS

Establishing goals and objectives and monitoring their execution requires a sound knowledge of the business planning process. Business planning consists of five main activities:

1. Identify the business opportunity and establish initial goals and objectives based on the potential market.
2. Establish a strategic plan for your business.
3. Produce a business plan that will guide you through the implementation process in accordance with the strategic goals and objectives.
4. Conducting a SWOT analysis to reduce the risks during implementation and growth of the business.
5. Implement the business plan.

Now let's examine each one.

**DEFINING THE POTENTIAL MARKET**

Defining your potential market is both an art and a science. As an agribusiness professional you must monitor customer current and future demands and where possible provide products that meet or exceed those demands. For example the demand for organically certified produce and meats are growing. You may want to consider changing the output of your farm to embrace the demand for organic foods. But this type of change requires careful planning and implementation to ensure it becomes a profitable business.

The potential agri-market is impacted by a variety of short term and long term variables. Some of these include:

1. Cost of transportation.
2. Access to a agri-supply chain that can support storage and distribution.
3. Weather and its impact on your crops or livestock.
4. The ability to access labour.
5. The changing tastes and demands of your potential customers.
6. The regulations that govern the growing and distribution of food stuffs (both locally and internationally).
7. The quality of your land and infrastructure to support new crops or livestock.
8. The impact of disease and other biological agents that impact crop and livestock quality.

The potential market can be divided into three parts: local markets that are easy to access; national markets that may require a local distribution system; and global markets that will require a number of different international partners who support the wholesale, transportation and storage process. Each market requires different types of services and support and thus there is a resource bill and cost to providing these services, support, packaging methods, etc. What market you wish to engage in must be taken into consideration when determining what you future plans are as you go forward.

**ESTABLISHING GOALS AND OBJECTIVES**

Once you have clearly defined your potential market you must begin the detailed planning process. The first step is to clearly identify the goals and objectives that your agribusiness wishes to purpose.

Goals and objectives are clearly defined targets stated in measureable terms that help define the direction that your business wishes to move. They should be used to guide the strategic planning process and to measure whether you have succeeded in pursuing your desired market opportunities.
Goals and objectives should be considered hierarchical. Goals are the desired outcomes. A goal may take many years to achieve. A single goal can consist of a number of different objectives. Each objective or step builds upon one another so that when all objectives have been achieved your agri-business should have achieved the stated goal.

**Example Goals and Objectives Statements**

**Goal:** By 2013, embrace organic farming methods for all our produce in accordance with the standards and guidelines published by OCIA International.

**Objectives:** The following objectives flow from the above goal.

*Objective 1:* Employ organic growing and cultivation best practices in the planting of our farm produce.

*Objective 2:* Establish a relationship with a wholesaler and distributor who specialize in the sale and distribution of organic produce to a North American market.

*Objective 3:* Implement a marketing plan that informs our North American clients of our organically grown products.

*Objective 4:* Increase our profitability by 50% on or before 2013.

**STRATEGIC PLANNING**

Once you have established some potential business goals and objectives agribusiness professionals should implement a more detailed strategic planning process. A well designed strategic plan articulate a vision for the business and then identifies the multi-years strategic goals and objectives, the strategies required to achieve the desired goals and objectives and the resources and budget that is needed to implement the strategic goals.
In 1999, Walcoff identified the following steps in the strategic planning process.

You must embrace a systematic planning and implementation process if you wish to create a strategic plan. The first part is to define what your vision is for your agribusiness.

**Vision Statement:** Walcoff (1999) indicates that an organization’s vision should be “an attempt, in a very few words to paint a picture of your dream – your company in the minds of your customers, employees and stakeholders”. Tiffany & Peterson (1997) describe a vision statement as “a well-crafted set of words announcing where your company wants to go or painting a picture of what you company wants to become. To people inside and outside your company, your vision statement is your compass, showing the whole world the direction in which your company is headed”.

**Mission Statement:** Mission statements evolve from the vision and describe what an organization does or the type of products and services the organization provides to its customers. Stutley (2002) believes a mission statement should “describe exactly what you are doing for the next three to five years (why, where, how) and what you want to achieve. It should be a statement of purpose ...”.

**Example Vision and Mission Statements**

**Source:** Ephraim Mountain Farm Web Site
(http://www.ephraimmountainfarm.com/Mission.html)

**Our Vision:** Our vision is to create a diversified farm that grows clean, nourishing food for our family and others in Central and Southern Vermont. **We are small scale and we like it that way.** We can’t always compete with large-scale Agribusiness on price, but we absolutely out-compete most large operations on other things that matter:
- Flavour and taste;
- Environmental responsibility;
- Relationship with consumers;
- Independence from government subsidies;
- Community involvement;
- Humane care and respect for our animals.

**Our Mission:** Here in the Green Mountains of Southern Vermont, we seek to raise healthy, content animals in an environmentally sustainable fashion while producing high-quality beef and poultry products, serving as valuable members of our community.

