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Ministry of Labor and Skills

CROP PRODUCTION

LEVEL-IV

Based on March, 2022 Version IV Occupational Standard



Module Title: Managing and Implementing Quality Standards in Storage

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Introduction to The Module

This module covers the knowledge, skills and attitude required for Managing and implementing quality standards in storage, maintain hygiene in storage areas, monitor crop produce arrival and dispatch, monitor and maintain crop produce conditions in storage and control storage pests.

LG #33	LO #1- Maintaining hygiene in storage

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Selecting of storage facilities
- Identifying problems of storage facility
- Identifying insect life cycle and optimum condition for development
- Assessing storage conditions
- Identifying and implementing storage systems and purpose of storage
- Identifying the need for repairs and maintenance
- Applying treatments to storage facility
- Preparing storage plan
- Recording the application of all treatments used in the storage program

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Select storage facilities
- Identify problems of storage facility
- Identify insect life cycle and optimum condition for development
- Assess storage conditions
- Identify and implement storage systems and purpose of storage
- Identify the need for repairs and maintenance
- Apply treatments to storage facility
- Prepare storage plan
- Record the application of all treatments used in the storage program

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet 1

Introduction

Seed are the natural means for a plant species to propagate and spread. They also enable the species to survive during the period between growing seasons when weather conditions are unsuitable to support plant growth.

Storage is the principal objective in any grain storage system is to maintain the stored grains in good condition so as to avoid deterioration both in quantity and quality. During storage, the grain must remain dry and clean. Grain storage can be extended for up to 2 years without any significant reduction in quantity and quality. However, the majority of farmers sells off their grains cheaply soon after harvesting due to anticipated losses in storage and later buy food at exorbitant prices. There are improved storage structures that can prolong the storage duration until market prices for grains are favorable.

1.1 Selecting storage facilities

1.1.1 Safe storage conditions for grain

Safe storage of grains for longer periods is possible if three conditions are met:

- Grain is maintained at moisture levels of 14% or less and seed is stored at 12% or less
- Grain is protected from insects, rodents and birds
- Grain is protected from re-wetting by rain or imbibing moisture from the surrounding air.

The longer the grain needs to be stored, the lower the required moisture content will need to be. Grain and seed stored at moisture contents above 14% may experience the growth of molds, rapid loss of viability and a reduction in eating quality.

Grain damage by fungi will be reduced when grain and seed is:

- Stored at moisture contents below 13-14%. It is important to be aware that there is variation in moisture content through a grain mass and fungi will grow where moisture is suitable and not according to the average moisture content of the grain stack.
- Stored at temperatures below 20^{o}C and above 40^{o}C.
- Not cracked and broken kernels or contain large amount of foreign material - broken or cracked kernels are more likely to be contaminated going into storage and more likely to be invaded once they are in storage than whole kernels.

- Free from fungi coming into store. Grains moderately invaded by storage fungi develop damage at lower moisture content, at a lower temperature and in a shorter time period than grain free or almost free of storage fungi.
- Stored for a shorter period. Grain that is to be stored for only a few weeks before processing can be stored safely with a higher moisture content and more extensive invasion by storage fungi and can be kept at a higher temperature than grain that is to be stored for months or years.

Free from insect and mites. Insects and mites can carry fungal spores on their bodies thus introducing storage fungi into the grain mass. Insect activity in a grain mass leads to an increase in both the temperature and moisture content of the grain surrounding the insect infestation. In these 'hot spots' conditions may be favorable for mold growth.

Table-1: **Safe moisture contents for storage of grain**

Storage duration	Required MC for safe storage	Potential problems
Weeks to a few months storage	14 % or less	Molds, discoloration, respiration loss, insect damage, moisture adsorption
Storage for 8 to 12 months	13 % or less	Insect damage
Storage of farmer's seeds	12% or less	Loss of Germination
Storage for more than 1 year	9 % or less	Loss of germination

- ❖ A rule of thumb for seed is that the life of the seed will be halved for every 1% increase in moisture content or a **5^0C** increase in storage temperature.

1.1.2 Grain storage systems

Grain storage systems can be classified as either **bag** or **bulk**.

I Bag storage system

In most parts of Ethiopia grain is stored in 50-100kg bags made from either jute or woven plastic. Depending on the size of storage, these bags are normally formed into a stack.





Figure.1. Properly stored bags Plastic bag/hermetic

When using bag storage consideration needs to be given to the following:

- Jute bags should not be stacked higher than 4m and plastic bags 3m. Plastic bags are more slippery and the stacks will be less stable.
- Bags should be stacked under cover e.g. under a roof, in a shed or granary or under water proof tarpaulins.
- A one meter gap should be left between and around stacks and 1.5 meters clearance between the top of the stack and the roof.
- Bags should be stacked on pallets or on an above ground structure to avoid the possibility of absorbing moisture from the floor.
- Bags should be stacked so that fumigation can be undertaken easily. The dimensions of the stacks should be set to facilitate sealing with a single fumigation sheet.
- The efficiency of bag storage can be improved if a hermetic plastic liner bag is used.

Some farmers use bag storage in outside granaries, which have been constructed from timber or mud/cement or large woven bamboo or palm leaves.

II Farm level bulk storage

At farm level grain is often stored in bulk in small outside granaries or in woven baskets or containers made from wood, metal or concrete, which are located under or inside the house. These storages vary in capacity from 200-1000kg.



Figure. 2 Wooden granary

Losses from insects, rodents, birds and moisture uptake are usually high in traditional bulk storage systems.

III Commercial bulk storage



Figure. 3 Silos

The large export mills and collection houses sometimes use metal or concrete silos. These silos range in size from 20 to 2,000 ton capacity. Silos have the advantage that they can be more easily sealed for fumigation and less grain is spilt or wasted. Metal Silos are not very common in Ethiopia because of problems with moisture migration inside the silo which results in hot-spots and molds.

1.1.3 Purpose of storage

The purpose of any grain storage facility is to provide safe storage conditions for the grain in order to prevent grain loss caused by adverse weather, moisture, rodents, birds, insects and micro-organisms like fungi by allowing proper storage hygiene and also for:

- Ease of loading and unloading.
- Efficient use of space.
- Ease of maintenance and management.
- Prevention of moisture re-entering the grain after drying.

1.1.4 Storage hygiene

Purpose of storage hygiene

Good hygiene in the grain store or storage depot is important in **maintaining grain and seed quality**.

Guidelines for hygiene in the grain store include:

- Keep storage areas clean. This means sweeping the floor, removing cobwebs and dust, and collecting and removing any grain spills.
- Clean storage rooms after they are emptied and this may include spraying walls, crevices and wooden pallets with an insecticide before using them again
- Placing rat-traps and barriers in drying and storage areas. Cats deter and help control rats and mice
- Inspect storage room regularly to keep it vermin proof.
- Inspect the stored seeds once a week for signs of insect infestation. When necessary and only under the direction of a trained pest control technician, the storage room or the seed stock may be sealed with tarpaulin and treated with fumigants.



Figure. 4 Examples of dirty and messy storage: This might attract insects and rodents.

Video link: - https://youtu.be/XoJFhX9VCFE (Date accessed 20/01/2024)

Video link: - https://www.youtube.com/watch?v=m0Xqs_1-Qk8 (Understanding Temperature Control (HACCP Lesson - Part 06) - YouTube)

1.2 Identification of problems of storage facility

The identification of problems in grain or crop storage facilities can be done using various methods. Some of the common methods and factors to consider include:

- Moisture content: The amount of moisture in the grain can affect its quality and storage life. High moisture content can lead to mold growth and spoilage, while low moisture content can cause the grain to become brittle and lose its nutritional value.
- Temperature: The temperature inside the storage facility can affect the grain's quality and the rate at which it loses that quality. Different types of grain have different optimal temperature ranges for storage.
- Oxidation: Oxidation is a chemical process that can cause changes in the grain's quality. The rate at which the grain oxidizes can indicate the presence of problems in the storage facility.
- Contamination: Contamination by insects, rodents, birds, or other pests can reduce the quality of the grain and make it unsafe to eat. Regular inspections and implementing integrated pest management strategies can help prevent contamination.
- Storage system: Different types of storage systems, such as grain elevators, have their own advantages and disadvantages. The design and maintenance of the storage system can affect the grain's quality and the ease of troubleshooting potential problems.
- Grain handling: The way grain is handled can affect its quality. For example, grain that is picked up from the ground or spilled on the ground can become contaminated, leading to quality issues.
- Design of storage structure: The design of the storage structure can affect its durability and effectiveness in storing grain. For example, flat floors are often preferred over sloped floors in grain storage structures because they are easier to clean and more effective in preventing the spread of mold and other contaminants.
- Grain sampling and testing: Grain sampling and testing can help identify problems in the grain itself. For example, the grain sampling and testing process described in involves taking grain samples from different locations and at different times to ensure representative results.

To identify problems in grain or crop storage facilities, it is essential to consider these factors and use appropriate methods to monitor and maintain the grain's quality during storage.

1.3 Insect life cycles and optimum conditions for development

Stored grain insect pests, such as beetles and moths, can cause significant damage to stored crops. Their life cycles and optimum conditions for development are important to understand in order to prevent infestations. Here are some key points based on the search results:

- Life Cycle: Stored grain insect pests, such as beetles and moths, go through four stages: egg, larva, pupa, and adult. The life cycle from egg to adult can vary depending on the species, temperature, and other environmental factors. For example, the life cycle of the rice weevil can range from four to five months, while the life cycle of other pests may take about 25 days under ideal condition.
- Optimum Conditions: The development of stored grain insect pests is influenced by factors such as temperature and humidity. For instance, the optimum temperature for the growth of stored-grain molds, which is also relevant to insect development, is around 25–30°C. Additionally, the life cycle of insect pests may take from 3-6 weeks depending on the temperature, with adults living up to two months under certain conditions

Understanding the life cycles and optimum conditions for the development of stored grain insect pests is crucial for implementing effective prevention and control measures in crop storage facilities. By monitoring and managing these factors, it is possible to reduce the risk of infestations and preserve the quality of stored crops.

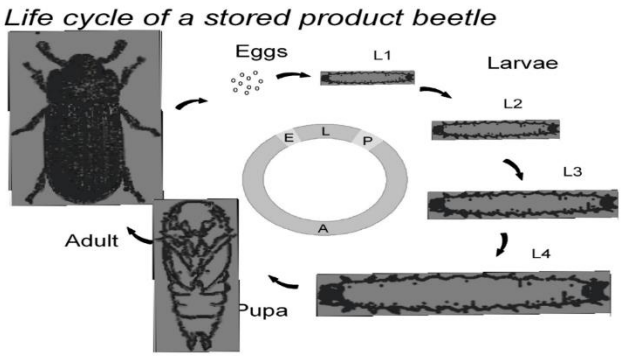


Figure 5: Life cycle of insects/pests

1.4 Assessment of Storage conditions

Assessment of storage conditions for grain is crucial to maintain the quality of the grain and prevent spoilage. Key factors to consider include:

- **Moisture Content**: Grain should be stored at a moisture level of 14% or less, and seed should be stored at 12% moisture level or less. The longer the grain needs to be stored, the lower the moisture content required. Grain and seed stored at moisture content above 14% may experience growth of mold, rapid loss of viability, and a reduction in eating quality.
- **Temperature**: Grain should be stored at a temperature below 10°C to prevent the development of insects and mold. Grain is typically put into storage when the grain temperature is 50-80°F, and perhaps higher. Grain going into long-term storage should be dried and cooled rapidly after harvest. The allowable storage time (AST) is an estimate of the life of the grain until it has deteriorated. The AST is cumulative, so if one-half of the storage life is used before the grain has been dried and cooled, only about one-half of the life is available for the drier grain.
- **Protection from Pests**: Grain should be protected from insects, rodents, and birds. Insects and molds are the main contributors to grain spoilage and quality loss. High levels of temperature and humidity stimulate their growth. To prevent this, it is very important to keep the grain cool and dry. Grain storage facilities should be designed to prevent moisture from re-entering the grain after drying, provide protection from insects, rodents, and birds, have efficient space, and be easy to maintain and manage.
- **Monitoring**: During the storage period, surveillance, observation, and monitoring tasks of the grain are essential. Monitoring temperature and moisture is important to achieve good conditions for safe storage. Ventilation is used to cool the grain or to keep it within safe storage conditions. In addition to cooling, the ventilation causes a slight grain drying which can be used to correct small moisture content.

1.5 Identification and implementation of storage systems and purpose of storages

Storage systems are essential for maintaining the quality of goods and materials. Here are some key points:

- **Purpose of Storage**: The purpose of storage is to protect goods and materials from damage, theft, and spoilage. Storage systems are designed to provide a safe and secure environment for goods and materials, ensuring that they remain in good condition until they are needed.
- **Types of Storage Systems:** There are several types of storage systems, including static shelves, mobile shelving, pallet racking, mezzanine flooring, and automated storage and retrieval systems (AS/RS). Each type of storage system has its own advantages and disadvantages, and the choice of system will depend on the specific needs of the organization.
- **Identification and Implementation of Storage Systems**: The identification and implementation of storage systems should be based on the specific needs of the organization. Factors to consider include the type of goods or materials being stored, the amount of space available, and the level of security required. RFID technology can be used to track and manage inventory in real-time, while storage security measures such as network security, data redundancy, and user behavior policies can help protect against unauthorized access and data loss.
- **Warehouse Labeling and Identification**: Warehouse labeling and identification are important for creating a system where every position of available space, every unit, every rack, and every shelf has a unique identifier. This system aids workers in quickly finding and storing items, reducing errors and boosting customer satisfaction.
- **Monitoring and Management**: Monitoring and management of storage systems are essential to ensure that goods and materials remain in good condition. This includes monitoring temperature and humidity levels, implementing ventilation systems, and regularly inspecting the storage facility for signs of damage or pest infestations.

By understanding the purpose of storage, the types of storage systems available, and the factors to consider when identifying and implementing storage systems, organizations can ensure that their goods and materials remain in good condition and are readily available when needed.

1.6 Identifying the need for repairs and maintenance

Identifying the need for repairs and maintenance in crop grain storage is essential to ensure the quality of the stored grain. Here are some key points:

- **Cleaning and Inspection**: The most important aspect of grain storage is to keep it clean. Regular cleaning and inspection of grain bins for signs of damage or wear, such as cracks or holes, can help prevent pests from entering and make other management practices more effective. Cleaning out old grain or other pest refuges and equipment that handles grain is also important
- **Pest Control**: Pest control is essential to prevent damage to the stored grain. Eliminating any pests and sealing up any holes or cracks can help prevent pests from entering the storage facility
- **Repairing Damaged Equipment**: Repairing any damaged equipment immediately is important to ensure that the grain handling system works efficiently and safely.
- **Maintaining the Environment**: Maintaining the surrounding environment, such as temperature and humidity levels, is important to ensure that the grain remains in good condition. Cooling and drying grain before storage can help prevent mold growth and grain pest survival.
- **Regular Maintenance**: Regular maintenance of the grain handling system is essential to its longevity, quality, and durability. Inspections and improvements can be the difference between a slow facility and an efficient one. By performing preventative maintenance, such as cleaning, inspection, and repair, it is possible to prevent issues from arising and ensure that the system works efficiently.

