UNIT 3 HARVESTING, TRANSPORTATION, HANDLING AND STORAGE

Structure

3.0 OBJECTIVES

After reading this unit, you should be able to:

- explain different methods of harvesting and harvesting practices for cereals, pulses and oilseeds.
- learn various methods of transportation of foodgrains and their suitability.
- know about different methods of packing and storage.
- identify various material handling devices.
- learn about various factors which cause damage during storage.
- explain different storage structures and their benefits.
- know about the controlled and modified atmosphere storage for food grains.

3.1 INTRODUCTION

For sustainable development of agriculture and enhancement of productivity, improved farm implements, and machinery are important inputs to achieve timeliness of farm operations, which in turn enables efficient use of other precious inputs such as high yielding seeds, chemicals, fertilizer and water. Similarly, harvesting, transportation, handling and storage are very important unit operations once a good crop is raised with all care and energy.

Farmers practices in the above areas were mostly based on the traditional practices, which as many of us know, involve high drudgery, time and labour consuming and are not efficient to give us quality processed products. Due to the research and

development initiation by many agricultural universities and research organizations/ institutions, many tools and equipments have been developed to help farmers. As you are aware, India is a vast country and we grow all types of cereals, pulses and oilseeds. Interestingly, we find today, many new developments to address the issues of harvesting, transport, handling and storage aspects of these crops. Some examples would be a serrated sickle to replace the age old locally made sickle for harvesting manually. Further, in the form of mechanization, power operated harvesters such as self-propelled reapers, combines, diggers for groundnut and tuber crops have been developed and are already in use in various parts of the country.

The age old methods of transportation of threshed grains to the farm house and also to the mandies or markets were traditionally on head and by local bullock carts. These have been replaced by tractor drawn trailers and trucks, there by the produce is transported with minimum losses and work is completed in a very less time. For handling the grain in a food industry, many types of handling and conveying equipments have been developed and adopted for bulk handling in an efficient way.

Storage is another aspect in the post harvest chain. At the national level, we are loosing about 3% of the grains due to prevailing poor storage practices. Most of the storage practices are traditional. The damages in storages are many such as field infestation, infestation in transport, infestation of stores and stocks. These are simple and can easily be overcome by any farmer adopting scientific techniques. The improved technologies have been slowly getting into the adoption by the farmers and technologies have been under promotion in the rural areas.

The country's annual post harvest losses of grains are nearly about 10%. Out of this, the storage losses alone are about 3% which are very high. The simple concepts on which grain can be stored such as moisture content and temperature of the environment are not properly understood by the farmers yet.

Lastly, cold storages are important facilities for safe and long storage of grains, and other horticultural products. The cold storages control, bacteria growth and respiration rate of produce preventing produce spoilage.

All these issues have been briefly discussed in the following text to make you understand the importance of the developed tools and equipments in the Indian agriculture.

3.2 HARVESTING

The goals of harvesting are to gather a commodity from field at the proper level of maturity / moisture content of produce, with a minimum of damage and field loss, as rapidly as possible, this has to be achieved at a minimum cost. In today's agriculture, these goals are achieved through manual and mechanical harvesting equipments for drudgery, time and labour saving. It involves cutting, digging, picking, laying, gathering, curing, transport and stacking of the crop. In case of cereals like wheat and paddy, the plants are straight and smooth and ears containing grains are at the top. On the other hand most of the oilseeds and pulse crops have branches creating problem for easy harvesting either by manual or mechanical means. Harvesting is the last step in crop production and is also a very important unit operation.

Traditional Harvesting (Manual / Hand Harvesting)

We would be discussing in brief the harvesting methods that are being traditionally followed in the country. The harvesting of crops is traditionally done by manual methods. Harvesting of major cereals, pulse and oilseed crops are done by using sickles. On the other hand harvesting of tuber crops is done using a country plough or a spade. Interestingly, all these traditional methods involve drudgery and take long time.

Some Advantages

1. Humans can accurately select for maturity, allowing accurate grading and multiple harvest
2. Humans can handle the produce with minimum damage
3. Rate of harvest can be increased by hiring more workers, and
4. It requires minimum capital investment

The main problems with manual harvesting are labour availability and management during peak season, drudgery to humans and time consuming. Timely harvesting is a critical issue to avoid losses, and based on the prevailing cost of labour, the cost of harvesting an acre of crop is much higher than mechanical harvesting.

Mechanical Harvesting

As we know already that timeliness of harvest is of prime importance. During harvesting season, often rains and depressions occur causing considerable damage to standing crops. The use of machines can help to harvest at proper stage of crop maturity and reduce drudgery and operation time. Considering these factors, improved harvesting tools, equipments and combines are being accepted by the farmers. Further, effective use of mechanical harvesters requires operation by dependable, well trained people. Improper operation results in costly damage to expensive machinery and cause crop damages also. Therefore, the person using the machineries and harvesters should be well trained before using them.

Advantages

1. Large area can be harvested in an unit time
2. Minimum drudgery and labour saving

Disadvantages

1. Processing and handling capacity may not be able to handle high rate of harvest
2. There are social impacts to lower labour requirements

Different types of mechanical harvesting tools/equipments for different crops

Let us know about technology development and availability of different harvesting tools and equipment for various field crops. You will certainly appreciate the development of many mechanical harvesters that have been the result of research by various institutions in the country.

Serrated blade sickle

It has a serrated curved blade and a wooden handle. The handle of improved sickle has a bend at the rear for better grip and to avoid hand injury during operation. Serrated blade cuts the crop by principle of friction cutting like in saw blade. The crop is held in one hand (generally in left hand) and sickle is pulled along an arc for cutting by the right hand. You can cut the crop close to the ground using a

modified handle. The energy requirement is about 80-110 man-h/ha. It is very effective for harvesting of wheat, paddy and grasses. Few examples are : Naveen sickle and Punjab sickle.

Vertical Conveyor Reaper

The recent development in harvesting machinery is the reaper. Reapers are used for harvesting of crops mostly at ground level. In a reaper, you can see a crop-row-divider, cutter assembly, feeding and conveying devices. The most popular reaper in the field is the vertical conveyor reaper.

In this reaper, you can see a crop row divider, star wheel, cutter bar, and a pair of lugged canvas conveyor belts. The machine cuts the crop and conveys vertically to one end and windrows (meaning, lays on the ground uniformly) the crop on the ground uniformly. Collection of crop for making bundles later is easy and is generally done manually. Commercially, farmers can get self-propelled walking type, self-propelled riding type and tractor mounted type reapers. These types of reapers are suitable for wheat and rice crops. The field capacities of these machines vary from 0.20-0.40 ha/h.

