1 Concepts of Agricultural Mechanization

1.1 Definition

Farm mechanization is the application of engineering and technology in agricultural operations to do a job in a better to improve productivity. This includes development, application and management of all mechanical aids for field production, water control, material handling, storing and processing. Mechanical aids include hand tools, animal drawn equipment, power tiller, tractor, oil engines, electric motors, processing and hauling equipment. *The ultimate objective of mechanization is to increase production in two major ways: firstly, the timeliness of operation and secondly the good quality of work.*

1.2 Benefits of Farm Mechanization

(i) Extension of Cultivated Areas

With the use of machines, more land can be brought under cultivation. Most agricultural operations (such as land leveling, seed bed preparation, sowing, weeding & inter-culture, fertilizer application and harvesting & threshing) are time dependent. For example, farmers who have access to machines can quickly complete their farm work within the available time of the period for tillage. This implies that they can use the remaining time to do other things including bringing more land under cultivation.

(ii) Increased Economic Returns to the Farmers

With mechanization and more land under cultivation, the scale of operation of the farmer is increased. Usually, when goods are produced in large quantities the unit cost of production drops substantially. Thus, with more products, and lower per capital production costs, the farmer makes more money. This has the potential of increasing the economic base of the farmer.

(iii) Improved Timeliness and Precision of Operations

Every farm operation must be done within a specified period of time. Timeliness of operations means that the particular activity is carried out on time. We know that if planting is delayed for example, it can lead to decreased yields and hence economic loss. The use of machines ensures that no matter the size of the farmland, the operations can be planned to be completed in good time. Closely related to timeliness is precision. In mechanized systems, operations are done with precision, without the inconsistencies inherent in human actions. Thus, a planter that is set to plant seeds at 20cm depth will do that religiously even if it plants 100,000 seeds. If such a task is to be done by laborers, after working for 2 hours, they may get tired. This will introduce errors in placement of the seeds, resulting to non-uniform planting depth.

(iv) Improvement of the Working Environment

One of the reasons why youths do not want to take to farming is the difficult and dirty working environment characteristics of farming with hand tools. With the introduction of machines, there is some “distance” between the farmer and the soil. This reduces the farmer's contact with dirt. In fact, in modern day agriculture with machines, there is no reason why a farmer should not be in his suit while working, if he chooses. Nowadays, there are tractors with air-conditioned cabins, protecting the farmer from sunshine, wind and harsh weather conditions.

(v) Reduction of Drudgery of Farm Work

Farm work using hand tools is tedious and difficult. The use of hoes and machetes for farm work demands a lot of energy from farmers. With mechanization, the suffering is transferred to a machine. The operator may only have to learn how to operate the equipment. In addition to the tedious nature of farm work, the same operation has to be repeated over and over again. With machines, this is not a problem. A tractor can work for over six hours without getting tired. As long as there is fuel in it, the engine continues to supply power for the work. The advantage of removing the drudgery in farm work is that anybody, young or old, male or female can work in the farm.

(vi) Improved Dignity of the Farm Worker

One of the reasons why the traditional farming environment is not attractive to many young people is the low esteem associated with it. If somebody is a doctor, lawyer, engineer, pilot or pharmacist, he has some dignity and respect in the society. This situation is informed by what the society associates with being any of these professionals may be due to financial power and intellectual ability. In the case of farming, because of the low level of operations, farmers are known to be poor and so accorded low dignity. With mechanization, the economic base of the farmer improves substantially. This comes with it some dignity, as the society begins to accord some respect to them.

(vii) Increased Agro-Business Activity

Under the traditional farming system with hand tools, there are limitations as to the quantity of farm products. When farms are mechanized, production increases from subsistence to commercial level. The meaning of this is that for each agricultural produce, the quantity will be much more than can be consumed and stored. This has the potential of fueling the establishment of other agro-business activities such as distribution, trading in produce, processing, and cottage industries. A good example is the story of groundnut in the United States of America. With commercial production, people developed many other uses of groundnut to the extent that one can count over 20 products made from groundnut.

1.3 Limitations and Status of Agricultural Mechanization

Some of the limitations of agricultural mechanization include:

(a) Reduces social interaction associated with farm work

(b) Not suitable for small holdings

(c) Initial capital investment is high; fuel is costly and repairs and maintenance needs technical knowledge. Farmers especially in developing countries are poor & unable to purchase tractors & heavy machineries

(d) Problem of unemployment: Since most of our citizens are engaged in agriculture, the introduction of machines will result in massive unemployment, as many of them will be displaced. However, it should be noted that the surplus products that will come through mechanization will increase agro-business activities, which in turn will create more employment opportunities, on a global basis. The state of mechanization shows agricultural system all over the world has undergone changes in terms of cropping system, type of power sources used and application of inputs to achieve high level of productivities. These days, one can observe that there are factors which strongly propel mechanization for example the more labor-intensive operations, such as pumping of irrigation water, land preparation and threshing operations need to be mechanized. Large amount labor or draft power, which can be replaced through machines, provides a strong incentive to mechanize.

1.4 Levels of Mechanization

Three broad levels of agricultural mechanization technology:

(1) Hand Tool Technology (HTT)

(2) Draft Animal Technology (DAT) and

(3) Mechanical Power or Engine Power Technology (EPT)

(1) Hand Tool Technology (HTT)

It is the most basic level of agricultural mechanization, where a human being is the power source, using simple tools and implements such as hoes, machetes, sickles, etc. Human power ***(****Power rating of 0.1 HP) is the most primitive, highly inefficient, high energy consumption & Low cultivated area*. Human beings are the main sources of power for operating small tools and implements at the farm. They are also employed for doing stationary work like threshing, winnowing, chaff cutting and lifting irrigation water. On an average, a man develops nearly 0.1 horse power (hp). It doesn't keep timeliness of work, which means it is low efficient.

Advantages: Easily available and used for all types of work.

Disadvantages: Costliest power compared to all other forms of power, very low efficiency, requires full maintenance when not in use and affected by weather condition and seasons.

(2) Draft Animal Technology (DAT)

Draft animals-usually an animal team controlled by one person-are conveniently maintained and trained. Animals are the main sources of power. Animal power (*Power rating of 1-5 HP) is better than manual/human, larger capacity for animal drawn tools, prone to tsetse fly infestation &competition for meat/milk by humans).* Animal power is the most important source of power on the farm all over the world. It is estimated that, nearly 80% of the total draft power used in agriculture throughout the world is still provided by animals.

Advantages: (a) Easily available (b) Used for all types of work (c) Low initial investment (d) Supplies manure to the field and fuels to farmers (e) Live on farm produce.

Disadvantages:(i) Not very efficient (ii) Seasons and weather affect the efficiency (iii) Cannot work at a stretch (iv) Requires full maintenance when there is no farm work (v) Creates unhealthy and dirty atmosphere near the residence (vi) Very slow in doing work

(3) Mechanical Power or Engine-Power Technology (EPT)

Engine powered machinery technology consists of a range of tractor sizes used as mobile power for field operations; engines or motors using petrol or diesel fuel or electricity to power such machines as threshers, mills, irrigation pumps, grinders, aircraft for spraying and self-propelled machines for production, harvesting and handling of a wide variety of crops. Mechanical power ***(****Power rating of 10-200HP) can cover more hectarage of land, highly efficient, high productivity, expensive &needs skilled labour).* It is the third important source of farm power that is available through tractors and oil engines.

Advantages: (a) Efficiency is high (b) Not affected by weather (c) Can run at a stretch (d) Requires less space and (e) cheaper form of power.

Disadvantages: (a) Initial capital investment is high (b) Fuel is costly and (c) Repairs and maintenance needs technical knowledge.

2 Farm Machinery

2.1 Definitions

***Tool* -** It is an individual working element such as disc or shovel.
***Implement* -** It is equipment generally having no driven moving parts, such as harrow or having only simple mechanism such as plough.
***Machine* -**It is a combination of rigid or resistant bodies having definite motions and capable of performing useful work.

2.2 Methods of attachment to tractor power source

Tractor-powered implements can generally be categorized as being: *(1) Trailed (2) Semi-mounted or (3) Mounted*

(1) Trailed: Trailed implements are attached to, and pulled by the tractor's *drawbar hitch point*. The machine requires its own transport/depth control wheels to provide the additional support required.
(2) Semi-mounted: Semi-mounted implements are those that are pivotally attached to the tractor's two lower three-point linkage points but also require transport (or depth) wheels positioned towards the rear of the machine's frame to provide additional support.
(3) Mounted: Mounted implements are attached to, and are capable of being fully supported by the tractor. Typically, these machines are attached to the tractor via a *three-point linkage system* located in front of the tractor's front wheels, between the front and rear wheels or behind the rear wheels (front, mid or rear mounted respectively). The machine/implement is raised/lowered by the tractor hydraulic system and carried fully by the tractor when out of work.

The attachments of implements to tractor power source can be done through:
(a) The Hitch system (Drawbar hitch and three point linkage) (b) PTO drive system

✓ **Drawbar hitch:** Drawbar is a device by which the *pulling power* of the tractor is transmitted to the trailing implements. It consists of a crossbar with suitable holes, attached to the lower hitch links. It is fitted at the rear part of the tractor.

✓ **Three-point hitch system**: Three-point hitches are composed of three movable arms. The two lower arms, the hitch lifting arms, are controlled by the hydraulic system and provide lifting, lowering, and even tilting to the arms. The upper center arm-called the top link-is movable, but is usually not powered by the tractor's hydraulic system. Each arm has an attachment device to connect implements to the hitch. The draft of the implement, the amount of force it is taking to pull the implement, is sensed on the lower arms and the hydraulic system automatically raises the arms slightly when the draft increases and lowers the arms when the draft decreases. The primary benefit of the three-point hitch system is to transfer the weight and stress of an implement to the rear wheels of a tractor. Advantages of three point linkages are easy control of working implements, quick setting of implements, automatic hydraulic control of implements such as position control, draft control etc., and good balancing of attached implements.

✓ **PTO drive (Power take off):** Tractor provides an auxiliary rotary power through a shaft to implements that require a rotary movement. Pairs of universal joints attached to a long shaft are used to transmit PTO drive.
Universal joints allow torque transmission through misalignment angles of up to about 20°.

✓ **Self-propelled Machineries:** These have propelling power unit as an integral part of the machine. Example- modern combine harvesters

2.3 Sources of Power-Internal Combustion Engine (IC Engine)

There are different sources of farm power which are classified as: (i) Human power (ii) Animal power (iii) Mechanical power (Tractors, Power tillers and Oil engines). Broadly speaking, mechanical power includes stationary oil engines, tractors, power tillers and self-propelled combines. Internal combustion engine is a good device for converting liquid fuel into useful work (mechanical work). It is called *internal combustion engine (IC engine), because the* combustion of fuel takes place inside the engine cylinder itself.

I.C. engines are of two types: (i) Petrol or Kerosene engines (spark ignition engine, carburetor type) and (ii) diesel engines (compression ignition engine).

Petrol or Kerosene engines: It is the engine, in which liquid fuel is atomized, vaporized and mixed with air in correct proportion before entering onto the engine cylinder during suction stroke. The fuel is ignited in the cylinder by an electric spark. This is called constant volume combustion (C.V.B).

Diesel engines: In this engine, during suction stroke, only air is entered into the cylinder and compressed. The fuel is injected through fuel injectors and ignited by heat of compression. This is called constant pressure combustion (C.P.C), because when the combustion takes place, the pressure in the cylinder is almost constant.

Depending on the period required to complete a cycle of operation, IC engines are further classified in to two. These are four stroke and two stroke engines. When the cycle is completed in two revolutions of the crankshaft, it is called *four stroke cycle engines*. When the cycle is completed in one revolution of the crankshaft, it is called *two stroke cycle engines*.

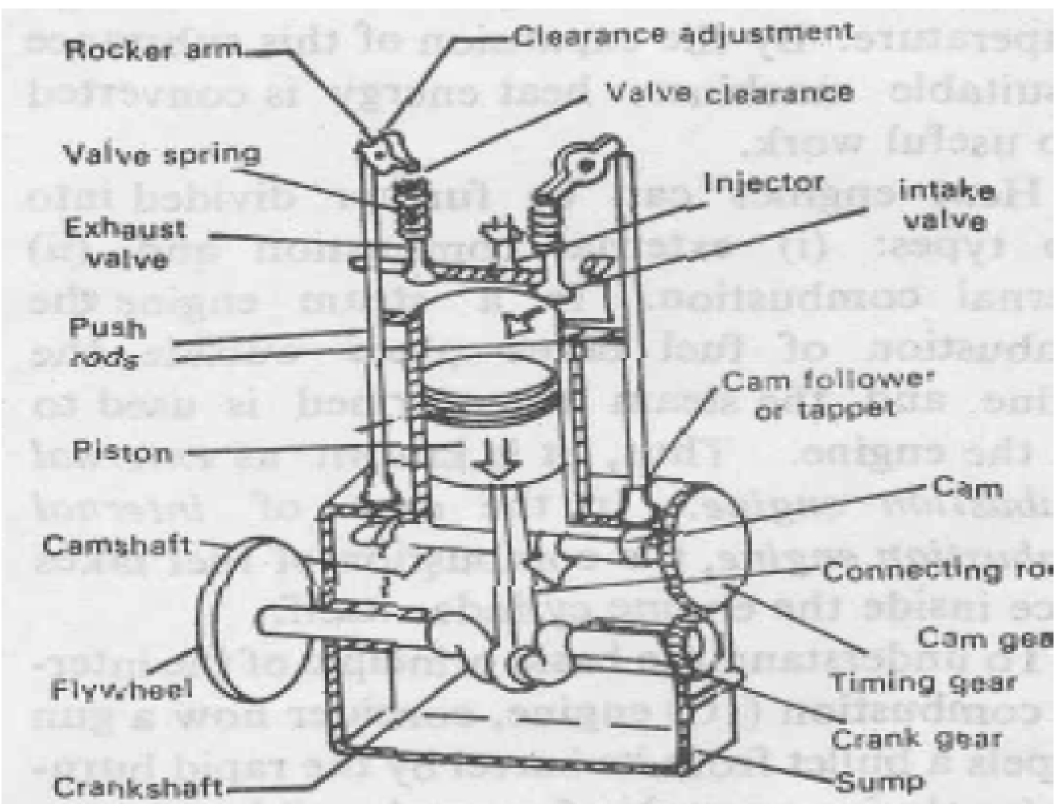


Figure 2.1 Cross-section of a diesel engine

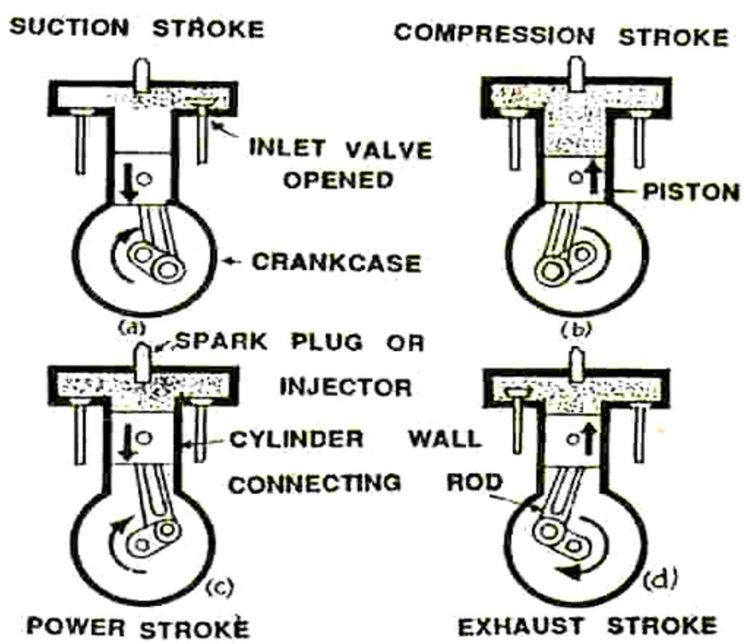
Materials used for engine parts:

S. No.	Name of the Parts	Materials of Construction
1.	Cylinder head	Cast iron, Cast Aluminium
2.	Cylinder liner	Cast steel, Cast iron
3.	Engine block	Cast iron, Cast aluminum, Welded steel
4.	Piston	Cast iron, Aluminium alloy
5.	Piston pin	Forged steel, Casehardened steel.
6.	Connecting rod	Forged steel. Aluminium alloy.
7.	Piston rings	Cast iron, Pressed steel alloy.
8.	Connecting rod bearings	Bronze, White metal.
9.	Main bearings	White metal, Steel backed Babbitt base.
10.	Crankshaft	Forged steel, Cast steel
11.	Camshaft	Forged steel, Cast iron, cast steel,
12.	Timing gears	Cast iron, Fiber, Steel forging.
13.	Push rods	Forged steel.
14.	Engine valves	Forged steel, Steel, alloy.
15.	Valve springs	Carbon spring steel.
16.	Manifolds	Cast iron, Cast aluminium.
17.	Crankcase	Cast iron, Welded steel
18.	Flywheel	Cast iron.
19.	Studs and bolts	Carbon steel.
20.	Gaskets	Cork, Copper, Asbestos.

Let's see the working principle of four-stroke cycle diesel engine

1. Suction stroke: During this stroke, the piston is shown descending and only pure air is drawn into the cylinder through the inlet valve, whereas, the exhaust valve is closed. These valves can be operated by the cam, push rod and rocker arm.

2. Compression strike: The next stroke is the compression stroke in which the piston moves up with both the valves remaining closed. The air, which has been drawn into the cylinder during the suction stroke, is progressively compressed as the piston ascends. As the air is progressively compressed in the cylinder, its temperature also increases. When the piston is near the top of its compression stroke, a fuel, such as diesel oil, is sprayed into the combustion chamber under high pressure. After ignition, tremendous amount of heat is generated, causing very high pressure in the cylinder which pushes the piston backward for useful work. Both valves are closed during this stroke.