By following these guidelines, it is possible to identify the need for repairs and maintenance in crop grain storage and ensure that the stored grain remains in good condition.

1.7 Applying treatments to storage facilities

1.7.1 Grain treatments in storage

It is not recommended to use synthetic insecticides with grain that is for consumption. Only chemicals registered for direct application to grain should be used and these should be applied according to the label.

A. Malathion

Malathion is a widely used chemical and is toxic to insects if it comes into direct contact with the pest. Malathion is considered one of the safest organophosphate insecticides as it is not highly toxic to humans or pets/tame animal/, and breaks down fast under tropical conditions. Malathion will not penetrate piles of grain. Although it is not usually recommended, it is still legal to treat grain with Malathion at 8 parts per million concentrations. As a grain treatment Malathion is applied at the time grain is stored. Treated grain should not be sold for at least 7 days nor eaten within 60 days of treatment. Safety precautions must be observed when applying Malathion or any other chemical.

B. Fumigation

Fumigants are effective against storage pests because as gases they can reach the pests in the most remote hiding place. The range of safe fumigant chemicals that can be used is now restricted to phosphine and carbon dioxide.

C. Phosphine fumigation

Phosphine fumigation is undertaken using tablets and pellets. These tablets and pellets release phosphine gas when they come into contact with humid air. Phosphine is toxic to all insects. When insects are exposed to fumigation in a sealed environment all stages of development from the eggs, larvae, pupae to adults are killed. Phosphine does not impair the grain nor leave residues that could be hazardous to the consumer when correctly applied and the grain aerated. Care must be taken when using phosphine as a gas as it is very toxic to humans. Fumigation must take place in an enclosure that can be tightly sealed. Once the exposure time is ended, the grain must be aerated and the bin checked for residual phosphine gas before entry.

Table.2:-Optimum storage condition for different grain treatment chemicals.

Temperature(in ^{0} Celsius)	Tablets (days)	Pellets (days)
Under 5	No fumigation	No fumigation
5-10	10	8
11-15	5	4
16-25	4	3
Over 25	3	3

Example: At 25^{0}C, the minimum exposure time for tablets and/or pellets is 3 days.

D. Carbon dioxide fumigation

Insects need oxygen for respiration. With carbon dioxide fumigation, much of the oxygen in the storage bin is replaced by carbon dioxide that suffocates, dehydrates and also produces toxic chemicals in the blood of the insects. To be effective, elevated carbon dioxide levels must be maintained until all insects die. The required exposure time depends on the percentage of carbon dioxide and the temperature of the grain. The cost of CO2 fumigation is high. Guidelines for

Table.3 Carbon Dioxide Application:

Grain temperature(in ^{0} Celsius)	Minimum CO2 Levels (%)	Days for control
25-30	80	8.5
25-30	60	11
25-30	40	17
25-30	20	Weeks to months

Infected seeds can be treated by either physical or chemical treatments, or a combination of both methods.

Seed borne bacteria can be treated by dry heat at 65^{o}C for 6 days or dipping in hot water treatment at 52-55^{o}C. Seeds can also be treatment with fungicides such as Dithane M-45 and Benlate at the rate of 3 grams kg^{-1}.

The most effective method of treating mycotoxin problems is avoidance. This is possible by drying the grain to safe moisture content before storage, reducing physical damage to the grain during harvesting and storage and ensuring clean, dry insect-proof storage conditions.

1.7.2 Minimize Damage

Little can be done to prevent or reduce the invasion of crops in the field by fungi. However, the following recommendations should help prevent storage fungi problems or minimize damage from storage fungi in stored grains.

- Harvest as soon as the moisture content allows for minimum grain damage.
- Adjust the harvesting equipment for minimum kernel or seed damage and maximum cleaning.
- Clean all grain harvesting and handling equipment thoroughly before beginning to harvest. Clean bins or storage facilities thoroughly to remove dirt, dust and other foreign material, crop debris, chaff and grain debris.
- Clean grain going into storage to remove lightweight and broken kernels or seeds as well as foreign material and fines.
- Moisture content is by far the most important factor affecting the growth of fungi in stored grain. After harvest, grain should be dried to safe moisture contents as quickly as possible.
- Aerate grain to safe and equalized temperatures through the grain mass.
- Protect grain from insect and mite damage.
- Check stored grain on a regular basis and aerate as needed to maintain low moisture and proper temperature.

1.8 Preparing storage plan

To prepare a crop storage plan, it is important to consider the following factors:

- **Storage Structures**: The storage structure should be capable of maintaining the quality and quantity of the crop for as long as it is stored. It should eliminate the destructive effects of weathering, loss of crop structure through dehydration, germination of seeds or

sprouting of tubers while in storage, and loss of viability. The utilization of the structures should be based on the specific function each structure performs.

- **Preparation of Storage**: Before storing the grains into the silos or bins, it is important to make sure that the storage is clean. Farmers should remove any grain left from the previous harvest and thoroughly clean their silos or bins. In case of insect pest or disease infestation from the previous season, best practices recommend spraying with suitable chemicals and cleaning the storage in detail. It is also important to check harvested grains for the presence of insect pests or diseases.
- **Temperature and Humidity Control**: The moisture content is one of the burning factors that will determine how long the grain can remain. The temperature and humidity levels should be monitored and controlled to ensure that the grain remains in good condition. Cooling and drying grain before storage can help prevent mold growth and grain pest survival.
- **Pest Control**: Pest control is essential to prevent damage to the stored grain. Eliminating any pests and sealing up any holes or cracks can help prevent pests from entering the storage facility.
- **Regular Maintenance**: Regular maintenance of the grain handling system is essential to its longevity, quality, and durability. Inspections and improvements can be the difference between a slow facility and an efficient one. By performing preventative maintenance, such as cleaning, inspection, and repair, it is possible to prevent issues from arising and ensure that the system works efficiently.

By considering these factors, it is possible to prepare a crop storage plan that will ensure the quality of the stored crop and prevent spoilage.

1.9 Recording the application of all treatments used is in storage program

Failing to monitor grain conditions throughout the entire storage period is a mistake that many producers make. Regular inspections are essential if mold and insect activities are to be detected early. A small area that starts to heat or otherwise go out of condition can quickly get out of control and spread within the bin.

How often you need to check the grain in storage will vary with the time of year, the initial condition of the grain and how often the grain is aerated. Generally, grain should be inspected at least once a month during the winter and every two weeks during the spring, summer and fall. Grain checking is extremely important during the summer, because grain is being held at higher temperatures and aeration conditions are less favorable than during the rest of the year.

Grain temperatures should be checked and recorded during each inspection. Without temperature records, it is difficult to tell whether evaluated grain temperatures are caused by normally occurring outside temperatures or by heating due to mold activity. Use a deep bin probe to obtain samples at different locations in the bin to determine the moisture content, the amount of trash and fines and the general condition of the grain. An accurate moisture tester is required to determine actual moisture contents. You can check the accuracy of your tester by checking readings with your local elevator.

When checking your bins, look for;

- Condensation on the grain surface, crusting, wet areas, molds and insects.
- Leaks or condensation on the bin roof.
- Non-uniform temperatures in the grain mass, pockets or layers of high-moisture grain, molds and insects.
- Musty or sour odors, spoiled grain gives off a detectable odor, but in most cases, the spoiling grain must be near the surface of the grain and the grain must have under gone considerable spoilage before you can detect any odor. Generally, if you can smell a musty odor, a problem is already under way.

Any problems that are found n to be evaluated and corrected as soon as possible. This may include cooling with aeration, further drying or fumigation for insect control.

Self-check 1	**Written test**

Directions: Answer all the questions listed below.

I. True or False Questions

1. Grain can be stored for up to 2 years without any significant reduction in quantity and quality.
2. Grain and seed should be stored at moisture levels of 14% or less, and seed is stored at 12% or less to prevent mold growth and viability loss.
3. Insects and mites can carry fungal spores on their bodies, introducing storage fungi into the grain mass.
4. Malathion is considered one of the safest organophosphate insecticides and can penetrate piles of grain to eliminate pests.
5. Regular cleaning and inspection of grain bins for signs of damage or wear are not essential for preventing pests from entering the storage facility.

II. Multiple Choice Questions

1. When selecting storage facilities, what are the safe storage conditions for grain?
   a. Maintaining a moisture level of 20% or less
   b. Protecting grain from insects, rodents, and birds
   c. Storing grain at temperatures above 40°C
   d. All of the above
2. What is the purpose of any grain storage facility?
   a. To provide safe storage conditions for the grain
   b. To prevent grain loss caused by adverse weather
   c. To allow proper storage hygiene
   d. All of the above
3. What is the recommended moisture content for grain and seed stored for more than 1 year?
   a. 14% or less
   b. 13% or less
   c. 12% or less
   d. 9% or less
4. What is the optimum temperature for the growth of stored-grain molds and insect development?
   a. Below 10°C
   b. 20-25°C

c. 25-30°C
d. Above 40°C

5. What are the key factors to consider when identifying and implementing storage systems?
   a. The type of goods or materials being stored
   b. The amount of space available
   c. The level of security required
   d. All of the above

6. What is the purpose of grain storage?
   a. To increase the quantity of grain
   b. To decrease the quality of grain
   c. To maintain the stored grains in good condition to avoid deterioration in both quantity and quality
   d. To store grain for more than 2 years without any significant reduction in quantity and quality

7. What is the safe moisture content for storage of grain for weeks to a few months?
   a. 14% or less
   b. 13% or less
   c. 12% or less
   d. 9% or less

III. Test II: Short Answer Questions

1. Discuss how to maintain hygiene in storage areas?
2. What is the most effective method of treating mycotoxin problems?
3. List the different ways of grain treatments in storage?

Operation Sheet -1

1.1. Techniques of testing seeds for quality and viability.

A. Tools and equipment's

- Seed Samples
- Staining solutions
- Sieves of various sizes
- Pans or containers
- Magnifying glasses
- Sterile equipment
- Agar plates
- Culture media

B. Procedures/Steps/Techniques

- Randomly collect samples from different parts of the seed lot
- Mix the samples thoroughly to create a composite sample.
- Separate the seed sample into different components using methods like sieving or hand-picking.
- Weigh and record the amount of pure seed, weed seeds, and other impurities.
- Weigh a known number of seeds and calculate the average seed weight.

LAP TEST-1	**Performance Test**

Name……. ID……..

Date…….

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **1** hour. The project is expected from each student to do it.

Task-1 Perform Seed testing for quality and viability?

LG #34	LO #2- Monitoring crop produce arrival and dispatch

Instruction sheet 2

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Taking samples before storing crop produce.
- Calculate mass and volumes of grain and horticultural produce
- Checking quality of the produce at dispatch.
- Taking, preparing and forwarding test samples for analysis
- Selecting transportation facilities
- Undertaking all activities around the storage facilities based on OHS guidelines.

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Taking samples before storing crop produce.
- Calculate mass and volumes of grain and horticultural produce
- Checking quality of the produce at dispatch.
- Taking, preparing and forwarding test samples for analysis
- Selecting transportation facilities
- Undertaking all activities around the storage facilities based on OHS guidelines.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet 2

2.1 Taking samples before storing crop produce

Seed testing includes those tests necessary to properly evaluate the quality of the planting seed to be used by the cultivator. The international seed testing association (ISTA) lays down the procedures and methods for seed testing. The most important seed tests are moisture content, purity physical (mixture), germination and vigor health genetic composition.

A. Sampling and working procedures

Seed sampling is one of the most important factors in seed quality control activities. The objective of seed sampling is to draw a representative sample from the seed lot for seed testing purpose. The value of test results depends to a large extent on the degree to which the seeds tested represent the total seed lot. Poor sampling may cause misleading results. Random samples are taken from a seed lot and combined to obtain a sample that is representative for the entire seed lot. The samples are mixed and from this composite sample the desired quantity for the sub-samples can be taken.

B. Important terminologies in sampling

Seed lot: is a specified quantity of homogenous seed.

Seed sampling: is a method by which a representative sample is taken from a seed lot to be sent to a laboratory for analysis.

Seed sample: is a very small quantity of seed, which represents the overall quality of the lot.

Primary sample: a number of single samples drawn from different bags or from different locations of the seed lot in containers or stored in bulk.

Composite sample: a mixture of all primary samples from a seed lot.

Submitted sample: part of the composite sample reduced as necessary and submitted to a testing Station.

Working sample: a reduced sample taken from the submitted sample in the laboratory given for a given quality test.

C. Sampling requirements

The seed for sampling should fulfill the following requirements:

- The lot to be sampled should not have volume larger than specified subject to a 5% tolerance.
- The bags or containers should be easily accessible for the sampler.
- The lot should be in properly sealed or sealable bags or containers and loose seeds should not be sampled.
- All containers must bear a lot identification number.
- The sealed lot should be uniform or homologous.

D. Sampling equipment's and methods

I. Bin or bag samplers

a. Automatic samplers. They are attached to a stationary processing plant and are not flexible which are used to take samples from the whole cross section of the seed stream while cleaning and packing. Triers are most common and efficient sampling instruments especially for sampling seed in bags or small containers. The common triers are:

- **Hand triers**: They are smaller in size used to take samples from different positions of bags and sacks.
- **Stick triers**: stick or sleeve trier consists of two metal tubes with slots in which one is fitted inside the other. The outer fixed part has a pointed end were as the inner tube is fitted with handle, which can be used to rotate it for closing and opening the slots.
- **Noble trier**. (Dynamic spear): it is a modified trier used for greater accuracy. It consists of one tube with a pointed end and at the end a hole through which the seeds will enter. The tube should be long enough to reach the center of the bag to be sampled.

b. Hand samplers:

They are used only for chaffy noon-free flowering species which are not suitable to insert triers

II. Laboratory samplers

The working sample from the submitted should be taken by repeatedly dividing on fiat surface4 into smaller portion.

E. Sample size

The quantity of sample to be sent to the seed-testing laboratory should be large enough to represent any variability that exists within the seed lot. The sample weight to seed lot ratio for most cereals and legumes is 1:10000 or 20 00. For moisture content determination. Approximately 100g for species that has to be ground and 50g for others should be submitted.

Taking samples before storing crop produce is a crucial step in ensuring its quality and long-term viability. It allows you to assess factors like moisture content, pest infestation, and overall health, guiding appropriate storage strategies and preventing potential losses. Here's a breakdown of why and how sampling is done:

Why sample before storing?

- Assess moisture content: High moisture content promotes mold growth and spoilage. Sampling helps determine if drying is necessary before storage.
- Detect pests and diseases: Early detection allows for pest control measures to prevent contamination and spread during storage.
- Evaluate quality: Sampling provides information about the produce's maturity, blemishes, and overall quality, influencing storage decisions and marketability.
- Monitor storage changes: Over time, factors like moisture and temperature can affect the stored produce. Taking initial samples allows you to monitor such changes and adjust storage conditions as needed.

How to take samples effectively:

- Timing: Sample before major storage, ideally during or immediately after harvest.
- Sample size and distribution: Collect enough samples (typically 0.5-1% of the total produce) to represent the entire batch. Take samples from different locations within the storage area, considering variations in temperature and airflow.