Diggers

The design of groundnut and potato diggers of animal drawn and tractor drawn types are now available. The digging unit consists of V-shaped or straight blade and lifter rods are attached behind the share. These are known as lifter rods and are spaced to allow the clods and residual materials to drop while the implement is in operation. One has to collect the plant along with pods / tubers manually, once dug. These tools are labour and time saving and a boon to groundnut growers.

Combines

Various designs of combine harvesters having 2-6m long cutter bars are commercially available. You will see more than one unit operation in this machine. The function of a combine harvester is to cut, thresh, winnow and clean grain/seed. It consists of an header unit, a threshing unit, a separation unit, cleaning unit and grain collection unit. The function of header is to cut and gather the crop and deliver into the threshing cylinder. The rotating reel pushes the straw back on to the platform while it is cut by the cutter bar. The crops are threshed between cylinder and concave due to impact and rubbing action. The threshed material is shaken and tossed back by the straw rack. The grain moves and falls through the openings in the rack onto the cleaning shoe while the straw is discharged at the rear. The cleaning mechanism consists of two sieves and a fan. The grain is conveyed with a conveyor. In other words, you can observe that this particular machine does harvesting, cleaning of grains, and finally cleansed grains are stored in a hopper for bagging.

Factors affecting performance of harvesting machine

a) *Crop Factors*

   Crop variety

   Ambient temperature

   Maturity of crop

   Crop moisture

   Crop density

b) *Machine factors*

   Shape and size of crop divider

Reel position and speed

Cutting blade shape and speed

Conveyor speed

Machine vibrations

Machine settings

c) *Operational Factors*

Height of cut

Operation speed

Field and Crop Requirements for Mechanical Harvesting

While attempting to use mechanical harvesters successfully you require to know the following points :

i. Harvesting field must be fairly level without any undulations to facilitate smooth operation of the machine

ii. For small reapers crops should be grown in rows

iii. Water should be drained at least a week early and field should be dry while harvesting rice crop

iv. Field efficiency of harvesting is high in large fields

Check Your Progress 1

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. What is the most important traditional tool used for harvesting in India; could you give some advantages and disadvantages of manual harvesting ?

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2. Do you see advantages of using mechanical harvesters ? List a few of them.

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3. What are the field and crop requirement for mechanical harvesters?

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4. List the factors affecting the mechanical harvesters' performance.

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3.3 HARVESTING PRACTICES FOR IMPORTANT CEREALS, PULSES AND OILSEED CROPS

Harvesting of different crops need different attention. Harvesting of paddy and soybean has to be done carefully as the matured grains easily detach from the earheads / pods. Therefore, you cannot use fast working tools or machines for these crops. Further, bengalgram and greengram are to be harvested at ground level. Oilseed crops pose different type of problems. Safflower is a spiny crop and is difficult to harvest even manually. Harvesting of sunflower is easier as only flower heads to be collected. Farmers use different methods for harvesting of mustard and pigeon pea (redgram). Most farmers harvest these crops at branch level, but small farmers harvest at ground level. Harvesting of root cops require digging, shaking to remove the adhering soil, windrowing and picking.

The harvesting methods followed by farmers for major crops are given below for your further learning :

Cereals crops

a) Wheat and Rice

Harvesting cereal crops is traditionally done by using local sickle. Improved self serrating type sickles have been developed and you can use them more efficiently. In addition, you have the following machines available for efficient harvesting of these crops:

i. Self-propelled walking type reaper

ii. Tractor front and rear mounted reapers

iii. Combine harvesters

b) Sorghum

Harvesting by a local sickle is the traditional practice by farmers. Suitable mechanical harvesters are yet to come in India. The research and development is in progress.

c) Maize

Farmers collect (harvest) the cobs manually from the main plant. Combines equipped with corn-head snapping unit are being used in developed countries like Canada and America.

Pulse crops

a) Bengalgram

Once again, for this crop also, harvesting is by local sickle. Improved serrated sickles are being popularized among pulse growing farmers.

b) Pigeon pea (redgram)

Traditionally this crop is harvested at ground level by using a sickle or a chopper. Improved serrated sickles are used these days. No suitable harvesting machine is available yet in the country.

c) Urad, Moong & Cowpea

Traditionally these crops are harvested at ground level by using a sickle or a chopper. Improved serrated sickles are also in use.

Oilseed crops

a) Groundnut

Digging groundnut crop with a country plough or a blade hoe at proper soil moisture level is the common traditional practice. Manual pulling of crop and gathering of pods using a hand hoe is another traditional method of harvesting.

Animal drawn and tractor operated diggers are the improved implements that have been developed for groundnut harvesting. You can also see blade harrow widely used for digging groundnut in Gujarat. Tamil Nadu Agricultural University and Central Institute of Agricultural Engineering designs are some of the improved animal drawn groundnut diggers that are commercially available. Tractor operated groundnut diggers have a wide blade which covers 1.25 to 2 meter width and operates at 10 to 15 cm depth in the soil.

b) Mustard

The traditional practice is to harvest mustard manually using sickles. In tall varieties, farmers cut plants above ground level and leave long stubbles in the field which are subsequently ploughed in.

Mechanical harvesting of crop is carried out by the following type of machines:

i. Self- propelled walk behind type vertical conveyor reaper
ii. Tractor front or rear mounted pto (power take off) operated reaper, and
iii. Combine harvester

c) Soybean

Harvesting of soybean crop by the local sickle is the traditional farmers practice. However, improved serrated sickle is being recommended as plant stem is about 8 to 12 mm thick.

You have the following harvesting machines that can be used for harvesting of soybean :

i. Self vertical conveyor reaper windrower
ii. Tractor rear mounted reaper, and
iii. Combine harvester

d) Sunflower and Castor

The prevailing traditional practice is to manually harvest sunflower heads and castor plants. At present, suitable machines are not available for harvesting of these crops. Harvesting of whole plant would require separation of flower heads for threshing. Consequently, the time saved by harvesting the whole plants would not reduce the labour requirement.

e) Safflower

The farmers practice is to manually harvest the crop using sickles. Because of thorny and spiny nature of crop, harvesting and handling of safflower plants is a complex unit operation. Use of hand gloves and covers on legs and arms is recommended when harvesting. You require to use hay forks for gathering and stacking the plants in the field and while loading to trailers for transportation to the threshing yard.

For mechanical harvesting of safflower the following machines are recommended:

i. Self-propelled (1 meter wide) vertical conveyor reaper

ii. Combine harvester

Further, in tall varieties, plants in rows are entangled with each other causing difficulty in harvesting. Therefore, in combine harvesters, a vertical cutter bar is used at the outer end to cut and separate the plants of harvested row.

Check Your Progress 2

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. List a few tools for harvesting of cereals like wheat and paddy crops.

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2. List a few tools for harvesting of pulses. Do you see changes in the tool types used.

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3. Give few examples of harvesting tools used for oilseeds harvesting. What are the important mechanical harvesters already in use by farmers?