**Supplementary Readings:** To learn more about creating an effective vision and mission statement it is recommended you review the following:


**SWOT ANALYSIS**

Before you proceed with the development of the strategic goals and objectives and implementation planning, the agribusiness professional should complete a SWOT analysis of the proposed market opportunity, the goals and objectives of the proposed business and the vision and mission statement.

A SWOT analysis is a way of assessing the risk of the proposed business and establishing strategies to reduce or eliminate risk. Using the SWOT analysis approach the risk is categorized as: Strengths, Weaknesses, Opportunities and Threats.

**Internal Risk Assessment:** During analysis of the strengths and weakness of your agricultural organization, owners must concentrate on the current internal environment or processes of the organization. These processes could include:

- Agri-business Practices.
- Farm Production Processes.
- Customer Service.
- Financial Health of the Organization.
- Human Resources.
- Sales and Marketing.
- The Management Team.
- Farm Infrastructure Requirements.
- Farm Practices.
**Strengths:** You must review your organization and determine what strengths you currently have as it relates to the strategic direction you wish to move. If your organization wishes to become an organic produce provider to a North America audience and you already have embraced many of the best practices of the organic industry, then a specific strength could be “Currently employs organic growing practices”. You need to develop a list of all the organization’s strengths based on an assessment of your current environment and capabilities.

**Weakness:** The assessment of your organization’s weakness must be based on the vision and mission you wish to achieve and the type of business you want to be as you implement your plan. The organization must assess its current environment and capabilities and determine what areas need improvement if it is to succeed. An example of a weakness for the creation of an organic farm could be “Under-funded. Company need infusion of cash if we are to grow.” A weakness can be similar to a strength. For example if the farm operation identified the following as a strength “Possess well qualified and experienced farm employees “but the farm wishes to embrace new growing procedures, then a weakness that mirrors the strength is “Need to provide additional training to my farm employees to help them master organic growing methods”.

**External Risk Assessment:** Strengths and weaknesses have an internal focus. They look at how the farm currently works. Opportunities and threats focus on the external environment surrounding, supporting or competing with the farm operation. For example you do not control the companies that provide you storage services, wholesale support or transportation. Therefore these are potentially a threat if they do not do what they promise.

External factors are those things that an organization does not directly control, but that have potential to impact the operation of the organization. During analysis of the external environment, the proposed organization should consider:

- The Competition.
- Current and Potential Customers.
- External Partners.
- Suppliers.
- Contractors/Sub-Contractors.
- Financial Institutions.
- Government Regulations/Laws.
- Regulatory/Certifying Organizations/Agencies.

**Opportunities:** As you consider what opportunities exist for your organization, analysts must think about how to go from where you are now, to where you want to be in the future, as defined by your vision and mission statement and the assessment of your potential market. Opportunities in a farm operation could include: a growing market for...
your produce; new storage facilities being established in the local community; faster transportation methods to get your products to market; etc.

**Threats:** External threats exist in everything that we do in planning and operating a distance education enterprise. Threats are, as implied, resources, activities, processes or circumstances that will prevent an organization from achieving its mission or vision. When considering threats, analysts must ask “What will cause us to fail?” A stated weakness can potentially be an indicator of an external threat. For example a weakness statement like “Being under-funded” may also indicate “Financial institutions unwilling to lend money to a start-up farm operation.” Often threats evolve around the competition, funding sources, suppliers, customers, regulations and labour unions. A list of potential threats for any farm operation could include:

- Competition provides services and products at a cheaper price.
- Competition has higher quality produce and meat products.
- Potential customers do not know about your farm operation and what you provide.
- Suppliers will not provide equipment.
- Existing customers are not return customers.
- Government changes legislation governing the agricultural industry.

Each of these SWOT items must be assessed and you must ask yourself how can eliminate the threats, address the weaknesses, build upon my strengths and seek out and build upon the opportunities. This analysis will lead to a list of strategic goals and objectives.

**STRATEGIC GOALS AND OBJECTIVES**

To counter the weaknesses and threats identified in the SWOT, build upon the identified strengths and opportunities and to guide the implementation of the business opportunity an agri-professional needs to create a number of multi-year strategies to guide the organization to the effective implementation of its mission and move it towards its vision. The strategic planning cycle will vary by the type of agribusiness being pursued, but it is usually in the range of three to five years.

Strategic goals and objectives evolve from the visioning and mission planning process and the completion of a SWOT analysis. When developing strategies, the agri-professional must ask:

- What do I need to do to achieve my vision and implement my mission?
- What must I do to reduce the business risk identified in the SWOT?
- The characteristics of effective strategies are:
  - They represent the long-term (two to five years).
  - They help the organization move towards its vision.
  - They reflect the values important to the organization.
  - They require the commitment of time, resources, budget and personnel.
• They help reduce or eliminate the risks identified in the SWOT process.
• They are achievable given the right resources and support.
• Successful completion of all of the strategies should result in the achievement of the mission and vision.