- Sampling method: Use clean, sanitized tools to avoid contamination. The method depends on the produce type and storage context. For grains, use probes or scoops. For fruits and vegetables, pick representative samples that display visible characteristics.
- Sample handling: Label samples clearly with identifiers like date, location, and variety. Store them in cool, dry conditions until analysis or storage.

Additional tips:

- Consult local resources: Agricultural extension services or crop-specific organizations often provide detailed sampling guidelines for various produce types.
- Maintain hygiene: Clean and sanitize equipment between samples to prevent cross-contamination.
- Analyze samples promptly: Delays can affect accuracy and limit opportunities for corrective action.
- Record and keep records: Maintain records of sampling procedures and analysis results for future reference and traceability.

By taking accurate and timely samples before storing your crop produce, you can make informed decisions about storage methods, monitor quality throughout storage, and maximize the value and market potential of your harvest.

Remember, the specific sampling strategies will vary depending on the type of crop you're storing and the available resources. Don't hesitate to consult with experts in your region for detailed recommendations tailored to your situation.

2.2 Calculate mass and volumes of grain and horticultural produce

Accurate, early estimation of grain yield is an important skill. Farmers require accurate yield estimates for a number of reasons:

- crop insurance purposes
- delivery estimates
- planning harvest and storage requirements
- cash-flow budgeting

Extensive personal experience is essential for estimating yield at early stages of growth. As crops near maturity, it becomes easier to estimate yield with greater accuracy.

Estimation method

There are many methods available for farmers and others to estimate yield of various crops. Some are straightforward whereas others are more complicated. The method presented here is one that can be undertaken relatively quickly and easily

Steps are as follows:

a. Select an area that is representative of the paddock. Using some type of measuring rod or tape, measure out an area of $1m^2$ and count the number of heads or pods.
b. Do this 5 times to get an average of the crop (A)
c. Count the number of grains in at least 20 heads or pods and average (B)
d. Using Table 1 determine the grain weight for the crop concerned (C)
e. Yield in t/ha = (A × B × C) / 10,000

For example, to calculate a wheat yield where:

- Average number of heads/pods per m^2 is 220 (A)
- Average number of grains per head/pod is 24 (B)
- Weight of 100 grains of wheat is 3.4g (per Table 4) (C)

Yield in t/ha = (220 × 24 × 3.4) / 10,000 = 1.79

Accuracy of yield estimates depends upon an adequate number of counts being taken so as to get a representative average of the paddock. The yield estimate determined will only be a guide and assumptions made from the estimates contain a degree of uncertainty.

This type of yield estimation is one of the easiest and quickest to complete and should be able to be used in a number of situations on a grain growing property. Grain losses both before and

during harvest can be significant and an allowance for 5 to 10% loss should be included in your final calculations.

Table 4. Grain weights expressed as weight per 100 grains.

Crop type	Weight of 100 grains (in grams)
Canola	0.4
Wheat	3.4
Lentils	3.0 to 5.0
Safflower	3.8
Oats and triticale	4
Barley	4.2
Lupin (narrow leaf)	16
Chickpea (desi)	18
Field pea	20
Lupin (broad leaf)	30

Crop type	Weight of 100 grains (in grams)
Chickpea (kabuli)	40
Faba bean	50

2.3 Checking quality of the produce at dispatch

2.3.1 Quality Control Tailored for the Produce Industry

Fresh produce is a sensitive product category that requires fast shipping and proper storage. Any delay in your supply chain or a disruption in storage conditions can seriously impair your product's quality. For a fresh produce supplier, it is equally important to check the condition of their inventory at departure from the farm or packaging facility and upon its arrival at the destination.

QIMA (Quality Inspection Management Association) offers product inspections for your produce, helping you receive an accurate picture of your merchandise every step of the way. We will check the quality of your produce before it's shipped, and will be at your destination to inspect it again after transit.

QIMA provides specialized inspections for:

- Berries: blueberries, blackberries, cherries
- Tropical fruits: mangos, pineapples, asparagus, kiwi
- Traditional fruits: apples, pears, avocados, grapes, lemon, orange, clementines
- Other fruits and vegetables: lettuce, tomatoes, chilies
- Beans, corn, nuts, grains, cereals



Figure 6: Produce Inspection Expertise

QIMA produce inspectors follow detailed inspection protocols, prepared by our experts based on international regulations, standards of your destination market, and your own requirements. To ensure that every sample we collect objectively represents your shipment, we follow the guidelines and sampling plans prescribed by the World Health Organization Food Code (the Codex Alimentarius).



Before your produce is loaded onto the truck, our specialized inspectors will conduct a check of its condition, including quality, quantity, packaging, and labeling. As soon as your shipment arrives at the destination, our team will be there to make a complete inspection of your produce, ensuring that it has not been damaged or otherwise compromised during transit.



All of our findings are recorded in detailed inspection reports, which are delivered to you on the day of the inspection, enabling you to make timely and informed decisions for your supply chain. You also receive access to detailed supplier data via the QIMA dashboard, which provides you with real-time supply chain intelligence. Using this data, you can benchmark your suppliers, monitor trends, and gain deep insight into your supply chain.



Solutions for Produce Safety:

- Quality check (color, maturity, firmness, shape)
- Weight and diameter check
- Defects check (including amount and seriousness of defects)

Video link: - https://youtu.be/YnKXvtWZ-LE (date accessed 20/01/2024)





Produce Supplier Audits

QIMA supplier audits keep you up to date on the safety and compliance status of your produce suppliers, helping you identify areas in need of improvement and take corrective action.

Ethical audits investigate your suppliers for social compliance, including working conditions and worker rights, helping you eliminate any instances of labor abuse from your produce supply chain.

Farm and greenhouse audits investigate areas of potential contamination during growing, including fertilizer usage, water usage and irrigation, pest control, harvest control, food security, the use of adjacent land, and employee safety & hygiene.

Harvest crew audits address the working practices, safety and hygiene of employees directly involved in food harvesting, and food security issues.

Food safety audits help ensure compliance throughout your food supply chain and improve your and your supplier's quality management systems. QIMA offers hygiene audits (GHP), Good

Agricultural Practices (GAP) and Good Manufacturing Practice (GMP) audits for your fresh produce supply chain.

Certifications for the Fresh Produce Industry

QIMA, through our subsidiary QIMA/WQS, can audit your processes and systems against the requirements of applicable standards to achieve certification under the following schemes:

- HACCP (Hazard analysis and critical control points)
- UTZ and 4C certification (for coffee)
- GFSI approved certification schemes:
  - ✓ Primus GFS
  - ✓ SQF
  - ✓ Global G.A.P.
  - ✓ BRC Global Standards
  - ✓ IFS

2.4 Taking, preparing and forwarding test samples for analysis

To obtain accurate results from crop analysis, it is important to follow a standard sampling procedure. Here are some general steps to follow:

Selecting the sample: Select a representative sample of the crop that you want to analyze. The sample should be taken from the same area of the field, and should be of the same age and variety.

Collecting the sample: Collect the sample in a clean container. Avoid using containers that may contaminate the sample, such as those that have been used to store chemicals or other materials.

Preparing the sample: Once the sample has been collected, it should be prepared for analysis. This may involve drying, grinding, or other treatments, depending on the type of analysis that will be performed.

Forwarding the sample: The sample should be forwarded to a laboratory for analysis. It is important to ensure that the sample is packaged and shipped properly to avoid contamination or damage during transit.

It is important to note that plant nutrient composition varies with age, the portion of the plant sampled, and many other factors. Mistakes or carelessness in selecting, collecting, handling, preparing, or shipping plant tissue for analysis can result in unreliable data, which may lead to incorrect interpretations and recommendations.

If you need more specific information on how to take, prepare, and forward test samples of crop analysis, it is recommend consulting a local agricultural extension office or a professional crop consultant.

Accurately collected and prepared samples are crucial for reliable analysis of your crop's health and nutrient status. Here's a guide to ensure your samples reach the lab in optimal condition:

Taking Samples:

- **Timing**: Take samples before significant environmental changes impact the crop, like heavy rain or fertilizer application. Aim for consistent timing across samplings for comparison.
- **Sample Size**: Follow lab guidance or use general recommendations. For soil samples, 10-15 sub-samples from different areas form a composite sample. For plant tissue, collect 10-20 representative samples representing different growth stages.
- **Location**: Consider factors like soil variability, topography, and past management practices. For soil, sample diagonally across slopes and avoid areas like furrows or edges. For plant tissue, select healthy, mid-stem leaves or specific organs as instructed by the lab.
- **Tools**: Use clean and sanitized tools to avoid contamination. Tools may vary depending on the sample type, like soil augers or clean scissors for leaves.

Preparing Samples:

- **Labeling**: Clearly label each sample bag with identification like date, location, crop type, and any relevant information requested by the lab.
- **Drying**: Certain samples need drying before analysis. Follow lab instructions for soil (usually air-dried) and plant tissue (often oven-dried at specific temperatures). Avoid direct sunlight or overheating.
- **Grinding**: Some analyses require ground samples. Use clean mills or grinders and avoid cross-contamination between samples.

- **Packaging**: Ensure secure packaging that protects samples from damage and leaks. Use appropriate containers like zip-lock bags for dry samples or coolers with ice packs for moist samples.

Forwarding Samples:

- **Shipping** Speed: Prioritize swift delivery to the lab, especially for perishable samples. Consult the lab for preferred shipping methods and deadlines.
- **Documentation**: Include a completed chain-of-custody form provided by the lab, detailing collection, preparation, and shipping details.
- **Tracking**: Keep track of the shipment and confirm receipt by the lab.

Additional Tips:

- **Consult the lab:** Always refer to the specific instructions provided by the lab you're sending the samples to, as protocols may vary slightly.
- **Personal Protective Equipment (PPE):** Wear appropriate PPE while collecting and handling samples, especially if dealing with potentially harmful substances like pesticides.
- **Safety:** Dispose of used tools and sample containers responsibly.

By following these guidelines, you can ensure your crop test samples arrive at the lab in optimal condition, leading to accurate analysis and valuable insights for managing your crop's health and productivity.

2.4.1 Sample analysis

I. Seed purity test

The goal is to determine the composition by weight (in %-age) of the seed lot being tested. It also helps to estimate the amount for seed to be sown per unit area. Possible components of seed loot,

a. Pure seed

b. Foreign seeds (weed seeds, and other crop species)

c. Inert matter (chaff, empty seeds, debris, etc.)

The sample from a seed lot can be taken on the basis of number count or weight, depending on the crop species under consideration. Before sampling a seed lot, it is important to see that the lot

is uniform. Then a sub-sample is prepared which is known to contain about 25 000 seeds in number with a maximum of 1000g. This can be estimated based on the 100 or 1000 seed weight of the crop. The estimated weight of 25 000 seeds in number of some crops is given in the following table.

Table 5. Sample weights for number count tests

Crop	Weight to be tested (g)
Pearl millet	150
Rice	400
Lentil	600
Sorghum	900
Wheat, barley, oats	1000
Chickpea, grams	1000

The number count test is particularly relevant in crops that are machine harvested since significant amount of damaged seeds admixtures are expected. This method is applied to most field crops and is less useful for crops, which are not expected to contain other seeds: e.g. most hand-picked fleshy fruits and vegetable crops such as tomatoes, eggplant or cucumber as well as large-sized seeds like beans and maize usually.

II. Germination test

Germination is the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question. It also indicates the seeds applied to produce normal plants under favorable conditions in the soil. The main goal of germination test is to determine the intrinsic (real) seed germination capacity of a lot and percentage of normal seedlings, which can be produced by the lot under more or less ideal condition. Samples are often grown in laboratory determine percentages of.

a. Normal seeds
b. Subnormal seeds
c. Dead seed

d. Hard seeds (with hardened coat)

Pure live seed= $\frac{\%\ \text{germination} \times \%\ \text{purity}}{100}$

2.5 Selecting transportation facilities

When selecting transportation facilities, it is important to consider factors such as cost, distance, time, capacity, and demand. A facility location decision model for multinational corporations (MNC) should incorporate transportation factors into the decision-making process. The model should allow the user to decide not only on the location of the facility and the mode of transportation, but also on the ports which are more convenient.

The transportation factor is complex, with many components such as nodes, routes, costs, time, distance, capacity, and demand. The integration of more transportation factors into facility location models will transform the interdependencies between the MNC supply chain network and the Global Transportation Network from functional or transactional to a more structural and reciprocal format, thereby enhancing global competitiveness.

In order to select the right port for your transport needs, you should consider proximity to cut transportation costs by using a port located near your trading partners. Evaluating multiple transportation routes of shipping goods from multiple origins to multiple destinations and finding or developing the least cost route is another technique that is often used in determining facility locations for evaluating transportation costs of routes by selecting different facility locations.

2.6 Undertaking all activities around the storage facilities based on OHS guidelines.

The warehouse should be a safe place not only for the emergency supplies but also for the people who work with them. Occupational health and safety measures must therefore be designed in advance and implemented rigorously.

- There should be no smoking in the warehouse
- All the staff must be aware of existing hazards and security measures to prevent accidents

- Maintenance staff must wear protective devices for their backs and hands handling shipments. Any other protection devices or tools required to carry out their tasks safely must be rigorously employed at all times
- Signs and labels alerting workers to any type of danger should be clearly visible
- Fire extinguishers and first-aid equipment should be clearly visible, located in an accessible place, and be in good working condition. The people who work in the warehouse should know how to use all such equipment

Self-Check 2	**Written Test**

I. True or False Questions

1. The goal of seed testing is to determine the moisture content of the seed lot.
2. The international seed testing association (ISTA) lays down the procedures and methods for seed testing.
3. Seed sampling is a method by which a representative sample is taken from a seed lot to be sent to a laboratory for analysis.
4. The main goal of germination test is to determine the intrinsic (real) seed germination capacity of a lot and percentage of normal seedlings, which can be produced by the lot under more or less ideal condition.
5. The sample from a seed lot can be taken on the basis of number count or weight, depending on the crop species under consideration.

II. Multiple Choice Questions

1. Which of the following is not a component of a seed lot?
   a. Pure seed
   b. Foreign seeds (weed seeds, and other crop species)
   c. Inert matter (chaff, empty seeds, debris, etc.)
   d. Moisture content
2. Which of the following is not a seed test performed by the international seed testing association (ISTA)?
   a. Moisture content
   b. Purity physical (mixture)
   c. Germination and vigor health genetic composition
   d. Soil analysis

3. Which of the following is not a method used for seed sampling?
   a. Automatic samplers
   b. Hand samplers
   c. Laboratory samplers
   d. Bin or bag samplers

4. Which of the following is not a method used for seed sampling in bags or small containers?
   a. Hand triers
   b. Stick triers
   c. Noble trier (Dynamic spear)
   d. Hand samplers

5. Which of the following is not a requirement for seed sampling?
   a. The lot to be sampled should not have volume larger than specified subject to a 5% tolerance.
   b. The bags or containers should be easily accessible for the sampler.
   c. The lot should be in properly sealed or sealable bags or containers and loose seeds should not be sampled.
   d. All containers must bear a lot identification number.

III. Short Answer Questions

1. Before the grain is **stored**, **samples** are taken. Why?
2. A good storage structure should be_____?
3. Seed purity is governed by_____?
4. What is the importance of Clear and accurate records of grain movements in and out of storage?