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3.4 METHODS OF TRANSPORTATION AND THEIR SUITABILITY

Rural Transportation

After harvesting of crops, the next unit operation in the chain is the transportation of crops from the field to the threshing yard, from threshing yard to the farm house. The various animals used for field operations or transportation purposes are bullocks, horses, mules, camels and buffaloes. You may be aware that in India, about 50% of farm power is provided by bullocks. According to various expert estimates, about 10 million kilometer freight is carried by carts all over the country and nearly 70% of the arrivals of agricultural products at mandies or markets, are carried by bullock carts. As a result, there is a heavy investment in animal drawn transportation system, which is estimated to be around Rs. 3000 crores. The bullock cart transportation system is an extremely important part of India's rural transportation. The clumsy looking, slow moving bullock carts (Fig. 1), the traditional lifeline of the rural community in India, can not only help ease the fuel crisis but also save the environment from pollution. The bullock carts will generate an annual earnings of about Rs.2000 crores.

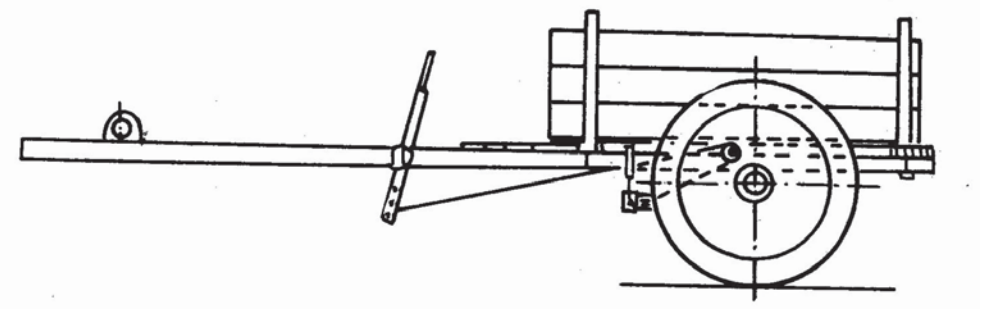

Fig. 1: A schematic of a bullock cart

There are an estimated 20 million bullock carts with 25 million people depending on them for their sustenance, especially, the farmers who simply can't do without them.

You will surprised to know that the bullock carts carry about 45 to 55 billion tonnes of agricultural produce and related goods annually against 200 million tones of goods by other means of transport in other metropolitan cities. Bullock cart is the cheapest form of transport, but also the only form of transport available in some remote corners of the country. Therefore, improvement in designs of bullock carts can further enhance efficiency and earnings.

Tractors are the other important source of transportation in agriculture. There were only 8635 imported tractors in use in 1951. The local tractor production started in 1961-62 with 880 numbers. Today India is manufacturing more than 2,62,000 tractors per year (1999-2000) with a total estimated population of more than 1.80 million in 1996-97. The growth has been about 10% per annum since 1970-71. The average availability of tractor in the country is about 78 ha/tractor or 12.85 tractor / thousand ha. This varies from state to state from 14 to 1145 ha/tractor. The use of tractor in agriculture is limited to about 35%, but for the rest of time they are used for transportation of other goods. Similarly, Power Tiller was introduced in the country in the 60s. The use of power tiller is presently more in rice and sugarcane producing areas of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, West Bengal, Orissa, Bihar and Maharashtra states. As in the case of tractors, the power tillers are also used for transportation of produce from the harvested site to threshing place, transporting of manures and fertilizers to the fields, besides ploughing operations.

These days of modern agriculture, mini trucks are also used in rural locations closer to cities and towns for transportation.

Transportation of grains

Transportation of food grains is an important activity for two reasons. Firstly, it presents logistic problems to the farmers to ensure that the grain is taken out immediately after bagging to minimize losses due to deterioration in grain quality. It may happen especially during the off-season harvest. Secondly, transportation costs are important components of the total grain production cost.

Grain after harvesting and threshing are bagged. They may be transported to the procurement centers, directly to the milling complexes or to any licensed or private buyers. Transportation of grains are mainly carried by bullock or animal carts, trucks, tractor with trailers, etc. At the procurement centers, selling and buying of grains are concluded. After buying, it becomes the reasonability of the buyers to store grains and finally transport to the milling complexes.

These days, you will experience an increased demand for transportation services in shipping of agricultural products from the production sites. This has been mainly contributed by inter–regional agricultural products, growth in population and increase in demand for food.

Check Your Progress 3

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. Which is the most important rural transport vehicle used by our farmers?

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2. List down other vehicles used for grains transport in today's agriculture.

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3.5 PACKING, STORAGE AND TRANSPORTATION (BAGS AND BULK)

Packing

There was a time when families were pretty much self sufficient and not part of a complex and interdependent society. They grew most of their own food. And, how well they ate depended on the climate where they live, the soil and what season of the year it happened to be. But there was a time when we were basically a farm-oriented society. As we became more urbanized and great sprawling cities developed, the way we could obtain our basic necessities changed.

Packaging has played a vital role in food handling chain. Due to packaging technology distribution of all types of products in abundance is now possible from one area to the other areas.

Packaging performs a number of functions in bringing products into consumers' hands. Packaging reduces food costs by reducing processing cost. Food products can be processed where they are grown. With this, waste stays at the processing point; shipping and transportation costs are reduced. Packing protects the food product during distribution and storage against moisture, dirt, micro-organisms which can cause severe spoilage. This is one of the most important issue you should remember in agricultural products safe handling.

Packaging protects against loss of ingredients, loss of fragrance/aroma, and hence food retains its nutritional value. Another important function of packing is its ability to communicate with the consumer (buyer). The package should communicate identity of content, brand, ingredients, instructions, cautions and warranties in a self-service situation.

The basic packaging materials were cloth bags and jute bags. Generally, these were used for transporting bulk quantities of grains. As mentioned, jute bags and cloth bags were the major bulk containers for grains packaging. Polymer based packages have been in greater use and demand for packing of secondary processed food commodities of cereals, pulses and oilseeds.

Storage

Storage is an interim arrangement during transit of agricultural products from the producer to the processor and its products from processor to consumer. In the farmers' context, agricultural products need to be stored from one harvest to next harvest. This is necessary to safeguard against the following crop failures or poor quality, speculation in prices and market demand or against shortage and famines.

The objective of proper grain storage management is to maintain the characteristics of grain throughout the storage period. You must note here that storage cannot improve the quality of the grain. Grain improperly harvested and dried remains at low quality regardless of how well it is stored. The viability should be preserved for the seed grain, milling and baking qualities for food grain, and the nutritive properties of the feed grain. The principal sources of loss in quality and quantity in cereal grains during storage are the molds, insects, mites and rodents. The secret of keeping stored grains in good condition is to maintain the grain mass at uniformly cool and dry conditions and in an air tight condition.