Examples of Strategies

Strategy to Address Financial Threat: Produce and implement a financial plan that will ensure profitability in the first two years of operation.

Strategy Address HR Issue: Organize training for farm labourers to educate them in the implementation of organic farming methods.

Supplementary Readings: To learn more about the strategic planning process you should review the following online articles:

Steps of the Strategic Planning Process.  
[http://www.entrepreneur.com/stratplan/plngsteps.htm]

Van der Werff, T.J. (n.d.). Strategic planning for fun and profit.  
[http://www.globalfuture.com/planning.htm]

THE BUSINESS PLAN

The final step in the planning process is to translate the multi-year strategic goals and objectives into an annual business plan and implementation plan. The process should result in the following outputs:

1. Production Plan (including quality control process).
5. Infrastructure Improvement Plan.

The business plan should guide the operation of the farm for the entire year. If you follow the plan then you will be moving towards your vision and mission and contributing to your strategic goals.

Supplementary Readings: To learn more about business planning in the agricultural sector and to see the contents of a typical business plan you should read the following articles.

Agricultural Marketing - Business Planning. Penn State.  
[http://agmarketing.extension.psu.edu/Business/BusPlan.html]

How to Write a Business Plan.  
[http://www.ciras.iastate.edu/beefmanual/Section2.pdf]


SUMMARY

During this lesson you learned that planning is an essential part of any successful agribusiness. The planning process includes defining your market, creating a strategic plan for your business and translating the strategic plan into an annual business plan. This process, if followed, will help agri-professionals effectively manage their business and help grow and become profitable.
LESSON 4.3 – THE MARKETING PLAN

OVERVIEW
Marketing is of increasing significance to agribusiness in small states. This section leads to a rationalization of the concept of marketing and an understanding of the nature of marketing systems. The description of the principal functions of marketing then follows; with suggestions as to how these can be carried out in a customer focused fashion to identify niche markets for small states.

OBJECTIVES
Upon completion of this lesson you will be able to create a marketing plan for your agribusiness.

WHAT IS MARKETING?
Marketing deals with identifying and meeting human and social needs. The marketing of agricultural goods is highly complicated by the following factors:

- Agricultural products are produced on a small scale by a very large number of producers.
- Agricultural production is very seasonal in character.
- A large portion of farm production is perishable.
- Agricultural production varies greatly in quality and quantity from season to season.

As a result of these factors the physical functions of assembling, transportation control, grading, and storing are exceedingly important.

Marketing methods are also used to raise the awareness of your potential customers about the products that you provide.

MARKETING MIX
The concept underlying marketing holds that the key to achieving organizational goals consists of the enterprise being more effective than his competitors in creating, delivering, and communicating customer value to the chosen target markets.

The marketing mix (below) describes the different concepts engaged in the marketing process. They all converge on the potential customers and existing customers who should be the focus of the marketing effort.
The term "product" refers to tangible, physical products as well as services. The product decisions should consider the product's advantages and how they will be leveraged. Product decisions should include:

- Brand name
- Functionality
- Styling
- Quality
- Safety

Packaging

In the context of the marketing mix, promotion represents the various aspects of marketing communication, that is, the communication of information about the product with the goal of generating a positive customer response. Marketing communication decisions include:

- Promotional strategy (push, pull, etc.).
- Advertising.

Distribution is about getting the products to the customer. Some examples of distribution decisions include:

- distribution channels;
- market coverage (inclusive, selective, or exclusive distribution);
- specific channel members;
- a pricing strategy includes:
• pricing objectives;
• pricing methods; and
• factors to consider when developing a pricing strategy.

Pricing is an important strategic issue because it is related to product positioning, and affects other marketing mix elements such as product features, expected volume etc., examples of pricing decisions to be made include:

• Pricing strategy (skim, penetration, etc.)
• Suggested retail price
• Volume discounts and wholesale pricing

MARKETING MANAGEMENT PROCESS

The marketing management process consist of analyzing market opportunities, researching and selecting target markets, planning marketing programs and organizing, implementing and controlling marketing efforts.

Analyzing Market Opportunities

The market’s initial tasks are to evaluate the various opportunities, assess buyer’s needs and wants as well gauge the market size.

Designing Marketing Strategies

In this step, the marketer prepares a positioning strategy for each new and existing product progress through the life cycle.

Planning Marketing Programs

At this stage of the process, marketers will examine the marketing mix, marketing allocation and marketing expenditure needed to achieve the marketing objectives.

Organizing, Implementing and Controlling the Marketing Efforts.

Managing the marketing effort is the final step. Managers will organize their resources to implement and control the marketing plan. Feedback and control mechanisms are imperative to the process as unforeseen situations may arise throughout the implementation stages.
MARKETING - THE EXCHANGE FUNCTION

The marketing concept holds that the buyer’s motive is the opportunity to maintain and increase profit margins. Hence the concept holds that the needs of the consumer are of vital importance.