Operation Sheet -2

2.1. Techniques for seed moisture testing for storage

A. Tools and equipment's

- Seed Samples
- Containers
- Moisture Analyzer
- Calibration Standards
- Balance
- Oven
- Calculator
- Culture media

B. Procedures/Steps/Techniques

- Collect a representative sample of seeds from the seed lot
- Clean the seeds to remove debris or contaminants.
- Mix the sample thoroughly to ensure homogeneity.
- Weigh a precise amount of the seed sample using a precision balance.
- Calibrate the moisture analyzer according to the manufacturer's instructions.

LAP TEST-2	**Performance Test**

Name……. ID……..

Date…….

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **1** hour. The project is expected from each student to do it.

Task-2:- Perform seed moisture testing for storage?

LG #35	LO #3- Monitoring and Maintaining Crop Produce Conditions in Storage

Instruction sheet 3

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Identifying options for maintaining or improving produce quality.
- Conducting regular checks of storage to avoid contaminants and deterioration.
- Conducting periodical checks of long-term storage for quality factors and viability
- Creating, maintaining and keeping clear and accurate records of tests and inspections.
- Monitoring condition of storage facilities using schedule and methods outlined.
- Taking appropriate corrective action to maintain the quality of stored produce
- Undertaking crop produce waste disposal

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify options for maintaining or improving produce quality.
- Conduct regular checks of storage to avoid contaminants and deterioration.
- Conduct periodical checks of long-term storage for quality factors and viability
- Create, maintain and keep clear and accurate records of tests and inspections.
- Monitor condition of storage facilities using schedule and methods outlined.
- Take appropriate corrective action to maintain the quality of stored produce
- Undertake crop produce waste disposal

Learning Instructions:
1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3. Read the information written in the information Sheets 4. Accomplish the Self-checks

Information Sheet-3

3.1 Identifying options for maintaining or improving produce quality

Maintaining or improving produce quality is essential for ensuring that the food we consume is safe and nutritious. Here are some options for maintaining or improving produce quality:

- Proper storage: Storing produce at the right temperature and humidity can help maintain its quality. For example, storing fruits and vegetables in a cool, dry place can help prevent spoilage and extend their shelf life.
- Regular cleaning: Cleaning produce regularly can help remove dirt, bacteria, and other contaminants that can affect its quality. It's important to wash produce thoroughly with clean water before consuming it.
- Harvesting at the right time: Harvesting produce at the right time can help ensure that it is at its peak quality. For example, harvesting fruits and vegetables when they are fully ripe can help ensure that they are flavorful and nutritious.
- Using the right equipment: Using the right equipment for harvesting, transporting, and storing produce can help maintain its quality. For example, using sharp knives to cut produce can help prevent bruising and damage.
- Proper packaging: Proper packaging can help protect produce from damage and contamination. For example, using breathable packaging for fruits and vegetables can help prevent moisture buildup and spoilage.
- Quality control: Regular quality control checks can help identify issues with produce quality and prevent them from becoming more serious. For example, inspecting produce for signs of damage or spoilage can help ensure that only high-quality produce is sold to consumers.

These are some of the options for maintaining or improving produce quality. By following these practices, you can help ensure that the food we consume is safe, nutritious, and of the highest quality.

3.1.1 Management to Maintain Stored Grain Quality

Grain quality will not improve during storage. At best, the initial quality can only be maintained. When stored grain goes out of condition, it is usually the cumulative result of several interrelated management factors that include:

- Harvesting, Handling and Storage Equipment
- Initial Grain Condition
- Moisture Content
- Grain Temperature
- Aeration System Management
- Insect and Mold Control
- Monitoring Grain Condition

An effective management program greatly enhances the likelihood of maintaining top quality grain.

3.1.1.1 Seed quality control

Quality control is a systematic approach towards achieving and maintain at least minimum standards set by a given seed system. To keep the quality of the processed seed, proper and suitable storage conditions are necessary to avoid seed deterioration. All this quality assurance measures have to be taken by authorized organizations or monitoring service providing agencies. These organizations are responsible to make frequent checkup and give their approval whether the storage inspection and processing procedures are to the standard of national and international guidelines.

3.1.1.2 Crop protection measures during storage

- Construction of adequate storage facilities

- Optimization of drying procedures
- Spraying the store with appropriate chemicals
- Regular turning of sacks (heaps)
- Fumigation
- Rodent control

3.2 Conducting regular checks of storage to avoid contaminants and deterioration.

Conducting regular checks of storage is crucial to avoid contaminants and deterioration. Proper management, storage, and handling of hazardous materials is critical for reducing the possibility of storm water contamination through leakage and spills. Here are some best practices for hazardous materials storage:

- Properly inspect, label, and seal all containers.
- Segregate incompatible materials based on physical and chemical properties and secondary containment requirements.
- Store all hazardous materials in areas that will not be subject to rain, flooding, or vandalism (under lock and key if necessary).
- For outdoor storage locations, provide proper ventilation, storage foundations (e.g., pallets or a concrete slab), and secondary containment as recommended by the manufacturer or required by regulation.
- Confine storage of hazardous materials to designated areas.
- Ensure enough aisle space to ease inspections and handling and minimize the chance of accidental spills.
- Store hazardous materials away from high-traffic areas.

It is also important to implement a regular inspection program. In particular, routinely inspect storage spaces and containers for leaks, signs of cracks or deterioration, or any other signs of leakage. By following these guidelines, you can ensure that your storage is safe and free from contaminants.

3.3 Conducting periodical checks of long-term storage for quality factors and viability

Periodical checks of long-term storage are essential to ensure the quality and viability of stored items. The frequency of these checks depends on the type of item, storage conditions, and the duration of storage.

For example, in the case of **grain storage**, regular checks are necessary to maintain continued freedom from contaminants and deterioration. Appropriate periodical checks of grain in long-term storage for quality factors and viability should be conducted. Samples of grain should be taken, prepared, and sent for testing in a laboratory setting appropriate to industry quality assurance and laboratory requirements.

In the case of **environmental samples**, it is important to consider the stability of the samples in storage. The storage conditions and stabilities of the samples should be taken into account.

In general, it is good practice to refer to the storage devices' history to determine equipment failures, power outages, moves, that could possibly impact sample integrity.

It is important to note that the frequency and nature of periodical checks may vary depending on the type of item and storage conditions. It is recommended to consult with experts in the field to determine the appropriate checks for your specific storage needs.

3.4 Creating, maintaining and keeping clear and accurate records of tests and inspections.

To ensure the quality of crops, it is important to maintain clear and accurate records of tests and inspections. This helps to identify potential issues and take corrective actions in a timely manner. Here are some tips for creating and maintaining such records:

- **Use a standardized format**: Develop a standardized format for recording test and inspection results. This will help ensure that all relevant information is captured and that records are consistent across different crops and tests.
- **Record all relevant information**: Record all relevant information about the crop, including the date of the test or inspection, the type of test or inspection performed, the results of the test or inspection, and any corrective actions taken.

- **Keep records up-to-date**: Ensure that records are kept up-to-date and that any changes or updates are recorded promptly. This will help ensure that the most current information is available when needed.
- **Store records securely**: Store records in a secure location to prevent loss or damage. Consider using electronic records to reduce the risk of physical damage or loss.
- **Review records regularly**: Regularly review records to identify trends or patterns that may indicate potential issues. This will help you take corrective actions before problems become more serious.
- **Train staff on record keeping**: Train staff on the importance of record keeping and how to maintain accurate records. This will help ensure that everyone involved in the process understands the importance of maintaining clear and accurate records.

By following these tips, you can create and maintain clear and accurate records of tests and inspections for crops, which will help ensure the quality of your crops and identify potential issues before they become more serious.

3.5 Monitoring condition of storage facilities using schedule and methods outlined.

3.5.1 Monitoring grain condition

Frequently monitor grain condition to verify that the desired temperature control is achieved. Regular examinations are essential if mold and insect activity are to be detected and controlled in a timely fashion. The method and frequency of checking will vary with time of year, initial grain condition, and aeration procedure. Generally, grain should be inspected at least once a month during the winter and every two weeks at other times of the year. Extreme caution should be exercised when checking grain. Bridged grain is very dangerous, and collapse of the bridged area can result in suffocation. Always use a safety harness, lifeline, and grab rope, and have a second person outside the bin to assist in case of an emergency. Monitoring grain condition is extremely important during the summer because grain is held at higher temperatures and aeration conditions are less favorable. Grain temperatures should be checked and recorded at least every

two weeks. Without records, it is difficult to tell whether elevated temperatures are caused by normally occurring outside temperatures or by heating due to mold activity. Use a grain probe to locate any moisture pockets where molds will develop rapidly as temperatures warm. Insect activity is also at a peak during the summer, and frequent checking is required if infestations are to be controlled before they develop into major problems.

Failure to monitor grain condition throughout the entire storage period is a frequent mistake. A small area that starts to heat or otherwise "go out of condition" can quickly get out of control and spread within the bin. Think of the grain as being cash in the bin, and consider how frequently it would get checked if that were the case.

Some areas and conditions to check when monitoring grain quality include:

- Grain surface for condensation, crusting, wet areas, molds, and insects.
- Bin roof for condensation and leaks.
- Grain mass for non-uniform temperatures, high moisture pockets or layers, molds, and insects.
- Exhaust air for any off-odors.

If problems are detected, they need to be evaluated and corrected as soon as possible. This may include cooling with aeration, further drying, or fumigation for insect control.

Following the above aeration schedule will help maintain grain quality. However, grain condition needs to be monitored to verify that the desired temperature control is being achieved. Further, a regular checking schedule is essential if mold and insect activity are to be detected and controlled in a timely fashion. The method and frequency of checking will vary with time of year, initial condition of the grain, and aeration procedure. Generally grain should be inspected at least once a month during the winter and **every two weeks over the spring, summer, and fal**l.

Grain checking is extremely important during the summer because grain is being held at higher temperatures and aeration conditions are less favorable than during the rest of the year. Grain temperatures need to be checked and recorded on a regular basis. Without temperature records, it is difficult to tell whether elevated grain temperatures are caused by normally occurring outside

temperatures or by heating due to mold activity. The grain needs to be probed to locate any moisture pockets where molds will develop rapidly as temperatures warm.

I. Initial Grain Condition

Good quality, clean, sound grain is much easier to maintain in storage than cracked and broken grain. Broken kernels will mold three to four times faster than whole kernels. Broken grain also is more susceptible to insect attack, since some insects feed only on broken or cracked kernels. It is critical that initial grain condition receives considerable attention.

In addition to careful combine adjustment and operation, moisture content is a key factor influencing grain damage during harvest. The least grain damage generally occurs at moisture contents of 18 to 20 percent. The amount of damage increases slightly for moisture contents below this range, but increases rapidly for moisture contents above this range. Also, frozen grain damages easily, and combining or handling should be avoided if possible.

Grain quality will not improve during storage. At best, initial quality can only be maintained. To help assure that only high quality grain goes into storage, the following is recommended:

- **a.** Clean around the bin site.
- **b.** Remove any old grain, grass, weeds, and other debris.
- **c.** Remove all traces of old grain from the bin and harvesting and handling equipment.
- **d.** Properly adjust the combine to minimize grain damage.
- **e.** Clean the grain as it is put into the bin, preferably using a rotating grain cleaner.
- **f.** Cool the grain to the prevailing outside air temperature as soon as it is put into the bin.

II. Moisture Content

If grain moisture content is too high, even the best aeration equipment and monitoring management will not keep the grain from spoiling -- it only delays the inevitable. These recommendations refer to the **wettest grain in the bin, not the average moisture content.**

These values should be reduced by one to two percentage points when storing lower quality grain such as immature or drought-stressed grain, severely cracked or damaged grain, and grain previously subjected to insects or molds.

Since small grains are harvested in the summer and held through warm weather, moisture contents should be less than those for corn and sorghum

If high temperature drying is used, operate the dryer at the lowest temperature possible. High temperatures reduce grain quality and make grain more susceptible to breakage and stress crack development. Excessive temperature also binds lysine in corn, making it unavailable to livestock. High temperature drying should be discontinued when the grain moisture is about two percentage points above the desired final moisture content. The remaining moisture will be removed in the cooling process. Cooling to ambient temperatures should take place over a four to six hour period. During this time the grain goes through a "steeping" process where moisture in the kernels redistributes and equalizes. Cooling the grain too rapidly can cause stress cracks; cooling too slowly encourages spoilage. If grain is cooled in storage bin, do not turn the fan off until all the grain has been cooled, regardless of weather conditions. Holding warm grain in a bin for even a few days is a needless risk. Natural air drying is an excellent way to minimize grain damage. Extended periods (6 to 12 weeks), depending on the weather and initial grain condition. One critical aspect of natural air drying is that the initial drying front must be moved through the full depth of the grain bin as quickly as possible. To accomplish this, the fans must be operated continually.

Drying costs and grain damage can be reduced if the grain is allowed to dry in the field. However, this must be weighed against the uncertainty of future weather conditions, and possible increased harvest losses.

Going into storage at the proper moisture content does not guarantee grain will remain at that moisture. Grain may be rewet as a result of bin roof or sidewall leaks. Moisture also can enter through downspouts from a bucket elevator or through hatches that have been left open.

Condensation also can cause localized increases in moisture content. Condensation, particularly on bin roofs and sidewalls, is common when warm grain (50°F or above) is cooled during cold weather (30°F or less), or when hot grain from a dryer is cooled in a storage bin. Minimize these condensation problems by cooling stored grain in stages during the fall; cooling hot grain from

the dryer in a separate cooling bin before moving it to storage; and by providing adequate exhaust vents in the cooling bin.

III. Grain Temperature

Whether holding wet grain for a short period of time or storing dry grain for longer periods, it is important that grain temperature be controlled. Because both wet grain and molds respire and give off heat, aeration is needed to keep the grain cool and to slow mold growth. Aeration is the movement of relatively low volumes of air through stored grain. Airflow rates typically range from 0.1 to 0.75 cfm/bu. properly aerated grain generally can be held safely about four times longer than non-aerated grain.

Aeration is needed to keep the grain mass at the desired temperature and to keep temperatures equalized, even if grain is dry and cool when placed in storage. Temperature differences within the grain mass create convection currents that can move and concentrate moisture in the top center of the bin.

IV. Aeration System Management

The primary objectives of aeration are:

a. To keep the grain at a seasonally cool temperature, within 10°F of the average monthly ambient air temperature; and
b. To maintain a relatively uniform temperature within the grain mass -- preferably no more than a 10°F difference in temperature from one part of the bin to another.

Grain mass temperature needs to be controlled throughout the year: cooled in the fall; held at 35 to 40°F through the winter; warmed in the spring; and held at about 60°F through the summer.

A cooling or warming zone moves through the grain in the same direction as the airflow.

A commonly expressed concern is running aeration fans during rainy or humid weather. Rewetting of the grain is normally not a problem during the relatively short time it takes to move a cooling or warming zone through the grain. The effects of operating the fan during damp conditions usually are more than offset by the time the fan is operated under more favorable conditions.

- A common question is whether the airflow should be upwards or downwards through the grain mass.