Also, the objective of grain storage structures is to protect the stored grain from weather, birds, rodents and insects. Many R & D institutions in the country have developed many scientific storage structures for the cereals. Grain is stored in metal bins, reinforced cement concrete structures, and structures constructed using brick and cement mortar. These can be built both indoor and outdoor for different quantities in a typical farmers' situations. Some of the storage structures are given below for your knowledge base.

Corrugated GI Sheet Bin

It has been developed at the Indian Grain Storage Institute, Hapur. It is a flat bottom storage structure of 76 cu-m capacity. It is fabricated from corrugated and plain galvanized steel sheets and mild steel (MS) sections. The structure is erected on a brick masonry and cement concrete base, 675 mm above the ground level. The sheets are rolled in sheet rolling machine to provide a curvature of 2770 mm radius. MS ring is provided at the bottom of the structure with anchoring bolts embedded in the cement concrete to provide adequate strength as well as to secure structure firmly. Similar ring is provided at the top of the structure. The roof panels and stiffeners are fabricated from 24 and 18 gauge galvanized plain sheets, respectively. An inlet of 500 mm diameter is provided at the top for loading and an inclined outlet of 200 mm diameter at the bottom for unloading purposes. Steps are provided to the roof for loading of the bin. Besides, a manhole is provided in the wall section to facilitate further unloading of grain from structure. This bin is suitable for storage of wheat and other cereals.

RCC Ring Bin

This bin was also developed by the Indian Grain Storage Institute, Hapur (UP). You will appreciate here that the storage structure is made out of RCC rings. Mild steel reinforcement is provided both in horizontal and vertical direction for casting RCC rings. The edges of the ring are made such that the bottom edge of one ring will sit tightly over the top edge of the ring below. The shape of the joint is such

that water can not get into the bins as the slope is outward. The joints are sealed with cement motor of 1:2 proportions. Floor is of plain cement concrete of 1:2:4 proportions and it is 75 mm thick. The roof is of RCC with a cement inlet at the top. Roof projects beyond the walls by about 75 mm with a gentle slope from the centre. To cover the inlet, an RCC lid is provided. Grain is taken out from square opening provided at the bottom at ground level covered with a metal sheet. This bin is good for storage of wheat and other cereals.

CIAE Out door metal bin

This is developed from Central Institute of Agricultural Engineering, Bhopal. It is made of aluminum sheets. The sheets are revitted. Proper sealing of joints is done by 3 mm thick bitumen sheet. The sheets are rolled over a mild steel angle and flat iron frame put for reinforcement. The structure rests on a cement concrete platform sloping in two directions from centre. Top of the bin is inclined to allow quick drainage of rain water and dew. Well dried, clean and cool grain is filled in the bin from the opening provided on the roof. The opening is then sealed properly. Two outlets are provided at the lowest point of slopping which could be locked. Bin of 2.5, 10, 20 and 35 tone storage capacity are also available with similar design. Wheat and other food grains and oil seeds could be safely stored in this bin.

Transportation

For short distance bulk transportation of grains, tractors and small and heavy trucks are being used by the farmers, wholesale traders and retailers. For long distance transportation, heavy trucks and rail transport are also used. The grains are packed in proper size jute bags before loading to the transporting vehicle.

Check Your Progress 4

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. How do you justify the need for a package for food materials? List the contents that a package communicates to a buyer.

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2. Is storage really important for agricultural produce, justify. List the important storage bins for cereals storage.

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3.6 MATERIAL HANDLING DEVICES AND THEIR SUITABILITY

Objectives of Material Handling

The most important operation in food chain is the material handling and let us understand it little briefly. Material handling includes a number of unit operations that can be executed either by hand (manual) or by mechanical means or devices

to convey material and to reduce human drudgery. Also, mechanical handling devices aim to lighten the work of human labour.

After harvesting and threshing, the grains are moved, transported or conveyed from one place to another. In earlier days of agriculture, all these operations were done manually. The grains were threshed and bagged by human labour. Grains were transported several times through storage to milling plants, and the milled products were conveyed manually to consumers. Thus, grains were handled too many times involving increased costs and human drudgery. In modern times, mechanical devices have replaced human labour. Hope you will appreciate developments in this sector.

The most common types of material handling mechanical devices for grains are:

1. Belt conveyor
2. Bucket elevator
3. Screw conveyor
4. Pneumatic conveyor

It is important to know briefly each one of them.

Belt Conveyors

A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers. The belt may be flat for transporting bagged material or V-shaped or some other enclosed shape for moving bulk grains. The belt conveyor consists of a belt, a drive mechanism and end pulleys, idlers and loading and discharge devices (Fig. 2).

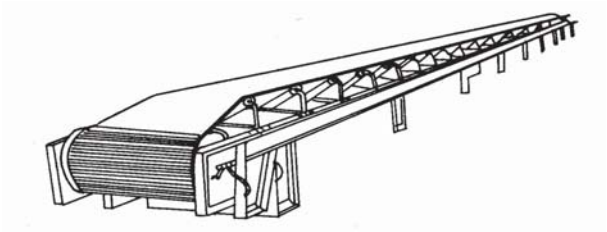

Fig. 2: Belt conveyor

Belt conveyors have antifriction bearing, therefore, these have a high mechanical efficiency. Material carried by belt conveyor lie still on the surface of belt, in other words, there is no relative motion between the product and belt. Horizontally the material can be transported to longer distances but there is a limit to carry the material in the case of vertical movement. A properly designed and maintained belt conveyor has a long service life and low operating costs. Compared to other types of horizontal conveying system, the initial cost of belt conveyor is high for short distances. But for longer distances, the initial cost of belt conveying system is competitive or low. For these reasons belt conveyors are used to carry grains in processing plants and other food handling industries.

Bucket Elevator

After knowing belt conveyer let us move on to another important material handling gadget, the bucket elevator. As the title indicates, the bucket elevator consists of buckets attached to a chain or belt that revolves around two pulleys one at top and the other at bottom. The vertical lift (distance) of the elevator may range between few meters to more than 50 m. Capacities of bucket elevators may vary from 2 to 1000 t/h. Bucket elevators are broadly classified into two general types, (1) spaced bucket elevators and (2) continuous bucket elevators. The above two types are further subdivided into various classes.

The spaced bucket elevators are further classified as, (i) centrifugal discharge elevators, (ii) positive discharge elevators, (iii) marine leg elevators and (iv) high-speed elevators. The continuous bucket elevators are classified as, (i) super capacity bucket elevators, and (ii) internal-discharge bucket elevators.