**Buying:** A producer can be said to have adopted a market orientation when production is purposely planned to meet specific demands or market opportunities.

**Selling:** Phillip Kotler in his book *A Framework for Marketing Management* second edition, 2003 suggests that, “Most firms practice the selling concept when they have over capacity. Their immediate aim is to sell what they can make rather than to make what they can sell. Selling is part of the marketing mix, directed towards persuasion which is one of the four elements of the marketing mix.

MARKETING - PHYSICAL FUNCTION

**Storage:** An inherent characteristic of agricultural production is that it is seasonal while demand is generally continuous year round. This explains the need for storage in order to allow a smooth, and as far as possible, uninterrupted flow of product into the market. A farmer does not enjoy the same flexibility as his manufacturing counterpart in being able to adjust the timing of supply to meet demand as he is dealing with a biological product.

**Transportation:** The transport function is chiefly one of making the product available where it is needed, without adding unreasonably to the overall cost of the produce. Adequate performance of this function requires consideration of alternative routes and types of transportation, with a view to achieving timeliness, maintaining produce quality and minimizing shipping costs.

**Processing:** Most agricultural produce is not in a form suitable for direct delivery to the consumer when it is first harvested. “The processing function is sometimes not included in a list of marketing functions because it is essentially a form changing activity. The form changing activity is one of that adds value to the product. How the form of produce is to be
changed and the methods to be used in bringing about such changes are marketing decisions.
MARKETING - THE FACILITATING FUNCTION

The facilitating functions include product standardization, financing, risk bearing and market intelligence. Facilitating functions are those activities which enable the exchange process to take place. Marketing, in simple terms, is the act of supplying products to someone in exchange for something perceived to be of equal or greater value, (usually, but not always, a given sum of money). Facilitating functions are not a direct part of either the exchange of title or the physical movement of produce.

Standardization: Standardization is concerned with the establishment and maintenance of uniform measurements of produce quality and/or quantity.

Financing: In almost any production system there are inevitable lags between investing in the necessary raw materials (e.g. machinery, seeds, fertilizers etc.) and receiving the payment for the sale of produce. During these lag periods some individual or institution must finance the investment. The question of where the funding of the investment is to come from, at all points between production and consumption, is one that marketing must address.

Risk Bearing: In both the production and marketing of produce the possibility of incurring losses is always present. Physical risks include the destruction or deterioration of the produce through fire, excessive heat or cold etc. Market risks are those of adverse changes in the value of the produce between the processes of production and consumption.

Market Intelligence: Marketing decisions should be based on sound information. The process of collecting, interpreting, and disseminating information relevant to marketing decisions is known as market intelligence. The role of market intelligence is to reduce the level of risk in decision making.
THE MARKETING PLAN

The marketing plan is the foundation for all your marketing efforts, the plan must be based upon the goals and objectives identified within the business plan. A simplistic marketing plan looks at the following:

Executive Summary

The overview is a brief description of your plan, philosophy of your business, the major marketing objectives you will accomplish through your plan in quantifiable terms. It briefly outlines the plan’s main goals and recommendation; it is followed by a table of contents.

Situational Analysis

Sales, costs, profits, the market, competitors, distribution and the macro-environment are areas that this section presents relevant background data on. This information is used also to carry out the SWOT analysis. The marketing weaknesses, strengths, opportunities and threats identified during the SWOT analysis should be reflected in the marketing plan.

The situational analysis examines the following:

- Company Analysis (Goals, Focus, Culture etc.)
- Customer Analysis (Type, Value drivers, Decision process)
- Competitor Analysis (Market share/ position, strength etc.)
- Climate - Marco environment (PEST analysis) which includes:
  - Political and legal environment
  - Economic environment
  - Social and cultural environment
  - Technological environment

Opportunity and Issue Analysis

At this stage the entrepreneur review the main opportunity found in the SWOT analysis and identifies the key issues likely to impact the achievement of the objectives identified.

Marketing Strategy and Objectives

Objective- This section outlines the plan’s major financial and marketing objectives.

Marketing Strategies -Here the entrepreneur or product manager defines the target segments, namely, those groups and the needs the marketing offerings are intended to satisfy, and establish the product line’s competitive positioning. This is all done with inputs from other areas to ensure proper support for effective implementation.
Action Program

The action program denotes the actual marketing agenda resulting from the marketing strategy, to be used in achieving the objectives. Each strategy should answer questions such as: What will be done? When will it be done? Who will do it? How much will it costs? How will progress be measured?

Financial Objectives

Financial Forecast

For many organizations the ultimate goal of the marketing plan is the effect it will have on the bottom line. Examine closely:

- Customer and Channel sales (by volume and growth percentage)
- Channel
- By segment

Controls

This section should contain various performance measurement metrics including the financial implications of the plan in terms of contributions to the company’s bottom line. It should also outline some contingency plans handling specific environmental developments.