From the standpoint of aeration system performance, the effect of airflow direction is negligible. However, from a management standpoint, upward airflow is preferred since the top of the grain mass will be the last area to change temperature when a cooling or warming zone is moved through the bin. This makes it easier to determine if the zone has moved completely through the grain. Uniform airflow distribution is necessary for the most satisfactory temperature control.

This requires

- ✓ Clean grain
- ✓ A level grain surface, and
- ✓ A well-designed aeration system, preferably with a fully perforated floor. Monitoring grain condition is especially important in facilities where these conditions are not present

3.5.2 Effective Grain Storage Critical to Ensure Quality

Grain going into on-farm storage should have a maximum of 12 percent moisture. This means that growers storing grain on farm will need to measure moisture levels as grain is put into storage and then monitor stored grain moisture, temperature and insect activity regularly. Grain stored at too high a moisture level can be affected by mould and fungal growth and will be at a higher risk of insect attack.

It's important not to expect aeration to dry grain to any great degree of typical aeration on-farm is for cooling, aeration drying is a whole different practice. If growers are considering aeration to dry grain then it is important they seek correct advice and use equipment which can do the job.

Grain quality can steadily deteriorate if the storage environment is not managed correctly. Generally, the combination of good farm hygiene plus well-managed aeration cooling can

overcome storage pest problems. When managing stored grain, prevention is better than cure and a number of basic steps can be taken to minimize problems that can result in reduced grain quality. Including:

- Maintaining good farm hygiene. Clean up grain residues in empty storage facilities and all grain handling and carriage equipment before new grain is stored and equipment used. Clean up spillages in areas around silos and destroy all residues to prevent re-infestation.
- Ensuring insect pests or weeds are not carried onto properties on farm equipment such as harvesters. All equipment should be thoroughly cleaned down after use. The first grain through
- Once storages and equipment have been cleaned, treat them with a diatomaceous earth treatment.
- Check the seals on gas-tight sealed silos before each filling and replace them if they are worn or damaged. Carry out a pressure test to be sure the silo is gas-tight before fumigating.
- Install aeration cooling fans in storages to cool grain, and for best results install an aeration controller. Freshly harvested grain usually has a temperature around 30°C which is an ideal breeding temperature for many storage pests. Aeration fitted to stores can rapidly reduce grain temperature which reduces insect breeding and assists in maintaining grain quality.
- Monitor grain monthly for insects, moulds, grain temperature and moisture. Generally, grain stored for more than six weeks should be treated for insect pests. Fumigation must be done in pressure-tested sealable gas-tight silos.

3.5.3 Grain sampling and monitoring during storage

Grain sampling and monitoring during storage

- In-store grain quality
- Grain sampling from static bulks

- Monitoring moisture and temperature in stored grain
- Record keeping

Grain remains a ‘living’ crop – it respires and is susceptible to infection by moulds and infestation by pests. To inform management, it is important to understand the quality and condition of grain.

In-store grain quality

Key quality parameters are assessed by trade-assured testing facilities, sometimes provided by a merchant or other independent testing laboratory. Parameters may include (depending on the market):

- Protein/nitrogen quantity
- Specific weight
- Hagberg Falling Number
- Germination

Most quality parameters do not change during storage. If effective sampling occurred at intake and the location of individual sampled loads (or lots) can be accurately identified within the store, such samples are sufficient for quality assessments.

In-store mycotoxin management

If grain has been harvested 'dry' or has been dried quickly, and is kept sufficiently dry in the store, storage mycotoxins (such as ochratoxin A) should not be a risk.

Legally, all producers must know whether grain destined for human consumption meets the food safety standards for the presence of the fusarium mycotoxins, DON, ZON, T2 and HT2.

Many processors require this information, especially at the start of each new harvest year. Samples taken in store may be used to provide this information.

3.5.3.1 Management of storage pests

Although it is possible to draw physical samples from a bulk or bin for examination for storage pests, it is a laborious process. Traps are more than ten times more effective than sampling, especially at detecting low numbers of insects and mites.

3.5.3.2 Grain sampling from static bulks

The best opportunity to generate representative grain samples is as stores are filled or from a dryer.

However, this is not always practical. As a result, it is sometimes necessary to sample grain bulks in flat stores. As always, it is important to follow best practice to ensure that final samples are representative of the bulk.

How to take incremental grain samples

Based on examples of industry practice and the relevant ISO standard (13690), a suggested minimum of 5 x 500 g incremental samples should be used to form a single (composite) final sample that represents no more than:

- 50 t for grain destined for human consumption (milling wheat, malting barley and food oats)
- 100 t for grain destined for feed

Use grain sampling spears to extract incremental samples from a static (i.e. not being moved by stirrers) bulk.

- Ideally, use a two-metre, multiple-aperture, spear capable of drawing a 500 g incremental sample
- Set the spear so apertures open in sequence, starting from the bottom compartment
- Insert the spear into the grain, at a slight angle from vertical with the slots facing upwards
- Turn the spear's inner tube through 180° (which opens and closes the intake apertures) to collect a sample
- Use a grid system to take incremental samples that best represent the bulk. For example, from the front, middle and back of the heap or bay

How to make a representative grain sample

Good distribution of the incremental samples and thorough mixing of the composite sample is essential, so it is representative of the bulk. Place each final sample in a well-filled, clearly

labelled and sealed bag. Analysis of such samples will provide growers and merchants with the most accurate view of the grain. Consult grain merchants for further guidance on how to sample grain accurately and safely.

3.5.3.3 Monitoring moisture and temperature in stored grain

It is important to monitor the moisture content of grain. High moisture in stored grain promotes the development of moulds and mites. Certain moisture contents and temperatures also encourage the production of a storage mycotoxin – ochratoxin A. It also critical to take regular recordings of grain temperature, as part of efforts to keep temperature/time targets on track, and identify hot spots associated with insect activity or water leaks.

3.5.3.4 Detecting Infestations

Before any control measure can be taken, the problem must first be detected. Sampling the grain every 2 weeks to check for insects and heating may ensure early detection of spoilage.

A. Checking for insects

A sieve (4 meshes/cm or 10/in) can be used to screen samples from the surface. A sampling probe may aid in obtaining deep samples. The siftings can then be observed over slight heat to detect movement of insects. Other insect detection devices consist of probes or pipes perforated with small holes that will exclude grain kernels but allow insects to drop into the trap. Also plastic cups filled with water may be inserted in the bin to trap insects during summer. The two most important insects of stored grain in Canada are the rusty grain beetle and the red flour beetle. The rusty grain beetle larvae feed internally. The adult beetle is long (0.2 cm), flat, reddish-brown and its' antennae are not club shaped. It is usually the adult beetle which is detected in grain.

B. Checking for mites

For mite infestations, grain samples may be sieved through a sieve (12 meshes/cm; 30/in]. The dust and screenings should be warmed to room temperature and examined with a magnifying glass. While it is harder to see smaller numbers of mites, the larger numbers in grain sittings look

like clumps of moving dust. The red flour beetle is twice as long as the rusty grain beetle and has club shaped antennae.

3.6 Taking appropriate corrective action to maintain the quality of stored produce

To maintain the quality of stored produce, it is important to take appropriate corrective actions when necessary. According to the Food and Agriculture Organization of the United Nations (FAO), corrective actions may include revising data gathering, strengthening training, increasing technology transfers, and more.

It is also important to take immediate corrective actions when signs of spoilage or pest infestation are detected. Examples of immediate corrective actions include throwing out food items that show signs of spoilage, rejecting a food delivery with bite marks on the packaging, and transferring unrefrigerated perishable food items into cold storage.

In addition, quality systems can help identify opportunities for corrective actions. These opportunities can be found through workplace inspections, testing, inspecting, and monitoring of plant and equipment, consulting with staff, customer feedback, audits, hazard reporting, dealing with any non-conforming product, and more.

By taking appropriate corrective actions, you can help maintain the quality of stored produce and ensure that it remains safe for consumption.

3.6.1 Conditions of storage facilities

When workers enter storage bins, employers must (among other things):

- Turn off and lock out all powered equipment associated with the bin, including augers used to help move the grain, so that the grain is not being emptied or moving out or into the bin. Standing on moving grain is deadly; the grain acts like 'quicksand' and can bury a

worker in seconds. Moving grain out of a bin while a worker is in the bin creates a suction that can pull the workers into the grain in seconds.

- Prohibit walking down grain and similar practices where an employee walks on grain to make it flow.
- Provide all employees a body harness with a lifeline, or a boat swain's chair, and ensure that it is secured prior to the employee entering the bin.
- Provide an observer stationed outside the bin or silo being entered by an employee. Ensure the observer is equipped to provide assistance and that their only task is to continuously track the employee in the bin.
- Prohibit workers from entry into bins or silos underneath a bridging condition, or where a build-up of grain products on the sides could fall and bury them.
- Test the air within a bin or silo prior to entry for the presence of combustible and toxic gases, and to determine if there is sufficient oxygen.
- Ensure a permit is issued for each instance a worker enters a bin or silo, certifying that the precautions listed above have been implemented.

As an employer of workers facing these hazards, you have the legal obligation to protect and train your workers. OSHA will not tolerate non-compliance with the Grain Handling Facilities standard. OSHA has investigated several cases involving worker entry into grain storage bins where we have found that the employer was aware of the hazards and of OSHA's standards, but failed to train or protect the workers entering the bin. OSHA has aggressively pursued these cases and we will continue to use our enforcement authority to the fullest extent possible. Just in the last 10 months, OSHA has issued three large penalty citations to grain elevator operators for these very hazards.

Maintaining the quality of grain in storage requires an integrated approach that incorporates a number of tools and practices. Storing only clean grain at the proper moisture content and temperature, sanitizing the bin before loading, checking the grain condition regularly and

correcting problems before they get out of hand are critical management strategies that must be implemented to prevent grain deterioration and possible economic loss.

It is critical to carefully manage stored grain to prevent grain deterioration and possible serious economic loss. This management should include:

- A well-designed and properly-operated storage system with adequate aeration capacity.
- Storing only clean grain at the proper moisture content and temperature.
- Checking the grain condition regularly and correcting problems before they get out of hand.

3.7 Undertaking crop produce waste disposal

Agricultural waste and by-products are generated by all activities related to cultivation of crops; vegetable and fruit production and processing; and dairy, poultry, aquaculture and meat production associated with intensive agriculture practices and use of fertilizers. The ever-increasing world population requires increased food and fodder supply which results in increased agricultural waste biomass production. Proper management of crop residue requires reliable forecast about crop residue to be generated in each season/crop-wise and related policies of the government to handle this biomass.

There are several ways to dispose of agricultural waste. One popular method is composting. Composting is a process that involves the decomposition of organic matter into a nutrient-rich soil amendment. Kitchen waste or crop wastage can also come in use as animal feed, fertilizer and bioenergy. It converts into animal feed by sterilization, bioenergy by anaerobic digestion and fertilizer by composting. Another method is anaerobic digestion. This process involves the breakdown of organic matter in the absence of oxygen, producing biogas and a nutrient-rich fertilizer. Other methods include burning, burial, biochar production, and mulching.

It is important to note that proper utilization of available resources will solve many socio-economic as well as environmental problems and help in improving living of people in rural areas particularly in developing countries. Plant-based residue or biomass generated by

agricultural activities and agriculture-based industry is briefly presented as problem, and remedial measures are required for the benefit of both environment and farmers. Emerging novel technologies are being developed to obtain useful metabolites and products from agricultural waste.

Video link: - https://telesense.com/ TeleSense – Agriculture Commodity Monitoring (date accessed 20/01/2024)

Self-Check 3	**Written Test**

I. True or False Questions

1. All producers must know whether grain destined for human consumption meets the food safety standards for the presence of fusarium mycotoxins, DON, ZON, T2, and HT2.
2. Traps are more than ten times more effective than sampling, especially at detecting low numbers of insects and mites.
3. Grain sampling from static bulks is not necessary, as it is always possible to draw physical samples from a bulk or bin for examination.
4. Incremental grain samples should be taken using a two-metre, multiple-aperture, spear capable of drawing a 500 g incremental sample.
5. Proper storage is not essential for maintaining produce quality.

II. Multiple Choice Questions

1. What is the best opportunity to generate representative grain samples?
   a) As stores are filled or from a dryer
   b) During the harvesting process
   c) After the grain has been stored for several months
   d) When the grain is being transported

2. What is the suggested minimum number of incremental samples for a single (composite) final sample for grain destined for human consumption?
   a) 5 x 500 g
   b) 10 x 500 g
   c) 20 x 500 g
   d) 50 x 500 g

3. What is the primary objective of aeration in grain storage?
   a) To keep the grain at a seasonally cool temperature, within 10°F of the average monthly ambient air temperature
   b) To maintain a relatively uniform temperature within the grain mass -- preferably no more than a 10°F difference in temperature from one part of the bin to another
   c) To prevent insect and mold infestations in the grain
   d) To reduce the moisture content of the grain

4. What is the recommended frequency for checking grain condition during the winter?
   a) Once a month
   b) Every two weeks
   c) Once a week
   d) Every three weeks

5. What is the recommended frequency for checking grain condition during the spring, summer, and fall?
   a) Once a month
   b) Every two weeks
   c) Once a week
   d) Every three weeks

IV. Short Answer Questions

1. Write the advantage of Regular checks of grain in storage
2. Mention the popular methods to dispose agricultural waste?
3. What is OHS guidelines detailed in the grain storage program?
4. Describe/Define anaerobic digestion?

LG #36	LO #4- Controlling storage pests

Instruction sheet 4

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Identification of storage pest
- Monitoring crop produce
- Taking samples of stored produce to test for pest infestation.
- Controlling storage pests
- Fumigating enclosed storage area and following integrated pest management strategy.
- Identifying the sources of any infestations and taking action to control them.
- Undertaking pest control activities in line with the OHS hazard guidelines.
- Chemical handing and dangerous goods requirements

Recording and reporting treatments made to the stored produce and storage facilities.This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify storage pest
- Monitor crop produce
- Take samples of stored produce to test for pest infestation.
- Control storage pests
- Fumigate enclosed storage area and following integrated pest management strategy.
- Identify the sources of any infestations and taking action to control them.
- Undertake pest control activities in line with the OHS hazard guidelines.
- Handle chemical and dangerous goods requirements

Learning Instructions:
1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3.Read the information written in the information Sheets 4.Accomplish the Self-checks

Information Sheet 4

Introduction

4.1 Identification of storage pest

Losses of grain in storage due to insects are the final components of the struggle to limit insect losses in agricultural production. These losses can exceed those incurred while growing the crop. Losses caused by insects include not only the direct consumption of kernels, but also include accumulations of frass, exuviae, webbing, and insect cadavers. High levels of this insect detritus may result in grain that is unfit for human consumption. Insect-induced changes in the storage environment may cause warm, moist 'hotspots' that are suitable for the development of storage fungi that cause further losses. Worldwide losses in stored products, caused by insects, have been estimated to be between five and ten percent. Heavier losses occurring in the tropics may reach 30%.

