B.Sc. AGRICULTURE LAB MANUAL

1st Semester

MIDNAPORE CITY COLLEGE

MCC

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Prepared By

Biological Science Dept.

Agriculture

MIDNAPORE CITY COLLEGE

AGRONOMY

'Agriculture' term is derived from Latin words – '*Ager* or *Agri*' means '*Soil'* and '*Cultura*' means '*Cultivation*'. It is encompassing of 'Crop production' and 'Land management' and allied sectors like *'Horticulture or Garden farming, Animal farming including Dairy and Fishery, Forestry, Pisiculture, Grassland and Forage etc.* ***'Agronomy'*** is the main branch of agriculture which means '*The science of manipulating the crop environment complex aims of understanding the process and improving the crop productivity'*. It is derived from Greek word *'Agros'* means *'Field'* and *'Nomos'* means *'To manage'*. Today considering the 'Food security and Rainbow revolution' 'Agriculture' is converted to 'Agriculture and allied sectors'.

History of Agriculture

Earlier 10,000 B.C.	Hunting and gathering	8700 B.C.	Domestication of Sheep
7500 B.C.	Cultivation of crops Wheat and Barley	7700 B.C.	Domestication of Goat
4400 B.C.	Cultivation of crop Maize	6000 B.C	Domestication of Cattle and Pigs
3500 B.C.	Cultivation of crop Potato	2700 B.C.	Domestication of Silk Moth
2300 B.C.	Cultivation of crops Chick pea, Pear, Rapeseed-mustard, Cotton	2300 B.C.	Domestication of Fowl, Buffalo and Elephant
2200 B.C.	Cultivation of crop Paddy	1700 B.C.	Domestication and Taming of Horse

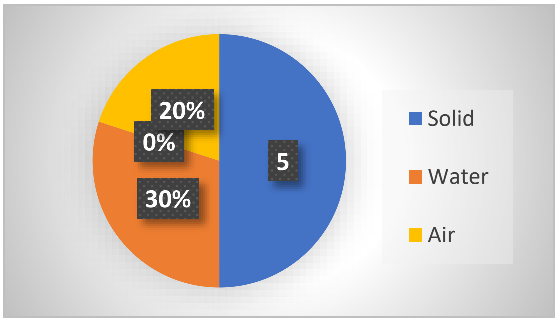
1800 B.C.	Cultivation of crop Finger millet	1400 B.C.	Use of Iron
1725 B.C.	Cultivation of crop Sorghum or Bajra	3400 B.C.	Wheel was invented
1500 B.C.	Cultivation of crop Sugarcane	3000 B.C.	Bronze was used to make tools
		2900 B.C.	Plough was invented; Irrigation farming
15th Century A.D.	Cultivation of Sweet orange, wild Brinjal, Pomegranate	1500 B.C.	Irrigation from wells
16thCentury A.D.	Cultivation of all crops		

The agricultural field crops are classified into following common groups are

Cereals (source of carbohydrate)	Paddy, Wheat, Maize, Barley, Oat, Sorghum
Millets (source of carbohydrate)	Jower, Bajra, Finger millet, Pearl millet, Ragi
Pulse crops / Legume crops (source of protein)	Black gram, Green gram. Red gram, Bengal gram, Lentil, Chick pea, Beans
Oilseed crops (source of oils)	Rapeseed- mustard, Sunflower, Linseed, Safflower, Sesamum, Castor, Niger, Palm, Coconut and Non-traditional oil crops

Leguminous Oilseed crops	Groundnut and Soybean
Sugar crops	Sugarcane, Sugar beet, Water melon
Tuber and Bulb crops	Potato, Sweet potato, Foot yam, Onion
Fiber crops	Jute, Mesta, Ramie, Cotton, Khimp, Sunnhemp
Vegetables	Brinjal, Tomato, Ladies finger, Cauliflower, Cabbage, Bitter gourd, Snake gourd, Ridge gourd, Cucumber, Pointed gourd etc.
Fruit crops	Mango, Litchi, Banana, Guava, Apple, Orange, Pine apple etc.
Plantation crops	Tea, Rubber, Sal, Teak, Palash, Jatropha, Neem, Mahua etc.
Spices and Condamins	Black pepper, Labanga, Haritaki, Amloki, Elachi
Medicinal crops	Tulsi, Brahmi, Mahavringharaj, Kesut, Sechi, Bon marich, Detol, Kalmi, Dhron, Amrul, Susni, Isobgul, Thankuni, Chagalbati etc.
Cash Crops	Sugarcane, Potato, Cotton etc.

- **Soil environment:** A soil normally having solid, water and air parts. All are varied according to soil texture, bulk density and particle density. Particle density depends on solid % of a soil particle where as bulk density depends on porosity (air) %.



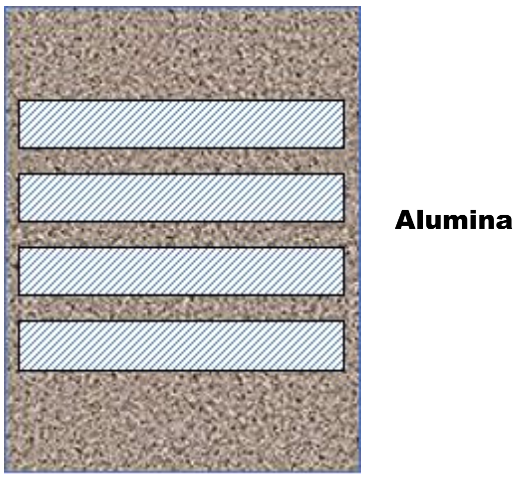
The top soil is most important for crop growing as excepting some deep rooted crop all crop roots are in this zone. This is known as **Rhizosphere soil layer. This may be varied 5 cm – 1 m.** The Rhizosphere soil contains average 700 m microflora while Non-Rhizosphere soil (below 1 m soil surface) having around 25 m microflora.

❖ **Soil Physical Environment:** It is comprised of soil texture, soil structure, aggregates, soil colour, soil water, soil air, soil temperature, soil profile etc. **Soil tilth** is the physical condition in which the soil is in an optimally loose, friable and porous assemblage of aggregates permitting free movement of water and air, easy cultivation, planting, germination and root growth.

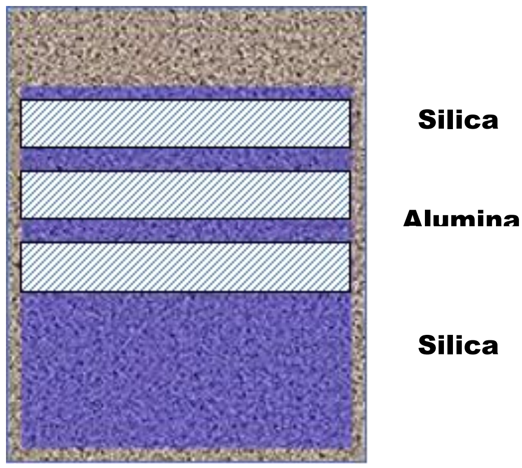
Soil texture: According to soil texture the Indian soil is primarily classified into Sandy soil (having sand above 80%), Silt soil (having silt above 80 %) and clay soil (having clay 40 -60 %). Though there are many subdivisions like sandy loam soil, loamy soil, silty loam soil, clay loam soil etc.

Soil structure: It is the arrangement of soil primary particles (sand, silt & clay) and their aggregates in various pattern in the soil. Soil aggregates are Platy, Blocky, Columnar etc.

Clay minerals: Soil is basically a columnar type **where Silica and Alumina layers are in 2:1 or 1:1.** On the basis of arrangement soil may be termed as Kaolinite, Montmorillonite, Illite etc. Non-silicate soil normally contains morered /yellow coloured Hydrous oxide. Allophanes soil having silica+ sesqui oxide.



Silica1: Alumina 1



Silica 2: Alumina 1

❖ **Soil Chemical Environment:** It is comprised of Soil pH, Clay minerals, Humus, Cation exchange capacity (CEC), Anion exchange capacity (AEC), Soil solution, Soil nutrients (transformation, leaching, fixation, availability, uptake etc.)

Soil pH: On the basis of soil pH soil is classified in to Neutral (pH- 7) , Acidic (lower than pH 7) and alkali (above pH 7). Most of the soil nutrients are available in neutral soil (N, P,K, Bo, Cu, Zn, Mn etc.). S is mostly available above pH 6 while Fe is available below pH 6. Ca, Mg, Mo are normally available in above pH 7.

Soil humus: Soil humus is the available products of animal and plant residues. Humus determines the carbon status of soil which ultimately highlights the soil biota and soil organic matter content. Soil organic matter are increased in zero till or minimal till conservation agriculture.

- **Soil Biological Environment:** It is the most important part of the soil a it controls the availability of soil nutrients by the presence of soil biota.Both the soil fertility or productivity depend on it. **All productive soil is fertile but all fertile soil may not be a productive soil.**

Soil fertility: It is the inherent capacity of soil to supply nutrients to plants.

Soil productivity: It is the capacity of a soil to produce crops.

Soil biota: Different soil organism are termed as soil biota. Soil having **Flora and Fauna**. Soil flora includes **Microflora (Bacteria, Fungi, Actinomycetes etc.)** and **Macroflora like Root**. Similarly, the soil fauna having **Microfauna (Protozoa, Nematodes etc.)** and **Macrofauna like Earthworm, Ants, Moles etc.**

Soil enzymes: Enzymes have played a key role in nutrient availability. In nitrogen fixation by legume plants through symbiotic process both Rhizobium bacteria and Nitogenase enzyme are similar importance. Urease enzyme is also responsible for similar many activities.

Plant enzymes: Plant contains many enzymes like AAA (Aryl Acyl Amidase); GST (Glutathione synthetase transferage), Glutamine synthatase, Acetolactate synthase, Acetyl CoA Carboxylase etc. These are responsible for many plant functions including selectivity of pesticides.

N-Fixation: Because of Symbiotic association Rhizobium takes water and carbohydrate from leguminous plant roots, fix atmospheric N and supply to host plant. The aerobic Rhizobium bacteria present in root nodules form ***'Bacteroides'*** that produce reddish protein '***Leghaemoglobin'*** which during maturity turns to pinkish colour. Nitrogen in bacteroides reduced to ammonia by nitrogenase enzyme. In fact a part of the N- produced be legumes is held in soil as Amino acid. Leguminous plants like pulses, soybean, groundnut, dhaincha, etc. in aerobic ecosystem in their roots can able to fix atmospheric nitrogen 20 kg/ha (black gram) – 250 kg/ha b (lucern) which is in an average 190 mt/annum. The industrial fixation is only 50 mt/annum.

In anaerobic ecosystem *Azolla pinnata*can also fix nitrogen in similar way**. Nostac, Anabaena, *Clostridium pastourrianum***etc. are sustainable in anaerobic situation**.**

The non-legume plant *Causurina alder*can also fix some atmospheric nitrogen with the help of **Actinomycetes.**

The microflora responsible for non-symbiotic nitrogen fixation are *Azotobacter chroccum, Azotobacter vinefandd, Clostridium pastourrianum, Azospirrillum, Rhodospirillum* etc. *Azotobacter* is a heterotrophic bacteria thus very much sensitive to acidic situation.

Nitrification and Denitrification:

Nitrogen transformation: In general, organic matter on hydrolysis turns to Polypeptides and subsequently Amino acid (Ammonification by *Bacillus, Pseudomonas* etc.). Through Nitrification (by *Nitrosomonas*) it converted to Nitrite and further by *Nitrobactor* to Nitrate that is useful to plant.

In Denitrification Nitrate is converted to nitrogen by *Thiobacillus* or *Pseudomonas* bacteria. This mostly happen in aerobic situation and the GHG Nitrous oxide is evolved.

Agriculture is one of the major contributors to the production and atmospheric accumulation of **methane** (CH_4), which is produced by soil organisms (**methanogens**) that live under anaerobic conditions, i.e., in the absence of oxygen. The flooding of rice paddies to grow irrigated rice is one of the major sources of methane within the agricultural sector. Flooded rice paddies apparently account for between 6 and 29% of the methane for which human beings are responsible.

- **Soil Aerial Environment:**

Climate and Weather:

Weather is a state of atmosphere in a given time and given place, but **Climate** is a generalized weather over a given period in any region. **Agro-climatology** deals with relationship between climatic regions and agricultural production. **Atmosphere** having 78. 088 % N, 20.948 % Oxygen and 0.033 % carbon di oxide beside argon (0.930%) and some traces. The various layers of **Atmosphere** are **Troposphere** (lower layer 8-18 km altitude), **Stratosphere** (upto 50 km altitude), **Mesosphere** (upto 80 km altitude)and in the top **Thermosphere** (above 80 km altitude) is the outermost layer that separated **Mesopause** from the **Mesosphere**. The lower layer of Thermosphere is known as **Ionosphere.** Crop cultivation is related to Troposphere**.**

Because of Climate change effect (Global warming) which can be easily determined by sea top water level temperature the C4 plants are dominating than the present C3 plants (biodiversity plant type change). Based on the method of reduction of Carbon dioxide plants are classified into

C3 plant: The initial product of Carbon assimilation is the 3- carbon compound (Pyruvic acid). The enzyme involved in the primary carboxylation is Ribulose-1, 5-bisphosphate carboxylase. Photorespiration is high in these plants e.g. rice, wheat, cotton, soybean, groundnut, barley, oat, sunflower, rye, potato, sweet potato, tomato, sugarbeet etc.

C4 plant: In these plants the primary product of carbon fixation is 4- carbon compound (Malic acid) and the enzyme responsible for carboxylation is Phosphoenol pyruvic acid carboxylase. This enzyme has high affinity for carbon dioxide and capable of assimilating CO2 at lower concentration. Photo respiration is negligible in this type of plants e.g. maize, sorghum, millets, sugarcane, amaranthus, etc.