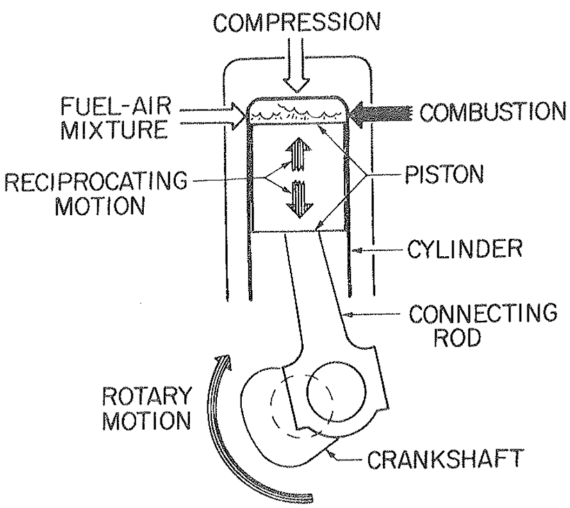
3. Power stroke: During power stroke, the high pressure developed due to combustion of fuel causes the piston to be forced downwards. The connecting rod with the help of crankshaft transmits the power to the transmission system for useful work. Both valves are closed during this stroke.

4. Exhaust stroke: The inlet valve is still closed and exhaust valve remains open during this stroke.
The exhaust gases are swept out on the following upward stroke of the piston. The exhaust valve remains open throughout the whole stroke and closes at the top of the stroke.

Exhaust gases go out through exhaust valves during this stroke. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh air. The inlet valve is closed and exhaust valve remains open during this stroke. The exhaust valve is closed just after the end of the exhaust stroke, and the inlet valve is opened just before the beginning of the suction stroke to repeat the cycle of operation.

When the piston is at the top of its stroke, it is said to be at the top dead center (TDC). When the piston is at the bottom of its stroke, it is said to be at its bottom dead center (BDC).

The reciprocating motion of the piston is converted into the rotary motion of the crankshaft by means of a connecting rod and crankshaft. The crankshaft rotates in the main bearings, which are set in the crankcase. The flywheel is fitted on the crankshaft in order to smoothen out the uneven torque that is generated in the reciprocating engine. The power output of an engine is a function of the average pressure on the piston top and the engine crankshaft speed. The average pressure acting on the piston top is referred to as the mean effective pressure. Indicated power (P_i) is the theoretical power an engine should develop from the mean effective pressure acting on the piston top. Indicated power is of academic interest to most engine users but is important to engine designers. The engine power actually delivered from the engine crankshaft is called brake power (P_b). P_b is smaller than P_i due to friction between the various internal parts of the engine. P_i – P_b = friction power (P_f). Friction power represents the power lost within the engine and ultimately shows up as heat which is dispensed into the atmosphere. Brake power then is useful power which may be used to do work. It is measured with an instrument called absorption dynamometer.

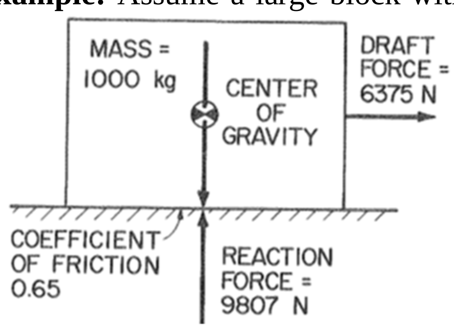


2.4 Basic Principles (Force, Work and Power)

Force: A force may be described as the action of one body upon another that tends to produce motion, change the rate of motion or change the direction of motion. For any force an equal and opposite force balances the force. Force = Mass x acceleration

Friction between bodies: When two bodies are in contact with each other and one of the bodies is moved, friction between the bodies tends to restrict the movement. The relative amount of the friction is referred to as coefficient of friction and is calculated by dividing the force required to move a body by the force exerted by the body normal to the surface. $\mu = F / W_f$ μ is coefficient of friction in decimal; F is force required to move a body in newton and W_f is force of body against surface in newton.

Example: Assume a large block with a 1 ton mass rests on a horizontal surface. The weight force against the surface is 9807N and the coefficient of friction is 0.65. The force required to move this block horizontally is then **6375N.**



In farm machinery, horizontal forces due to friction must be overcome to move the machines. Examples are soil moving over tillage tools, shafts turning in bearings and crop material sliding over machine surfaces. The frictional forces contribute to the total forces required to pull the machines.

Implement Draft Forces: The force required to pull a machine in the field is called its draft. The draft force is located at the implement hitch, its direction is in the direction of travel and its magnitude may be measured with a dynamometer scale. Total draft is the draft force required to pull a complete machine in the field. Unit draft or specific draft is the draft force required per some unit of the machine. Specific draft multiplied by machine width will give us total draft.

Example: Determine the total draft for a heavy tandem disc harrow which is 5m wide if the specific draft is 4kN/m.
Solution: Total draft = width x specific draft = 5m x 4kN/m = 20kN
For moldboard plows the specific draft is often reported per unit area of the furrow slice.

Example: Determine the total draft for a six bottom 0.41m plow operating in a medium soil at a depth of 20.3cm if the specific draft is 5.5 N/cm^2
Solution: The width of strip plowed will be 6 x 0.41m = 2.46m = 246cm
The total area of all furrow slices will be 246 x 20.3 = 4994cm^2
The total draft for the plow then becomes the area of all furrow slices times the specific draft:
Total draft = 4994 x 5.5 = 27467 N = 27.47 kN

Work and Power: Work (W) is technically defined as the action of a force (F) through a distance (S). W = FS. Power is defined as rate of doing work. This definition introduces the element of time and, therefore, implies that a certain quantity of work is done in a given unit of time.
Power (watts) = [Force (newton) x Distance (meter)] / Time (second)
Example: Determine the power required to pull a heavy tandem disk harrow which has a total draft of 20kN if it travels a distance of 100m in 50 seconds.
Solution: P = (20000 x 100) / (50 x 1000) = 40kW

Power Sources from Tractors: Power is made available from tractors in at least four different ways. Pulled implements are powered from the tractor's drawbar or three-point hitch. Machines which require rotary power receive this power from the tractors power-take-off (PTO) shaft. The tractors hydraulic system is available to provide both linear and rotary power for a variety of uses on machines. Some implements require electrical power for various jobs and this is often provided by the tractor electrical system. In short, f**our sources of power (drawbar, PTO, hydraulic and electric)** provided by a tractor to operate machinery.
Drawbar power: The power required to pull implements is often called drawbar power. ***Pd = (F x V) / 3.6*** Where Pd is drawbar power in kW; F is implement draft or tractor pull force measured in kN and V is speed of travel in km/hr.

PTO power: The tractor PTO shaft permitted direct transfer of power from the tractor through shafts and universal joints to the machine.
Example: Assume a forage harvester cutting corn for silage requires 1.7 kWh/ton and is harvesting at a rate of 60 ton/hr. The PTO power required would be 1.7 kWh/ton x 60 ton/hr = 102 kW

Hydraulic power is the fluid power required by the implement from the hydraulic system of the tractor or engine. Implements hydraulic power can be computed as: *Hydraulic power (kw) = fluid pressure (kPa) x fluid flow (liter/sec)/1000*
Example: What hydraulic power is available from a tractor hydraulic system if the flow rate is 1.6 liter/seconds and the maximum pressure is 15400 kPa.
Solution: Hydraulic power = (15400 x 1.6) / 1000 = 24.6 kW

Electric power is required to operate components of some implements. Electric power required by the implement (kw) = electric current (A) x electric potential (V)

Example: Determine the electrical power needed to drive the electric fans on a six row planter if a single fan is used for each row and each motor draws 5 Amperes from the 12 volt system on the tractor.
Solution: The total current flow will be 6 rows x 5 A/row = 30 A. Electrical power = 30 x 12 = 360W

Method for estimating tractor power available for PTO or drawbar work

Different ways of rating tractor power and variations in the amount of power needed to simply move the tractor itself through different soil conditions make it difficult to size implements to fit tractors or to size tractors to implements. If the maximum engine power is known, multiply it by 0.86 to estimate PTO power. We can estimate drawbar power by multiplying the PTO power by the appropriate value given in standard tables or values from actual field experiments.

Tractor type	Concrete	Firm soil	Tilled soil	Soft soil
2-wheel drive	0.87	0.72	0.67	0.55
Front wheel assist	0.87	0.77	0.73	0.65
4-wheel drive	0.88	0.78	0.75	0.70
Tracks	0.88	0.79	0.80	0.78

Example: Find the needed tractor size to operate a 6-row planter with all attachments to be operated at a field speed of 7.2 km/hr in tilled soil.
Solution: From standard table, the draft per row unit is 2kN/row. The total draft is 6 rows x 2kN/row = 12kN.
The drawbar power required is = FV/3.6 = (12 x 7.2)/3.6 = 24kW
The PTO power = drawbar power / 0.67 (Assume 2-wheel drive tractor) = 24 /0.67 = 35.82 kW
The engine power (brake power) = PTO power / 0.86 = 35.82 /0.86 = 41.65 kW
Therefore, to pull this planter one would need a tractor with a PTO power of at least 35.82 kW or with an engine with a power of 41.65 kW.

Assignment 1 (10%)

1. What drawbar power will be required to operate an eight-row planter with all attachments if the unit draft is 2kN/row and the planter is operated at a field speed of 6.4 km/hr?

2. What size tractor, in terms of PTO power, would be required to operate the planter in Q1 if the field is tilled as is normal for planting?

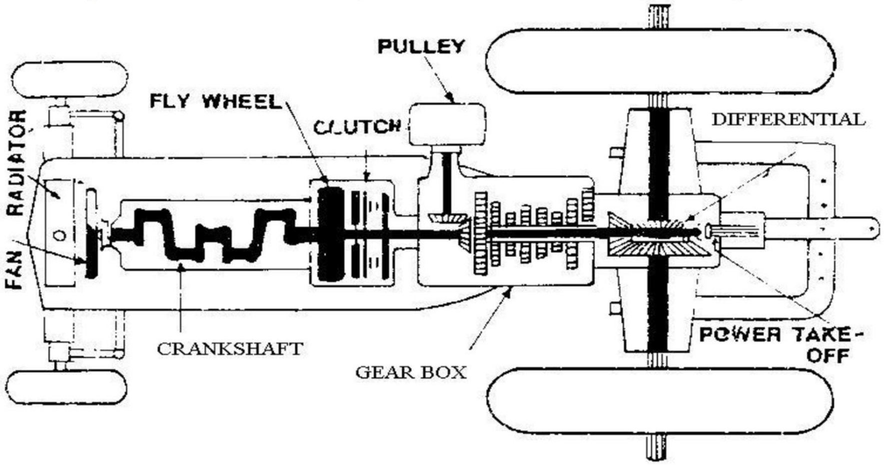
3. What hydraulic power may be developed with a tractor hydraulic system operating at a pressure of 13790 kPa if the flow rate of fluid is 1.26 liter/second?

4. A twelve-row planter has electric blowers on each row unit that requires 5 amperes of current for each motor. The tractor electrical system operates at 12 volts. What total current draw and electrical power will the planter require?

3 Transmission of Power

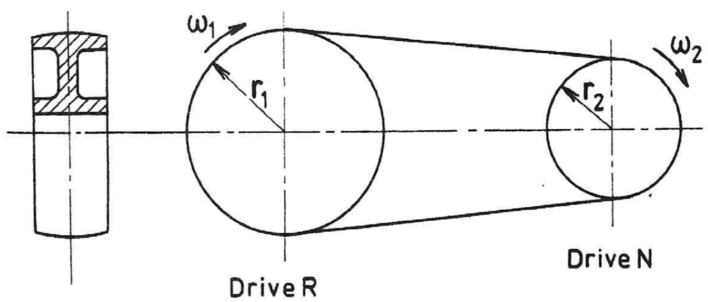
3.1 Methods of Power Transmission

Engines convert fuel chemical energy into mechanical power. Combustion of the fuel causes one or more reciprocating pistons, each contained in a cylinder, to turn a crankshaft. The crankshaft delivers the power via a flywheel and an output shaft to the desired load. ***Power transmission is then the movement of energy from its place of generation to a location where it is applied to performing useful work.*** Power transmission is normally accomplished by belts, ropes, chains, gears, couplings and friction clutches. The tractor power transmission system is revealed using the figure shown below.



Power is transmitted from one shaft to another shaft by means of belts, chains and gears. For *large distance* between the shafts, belts and chains are used; however, for *small distances* gears are used.

(1) Belt Drives: A belt drive is used to transmit power from one shaft to another. The drive is transmitted by a continuous flexible belt which runs on pulleys mounted on the two shafts.



Velocity Ratio of Belt Drive: It is the ratio between the velocities of the driver and the driven pulley. Velocity ratio = $N_2/N_1 = D_1/D_2$ Where: D is diameter of the pulley and N is speed in revolution per minute (rpm). The small pulley has the faster rotational speed and the lower torque. Note, however, that both pulleys rotate in the same direction.

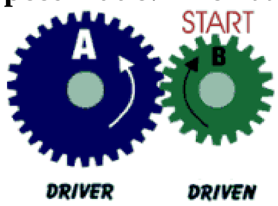
Characteristics of belt drives

(a) Belt drives are suitable for medium to long center distances compared with gears, which are suitable only for short center distances. (b) Belt drives have some slip and creep (due to the belt extending slightly under load) and therefore do not have an exact drive ratio. (c) Belts provide a smooth drive with considerable ability to absorb shock loading. (d) Belt drives are relatively cheap to install and to maintain. A well-designed belt drive has a long service life. (e) No lubrication is required. In fact, oil must be kept off the belt. (f) Belts can wear rapidly if operating in abrasive (dusty) conditions.

(2) Gears: A toothed wheel that engages another toothed mechanism in order to change the speed or direction of transmitted motion. A gear is a component within a transmission device that transmits rotational force to another gear or device. A gear is different from a pulley in that a gear is a round wheel which has linkages ("teeth" or "cogs") that mesh with other gear teeth, allowing force to be fully transferred without slippage. According to the peripheral velocity, gears may

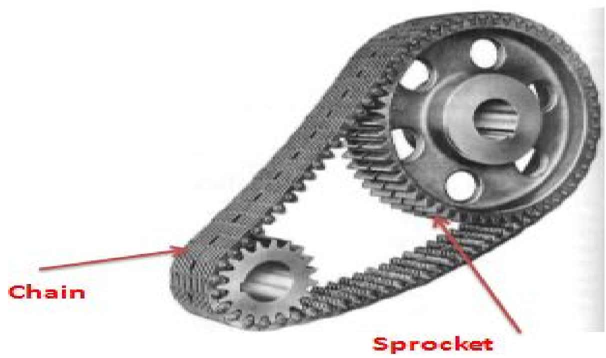
be classified as : *(a) Low velocity gears*: gears having velocity less than 3 m/s *(b) Medium velocity gears*: gears having velocity between 3 and 15 m/s *(c) High velocity gears*: velocity of gears more than 15 m/s.

Speed ratio: The ratio of the number of revolutions of the driving (or input) gear to the number of revolutions of the driven (or output) gear, in a unit of time.



Speed ratio = $N_A/N_B = T_B/T_A$. [N_A = Speed of gear A (or driver) in r.p.m., N_B = Speed of gear B (or driven or follower) in r.p.m., T_A = Number of teeth on gear A, and T_B = Number of teeth on gear B].

(3) Chain Drives: The name 'sprocket' applies generally to any wheel upon which are radial projections that engage a chain passing over it. It is distinguished from a gear in that sprockets never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth. The most commonly known examples of sprockets are on bicycles, tracked vehicles like tanks and bulldozers, film cameras, and film projectors.



Characteristics of Chain Drives

(a) Chains transmit shock loading, whereas belts tend to absorb any shock loading which may occur.

(b) The speed ratio is determined by the number of teeth on the two chain wheels or sprockets, although calculations based on sprocket pitch diameters and pitch line velocities are equally valid.

(c) A chain drive is more costly to set up than a belt drive, but has a long life.

(d) Very high torques may be transmitted by chains, beyond the capacity of belt drives.

(e) Chains generally require lubrication and a heavy-duty chain drive may require a sealed housing incorporating bath or jet lubrication, thereby increasing cost.

(f) Abrasive material rapidly destroys a chain drive.

3.2 Lubrication

IC engine is made of many moving parts. Due to continuous movement of two metallic surfaces over each other, there is wearing of moving parts, generation of heat and loss of power in the engine. Lubrication of moving parts is essential to prevent all these harmful effects.

Purpose of lubrication

Lubrication of the moving parts of an IC Engine performs the following functions:

(i) Reduces the wear and prevents seizure of rubbing surfaces (Reduce wear)
(ii) Reduces the power needed to overcome the frictional resistance (Reduce frictional effect).
(iii) Removes the heat from the piston and other parts (Cooling effect)
(iv) Serves as a seal between piston rings and cylinder (Sealing effect)
(v) Removes the foreign material between the engine working parts

4 Tillage

4.1 Introduction to Tillage

Tillage may be called the practice of modifying the state of soil to provide favorable conditions for plant growth. *Soil tillage consists of breaking the compact surface of earth to a certain depth and to loosen the soil mass, so as to enable the roots of the crops to penetrate and spread into the soil.* Tillage operation is most labor consuming and difficult operation, compared to all subsequent operation in the field.