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Grain monitoring target in storage
- Control storage pests
- Fumigate storage areas
- Sources of infestation in storage

4.1.1 Grain monitoring target in storage

- ✓ To store grain for a long period of time
- ✓ To protect grain from insect damage
- ✓ To protect stored grain from contamination of inert matter
- ✓ To store weed free grain

- ✓ To protect grain from storage diseases e.g. fungal disease…

4.1.2 Control storage pests

A. Biological Control of Stored-Product Pests

"Stored products" include all durable agricultural commodities that can be dried and stored in bulk, such as cereal grains, flour, oil seeds, legumes, nuts, dried fruits, animal products, and packaged, baked or processed foods. Of these, cereal grains make up the majority of commodities maintained in storage, and represent an important component of the world food supply. Insects have infested stored food products since the beginning of human civilization. Interestingly, many of the pest species found in stored products do not normally occur on wild host plants or in non-human habitats, but are fully adapted to the storage system, much like house flies and certain cockroaches are adapted to human habitations. Thus in addition to grain-eating beetles and moths that are expected in stored grain, one also can find habitat-specific and host-specific natural enemies that utilize these pest insects as food. Most pests and their natural enemies have worldwide distributions because they have been spread by people. Common storage pests include the Indian meal moth and Mediterranean flour moth that infest grains, flours, animal feed, and people's pantries; red and confused flour beetles in the genus Tribolium, together with sawtoothed and flat grain beetles in the genera Oryzaephilus and Cryptolestes, that are found in many grain products; and the more serious internal grain feeders such as rice, maize and granary weevils in the genus Sitophilus, and the lesser and larger grain borers, bostrichid beetles that riddle stored grains with their tunneling activities. Populations of all of these pests can be impacted by one or more species of natural enemy.

There is great potential for using biological control to control pests in stored products. Research is continuing to determine the proper prescriptions for use of natural enemies in stored grain. Behavioral, ecological and physiological data are being collected that will facilitate effective deployment of parasitoids and predators. Storage situations other than grain bins, such as feed mills, food warehouses, and food factories may be targeted areas for biological control in the

future. As part of an IPM system for stored product management, biological control should help reduce the use of pesticides on food and provide for high quality food products.

B. Pest Control tips for home storage

Many pest control experts agree that preventive pest control is the best way to deal with attic pests, particularly when storing precious heirlooms or other irreplaceable items. The following are five pest management tips for preserving your stored items.

i. Use plastic storage containers with tight lids.

When it comes to home storage and preventive pest control, a less natural storage environment is better. Be it for your attic, storage unit, shed, basement or even a large closet, you want to maintain an environment that is unwelcoming to pests. Plastic storage bins and barrels provide the best protection, as they can't be chewed through or torn open. Choose bins with tight-fitting lids, and keep them sealed while in storage. Replace any bins that have become cracked or broken.

Avoid cardboard boxes that are old or loose, and do not keep food, plants or plant materials in or near you storage containers, as these will attract insects.

ii. Keep it clean.

Keeping your storage area clean is another crucial preventive pest control practice. Not only do food bits and sticky spills attract ants and other insects, but dust, dirt residue and other organic material can also help storage pests thrive. Clean your storage area thoroughly before moving in. Sweep and mop where needed, and remove old cobwebs and dead insects. If you spot a few harmless spiders, so much the better - these will help keep pest populations down.

iii. Maintain a cool, dry climate.

When it comes to preventive pest control, rain poses one of the biggest challenges for Portland pest control professionals. Wet conditions outside will drive insects and critters inside, and any moisture that gets indoors provides a handy water source for pests.

To offset the problems posed by Portland rains, patch up any leaks or cracks that might allow water to trickle through, and keep the climate in your attic or storage space cool and dry. Don't keep it too cold, however, or it can become a haven for pests in the hotter summer months.

iv. Use preventive pest control products.

Pest repellents for silverfish, moths and other storage pests are widely available and fairly effective. For the health of your family and pets, it's best to minimize use of chemical preventive pest control products. Instead, look for natural alternatives such as cedar blocks, scented soaps or even Diatomaceous earth (a natural ground material that only harms insects and microscopic bugs). Traps can also be effective deterrents, as long as you use them safely and carefully.

v. Check it out before you pull it out.

Portland pest control professionals often receive emergency calls from homeowners who have unknowingly brought down infested boxes from the attic, only to discover they've helped the pests spread into other areas of the home. To avoid this, inspect your boxes for evidence of pests before bringing them out of storage. Continue inspecting as you unpack the contents, and vacuum each item thoroughly to remove any pests or eggs.

By putting a little effort into preventive pest control for your home storage items, you can ward off most infestations before they happen. However, if the problem has become unmanageable or you're not sure how to go about securing your storage space against pests consult a Portland pest control service that specializes in preventive pest control or Integrated Pest Management. You'll thank yourself later on, when you rummage through storage and find that family heirloom or Halloween costume still in pristine, pest-free condition.

C. Insect and mold control

- Insects are generally not a problem in grain stored for less than 10 months or a year. However, if grain is to be stored for longer than this, or if a bin has had an insect problem in the past, special precautions should be taken. These include:
  - ✓ Spray the inside of the bin with protective insecticides 2 to 3 weeks before new grain is added.
  - ✓ Treat the grain with an approved insecticide as the bin is filled.
  - ✓ Top-dress the grain with an approved insecticide after the bin has been filled and the grain surface has been leveled.
- Left untreated, an insect infestation will eventually lead to other storage problems. Insects give off moisture which can cause grain moisture contents to increase enough to create a mold problem. Mold activity will in turn raise temperatures and result in an increased rate of insect reproduction. Greater numbers of insects create more moisture, and the cycle is repeated at an ever increasing rate.

4.1.3 Fumigate storage areas

Properly conducted fumigation will stop insect infestation and grain degradation from getting progressively worse. When fumigation is effectively conducted in late fall, pest populations can be drastically reduced.

Fumigation is recommended if:

- Grain samples reveal the presence of insect-damaged-kernals (IDK).
- Samples or traps capture harmful insects (lesser grain borer, granary weevil).
- Trapping or sampling indicates that a population of secondary pests like the rusty grain beetle is expanding rapidly.

Fumigants registered for use are phosphine, either released from aluminum or magnesium phosphide or directly as a gas, methyl bromide, and chloro-picrin (used for empty bin treatment only). Tablets or pellets of aluminum or magnesium phosphide are sold under Weevilcide, Fumitoxin, and Phos-toxin trade names. Phosphine gas mixed with carbon dioxide is sold in gas cylinders as ECO_2 Fume. Methyl bromide is expensive, difficult to use properly on raw grain, kills the germ, and is not recommended for stored grain, especially seed wheat.

In addition, methyl bromide use is being phased out due to its status as an ozone depleter under the Montreal protocol.

4.1.4 Controlling Infestations

Before grain is stored the empty bin should be sprayed with a recommended insecticide to control any insects which may already be present.

Once infestations are detected in stored grain, it is important to control them as soon as possible in order to keep them from spreading to other bins. The kind of control measure depends on the condition of the grain, kinds of mites or insects present, grain temperature and the season of the year. Infested grain can be cold weather treated or fumigated.

A. Cold weather treatment

Lower the grain temperature by augering grain from one bin to a truck then to another bin. This is quite often an effective way to control infestations. Although only the grain that is heating may be moved, many transfers may be required to the cool grain to below 0 °C. As mentioned earlier, insects do not multiply or damage grain at 0 °C.

B. Grain fumigation

Grain can be fumigated using liquid or solid fumigants. Fumigants are toxic to farm animals, humans and insects, therefore fumigations should be applied only by trained people. Follow the instructions as well as any precautionary measures indicated on the container (Table 6).

Table 6. Stored Grain Insects

Pest and location	Insecticide	Metric	Rate of Measure	Application	Remarks
EMPTY BINS Rusty grain beetle, Red flour beetle Saw-toothed grain beetle, Granary weevil	malathion 500	300ml/5L water	10 fl oz of 50% EC/1 gal water	5 L/100m² (1gal/1000 ft²)	Apply to inside surfaces of bins. Also clean and spray area below perforated floors in bins with air drying systems. Wait one day before filling.
Treatment for stored grain and empty grain bins Rusty grain beetle, rice weevil, granary weevil, Indian meal moth, Mediterranean flour moth, red flour beetle	Diatomaceous earth – Protect-it	5 kg. Bag of powder	100 – 1000 grams/metric tonne of grain depending on insect and crop type		For wheat the Wheat board suggests no more than 100 gms/tonne as a maximum. As the activity of product produces death through dehydration, wait 4 weeks before mixing grain.

FUMIGATION OF GRAIN IN STORAGE	Phostoxin Gastoxin	Ready to use tablets or pellets	Ready to use tablets or pellets	Inject tablets or pellets evenly throughout grain according to label instructions	Wax coating on pellets prevents release of gas for 4 hours after opening container. Phostoxin is a very toxic gas; seal granary and post warning signs. Work in pairs. Use only when grain temp. is above 5°C (40°F).
Fumigation Period		Grain Temperature 4°C-12°C 12°-15°C1 16°-20°C	Fumigation Period 10 days 5 days 4 days		Following fumigation, aerate bins for 48 hours or until odor dissipates. Grain can be used for livestock feed following aeration.
CONTROL BY COLD TEMPERATURE	Rusty grain beetles an other stored grain insects can be killed by periods of cold temperatures as follows:				

		Grain Temperature -5° -10° -15°	Time required to kill insects 6 weeks 4 weeks 2 weeks		
	Grain temperatures can be lowered by aeration. Moving grain several times during cold weather may lower temperatures enough to kill insects.				

4.1.5 Sources of infestation in storage

4.1.5.1 Factors Contributing to Storage Problems

Regardless of whether the grain moisture content and temperature have been determined and rated as safe, problems may yet occur. The relationships between moisture and temperature can dictate the severity of the problem (Figure 2). Safe storage time can be increased by cooling the grain and lowering its moisture content. If the grain has been stored in a "tough" condition [greater than 14.8% (feed barley), 14.5% (wheat), 14.0% (triticale and oats) moisture] examine the grain at least every two weeks by pushing your hand into the surface, as deeply as possible, to feel for warmth or crusting. Insert a long metal rod deeply into the grain to test for warmth and crusting at various depth. Feel the rod for warmth as soon as the rod is withdrawn from the grain. Additional factors may contribute to grain heating and deterioration in only localized parts of the bin.

I. Moisture migration

At the time grain is first stored, grain moisture content is fairly uniform throughout the bin. With time, localized high moisture zones may develop due to changes in outdoor air temperatures. The low outside temperature cools the wheat nearer the wall. This results in a downward air flow

through the grain and upward towards the center of the bin. As the air moves through the grain it becomes warmer and begins to pick up moisture from the grain. Condensation occurs when the warm moist air hits the cool surface of the grain near the center of the bin, thus leading to grain spoilage Figure 7.

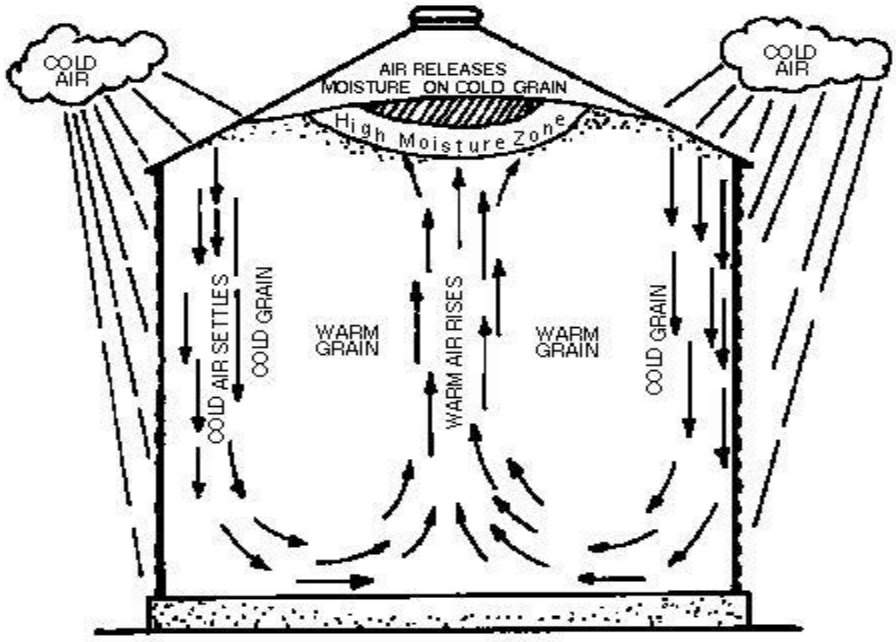


Figure 7. Moisture migration in storage bin in cold weather

The reverse airflow may occur if grain is still in storage in the late spring. Warming action from the sun on the outside of the bin causes moisture currents to move up and into the bin through the centre of the bin. High moisture due to condensation therefore occurs at the bottom of the bin in Figure 7. In addition, wet zones may form in the grain when rain or snow gets into the storage through ventilators and cracks in the roofs and walls.

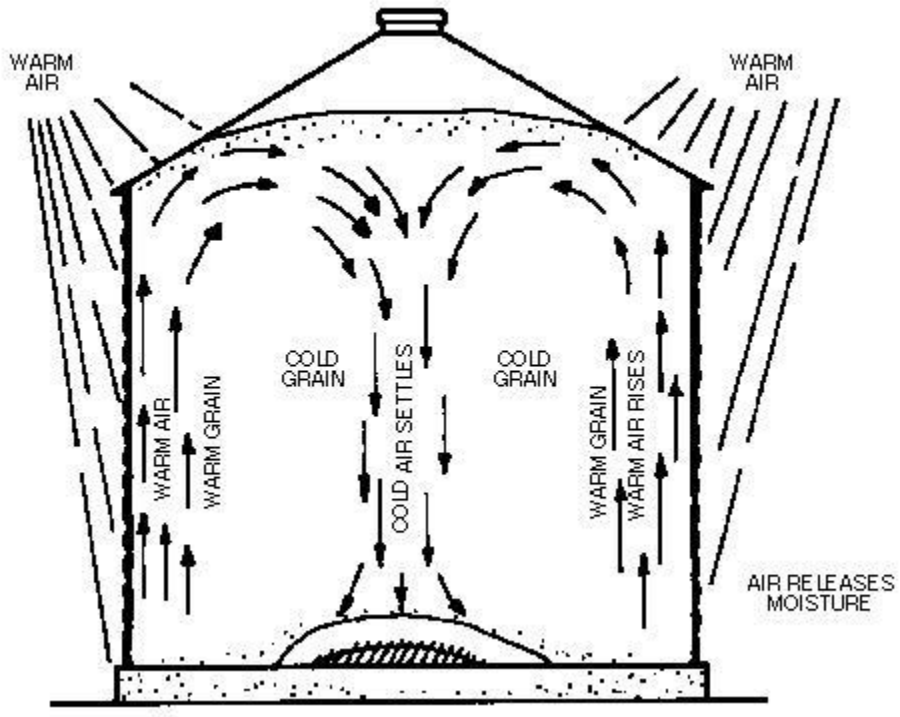


Figure 8. Moisture migration in storage bin in warm weather.