CAM (Crassulacean Acid Metabolism) plant: In these plants the stomata are open at night instead of normal day time and large amount ofCO2 is fixed as Malic acid which is stored in vacuoles e.g. pine apple, onion, garlic, sisal, hasnuhana etc.

<u>Agricultural Land Types:</u>

Anaerobic Ecosystem: Submergence of water; Less Oxygen

Aerobic Ecosystem: More Oxygen, No submergence of water

(***except during kharif season heavy rainfall period)***

- ✓ **Cultivated field:** Crops are grown for biological yield for certain period. It may be aerobic ecosystem (up- medium lands) or anaerobic ecosystem (low land).
- ✓ **Fallow land:** Fields remain uncultivated for certain time / period
- ✓ **Wasteland:** No crops are grown – keep fallow due to some reason
- ✓ **Degraded land:** Land may be converted in cultivated land aftermaking treatments
- ✓ **Forage / pasture land:** Crops are raised for animal feed

Agriculture crop cultivating seasons with crops:

- ➢ **Seasonal crops-** Generally grown within a season
- ➢ **Annual crops-** Generally taken one year
- ➢ **Perennial crops-** Generally taken more than a year

Pre-kharif/Summer				*Kharif* / Rainy				*Rabi* / Winter			
FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN
Summer rice, Maize, Jute, Sesame, Groundnut, Soybean Black gram, Green gram, Cowpea, Vegetables				Lowland- Aman rice Up-medium land - Aus rice, Maize, Jute, Groundnut, Soybean, Cowpea, Black gram Vegetables				Potato, Wheat, Maize, Rapeseed-mustard, Sunflower, Safflower, Linseed, Chickpea, Lentil, Onion, Vegetables			
Sugarcane (Annual), Colocasia (Perennial) Fruit crops (Perennial) - Banana, Guava, Mango, Papaya, Litchi etc.											

Methods of Cropping: Crops are growing in a cultivated field with various systems

- **Mono Cropping:** Growing one crop annum^{-1} in a land e.g Rice (Cropping intensity - 100 %)

- **Double Cropping:** Growing of two crops annum^{-1}in a land e.g Rice (Aman) – Rice(Boro) in anaerobic ecosystem; Jute - Vegetables in aerobic ecosystem (Cropping intensity - 200 %)

- **Multiple Cropping:** Growing of more than two crops annum^{-1}in a land e.gSesbania (prekharif)- Rice (Aman) – Rice(Boro) in anaerobic ecosystem; Black gram / Green gram - Vegetables - Rapeseed - mustard / Potato / Gram etc. in aerobic ecosystem (Cropping intensity - 300 %)

- **Mixed Cropping:** Growing of more than one crops simultaneously in a land either may be by mixing of seeds (Lentil + Coriander) or as Intercropping with some alternate rows(e.g. Wheat + Linseed) or as guard crops (e.g. Pigeon pea with vegetables, Dhaincha with rice etc.)

- **Multistoried Cropping:** Using the advantages of space and height of the crops growing of more than one crops in same land (e.g. - Arecanut - Black pepper - Turmeric)

- **Mixed Farming:** Growing of more than one enterprise in a land (e.g. Rice cum fish culture)

- **Integrated Farming:** Integration of more than one enterprise / farming for better utilization of resources for the benefit of all farming e.g. Cattle Farm + Ag. Farm – Cow dung/urine etc. are used to prepare FYM that apply in Ag. Farm for crop production.

- **Cropping Pattern:** Sequence of crops growing in a region depending on the available resources (e.g. in NAZ-Vegetables (summer)- Vegetables (kharif) - Rapeseed (rabi) or in OAZ- Sesamum (summer)- Rice (kharif) - Potato (rabi)

- **Cropping Sequence:** For better utilaztion of available resources and the marketing facility raising of crops in any farm (e.g. 400 % Cropping intensity- Green gram (summer)- Jute + leafy vegetables (kharif) - Cauliflower / Cabbage (rabi) - Cauliflower / Cabbage (rabi)

- **Crop Rotation:** Crops grown in sequence in a farm depending on the available resources (e.g. Green gram (summer)- Vegetables (kharif) - Rapeseed (rabi) or - Rice (kharif) - Rice (summer)

- **Cropping Intensity:** Number of crops grown in a sequence / rotation in any farm / region / State [e.g. Soybean (summer)- Rice (kharif) - Rapeseed (rabi) - 300% CI] or [Rice (kharif) - Rice (summer) - 200% CI] - State CI is around 180 %

- **Intensity of Cropping:** Growing of a crop in a farm / zone or any region - Rice at NAZ (Area of rice in NAZ / Area of Rice in WB x 100) e.g. In NAZ vegetables intensity is more while in OAZ paddy intensity is more.

- **Integrated Farming System (IFS):** The major criteria in IFS is location specific, farmers need and the resources available. In past this concept is recognized as "Permaculture". In this farming system the crop, animal sciences including fishery, duckery, sericulture, pisiculture, agro-forestry etc. all or some of these enterprises are integrated according to resources are available. One enterprise of this farming system must use the products of the other enterprise to avail the benefits of this system. An example is as follows- In a farm one side the crop is raised surrounded by some fruit crops with spices (black pepper in arecnut) along with bee keeping and sericulture; in middle a water tank that supply water to crops, fish is grown this tank, ducks are there in a bamboo constructed shelter (Maccha) and the excreta are using by fish; the bunds of the pond is used by growing some vegetables / spices like turmeric, zinger some common medicinal plants are raised in this farm.

Major crops grown in India and their distribution

Cereals and Millets (Source of Carbohydrate)	
Paddy (Rice) *Oryza sativa*	Cultivating almost in all states of India. In N-E states mainly organic rice is grown. It is grown in both *kharif* (June- October) and summer (February- May) season. Summer rice is known as *BORO RICE*. Generally, yield of rice is more in summer (4-5 t /ha) in comparison to kharif rice (3-4 t/ha). Kharif rice is also known as *AUS RICE* (Direct seed sowing, Direct seeded puddle rice, early sowing, short duration and early harvesting); *AMAN RICE OR WINTER RICE* (harvested in winter, transplanted in puddled soil). Rice bran oil is used as edible. Duration 4 months (N- states more)
Wheat *Triticum aestivum*	Cultivating almost in all states of India in winter. Major areas are in N-C states. Cultivating in up-medium land situation. Duration 4 months
Barley *Hordeum vulgare*	Mainly cultivating in N states of India. It is grown in winter as grain in up-medium land situation. Two types 6-row and 2-row. Duration 4 months
Oat *Avena sativa*	Mainly cultivating almost in all N-E states of India. It is grown in winter as grain and as fodder in up-medium land situation. Duration 4 months
Maize *Zea mays*	Cultivating almost in all states of India throughout the year. Baby corn is also popularizing. It is grown in up-medium land situation. Corn oil is also famous and used as edible. Duration 4-5 months
Jower *Sorghum vulgare*	Cultivating almost in all states of India throughout the year as fodder but as grain in N-S states. Duration 4 months
Pulses (Mostly Leguminous and Source of Protein)	
Black gram *Vigna mungo*	Cultivating in E-S-C- states of India throughout the year in upland situation. Leguminous and thus helps in soil health improvement. It is short duration 3 months crop. Suitable for mixed cropping.
Green gram *Vigna radiata*	Cultivating in E-S-C- states of India throughout the year in upland situation. Leguminous and thus helps in soil health improvement. It is short duration 3 months crop. Suitable for mixed cropping.

Bengal gram / Chick pea *Cicer arietinum*	Cultivating in E-S-C states of India during winter in upland situation. Leguminous and thus helps in soil health improvement. It is also grown as mixed cropping with most of the winter crops. Suitable for mixed cropping. Duration 4 months
Red gram *Cajanus cajan*	Cultivating in mostly in C- states of India throughout the year in upland situation. Leguminous and thus helps in soil health improvement. Suitable for border crop and mixed cropping. Duration 4 months.
Khesari / Chickling pea *Lathyrus sativa*	Cultivating in all rainfed areas of all states of India during winter in upland situation. Leguminous and thus helps in soil health improvement. It is low water requirement crop and thus suitable for paira cropping. Duration 4 months.
Lentil *Lens esculenta*	Cultivating in all rainfed areas of all states of India during winter in upland situation. Suitable for mixed and paira cropping in conservation agriculture. Duration 4 months. Leguminous and thus helps in soil health improvement.
Cowpea *Vigna sinensis* (grain) / *unguiculate* (fodder)	Cultivating in all states of India during kharif and pre-kharif seasons in upland situation. Leguminous and thus helps in soil health improvement. Most suitable cover crop and grown as both for grain or fodder purpose. Duration 4 months.
Pea *Pisum sativum*	Cultivating in all rainfed areas of all states of India during winter in upland situation. Leguminous and thus helps in soil health improvement. It is low water requirement crop and thus suitable for paira cropping. Duration 4 months.
Beans *Phaselous vulgaris / Dolichos biflorus /lablab*	Cultivating in all states of India throughout the year in upland situation. Leguminous and thus helps in soil health improvement. It is suitable for mixed cropping and duration 4-5 months. Different types are available French bean, Kidney bean, Moth bean, Bush bean, Pole bean etc.
Oilseeds (Source of Oil/Fat/ Lipid)	
Groundnut *Arachis hypogea*	Cultivating in all states of India throughout the year in upland situation. Leguminous and thus helps in soil health improvement. It is suitable for mixed cropping and duration 4-5 months.
Soybean *Glycine max*	Cultivating in all states of India throughout the year in upland situation. Leguminous and thus helps in soil

	health improvement. It is suitable for mixed cropping and duration 4-5 months.
Rapeseed (Toria/sarson) *Brassica campestris* Mustard *Brassica juncea*	Toria and Sarson are the two major groups of Rapeseed. It is cultivating in E- states of India during *rabi* season in upland situation. It is short duration 3 months crop. Toria is below 3 months and thus grown as pre-rabi (Sep-Nov). Gobhi sarson is famous in N-India. Mustard is grown in all states of India. Duration is 4-5 months. The oil has pungency but oil recovery is 35% lesser than all others (Oil % 40-50%)
Sunflower *Helianthus annus*	Cultivating in all states of India in winter in upland situation. Bird attack is common in this crop after fruit setting. Duration is 4-5 months.
Safflower *Carthemus tinctorius*	Cultivating in all states of India in winter in upland situation. Duration is 4 months. Most suitable healthy oil and costly. Inflorescence uses for colouring.
Sesame *Sesamum indicum*	Cultivating in all states of India in summer in upland situation. The "Tilnaru" is using as edible and in pujas. It is black-brown and white types.
Linseed *Linum ustatistinum*	Very suitable for conservation agriculture. Cultivating in winter in uplands in all states of India. The plant stem uses for fibre production. Duration 4 months.
Niger *Guizotia abyssinica*	Commonly grown as rainfed crop. Seed is used for bird feed. Grown in winter and pre-rabi in C-E India in uplands. Duration 4 months.
Castor *Ricinus communis*	Because of presence of some toxic chemicals castor is nowadays not preferred by farmers. Commonly found in roadside throughout the year.
Taramira *Eruca sativa*	Commonly grown as rainfed winter crop. Plant having low water requirement, glossy stem and white flower thus no attack of aphid. Duration 4 months.
Palm *Elaeis guineensis*	Perennial plantation crop. Oil is present both in seed and pulp. Prefer sandy soil. Recently edible palm oil is available in market.
Coconut *Cocos nucifera*	Perennial plantation crop. Nut oil is used for both edible and industrial purpose. Prefer coastal and saline areas almost in all states of India.
Non-Traditional oilseeds	Rice bran, Seeds / Kernels of Cotton, Corn, Sal, Mahua, Karanja, Neem, Jatropha, Pisa, Pilu, Undi, Nahor and leaves of Vetivar, Citronella etc. Oils/fats of non-traditional oilseeds are used in many industries like pharmaceutical, cosmetic, textile, woolen, confectionary, pesticides, soap, toothpaste, chocolate,

	paint and varnishes, nitrification inhibitor, antioxidant & hypocholesterolacmic etc. India is earning through exporting these products .
Fibre crops (Source of textile products)	
Jute (Tita/ Mitha) *Corchorus olitorius/ capsularis*	Cultivating in E- India mainly West Bengal in pre-kharif in upland situation. In North Bengal Tita jute (*C. capsularis*) is also grown in medium lands. Jute sticks are used as fuel and Jute fibres are used in textile industry. Duration 4 months. For Jute fibre processing water is required.
Cotton *Gossypium hirsutum*	Cultivating in all S-C states of India throughout the year in upland situation. It is best grown in black cotton soil. Duration 5-6 months. Cotton seed oil is edible and kapas used in textile industry
Other Fiber crops	Mesta, Ramie, Sunnhemp etc. These are grown in some limited areas.
Tuber and Bulb crops (Source of carbohydrate / spices)	
Potato *Solanum tuberosum*	It is cultivating throughout the year in all states of India depending on cool temperature and in West Bengal during during winter. Duration is 3 -4 months. Potato is modified stem having buds in potato seed. It is rich in starch, vitamins, minerals and uses as a substitute of rice
Onion *Allium cepa*	It is cultivating throughout the year in all states of India depending on cool temperature. Duration is 4 months. Onion is modified bulb having roots. It is rich in vitamins, minerals and uses as a salad. It has pungency in some breeds.
Corm (Kachu) *Colocasia esculenta*	Corm is also modified stem and cultivates during summer / kharif season both in aerobic and semi an-aerobic situation. It is rich in starch, minerals etc. Different types are available. The plant is also used as food. It is perennial.
Foot yam (Ool) *Amorphophallus paeoniifolius*	It is cultivating during summer season in India. The elephant foot yam or white spot giant arum tuber is common in Africa. It is used as a source of carbohydrate. It is perennial in nature. In India it is grown in uplands
Sugar crops (Source of Glucose)	
Sugarcane *Saccharum officinarum*	Cultivating mostly in C-E-S but in other states of India also. Duration 6 -10 months Wide spacing thus suitable for intercropping. In Australia and many other countries Sugarcane is grown for Brewery industry