Sample Marketing Plans

Mixed Greens Salad Garden Marketing Plan
(http://www.mplans.com/agriculture_produce_farm_marketing_plan/situation_analysis_fc.php)

How to Write a Business Plan - Template
(http://www.ciras.iastate.edu/beefmanual/Section2.pdf)

MARKETING IN SMALL STATES

Niche Marketing

A niche is a more narrowly defined group seeking a distinctive mix of benefits. A niche market is the subset of the market on which a specific product is focusing; therefore the market niche defines the specific product features aimed at satisfying specific market needs.

The BCG Growth-Share Matrix is a portfolio planning model developed by Bruce Henderson of the Boston Consulting Group. The growth-share matrix thus maps the business unit positions within these two important determinants of profitability.
The growth share matrix is divided into four cells, each indicating a different type of business. **Question Marks** are representative of firms operating at in high growth markets but have relatively low market shares. Cash is usually required as much is spent on equipment etc. **Stars** are market leaders, **Dogs** are business with weak shares and in low-growth markets, whilst, **Cash Cows** are former stars with relatively large market share in slow-growth markets. A cash cow produces a lot of cash for the enterprise. Cash crops such as Irish Potato, Hot Peppers etc. are usually considered cash cows in many small states.

**Linkage Suitability for Small States to Niche Markets**

The link between agriculture and food continually evolves. New marketing links between agribusinesses, large retailers and farmers requires development, for example, through contract farming or group marketing, with those working in marketing and agribusiness being assisted to join together in associations to promote their common goals. As disposable incomes increase, the food industry will increase the quality and diversity of the products it produces. Food manufacturers will have particular expectations of agriculture as a supplier of their raw materials.

**SUMMARY**

Marketing is essential to any business, but is especially important to an agri-business. You need to understand the needs of your potential customers, you must find ways of informing the potential customers about your products and you need identify ways of selling the products to the potential customers. Marketing costs money and must be managed. Marketing requires a process that is part of the overall management routine of a successful farm.
LESSON 4.4 – THE VALUE CHAIN AND COOPERATIVES

OVERVIEW

Chains can be composed of companies (or individuals) that interact to supply goods and services. They are varyingly referred to as production chains, value chains, marketing chains, supply chains, or distribution chains. These concepts vary mainly in their focus, in the activity that is emphasized, and in the way in which they have been applied. However, they all describe the interactions of firms and processes that are needed to deliver products to end users, and they all aim to identify opportunities for and constraints against increasing productivity.

OBJECTIVES

Upon completion of this lesson you should be able to:

1. Describe the agricultural sector value chain.
2. Explain the role of value chain companies.
3. Describe the role of farmers’ cooperatives and their contribution to the agricultural sector value chain.

THE VALUE CHAIN CONCEPT

A value chain describes the full range of activities required to bring a product or service through the different phases of production, including:

- the physical transformation,
- the input of various producer services, and
- response to consumer demand.

As such, value chains include the vertically linked interdependent processes that generate value for the consumer. In contrast, the term supply chain is used internationally to encompass every activity involved in producing and delivering a final product or service, from the supplier’s supplier to the customer’s customer.

The primary focus of value chains are on:

- Value creation,
• Innovation,
• Product Development, and
• Marketing.

VALUE CHAIN COMPANIES

Value chains have also been used as a tool for SME development, with new methods of linking SME suppliers and service providers to the value chains of lead processors or marketers. Value chain analysis sheds light on the size of the firms participating in each link, how they are participating or could be participating in the chain, and opportunities to facilitate or improve those linkages.

An agriculture-based value chain company is a company set-up to add value at every stage of production, from the harvesting time until it reaches the consumer. It requires heavy funding from the government or other donor agencies and their needs to be a motivation for all the various stakeholders to come together, including the existing farmers, wholesalers, retailers, processors...etc.

Although the concept is fairly new in the agriculture sector and is something that can be used by the small states. Establishing a value chain company that focuses purely on the development of agriculture will:

• Increase diversity in products.
• Guarantee more markets.
• Reduce wastage in agriculture.
• Add value to the product.
• Improve livelihoods in the community.
• Bring the farmer, the processor and the consumers closer.

However, you should keep in mind that;

• Value chains are not fixed or static.
• Market dynamics matter.
• Quality and service is also important.
• A simple cost analysis will not be sufficient.
• The external environment also needs to be considered.
• Creating more value is the objective, NOT shifting value within the value chain.

VALUE CHAIN FARM ASSOCIATIONS

An association is simply a formal organization of individuals or groups of people. This is no different in agriculture. A Farmers association is the voluntary union of the farmers in to a formal body or organization to accomplish a common purpose; usually to protect the rights of farmers and develop the sector as a whole. A farmers association is usually found at the very top of a chain. They represent all the farmers in the country / province or community,
which makes them highly influential in the agriculture sector. They act as a link between the average farmer and the agriculture ministry in the government.