II. Insects, mites and molds

Failing to protect grain from infestations may result in quality losses; a price that may be too high to pay. The insects, mites and molds that cause grain to heat and lose condition are inactive at low temperatures (below 8 °C (48.4 °F) for insects, 3°C (37.4°F) for mites and 8°C (17.6 °F) for molds). Moisture content of grain below 13% arrests the growth of most molds and mites. Moisture content below 10% limits the development of most stored grain insects and pests. In addition to actual moisture content of the grain, bulk of grain stored also affects the rate of cooling. Tough (moisture content 14.6%-17.0 %) and damp (moisture content> I 7.0 %) grain stored in bulks of less than 27 tonnes usually cools rapidly and evenly during winter. However a bulk larger than 50 metric tonnes or more cools more slowly, hence temperature differences between the centre may cause condensation and spoilage.

Practical farm storage conditions are summarized in Figure 10. The ideal condition would be a moisture content of 12% or less and a temperature of 3 °C or less.

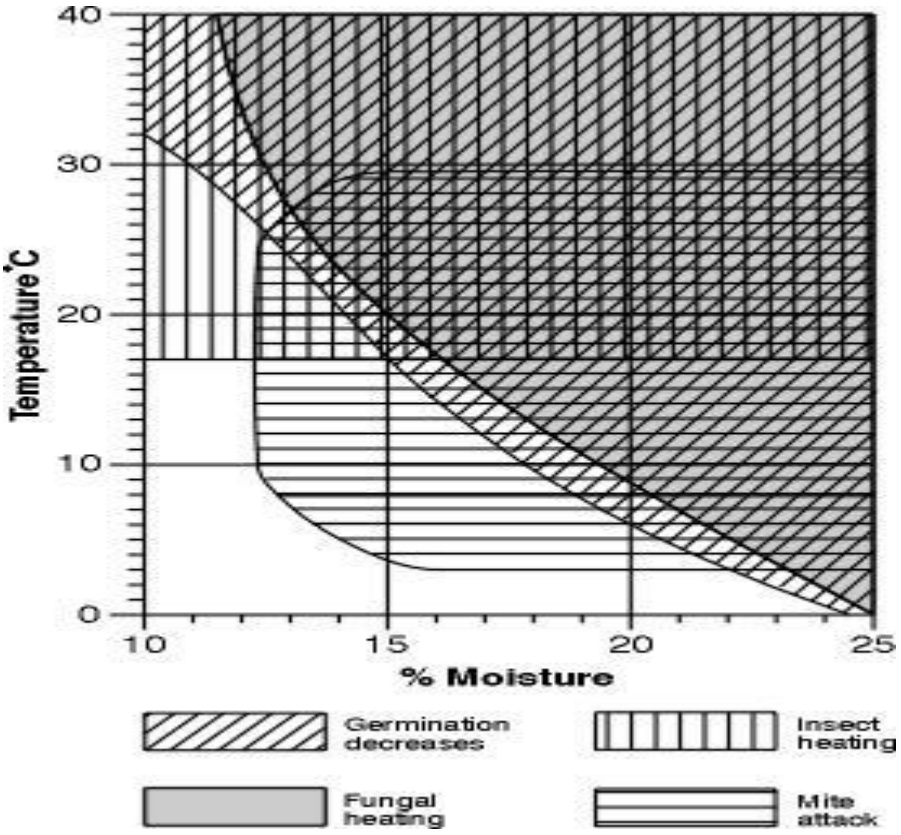


Figure 9. Practical farm storage conditions

III. Losses due to poor storage

a. Mould

Microbial infection in storage occurs due to inadequate drying of produce. The situation I made worse when there are large numbers of insects present or when the stored crop is exposed to high humidity or actual wetting due to poor storage management. Fungal infection results into rots and development of aflatoxins, which are poisonous compounds to live stock and cause cancer in human.

Conditions that favour aflatoxin contamination in maize grains

Aflatoxin contamination is encouraged by:

- Inadequate drying
- Physical damage due to poor shelling/threshing methods
- Poor storage methods (exposure to moist condition)
- Insect infestations.

Aflatoxin cannot be seen with a naked eye. However, suspect materials tend to:

- Be rotten
- Be mouldy
- Be discolored
- Have unpleasant smell
- Have bitter taste
- Have poor milling quality
- Be warmer than room temperature.

Losses due to mould

- Loss of weight
- Loss of quality (smell, taste, color, nutritional value, germination)
- Further increase in temperature and moisture, causing more grain deterioration.

b. Spillage

Careless handling of either maize cobs or grains can lead to spillage. This leads to loss in terms of quantity. Spillage can also lead to loss of quality in case contaminated grains or cobs are again mixed with the clean stuff. In this case, contamination will lead to mould development. The situation will be worse if the spill gets into contact with moisture. Losses due to spillage are common during shelling that is done by beating the cobs with sticks.

Video link: - https://youtu.be/5F2alCp-eE0 (date accessed 20/01/2024)

Summary

It is critical to carefully manage stored grain to prevent deterioration and possible serious economic loss. This should include:

- A well-designed and properly operated storage system with adequate aeration capacity.
- Storing only clean grain at the proper moisture content and temperature.
- Checking the grain condition regularly and correcting problems before they get out of hand

4.2 Monitoring crop produce

Monitoring crop produce is crucial for optimizing yield, preventing losses, and ensuring quality at harvest. It involves tracking various factors throughout the growing season and after harvest during storage. Here are some key aspects of crop produce monitoring:

During Growth:

- Plant Health: Regularly observe for signs of pests, diseases, nutrient deficiencies, and stress. Monitoring methods include visual inspection, traps, and diagnostic tools.
- Growth Stage and Development: Track development stages like germination, flowering, and fruit set to ensure timely interventions like irrigation, fertilization, or pest control. Monitoring may involve visual checks, plant measurements, and records.
- Environmental Conditions: Monitor temperature, humidity, rainfall, and wind patterns to understand their impact on growth and predict potential risks like frost or water stress. Utilize weather stations, online data, or local forecasts.
- Resource Utilization: Track water and fertilizer usage to optimize application and prevent waste. Sensors, meters, and water flow calculations can be helpful.

After Harvest:

- Storage Conditions: Monitor temperature, humidity, and ventilation in storage facilities to prevent spoilage, mold growth, and quality decline. Use thermometers, hygrometers, and airflow detectors.
- Physiological Changes: Track moisture content, respiration rate, and ethylene production in certain produce to estimate storage life and predict optimal timing for market or consumption. Specialized measuring instruments might be needed.
- Pest and Disease Activity: Inspect stored produce for pest infestations and disease development to implement control measures and prevent further losses. Regular visual checks and traps are common methods.
- Quality Loss: Monitor changes in appearance, texture, and firmness to identify early signs of spoilage and determine optimal consumption or market timing. Standardized grading systems and visual checks are often used.

Monitoring Technology:

Various technologies can enhance and automate crop produce monitoring:

- Remote Sensing: Satellites and drones provide aerial images to monitor field conditions, assess plant health, and identify potential issues.
- Precision Agriculture Sensors: Sensors in the field or attached to plants can track temperature, humidity, soil moisture, and nutrient levels, providing real-time data for informed decisions.
- IoT-based Monitoring Systems: Networks of sensors and devices can collect data from fields and storage facilities, allowing for remote monitoring and automated alerts for potential problems.

Benefits of Effective Monitoring:

- Increased Yield: Early detection and response to issues can minimize losses and boost harvest quantity.

- Improved Quality: Proper storage and control measures can lengthen shelf life and maintain produce quality for better market value.
- Reduced Costs: Optimized resource use and proactive management can save on water, fertilizer, and pest control expenses.
- Sustainable Practices: Data-driven decision-making enables efficient resource use and minimizes environmental impact.

Remember, the specific monitoring methods and technology will depend on the type of crop, available resources, and individual farm needs. Adapting a comprehensive monitoring approach can significantly improve crop production and success.

4.3 Taking samples of stored produce to test for pest infestation.

Taking samples of stored produce to test for pest infestation is a vital step in preventing spoilage and maintaining quality. Here's how to do it effectively:

Timing:

- Regularly: Schedule periodic sampling, especially if you suspect or have a history of pest issues. The frequency may depend on the storage duration, pest type, and storage conditions.
- Targeted: Sample more frequently if you notice signs of infestation like webbing, frass (insect droppings), or damaged produce.

Sample Size and Distribution:

- Number: Take enough samples to represent the entire storage unit. Aim for 10-20 samples from different locations within the unit, considering variations in temperature, humidity, and airflow.
- Depth: For bulk storage like grains, use probes or scoops to reach deeper layers where infestations might be concentrated.

Sampling Method:

- Cleanliness: Use clean and sanitized tools to prevent cross-contamination between samples and storage units.

- Minimizing Damage: Choose sampling methods that minimize damage to the produce while effectively collecting potential pests. For fruits and vegetables, use forceps or gloved hands for gentle handling.
- Variety: Depending on the pest type, consider targeting specific areas they prefer. For example, moths lay eggs on the exterior of grains, while weevils burrow inside kernels.

Sample Handling and Analysis:

- Labeling: Clearly label each sample with identifiers like date, location within the storage unit, type of produce, and suspected pest (if any).
- Storage: Keep samples cool and dry until analysis, following any specific lab instructions. Avoid exposing them to extreme temperatures or sunlight.
- Analysis: If you don't have the expertise or equipment to analyze the samples yourself, send them to a qualified laboratory for pest identification and infestation level assessment.

Additional Tips:

- Consult experts: Seek advice from agricultural extension services or pest control professionals for specific sampling recommendations based on your crop, storage conditions, and suspected pest concerns.
- Maintain hygiene: Implement strict sanitation practices in your storage facility to minimize pest attraction and breeding grounds.
- Preventative measures: Combine sampling with proper storage practices like temperature and humidity control, proper ventilation, and exclusion barriers to prevent infestations in the first place.

By following these guidelines and adapting them to your specific needs, you can effectively utilize sampling to detect and manage pest infestations in your stored produce, minimizing losses and maximizing quality.

Remember, early detection and intervention are key to minimizing the impact of pests on your stored produce. Don't hesitate to ask if you have any further questions about specific types of pests, storage conditions, or pest control strategies.

4.4 Controlling storage pests

Controlling storage pests requires a multi-pronged approach, combining preventative measures with proactive and reactive strategies. Here's a comprehensive guide to effectively manage pests in your stored produce:

Preventative Measures:

- Hygiene: Keep your storage facility clean and tidy. Remove old produce residues, dust, and spilled grains, which attract and harbor pests. Regularly clean and sanitize the space and equipment.
- Sealing: Ensure your storage structure is airtight and pest-proof. Seal cracks and crevices, repair damaged doors and windows, and use screens on ventilation openings.
- Temperature and Humidity Control: Maintain cool and dry conditions in your storage area. Most pests thrive in warm and humid environments. Use thermometers, hygrometers, and ventilation systems to control these factors.
- Proper Storage Practices: Store different types of produce separately to prevent cross-contamination of pests. Follow recommended storage temperatures, humidity levels, and stacking practices for each type of produce.
- Natural Deterrents: Utilize natural pest repellents like diatomaceous earth, dried herbs like lavender or mint, or essential oils to create an unwelcome environment for pests.

Proactive Measures:

- Monitoring: Regularly inspect your stored produce for signs of infestation like webbing, frass (insect droppings), damaged kernels, or unusual activity. Use traps and monitoring devices to detect early pest presence.
- Sampling: Take samples of stored produce and send them to a lab for pest identification and assessment of infestation levels. This helps guide targeted control measures.

- Biological Control: Introduce natural predators or competitors of the specific pest species in your storage. This can be an eco-friendly and long-term solution for certain pests.

Reactive Measures:

- Chemical Control: Use insecticides or fumigants as a last resort if other methods fail or the infestation is severe. Choose safe and authorized products, follow application instructions carefully, and wear protective gear. Consider targeted and localized applications to minimize environmental impact.
- Physical Removal: Manually remove visible pests like adult insects or larvae with gloved hands or vacuums. This can be effective for small infestations or isolated areas.
- Temperature Manipulation: Extreme temperatures can be lethal for certain pests. However, this method requires careful control and might not be suitable for all produce types.

Additional Tips:

- Seek professional advice: Consult with pest control professionals or agricultural extension services for tailored recommendations based on your specific storage situation, pest type, and produce.
- Integrated Pest Management (IPM): Combine different control methods from preventative to reactive stages for a holistic and sustainable approach to pest management.
- Record-keeping: Document your pest control efforts, including observations, interventions, and their effectiveness. This helps track progress and adapt strategies over time.

By implementing these strategies and adapting them to your specific needs, you can effectively control storage pests and maintain the quality and value of your stored produce. Remember, prevention is key, so prioritize hygiene, proper storage practices, and early detection to minimize pest impacts.

4.5 Fumigating enclosed storage area and following integrated pest management strategy.

Fumigation and Integrated Pest Management (IPM) in Enclosed Storage Areas

Fumigation can be a powerful tool for controlling pests in enclosed storage areas, but it should always be part of a comprehensive Integrated Pest Management (IPM) strategy. Here's a breakdown of both approaches and how they can be combined effectively:

Fumigation:

- Benefits: Offers broad-spectrum control, eliminating various types of pests like insects, rodents, and even some fungi. Can be effective for reaching into cracks and crevices where other methods might struggle.
- Drawbacks: Highly toxic chemicals are used, requiring strict safety precautions and specialized training for application. Can harm beneficial insects and other organisms within the environment. Expensive and often disruptive to storage operations.
- Considerations: Only use as a last resort when other IPM methods have failed or are impractical. Carefully select target pests to choose the appropriate fumigant type. Ensure proper sealing of the storage area and follow all safety protocols during application and aeration.

Integrated Pest Management (IPM):

- Benefits: A holistic approach that focuses on preventing pest problems in the first place while minimizing reliance on harsh chemicals. Promotes long-term pest control by addressing underlying conditions that attract and support pest populations.
- Components: Includes preventative measures like sanitation, proper storage practices, temperature and humidity control, natural deterrents, and monitoring for early

detection. May also involve targeted interventions like biological control or localized chemical applications.

- Considerations: Requires a proactive and planned approach. May take longer to achieve results than fumigation, but offers more sustainable and environmentally friendly pest control.

Combining Fumigation and IPM:

- Fumigation as a shock treatment: Use fumigation as a one-time intervention to eliminate existing pest populations, followed by implementing a strong IPM program to prevent re-infestation.
- IPM as the foundation: Focus on preventative and proactive IPM strategies and only consider fumigation when absolutely necessary as a targeted approach for specific, persistent pest problems.

Additional Tips:

- Seek professional advice: Consult with certified pest control professionals for guidance on the most effective and safe pest control strategy for your specific storage area and produce type.
- Document and monitor: Keep records of your pest control efforts, including fumigation applications and IPM methods used. Regularly monitor the storage area for signs of pest activity to adjust your strategy as needed.
- Prioritize sustainability: Aim for long-term solutions by combining effective pest control with practices that minimize environmental impact and promote healthy storage conditions.

Remember, fumigation should be a carefully considered intervention within a comprehensive IPM approach. By prioritizing prevention, monitoring, and targeted control methods, you can achieve effective pest management while protecting your stored produce and the environment.

Feel free to ask further questions about specific pests, storage conditions, or any aspect of pest control strategies you'd like to explore in more detail. I'm here to help you keep your enclosed storage area pest-free and your produce safe.