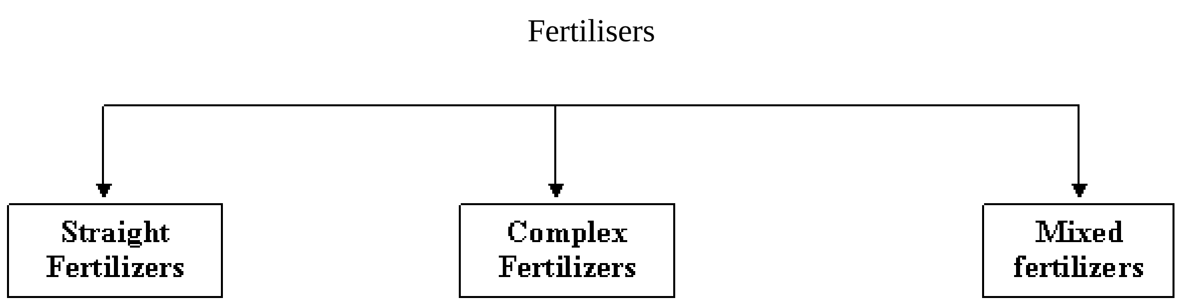
Sugar beet *Beta vulgaris*	Cultivating mainly in coastal and saline belt. Duration above 6 months. Fruit directly edible and uses as salad purpose
Cash crops (Enrich farmers with huge profit – net income more)	
Sugarcane and Potato	Both crops are grown mainly as cash crops a the benefit : cost ratio is more than 200 % . Nowadays many fruits / vegetables are called as cash crops and farmers are converting lesser profitable crop lands (rice, jute, oilseed etc.) to higher profitable crops like flower, fruit, vegetables etc.
Horticultural crops – Vegetables (generally seasonal crops and grown in all states of India); Flowers; Fruits; Spices; Plantation crops like Tea, Coffee, Sal, Segun etc. are mostly perennial but the economic part is available in seasons. These are grown in up-medium lands in aerobic ecosystem.	

STUDY ON AGRICULTURAL FERTILIZERS

FERTILIZER

Fertilizer is any material of natural or synthetic origin added to the soil to supply one or more plant nutrients.

CLASSIFICATION OF FERTILISERS



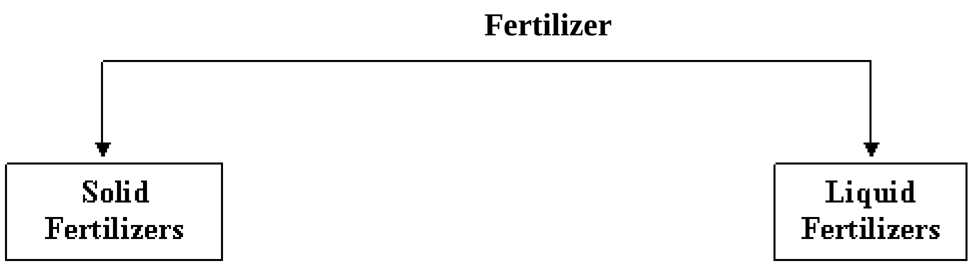
1. Straight fertilizers: Straight fertilizers are those which supply only one primary plant nutrient, namely nitrogen or phosphorus or potassium. eg. Urea, ammonium sulphate, potassium chloride and potassium sulphate.

2. Complex fertilizers: Complex fertilizers contain two or three primary plant nutrients of which two primary nutrients are in chemical combination. These fertilisers are usually produced in granular form. eg. Diammonium phosphate, nitrophosphates and ammonium phosphate.

3. **Mixed fertilizers**: are physical mixtures of straight fertilisers. They contain two or three primary plant nutrients. Mixed fertilisers are made by thoroughly mixing the ingredients either mechanically or manually.

Fertilisers can also be classified based on physical form:

1. Solid
2. Liquid fertilizers



Solid fertilizers are in several forms *viz*.

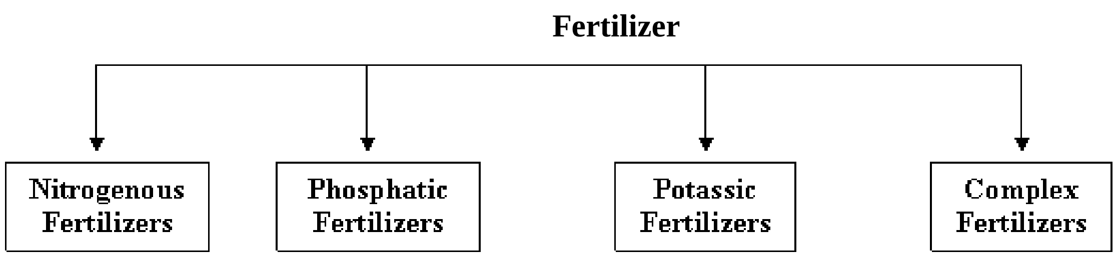
1. Powder (single superphosphate),
2. Crystals (ammonium sulphate),
3. Prills (urea, diammonium phosphate, superphosphate),
4. Granules (Holland granules),
5. Supergranules (urea supergranules) and
6. Briquettes (urea briquettes).



Urea prills **Granulated urea** **Ammonium sulphate**

Liquid fertilizers:

1. Liquid form fertilizers are applied with irrigation water or for direct application.
2. Ease of handling, less labour requirement and possibility of mixing with herbicides have made the liquid fertilisers more acceptable to farmers.



Nitrogenous fertilizer

Ammoniacal	Nitrate	Ammoniacal and Nitrate	Amide fertilizer
1. Ammonium Sulphate 2. Ammonium chloride 3. Anhydrous	1. Sodium Nitrate 2. Calcium Nitrate 3. Potassium	1. Ammonium Nitrate 2. Calcium Ammonium Nitrate 3. Ammonium	1. Urea 2. Calcium Cyanamide

ammonia	Nitrate	Sulphate Nitrate	

A

. Nitrogenous fertilizers

1. Nitrogenous fertilizers take the foremost place among fertilizers since the deficiency of nitrogen in the soil is the foremost and crops respond to nitrogen better than to other nutrients.
2. More than 80 per cent of the fertilizers used in this country are made up of nitrogenous fertilizers, particularly urea.
3. It is extremely efficient in increasing the production of crops and the possibilities of its economic production are unlimited.

The nitrogenous fertilizers can be further classified as given below:

1. Ammoniacal fertilizers

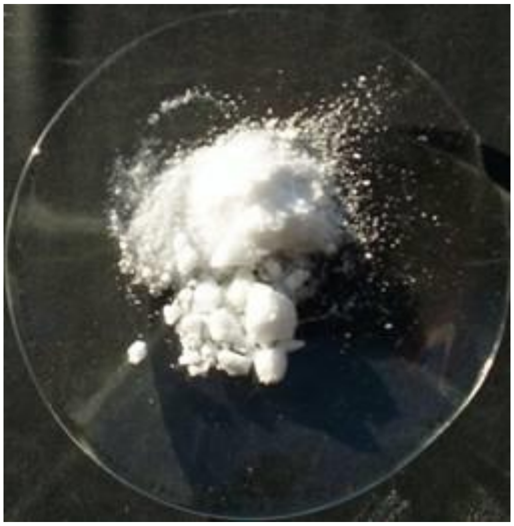
1. Ammoniacal fertilizers contain the nutrient nitrogen in the form of ammonium or ammonia.
2. Ammoniacal fertilizers are readily soluble in water and therefore readily available to crops.
3. Except rice, all crops absorb nitrogen in nitrate form. These fertilizers are resistant to leaching loss, as the ammonium ions get readily absorbed on the colloidal complex of the soil.

a) Ammonium sulphate [(NH4)2 S04]

1. It is a white salt completely soluble in water containing 20.6 .per cent of nitrogen and 24.0 per cent of sulphur.
2. It is used advantageously in rice and jute cultivation.
3. It is easy to handle and it stores well under dry conditions. But during rainy season, it sometimes forms lumps.
4. It can be applied before sowing, at the time of sowing or as a top-dressing to the growing crop.

b) Ammonium chloride (NH4Cl)

1. It is a white salt contains 26.0 per cent of nitrogen.
2. It is usually not recommended for tomato, tobacco and such other crops as may be injured by chlorine.



c) Anhydrous ammonia (NH4)

1. It is a colourless and pungent gas containing 82.0 per cent nitrogen.
2. It is the cheapest and can be applied directly to soil by injection using blade type applicator having tubes.
3. It becomes liquid (anhydrous ammonia) under suitable conditions of temperature and pressure.

2. Nitrate Fertilizers

1. Nitrate fertilizers contain the nitrogen in the form of NO3
2. These ions are easily lost by leaching because of the greater mobility of nitrate ions in the soil.

3. Continuous use of these fertilizers may reduce the soil acidity as these nitrogenous fertilizers are basic in their residual effect on soils.

a) *Sodium nitrate* (NaNO3)

1. Sodium nitrate is a white salt containing about 15.6 per cent of nitrogen.
2. It is completely soluble in water and readily available for the use of plants as such, without any chemical change in the soil.
3. It is easily lost by leaching and denitrification.
4. When large quantities of sodium nitrate are added year after year, the nitrate ions are absorbed by crops and sodium ions accumulate and affect the structure of the soil. Sodium nitrate is also known as *chile salt peter* or *chilean nitrate.*
5. Sodium nitrate is particularly useful for acidic soils

b) *Calcium nitrate* [Ca (NO3)2]

1. It is a white crystalline hygroscopic solid soluble in water containing 15.5 per cent nitrogen and 19.5 per cent calcium.
2. The calcium is useful for maintaining a desirable soil pH.

Calcium nitrate

c) *Potassium nitrate* (KN03)

1. The purified salt contains 13.0 per cent nitrogen and 36.4 per cent potassium.
2. The nitrogen of the potassium nitrate has the same properties and value as that of the sodium nitrate.

3. Ammoniacal and nitrate fertilizers

These fertilizers contain nitrogen in both ammonium and nitrate forms. The nitrates are useful for rapid utilization by crops and the ammonical is gradually available.

a) *Ammonium nitrate* (NH4N03)

1. It is white, water soluble and hygroscopic crystalline salt containing 35 per cent nitrogen half as nitrate nitrogen and half in the ammonium form.
2. In the ammonium form, it cannot be easily leached from the soil.
3. This fertilizer is quick-acting, but highly hygroscopic and not fit for storage.
4. It has an acidulating effect on the soil.
5. It is dangerous in pure form because of explosion hazard.

b) *Calcium ammonium nitrate* (CAN)

1. Calcium ammonium nitrate is a fine free-flowing, light brown or grey granular fertilizer, containing 26 per cent of nitrogen.
2. It is almost neutral and can be safely applied even to acid soils.
3. Half of its total nitrogen is in the ammoniacal form and half is in nitrate form.
4. It is made harmless by adding lime.

Calcium ammonium nitrate

c) *Ammonium sulphate nitrate* [(NH4)2S04 NH4NO3]

1. It contains 26 per cent nitrogen, three fourths of it in the ammoniacal form and the rest (6.5 per cent) as nitrate nitrogen.
2. In addition to nitrogen it contains 12.1percent sulphur.
3. It is a mixture of ammonium nitrate and ammonium sulphate.

4. It is available in a white crystalline form or as dirty-white granules.
5. It is readily soluble in water and is very quick-acting.
6. Its keeping quality is good and it is useful for all crops.
7. Its acid effect on the soils is only one-half of that of ammonium sulphate.
8. It can be applied before sowing, at sowing time or as a top-dressing.

4. Amide fertilizers

1. Amide fertilizers are readily soluble in water and easily decomposable in the soil.
2. The amide form of nitrogen is easily changed to ammoniacal and then to nitrate form in the soil.

a) *Urea* [CO (NH2)2]

1. It is the most concentrated solid nitrogenous fertilizer, containing 46 per cent nitrogen.
2. It is a white crystalline substance readily soluble in water.
3. It absorbs moisture from the atmosphere and has to be kept in moisture proof containers. It is readily converted to ammoniacal and nitrate forms in the soil.
4. The nitrogen in urea is readily fixed in the soil in an ammoniacal form and is not lost in drainage.
5. Urea sprays are readily absorbed by plants.
6. It may be applied at sowing or as, a top-dressing.
7. It is suitable for most crops and can be applied to all soils.

b) *Calcium cyanamide* (CaCN2)

1. Calcium cyanamide or nitrolime contains 20.6 per cent of nitrogen.
2. It is a greyish white powdery material that decomposed in moist soil giving rise to ammonia.

B. Phosphatic fertilizers

1. Phosphatic fertilizers are chemical substances that contain the nutrient phosphorus in absorbable form (Phosphate anions) or that yield after conversion in the soil.

Super phosphate **[Ca (H2PO4)2)**

1. This is the most important phosphatic fertilizer in use.
2. It contains 16 Per cent P2O5 in available form.
3. It is a grey ash like powder with good keeping or storage qualities.
4. Phosphatic fertilizer hardly moves in the soil and hence they are placed in the, root zone.

Triple super phosphate:

1. The concentrated super phosphate is called as *Triple super phosphate* and it contains 46 per cent P2O5.
2. This fertilizer is suitable for all crops and all soils.
3. In acid soils, it should be used in conjunction with organic manure.
4. It can be applied before or at sowing or transplanting.

C. Potassic fertilizers

1. Potassic fertilizers are chemical substances containing potassium in absorbed form (K+).
2. There are two potassium fertilizers *viz*., muriate of potash (KCI) and sulphate of potash (K2S04).
3. They are water soluble and so are readily available to plants.

a) *Potassium chloride* (KCI)

1. Potassium chloride or muriate of potash is a white or red, crystal containing 60.0 per cent K2O.
2. It is completely soluble in water and therefore readily available to the crops.
3. It is not lost from the soil, as it is absorbed on the colloidal surfaces.
4. It can be applied at sowing or before or after sowing.
5. The chlorine content is about 47.0 per cent.