The spaced-bucket centrifugal discharge type is most commonly used for elevating grains. A centrifugal discharge bucket elevator is shown in Fig. 3. The bucket elevator is a very efficient device for the vertical conveyance of bulk grains. Bucket elevators with belts are employed in food industries for vertical conveyance of grains, its derivatives and flours. Bucket elevators are usually mounted at a fixed location, but they can also be mounted in a mobile frame. Bucket elevators have high capacities and it is a fairly cheap means for vertical conveyance of grains, and hence it is largely used in the industry.

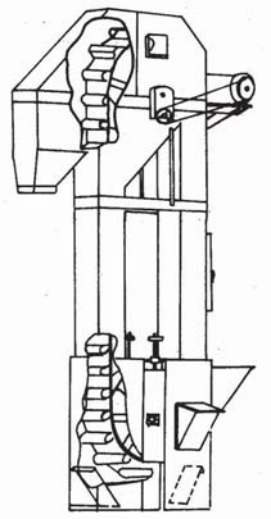

Fig. 3: Bucket Elevator

Screw Conveyor

Now, let us move on to the other type of conveyor which is largely used in food and animal feed making industries. The screw conveyor consists of a tubular or U-shaped trough in which a shaft with spiral screw revolves. The screw shaft is supported by hanger bearings. The rotation of screw pushes the grain along the trough. A typical screw conveyor is shown in Fig. 4. The screw conveyor is used in grain handling facilities, animal feed industries and other installations for conveying of products generally for short distances. The screw conveyor requires relatively high power and is more susceptible to wear than other types of conveyors.

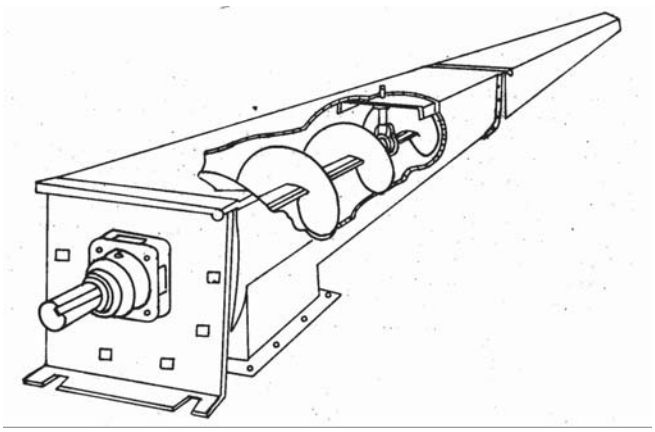

Fig. 4: Screw Conveyor

The screw conveyor's driving mechanism is simpler and no tensioning device is required, hence the initial cost of the conveyor is lower than any other conveyor with the same length and capacity. The main parts of a screw conveyor are, screw blade, screw shaft, coupling, trough, cover, inlet and outlet gates, bearings and drive mechanism. Generally, screw conveyor is used to move grains horizontally in the industry.

Pneumatic Conveyor

The pneumatic conveyor moves grain and granular materials in a closed duct using a high velocity air stream. Pneumatic conveying is a continuous and flexible transportation method. The material is carried in pipelines either by suction or blowing pressure of air stream. The granular materials because of high air pressure, are conveyed in dispersed condition. For dispersion of bulk material, air velocities in the range of 15-30 m /s are necessary.

The pneumatic conveying system needs a source of air blowing or suction, means of feeding the product into the conveyor, ducts and a cyclone or receiving hopper for collection of product. There are three basic systems of pneumatic conveying. These are : pressure or blowing system, suction or vacuum system, and combined push-pull or suck-blow system.

Check Your Progress 5

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. What are the objectives of material handling devices?

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2. List the important material handling devices used in grain handling industry.

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3.7 ENERGY REQUIREMENTS OF MATERIAL HANDLING DEVICES

Power Requirements for Belt Conveyors

The power requirement for movement of materials by belt conveyors is made by ascertaining lifting materials with traditional engineering methods, resistance of belt, frictional resistance of various pulleys and zig-zag devices. However, constants used in this process change in actual operating conditions. Belts between supporting pulley and lowering of load also absorb energy.

Horse power required for
operating empty conveyor = belt speed (ft per hour) x (A+BL)/100 …(1)

Where, L = Conveyor length, feet

A and B = Constants, these depend on the widths of belts and the constant A varies from 0.20 to 1.05 and constant B varies from 0.00140 to 0.00765.

Horse power requirement for conveying materials on flat surface = Material (tonnes per hour) x (0.48+0.00302L)/100 (2) …….(2)

Horse power requirement for
lifting materials = Lift (ft) x 1.015 material (tonnes per hour) / 100 …. (3)

The total horse power requirement is the sum of calculated horse powers from the above three equations

Power Requirements for Screw Conveyor

Let us also look into the calculations of the power requirement of a screw conveyor. It is the resultant of conveyor length, elevation, type of hanging shells and flights, viscosity or coefficient of friction of material at the internal resistance flights and weight of the material.

Power requirement of screw conveyor to be operated depends on the dimensions of the system and characteristics of materials. A rough estimation for normal horizontal operations can be obtained from the following equations:

$$\text{Horse power} = \frac{CLWF}{4500} \qquad \text{……..(4)}$$

where, C = Capacity of conveyor, (m^3/ minute)
L = Length of conveyor (in meter)
W = Bulk weight of the material (kg/ m^3)
F = Material coefficient

If the calculated horse power is less than 1.0, double the value.

Horse power	=	1 to 2	multiply the value by 1.50
Horse power	=	2 to 4	multiply the value by 1.25
Horse power	=	4 to 5	multiply the value by 1.10

For horse power value of more than 5, no correction is required.

Power requirements for Bucket elevator

$$\text{Horse power} = \frac{QH}{4500} \qquad \text{…….(5)}$$

where, Q = belt speed per minute x number of buckets / meter x capacity of buckets (kg.)
H = Lift (in meter)

There should be 10 to 15 per cent increase for the provision of friction and feeding power requirement. In case of under load operation and high load conditions repeatedly, then additional power should be considered.

Check Your Progress 6

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. Write the equation for power calculation for a belt elevator and mention the terms used and their units.

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3.8 SELECTION OF MATERIAL HANDLING DEVICES

After understanding different material handling devices, types of devices and the energy calculations, let us now move on to the selection of material handling devices. The selection of proper conveying system is very important. The ease of operation and getting a long lasting and desired capacity for a particular food product are most important. Therefore, before selecting a conveying system, the following principles should be considered carefully:

1. The conveying device should be selected according to the characteristics of the products being handled
2. The stability of the conveyor must be ensured under all normal working and climatic conditions
3. The capacity of conveying and speed rating should be maintained at specified limits
4. The dead load of the conveyor should be low in relation to the weight of transported product
5. In a conveying system possibility of use of gravity should be taken into consideration
6. The capacity of handling / conveying equipment should match with the capacity of processing unit or units
7. Spoilage of conveyed products should be avoided. Pollution of the environment due to noise or dust by the conveying system should also be avoided.