The association can only function properly when;

- They are registered as a legal body so that they can assistance from foreign agencies,
- They have a representative with leadership abilities to represent them both locally and internationally,
- They have a common interest,
- Their voices are being heard, and
- They support each other in their decisions.

**Benefits to its Members**

Different types of farmers associations exist across the small states of the world. They work to provide its members with;

- Technical assistance.
- Commercial businesses opportunities.
- Better market opportunities.
- Better financial stability.
- Research and development opportunities.

The way the associations operate, its structure, the available power...etc is different between the different states. However, there are some similarities; the members are both the owners and the users of the association, there is no bias based on gender, race or ethnicity, and all the members work to benefit the farmers and the agriculture environment.

**Role in the Value Chain**

The associations’ role in a value chain company will be in ensuring that the rights of the individual farmers and farmer cooperatives are protected. Based on the overall objectives and goals of the value chain company it is associated with, the association will ensure that:

- All the farmers or farmer groups have fair opportunity to join and work together with the value chain company.
- Commercial scale farmers do not undermine the small scale farmers
- The overall impact of the value chain company is beneficial to the community it is established in.

The farmers’ association working together with a value chain company will benefit from having a formal organization that is more dedicated to adding value to the local agricultural
produce, increase innovations in agriculture, improve agro-processing methods through research and provide better markets for its members.

FARMERS’ COOPERATIVES

A cooperative is similar to an association but generally farmers work more closely together in this arrangement. They often plan:

- What crops they will grow.
- Who will grow which crop.
- When they will start production.
- For whom they are going to sell to
- Help one another with;
  - Planting,
  - Management of pests and diseases,
  - Harvesting of the produce, and
  - Processing and Marketing.

With proper planning, the farmers working together in a cooperative can plan and grow their crop to ensure that they deliver the produce at the right time when the demand is at its highest. This would put them in a better position to negotiate for a better price, and all the farmers working together and sharing transportation will reduce shipping costs as well.

However, the sharing of the profits will depend on the amount of:

- Financial investment made by the contributing member.
- The production output produced by the contributing member.
- Labour hours the contributing member has invested in the cooperative.

One core element of a cooperative is that, people set-up or joins a cooperative to improve their economic and social conditions through a joint action for the good of all members rather than through individual concerns only.

Principles of Cooperatives

According to the International Cooperative Alliance Congress held in 1995, there are a total of seven fundamental principles that govern any form of cooperative organization.

1st Principle: Voluntary and open membership

Cooperatives are voluntary organizations open to all persons are able to use their services and willing to accept the responsibilities of membership without gender, social, racial, political or religious discrimination.
2nd Principle: Democratic member control

Cooperatives are democratic organizations controlled by their members, who actively participate in setting their policies and making decisions. Men and women serving as elected representatives are accountable to the membership. In primary cooperatives, members have equal voting rights (one member equals one vote), and cooperatives at other levels are also organized in a democratic manner.

3rd Principle: Member economic participation

Members contribute equitably to, and democratically control, the capital of their cooperative. They usually receive limited compensation, if any, on capital subscribed as a condition of membership. Members allocate surpluses for any of the following purposes: developing their cooperative enterprise, possibly by setting up reserves, part of which at least would be indivisible; benefiting members in proportion to their transactions with the cooperative and supporting other activities approved by the membership.

4th Principle: Autonomy and independence

Cooperatives are autonomous, self-help organizations controlled by their members. If they enter into any form of agreements with other organizations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their cooperative autonomy.

5th Principle: Education, training and information

Cooperatives provide education and training for their members, elected representatives, managers, and employees so that they can contribute effectively to the development of their cooperatives. They inform the general public, particularly young people and opinion leaders about the nature and benefits of co-operation.

6th Principle: Co-operation among cooperatives

Cooperatives serve their members most effectively and strengthen the cooperative movement by working together through local, national, regional and international structures.

7th Principle: Concern for community

Cooperatives work for the sustainable development of their communities through policies approved by their members.
Reason for Cooperatives

A practical motivation for the creation of agricultural cooperatives can be described as "overcoming the curse of smallness". A cooperative, being a union of a large number of small farmers, acts as a large business entity in the market, reaping the significant advantages of economies of scale that are not available to its members individually.

Cooperatives may form to create a:

**Machinery Pool:** A family farm may be too small to justify the purchase of a tractor or another piece of farm machinery for its own use. A machinery pool is a cooperative that purchases the necessary equipment for the joint use of all its members as needed.

**Marketing Cooperative:** A small farm does not always have the means of transportation necessary for delivering its produce to the market, or else the small volume of its production may put it in an unfavourable negotiating position with respect to intermediaries and wholesalers. A cooperative will act as an integrator, collecting the output of its small members and delivering it in large aggregated quantities downstream through the marketing channels.