6. Its chlorine content is objectionable to some crops like tobacco, potato, etc where quality is the consideration.

b) Potassium sulphate **(K2S04)**

1. Potassium sulphate or sulphate of potash is a white salt and contains *48* per cent K2O.
2. It is soluble in water and therefore readily available to the crop.
3. It does not produce any acidity or alkalinity in the soil.
4. It is prefered for fertilization of crops like tobacco, potato etc., where quality is of prime importance.
5. It is costly because it is made by treating potassium chloride with magnesium sulphate.

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E. Secondary major-nutrient fertilizers

a. Magnesium fertilizers

These are chemical substances containing the nutrient magnesium in the form of magnesium cations (Mg2+).

b.Magnesium Sulphate **(MgSO4)**

The utilization rate of magnesium fertilizers decreases w,ith incr,easing potassium supplies.

b. Calcium fertilizers

1. These are the chemical substances containing the nutrient calcium in absorbable calcium cations ('Ca2+) form.
2. The raw material of calcium fertilizers is lime found in nature.

Calcium Chloride (CaCl2 **6H2O)**

1. It contains at least 15 per cent calcium.

2. It is highly water soluble and can, therefore, be dissolved for application as a foliar nutrient.

C. Sulphate Fertilizers

1. These are chemical substances containing the nutrient sulphur in the form of absorbable sulphate anions (SO42-).
2. The sulphur requirements of plants are about two third of their phosphorus requirements.
3. Substantial sulphur supplies occur as minor constituents of various N, P and K fertilizers.
4. Fertilization with sulphur becomes necessary with increasing removal from the soil with rising agricultural production especially in plants with high sulphur requirements. e.g. mustard

D. Micronutrient Fertilizers

1. The importance of fertilization of crops with micro-nutrients is increasing mainly because of greater removal from the soil, intensive liming of soil, intensive drainage of soil, higher use of nitrogenous, phosphatic and potassic fertilizers etc.
2. There are seven essential micronutrients required by plants.

These are iron, manganese, zinc, copper, chlorine, boron and molybdenum.

A. lron fertilizers

1. These are generally water soluble substances, predominantly sprayed as foliar nutrients on the crops.
2. Plants absorb iron in the form of Fe2+.

Commonly used iron fertilizers are as follows.

***Ferrous sulphate* (FeSO4 7H2O)**	It is a water soluble fertilizer containing 20 % Fe

Fe – Chelates Fe-EDTA Fe-EDDPA	Suitable for application as foliar nutrients

B. Manganese fertilizers

The manganese (Mn) fertilizers are as follows:

Manganous Sulphate ($MnSO_4$ $7H_2O$)	It is the well known water soluble Mn fertilizer. It is pink salt containing 24 % Mn. It dissolves in water and is suitable for foliar application.
Mn – chelates (Mn – DTA)	It contains 13 % Mn. It plays an important role in the crop fertilization.

C. Zinc fertilizers

Zinc (Zn) fertilizers play an important role in Zn deficient areas.

Zinc sulphate ($ZnSO_4$ $7H_2O$)	It is water soluble whitish salt containing 23 % Zn. It is applied as foliar nutrient. Its acidic action causes corrosion damage to plants
Zinc-oxide(ZnO)	It contains 70 % Zn. It is slightly soluble in water It is used as slow acting foliar nutrient

D. Copper Fertilizers

Copper fertilizers have been used to correct copper (Cu), deficiencies.

Copper sulphate ($CuSO_4$ $5H_2O$) – 25 % Cu

Copper sulphate ($CuSO_4$ H_2O) – 36 % Cu

E. Boron Fertilizers

Borax (Na2B4O 10H2O)	It contains 11 % B It is water soluble white salt It can be applied as a soil dressing or foliar application
Boric acid (H3BO3)	It contains 18 % B It is a white crystalline powder It is applied as a foliar nutrient

F. Molybdenum Fertilizers

Sodium molybdate (Na2MoO42H2O)	It contains 40 % Mo
Ammonium molybdate (NH4)6Mo7O244H2O)	It contains 54 % Mo

1. **These are water soluble salts which contain Mo**
2. **They are suitable for soil application and foliar application as well**

Fertiliser Grade

1. Fertiliser grade refers to the guaranteed minimum percentage of nitrogen (N), phosphorus (P) and potash (K) contained in fertiliser material.
2. The numbers representing the grade are separated by hyphens and are always stated in the sequence of N, P, and

For example, label on the fertilizer bag with a grade 28-28-0 indicates that 100 kg of fertiliser material contains 28 kg of N, 28 kg of *P* and no potash.

Different grades of fertilisers are available in India.

Some of them are:
28-28-0, 20-20-0, 14-35-14 , 17-17-17, 14-28-14 .

FERTILIZER RATIO

It refers to the ratio of the percentage of N, *P2O5* and K2O in the fertilizer mixture e.g., the fertilizer grade 12-6-6 has a fertilizer ratio of 2:1:1.

SUPPLIERS OF PLANT NUTRIENTS

These are straight fertilizers added to supply the plant nutrient mentioned in the grade.

CONDITIONERS

These are low grade organic materials like peat soil, paddy husk, groundnut hulls etc., which are added to fertilizer mixtures during their preparation for reducing hygroscopicity and to improve their physical condition.

Peat soil

Paddy husk

FILLER

A filler is a weight make material like sand, soil, coal powder etc, added to the fertilizer ingredients so as to produce a mixture of the desired grade.

Coal powder **Sand**

NEUTRALIZERS OF RESIDUAL ACIDITY

These are the materials like dolomite, lime stone etc, added in fertilizer mixtures to counteract the acidity of nitrogenous fertilizers.

NUTRIENT

The concept of sustainable agriculture emphasizes on the conservation of the natural resources and maintains the quality of environment.Thus, **Sustainable agriculture is the successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment and conserving the natural resources**.

Whether sustainable agriculture and organic agriculture is same? No, both are different concepts. In sustainable system agriculture resources are used properly and for that natural or synthetic organic chemicals having very little harmful effect on the soil and the environment may be used while organic agriculture strictly avoids the use of any toxic chemicals like fertilizers and pesticides. Therefore, **sustainable agriculture is a broad term that includes organic agriculture as well**. It is a balanced management system of renewable resources including soil, wildlife, forests, crops, fish, livestock, plant genetic resources and ecosystems without degradation and to provide food, livelihood for current and future generation maintaining and improving productivity and ecosystem services of these resources. Sustainable agriculture systems are designed to use existing soil nutrient and water cycles, and naturally occurring energy flows for food production. Chemicals dependent modern agricultural practices have caused several problems.

In modern agriculture there has been consistent use of few high yielding hybrid crop varieties which has resulted into the depletion of land varieties (desi varieties) that are not only nutritious like *Murgibalam* but also possess several useful characters like aroma, drought, disease and pest resistance. Therefore, genetic erosion has emerged as major problem of modern agriculture. The gradual loss of variability in the cultivated forms and in their wild relatives is referred to as genetic erosion. This variability arose in nature over a long period of time and if lost, would not be reproduced during a short period.

Overuse of inorganic fertilizers has led to the problem of soil erosion. Fertilizers destroy the soil structure making the soil susceptible to erosive forces like water and wind. Overuse of nitrogenous fertilizer urea has caused the soil acidity. Excessive nitrogen suppresses biological activity including mycorrhizae (non-pathogenic association of fungi with roots of plants which helps in phosphorus uptake by plants), reduce nodulation in leguminous plants give a competitive advantage to the weed over crop and increase pest incidence. Balance nutrition is preferable by using more organic manures integrated with inorganic fertilizers at initial which gradually replaces the chemical fertilizers. This system aims to produce food that is both nutritious and without toxic products that harm human health.

At present freshwater withdrawals have doubled every 30 years in last 100 years, about 4000 km^{-2} year. In India nearly 80% of the surface water is utilized for agriculture. Out of 54% of the world's accessible freshwater, 70% consumption is accounted for agricultural purposes. 80% of the water used in agriculture is consumed by thirsty crops. Mismanagement of surface and ground water resources has led to the problem of water logging, soil salinity and alkalinity. Moreover, extraction of water for irrigation has caused the lowering of ground water table. Deforestation has resulted into the problem of global warming, depletion of biological diversity, drought and the siltation of water reservoirs.

Use of nutrients has a great role in plant health including pest management. Application of integrated nutrient management (neem cake, vermicompost or any organic manure + NPK) i.e. balance nutrition helps to reduce pest problem.**A theory called *trophobiosis (plants' vulnerability to attack by weed plants, insect, bacteria, fungi, even viruses, is directly a***

consequence of imbalances or deficiencies in the plants' nutrition)**proposed by a French agricultural scientist, Chaboussou (2004),** is consistent with what we observe with less chemicals (fertilizer and agrochemicals). This is associated with shortcomings in the plants' metabolism which is supposed to (a) convert amino acids into more complex protein molecules and (b) metabolize simple reducing sugars into complex polysaccharides. **When nitrogen fertilizer is provided to plants, they take up more N and synthesize amino acids, the building blocks for proteins. But with imbalanced nutrition, they will not be able to quickly and effectively convert amino acids into proteins. This leaves a surplus of amino acids in the plants' sap and cell cytoplasm, which is attractive to insects, pathogenic bacteria and fungi, even viruses.** Nitrous oxide (N_2O) produced by microbial action on the nitrogenous fertilizers is responsible for the thinning of the stratospheric ozone layer which provide protection against the harmful ultra violet radiation of the sun. Excessive use of pesticides to control pests in modern agriculture practices has led to the problem of pesticide resistance resulting into the rise of pest population. In addition to this, pesticides are also responsible for the environmental pollution which indirectly or directly affects the human health.

Similarly, with the application of pesticides, particularly chlorinated ones, plants' metabolism is interfered so that the **simple sugars created through photosynthesis do not get consolidated quickly and continuously into polysaccharides. This produces an abundance of sugars in the sap and cytoplasm which offers various insects and pathogens an opportunity to feed easily and expand their population. 'Surpluses' of amino acids and simple sugar make plants vulnerable to predation and disease.** Another possible explanation for SI resistance to pests is that SRI plants are grown in lesser submerged soil will have more uptake of silicon. This would account for the stalks (tillers) and leaves on SRI plants being tougher and stronger, resisting being blown over and lodged by strong winds and rain. Insects would also be deterred by this quality. The phenomenon of SI crop resistance to pests, while not always observed, is confirmed by many farmers from experience and research at new alluvial zone on SRI.

Because of poor storing, marketing and food preservation system of present agriculture management farmers are becoming helpless to sell their produce immediate after harvest with required profit. The middle-men take these advantages and without thinking the future effect on human health mix toxic chemicals with the fresh harvested produces (to change colour, more attractive and keeping more days). Recently some business -men gaining one step more by using rot materials with food products losing their all good wishes.

Most of the government policies regarding development of agriculture (for implementing some important beneficial policy like watershed management, Krishi-market, agri-skill etc.) have been failed as instead of scientists these are controlled by some politicians who have a poor knowledge in agriculture besides more interested to achieve political success. The young generation are not showing interest in agriculture rather they use to convert agricultural land for some other purposes.

For implementation of sustainable agriculture, it is therefore, highly needed to take the responsibility by the agri-scientists and the government agri- officers to implement all the policies properly and in time to create more interest of farmers in agriculture and for the benefits of our society and our nation.

Basic Concept of Integrated Nutrient Management (INM)

The use of balance nutrition is the basic concept of sustainable system agriculture. Application of various useful plant nutrients in proper amount and in proper plant physiological stages is also necessary for successful implementation of INM. It is well known that "soil feed the plant" and thus the use of INM is also depending on the nature and type of soil in addition to its environment.

Nutrient - Definition: Nutrient is the food substance used by an organism to survive, grow and reproduce. The requirement for dietary nutrient intake applies to animals, plants and biota. Nutrients can be incorporated into cells for metabolic purposes or excreted by cells. Some nutrients can be metabolically converted to smaller molecules in the process of releasing energy through carbohydrates, lipids, proteins and fermentation products (ethanol or vinegar), leading to end-products of water and carbon dioxide. All organisms require water. Plants require more diverse minerals absorbed through roots, in addition to carbon dioxide and oxygen absorbed through leaves. Fungi live on dead or living organic matter and meet nutrient needs from their host.

Different types of organism have different essential nutrients. Ascorbic acid (vitamin C) is essential, meaning it must be consumed in sufficient amounts, to humans and some other animal species, but not to all animals and not to plants, which are able to synthesize it. Nutrients may be organic or inorganic: organic compounds include most compounds containing carbon and energy-providing compounds and vitamins, while all other chemicals are inorganic. Inorganic nutrients include iron, selenium, and zinc etc.

A classification used primarily to describe nutrient needs of plants divides nutrients into macronutrients and micronutrients. Consumed in relatively large amounts (grams or ounces), macronutrients (carbohydrates, fats, proteins, water) are used primarily to generate energy or to incorporate into tissues for growth and repair. Micronutrients are needed in smaller amounts (milligrams or micrograms); Edible plants also contain thousands of compounds generally called phytochemicals which have unknown effects on disease or health, including a diverse class with non-nutrient status called polyphenols, which remain poorly understood as of 2017. Plant nutrients consist of more than a dozen minerals absorbed through roots, plus carbon dioxide and oxygen absorbed or released through leaves. All organisms obtain all their nutrients from the surrounding environment.

Types of Nutrient:

Basic Nutrients: Plants absorb carbon, hydrogen and oxygen from air. These three, in the form of water and carbon dioxide. Carbon (C), oxygen(O) and hydrogen (H) are the basic nutrients.The chemical elements humans consume in the largest quantities are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur, summarized as CHNOPS and provide bulk energy are classified as carbohydrates, proteins, and fats. Water must be also consumed in large quantities.