4.6 Identifying the sources of any infestations and taking action to control them

Identifying the source of a pest infestation is crucial for effectively controlling it and preventing future problems. Here's a guide to help you pinpoint the cause and take appropriate action:

Investigating the Infestation:

- Inspect: Examine the infested area thoroughly, searching for signs of the pest itself, like droppings, frass, webbing, or damage to your stored produce. Pay attention to specific locations where the infestation seems concentrated.
- Identify the Pest: Knowing the type of pest you're dealing with is key to understanding its habits and vulnerabilities. Take pictures or collect samples if necessary for professional identification.
- Trace the Entry Point: Look for potential entry points into your storage area, such as cracks, crevices, damaged doors or windows, ventilation openings, or gaps around piping.
- Consider External Factors: Think about possible sources of the infestation outside the storage area, like nearby fields, previous infestations in the building, or contaminated materials brought in.

Taking Control Measures:

- Sealing Entry Points: Once you've identified the entry points, repair cracks, seal gaps, and install screens on ventilation openings to prevent future access.

- Targeted Pest Control: Based on the identified pest type, choose specific control methods like traps, baits, biological control agents, or targeted insecticide applications. Prioritize environmentally friendly methods whenever possible.
- Hygiene and Sanitation: Clean and sanitize the infested area thoroughly to remove any remaining pests and their breeding grounds. Dispose of infested materials safely and follow safe practices when handling cleaning chemicals.
- Monitoring and Follow-up: Regularly monitor the area for signs of pest activity and repeat control measures if necessary. Keep a record of your observations and actions to track progress and adjust your strategy as needed.

Additional Tips:

- Professional Assistance: In severe infestations or when unable to identify the pest, seek professional help from pest control experts. They have the experience and expertise to diagnose the problem and recommend the most effective control strategies.
- Integrated Pest Management (IPM): Combine multiple control methods within an IPM framework for long-term success. This approach emphasizes preventative measures like proper storage practices, temperature and humidity control, and natural deterrents alongside targeted interventions when needed.
- Documentation: Keep detailed records of your observations, pest identification, control measures taken, and their effectiveness. This information is valuable for future reference and can help you develop a more effective pest management plan over time.

By carefully investigating the source of your infestation, choosing appropriate control measures, and implementing preventative strategies, you can successfully take control of the pest problem and protect your stored produce. Remember, early detection and proactive action are key to minimizing damage and achieving long-term pest control success.

Feel free to ask any further questions about specific pests, control methods, or any aspect of your situation that you'd like to discuss in more detail. I'm here to help you identify the source of your infestation and implement effective solutions.

4.7 Undertaking pest control activities in line with the OHS hazard guidelines

Undertaking pest control activities while adhering to Occupational Health and Safety (OHS) hazard guidelines is crucial for protecting yourself and others from potential harm. Here are some key aspects to consider:

Before starting:

- Risk Assessment: Conduct a thorough risk assessment of the specific task and chemicals involved. Consider the type of pest, the chosen control method, potential hazards arising from the chemicals, and the environment where the activity will take place.
- Personal Protective Equipment (PPE): Choose and wear appropriate PPE based on the risk assessment. This may include gloves, goggles, respirators, coveralls, and boots. Ensure the PPE is in good condition and fits properly.
- Training: Ensure everyone involved in the pest control activity has received proper training on safe handling, application, and disposal of the chosen chemicals, as well as emergency procedures in case of exposure.
- Communication: Inform colleagues and any occupants in the vicinity about the planned pest control activity and any necessary precautions they should take.

During the activity:

- Follow Label Instructions: Meticulously follow the manufacturer's instructions on the pesticide label regarding mixing, application rates, dilution, and application methods. Do not deviate from the recommended procedures.
- Minimize Exposure: Avoid direct contact with pesticides by wearing appropriate PPE and avoiding unnecessary contact with treated areas. Wash hands thoroughly after handling chemicals or PPE.
- Safe Application: Use appropriate equipment for applying pesticides, such as sprayers or dusters, and ensure they are in good working condition. Avoid spraying directly on people or food items.

- Ventilation: When working with pesticides indoors, ensure proper ventilation to avoid inhalation of airborne chemicals. Open windows and doors or use exhaust fans for adequate air circulation.
- Spill Response: Have a plan for handling spills of pesticides. Use designated spill kits and dispose of contaminated materials safely according to regulations.

After finishing:

- Decontamination: Wash exposed skin thoroughly with soap and water after removing PPE. Clean and properly store or dispose of contaminated equipment and clothing.
- Waste Disposal: Dispose of unused pesticides and contaminated materials as per the manufacturer's instructions and local regulations. Never dispose of chemicals down drains or in the trash.
- Monitoring: Monitor the treated area for potential adverse effects of the pest control activity, both on humans and the environment. Report any unexpected issues to relevant authorities.

Additional Tips:

- Seek professional help: If you are unsure about any aspect of the pest control activity or if the infestation is extensive, consider seeking assistance from a licensed pest control professional.
- Emergency procedures: Ensure everyone involved knows emergency procedures in case of accidental exposure to pesticides. Have access to emergency contact information and first-aid supplies readily available.
- Stay informed: Regularly update your knowledge about OHS regulations and best practices for safe pest control. Attend training courses and consult relevant resources to stay informed about the latest safety guidelines.

By following these guidelines and actively prioritizing safety throughout the pest control process, you can significantly reduce the risk of accidents and protect the health and well-being of everyone involved. Remember, responsible and OHS-compliant pest control practices are essential for both effective pest management and ensuring a safe working environment.

4.8 Chemical handing and dangerous goods requirements

Chemical handling and dangerous goods requirements are crucial for protecting yourself, others, and the environment. These regulations ensure safe storage, transportation, and use of potentially hazardous materials. Here's a breakdown of key aspects to consider:

General Requirements:

- **Risk Assessment**: Always conduct a risk assessment before handling any chemical. Identify its hazards, potential exposure routes, and necessary control measures.
- **Personal Protective Equipment (PPE):** Use appropriate PPE based on the risk assessment. This may include gloves, goggles, respirators, aprons, and boots. Choose the correct level of protection for the specific chemical and activity.
- **Labeling and Safety Data Sheets (SDS):** Ensure all chemicals are properly labeled with their name, hazard symbols, and risk phrases. Keep readily accessible Safety Data Sheets (SDS) for each chemical, containing detailed information about its properties, hazards, and safe handling practices.
- Training: All personnel handling chemicals must receive adequate training on safe handling procedures, identification of hazards, emergency response protocols, and spill containment measures.

Storage Requirements:

- Segregation: Store chemicals separately based on their compatibility and hazard class. Avoid storing incompatible chemicals together to prevent potential reactions.
- Secondary Containment: Use secondary containment structures like trays or bunds to contain spills and prevent environmental contamination.
- Temperature and Humidity Control: Maintain appropriate storage temperature and humidity for each chemical to ensure its stability and prevent degradation.
- Security: Implement measures to secure hazardous materials and prevent unauthorized access.

Transportation Requirements:

- Packaging and Labeling: Package chemicals according to international and national regulations. Use appropriately labeled and certified packaging for the specific hazard class and transport mode.
- Documentation: Prepare and carry required documentation, such as shipping papers and declarations, according to transport regulations.
- Emergency Response: Ensure drivers and personnel involved in transport are trained on emergency response procedures for spills, leaks, or fires.

Regulatory Compliance:

- Know the regulations: Familiarize yourself with relevant regulations and licensing requirements for chemical handling and storage in your region. These may vary depending on the type of chemicals and your industry.
- Inspections and Audits: Be prepared for periodic inspections and audits by regulatory authorities to ensure compliance with safety regulations.
- Recordkeeping: Maintain records of your risk assessments, training activities, chemical inventories, and incident reports for regulatory compliance and future reference.

Additional Tips:

- Consult experts: If you have any doubts about chemical handling procedures or regulatory requirements, seek guidance from safety experts or regulatory authorities.
- Seek continuous improvement: Regularly review and update your safety procedures and training programs to reflect best practices and changes in regulations.
- Promote a safety culture: Foster a culture of safety within your workplace by actively promoting safe work practices and encouraging the reporting of any unsafe conditions or incidents.

By adhering to these requirements and best practices, you can ensure safe and responsible handling of chemicals and dangerous goods, minimizing the risk of accidents and protecting the health and well-being of yourself, others, and the environment.

Remember, chemical safety is a shared responsibility. We all have a role to play in ensuring the safe handling and storage of these materials.

4.9 Recording and reporting treatments made to the stored produce and storage facilities.

Recording and reporting treatments made to stored produce and storage facilities is crucial for several reasons:

Benefits of Recording and Reporting:

- Traceability: Provides a clear record of the types, quantities, and dates of treatments applied to the produce and facilities, enabling traceability in case of quality issues or foodborne illness outbreaks.
- Monitoring and Evaluation: Allows you to monitor the effectiveness of different treatments over time and adjust your strategy as needed. This data can be invaluable for optimizing pest control, hygiene, and storage conditions.
- Regulatory Compliance: May be required by certain regulations or standards depending on the type of produce, storage facility, and market. Proper documentation helps demonstrate compliance and avoid potential penalties.
- Knowledge Sharing: Sharing treatment records with other producers or facility managers can contribute to wider knowledge sharing and the development of best practices within the industry.
- Decision-making: Provides a valuable resource for future decision-making about storage and pest management strategies. By analyzing past data, you can identify patterns, predict potential issues, and make informed decisions to improve your operations.

What to Record:

- Date and Time: Record the exact date and time of each treatment application.

- Type of Treatment: Specify the specific treatment used, including brand name, active ingredient(s), and application method (e.g., fumigation, spray, trap).
- Target Pest: Identify the specific pest or problem the treatment was intended to address.
- Application Details: Record the quantity of treatment applied, treated area or produce quantity, and any specific instructions or deviations from manufacturer guidelines.
- Observations and Results: Note any observations during or after the treatment, such as pest activity, product damage, or unexpected outcomes.
- Storage Facility Conditions: Include information about the ambient temperature, humidity, and any other relevant conditions in the storage facility during treatment.

How to record:

- Use a standardized format for consistency and ease of analysis. This can be a dedicated logbook, digital spreadsheet, or a specific software system.
- Ensure clear and legible entries with concise but informative details.
- Consider photographic documentation for visual reference, especially for specific actions or observations

Reporting:

- Frequency: Depending on your specific needs and regulations, report treatment information regularly, such as monthly or quarterly.
- Format: Choose a format that is easily accessible and understandable, such as spreadsheets, databases, or standardized reporting forms.
- Recipients: Share reports with relevant stakeholders, such as regulatory authorities, buyers, or other producers, as required or appropriate.

Additional Tips:

- Standardize your recording system: Develop a clear and consistent system for recording treatment details to ensure accuracy and ease of reference.
- Use technology: Consider using digital tools or software to record and store treatment information for convenient access and analysis.

- Train personnel: Ensure all personnel involved in treatment applications understand the importance of recording details and how to do it accurately.
- Regularly review and update: Regularly review your reporting system and adjust it as needed based on changes in regulations, storage practices, or technology.

By diligently recording and reporting treatments made to your stored produce and storage facilities, you can reap significant benefits for traceability, monitoring, compliance, and overall optimization of your operations. Remember, effective record-keeping and reporting contribute to a safer, more efficient, and sustainable food system.

By establishing a detailed and efficient system for recording and reporting treatments in your storage facilities, you can improve the safety, quality, and long-term viability of your stored produce while contributing to knowledge sharing and best practices in the field.

Self-Check 4	**Written Test**

I. True or False Questions

1. Insects, mites, and molds that cause grain to heat and lose condition are active at low temperatures.
2. Moisture content below 13% arrests the growth of most molds and mites.
3. Insects have infested stored food products since the beginning of human civilization.
4. Inadequate drying of produce can lead to microbial infection in storage.
5. Aflatoxin contamination in maize grains is encouraged by adequate drying.

II. Multiple Choice Questions

1. **Which of the following is NOT a factor contributing to grain heating and deterioration in localized parts of the bin?**

   A) Moisture migration

   B) Inadequate drying

   C) Physical damage

   D) Poor storage methods

2. **What is the ideal condition for practical farm storage?**

   A) Moisture content of 15% and a temperature of 5 °C

   B) Moisture content of 10% and a temperature of 15 °C

   C) Moisture content of 12% or less and a temperature of 3 °C or less

   D) Moisture content of 20% and a temperature of 10 °C

3. **Which of the following is a preventive pest control practice for home storage?**

   A) Maintaining a warm, humid climate

   B) Using cardboard boxes for storage

   C) Keeping the storage area clean

D) Using preventive pest control products

4. **What is the recommended moisture content to limit the development of most stored grain insects and pests?**

   A) Below 8%

   B) Below 13%

   C) Above 15%

   D) Above 20%

5. **What is the temperature at which insects, mites, and molds that cause grain to heat and lose condition are inactive?**

   A) Below 5 °C

   B) Below 10 °C

   C) Below 3 °C

   D) Below 15 °C

III. Short Answer Questions

1. List Losses due to poor storage
2. What are the Factors Contributing to Storage Problems
3. What Bio-agents are used to Control Stored-Product Pests

Reference Materials

Ingram, J. S., and J. R. O. Humphries, Cassava storage review, Trop. Sci. 14:131 (1972).

Field crop production material's transportation. https://www.youtube.com (access date 20/01/24)

FAO, Appropriate seed and grain storage systems for small scale farmers, FAO, 2014 (access date 18/01/2024)

Principles of Field Crop Production. https://www.youtube.com(access date 29/08/22)

M. Avung'ana Mushira, FAO Consultant, Manual on Grain management & Equipment Maintenance in silos (access date 15/01/2024)

International Journal of Sciences: Basic and Applied Research (IJSBAR), http://www gssrr.org/index.php?journal=Journal of Basic and Applied Research (access date 10/01/2024)

8. https://youtu.be/_W4PH6FqwDA (access date 22/01/24)
9. https://www.perplexity.ai/search/Identification-of-problems su3uzybQQGmWDYsh5n0d3A?s=c (access date 17/01/2024)
10. https://youtu.be/XoJFhX9VCFE (date accessed 20/01/2024)
11. https://www.youtube.com/watch?v=m0Xqs_1-Qk8 (date accessed 20/01/2024)
12. https://youtu.be/YnKXvtWZ-LE (date accessed 20/01/2024)
13. https://telesense.com (date accessed 20/01/2024)
14. https://youtu.be/5F2alCp-eE0 (date accessed 20/01/2024)

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The experts who developed the learning guide

No	Name	Qualification	Educational background	College	Phone number	E-mail
1	Dabi Kebede	MSc	Agronomy	Agarfa	0922685140	dhabik@gmail.com
2	Eyob Birhane	MSc	Agronomy	Alagie	0913047105	yeroosaan@gmail.com
3	Tefera Merga	MSc	Plant protection	Holleta	0956052325	tafemerga@gmail.com
4	Isa Ibrahim	MSc	Agronomy	Gewane	0917388460	isaibrahim67@gmail.com
5	**Muftah Mohammed**	**MSc**	**Horticulture**	**Mizan**	**0979729703**	**muftahkawo@gmail.com**