Check Your Progress 7

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. How important is selection of material handling devices? What criteria are to be considered most?

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3.9 DAMAGE DURING STORAGE

Insects and pests form one of the most important factors responsible for losses in agricultural production at various stages. Living organisms and environment interact to bring about spoilage of stored products. Living organisms may be plant insects,

pests, man, animal, bacteria, fungi, etc. The number of insects species may be nearly 1.0 million, but only 1% of the species may perhaps be harmful to man by consuming and contaminating the food. Insects have the capacity to adapt to any environmental conditions. Several species can live in stored grain having very low moisture content. They enter to any hard-to-get-to places because of their tiny size. Some insects can live in darkness while some others live in light.

Direct Damages

1. Some insects consume germ, some endosperm and others eat away both. These results in loss of weight, loss or conversion of nutrients, loss of germination power, loss in gradation and consequently fall in the market value.
2. The contamination with the dead bodies, cast skin, excreta, obnoxious odour and webbings
3. Structures and containers may also be damaged by causing tunnelling in wooden parts resulting in weakening of the structure / container

Indirect Damages

1. It may be due to warming and migration of moisture
2. It may create distribution of parasites to human beings. Certain tape worms use stored grains insects as intermediate hosts.
3. It causes customers resistance which may lower the prestige

Source of Infestation and Control

Insects are the greatest threat to food grains. Insects are highly adaptable, small size, can easily conceal themselves. The main source of infestations is given below:

Field Infestation

Grains in the field are infested from nearby mills or stores. They lay eggs on maturing grains and these eggs hatch to larvae, and are present when grains reaches stores (hidden infestation).

Transportation

Harvested grains are transported to godowns by trucks, trolleys, carts. These serve as source of cross infestation to fresh stock. The transport vehicles for grains should not be used for transporting infested animal feed, etc. Transport vehicles should be periodically cleaned, dusted and fumigated, if used for grain transport.

Infested Stores

When fresh grains from field are stored in previously infested store where previous grains are emptied leaving a few infested grains contaminate the entire fresh grain. They breed and accumulate in corners, cracks and crevices. Before storing fresh produce the stores should be thoroughly cleaned and fumigated.

Infested Stocks

When fresh and sound stocks are brought to a godown where already infested stocks are present in storage, cross infestation takes place.

Infested Gunny Bags or Containers

The general practices observed are to keep empty bags without cleaning. Eggs and larvae remaining in mesh and seams of bag feed on grain fragment, and infest fresh grain that is filled into these bags. Gunny bags must be fumigated before refilling or use new bags.

Check Your Progress 8

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. List the direct and indirect possible damages in a storage.
2. What are the main sources of infestation in storage.

3.10 LOSSES IN STORAGE

It is estimated that 5 to 10 % of the world's food production is damaged by insects during storage. The estimated losses due to insects in India, is around 3 % country's production. Insects feed on the grain germ and endosperm causing loss in weight and nutrients. They also cause contamination with their excreta and dead bodies. The damage can be grouped into direct damages and indirect damages. The storage structures just explained above and the damage control methods, if properly understood and adopted, the losses in storage could be brought down drastically.

3.11 TRADITIONAL IMPROVED AND MODERN STORAGE STRUCTURES

Traditional Storage Structures

Farmers generally store their grains by using indigenous traditional knowledge since ages. Some of these traditional storage structures for storage of grains in rural areas are briefly described here under.

Morai Type Storage Structure

In rural areas of eastern and southern regions of India, Morai type storage structures are used. In Morai structure generally grains such as paddy, maize and sorghum are stored. Its capacity varies from 3 to 18 tonnes and its shape is like an inverted truncated cone. These structures are made on a raised platform supported on wooden or masonry pillars.

In the improved Morai storage structures, the circular wooden floor is supported on timber pillars. The floor planks are joined together with lap joints. This wooden floor is surrounded by 22 gauge corrugated metal cylinder of 90 cm height. The cylinder is nailed to the wooden floor. Inside the cylinder, 7.5 cm diameter ropes made out of paddy straw or similar material is placed, up to the height of metal cylinder. Then bamboo splits are placed vertically along the inner surface with no gap in between. The height of bamboo splits is kept equal to the desired height of storage structure. Now grain is loaded inside the bin so formed up to a height of 90 cm or equal to metal cylinder. Now, the bamboo split becomes erect in position. Afterwards, loading of grains and winding of straw rope on splits go on simultaneously. The grains are thus loaded up to the total height of Morai structure. About 1 cm thick mud plaster is done on the straw rope. The structure is covered with a conical roof with ample overhang all round.

Bukhari

Bukhari type storage structures are cylindrical in shape and are used for storage of sorghum, wheat, paddy, bengalgram, maize, etc. Bukhari structures generally have capacities between 3.0 to 18 tones. However, smaller capacity structures also exist. This may be made by mud alone or by mud and bamboo. The cylindrical storage structures are raised above the ground by wooden or masonry platform.

The floor of the bin is made either by timber planks or by bamboo splits, plastered with mud mixed with dung and paddy straw. The wall of the structure is made of timber or bamboo framework and bamboo matting. Over the walls, mud-straw plaster is applied on both sides, i.e., inside and outside. The roof is generally made of bamboo framework and straw.

In improved Bukhari type structure, the basic shape remains the same but the material and method of construction have been improved to make the structure more safe and durable. The circular floor of structure is made of wooden planks. Over the floor, about 5 cm thick mud plastering is provided. The walls of structure are made of two sets of strong bamboo framework. The inter-space is filled with mud. The walls on both sides are plastered with mud. The roof is conical and made of bamboo framework. It is then covered with paddy straw or similar other thatching material. The top of the conical roof is covered with 4 to 5 cm thick mud layer to provide additional protection from rains. The structure is raised on timber or masonry pillars to a height of about 1.5 m. Rat proofing cones are placed on all the four pillars to avoid rats entering the storage structure.

Kothar Storage Structure

These are used to store paddy, maize, sorghum, wheat, etc. Their capacity varies between 9 to 35 tonnes. The storage structure is a box like made of wood and raised on pillars. Both the floor and walls are made of wooden planks. The thatched or tiled roof is placed over it to protect the grains from the sun or rain.

The improved Kothar structure is generally made of 5 cm thick wooden planks and beams. The walls and floor are made with no gap existing between the planks. The gabled roof on top may be made of planks or corrugated metal sheets and should be sufficiently overhang on all sides. The storage structure is raised on timber post to a height of about 1.5m above the ground. Rat proofing cones are provided on all posts to avoid entry of rats in the structure.