Macro and Micronutrients: Other 17 important nutrients for plants are absorbed from soil (exceptions include some parasitic or carnivorous plants).

Macronutrients: Macronutrients provide energy. The major six macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S) and magnesium (Mg). In addition to carbon, hydrogen and oxygen, nitrogen, phosphorus, and sulphur are also needed in relatively large quantities. Together, the "Big Six" are the **Elemental macronutrients** for all organisms. They are sourced from inorganic matter (for example, carbon dioxide, water, nitrates, phosphates, sulphates and diatomic molecules of nitrogen and especially, oxygen) and organic matter (carbohydrates, lipids, proteins).

Micronutrients: The important eight micronutrients are iron (Fe), boron (B), chlorine (Cl), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo) and nickel (Ni).

Carbohydrate, Fat and Protein: These three are essential elements of a plant and also in a seed. Fat has an energy content of 9 kcal/g (~37.7 k J/g) and proteins and carbohydrates 4 kcal/g (~16.7 k J/g). These are main source of all micronutrients.

- Carbohydrates are compounds made up of types of sugar. It is classified according to their number of sugar units: mono saccharides (such as glucose and fructose), disaccharides (such as sucrose and lactose), oligosaccharides and polysaccharides (such as starch, glycogen, and cellulose).

- Proteins are organic compounds that consist of amino acids joined by peptide bonds. Since the body cannot manufacture essential amino acids, to supply these the food is the main source Through digestion, proteins are broken down by proteases back into free amino acids.

- Fats consist of a glycerin molecule with three fatty acids attached. Fatty acid molecules contain a -COOH group attached to unbranched hydrocarbon chains connected by single bonds alone (saturated fatty acids) or by both double and single bonds (unsaturated fatty acids). Fats are needed for construction and maintenance of cell membranes, to maintain temperature, and to sustain the plant health. Essential fatty acids must be obtained through plant food

- **Soil enzymes:** Enzymes have played a key role in nutrient availability. In nitrogen fixation by legume plants through symbiotic process both Rhizobium bacteria and Nitogenase enzyme are similar importance. Urease enzyme is also responsible for similar many activities.

- **Plant enzymes:** Plant contains many enzymes like in rice AAA (Aryl Acyl Amidase); in maize GST (Glutathione synthetase transferage), Glutamine synthatase, Acetolactate synthase, Acetyl CoA Carboxylase etc. These are responsible for many plant functions including selectivity of pesticides.

- **N-Fixation:** Because of Symbiotic association Rhizobium takes water and carbohydrate from leguminous plant roots, fix atmospheric N and supply to host plant. The **aerobic Rhizobium bacteria** present in root nodules form ***'Bacteroides'*** that produce reddish protein '***Leghaemoglobin'*** which during maturity turns to pinkish colour. **Nitrogen in bacteroides reduced to ammonia by nitrogenase enzyme**. In fact, a part of the N- produced be legumes is held in soil as Amino acid. Leguminous plants like pulses, soybean, groundnut, dhaincha, etc. in aerobic ecosystem in their roots can able to fix atmospheric nitrogen 20 kg/ha (black gram) – 250 kg/ha b (lucern) which is in an average 190 mt/annum. The industrial fixation is only 50 mt/annum.

In anaerobic ecosystem ***Azolla pinnata***can also fix nitrogen in similar way**. Nostac, Anabaena,** ***Clostridium pastourrianum*** etc. are sustainable in anaerobic situation**.**

The non-legume plant ***Causurina alder***can also fix some atmospheric nitrogen with the help of **Actinomycetes.**

The microflora responsible for non-symbiotic nitrogen fixation are *Azotobacter chroccum, Azotobacter vinefandd,Clostridium pastourrianum, Azospirrillum, Rhodospirillum* etc. *Azotobacter* is a heterotrophic bacteria thus very much sensitive to acidic situation.

- **Nitrification and Denitrification:**

Nitrogen transformation: In general, organic matter on hydrolysis turns to Polypeptides and subsequently Amino acid (**Ammonification by** ***Bacillus, Pseudomonas*** etc.). Through **Nitrification by** ***Nitrosomonas*** it converted to **Nitrite** and further by ***Nitrobactor***to **Nitrate** that is useful to plant.

In **Denitrification Nitrate** is converted to N**itrogen** by ***Thiobacillus*** **or** ***Pseudomonas*** bacteria. This mostly happen in **aerobic situation** and the **GHG Nitrous oxide(N_2O)** is evolved.

- **Green House Gases (GHG):** Agriculture is one of the major contributors to the production of **GHG (CO_2, CO, N_2O and CH_4)** and ultimately global warming. During **decomposition of natural substances CO_2 and CO** are produced. It is questionable that for organic farming (no chemical) when huge amount of organic manures is required then what will be the fate of CO_2 and CO that are produced during producing time of organic manures. **GHG Methane(CH_4)** is produced by soil organism ***Methanogens*** that live under **anaerobic conditions**, i.e., in the absence of oxygen.

The flooding of rice paddies to grow irrigated rice is one of the major sources of methane within the agricultural sector. On the other hand**, in aerobic situation the GHG Nitrous oxide(N_2O) is evolved through denitrification.** Flooded rice paddies or crops in aerobic dry soil apparently account for between 6 and 29% of methane and 10-50 kg of Nitrous oxide for which human beings are responsible.

Crop logging: A record of progress of crop containing a series of chemical / physical measurements. This will indicate the general condition of the crop and suggest changes in management that are necessary to obtain maximum yield. Critical nutrient concentration is used in crop log system.

Crop lodging: May be due to excessive nutrients or submergence of water when crops are failed in soil surface in the field instead of standing. This will indicate yield loss.

Nanotechnology in plant nutrition: It is the understanding and control of matter and dimensions at 1-100 nm (nanometer) in size with a surrounding interfacial layer where the unique physical properties make novel application possible. Soils contain matter of dimensions of 1-1000 nm the colloids (inorganic, organic humic substances, and large biopolymers) of nano particles (NPs) size.

Manure: Organic materials derived from various residues that contain plant nutrients in complex organic forms They are low nutrient content but having longer residual effect in addition to improving soil physical properties. e.g. Cattle shed wastes (cow dung, urine, slurry), human habitation wastes (night soil, urine, sewage, sludge, house waste, fish waste etc.), byproducts of agro-industries (oil cakes, pressmud etc.), crop wastes (crop residues, stubbles etc.), weed wastes and green manure crops or green leaf manuring. Manures may be bulky with low nutrient content (FYM, compost) or concentrated with slightly high nutrient content (green manure, oil cakes, bone meal etc.). No single nutrient element can be used or applied separately in organic manure as these are having a combination of complex nutrients. **Vermicompost** is prepared through a system where organic wastes are decomposed using earthworms (*Erudrilus evegeniae, Eisenia foetida* etc.). Earthworm and micro-organisms play a vital role in degrading organic wastes. The entire biodegradation process of organic wastes by earthworm and micro-organisms is known as Vermicomposting and end product is Vermicompost

Mineral Fertilizer: Synthetically producing through industrial process in liquid or solid form. They have higher nutrient contents than organic manures. Any nutrient can produce either sole or in complex / compound form (N- Urea sole N – Suphala N:P:K:: 20:20:20 compound fertilizer). **Annually, India is losing nearly 0.8 mt of nitrogen, 1.8 mt of phosphorus and 26.3 mt of potassium. The major fertilizer consumption in India is now around 28 mt (N- 17.30 mt, P- 7.91 mt and K-2.58 mt) dominating inorganic nitrogen resulting imbalanced use of nutrition. Total fertilizer production is more than 33 mt.** Average consumption of fertilizers are N 60 kg /ha, P- 22 kg /ha, and K 9 kg /ha i.e. a total of 91 kg /ha in our country. **Highest nutrient content is in Anhydrous ammonia 81.5 % (ammonical nitrogen). Urea, a diamide carbonic acid is known as organic fertilizer as it has the structure NH_2 $COONH_4$ having Carbon**. The important single fertilizers are Urea , Anhydrous ammonia, Single / Double / Triple super phosphate etc. The compound fertilizers are Ammonium nitrate, Ammonium sulphate, Calcium ammonium nitrate, Dicalcium Phosphate, Ammonium phosphate sulphate, Nitrophosphate, Potassium sulphate, Potassium Chloride, Suphala, Gromor, Diammonium phosphate etc. Presently various coated fertilizers are used in water submerged soil which are coated with sulphur or neem etc. that helps in slowly release and reduce loss of nutrients.

Organic manure	Inorganic fertilizer
Complex mixture of natural plant and animal residues and prepared naturally by biota	More or less pure minerals and prepared synthetically – Chemical substances
Available only in nutrient mixture as bulky or concentrate having poor (0.5-5.0%) in each nutrient	Available both as single or compound / complex nutrient having rich (10-82%) in nutrient content
Release of nutrient slowly depending on soil biota	Release of nutrient rapidly depending on soil biota
Less water soluble , thus leaching loss is less	Highly water soluble thus more leaching loss
Supply more nutrients in small quantity	Supply one to three nutrients in higher

	quantity
Improve soil biological and physical condition	No effect on soil physical & may hamper biological
No scope of applying single nutrient or any fixation	Scope of fixation like P, K in the soil
Very little scope of applying as foliar spray	High possibility of spraying like fertigation
Not suitable as top dressing	Suitable to use as top dressing

Nowadays bionutrinets (prepared from microflora) are available in both liquid or tablet form in single or compound form having one or more nutrient content.

Difference between organic manure and inorganic fertilizer

Average NPK content (%) of some important organic manures and inorganic fertilizers

Organic manures	N	P_2O_5	K_2O	Inorganic fertilizers	N	P_2O_5	K_2O
FYM	1.0	0.5	1.0	Anhydrous Ammonia	81.5		
Compost	1.5	1.0	1.5	Urea Diamide Carbonic Acid	46.0		
Vermicompost	2.5	3.0	2.0	Single Superphosphate	S-22.4	16.0	Ca-19.5
Green manure	2.5	0.2	0.5	Triple Superphosphate		48.0	Ca-14.3
Bone meal	4.0	20.0	0.1	Muriate of Potash			60.0

Neem cake	5.5	1.0	1.5	Potassium Sulphate	S-17.8		52.0
Rapeseed cake	5.0	2.0	1.0	Gypsum	S-23.5 and Ca- 29.2		
Sesame (Til Cake)	6.0	2.0		Copper Sulphate	S-12.8		
Ammonium sulphate	0.6	S- 23.7		Calcium Ammonium Nitrate	25.0	Ca-8.1	
Dicalcium Phosphate		34.0	Ca-22	Calcium Metaphosphate		63.0	
Rock Phosphate		27.0		Di Ammonium Phosphate DAP	18.0	46.0	S-4.5
Suphala	20.0	20.0	20.0	Nitrophosphat	20.0	20.0	

Nutrient Functions

Plants cannot take any nutrients directly from the soil sap through root hairs. All nutrients after application in moist soil at first mixed in soil and then with the help of microorganisms convert to plant’s uptaking form. In general, Indian soil is rich in potash. Phosphorus are fixed in soil and along with organic manures are slowly released in soil. Therefore, all P and OM should apply as basal at the time of final land preparation.

Important Nutrient indicator plants, Deficiency and Toxicity Symptoms.Indicator plants and deficiency / toxicity symptoms of nutrients are varied in respect to soil, climate and plant types

Nutrient	Indicator plants	Nutrient Deficiency and *Toxicity* Symptoms
N	Cauliflower, cabbage	Stunted growth, reduced tillering, yellowing from lower leaves (chlorosis). *NO_3 toxicity -marginal burn of older leaves; NH_4 toxicity- blackening of older leaf tips, necrosis. Abundant foliage with dark green colour*
P	Rapeseed	Purple orange colour of older leaves, new leaves dark green, poor root system, stunted growth.*Necrosis and up dieback, interveinal cholorosis of young leaves, older leaves marginal scarch.*
K	Potato	Older leaves show spots or marginal burning from tip. *May lead to Mg, Mn, Zn and Fe deficiency*
S	Mustard	Chlorosis of younger leaves, severe deficiency leads to chlorosis of entire plant. *Reduction of leaf size, interveinal yellowing/ leaf burning*
Mg	Potato	Interveinal chlorosis of older leaves but veins remaining green, pinkish colour of older leaves. *May induce K deficiency*
Fe	Sorghum, Sugarbeet	Interveinal chlorosis of young leaves, severe deficiency leads to yellowing later turns to white. *In lowland rice bronzing of older leaves, induced P, K and ZN deficiency*
B	Sunflower, Sugarbeet	Thickened or curled leaves, petioles and stems cracked, thickened, water soaked, Cracking of fruits and plant roots. *Interveinal chlorosis*
Mn	Oat, Potato, Sugarbeet	Interveinal chlorosis of young leaves, severe deficiency leads to yellowing later turns to die unlike Fe deficiency. *Yellowing at older leaves at edge, uneven chlorophyll distribution, interveinal bronze-yellow chlorosis in leaf*

Cl/Fl	Gladiolus	Failure of terminal bud and root tip, growing point die and curl, new leaves become white. *Burning of leaf tips and margins, reduced leaf size*
Zn	Paddy, Maize	Zinc deficient leaves remained small with extended necrotic spots and interveinal chlorosis on the upper leaf. Zn deficient plants showed stunted growth and reduced tillering,Sorghum – white bud, cotton- little leaf, fruit tree – clustering of top leaves, paddy- khaira disease. *Induce Fe Chlorosis*
Cu	Potato	Chlorosis and rolling of young leaves, dead tissue at tips and edges in leaf, stem and root like potassium. *Stunting and reduced branching, induce FE chlorosis*
Mo	Paddy	Young leaf pale appearance. *Bleaching of leaves*.
Al	None	Older leaves yellowing with white interveinal stripes. *Yellowing with white interveinal stripe on older leaves*