**Credit Union:** A small farmer may be charged relatively high interest rates by commercial banks, which are mindful of high transaction costs on small loans, or may be refused credit altogether due to lack of collateral. A farmers' credit union will be able to raise loan funds at advantageous rates from commercial banks because of its large associative size and will then distribute loans to its members on the strength of mutual or peer-pressure guarantees for repayment.

Establishing a Cooperative

A cooperative organization is based on several fundamental conditions. In case any one of these conditions is missing, it will be very difficult for the cooperative to achieve its overall objectives.

These conditions include:

1. A set of existing problems / constraints within the community that cannot be solved individually.
2. A group of farmers who share these common problems and are motivated to work together.
3. There is no alternative to cooperative self-help, i.e. help from family, local NGO’s, social institutions, the government...etc is unavailable.
4. The advantages of being a member (e.g. access to inputs, products, loans, services, markets...etc) outweighs the duties of being a member (e.g. contribution of funds, time, agricultural land, equipment...etc)

5. The availability of a hardworking, reliable, charismatic person within the group, who possess leadership abilities to take the initiative and represent them to other stakeholders.

6. The legislative environment to be favourable and have no legal or political restrictions on groups being able to select executive members, market their products, earn profits and make their own decisions on distribution of profits and products...etc.

**Advantages of Cooperatives**

Farmers can either produce inputs themselves or purchase them. Cooperatives are one way individuals buy products and services. To be attractive, therefore they must offer advantages over the alternatives.

Cooperative organizations will have advantages over their competitors when they can either offer the same services/activities at lower costs through:

1. Economies of scale (e.g. bulk purchase).
2. Decreasing transaction costs; for information, implementation, control and exchange of goods and services.
4. Avoiding linked markets, i.e. where for example the buying of inputs or the marketing of produce are linked to the provision of loan facilities.
5. They can offer new services / access to external resources / services not otherwise available.

Since members are not only customers, but also owners of the cooperative, they also participate in forming and steering their own organization which means they can help ensure it meets their needs and share its profits or distributed earnings the way they want it. Non-members do not have such benefits.

Some cooperative organizations consider it legitimate to allow non-members to make use of cooperative services where for example this allows for greater economies of scale or assists to attract new members. Non-members, however, are not allowed to contribute to the running of the cooperative.

**Reasons for Success or Failure**

There are a number of conditions which are essential if a cooperative is to continue to be successful after the initial enthusiasm of starting up.
The cooperative needs to produce visible and tangible (economic and social) benefits for members, outweighing the costs involved in cooperation. Cooperatives can only develop as autonomous self-help organizations when they are able and allowed to operate as business institutions equipped to succeed in market competition.

The cooperative has motivated, experienced and dynamic managers who are able to plan and implement business policies. They must be able to provide the services and goods required by the members, taking into account the interests and needs of members as well as the entrepreneurial goals of the cooperative enterprise.

The structure and management of the organization match up to the capabilities of its members. If members’ competence and motivation is low, the promotion of complicated and complex cooperative organizations does not make sense.

Members need to participate as both consumers and owners. Cooperatives are participative self-help organizations in which the members are also co-owners and have both the rights and obligations of participating in goal-setting, decision-making and control or assess the processes of their cooperative. Members make decision upon the services to be provided and benefit from what is produced or obtained by the cooperative. There should be inducement for them to contribute their own resources (capital, labour, produce) to the development of the cooperative. A major reason for the failure of cooperatives is the lack of participation of members. It is extremely important that members act as both users and owners in the development of cooperative organizations through participation at three distinct levels:

1. Participation in provision of resources (input participation), E.g. contribution of capital, labour, delivery of produce.
2. Participation in the decision-making processes of the cooperative organization as a member in the general assembly, section meetings, work groups, committees or as an elected leader on the board.
3. Participation in the produced benefits by sharing the surplus earned during the year by the cooperative enterprise, in the form of an investment refund, interest on share capital, or the use of joint facilities and services.

Cooperatives, as with any business organization, also need to be adaptable and able to change with the circumstances. At present, cooperative organizations all over the world are facing the duty of transforming and adjusting them to a new economic and political environment, market oriented conditions and increasing member demands.

This means a need to learn new production methods, new methods of organization and management, and in particular; ways to help maintain or increase, member faithfulness and commitment. This can be achieved through increased participation, communication and
information provided the organization's core activities are efficient in meeting members' needs.
GOVERNMENT IN THE VALUE CHAIN

In many cases, governments have set too many regulations and controls on the activities of cooperatives restricting them to be able to function effectively. If possible, they should act only to create the general framework conditions needed so that cooperative autonomy, self-financing and self-reliance is strengthened and not undermined. This means ensuring that legally, groups are allowed to elect their own leaders; to market their own goods; to earn profits and to make their own decisions about distributing surplus and to bring out numerous other business activities in the members’ interests. Government’s should not otherwise interfere in the internal organization or operations of a cooperative, and should keep all attempts to improve efficiency and to abide with cooperative principles and values to the members themselves.