Objectives of Tillage

(i) To prepare a suitable seed bed. A good seed bed is considered to imply finer soil particles at greater fineness soil in the vicinity of seeds. A fine soil structure is desirable to *allow rapid infiltration, provide adequate air capacity to exchange with in the soil and to minimize resistant to root penetration.*
(ii) To add more humus and fertility to soil by covering the vegetation
(iii) To destroy and prevent weeds
(iv) To aerate the soil for proper growth of crops
(v) To increase water absorbing capacity of the soil
(vi) To destroy the insects, pests and their breeding places and
(vii) To reduce the soil erosion
Tillage is divided into two classes: primary and secondary tillage

4.2 Primary Tillage

It constitutes the *initial major soil working operation*. It is normally designed to reduce soil strength, cover plant materials, and rearrange aggregates. The operations performed to open up any cultivable land with a view to prepare a seed bed for growing crops in known as Primary tillage. Implements may be *tractor drawn or animal drawn implements*. Animal drawn implements mostly include indigenous plough and mould-board plough. Tractor drawn implements include *mould-board plough, disc plough, rotary tiller, subsoil plough and chisel plough.*

Primary Tillage Equipments *(mould board plough, disc plough, rotary, chisel and subsoiler)*

The ploughing of land separates the top layer of soil into furrow slices. The furrows are turned sideways and inverted to a varying degree, depending upon the type of plough being used. It is a primary tillage operation, which is performed to shatter soil uniformly with partial or complete soil inversion.

Mould board plough: A mould board plough is very common implement used for primary tillage operations. This plough performs several functions at a time such as (1) Cutting the furrow slice (2) Lifting the furrow slice (3) turning the furrow slice (4) Pulverizing the soil.

Components: M.B. Plough consists of share, mould board, landside, frog and tail piece
(a) Share - It penetrates into the soil and makes a horizontal cut below the soil surface. It is a sharp, well-polished and pointed component.
(b) Mould board - The mould board is that part of the plough which receives the furrow slice from the share. It lifts, turns and breaks the furrow slice. To suit different soil conditions and crop requirements, mould board has been designed in different shapes.
(c) Land side - It is the flat plate which bears against and transmits lateral thrust of the plough bottom to the furrow wall. It helps to resist the side pressure exerted by the furrow slice on the mould board. It also helps in stabilizing the plough while it is in operations.
(d) Frog - Frog is that part of the plough bottom to which the other components of the plough bottom are attached. It is an irregular piece of metal. It may be made of cast iron for cast iron ploughs or it may be welded steel for steel ploughs.

(e) Tail piece - It is an important extension of mould board which helps in turning a furrow slice.

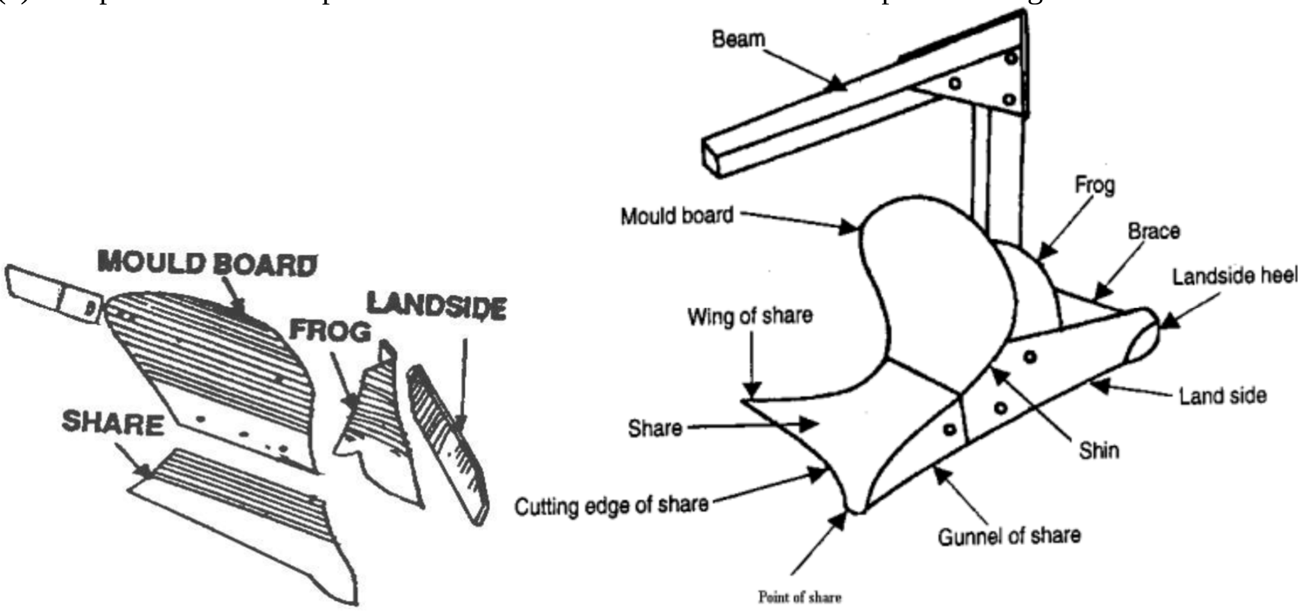
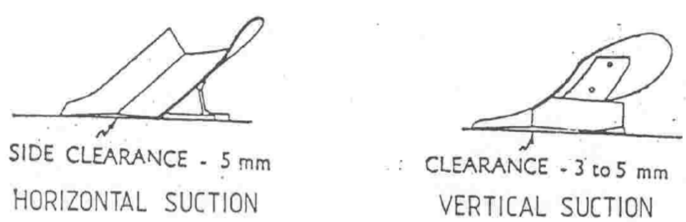


Figure 4.1 Components of mould board plough

Adjustment of Mould board Plough

(a) Vertical Suction (Vertical Clearance): It is the maximum clearance under the land side and the horizontal surface when the plough is resting on a horizontal surface in the working position. It is the vertical distance from the ground, measured at the joining point of share and land side. It helps the plough to penetrate into the soil to a proper depth. This clearance varies according to the size of the plough.



(b) Horizontal Suction (Horizontal Clearance): It is the maximum clearance between the land side and a horizontal plant touching point of share at its gunnel side and heal of land side. This suction helps the plough to cut the proper width of furrow slice. This clearance varies according to the size of the plough. It is also known as side clearance.

Disc Ploughs: It is a plough which cuts, turns and in some cases breaks furrow slices by means of separately mounted large steel discs. *A disc plough is designed with a view to reduce friction by making a rolling plough bottom.* A disc plough works well in the conditions where mould board plough does not work satisfactorily.

Advantages of disc plough: (1) Disc plough can be forced to penetrate into the soil which is too hard and dry. (2) It works well in sticky soil in which a mould board plough does not scour. (3) It is more useful for deep ploughing. (4) It can be used safely in stony and stumpy soil without much danger of breakage. (5) A disc plough works well even after a considerable part of a disc is worn off in abrasive soil. (6) It works in loose soil also (such as peat) without much clogging.

Disadvantages of Disc Plough

(i) It is not suitable for covering surface trash and weeds effectively as mould board plough does.

(ii) Comparatively, the disc plough leaves the soil in rough and cloddy condition than that of mould board plough. **(iii)** Disc plough is much heavier than mould board plough for equal capacities because penetration of this plough is affected largely by its weight rather than suction.

There is one significant difference between mould board plough and disc plough i.e., mould board plough forced into the ground by the suction of the plough, while the disc plough is forced into the ground by its own weight.

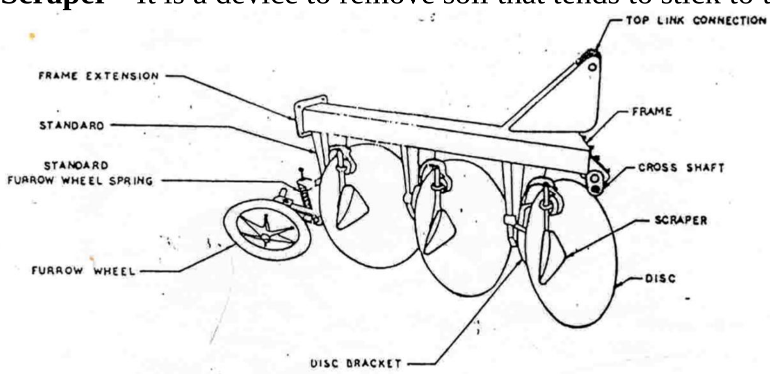
Few important terms connected with disc plough are explained below.

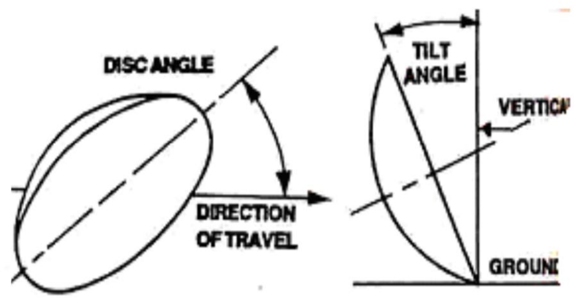
Disc - It is a circular, concave revolving steel plate used for cutting and inverting the soil. Standard disc plough consists of steel disc of 60 to 90 cm diameter, set at a certain angle to the direction of travel. The angle of the disc to the vertical and to the furrow wall is adjustable. Disc is made of heat treated steel of 5 mm to 10 mm thickness. The amount of concavity varies with the diameter of the disc. The approximate values being 8 cm for 60 cm diameter disc and 16 cm for 95 cm diameter.

Disc angle - It is the angle at which the plane of the cutting edge of the disc is inclined to the direction of travel. Usually the disc angle of good plough varies between 42° to 45°.

Tilt angle - It is the angle at which the plane of the cutting edge of the disc is inclined to a vertical line. The tilt angle varies from 15° to 25° for a good plough.

Scraper - It is a device to remove soil that tends to stick to the working surface of a disc.





Concavity - It is the depth measured at the center of the disc by placing its concave side on a flat surface.

Furrow wheel - It is wheel of the plough which runs in the furrow.

Rotary Tiller: The rotary cultivator is widely considered to be the most important tool as it provides fine degree of pulverization enabling the necessary rapid and intimate mixing of soil besides reduction in traction demanded by the tractor driving wheels due to the ability of the soil working blades to provide some forward thrust to the cultivating outfit.

Chisel Plough: Chisel ploughs are used to break through and shatter compacted or otherwise impermeable soil layers. Deep tillage shatters compacted sub soil layers and aids in better infiltration and storage of rainwater in the crop root zone. The improved soil structure also results in better development of root system and the yield of crops and their drought tolerance is also improved. The functional component of the unit includes reversible share, tyne (chisel), beam, cross shaft and top link connection. Similar in their action with sub soiler but differ mainly in their working depth.

Sub-Soiler: The function of the sub-soiler is to penetrate deeper than the conventional cultivation machinery and break up the layers of the soil, which have become compacted *due to the movement of heavy machinery or as a result of continuous ploughing at a constant depth. These compacted areas prevent the natural drainage of the soil and also inhibit the passage of air and nutrients through the soil structure.* The sub-soiler consists of heavier tyne than the chisel plough to break through impervious layer shattering the sub-soil to a depth of 45 to 75 cm and requires 60 to 100 hp to operate it. The advantages are same as that of chisel plough. It is heavy duty implement designed to operate below the normal depth of tillage and to loosen the soil by lifting / displacement. Mold board and Disc plough penetrates the top soil part whereas sub-soiler penetrates up to the sub soil.

4.3 Secondary Tillage

Tillage operations following primary tillage which are performed to create proper soil tilth for seeding and planting are secondary tillage. These are lighter and finer operations, performed on the soil after primary tillage operations. Secondary tillage consists of conditioning the soil to meet the different tillage objectives of the farm. The main objectives of secondary tillage are:

(a) To break the big clods and make the soil surface uniform and leveled as needed for a seed bed
(b) To destroy grasses and weeds in the field
(c) To cut crop residues and mix them with top soil

The implements used for secondary tillage operations are called secondary tillage implements. They include different types of harrow, cultivators, levelers and similar implements. These operations consume *less power per unit area* compared to primary tillage operations. Secondary tillage implements may be *tractor drawn or oxen drawn implements*. Oxen drawn implements include harrows, cultivators, hoes etc.

Secondary Tillage Equipments (harrows & cultivators)

Harrowing: It is secondary tillage operation which pulverizes, smoothens and packs the soil in seed bed preparation and/or to control weeds.

Harrow: A harrow is an implement that cuts the soil to a shallow depth for smoothening and pulverizing the soil as well as to cut the weeds and to mix materials with soil. It is an implement used to break the clods after ploughing, to collect trash from the ploughed land and to level the seed bed.

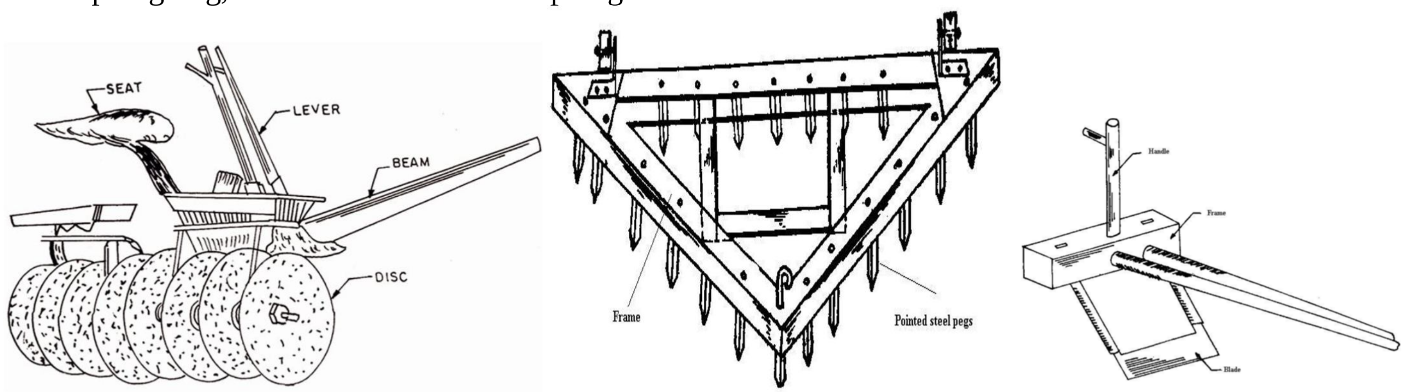
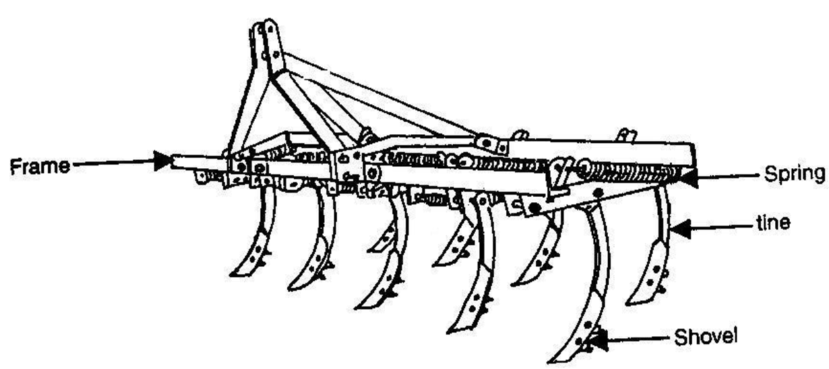


Figure 4.2 (a) Animal drawn disc harrow (b) Peg tooth or triangular harrow (c) Blade harrow

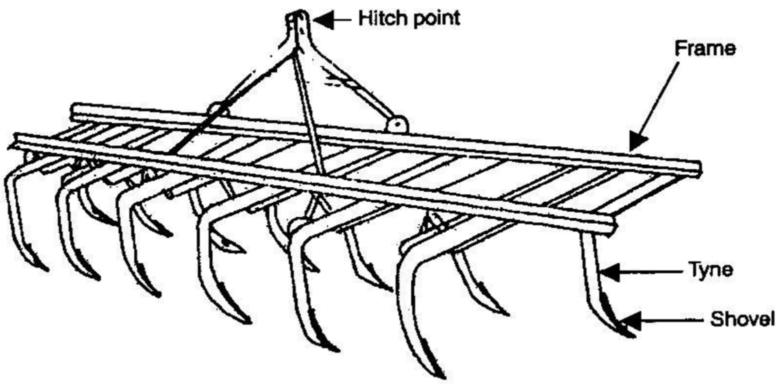
Cultivator: A cultivator performs functions intermediate between those of plough and the harrow. Destruction of weeds is the primary function of a cultivator.

Cultivator with spring loaded tines: A tine hinged to the frame and loaded with a spring so that it swings back when an obstacle is encountered, is called spring loaded tine. Each tine of this cultivator is provided with two heavy coil springs, tensioned to ensure minimum movement except when an obstacle is encountered. The springs operate, when the points strike roots or large stones by allowing the tines to ride over the obstruction, thus preventing damage. On passing over the obstruction, the tines are automatically reset and work continues without interruption. The tines are made of high carbon steel and are held in proper alignment on the main frame members. This type of cultivator is particularly



recommended for soils which are embedded with stones or stumps. A pair of gauge wheel is provided on the cultivator for controlling the depth of operation. The cultivator may be fitted with 7, 9, 11, 13 tines or more depending upon the requirement.

Cultivator with rigid tines: Rigid tines of the cultivator are those tines which do not deflect during the work in the field. The tynes are bolted between angle braces, fastened to the main bars by sturdy clamps and bolts. Spacing of the tines are changed simply by slackening the bolts and sliding the braces to the desired position. Since rigid tines are mounted on the front and rear tool bars, the spacing between the tynes can be easily adjusted without getting the tines chocked with stubbles of the previous crop or weed growth. A pair of gauge wheel is used for controlling the depth of operation.



4.4 Methods of Ploughing with a Tractor

Ploughing of the land separates the top layer of soil into furrow slices. The furrows are turned sideways and inverted to a varying degree, depending upon the type of plough being used. It is a primary tillage operation, which is performed to shatter soil uniformly with partial or complete soil inversion. There are a few important terms frequently used in connection with ploughing of land.