Recommended General Nutrient dose in Major crops

Depending on need (location specific) micronutrients may be applied

Crop	Season	OM:N:P:K:S (kg/ha)	Source
Paddy / Maize	Kharif	2000:60:30:30:0	NC/VM/OC: Urea: SSP: MOP
	Summer	5000:100:50:50:0	NC/VM/OC: Urea: SSP: MOP
Wheat / Maize	Rabi	5000:100:50:50:0	NC/VM/OC: Urea: SSP:

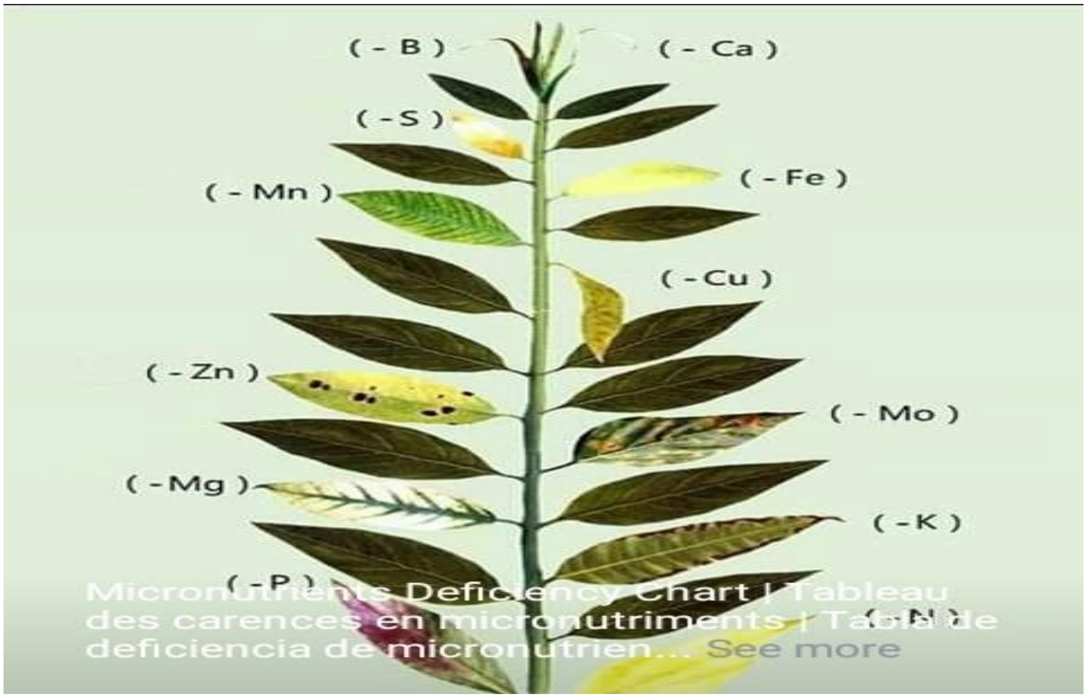
			MOP
Barley / Oat	Rabi	2000:60:30:30:0	NC/VM/OC: Urea: SSP: MOP
Sugarcane	All season	10000:100:50:50:0	NC/VM/OC: Urea: SSP: MOP
Pulses	All season	2000:20:40:40:0	NC/VM/OC: Urea: SSP: MOP
Oilseeds	All season	5000:80:40:40:30	NC/VM/OC: Urea: SSP: MOP:GS
Potato	Rabi	10000:150:100:100:0	NC/VM/OC: Urea: SSP: MOP
Cotton	All Season	10000:100:50:50:0	NC/VM/OC: Urea: SSP: MOP
Jute	Pre-Kharif	2000:60:30:30:0	NC/VM/OC: Urea: SSP: MOP
Spices	All Season	5000:60:30:30:0	NC/VM/OC: Urea: SSP: MOP
Vegetables	All season	5000:80:40:40:0	NC/VM/OC: Urea: SSP: MOP
Tea /Plantation	All Season	10000:100:50:50:0	NC/VM/OC: Urea: SSP: MOP

Fruits	All Season	10000:100:50:50:0	NC/VM/OC: Urea: SSP: MOP
Flowers	All Season	5000:80:40:40:0	NC/VM/OC: Urea: SSP: MOP

Nutrient Mobility (Prone to Leaching) in Soil and Major Plants:

Mobile nutrients are translocated within plants. Thus, nutrient deficiency symptom appears in lower leaves while in case of immobile nutrients symptoms occur in upper leaves

Types of mobility	Soil	Plants
High	N-NO_2, B, S-SO_4	N, P, K, Mg
Moderate	N-NH_4, K, Ca, Mg, Mo	S, Cu, Fe, Mn, Mo, Zn
Immobile	Organic N, P, Cu, Fe, Mn, Zn	B, Ca



Average Concentrations of Essential nutrients in dry matter sufficient for normal growth of crops

Nutrient	g/kg	Nutrient	mg/kg
Carbon (C)	450.0	Iron (Fe)	112.0
Oxygen (O)	450.0	Manganese (Mn)	55.0
Hydrogen (H)	60.0	Zinc (Zn)	20.0
Nitrogen(N)	14.0	Copper (Cu)	6.0
Phosphorus (P)	1.9	Boron (B)	22.0
Potassium (K)	9.8	Molybdenum (Mo)	0.1
Calcium (Ca)	5.0	Chlorine (Cl)	106.0
Magnesium (Mg)	1.9		
Sulphur (S)	1.0		

All nutrients are available in soil. So, testing of soil is important for recommending any nutrient dose in any crop in any field. Each micronutrient has the critical limit in soil. Micronutrients are required only when their content in soil is below their critical limit.

WEED MANAGEMENT

Thus, India's food security is and will continue to remain based on flourishing crop production through increasing productivity. This should be achieved only by wisely harnessing the available resources related to science, technology and innovation while ensuring sustainability of the system in as much possible eco-friendly environment. According to third advance estimates for ICAR 2016-17 total food grain production is approx. 286 mt (2020); 273.38 mt [21.81 mt (8.67% more than last year 2015-16) and 8.34 mt (3.15 % higher than 2013-14that was 265.04 mt)]. The current year production is also higher by 16.37 mt (6.37 %) than the average production of previous five years 2011-12- 2015-16. Rice production is 109.15 mt (2013-14 – 106. 65 mt), wheat 97.44 mt (2013-14 – 95.85 mt), course cereals 44. 39 mt, pulses 22.4 mt and total oilseeds 32.52 mt.

Finding solutions for this is at the heart of ***System Intensification*** **(SI),** a unique method ***best management practices of resources what farmers have,*** that involves integration of land, seed, nutrient, water, pest and quality management through biological approaches so that efficiency of the inputs including energy and labour is enhanced with concomitant gains of high productivity unit^{-1} of land and other inputs keeping the environment largely unpolluted for long-term sustainability. The **System intensification** along with other concepts like Permaculture, Sustainable agriculture, Organic farming, integrated farming system, Precision farming, Conservation agriculture etc. is based on three basic concepts

i) *Improve soil health*: Balance nutrition (INM) does more than feed the plant as *it feeds the soil, so that the soil can feed the plant*.

ii) *Improve plant health*: Improve sustainable soil health using more biological management helps more growth and development parameters- More productivity of crops

iii) *Farmers' improve thinking*: SI is not a fixed set of things that farmers 'must' do. Using the method requires *no material inputs* beyond what farmers already have, just a *change in their thinking and practice*.

Modern Concept of Weed Pest Management

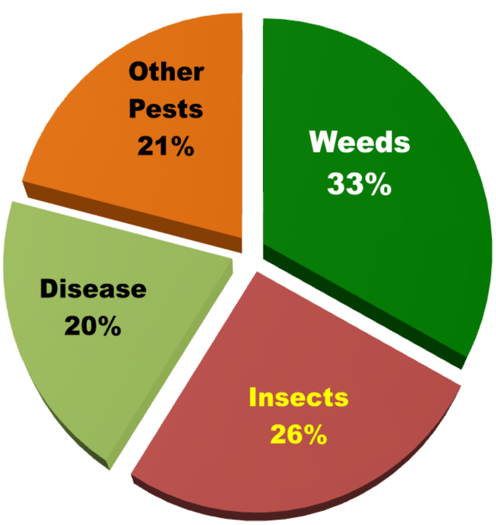
***Weed* – Definition and Importance:**

In the beginning of agriculture, there was no weed. The violet flowers *of Digera, Allium (*wild onion), *Chicorium* or even bluish *Eichhornia* (water hyacinth) or *Monochoria* (pana kachu) are beautiful and worthy of artistic praise for symmetry and colour. *Opuntia* is an effective fence plant as well a valuable plant in desert as it holds sand; *Amaranthus* (note), *Chenopodium* (Beta), *Ipomoea* (kalmi), *Nasturtium* (sarse), *Trapa* (panifal), *Alternanthera* (sechi),*Nymphaea* (saluk) , *Melilotus* (senji methi) or Ne*lumbo* (padma)all are cultivated in many areas for their economic uses as vegetables. I*mperata, Cynodon, Agropyron, Elensine* etc. act very good soil binding plants. Why we humans call such plants as "Weeds"? Who has the right to say some plants are unwanted in nature. The question still lies by what authority do we so easily assign the derogatory term "Weed" to a plant and say it interferes with agriculture, increases cost of production, reduces yields and may even detract from quality of life. Nature knows no such category of plant "Weed". It is the human who attempt to modify nature to grow high value crops for food, fodder, fibre, oil, medicinal, paper pulp and other purposes. Therefore, you decide what plants are weeds and when, whereas by which way they will be managed.

Thus, **Weeds are plants where it is not desired for any period of time**- Desire is purely a human trait and only for this reason any plant in nature is a weed only in terms of a human, attitude.

People say that a plant in a certain place is not desirable and therefore assign it the derogatory term "Weed". We make it the lowest of plant kingdom not because it is naturally harmful but because it is harmful to us.

Presently in India the total losses caused by **Pests (any harmful organism like weed, insect, disease, nematode, rodents, store grain pests etc.) is 33 %** amongst which **Weed Pest causes 10.9 % (33 % of total pest losses);** Insect pest 8.6 % (26 % of total pest losses); Disease pest 6.6 % (20 % of total pest losses) and Other pests including nematodes, store grain pests, rodents etc. cause 6.9 % (21 % of total pest losses) of total crop production losses. In our country in different crops the yield losses due to weed pest varies 12-78 %. **The major pest weed alone causes 11.5 % global food production losses (>287 mt)**. Therefore, minimizing the pest losses it would be possible to increase our production (National Food grain production - 260 mt, Oilseeds -30 mt and Horticultur 260 mt – Total 550 mt) and particularly even recovering only 10% losses due to weed pest the food grain production in India could be increased to the tune of 605 mt (National Food grain production - 286 mt, Oilseeds -33 mt and Horticulture 286 mt – Total 605 mt).



DWR (2015) - Vision 2050 DWR, ICAR

PEST (33 % National Production Loss)

- Weed pest - 33% of total pests
- Insect pests - 26% of total pests
- Disease/Pathogens -20% of total pests
- Other pests - Nematodes, Rodents, Store grain pests etc. - 21% of total pests

Production loss in India

Weed pest- 10.9% **(World- 11.5%)**
Insect pest– 8.6%
Disease pest- 6.6%
Other pests- 6.9%

Weed Science

Weed ecology	**Weed Management**			
Weed biology	**Weed Utilization**	**Pre-infested Weed Prevention**	**Post-infested Weed Control**	**Post-infested Weed Eradication**
Weed seed bank	**Compost making**	**Quarantine law (Should be more strict in airport & seaport)**	**Physical (Manual & Mechanical)**	**For Pernicious & invasive weeds (generally, not possible to complete eradication)**
Invasive weed	**Biopesticide**	**Seed law (may be revised)**	**Ecological (Mixed cropping, Mulching, Soil solarization etc.)**	
Dynamics of weed flora (Weed	**Medicine & vegetables**		**Biological (Bio agent, Bioherbicides)**	
	Other uses		**Chemical**	

biodiversity)			**(Inorganic, Organic Ecosafe)**	

Weed Science comprises of **Weed Ecology** and **Weed Management**. ***Weed ecology*** is the basic concept to know about the details of weed pest plants while ***Weed Management*** is defined as "***To create a favorable environment for proper growth & development of desired crop by minimizing undesired weed competition to our desired crop for all resources in any ecosystem".*** **Weed control** is a part of weed management where the focus is ***"to minimize the weed population below the ETL*** (economic threshold limit - 20%) ***in the critical crop weed competition period (CCWCP)***". **The integrated weed management** is often practiced where more than one control methods, particularly the combination of any direct and indirect methods of weed control, is combined to get a sustainable protection to our cultivated crops.

Weed Ecology:

Classification of Weeds:

(1) Ontogeny or Life period (Life cyclic): Based on duration of a weed plant life, the weeds are classified into three types as follows:

(a) **Annual:** Weeds, which live only for a season or year, are called '**annual**s'. The annual weed plants are again classified into two types. Short lived annuals called '***Ephemerals***'. They complete seed to seed cycle within 2-4 weeks e.g. *Phyllanthus niruri*

(i) **Monsoon or Rainy annual** - These weeds are generally found during rainy season and depending on monsoon these plants grow in different agro-ecological regions. e.g. *Brachiaria (Panicum) mutica, Cyperus iria, Cyperus difformis, Ammania baccifera, Boerhaavia diffusa* etc.

(ii) **Winter** or **Rabi annual** - Generally found in winter season e.g. *Chenopodium album, Digera arvensis, Physalis minima, Nicotiana plumbaginifolia, Gnaphalium luteoalbum, Sonchus arvensis* etc.

(b) Biennial: Weeds which generally complete their vegetative growth in the first season or year and produce flower & seed in the succeeding season or year are known as '**biennials'** e.g. *Alternanthera echinata, Daucus carota, Cirsium vulgare* etc.