It should be understood that cooperative organizations should not operate in any sense as agencies of the government. The potential which cooperatives have for gaining desirable economic and social conditions must be understood as the potential they have for reaching their objectives. Their overall purpose is to satisfy the needs and interests of their own members rather than directly influence the society in general.

There have been many attempts by governments to encourage the development of indigenous self-help organizations into formal cooperatives. Such a process however, seems most effective when it results from efforts of members themselves. They should be helped, either informally, by members of established cooperative organizations, or, more formally, by facilitators or cooperative promoters from representative organizations of cooperatives, or NGOs. Government intervention to precipitate or manage such a process in most cases has proven counter-productive. Governments need to understand that such conversion is only successful through self-motivation from the members themselves and that the government’s role must be restricted strictly towards the facilitation of this conversion smoothly.

SUMMARY

In this lesson we discussed the value chain and those organizations that contribute value to the agricultural sector. We examined the role of farmers associations and cooperatives in the value chain.

We noted that a farmers’ cooperative role as a value chain company will be in the production and processing stage. Based on the overall objectives and goals of the value chain company it is associated with, the cooperative will:

- Decide on what to produce and when to produce it.
- Prepare a production plan for its members.
• Have the product ready in its raw form, semi-processed or fully processed for the company.

A cooperative working together with other value chain companies will benefit from a guaranteed market. They can guarantee the sale of their produce to the company if the product meets the requirements and standards set out by the company. In addition the cooperative also seeks to benefit from any return on the investment or shares that they may own in the value chain company if the company is doing successful.
UNIT FOUR DISCUSSION

In small groups discuss the potential of setting up a value chain or farmers’ cooperative in your state for a certain production line. Your discussion should consider:

1. How it will benefit the individual farmer.
2. How it benefits the agriculture sector.
3. The role of the different stakeholders in its establishment.
4. What will the value chain or farmers’ cooperative look like and who will be involved.

UNIT FOUR ASSIGNMENT

Objective: Developing a Business Plan for an innovative agribusiness in a Small State.

Instructions:

As an agribusiness entrepreneur in a small state, you would like to introduce an innovative product. You are required to prepare a business plan to be submitted to a financial institution for funding.

Include in your plan the underlying reasons and feasibility study for your new venture; the marketing strategy you would adopt for the product; a cash flow budget for the first five years of operation.

Tasks: Under the guidance of your instructor:

1. Collect information on the preparation of business plans including major headings that should appear in the plan. Examples are available on the internet.
3. Include in your proposal an investment appraisal for your proposed agribusiness, stating the payback period, internal rate of return and viability of the business.
4. Once you have completed the SWOT and Marketing Plan you should submit it to instructor via the dropbox for review, feedback and grading by the instructor.
UNIT FOUR SUMMARY

In this unit you learned basic economic principles that use the concept of marginal analysis provide useful guidelines for managerial decision-making. They have direct application to the basic decisions of how much to produce, how to produce and what to produce. The production function describes the relation between input levels and corresponding output levels. When such information is combined with price information, the profit-maximizing input and output levels can be found.

The food industry is the most important consumer of agricultural products and commodities. As real disposable incomes increase in small states, the food industry must face and competitively satisfy the varying needs from its sophisticated consumers. Agricultural and food enterprises, in small states are becoming more demand driven and as such strengthen the argument of a consumer lead marketing system. The concept suggests that long term objectives are best achieve through the orientation of all of operations towards the charge of consistently delivering satisfaction to the customer. Consequently, the critical components of a marketing system are the organizations and enterprises that make up that system.

In this unit you also gained an understanding of the value chain and the various stakeholders that influence it, including the importance of setting up a value chain company in your state and its role in improving the existing chain.

The importance of farmer association in protecting the rights of individual farmers and how they benefit the community including their role in the value chain was also discussed in this unit.

A key issue in many states is the difficulty in grouping farmers together. In this unit we discussed the idea of farmer cooperatives, the necessary condition to set up one and the factors that influence its success. The role of the government in this process and the role of the cooperative in the value chain were also highlighted upon.

In addition students were also introduced to several institutions across the world that are supporting agriculture either directly or indirectly.
Congratulations, you have almost completed the course, but you have a few other things to complete. If you haven't done so already you need to finish your business plan project (Unit 4) and submit it into the dropbox. You also need to complete the final discussion on lessons learned and complete the Course Evaluation Survey below.

Finally, we wish to congratulate you on enhancing your career within the agriculture sector. No matter what professional you choose, whether it is a farmer, wholesaler, retailer or some other agri-professional within the industry the knowledge and skills gained through this course will provide you with a strong foundation for your future growth and education.