Mud Kothi

These storage structures are quite common in rural areas for storage of grains and seeds. The capacity of such storage structures varies from 1 to 50 tones. They are made from mud mixed with cowdung and straw. They are generally rectangular in shape but cylindrical Kothi is also common in some regions. There are many sizes and dimensions of Kothi made for storing grains (Fig. 5).

Fig. 5: Mud bin

Muda

These are used for storing grains in the rural areas of Bihar state. The capacity of Muda varies between 1 to 10 tonnes. It is being made of "Narai" ropes. The shape of Muda is cylindrical and is made in various sizes

Kanaj

Kanaj storage structures are very common in the rural areas of Karnataka and Maharashtra for storage of grains. The capacity of Kanaj varies between 1 to 20 tonnes. It is made out of bamboo splits. The shape of storage structure is cylindrical. The wall of storage structure is sealed with mud plaster on both sides. The roof of the structure is conical and thatched. The top roof overhangs on all sides.

Improved Storage Structures

We have gone through many traditional storage structures which are in use in large numbers in many regions of the country. In addition, many R & D institutions have developed improved, low cost and small capacity storage structures. These are described briefly for your understanding.

Pusa bin

Pusa bin is like any other traditional storage structures made of mud. To make the storage structure moisture proof a plastic film is used in all the inner sides of the bin (Fig. 6).

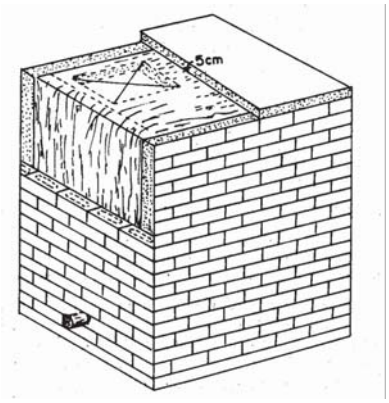

Fig. 6: Pusa bin

To construct Pusa bin first a platform of mud bricks is made. On this platform a sheet of 700 gauge plastic is spread over lapping the platform on all sides by at least 6 cm. On the plastic sheet a layer of 7 cm thick Kachcha bricks are laid. Walls are made of Kachcha bricks and these are sealed with mud plaster. When the walls are raised to proper height a wooden frame is placed on it. The upper roof is made of burnt bricks. For unloading of grains, an inclined wooden or steel pipe is fixed in such a way that grains may come out (please see figure 6). The mouth of pipe is closed by a cover. The inside of all the four walls and roof are covered by a plastic sheet. On the top, an open space of about 50 x 50 cm is left for loading of grains. Leaving this open space, the roof is sealed by mud. After the bin is filled with grains, the top open space is well covered by a plastic sheet so that air may not enter the bin. Material requirement for two different capacities of Pusa bin is given below:

2 tonne Pusa bin: Base 140 x 100 cm; height 160 cm, plastic sheet 180 cm wide and 8.5 m long; Kachcha bricks 1150 Nos., burnt bricks 100 Nos, and a pipe for outlet.

4 tonne Pusa bin: Base 172 x 152 cm; height 160 cm, plastic sheet 180 cm wide and 11.6 m long; Kachcha bricks 1650 Nos., burnt bricks 210 Nos, and a pipe for outlet.

Brick and Cement Bin (Grain House)

These storage structures are very strong and effects of seasonal changes on these are minimal. The bin is made on a platform raised at 60 cm above the ground. A ladder is provided on one side of the bin to load grains. A hole of 60 cm diameter is provided on the roof for loading of grains. The walls of bin are 23 cm thick with cement plaster on both sides. Roof is made of Reinforced Cement Concrete (RCC). The base of bin is made inclined and an outlet is provided for unloading grains. The capacity of the bin is between 1.5 to 60 tones. For cleaning of bin and complete unloading, a person can get inside using iron rings steps that are provided inside the bin.

'CAP' Storage structure: The word 'CAP' is used for cover and plinth; plinth from the bottom and cover from the top. This type of open storage is considered as transit storage and serves the purpose of storage of food grains in bags for short periods. This is cheaper compared to conventional bag storage godowns. The cover is rectangular in shape having five sides made from polyethylene film of 1000 gauge, leaving the bottom side open. The cover is used for protecting stack of bags. Normally the stack is built over a space of 9.11 x 6.1 m with a height of 18 bags which gives the storage capacity of around 150 tonnes. The cover having a dimension of 9.4 x 6.4 x 5.5m and normally weighs around 52 kg. Sometimes smaller covers are used for covering the stacks in covered verandah of conventional godowns. Such covers are called "Verandah covers". In storage of food grains under verandah covers, the stacks are built to a height up to 7 bags having an average capacity of 24 tonnes.

Temperature and Moisture Changes in Storage Structures

Moisture migration in stored grain results from temperature changes. Moisture content of grain is one the most important factors influencing its storage life. High moisture and a warm climate promote mold growth, insect growth and increase rate of respiration of grains. Moisture migration takes place in bin even though grains are at a moisture level generally considered for safe storage. One important thumb rule before storage of any grain is that you must ensure grains are free from any foreign materials (i.e., bits of crop, mud, and stone pieces) and ensure your grains are at the storable moisture content. Further, the grains should be stored in bins at a cooler place in the house.

Check Your Progress 9

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. Name three examples in traditional storage structures used in the country.

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2. Name three improved storage structures for grain storage and in your judgment which may is the best one among them?

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3. What is the specialty of Pusa bin over the other storage structures?

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3.12 CONTROLLED AND MODIFIED ATMOSPHERE STORAGE

The technique of modified and controlled atmosphere storage of grains involves alteration in the concentration of the normal atmospheric gases present in storage. The oxygen (21%) and carbon dioxide (0.03 %) composition in the regular atmosphere will be altered in modified atmosphere storage and packages. That means, the oxygen levels will be lowered down to 2 to 4 % and the carbon dioxide will be enhanced from 4 to 10 % or even above. Further, for best storage results, the modified atmosphere should be a supplemented with proper temperature and relative humidity management. This alteration is insecticidal and prevents mold growth and quality deterioration of stored product. Two classes of externally generated modified atmosphere are available: low oxygen atmosphere generated by adding nitrogen, or the gas mixture resulting from burning hydrocarbons or high carbon dioxide atmospheres made by adding carbon dioxide.

Modified or Controlled Atmosphere technology has permitted its increased use during transport, temporary storage, or long-term storage of horticultural commodities. Modified or controlled atmosphere has also been used for storage of grains in the western countries. These methods require gas tight facilities, which are more expensive and scarce in developing countries. Due to non use of chemicals for insecticidal treatments the operating costs are significantly lower than traditional storage method. However, higher use of instruments is the characteristic of modified or controlled atmosphere storage system and hence the initial investment is very high.

Potential Benefits

Modified atmosphere, if supplemented with proper temperature management can give the following benefits.