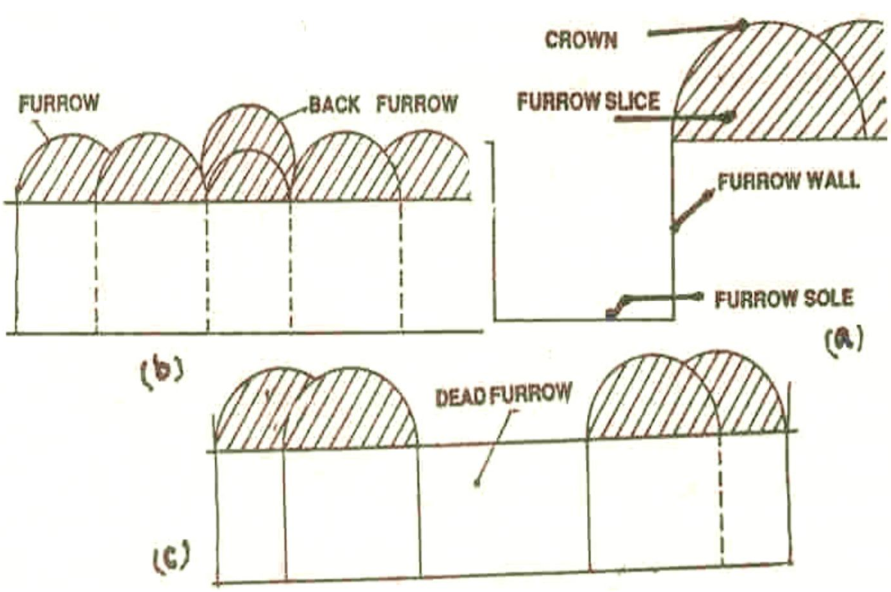
(i) Furrow -It is a trench formed by an implement in the soil during the field operation.

(ii) Furrow slice - The mass of soil cut, lifted and thrown to one side is called furrow slice.

(iii) Furrow wall - It is an undisturbed soil surface by the side of a furrow.

(iv) Crown - The top portion of the turned furrow slice is called crown.

(v) Back furrow - A raised ridge left at the center of the strip of land when ploughing is started from center to side is called back furrow. When the ploughing is started in the middle of a field**,** furrow is collected across the field and while returning trip another furrow slice is lapped over the first furrow. This is the raised ridge which is named as back furrow.

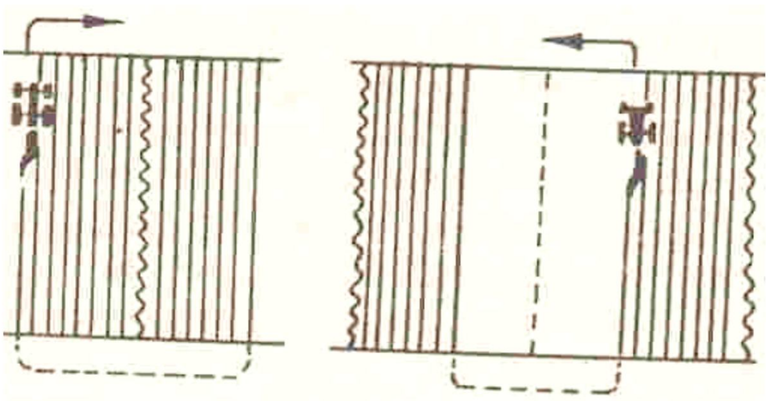


(vi) Dead furrow - An open trench left in between two adjacent strips of land after finishing the ploughing is called dead furrow.

(vii) Head land - While ploughing with a tractor to turn, a strip of unploughed land is left at each end of the field for the tractor to turn that is called head land. At the end of each trip, the plough is lifted until the tractor and the plough have turned and are in position to start the return trip. *The head land is about 6 meters for two or three bottom tractor plough and one meter more for each additional furrow.*

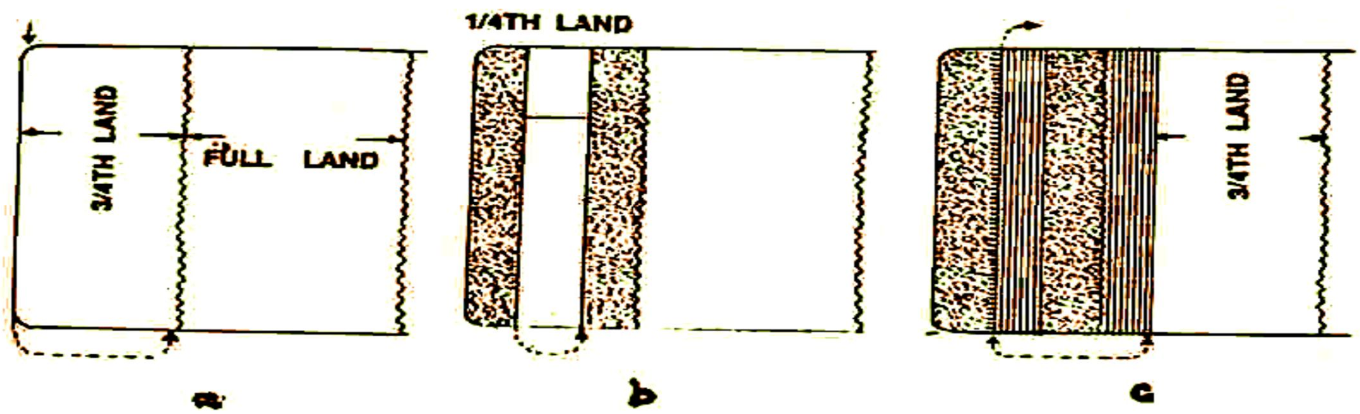
Methods of ploughing: A normal right-hand plough must always have an open furrow on the right in which to lay the next furrow slice. It is therefore, necessary to travel across the field in one place and come back in another. There are two ways of doing this by *"gathering" and "casting"*. That means in order to provide furrows at all times on the right-hand side of the plough two method of working are used (***a) gathering and (b) casting***.

Gathering *(1st part of the figure)***:** Whenever a plough works round a strip of ploughed land, it is said to be gathering. The tractor and plough turn to right each time the head land is reached. When the land is ploughed, a raised ridge (double width ridge) is formed in the center of the field. This however would be *uneconomical* way of working as *time is wasted at the start in making awkward turns*, while later, total idle running would be increased along the head land.



Casting *(2nd part of the figure)***:** Whenever a plough works round a strip of unploughed land, it is said to be casting. The tractor and plough turn to the left each time the head land is reached. When the land is ploughed in this way a wide furrow (double width furrow) will be left in the center and is termed as 'finish' or open furrow or dead furrow. *It is recommended that long field should be ploughed by gathering in one season and casting in another season. It avoids building up of a ridge in the center and an open furrow at each side or vice versa.* However, ploughing of a field either by casting or by gathering alone is normally uneconomical. For economical ploughing the following methods are used.

(a) Continuous ploughing method: In normal conditions, the continuous ploughing method is considered very convenient and economical.



This is a method usually used in which the tractor and plough *never run idle for more than three quarter land width along the headland and never turn in a space narrower than a quarter land width*. In this method, first the headland is marked and the first ridge is set up at three quarter of a land width from the side (Fig. a). The other ridges are set at full width over the field. The operator starts ploughing between the first ridge and the side land. The operator continues to turn left and cast in the three-quarter land until ploughing is completed in a quarter land width on each side (Fig. b). At this stage, the plough is lifted to half depth for the last trip down the side land of the field. This leaves a shallow furrow where the finish comes. After this stage, the driver turns right and gathers round the one fourth land already ploughed. Gathering is continued till the unploughed strip in first three-quarter land is ploughed and completed. This gathering reduces the first full land by a quarter (Fig. c). The remaining three-quarter land can be treated in exactly the same manner as the original three-quarter land completed earlier. This process is repeated for all other lands in the field.

(b) Round and round ploughing: In this method, the plough moves round and round in a field. This system is adopted under conditions where ridges and furrows interfere with cultivation work. The field can be started in two ways.

(i) Starting at the center: A small plot of land is marked in the middle of the field and it is ploughed first. After that, the plough works round this small plot and the entire plot is completed. This is not a very economical method.

(ii) Starting at the outer end: Tractor starts ploughing at one end of the field and then moves on all the sides of the field and comes gradually from the sides to the center of the field. Wide diagonals are left unploughed to avoid turning with the plough. There are no back furrows in this method. Conventional ploughing is usually done by this method.

(c) One-way ploughing: This system requires the use of a special type of plough known as reversible plough or one-way plough. Such a plough turns furrows to the left or right. After the head land has been marked, the operator plough along a straight side land mark. At the end of the first trip, he turns his tractor in a loop and returns down the same furrow. No dead and back furrows are left in the field. In gently sloping fields, this method is suitable.

5 Planting Equipment

5.1 Definition

Planting equipment (Planters) are machines that are used to place seeds/seedlings in the soil at a correct amount of seed per unit area (population), depth and spacing requirements.

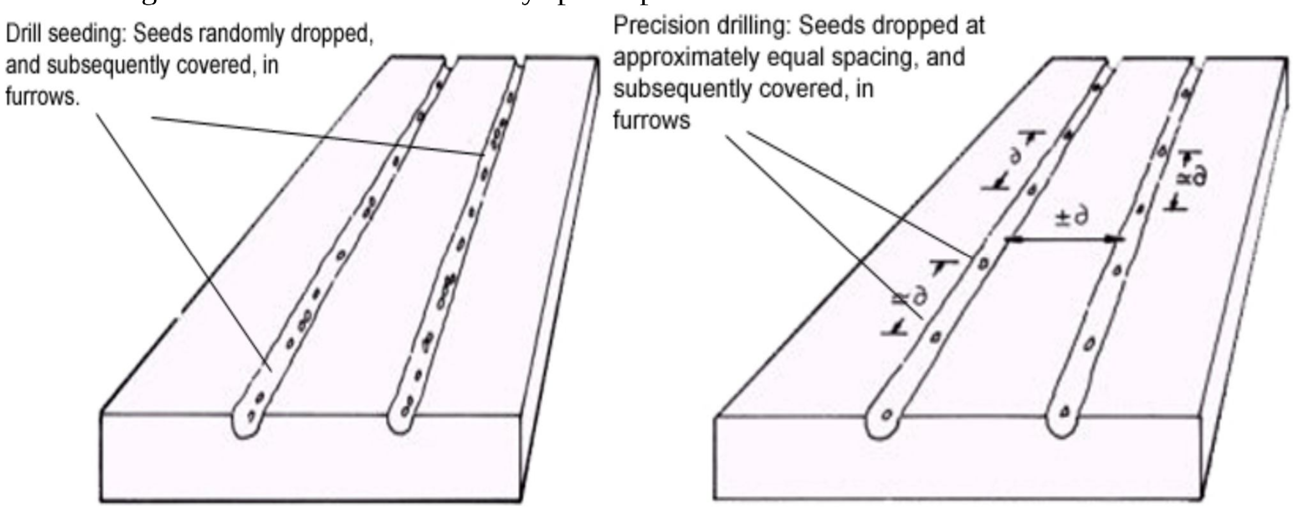
5.2 Planting Methods

The possible planting methods include

(1) Broadcast planting
(2) drill planting
(3) precision drill planting
(4) Hill drop planting
(5) check row planting and
(6) dibble/punch planting

(1) Broadcast planting: The pattern resulting from the random scattering of seeds on the soil surface.

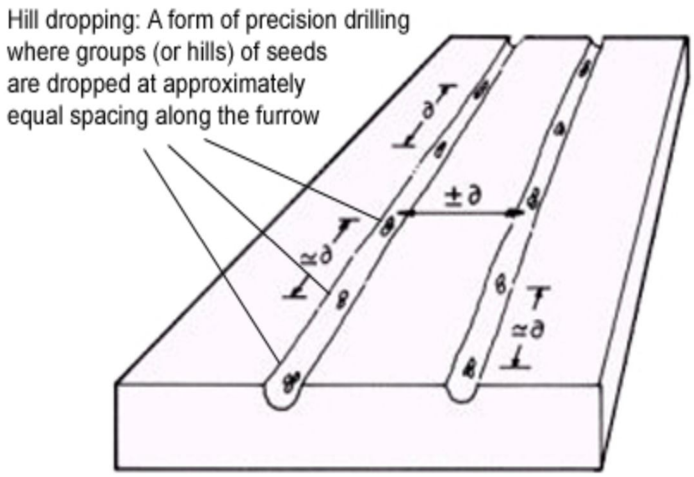
(2) Drill planting: The pattern resulting from the random dropping (and subsequent covering) of seeds in furrows to give definite rows of randomly spaced plants.

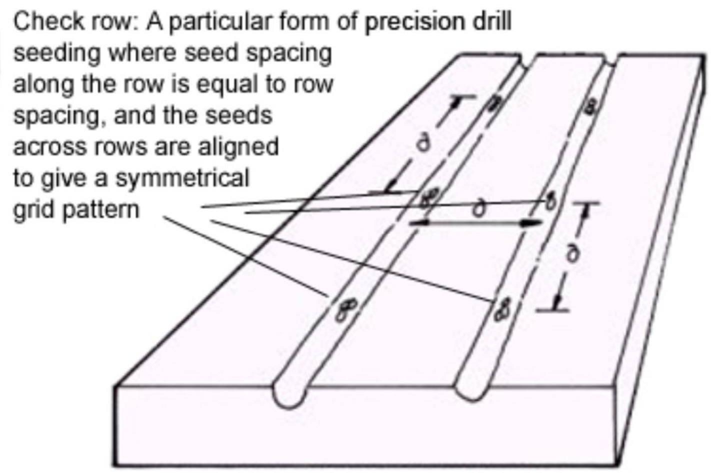


(3) Precision drill planting: The pattern resulting from the accurate placement (and subsequent covering) of single seeds in furrows at about equal intervals to give definite rows of almost equally spaced single plants

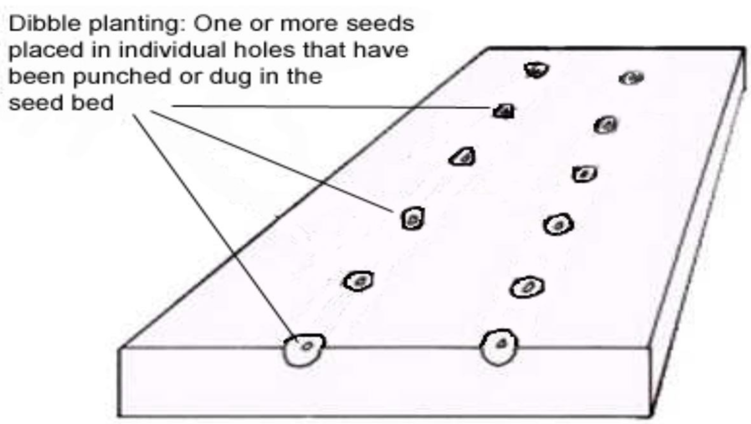
(4) Hill drop planting: The pattern resulting from the accurate placement (and subsequent covering) of groups (or hills) of seed in furrows at about equal intervals to give definite rows of almost equally spaced groups of plants.

(5) Check row planting: The square-grid planting pattern resulting from the accurate and indexed placement (and subsequent covering of seed) of individual seeds or groups of seed. Individual plants, or groups of plants, are spaced equidistant apart and aligned in perpendicular rows.





(6) Dibble or punch planting: The pattern resulting from placing single or multiple seeds in individual holes that have been 'punched' or otherwise dug in the seedbed. The holes are usually aligned to form rows of established plants. Nevertheless, when hand, rather than machine planting methods are used, the holes may be randomly placed over the seedbed surface



5.3 Classification of Planting Machinery

Planting machinery can be broadly classified on the basis of a combination, where applicable, of:
(i) The number of rows planted in one pass of the machine;
(ii) The method of attachment to and the type of power source used to propel the machine; and
(iii) The type of planting machine based on the resultant planting pattern.

A key for planter classification

Type of Planter	Power Source	Mounting	Mounting Options	Number of Rows
Broadcast or Drill or Precision or Dibble	Human	Hand held Hand pushed Hand pulled		As Applicable
	Animal	Pulled		
	Tractor	Trailed Semi mounted		
		Mounted	Rear Mid Front	

(i) The number of rows planted: The number of rows planted/holes punched per pass of the machine is directly related to how many furrow openers it has. Machines can be classified as single row, five row, 40 row, etc, depending on the number of furrow openers. On multi-row machines, the furrow openers are typically uniformly spaced across the full width of the machine.

(ii) The method of attachment to, and the type of, power source: On the basis of the power source used to provide the draft (i.e. the horizontal component of the force required to propel the machine through the soil), planters can usually be classified as: (1) Human (2) Animal or (3) Tractor-powered planters

Methods of attachment are those that typically get the planter pulled by, pushed by, or carried and pulled by the power source.

Human-powered planters: Human-powered planters can typically be categorized as being either:
(i) Hand held/carried or (ii) Hand pulled or pushed.

Animal-powered planters: Animal-powered planters are typically categorized as pulled.

Tractor-powered planters: Tractor-powered planters can generally be categorized as being: (1) Trailed (2) Semi-mounted or (3) Mounted

(iii) The type of planting machine based on the resultant planting pattern

Broadcast planters: Broadcast planters randomly distribute seed on the soil surface. As the seeds are deposited on the soil surface (i.e. not in furrows created by a furrow opener) an additional operation (e.g. harrowing) may be needed to cover seed. The use of a broadcast fertilizer spreader to distribute seed on the soil surface is the most common example of the broadcast planter. This type of planter is useful for establishing small seeds, particularly those with light requirements for germination (such as some pasture grasses). Broadcast planter types are not generally appropriate for cash crops because of the obvious limitations to controlling or meeting agronomic requirements.