(c) Perennial: These plants are normally lived for more than two years. They are very well adopted to withstand adverse condition**, e.g.** *Cyperus rotundus, Convolvulus arvensis, Eleusine indica, Imperata cylindrica. Cynodon dactylon.* They mostly propagate not only by seed but by underground stem, tuber, sucker etc., and based on propagation, they are classified into different groups.

(i) **Simple perennial**: Propagate by seed, e.g. *Sonchus arvensis.*

(ii) **Complex perennial:** Propagate and reproduce by modified plant parts:

(a) Bulbous perennial: Reproduce by bulb and seed e.g *Allium vineale*

(b) Cormy perennial: Reproduce by corm and seed e.g. *Colocasia esculenta.*

(c) Creeping perennial: Reproduce by rhizome e.g. *Cynodon dactylon* by stolon, *Convolvulus arvensis* by bud, *Cyperus rotundus* by tubers, *Sagittaria trifolia* by corm.

(iii) **Shallow or deep-rooted perennial.** Difficult perennial weeds are called '**Pernicious weed'** e.g. World worst weeds *Cynodon dactylon, Cyperus rotundus, Imperata cylindrica etc.*

(2) According to Habitat (Place of occurrence):

A. Crop land weed: Majority of the weeds observe in this category. These are also known as crop associated weeds. Some **Satellite** weeds and **Phenotypic Mimicry** weeds are also observed e.g. *Phalaris minor, Oryza rufipogon, Solanum nigrum, Nasturtium indicum* etc.

B. Non-crop land, Waste land (Industrial) weed: In the waste land, fallow land, roadside and bunds of fields these weeds are observed e.g. *Heliotropium indicum, Calotropis procera*

C. Pasture, Orchard, Forest and Plantation weed: In the forests, orchards, pasture lands and in plantation crops many weeds are observed which detoriating these areas and quality of the produce e.g. *Setaria glauca, Jatropha gossypifolia*. Some **creeping weeds** are also in this category e.g. *Vitis trilobus* (amar lata), *Mikania micrantha* (mile- a- minute or tara lata),

(3) According to Cotyledon (Seed):

A. Monocot Weed: Most of the narrow leaved having monocotyledonous and with leaves having perpendicular venation character are called '**monocot weeds'**. e.g. Grasses (family *Poaceae*) and Sedges (family- *Cyperaceae*). Only exception is Cattail *Typha latifolia* belonging to the family T*yphaceae*.

B. Dicot Weed: Mostly dicotyledonous in nature having leaves with reticular venation e.g. *Portuleca oleracea, Anagallis arvensis, Ludwigia octovalvis, Eclipta alba.* Only exception is *Commeilnabenghalensis* having broadleaf with perpendicular venation.

Shrubs and under shrubs are collectively called **Brush weed** e.g. *Lantana camara, Prosopis juliflora.*

(4) According to Origin:

A. Native or Indigenous: The weeds which are within the geographical limit of their origin are called '**Native or Indigenous weeds'** e.g. *Solanum torvum, Leucas aspera.*

B. Exotic or Invasive: Weeds are originated from other parts of the region, country and world and invaded in new places, called Invasive or **Alien Weeds or Anthrophytes.** Theinvasive alienweeds which are introduced from outside India are *Eichhornia crassipes* (Tropical America), *Lantana camera* (Central America), *Alternanthera philoxeroides* (South America), *Parthenium hysterophorus* (Mexico) etc. Quarantine people should need to identify Alien weeds to prevent their movement from one country to another.

5. According to Habitat:

(i) Crop field weed: Undesirable plants found in desired crop, fodder, orchard, home garden, plantations etc. e.g. *Leersia hexandra, Cyperus compressus, Scoparia dulcis, Leucas linifolia* etc.

(ii) Parasiticweed: Undesirable plants take shelter and food from other plants e.g. **Stem parasite** (Swarnalata *Cuscuta hyalina* and Loranthus *Dendrophthoe falcata)* or **Root parasite** (*Orobanche ceruna, Striga asiatica)*

(iii) Aquatic weed: Undesirable plants grow and complete at least a part of the life cycle in water e.g. Algae (BGA, Azolla, *Chlorella*) and Hydrophytes (Floating, Submerged, Emerged and Marginal types e.g. *Lemna minor, Scirpus grossus, Typha latifolia, Jussiaea repens, Trapa bispinosa* etc.).

Diversity of weed flora in anaerobic ecosystem

Monocots		**Dicots (Broadleaf)**	
Grass	**Sedge**	*Alternanthera philoxeroides*	*Lemna minor*
Brachiaria platyphylla	*Cyperus difformis*	*Ammania baccifera*	*Lindernia ciliate/ dubia*
Echinochloa colona/ crusgalli / formosensis	*Cyperus iria*	*Cardenthera triflora*	*Lindernia procumbans*
Ischaemum rugosum	*Cyperus flavidus*	*Cyanotis axillaris*	*Ludwigia octovalvis*
Leersia hexendra	*Cyperus pumilus / nitens*	*Drymaria cordata*	*Mersilea quadrifolia*
Leptochloa chinensis	*Cyperus polystachyos*	*Eclipta alba*	*Monochoria vaginalis*
Panicum repens	*Fimbristylis littoralis*	*Eriocaulon sieboldtianum*	*Oldenlandia corymbosa*
Panicum maximum	*Fimbristylis dichotoma*	*Hypericum japonicum*	*Oldenlandia diffusa*
Paspalum conjugatum	*Scirpus juncoides*	*Hydrilla verticillata*	*Polygonum glabrum*
Paspalum	*Scripus maritimus*	*Ipomoea aquatica*	*Sphenoclea zeylanica*
	Scirpus mucronatus	*Junchus papilliosus*	*Stellaria media*

distichum			
Algal Weeds	*Azolla pinnata, Anabena circinalis* (BGA) , *Anabena spiriodes klebahn* (BGA)		

Diversity of weed flora in aerobic ecosystem

Monocots	**Dicots (Broadleaf)**	
Grass	*Alternanthera sessilis*	*Melilotus alba / indica*
Avena fatua	*Amaranthus viridis*	*Melochia corchorifolia*
Brachiaria mutica	*Anagallis arvensis*	*Nicotiana plumbiginifolia*
Dactyloctaneum aegyptium	*Argemone mexicana*	*Oxalis corymbosa / corniculata*
Digitaria sanguinalis	*Blumea lacera*	*Parthenium hysterophorus*
Eleusine indica	*Borreria hispida / alata*	*Phyllanthus niruri*
Echinochloa colona	*Chenopodium album*	*Physalis minima*
Leersia hexendra	*Chicorium intybus*	*Portulaca oleracea*
Phalaris minor	*Cleome viscosa*	*Scoparia dulcis*
Sedge	*Commelina nudiflora / benghalensis*	*Solanum nigram*
Cyperus rotundus	*Corchorus acutangulas*	*Sonchus oleraceus*
		Spilanthes paniculata

Cyperus arometicus *Cyperus compressus* *Cyperus halpan* *Cyperus digitatus*	*Digera arvensis* *Desmodium triflorum* *Euphorbia hirta / tenella* *Fumaria purviflora* *Gnaphalium indicum/ luteoalbum*	*Spermacoce ocymoides* *Tithonia rotundifolia* *Trianthema portulacastrum / monogyne* *Vicia sativa / indica*

Diversity of weed flora in roadside /fallow land / wasteland ecosystem

Monocots	Dicots (Broadleaf)

Grass *Axonopus compressus* *Cynodon dactylon* *Dactyloctaneum aegyptium* *Digitaria sanguinalis* *Eleusine indica* *Paspalum conjugatum / distichum / dilatatum* *Phalaris minor* *Sporobolus diander*	**Sedge** *Cyperus rotundus* *Cyperus arometicus* *Cyperus compressus* *Cyperus esculentus* *Cyperus flavidus* *Cyperus polystachyos* *Cyperus pumilus*	*Abutilon indicum* *Acalypha indica* *Aeschynomene indica* *Ageratum conyzoides* *Alternanthera tenella / sessilis* *Amaranthus viridis* *Argemone mexicana* *Blumea lacera* *Borreria alata* *Boerhavia erecta/ diffusa* *Calotropis gigantea / procera* *Cannabis sativa* *Cleome viscosa / rutidosperma* *Commelina subulata* *Cyanotis axillaris* *Desmodium triflorum* *Eupatorium odoratum* *Euphorbia*	*Leucas linifolia / aspera* *Oxalis corymbosa / corniculata* *Parthenium hysterophorus* *Piperomia pellucida* *Phyllanthus niruri* *Physalis minima* *Pteridium aquilinum* *Rungia repens* *Scoparia dulcis* *Solanum torvum / incanum / sisybrifolia/ myriacanthum* *Spilanthes paniculata* *Spermacoce ocymoides* *Tephrosia purpuria* *Torenia bicolor* *Tridax procumbans*
Aquatic	**Climbers**		
Eichhornia crassipes *Ipomoea aquatica* *Lemna minor* *Monochoria haestifolia / vaginalis* *Polygonum hydropiper / glabrum* *Pistia stratiotes* **Green algae** *Euglena spp.* *Chaetomorpha indica / allichii* *Chara coralline* *Pithophora spp.* *Ulothrix zonata*	*Argyreia speciosa* *Coccinea grandis* *Convolvulus tridentata* *Cuscuta chinensis/reflexa* *Cucumis maderaspatana* *Dioscorea deltoida / pentaphylla* *Ipomoea linifolia / pes-tigridis* *Mikania micrantha* *Phaseolus adenanthus* *Stephania hernandifilia* *Trichosanthes cucumerina*		

Fresh water algae *Hydrodictyon indicum*	*Vitis trifolia*	*hirta/tenella Hydrocrotyle rotundifolia*	

Important Associate weed (Phenotypic Mimicry) of cultivated crops

Crop plant	**Weed flora**
Paddy (*Oryza sativa*)	*Oryza rufipogon; Echinochloa colona/ crusgalli / formosensis*
Wheat (*Triticum aestivum*)	*Phalaris minor; Avena fatua*
Jute (*Corchorus spp.)*	*Corchorus acutangulas; Melochia corchorifolia*
Sugarcane (*Saccharum officinarum*)	*Saccharum spontaneum*
Potato (*Solanum tuberosum*)	*Digera arvensis, Solanum nigrum*
Ground nut (*Arachis hypogea*)	*Cassia tora*
Rapeseed-mustard (*Brassica spp.)*	*Nasturtium indicum, Brassica sinensis, Cleome viscosa*
Khesari (*Lathyrus sativus*)	*Lathyrus aphaca*
Black & Green gram and Cowpea (*Vigna spp.)*	*Physalis minima* (Young stage)

Merits and demerits of various weed management practices

The weed management practices are classified into four major groups viz. Biological, Physical, Ecological and Chemical weed management.

- **Physical control:** (Manual and Mechanical control):

Manual control (Hand weeding, Hand pulling, Hand trampling etc.) method is now lesser accepting to farmers because of gradually increasing labour wages (3 times in last five years) and unavailability of skilled labour in Critical Crop Weed Competition Period (CCWCP - within 30 DAS/DAP/DAT), traditional. *Mechanical control* (using implements like tillage implements/ wheel hoe / paddy weeder etc.) because of low cost, time saving and creation of more oxygen supply to plant ecosystem is gradually becoming popularized. But it has the limitation of initial investment for implements by the farmers. The physical weed control approaches has advantage of ecosafe management as no harmful effects on environment but disadvantages are as follows (a) the desired crop roots are damaged very often and as a result the growth of crops may be affected; (b) the inter row weeds is hand weeded but intra-row weeds are escaped; c) in acute crop-weed competition stages availability of skilled labour is a problem in many areas and (d) the cost is six times more than biological & three times more than chemical management.

- **Ecological control** (Stale seed bed, Intercropping, Mulching, Soil Solarization etc.):

It continues since inception of agriculture. Jhum cultivation is an example. Stale seed bed technique and Soil solarization limit only in summer months and limitations of additional investment. Cover legumes like green gram (*Vigna radiata*), black gram (*Vigna mungo*), cowpea (*Vigna sinensis*) either as sole or intercrop in summer and bengal gram (*Cicer arietinum*), horse gram (*Dolichos biflorus*), lentil (*Lens esculenta*), field pea (*Pisum sativum*), butterfly pea (*Clitoria ternatea*), chikling pea or khesari (*Lathyrus sativus*); Senji methi (*Melilotus parviflora*) besides *Azolla* &*Lemna* mat in lowland during kharif season, may be advocated for better soil health management and reducing weed seed bank. Ecological management has the advantage of improving soil health, reducing weed seed bank and additional income but the limitations are farmers' willingness because of additional expenditure and diversified management practices.

- **Biological control:** The Plant world comprises a rich storehouse of renewable bioactive organic chemicals which could be more tapped as pesticides. The total number may exceed 4 million. Of these, only 10,000 are secondary metabolites. Allelopathy, the term coined by Prof. Hans Molisch, a German Plant Physiologist in 1937, is a new field of science. Allelochemicals are inhibiting primarily in two ways

- **Autotoxy:** Allelochemicals of same plant inhibits the seedling of same plant e.g *Parthenium hysterophorus* (allelochemicals - Sesquiterpene lactones + Phenol)

- **Teletoxy:** Allelochemicals of some plants inhibit the seedling of other plants e.g *Bambusa vulgaris* (allelochemicals Rutin, Tricin and Luteoalin) inhibits grassy weeds. Many natural plants with their allelopathic effects inhibit the weed pests through phytochemical based organic natural compounds (secondary metabolites).