1. Very low respiration rates.
2. Modified atmospheres can directly or indirectly affect post harvest pathogens. This will significantly inhibit development of bacteria and fungi.
3. Modified atmospheres can be a useful tool for insect control in some commodities

Check Your Progress 10

Note: a) Use the spaces given below for your answers
b) Check your answers with those given at the end of the unit

1. What do you understand by the controlled/modified atmosphere storage?

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2. What are the potential benefits of modified atmosphere storage?

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3.13 LET US SUM UP

For sustainable development of agriculture and enhancement of productivity, improved farm implements, and machinery in the production and after harvest are important farm operations. Our focus of the subject is on harvesting, transportation, handling and storage all of which are very important and these operations need to be done utilizing the improved machineries and technologies. By doing so, the drudgery in the farm operations can be reduced and high savings in time and labour can be achieved. All the unit operations are important for post harvest handling of agriculture produce. Storage is a must for the grains which require human consumption for an additional one season after harvest or round the year. The storage may require at all the three levels in the post harvest chain – at farmers level, at wholesale level and retailer level. The present level of storage losses can be brought down if storage is done scientifically. Material handling devices are important particularly when the industry handle large quantity of food material in a given time. Although many traditional storages are being used by the farming community, it is time that we encourage them to adapt improved storage structures to reduce losses and also to protect the grain quality. Controlled and modified atmosphere storage techniques are the latest ones and we may have to consider their application wherever it suits our storage requirements. Cold storage is essential and part of any food storage and handling situation. Each one of us have a role in guiding and motivating farmers to adapt to the new technologies in agriculture.

3.14 KEY WORDS

Belt conveyor : A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers.

CAP storage : Word used for cover and plinth type of storage normally done in outdoors.

Cereal crops : Wheat, rice, sorghum, maize etc.

Combines : The machine which can cut, thresh, winnow and clean grain/seed.

Controlled and modified atmosphere storage : The technique of controlled and modified storage of grains involves alteration in the concentration of the normal atmospheric gases present in storage.

Diggers : The equipment used to dig groundnut, potato from the underground.

Harvesting	**:**	Cutting of crop from the field.
Oilseed crops	**:**	Groundnut, mustard, soybean, sunflower, castor and safflower etc.
Pneumatic conveyor	**:**	It moves the grain or granular material in a closed duct using high velocity air stream.
Pulse crops	**:**	Bengal gram, urad, moong and cowpea etc.
Storage	**:**	Storage is an interim arrangement during transit of agricultural products from field to the processor.
Vertical conveyor reaper	**:**	A reaper with crop row divider, cutter assembly, feeding and conveying devices.

3.15 SOME USEFUL REFERENCES

1. Pandy, M.M., K.L. Majumdar., Gyanendra Singh and Gajendra Singh, 1997. Farm Machinery Digest, Published by the Central Institute of Agricultural Engineering, ICAR, Bhopal, India.
2. Pandy, M.M., and Ganeshan. 2005. Farm Mechanization package for dryland agriculture. Published by the Central Institute of Agricultural Engineering, ICAR, Bhopal, India.
3. Sahay, K.M. and K.K. Singh. 2003. Unit operations of agricultural processing. Vikas Publishing House Pvt. Ltd., New Delhi.
4. Ojha, T.P. and A.M. Michael. 2002. Principles of agricultural engineering (Volume 1). Jain brothers, New Delhi.

3.16 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Your answers should include the following points:
   - Popularly used traditional sickle without serration
   - The advantages of using traditional sickle by humans
   - Economical investment to the poor farmers
2. Your answer should include the following points :
   - Large area can be harvested in an unit time, and
   - Minimum drudgery, and high time and labour saving
3. Your answer should be on :
   i) crop different parameters (5 factors),
   ii) machine factors (6 factors), and
   iii) important operational factors (2 factors)
4. Your answer should focus on : i) undulated field conditions, ii) crops should have been grown in rows, and iii) No wet condition in the harvesting field.

Check Your Progress 2

1. Your answer should include the following tools
   - Self-propelled walking type reaper

- Tractor front and rear mounted reapers
- Combine harvesters
- Improved self serrating sickle

2. Your answer should be on the following two tools for pulses:
   - Traditional sickle and improved self serrated sickle
   - Traditional chopper
3. Your answer should make a mention on the following tools :
   - Self- propelled walk behind type vertical conveyor reaper
   - Tractor front or rear mounted pto (power take off) operated reaper, and
   - Combine harvester
   - Diggers

Check Your Progress 3

1. Your answer should include the traditional cart (we have many designs of such carts in the country)
2. Your answer should be on : improved bullock carts, tractor with trailor and diesel trucks of different capacities

Check Your Progress 4

1. Your answer should highlight on the role a package can play in the food chain with focus on its important functions and also its protection to the packed material inside the package. You should also include the contents of communication such as the brand name, ingredients inside the package, instructions for use and any warranties, weight of ingredients, etc.
2. Your answer should include justification of storage requirement as a transit arrangement between the production and consumption, production and processing, and processing and consumption. Here you have to include answers on the season of growing crop and consumption required round the year for public consumption. Further, the important bins are : corrugated GI sheet bin, RCC ring bin, and CIAE out door metal bin.

Check Your Progress 5

1. Your answer include objectives such as the unit operations executed both manually and mechanically to convey material and how important that movement of grains from one place to the other within an establishment like an industry.
2. Your answer should include the mechanical handling devices such as : Belt conveyor, Bucket elevator, Screw conveyor, and Pneumatic conveyor.

Check Your Progress 6

1. You should write the equation (5) for power calculation and mention all the terms with units.

Check Your Progress 7

1. You should involve the following answers – characteristics of products to be handled, capacity of conveying and speed of operation, advantage of using gravity flow, capacity of handling and conveying equipments, and spoilage if any in the system.

Check Your Progress 8

1. Your answer should include the following points :
   i) Direct damages are – insects heating germ and endosperm contamination with dead bodies, damage of storage structures in a storage.
   ii) Indirect damages are – warming and migration of storage environment, parasites and tape worms
2. Your points should cover the following points :

   Infestation from the field, infestation during transportation, infested stores, infested stocks, infested gunny bags or containers

Check Your Progress 9

1. Your answer should include the following points :

   Morai type storage structure, Bukhari, *Kothar storage structure,* Mud Kothi, *Muda, and* Kanaj storage structures
2. Your answer should include : Pusa bin, brick and cement bin and CAP storage structure. Pusa bin more scientifically designed
3. Your answer should involve the special use of 7000 gauge plastic film provided for preventing moisture migration.

Check Your Progress 10

1. Your answer should include the alteration of gases composition of the regular atmosphere.
2. Your answer should include the following points :
   i) Very low respiration rates,
   ii) direct or indirect effect of post harvest pathogens and bacteria, and
   iii) for control of insect in some commodities.