Drill planters: Drill planters randomly drop seeds in furrows to form definite rows of established plants. This type of planter uses a mass flow type seed meter where there is no need to place plants equidistant down the rows. For example, almost all cereal crops (oats, wheat, barley, etc) are planted by drill type planters. Reasonably accurate control over the planting rate per hectare can be attained. *Drill type planters are often known as solid crop planters because of the narrow row spacing typically used.*

Precision planters: These are typically used to plant crops that require accurate control of plant population, and spacing between and along the rows. Crops in this category include almost all the horticultural crops and field crops such as sorghum, maize, sunflower, soybeans and cotton. Precision seed metering systems giving a precision drill, hill drop or check row planting pattern are used on this type of planting machine.

Many of the crops requiring the use of precision planters are grown in summer are planted in wide rows and have individual seed boxes and associated seed meters for each row. Accordingly, precision planters are often referred to as summer crop planters, row crop planters or unit planters, respectively.

Dibble/punch planters: Dibble planters place a seed or a number of seeds in discrete holes, rather than furrows, dug in the seedbed. Typically, although not necessarily, the holes are equally spaced and aligned so as to form rows. Hand-operated dibble planters are commonly used to establish crops (particularly inter-crops) in small-scale, low-resource agricultural crop production systems. Tractor-mounted dibble type planters are commonly used in horticulture to plant seeds into seedbeds covered with plastic mulch. To date, few commercial dibble planters have been available for large-scale production systems, particularly where there are crop residues on the seedbed surface at planting. Considerable research is being undertaken to develop such machines because of the potential benefits in improving the ability of planters to handle residue and reducing planter energy requirements.

Specialized planters: Specialized planters are those that do not plant seeds but rather whole plants (i.e. seedling transplanters), plant stems (e.g. sugar cane whole stick or set type planters) or tubers (e.g. potato planters), etc.

5.4 Functional Requirements & Components of Planting Machinery

5.4.1 Functional Requirements of Planting Machinery

To successfully establish crops over the range of conditions likely to exist at planting, a planter should be able to:

(i) open a furrow
(ii) meter the seed
(iii) deliver the seed to, and place the seed appropriately in, the furrow
(iv) cover the seed in the furrow
(v) firm the seedbed; and
(vi) perform other functions as required, e.g. weed control, apply crop chemicals, etc. These functions must be performed at an *acceptable forward speed and with a high degree of reliability.*

5.4.2 Components of Planting Machinery

Planting machines can be considered as an assemblage of components, each designed to meet a particular function, e.g. open a furrow, meter the seed, deliver the seed to the furrow, close the furrow and firm the seedbed. Planter components can be logically grouped by function into the following categories:

(A) Soil-engaging components
(B) Furrow opener depth control components
(C) Seed metering system and
(D) Seed delivery components

(A) Soil-engaging components

The functions performed by the soil-engaging components include opening the furrow, placing the seed, covering the furrow and firming the seedbed. Where there are high levels of surface residue and relatively unprepared seedbeds, devices to cut or otherwise manipulate soil and residue (row preparation devices) may be required in addition to the furrow-opening device. Similarly, firming/re-leveling the seedbed after seed placement and covering may require the use of a non-row specific (i.e. full width) device (such as harrows or rollers) in addition to a row specific firming device (such as press wheels). Soil-engaging components sometimes have several functions, e.g. a single disc coulter used as a furrow opener may also perform a residue and soil cutting function. The full range of soil-engaging components available for use on planting equipment is classified under seven functional groups:

1. Soil and residue cutting devices
2. Row preparation devices

3. Furrow opening devices
4. Seed firming devices
5. Seed covering devices
6. Row specific seedbed firming devices
7. Non row specific seedbed firming/leveling devices

The relative position or location of these soil-engaging component groups, in relation to the direction of travel of a planter, is shown in the figure shown below.

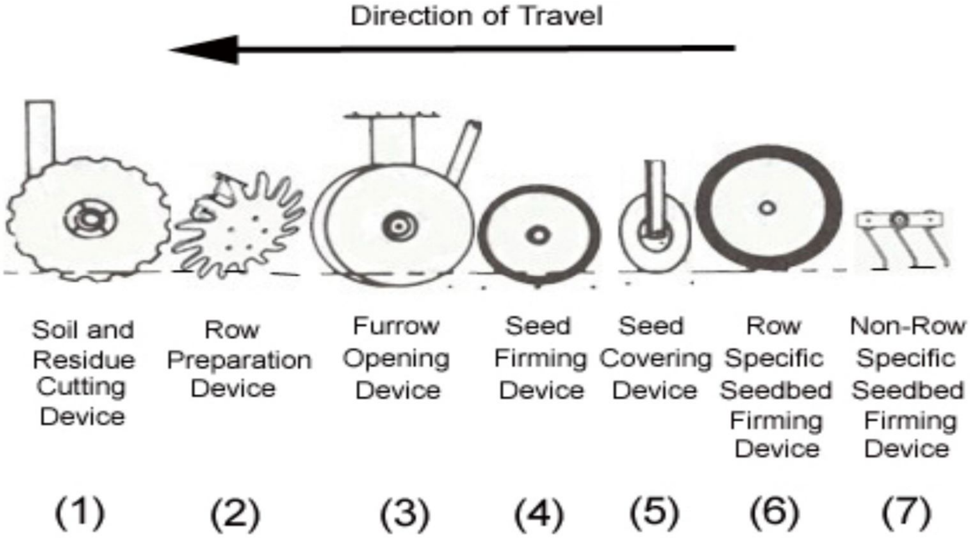
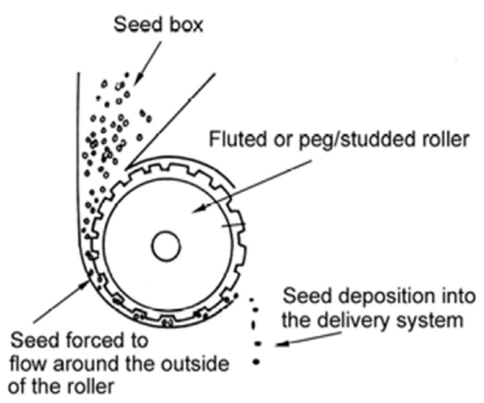


Figure 5.1 Planter soil-engaging component groups

(B) Furrow opener depth control components

As furrow depth is measured relative to the seedbed surface, the *functional requirements* of furrow opener depth control mechanisms include the ability to: (a) open the furrow to the required depth; (b) maintain uniformity of depth along the length of the furrow; and (c) on multi-row machines, maintain the same depth on all openers across the width of the machine.

(C) Seed metering system



Seed metering devices are those devices that meter the seed from the seed box and deposit it into the delivery system that conveys the seed for placement on or in the seedbed. The major functional requirements of seed metering systems are to:
(a) meter the seed at a predetermined rate/output (e.g. kg/ha or seeds/meter of row length); (b) meter the seed with the required accuracy (spacing) to meet the planting pattern requirements (i.e. drill seeding, precision drilling, etc); and (c) cause minimal damage to the seed during the metering process. In addition, the size of the seed box or boxes, the ease of filling and emptying these boxes, and the ease of calibrating, cleaning and adjusting the seed metering rate must all be considered as all affect the overall performance and efficiency of the planting operation.

(D) Seed delivery components

Seed delivery systems include those devices that convey the seed from the meter to the device that deposits the seed on the soil surface or in the furrow. The essential functional requirements of seed delivery systems are to: (a) convey the seed from the seed meter discharge point to the seed placement device; (b) maintain metering accuracy (seed spacing) during seed conveyance; and (c) enable the seed to be deposited on the soil surface or in the furrow in an appropriate manner in terms of both seed placement within the furrow and seed spacing along the row. Ideally, the seed delivery system should deposit the seed on the firm, moist base of the furrow (unless required otherwise for a specific reason). *The seed falls through a cavity or a tube from the seed meter to the soil by the use of gravity, mechanical assist; or Pneumatic (vacuum) systems.*

Summary:
(A) Soil-engaging components (i.e. soil and residue cutting device; row preparation device; furrow opener; seed firming device; seed covering device; row specific seed firming device and non- row specific seed firming/leveling device);
(B) Furrow opener depth control mechanism (i.e. frame section gauging or types within individual row gauging systems);
(C) Seed metering (i.e. specific types within mass flow or precision metering systems); and
(D) Seed delivery and/or division system (i.e. types within gravity drop, mechanical assisted or pneumatic delivery/division systems.

5.5 Calibration of Seed Drill and Seed-Cum-Fertilizer Drill

The seed drill is checked weather it delivers the seed in accordance with the recommended seed rate or not. If any discrepancy is found between seed delivery of the drill and the recommended seed rate, then the seed metering mechanism is adjusted to deliver correct seed rate. This is called calibration of a seed drill. It is necessary to calibrate the seed drill before operating in the field to get a predetermined seed rate of the machine so that accurate and efficient distribution of seed is ensured. The following steps are to be followed for calibration of seed drill or seed-cum-fertilizer drill.

1: Determine the nominal width (W) of drill. $W = M \times S$

Where M is the number of furrow openers and S is the spacing between the openers in meter and W is in meter.

2: Find the length of a strip (L) having nominal width W necessary to cover 1/25th of a hectare.

$$L = \frac{10000}{W} * \frac{1}{25} = \frac{400}{W} \text{ m}$$

3: Determine the number of revolutions (N) the ground wheel has to make to cover the length of the strip (L).

$$\pi * D * N = \frac{400}{W} \qquad \therefore \; N = \frac{400}{\pi * D * W} \quad \text{rpm}$$

4: Raise the seed drill in such a way that the ground wheels turn freely. Make a mark on the drive wheel and a corresponding mark at a convenient place on the body of the drill to help in counting the revolutions of the drive wheel.

5: Put selected seed and fertilizer in the respective hoppers. Place a sack or a container under each boot for seed and fertilizers.

6: Set the rate control adjustment for the seed and the fertilizer for maximum drilling. Mark this position on the control for reference.

7: Engage the clutch or on-off adjustment for the hoppers and rotate the drive wheel at the speed N.

$$N = \frac{400}{\pi * D * W} \quad rpm$$

8: Weigh the quantity of seed and fertilizer, dropped from each opener and record on the data sheet.

9: Calculate the seed and fertilizer, dropped in kg/ha and record on the data sheet.

10: If the calculated seed rate is higher or lower than the desired rate of selected crop, repeat the process by adjusting the seed rate control adjustment till the desired seed rate is obtained.

Problem 1: The following results were obtained while calibrating a seed drill. Calculate the seed rate per hectare.

No. of furrow openers = 8 Spacing between furrows =15 cm Diameter of drive wheel =1.5 m
RPM of the drive wheel = 600 Seed collected =25 kg.

Solution:

- ✓ Effective width of seed drill = 8 ×15 = 120 cm = 1.2 m
- ✓ Circumference of drive wheel = $\pi * 1.5$m
- ✓ Area covered in one revolution = $\pi * 1.5 * 1.2$=5.66 m^2
- ✓ Area covered in 600 revolutions = 5.66 ×600 = 3396 m^2
- ✓ Seed dropped for 3396 m^2 = 25 kg
- ✓ Seed dropped/ha = (25*10000)/3396 = 73.6kg
- ✓ Seed rate = 73.6 kg

Problem 2: Calculate the cost of seeding one hectare of land with ox drawn seed drill of 5×30 cm size. The speed of ox is 3 km/hr. Hire charges of ox is Br. 100/ pair/day, hire charges of seed drill is 200 Br per day and wage of operator is 200 Br per day of 8 hours.

Solution:

- Width of seed drill = 5×30 = 150 cm = 1.5 m
- Area covered per hr = width × speed = 1.5 ×3×1000 =4500 m^2 =0.45 ha
- To cover 0.45 ha of area, one hour is required
- To cover one ha of area, time requirement = 1/0.45= 2.22 hr
- Time taken/ha = 2.22 hr
- Cost of seeding/hr =(100+200+200)/8 = 62.5 Br
- Cost of seeding/ha = 62.5 ×2.22 = 138.75

Problem 3: A fluted feed seed drill has eight furrow openers of single disc type. The furrow openers are spaced 30 cm apart and the main drive wheel has a diameter of 110 cm. How many turns of main drive wheel would occur when the seed drill has covered one hectare of area.

Solution:

- Circumference of drive wheel =$\pi * 110$ = 345.7 cm
- Total width of seed drill = 8 × 30 = 240 cm
- Area covered per revolution = 345.7 × 240 = 82968 cm^2 = 8.29 m^2
- Number of turns per ha = 10000/8.29 = 1206.3

Problem 4: Maximum yield of maize is obtained with a population of 30,000 plants per hectare. The rows are 140 cm apart and an average emergence of 80% is expected. Find: (a) How many seeds per hill should be planted if hills are 140 cm apart? (b) What would be seed spacing if crop is drilled?

Solution:

- Number of seeds per ha = 30000/0.80 = 37500
- Area covered per hill = 140 × 140 = 19600 cm^2 = 1.96 m^2
- No. of hills per ha = 10000/1.96 = 5102
  - (a)No. of seeds per hill = 37500/5102 = 7.35 rounded to 8
  - (b) Total length of row = 10000/1.4 = 7142.85m
- Spacing of drilled seed = 7142.85/37500 = 0.19m = 19cm.

6 Fertilizer and Chemical Applicators

6.1 Broadcaster, Granular and Liquid Fertilizer Applicators

Fertilizer application equipment can apply chemicals in dry or liquid form. Solid fertilizer can be in the form of granular (particles size 1-4 mm) or powder (particles size smaller than 1 mm). Liquid fertilizer is a term used for fertilizers in suspension or solution and for liquefied ammonia. The application may be in broadcasting or in bands. The machinery that is used for the purpose of broadcasting is generally called broadcaster (broadcast spreader). Granular applicators are used to apply fertilizer or lime using band or broadcast methods. Banding places the fertilizer, dry or liquid, in a band (group) where the crop roots can best utilize the nutrients. Liquid fertilizer applicators use the methods of foliar application *(spraying of fertilizer solutions on the foliage of growing plants)*, fertigation (*application of water soluble fertilizers through irrigation water*), injection into soil (*use of pressure tank to prevent surface volatilization loss*) and aerial application (*in case of inaccessible places like hilly areas, forest lands, grass lands or in sugarcane fields*).

6.2 Sprayers & Dusters: Insect pests, weeds and disease cause considerable damage to crops. If not controlled in time, the entire crop will get lost. The chemicals for protecting the plants need to be applied in the form of sprays, dusts, mist etc. Sprayers and dusters are available in many forms for this purpose.

Sprayers: Sprayer is a machine to apply fluids in the form of droplets. Sprayer is used for the following purposes: (i) application of fungicides to minimize fungal diseases, (ii) application of insecticides to control insect pests, (iii) application of herbicides to remove weeds and (iv) application of micronutrients such as manganese or boron on the plants. **The main functions of sprayer are** (i) to break the liquid into droplets of *effective size* (ii) to distribute them uniformly over the plants and (iii) to regulate the amount of liquid to avoid excessive application that might prove harmful or wasteful. Extremely fine droplets of less than 100 micron size tend to be diverted by air currents and get wasted. **Desirable qualities of sprayer are** (a) The sprayer should produce a steady stream of spray materials in the desired fineness of the particle so that the plants to be treated may be covered uniformly. (b) It should deliver the liquid at sufficient pressure so that it reaches all the foliage and spreads uniformly over the surface of the plant. (c) It should be light weight, sufficiently strong, easily workable and repairable.

Sprayer's classification: (a) Based on **power source**, sprayers may be classified as:

(i) Hand operated machines-suitable for small holdings. They are operated at pressure ranging from 1 to 7 kg/cm^2. **(ii) Power operated machines** - suitable for treating a large area. They are operated at pressure ranging from 20 to 55 kg/cm^2. **(iii) Air planes**- suitable for large scale work (e.g. inaccessible hilly areas, sugarcane farms etc…)

(b) Based on **spray volume**, sprayers may be classified as:

(1) High volume sprayer - More than 400 liters of spray liquid per hectare is used. The dilute liquids are applied by hydraulic machines. It consumes more time and labour. (2) Low volume sprayer- Spray volume ranges between 5 to 400 liters per hectare is used. It uses air stream from a fan as a pesticide carrier with small quantities of liquid. There is saving of material and labour. (3) Ultra-Low volume sprayer- Spray volume less than 5 liters per hectare is used. Due to very low volume application features, the spray chemicals can be applied in very low dilution or no dilution at all with these sprayers. The selection of technique depends on type of vegetation, kind of pests and approach to the field.

(c) Based on **working principle**, sprayers may be classified as: (i) Hydraulic energy sprayers (ii) Compression sprayers

(i) Hydraulic energy sprayers: In this category of sprayers, hydraulic pressure is thrust upon the liquid by the hand operated pumps. As a result, the liquid is forced through the nozzle in the form of a spray of droplets (diameter in the range of 300-400μm). Sprayers of this type are high volume, high pressure and suitable for complete coverage of both ground and field crops.

(ii) Compression Sprayers: In these types of sprayers, air is compressed into the container by the compression air pump. When sufficient pressure is developed, then the delivery system is operated to obtain spray in the form of fine droplets. The compressed air forces the liquid through the nozzle and the desired type of spray is achieved. For this purpose, the tank is usually filled to three fourths of its capacity, leaving one-fourth volume for the compressed air. The air pump is fitted vertically inside the container which acts as a force pump.

Duster: It is a machine used to apply chemical in dust form. Dusters make use of air streams to carry pesticides in finely divided dry form on the plants. Dusters are no longer widely used for field crops. Sprayers and granular applicators are generally preferred. However, small, hand-held dusters and backpack dusters are still quite popular for use in gardens and around the home.

7 Harvesters and Threshers

7.1 Harvesting

It is the operation of cutting, picking, plucking and digging or a combination of these operations for removing the crop from under the ground or above the ground or removing the useful part or fruits from plants. Sickle, mower (a machine to cut herbage crops and leave them in swath) and balers are some of the equipment used for harvesting operation.

7.2 Harvesting Methods: They can be *(i) Traditional and (ii) Mechanical methods of harvesting.*
(i) Traditional method of harvesting: The harvesting of crops is traditionally done by manual methods. *These methods involve drudgery and consume long time.*
(ii) Mechanical harvesting method: Here, timeliness of harvest is of prime importance. The use of machines can help to (a) reduce drudgery and operation time (b) increase timeliness of work that enables to reduce/ avoid losses due to natural weather conditions (eg. rains and storms) during harvesting season, harvest at proper stage of crop maturity to reduce/avoid loss due to shattering and facilitates extra days for land preparation and earlier planting of the next crop.

7.3 Threshing: Thresher is a machine to separate grains from the harvested crop and provide clean grain without much loss and damage. During threshing, grain loss in terms of broken grain, un-threshed grain, blown grain, spilled grain etc. should be minimum. *Clean un-bruised grain get good price in the market as well as it has long storage life.*

7.4 Threshing methods: Two methods of threshing (1) traditional and (2) mechanical threshing methods
The traditional threshing methods may include foot threshing or trampling, use of flail, use of a pedal thresher or treadle thresher and etc. The threshed materials are subjected to *winnowing either in natural wind flow or blast from winnowing fan* for separation of grain from straw. These methods involve *drudgery and less timeliness of work.* N.B. For hand threshed crops, partial drying in the field for a couple of days may be necessary to lower the moisture content and make threshing easier. Care must be taken not to over-dry the crop if it is to be transported any distance before threshing as excessive shattering will occur.
Mechanical threshing methods (Machine Threshing): Here, drudgery is reduced and timeliness is increased. *Threshing is either done in the field, near the field or at the nearest road.* Place the thresher as close as possible to the harvested crop to minimize shattering loss during hauling.

7.5 Combine Harvester

It is a machine designed for harvesting, threshing, separating, cleaning and collecting grains while moving through standing crops. Bagging arrangement may be provided with a pick up attachment.

The main functions of a combine are then:

(i) Cutting the standing crops
(ii) Feeding the cut crops to threshing unit
(iii) Threshing the crops
(iv) Separating the grain from the straw and chaff
(v) Cleaning the grains for convenient handling
(vi) Collecting the grains in a container.

The size of the combine is indicated by the width of cut it covers in the field. A combine may be Self-propelled type and Power Take Off (P T O) driven type.

The whole machine is composed of the following components:

(1) Header (2) Reel (3) Cutter bar (4) Elevator canvas (5) Feeder canvas (6) Feeding drum (7) Threshing drum (8) Concave unit (9) Fan (10) Chauffer sieve (11) Grain sieve (12) Grain auger (13) Tailing auger (14) Tail board (15) Straw spreader (16) Return conveyor (17) Shaker (18) Grain elevator (19) Grain container.

Header is used to cut and gather the grain and deliver it to the threshing cylinder. The straw is pushed back on the platform by the reel. Small combines use *scoop type* headers, while large combines use T type headers with auger tables. Harvesting is done by a cutting unit, which uses a cutter bar similar to that of a mower. The knife has got serrated edge to prevent the straw from slipping while in operation. There is suitable cutting platform which is provided with a reel and a canvas. The reel is made of wooden slats which help in feeding the crops to the cutting platform. The reel gets power through suitable gears and shafts. The reel revolves in front of the cutter bar, while working in the field. The reel pushes the standing crops towards the cutting unit. The reels are adjustable up and down as in or out. The cutter bar of the combine operates like a cutter bar of a mower. It cuts the standing crops and pushes them towards the conveyor. The conveyor feeds the crop to the cylinder and concave unit. The grain is swept underneath the augers and conveyed behind them. The threshing takes place between the cylinder and concave unit of the combine. The basic components of the threshing unit of the combine are similar to a power thresher. As soon as the crops are threshed, the threshed materials move to a straw rake. These rakes keep on oscillating and separating the grains. The cleaning unit consists of a number of sieves and a fan. The cleaning takes place on these sieves with the help of the fan. The un-threshed grains pass through tailing augur and go for re-threshing. The clean grains pass through grain elevator and finally go to packing unit. Grains are collected in a hopper provided at suitable place. The fan is adjusted such that the chaff etc is blown off to the rear side of the machine.

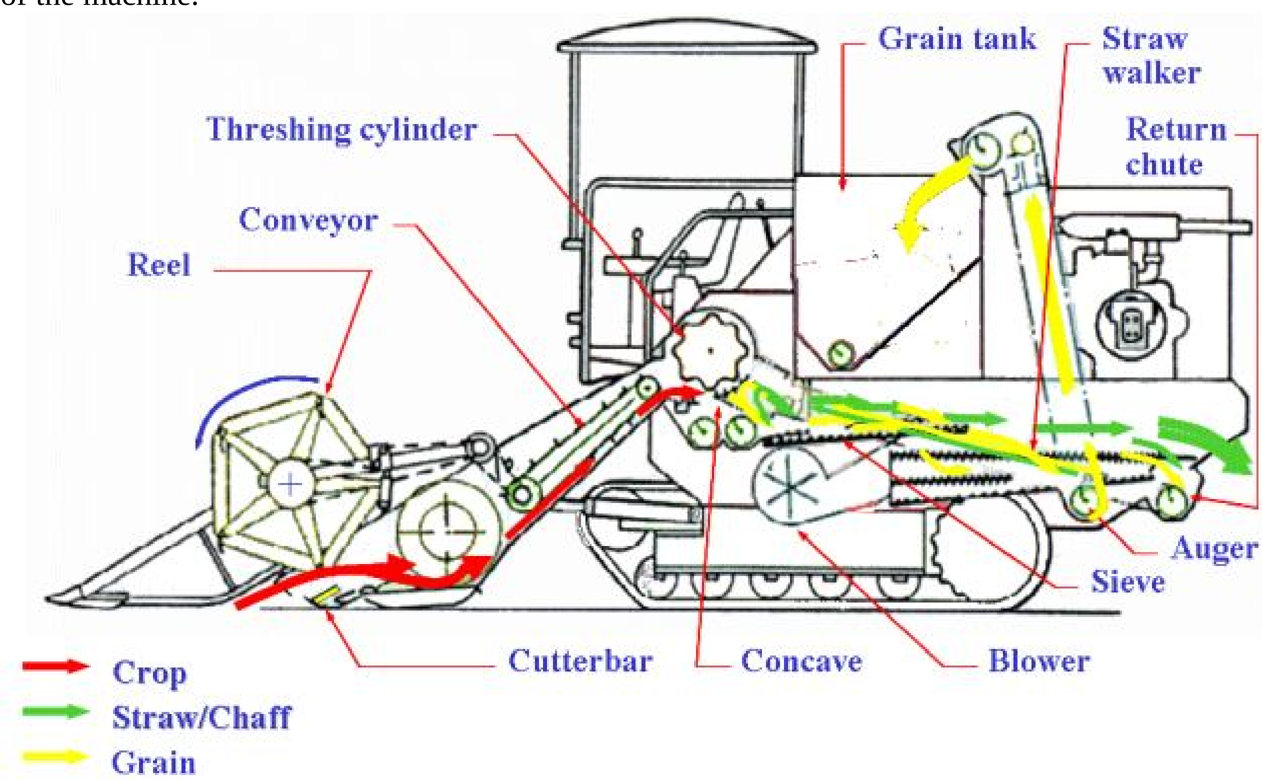


Figure 7.1 Components and crop flow in a combine harvester

8. Estimation of Cost of Farm Machinery

8.1 Machinery Costs

Farm machinery costs can be divided into three categories:

(a) Fixed costs (Ownership costs)

(b) Variable costs (Operating costs) and

(c) Timeliness Costs

(a) Fixed Costs (Ownership costs): Fixed costs are those outlays that *do not vary with machine use*. *They incurred regardless of the number of hectares or hours of use annually.* Other terminologies commonly used interchangeably with fixed costs are ownership and overhead costs. They include depreciation, interest on the capital, housing, insurance and taxes.

Depreciation: *Depreciation is the deterioration/change in the value of machinery because of age, obsolescence, and wear.* It is a cost resulting from wear, obsolescence, and age of a machine. The introduction of new technology or a major design change may make an older machine suddenly obsolete, causing a sharp decline in its remaining value. But age and accumulated hours of use usually are the most important factors in determining the remaining value of a machine. *As machinery ages, it not only wears out, but also becomes obsolete because of improvements in technology. Consequently, age has been shown to be the overriding factor in explaining losses in the value of farm machinery.* Before an estimate of annual depreciation can be calculated, an economic life for the machine and a salvage value at the end of the economic life must be specified. *The economic life of a machine is the number of years for which costs are to be estimated.* It often is less than the machine's service life because most farmers trade a machine for a different one before it is completely worn out. *A good rule of thumb is to use an economic life of 10 to 12 years for most new farm machines and a 15 year life for tractors*, unless it is known that the machine will be traded sooner. *Salvage value is an estimate of the sale value of the machine at the end of its economic life.* It is the amount the farmer can expect to receive as a trade-in allowance, an estimate of the used market value if he or she expects to sell the machine outright, or zero if the farmer plans to keep the machine until it is worn out. D = (C-S)/ (LH), where D is the depreciation per year, C is the capital investment/ purchase price/new cost, S is the salvage value, H is the number of working hours per year and L is the life of machine in years (L*H = age (economic life or useful life)). The remaining on-farm values (RFV), expressed as a percentage of new cost, are used to calculate average annual depreciation costs. D = {[New cost – (New cost x RFV/100)]/useful life}.

Example: What is the average annual depreciation for a 1-ton hay baler to be used 10 years and with a new cost of $135,000?

Solution: D = {[New cost – (New cost x RFV/100)]/useful life} = {$135,000 - [$135,000 x (28.24 / 100)]}/10

Depreciation = $9,688.   (The RFV of 28.24 is obtained from Table 8.1).

Example: For the 180-hp tractor, what will be the salvage value after 15 years with 400 hours of annual use?

Solution: The appropriate values in Tables should be multiplied by the current list price of a replacement machine of equivalent size and type, even if the actual machine was or will be purchased for less than list price. For the 180-hp tractor in the example, the salvage value after 15 years with 400 hours of annual use is estimated as 23.33 percent of the new list price:

Salvage value = current list price x remaining value factor (Table 8.3) = $110,000 x 23.33% = $25,663

Total depreciation = purchase price – salvage value = $93,500 – $25,663

Total depreciation = $67,837

Table 8.1 RFV expressed as a % of new cost for tillage equipment, various harvest machines, and others

Machinery life (years)	Mowers	Balers	Swathers and other harvest equipment	Plows	Disks and other tillage equipment	Planters	Manure spreaders and other misc. equip.
1	47.40	56.36	48.97	47.22	61.01	64.77	69.16
2	43.65	50.23	43.82	44.37	54.13	59.69	61.71
3	40.87	45.76	40.06	42.23	49.13	55.93	56.29
4	38.60	42.16	37.03	40.48	45.10	52.85	51.91
5	36.66	39.11	34.45	38.96	41.70	50.22	48.20
6	34.94	36.45	32.20	37.61	38.74	47.89	44.97
7	33.40	34.08	30.20	36.39	36.11	45.80	42.09
8	31.99	31.96	28.39	35.28	33.74	43.90	39.50
9	30.70	30.02	26.75	34.25	31.60	42.15	37.14
10	29.51	28.24	25.24	33.28	29.63	40.52	34.97
11	28.39	26.60	23.84	32.38	27.82	39.01	32.97
12	27.34	25.08	22.55	31.53	26.14	37.59	31.12
13	26.36	23.67	21.34	30.73	24.58	36.25	29.39
14	25.43	22.34	20.20	29.96	23.13	34.99	27.77
15	24.55	21.10	19.14	29.23	21.76	33.79	26.26

Source: American Society of Agricultural and Biological Engineers, ASABE Standards, 2009

Table 8.2 RFV of medium size tractors (80 -150 hp), expressed as a % of new cost for various ages and levels of annual use

Machinery life (years)	Annual use (hours)							
	100	200	400	600	800	1000	1200	1400
1	69.62	69.07	68.65	68.29	67.70	67.20	66.77	66.37
2	62.90	62.38	61.98	61.64	61.08	60.60	60.19	59.81
3	57.98	57.47	57.09	56.76	56.22	55.77	55.37	55.01
4	53.98	53.49	53.12	52.81	52.29	51.85	51.47	51.12
5	50.58	50.11	49.75	49.44	48.94	48.52	48.14	47.81
6	47.59	47.14	46.79	46.50	46.01	45.60	45.24	44.91
7	44.93	44.49	44.15	43.87	43.39	42.99	42.64	42.33
8	42.52	42.09	41.76	41.49	41.03	40.64	40.30	39.99
9	40.32	39.90	39.58	39.31	38.86	38.49	38.16	37.86
10	38.29	37.88	37.57	37.31	36.87	36.50	36.18	35.89
11	36.41	36.01	35.71	35.45	35.03	34.67	34.36	34.07
12	34.66	34.27	33.97	33.72	33.31	32.96	32.65	32.38
13	33.02	32.64	32.35	32.11	31.70	31.36	31.06	30.79
14	31.48	31.11	30.82	30.59	30.19	29.86	29.57	29.31
15	30.03	29.66	29.39	29.16	28.77	28.44	28.16	27.90

Source: ASAE standards, 2009

Table 8.3 RFV of large tractors (>150hp), expressed as a % of new cost for various ages and levels of annual use

Machinery life (years)	Annual use (hours)							
	100	200	400	600	800	1000	1200	1400
1	70.21	68.89	67.90	67.06	65.67	64.51	63.49	62.58
2	62.21	60.97	60.04	59.25	57.94	56.85	55.90	55.04
3	56.40	55.23	54.33	53.58	52.34	51.30	50.40	49.59
4	51.72	50.60	49.74	49.03	47.84	46.85	45.98	45.21
5	47.77	46.69	45.87	45.18	44.04	43.09	42.26	41.52
6	44.34	43.29	42.50	41.84	40.74	39.83	39.03	38.32
7	41.29	40.28	39.52	38.88	37.82	36.94	36.18	35.49
8	38.55	37.58	36.84	36.22	35.20	34.35	33.61	32.95
9	36.06	35.12	34.41	33.81	32.83	32.01	31.29	30.66
10	33.78	32.88	32.19	31.61	30.66	29.87	29.18	28.56
11	31.69	30.81	30.14	29.58	28.66	27.90	27.23	26.64
12	29.75	28.90	28.25	27.71	26.82	26.08	25.43	24.86
13	27.94	27.12	26.49	25.97	25.11	24.39	23.77	23.21
14	26.26	25.46	24.86	24.35	23.52	22.82	22.22	21.68
15	24.69	23.91	23.33	22.84	22.03	21.36	20.77	20.26

Source: ASAE standards, 2009

Interest: Interest on money spent on machinery is another fixed cost. This may be a cash cost when we borrow money, or an opportunity cost when we buy machinery with money that we've saved. Since interest cost does not vary with machine use, it is a fixed cost. If the operator borrows money to buy a machine, the lender will determine the interest rate to charge. But if the farmer uses his or her own capital, the rate will depend on the opportunity cost for that capital elsewhere in the farm business. If only part of the money is borrowed, an average of the two rates should be used. Interest is calculated on the average investment of the tractor taking into consideration the value of the tractor in first and last year.

$$I = \frac{C+S}{2} * \frac{i}{H} \quad \Rightarrow \quad \mathrm{I} = \frac{\mathrm{C+S}}{2} * \frac{\mathrm{i}}{100} * \frac{1}{H}$$

Where: I is the interest cost per hour. i is the % rate of interest per year

Housing: It provides machines protection against the weather. Such protection yields benefits in the form of longer machine lives, reduced repairs, better appearance, and greater convenience in working on machinery. The costs associated with the ownership and use of a machine shed should, of course, be charged against the housed machinery. Housing cost is calculated on the basis of the prevailing rates in the locality. In general, it may be taken as 1% of the initial cost of the tractor per year.

Insurance: *Farmers often choose to protect their capital investments in machinery from casualty losses such as fire, theft, vandalism, collisions, and so forth by purchasing insurance.* Insurance charge is calculated on the basis of the actual payment to the insurance company. In general, it may be taken as 1% of the initial cost of the tractor per year.

Taxes: Taxes is calculated on the basis of the actual taxes paid per year. In general, it may be taken as 1% of the initial cost of the tractor per year.

Total annual costs for property taxes, housing, interest, and insurance (THII) are estimated by multiplying the sum of the percentages representing each of these cost items (Table 8.4) by the average machine investment. Average machine investment (AMI) used to calculate taxes, housing, interest, and insurance costs (THII), is calculated as follows: AMI = {New cost + [New cost x (RFV in Table 8.1-3/100)]}/2

Example: Calculate the annual THII costs for the 1-ton hay baler valued at $135,000?
Solution: Annual THII = AMI x (THII factor in Table 8.4 / 100)
Annual THII = {$135,000 + [$135,000 x (28.24 / 100)] }/2 x (11.9 /100) = $10,301
Annual THII = $10,301

Table 8.4 Percentage of AMI charged for property taxes, housing, interest, and insurance (THII factor)

Machinery	Taxes (%)	Housing (%)	Interest (%)	Insurance (%)	Total (%)
Wheel tractor	1.4	0.3	8.0	0.9	10.6
Crawler tractor	1.4	0.2	8.0	0.9	10.5
Combine	1.4	0.5	8.0	2.1	12.0
Potato harvester	1.4	1.4	8.0	0.6	11.4
Bean cutter	1.4	1.1	8.0	0.6	11.1
Self-propelled forage harvester	1.4	1.3	8.0	2.1	12.8
Pull-type forage harvester	1.4	1.3	8.0	2.6	11.3
Self-propelled windrower	1.4	1.1	8.0	2.1	12.6
Bean windrower	1.4	1.1	8.0	0.6	11.1
Hay rake	1.4	—	8.0	0.6	10.0
Hay baler	1.4	1.9	8.0	0.6	11.9
Self-propelled automatic bale wagon	1.4	1.0	8.0	2.1	12.5
Pull-type automatic bale wagon	1.4	1.0	8.0	0.6	11.0
Self-unloading forage wagon	1.4	—	8.0	0.6	10.0
Drills, planters	1.4	2.4	8.0	0.6	12.4
Tillage equipment	1.4	—	8.0	0.6	10.0
Sprayer	1.4	—	8.0	0.6	10.0

(b) Variable Costs (Operating Costs): *They include those expenses that vary as machine use varies (These costs vary with the hours of machine use).*They include fuel, lubricants, repairs and maintenance, and wages.
(i) Fuel cost: It is calculated on the basis of actual fuel consumption in the tractor.
(ii) Lubricants: Charges for lubricants should be calculated on the actual consumption. In general, it may be taken 30 to 35% of the fuel cost.
(iii) Repairs and maintenance: *Annual repair costs for a given machine normally increase as use increases. However, accurate predictions of machinery repair costs are difficult to obtain. Even the repair costs required for identical machines used the same number of hours vary with different types of work or working conditions.* This cost varies between 5 to 10% of the initial cost of the tractor per year.
(iv) Wages: To estimate the annual labor cost to run a machine, multiply the hourly wage by the total hours required for the operation. The hourly labor cost may be the hourly wages of hired help, or an estimate of the operator's time based on the skill required to operate the machine and perform other tasks, such as management.

(c) Timeliness Costs: Every field operation is best done at a certain time. If the operation is not done at that time, the quantity and/or quality of the crop will be reduced. This is called timeliness cost, and can be calculated as a cost resulting from a decrease in income. The size of the cost depends on factors such as crop value, crop yield, machine operation, weather, and hours available for work per day. Timely performance of a field operation is highly dependent on the size and capacity of the machinery complement, the amount of time available to perform the task, weather condition and whether the operation began as soon as the field was ready. Good management practices, including routine machinery maintenance and proper operation, will certainly reduce timeliness costs.

Table 8.5: List of field efficiency, suggested forward speed and timeliness constants

Machine	Field Efficiency	Suggested Speed, mph	Timeliness Factor	Machine	Field Efficiency	Suggested Speed, mph	Timeliness Factor
Moldboard plow	0.7 - 0.9	3-6	0.00 - 0.010*	Picker sheller	0.6 - 0.75	2-4	0.003
Chisel plow	0.7 - 0.9	4 - 6.5	0.00 - 0.010	Combine	0.65 - 0.8	2-5	0.003
Disks	0.7 - 0.9	3-6	0.00 - 0.010	Mower cond., pull	0.55 - 0.85	3-6	0.010
Field cultivator	0.7 - 0.9	3-8	0.00 - 0.100	Mower cond., s.p.	0.6 - 0.9	3-6	0.010
Roller packer	0.7 - 0.9	3-6	0.00 - 0.010	Baler	0.6 - 0.85	2-5	0.028
Row cultivator	0.7 - 0.9	2.5 - 5	0.011	Forage harv., pull	0.55 - 0.75	1.5 - 5	0.028
Planter	0.5 -0 .75	3-7	0.005	Forage harv., s.p	0.6 - 0.85	1.5 - 6	0.028
Grain drill	0.65 -0.85	2.5 - 6	0.005	Boom sprayer	0.6 - 0.75	3 - 5	0.011

* Tillage timeliness factor is dependent on its effect on planting.
Source: 1990 Standards, American Society of Agricultural Engineers

Timeliness cost is calculated using factors and crop information. The formula is:

$$Timeliness\ Cost\,(Birr/hr) = \frac{T_c\ x\, Hectares\, x\, Crop\, value\ x\, Yield}{T_x\ x\ Hours\ x\, Passes}$$

Where: Tc = timeliness coefficient from Table; It can also be estimated from measured crop returns as they vary with the timing of machine operations

$$T_c = \frac{Y_l}{(t_o - t)^2}$$ Y_l is yield loss, percent; (t_o-t) is time deviation from optimum, days

T_x = 4 if operations can be balanced evenly around the optimal time, or T_x = 2 for premature or delayed schedule.
Hours = the average hours per day this machine can normally be used
Crop value = value of crop in birr/kg; Yield = crop yield in kg/ha
Passes = the number of trips over the field or the number of cuttings. Passes = effective machine capacity (ha/hr) times probability of a workday (decimal)

$$Number\, of\ passes = \frac{Width/Length\ of\ field}{Size\, of\ plough}\ ;$$

$$Dis\tan ce\ traveled\ = Width\ \ of\ \ field\ \ x\ \ Number\, of\ \ passes,\ if\ \ ploughing\ \ is\ \ width\ \ wise.\ Or,$$

$$Dis\tan ce\ traveled\ = Length\ \ of\ \ field\ \ x\ \ Number\, of\ \ passes,\ if\ \ ploughing\ is\ length\ wise.$$

Example: Calculate the cost of operation of a 35 HP tractor per hour and HP hour. Initial cost is 550,000Br, life of the tractor is 12 years, number of working hours are 1200 per year, interest on the capital is 10%, cost of the diesel is 40Br per liter, fuel consumption is 5 liters per hour, wages of the driver is 36, 000Br, lubricants cost is 35% of the fuel cost, repairs and replacements is 10% of initial cost; housing, taxes and insurance is 1.5% each of the initial cost.

Solution:

Data given: C = 550,000Br L = 12 years H = 1200 hours per year i = 10%
Cost of diesel = 40 Br per liter Fuel consumption = 5 liters/hour
Wages of the driver = 36,000Br per annum Lubricants cost = 35% of fuel cost
Repairs and replacements cost = 10% of initial cost
Housing, taxes and insurance = 1.5% each of the initial cost

Fixed costs:

(i) Depreciation: $D = \frac{C - S}{L * H}$ = 38.19Br per hour (Since salvage value is not given, hence it is taken as "0")

(ii) Interest: $I = \frac{C + S}{2} * \frac{i}{H}$ $= \frac{550000 + 0}{2} * \frac{10}{100} * \frac{1}{1200} = 22.92\, Br\ per\, hr$

(iii) Housing cost: $H = \frac{1.5}{100} * 550000 * \frac{1}{1200} = 6.87\, Br\ per\, hr$ Similarly,

(iv) Insurance is 6.87Br and (v) Taxes are 6.87 Br per hour

☞Total fixed cost per hour = 38.19+22.92+6.87+6.87+6.87 = 81.72Br

Operating costs:

(i) Fuel cost = 40 ×5 = 200.00 Br. per hour
(ii) Lubricants cost = (35/100)*200 =70.00 Br. per hour
(iii)Repairs and replacements cost = (10/100)*550000*(1/1200) = 45.83 Br
(iv)Wages = 36000/1200 = 30 Br

☞Total operating cost per hour = 200+70+45.83+30 = 345.83 Br

Total cost of operation per hour = Total fixed cost + Total variable cost = 81.72 + 345.83 = 427.55 Br

Total cost of operation per HP per hour = 427.55/35 =12.22 Br

Example: Consider a 15 horse power diesel power tiller with a list price of 150,000Br. An economic life of 10 years, and the tiller is expected to be used 500 hours per year.

Assumptions:

Salvage value (S): 10%	Interest rate: 10 %
Housing: 1 % of PP	Fuel consumption: 1lit/hour
Lubrication cost: 150 Br per lit	Lubrication consumption: 5% of fuel
Repair and maintenance: 5-8 %	Labour: 50 Br per hour
Insurance & taxes: 1% of PP	Fuel Cost = 50 Br per lit

Calculate the total cost of the tiller machine?

Solution: 1. Fixed Costs

(a) Depreciation = (C- S)/Age = (150000-15000)/10 = 13500 Br per year
(b) I = (C+S)/2 * i/100 = (150000+15000)/2 * 10/100 = 8250 Br per year
(c) Insurance & Taxes = 1% of PP(C) = 0.01 x 150000 = 1500 Br per year
(d) Housing = 1 % of PP = 0.01x 150000 = 1500 Br per year

Total fixed cost= 24750 Br per year ➔Total fixed cost per hour = 49.5 Br

2. Variable Costs

(a) Repair & Maintenance = 5% of PP = 0.05x 150000 = 7500 Br per year.
Per hour cost = 7500/500 = 15.0Br
(b) Fuel = 1x 50 = 50 Br per hour (c) Lubrication = 1x 0.05 x 50 = 2.5 Br per hour
(d) Labour cost = 50 Br per hour

Total variable costs =117.50 Br

Total cost = total fixed costs + total variable costs = 49.5 + 117.5 = 167.0Br

Example: Let crop yield = 5tons/ha; crop value = 8000Br/ton; Tc = 0.01(from table); Hours per day = 8; Area = 100ha; effective field capacity = 4.09ha/hr. Calculate timeliness cost?

Solution: Timeliness cost = crop value x yield x time factor x hectares/ (hours per day x4)

= 8000x5x0.01x100 / (8x4) = 1250Br/hr

Estimated annual time, hours = hectares x number of trips divided by effective field capacity

= (100 x 4) /4.09 = 97.8 hours

Hourly cost times hours = 1250 x 97.8 = 122249.39 Br

Note: Whenever actual data is unavailable, the data for

1. Estimates of the remaining value of tractors and other farm machines as a percentage of new list price
2. Capital recovery factors for various combinations of real interest rates and economic lives
3. Accumulated repair costs as a percentage of new List prices
4. List of field efficiency, suggested forward speed and timeliness constants, and others can be obtained from tables of Standards, American Society of Agricultural Engineers (ASAE).

9 Selection and Management of Farm Machinery

9.1 Machines Performance

Calculating field capacities is just part of the overall concept of farm machinery management. Successful farm machinery management does not guarantee a profit, but machinery costs are a major expense and they must be monitored and managed. Therefore, the efficient use of farm machinery starts with determining working capacity in conjunction with the amount of work to be accomplished in a timely manner. The term capacity means the amount of work that can be performed. The measures of capacity for agricultural machines are theoretical field capacity, effective field capacity and material capacity. Field capacity is measured in hectares per hour.

(1) Theoretical field capacity (FCT): It is a simple calculation involving speed (V) and width (W) with efficiency set at 100%. It can be calculated from the following equation: ***FC_T (ha/hr) = (W x V)/10.*** It is impossible to maintain the theoretical field capacity of a machine over long periods of time. Interruptions such as turning, filling seed and pesticide hoppers, emptying grain tanks(hoppers), and making minor repairs cause severe reductions in theoretical field capacity. However, delay activities that occur outside the field, such as daily service, travel to and from the field and major repairs are not included in a field efficiency measurement. The theoretical field capacity can be used as a benchmark for evaluating the performance of a machine or operator because it is the maximum capacity attainable at a given speed.

(2) Effective or Actual Field Capacity (FC_A): It is the actual coverage of the machine based on the total field time. Effective field capacity is usually expressed as **hectares per hour**. The effective field capacity (FC_A) of a machine in the field can be easily calculated by dividing the area completed by the hours of actual field time. Recording hectares and hours for several fields over the whole season can be used to find an average field capacity in different terrain and weather conditions. ***FC_A = Area / Time. FC_A = FC_T x field efficiency.*** *One-day calculation of the effective field capacity does not indicate what the effective field capacity would be for an entire year or growing season. The most accurate field capacity data should be collected for at least a two-week period of operation. This is a good example:*

Total calendar days = 14 Total hours in field = 88; Total working days = 11 Total hectares covered = 704

Then, FC_A = 704/88 = 8 hectares per hour.

(3) Field Efficiency: It is the ratio of effective field capacity to theoretical field capacity expressed as percent. Field efficiency accounts for failure to utilize the full operating width of the machine and many other interruptions such as breakdowns, waiting, turning, filling hoppers, etc.

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} x100 \qquad FC_A = \frac{VxW}{10} x \frac{E}{100} \text{ ha/hr}$$

Where**:** FC_A = effective field capacity, hectare per hr. V = speed of travel in km per hour.
W = theoretical width of cut of the machine in meter, and E = field efficiency in per cent.

The time during which the machine is actually performing its intended function is called effective operating time and the time that would be required at the theoretical field capacity is called theoretical time. A practical way of determining field efficiency is to determine the theoretical time required to cover an area and compare this with the actual time taken. ☞ *% Field efficiency = (operating time/ theoretical time) x 100%*

Typical field efficiency values for a range of different operations are listed in the following table. The higher figures represent operations in larger fields where the number of turns is minimized.

Table 8.6: Field Efficiency

Operation	Field Efficiency, %
Tillage Primary	70-85
Secondary working	65-85
Planting	60-80
Harvesting	50-70

(4) Material Capacity (MC): *Material capacity and effective field capacity are the two most common methods of measuring machine capacity. The material capacity is the measurement of volume throughput per hour and is expressed as bushels per hour or tons per hour. The formula for material capacity is total volume throughput divided by hours used to harvest the volume.* It can be the product of the machine's FC_A and the average yield of crop per hectare, and can be calculated from equation as: ***MC (tons/hr) = FC_A (Area/hr) x Crop Yield (tons/Area.***

Example: A baler with an FC_A of 2.5 ha/hr working in a field yielding 2 tons of hay per hectare would have an MC of 2.5 ha/hr x 2 tons/ha, or 5 tons/hr.

Problem 1: Determine the horse power required to pull a four bottom 32 cm plough, working to depth of 14 cm. The tractor is operating at a speed of 5.5 km/h. The soil resistance is 0.8 kg/cm^2.

Solution: Total width of ploughing = 32×4 = 128 cm Furrow cross section = 128 ×14 = 1792 cm^2
Total draft = soil resistance × furrow cross section = 0.8 × 1792 = 1433.6 kg
HP = (draft*speed)/75 = (1433.6*5.5*1000)/ (75*3600) = 29.2

Problem 2: Calculate the area covered per day of 8 hours by a tractor drawn four bottom 35cm plough if the speed of the ploughing is 5kmph, the time lost in turning is 10%.

Solution: $Area\ covered\ per\ hour = \frac{4*35}{100}*5*1000 = 7000m^2$

Area to be covered in 8 hrs = 7000×8 = 56,000 m^2 = 560000/10000 = 5.6ha
Turning loss = (5.6*10)/100 = 0.56ha Actual area covered in 8 hrs = 5.6 – 0.56 = 5.04 ha

Problem 3: Calculate the size of a tractor to pull a four bottom 35 cm MB plough through a depth of 8 cm. The soil resistance is 0.8 kg/cm^2. The speed of the tractor is 5.5 km/h, transmission and tractive efficiency of the tractor being 80% and 30% respectively.

Solution: Furrow cross section = 4*35*8 = 1120cm^2 ➔Total draft = 1120 ×0.8 = 896 kg

$$HP = \frac{896*5.5*1000}{75*3600}*\frac{1}{0.8}*\frac{1}{0.3} = 76$$

Problem 4: Total draft of four bottom, 35 cm MB plough when ploughing 18 cm deep at 5 km/h speed is 1600 kg. (a) Calculate the unit draft in kg/cm^2 (b) What is actual power requirement?
(c) If the field efficiency is 75% what is the rate of doing work in ha/hr.

Solution: Unit draft = 1600/ (4*35*18) = 0.635kg/cm^2
HP requirement = (1600*5*1000)/ (75*3600) = 29.6

$$FC_A = \frac{V*W}{10}*\frac{E}{100}$$

Where: FC_A is the effective field capacity, ha/hr V is the speed of travel in km/h
W is the theoretical width of cut of the machine in m E is the field efficiency in percent

$$\text{Area covered per hr}, FC_A = \left(\frac{5*4*35}{10*100}\right)*\frac{75}{100} = 0.525\,\text{ha/hr}$$

Problem 5. A 5 x 20 cm double action disc harrow is operated by a tractor having a speed of 5 km/h. Calculate the actual field capacity, assuming the field efficiency of 80 percent.
Solution: Size of the harrow (width) = 5 x 20 = 100 cm
Area of coverage = (V*W)/10 * E/100 = (1 x 5 x 80) / 1000 = 0.4 ha/h

Problem 6. A 3 x 30 cm plough is moving at a speed of 4 km/h. calculate how much time it take to plough 500 x 500 m field when the field efficiency is 70 %.

Solution: Width of the plough = 3 x 30 = 90 cm = 0.9 m
Effective field capacity = (0.9 x 4 x 70)/ 1000 = 0.25 ha/h = 2500 m^2/h
Time required = 500 x 500/ 2500 = 100 hr

Problem 7. A 4 bottom 40 cm mould board plough is operating at 5.5 km/h speed with 75 % field efficiency. Calculate what is the rate of doing work in hectares per hour.

Solution: Width of the plough = 4 x 40 = 160 cm = 1.6 m; Area covered = 1.6 x 5.5 x 75/1000 = 0.66 ha/h

Problem 8. An indigenous plough has a 20 cm wide furrow at the top and 10 cm depth. Calculate the volume of soil handled per day 8 hours if the speed of working is 2.5 km/h.

Solution: Furrow cross section = 10 x20/2 = 100 cm^2
Distance traveled in 8 hours = 8 x 2.5 x 1000 = 20,000 m
Volume of soil handled = 20000 x 100/ 10000 = 200 m^3

9.2 Matching Tractor Power and Implement Size

For tillage and planting implements the size of the machine that can be used is often limited by the size of the available tractor. The horsepower needed to pull a certain implement depends on the width of the implement, the ground speed, draft requirement, and soil condition.

(i) Determining the Size of Machine Required: The most critical field operation is often determined by the time available to get over the area between rainfall events. Local knowledge or a check of local rainfall records will usually help in this regard. By knowing the time available and the operating speed, the required width can be calculated. In this calculation allowance has to be made for field efficiency. The formula then is:

$$\text{Width} = \frac{\text{area (ha)} * 10\,\text{(constant)}}{\text{time (hr)} * \text{speed(km/hr)} * \text{field efficiency}}$$

Consider an example:
Establish the width of chisel plough that will allow the completion of 400 hectares in 8 days working 10 hours per day at a speed of 8 kilometers per hour, assuming a field efficiency of 80% (from Table 8.6).

$\text{Width} = \frac{400\text{x}10\text{x}100}{(8\text{x}10)\,\text{x}8\text{x}80} = 7.8\,\text{meters}$. With this simplistic approach, the effects of any input (hours/day, speed or field efficiency) can be evaluated. Care should be taken not to overestimate either the time available to complete the task or field efficiency.

In putting together a machinery set, it is also important to correctly match machinery sizes and tractor power. Using tractors with horsepower in excess of that required for the implement being pulled results in excessive depreciation and interest costs, while using too little horsepower may cause faster engine wear-out.

(ii) Tractor Capacities: Use of improper size can be costly. A tractor too small can result in long hours in the field, excessive delays and premature replacement. A tractor too large can result in excessive operating and overhead costs. It is vital to know how to determine the size and number of tractors needed for a farm operation. It is important to remember that *drawbar power is the product of pull and speed*; where an infinite number of pull / speed combinations could be used to give the same power. *Wheel tractors are designed to operate at higher speeds (greater than 8.0 km/h) and lower drawbar loads. If low forward speeds (under 5.5 km/h) and large pulls are to be consistently used, track layers should be considered.*

Table 8.7: Typical tractor efficiencies

Tractor Type	Rated crank-shaft power %	PTO power %	Drawbar power (Maximum) %	Drawbar power (Normal)%
2WD	100	85	50	40-45
FWD	100	85	55	45-50
4WD	100	85	60	50-55
Track	100		75	65-70

Note: PTO and Drawbar power are given as a percentage of rated crankshaft power. *Example normal drawbar power = 40% of rated power.* ➔ *Engine power = (Drawbar power x 100)/40*

9.3 Estimating Power Requirements

✓**Estimation of draft:** In order to determine the draft requirement of an implement it is necessary to use a pull meter. Estimation of likely draft requirements can be taken from Table 8.8. However, these values will vary according to soil type, soil moisture, depth of working, ground speed and manufacturer.

Table 8.8: Estimating draft requirements

Implement	Draft per Unit Width (kN/m)
Chisel plough	4.5-5.5
Blade plough	4.0-4.5
Disc plough	5.0-6.0
Scarifier	4.0-4.5
Cultivator	3.0-3.5
Planter	2.5-3.5

Total draft can be calculated by simply multiplying implement width by draft per unit width.

Considering the example using the chisel plough, then: Total draft = width (m) x draft / meter (kN/m) = 7.8 x 5 = 39 kN. If a scarifier was used to replace the chisel plough, the draft per unit width would decrease to 4.5 kN/m and the resultant total draft would be 35 kN. *Remember this is draft or pull, not drawbar power.*

✓**Estimation of drawbar power**

Drawbar power can be related to draft and speed, by using the formula below. Any one drawbar power level may be attained by a combination of pull and speed. That is, a large pull at a low speed could produce the same drawbar power as a small pull at high speed.

$$\text{Drawbar power}(kW) = \frac{\text{Pull}(\text{kN})\,\text{xSpeed}^*(\text{km/hr})}{3.6(\text{constant})}$$

Using the same chisel plough as in the previous example, the power requirements become:
Drawbar power = (39x8)/3.6 = 87kW (116hp). Note: 1hp = 746watts
*Speed has been determined by the initial assumption when working out the required implement width or can be estimated at the field from distance & time.

At this point, it would pay to work through all of the tillage operations and determine the requirements for each, after closely considering the time available and field efficiency. The largest power requirement would be then used in determining engine power.

✓**Estimating engine power**

Once drawbar power has been calculated, a decision needs to be made about what type of tractor is to be used. The selection decision between wheels or tracks is far too complex a topic to be covered in this chapter. Suffice to say that if set-up and matched correctly, the operating costs should be similar for either tractive type. The decision between two wheel drive and four wheel drive is much simpler as it is determined by the minimum available size of a 4WD and the maximum size of a 2WD (that is approximately 150 kW or 200 hp).From the Table 8.9 shown below , it is now possible to determine the size of tractor required. In using the comparative chart, it would be unwise to determine engine size using the maximum power figure as conditions vary both from season to season and even within any one season. Having a little extra capacity is also a safeguard against overloading. A more realistic figure is the normal operation level.

Table 8.9: Tractor crankshaft power (Chisel plough example)

actor	Drawbar HP/Efficiency	Crankshaft power (kW)
2WD	(87 x 100)/40	= 217 kW (290 hp)
FWD	(87 x 100)/45	= 193 kW (259 hp)
4WD	(87 x 100)/50	= 174 kW (232 hp)
Track layer	(87 x 100)/65	= 134kW (178 hp)

Conclusion: If a step by step approach is used when matching power units and implements, it is possible to eliminate the majority of guess work that is normally employed when a machinery purchase decision is made. This approach is simplistic but does allow changes to any of the inputs. Care must be taken not to overestimate either the time available to complete the task or field efficiency.

9.4 Machinery Management: Owning or Hiring?

Although most farmers own their own machinery, options such as custom hiring, renting and leasing are also popular. **Ownership** is by far the most popular method of acquiring long-term control of farm machinery services. By owning a machine, you control its use and the quality of its performance. You provide the labor to operate it, and you assume responsibility for repairs and maintenance, liquidation, and obsolescence.

Machinery ownership may be the least expensive choice in the long run, especially for high-use equipment. However, if you purchase machinery on a dealer finance plan or with credit from some other lender, you may have to pay for it over a short period of time, creating a cash flow problem. Investment capital is tied up for a long period of time when machinery is owned. If your farm business is expanding and there are high-return alternative uses for the available capital, other methods of acquiring machinery may be preferred.

Custom hiring: It is a popular method of gaining *short-term control of farm machinery*, particularly for harvesting and for applying fertilizer and pesticides. Custom services may be available from a neighbor, a local dealer, or a business specializing in custom farming that performs all types of field operations.

Advantages: It has several advantages compared to other methods of acquiring machine services.

(i) You get a machine and an operator. That means you don't have to assume the responsibility for operating the machine or its daily care. You can perform some other task such as hauling or drying grain while the machine is operating, reducing the need to hire extra help (ii) You have no long-term capital commitment in the machine. Costs of custom hiring can come from operating capital (iii) You have no responsibility or costs for machine repairs (iv) You have no responsibility for liquidation of the machine if you change production practices and no longer need it, or if you retire (v) You know in advance what your costs will be so you can budget and project your cash flow more accurately (vi) The custom operator's machine will probably be newer, in better mechanical condition, and larger than one you could afford to own yourself

(vii) Custom hiring is particularly useful for specialized machines that are expensive to purchase and used only seasonally (viii) This method also is attractive for operators with limited investment capital and for small-scale farmers.

Disadvantages: Custom hiring may also have some disadvantages, but their importance will depend on the situation in your local area. (i) There may not be a competent operator and machine available for hire (ii) You will not be operating the machine so you will not have complete control over the quality of the job performed (iii) The custom operator may not get to your farm exactly when you want or during the optimum time for your crop because of scheduling problems. Also some custom operators charge different rates for services, depending on the date they are completed.

10 Handling and Maintenance of Farm Machinery

10.1 Definition

Maintenance can be defined as the practice of keeping in form or shape of equipment, machine system or object in its original status as much as possible. Note that maintenance is not repairing a machine after it breaks or when it stops work. It is a means of achieving optimum value for equipment in order to perform its desired and designed functions. Thus, maintenance is protecting a machine so that it does not break down or wear out quickly. We must protect our machine from the following enemies;

(a) Wear- Grease and oil are used to protect machines from wears

(b) Dirt- Filters are used to catch and hold dirt before it gets inside and damages parts

(c) Heat- The cooling and lubrication systems protects the machine from heat. Regular maintenance is one of the prerequisites for a long living and reliable engine performance. Additional servicing is often necessary and depends on the type of operation the engine is subjected to.

NB: The recommended engine servicing procedure is contained in the Owners Handbook for each engine model.

Objectives of good maintenance practice include:

(i) To intervene before failure occurs

(ii) To reduce number of failure and shutdowns

(iii) To increase life of equipment

(iv) To reduce maintenance cost and cost due to production lost

(v) To be able to operate effectively and efficiently and

(vi) To maintain quality standards at all times

10.2 Types of Maintenance

Traditionally, maintenance is performed in either time based fixed intervals, called preventive maintenance, or by corrective maintenance. With the PREVENTIVE approach, Maintenance is performed in order to prevent equipment breakdown. With the CORRECTIVE approach, Maintenance is performed after a breakdown or an obvious fault has occurred. For some equipment and faults, CORRECTIVE maintenance action must be performed immediately, for others the maintenance action can be deferred in time, all depending on the equipment's function.

(1) Breakdown Maintenance: It is referred to by many different names: reactive maintenance, repair, fix when-fail, and run-to-failure (RTF) maintenance. The major downside of breakdown maintenance is *unexpected and unscheduled* equipment downtime. Breakdown maintenance of a machine can occur due to the following reasons*: (a) Unpredictable failures of components, which cannot be prevented and (b) Gradual wear and tear of the parts, which can be eliminated to a large extent by regular inspection.* In breakdown maintenance, defects are rectified only when the machine cannot carry out its function any longer. Breakdown maintenance may disrupt production process. This method is very expensive due to *increase in depreciation cost over time; payment of maintenance staff for doing and payment of idle operators during the period of machine down time.* This can be more serious for agricultural work which is dependent on weather.

(2) Preventive Maintenance (PM): It is used mostly along with corrective maintenance and condition-based maintenance (Diagnostic Maintenance) etc. Preventive Maintenance is a planned maintenance of plants resulting from periodic inspection in order to minimize the breakdowns and depreciation rates. This includes the followings: servicing; adjusting; operating; repairing and caring for agricultural machines so as to prevent unnecessary wear out of parts, and keep time loss due to breakdown to a minimum. *Preventive maintenance is divided into two categories; Condition Based Maintenance (CBM) and Predetermined Maintenance*. The condition-based maintenance *(example predictive maintenance)* can be defined as maintenance actions based on actual condition obtained from in-situ measurement. The condition of the equipment or some critical parts of the equipment are continuously monitored using sophisticated monitoring instruments so that failure may be predicted well before it occurs and corrective steps are taken to prevent failure. Predetermined maintenance (example periodic maintenance) is time-based maintenance, TBM scheduled in time that *consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.*

(3) Design out Maintenance: It is a design oriented curative means aimed at rectifying a design defect originated from improper method of installation or poor choice of materials etc. It calls for strong design and maintenance interface.

(4) Opportunistic Maintenance: When equipment is taken down for maintenance of one of few worn out parts, the opportunity can be utilized to change or maintain other parts which are wearing out even though they have yet to fail. This maintenance strategy is for non-monitored components.

(5) Proactive Maintenance: Unlike the preventive maintenance, proactive maintenance concentrates on *the monitoring and correction of root causes to equipment failures.*

10.3 Strategies for Extending Machinery Life

The five strategies to achieve maximum farm machinery life include:
(i) Machinery maintenance,
(ii) Oil analysis,
(iii) Machinery storage,
(iv) Engine tune-ups, and
(v) Avoiding modification of tractor engines.

(i) Machinery maintenance: Timely preventative maintenance and inspection will not only help reduce major problems and downtime, it will also help identify problems when they can be corrected with relatively minor repairs. An effective machinery service program requires good record keeping. It should not be based on the operator's feelings or memory as to when a machine needs attention. The maintenance program must be based on fact as determined by an accurate service record for each piece of equipment as recommended by the operator's manual and adjusted to individual conditions.

(ii) Oil analysis: A detailed look at a sample of engine, transmission or hydraulic oil is a valuable preventative maintenance tool. In many cases, it enables identification of a potential problem before a major repair is necessary and downtime during critical operations can be avoided. Oil analysis is a means of monitoring wear and oil contamination. When conducted on a regular basis, it establishes a baseline of normal wear and can indicate when abnormal wear or contamination occurs. By eliminating unneeded oil changes, you reduce the cost for oil and servicing and also reduce the amount of used oil to deal with. This is an important pollution prevention method - reducing the source! Oil sample analysis saves you repair and maintenance cost, has the potential to reduce used oil, and increases resale value of equipment.

(iii) Machinery storage: Keeping the most valuable and vulnerable machinery out of the weather can save a lot of money. Equipment stored inside has a significantly higher trade-in value compared to the same equipment stored outside. Storage also saves money by reducing repairs and time in the shop. Machines, including tractors, combines, planters, drills, forage choppers, trucks and pickups, should be kept inside.

(iv) Engine tune-ups: Diesel and gas engines require periodic tune-ups. *As engines operate, they lose power and fuel efficiency.* To obtain the optimum performance from an engine, the power produced and the fuel consumed should be checked and compared to the Tractor Test data. The tractor should be tested on a certified PTO dynamometer found at most equipment dealers. Attach the tractor's power take-off to a dynamometer, warm the engine up and check to see if it produces rated PTO horsepower. *If tractor power is down by more than 5 percent, adjustments or a tune-up is needed. A tune-up may include changing air and fuel filters, cleaning and adjusting injector nozzles, and adjusting engine timing.* Another important part of tractor operation is checking fuel efficiency. This can be done at the time the tractor is operating on the PTO dynamometer. After the tractor is warmed to operating temperatures, stop the tractor and fill the fuel tank completely full. Operate the tractor at rated speed and load for 30 minutes (longer for more accurate results), then stop the tractor and refill the tank to the previous level, keeping track of the gallons needed. *Fuel efficiency will give an idea of the engine's condition.* Specific fuel consumption or fuel economy is measured in horsepower-hours per gallon (hp-hr/gal), much as automobile fuel efficiency is measured in miles per gallon. To calculate the efficiency of the tractor, first determine the gallons of fuel used in one hour. For example, a diesel tractor producing 155 hp and using 5.5 gallons in 30 minutes would use 11 gallons in an hour. Divide the 155 horsepower by 11 gal/hr, which gives a fuel efficiency of 14 hp-hr/gal. Compare this figure to standard tractor test data during the PTO tests at rated horsepower. *If the current efficiency is 5 to 10 percent less than original, there may be a problem that needs correction. If an engine is showing a 5 percent reduction in fuel efficiency, it is wasting about 5 percent of the fuel.* In a 155 horse-power tractor burning 11gal/hr, this adds up to 0.55 gallons of fuel wasted every hour or 275 gallons wasted every 500 hours of use.

(v) Avoiding modification of tractor engines: A tractor engine may be "modified" to get more power. Frequent claims about pulling bigger loads, getting new "life" from older models, and more power from new models are true. Engine modification can be done by several means. The most common is *over fueling*, while others include adding alcohol or LP gas injection, and turbo-charging naturally aspirated engines. These all sound tempting when an operator is faced with covering more hectares in less time. But are the consequences of boosting engine horsepower beyond original ratings worth it? The first problem is warranty. Most manufacturers do not allow any changes from standard specifications without voiding the warranty, so we're on our own with the changes. *The second problem with engine modifications is an almost sure reduction in service life.* Every machine design is a compromise. The designer must compromise between strength, reliability and cost to come up with a tractor rugged enough to do a job, but still meet an affordable price. Power is a function of torque and speed (revolution per minutes, RPM). Tractors are designed to operate at different travel speeds, but the final drives are not designed for all possible torques theoretically available. If power is increased 20 percent on a tractor, you're assuming the manufacturer built the engine parts, clutch, transmission and final drive 20 percent stronger than originally needed. Speed also has an effect on service life. For the example just stated, the 20 percent increase of power could be used by keeping the tractor weight the same and travel faster. This would reduce the life of the transmission by about 15 percent. Conversely, if one uses the 20 percent additional power for 20 percent larger pulls and drives at a slower speed, the transmission life is reduced by 50 percent. Usually, to take advantage of the increased pulling ability, more ballast (weight) must be added to maintain effective traction. Then, all parts will be overloaded, and service life will suffer. In the end, the tractor probably will end up in the repair shop long before it should. *Changing the injector pump can* be the simplest, cheapest and easiest engine modification. By pumping in more fuel (over-fueling), the power of the engine will probably go up, but another problem arises. At the factory, most tractors are set to their most efficient operational level. If the engine is over-fueled, the fuel efficiency will decrease. This means the power output for the fuel poured into the engine will be less, so in the long run, the extra fuel will cost money.

If more power is needed, it is better, financially, to trade for a bigger tractor. Larger tractors are built for higher power from the radiator to the wheels and should give good service. Trying to get more power by modifying a tractor may prove to be extremely expensive. Finally, no single strategy will have a large effect, but a combination of practices can have a large impact on costs, improve machine reliability for many years to come, and improve profit margins.

Assignment 2 (10%)

A three-bottom, 60cm trailed MB plough costs Br.125000 and a two-bottom 60cm trailed MB plough costs Br.105000. The operating speed for both the ploughs is 5km/hr and expected field performance is 75 per cent. If the cost per hectare for tractor unit remains the same, what would be the size of land for which both the ploughs will be equally economical? Take labour charges as Br. 90 per day of 8 hours. Make necessary assumptions.

Attention! It should be submitted a week before the delivery of the final examination of the course.

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Thank You