Scintific Name of Insects	**Common name**	**Name of weed pest**	**Country**
Agasicles hygrophila	Flea beetle	*Alternanthera philoxeroides*	India
Bactra verutana	Shoot boring moth	*Cyperus rotundus*	India / Pakistan
Crocidosema lantana	Moth	*Lantana camera*	Mexico
Neochetina eichhorniae/ Neochetina bruchii	Beetle	*Eichhornia crassipes*	USA
Zygogramma bicolorata	Beetle	*Parthenium hysterophorus*	Mexico

Important Bioherbicides including Botanicals

Name of the bioherbicides	Name of plant/ pathogen	Name of the weed pest to control	Country originate
Botanicals	*Parthenium hysterophorus*	Most grassy weeds	India
	(young plants)	Most grassy weeds	India
	Calotropis procera (twigs)	Most grassy weeds	India
	Bambusa vulgaris (root & leaf)	Most grassy weeds	India
	Tectona grandis (leaf)	*Echinochloa spp*	Japan
	Some wild rice cultivars (root & leaf)		
Bialaphos	***Streptomyces hygroscopicus***	**General vegetation**	**USA**

Collego	*Colletotrichum gloiosporioides*	*Aeschynomene virginica*	USA
Casst	*Alternaria cassiae*	*Cassia occidentalis*	USA
Devine	*Phytophthora palmivora*	*Morrenia adorata*	USA
Dr. Biosedge	*Puccinia canaliculata*	*Cyperus esculentus*	Georgia

❖ **Chemical control:**

It saves farmers from undue and repeated inter cultivations that often causes loss of top soil and has helped farmers in satisfactory weed control particularly where physical and ecological approaches often fail.

Classification of Herbicides

1) **Based on Chemical structure:** Herbicides are grouped into two groups as follows:

(i) Organic herbicides: Organic herbicides contain carbon atoms in their molecules. They may be oils or non-oils. Majority of the present-day herbicides are organic compounds which are non-oils organic herbicides & are more effective and selective. They are divided in 42 groups. e.g. Acetamide, Aliphatic, Aryloxy Phenoxy alkanoic acids, Bipyrilidium, Diphenyl ether, Dinitroaniline, Imidazolinone, Isoxazolidinone, Oxadiazole, Phenol, Sulfonyl Urea, Triazine, Triazinone, Triazolinone, Urea, Unclassified herbicidesetc.

ii) Inorganic herbicides: Inorganic herbicides do not contain carbon atom in their molecules. They were the first chemicals used for control of weed before the introduction of the organic compounds during 1932. e.g. Sulphates of sodium, iron, copper & ammonium; Sodium arsenate, Sodium nitrates, Sodium borate, Sodium chloride, Sulphuric acid etc. These were used between 1896 and 1930s. Presently, they are a very little use of these inorganic chemicals excepting the **Copper sulphate (Blue vitrol) @ 25 kg ha^{-1}which is still using by farmers in lowland particularly to control algal weeds.**

(2) Based on Time of application: Herbicides may classify into four groups as follows:

(i) **Pre-Planting (PP)**: The herbicides that are applied in a fallow land either at least three weeks before the planting of any crops or 2-3 days in finally prepared leveled soil before planting of a crop are called pre-planting herbicides. e.g. Fluchloralin, Trifluralin (2-3 days before sowing); Glyphosate (3 Weeks before sowing) etc.

(ii) **Pre-emergence (PE)**: The herbicides that are applied 1 – 2 days after planting of crops or immediately after planting of a crop but before emergence of weed plants are called Pre-emergence herbicides. e.g. Pretilachlor, Oxyfluorfen, Metribuzin, Linuron etc.

(iii) **Early post-emergence (EPOE):** The herbicides that are applied 7 – 15 days after emergence of crops or in 1-2 leaf stages of weed plants are called Early Post emergence herbicides. e.g. Bispyribac Sodium, Butachlor, Orthosulfamuron, Atrazine etc.

(iv) **Post-emergence (POE)**: The herbicides that are applied after the full emergence of crop and 3-5 leaf stages of weed are called post emergence herbicides. These herbicides are actually applied between 20 – 40 days after planting of crop. e.g. Quizalofop ethyl, Pyrazosulfuron ethyl, Almix, Imazethapyr, Isoproturon, Sulfosulfuron, Clodinofop Propargyl etc.

3) Based on Selectivity: Herbicides may be classified into two groups as follows:

(i) **Selective herbicides**: The herbicides that kill only the targeted weed plants while crops are not affected are called selective herbicides. Selectivity of herbicides is mainly due to deactivation of or chemical transformation of the toxic molecules by activities of some plant enzymes. e.g. Trifluralin, Pendimethalin (PP), Pretilachlor, Oxyfluorfen (PE), Butachlor, Bispyribac sodium (EPOE), Isoproturon, Sulfosulfuron, Quizalofop ethyl (POE) etc.

(ii) **Non-Selective herbicides:** The herbicides that kill all vegetation when they come in contact with irrespective of crops and weeds are called non-selective herbicides. They are generally used as PP for crops & POE for non-crop, fallow land & waste land. e.g. Glyphosate, Glufosinate, Diquat, Paraquat, Diuron, Acrolein etc.

(4) Based on Method of application: Herbicide may be classified with two groups as follows

(i) **Soil applied herbicides**: The herbicides that are applied on soil and kill germinating or sprouting weed seeds, corms, bulbs, rhizome, etc and thereby eliminate the chance of early weed competition in the field are called soil applied herbicides e.g. (a) PP & PE herbicides like

Pretilachlor, Alachlor, Atrazine, Fluchloralin, Metribuzin, Pendimethalin, Trifluralin etc. (b) EPOE or POE herbicides: Butachlor, Almix, Sulfosulfuron, Quizalofop ethyl etc.

(ii) **Foliage applied herbicides**: The herbicides that are applied on foliage of plant are called foliage applied herbicides. Foliage applied herbicides have systemic, contact or both actions. e.g. Glyphosate, Paraquat, Ethoxysulfuron, Triasulfuron, 2,4-D etc.

(5) Based on Mode of action: Herbicides are classified into two groups as follows

(i) **Contact or Non-Systemic herbicides**: The herbicides that kill the weed by means of contact with germinating seeds and growing plants are called contact herbicides. However, in strict sense, contact herbicides are not purely contact in nature. e.g. Diquat, Paraquat, Propanil, Oxyfluorfen etc.

(ii) **Systemic or Translocated herbicides**: The herbicides that move from the site of application (i.e. soil, plant foliage etc.) to the site of action are called systemic herbicides. Most of the present-day herbicides are systemic in nature and thus needs to apply at recommended rates. e.g. Pretilachlor, Atrazine, Fluchoralin, Isoproturon, Glyphosate, Metribuzin etc.

(6) Based on Polarity: Polarity describes the electrical phenomenon of a molecule or ion. The Herbicides are classified into two groups as follows

(i) **Non-Polar (Lipophilic) herbicides:** Non polar compounds do not possess strongly electrically positive & negative areas and thus have greater affinity on oils and are soluble in oils & other non-polar solvents. Because having relatively uncharged molecules and normally exhibit low water solubility & high oil solubility these could be readily wet the waxy cuticle resulting better penetration. The active ingredient can be slightly altered by certain chemical process during commercial manufacturing (Formulation of Herbicides). e.g. Ester form of 2, 4-D

(ii) **Polar (Hydrophilic) herbicides:** Polar compounds have both strongly electrically positive & negative ions and thus have greater affinity on water and are soluble in water & other polar solvents. They generally form large spherical droplets that do not readily wet the waxy cuticle of the leaf surface and thus poor activity. Surfactants are generally used to enhance these herbicides activity e.g. Herbicides derived from phenols, alcohols or organic acids (Sodium or Dimethyl amine salts of 2,4-D).

(7) Based on residual action in soil: Residual & Non-residual herbicides **and**

(8) Based on spectrum of weed control: Broad spectrum and Narrow spectrum herbicides.

Surfactants, Safener and Formulation:

Surfactants: In the advance weed management for controlling weed pest the ecosafe criteria (the air, soil, water & consumable food products) is the topmost priority and for this the doses of the synthetic chemicals is gradually becoming decrease, thus safer herbicides are using with lower doses e.g. Dalapon was used @ 15 kg ha^{-1} (1970) and now (2010) Trifloxysulfuron is used @ 2 g ha^{-1} or Almix 4 g ha^{-1} etc. But while herbicide doses are reduced there may be a chance of reducing the activity of chemicals. To increase the activity of botanicals & synthetic chemicals for better controlling the weed plants various surfactants are mostly used along with changing formulation considering the polarity of herbicides (Ionic position – electrically positive or negative)**. Dose@ 1 lit. ha^{-1}.** e. g. Anionic – Vatsol-Ot Cationic- Aliquat-4 Non-ionic- S-145, Tween 20 etc.

In case of normal herbicide doses to increase activity, stickers are used e.g. APSA, Soap water, Urea, MOP, Main spread agriculture sticker.

Safener: When the reduced dose of herbicide is applied in a lower dense vegetation complex there may be good activity on weed plants & no phytotoxicity to crop plants and in addition it shows lesser toxic effect to soil microflora& fauna. But the same lower herbicide dose when apply in higher dense vegetation it is unable to control the weed flora to a desirable limit. Thus, it needs to increase the dose, but this may cause crop phytotoxicity as well as weed phytotoxicity. To reduce the phytotoxicity to crop plants, safener is used with higher dose of herbicides. **Dose: 1.2 Safener: : 1.4 Herbicide** e.g. Fenchlorin, Furilazole, Flurazole etc.

Pretilachlor 50 EC- Rifit or Erase; Pretilachlor + Safener 30.7 EC -Sofit or Erase N

Formulation: Though in chemical herbicides the new formulations have already used but its necessity is more in botanical herbicides. The present formulations are generally two types –

(I)Sprayable or Liquid formulations: EC (Emulsiable Concentrate), SP (Soluble Powder), WP (Wettable Powder), WG (Wettable Granule), SL (Soluble Liquid), SC (Suspension Concentrate), CS (Capsule Suspension), AS (Aqueous Suspension), DF (Dry Flowable), WSC (Water Soluble Concentrate), WDG (Water Dispersible Granule) etc.]

(II) Dry formulations: Granule (G), Pellets (P), Tablets (TB) and Dusts (D) etc.

Annual Planning of Weed Pest Management (APWPM)

Basic concepts of APWPM:

I. To reduce the weed bank in soil before planting of any desired crop so that the initial weed competition to crop could be minimized.

II. To reduce weed competition to crop during critical crop-weed competition period (CCWCP) that is within one month after planting of a crop so that crops may get an environment favourable for its growth and development with a minimum competition of resources from the weed pests.

- Three important selective organic herbicides may be applied as Pre-Planting of crop and Pre-emergence of weed flora (during land preparation at 1-2 DBP). These are highly volatile in nature and require incorporation to moist soil.

Crop	**Name of organic herbicides with active ingredient (a.i) and fomulation**	**Commercial name**	**Dose (g/ha)**
Vegetables, Pulse and Oilseeds	Fluchloralin 45 EC	Basalin, Nagflur	750
	Pendimethalin 30 EC (Also in Jute & Cotton)	Stomp, Tatapanida,Pendigold, Pendigan, Pendiherb, Speed, Dhanutop, Pendisul, Depend	750
	Trifluralin 48 EC	Treflan, Tiptop,Clean, Flota, Trifogan	750

❖ **Non-SelectiveOrganic Herbicides:** Apply only for weed management in **all orchards, plantation gardens and Non-crop land /Wasteland** like Banana, Guava, Mango etc. Orchards; Eucalyptus, Sal, Segun etc.; Railway, Roadside, NTPC, BSF etc. and any fallow cum wasteland. **Generally, most of the weed flora are appeared in season basis and in fruit & orchards earthing up (mechanical weeding) is common during rainy season.**

Organic herbicides	Formulation	Trade name	Dose g ha^{-1}
Glyphosate	41 SL, 62 WP 66 EC,	Round Up, Krup, Glycel, Weed off, Weed All, Glyfos, Randip, Fighter, Sweep, Globas, Nagglypo, Glytaf, Break, Gladiator, Vanish	3500
	71 SG	Glyphogan, Glyfos Dakar, Excel Mera 71	
Paraquat dichloride	24 EC, 24 SL	Gramoxone,Sweep,Weedol, Ozone,Filfuat,Kapiq,Paralac,Uniquat,Rhino, Chemspray, Nagat, Parashute,Peranax	2000
Glufosinate Ammonium	50 SC	Basta	1500
Diuron	**80 WP**	**Klass, Nagiron, Diurex**	**2000-5000**
# (Most suitable for Railway, Airport, BASF, NTPC and similar established non crop land)			

<u>List of important selective organic herbicides with dose</u>

- **Time of application: Pre-emergence of weed flora (0-1 DAS/DAT/DAP)**
- **Major criteria: Soil should be adequately moist**

- **Organic botanical herbicides: Apply in any crop**
- ✓ Allelopathic effect through natural chemical compounds
- ✓ Raw, Aqueous or Methanol extracts dose - @ 100 ml/litre of water

List of organic botanical herbicides

Name of Botanicals	Formulation type	Active ingredient
Bambusa vulgaris (root & leaf)	Aqueous extracts	Rutin, Tricin, Luteoalin
Calotropis procera (twigs)	Raw extracts	Calotropin / Mudarine
Parthenium hysterophorus (young plants)	Raw or aqueous extracts	Sesquiterpene lactones, Phenols
Tectona grandis (leaf)	Aqueous or Methanol extracts	Salicyclic acid, Phenols

❖ **Organic Synthetic chemical herbicides:**

✓ Inhibition effect through chemical compounds on germination; photosynthesis, respiration etc. by enzymatic functions during protein, amino acid, fat or lipid, aroma, carbohydrate, pigment, growth regulators etc. synthesis

✓ Application and dose depending on the selective herbicides against selective crops

Crop	Name of organic herbicides with active ingredient (a.i) and fomulation	Commercial name	Dose (g ha^{-1})
Paddy	Pretilachlor 30.7 EC	Sofit, Erase N, Petigan-S	500
	Pretilachlor 50 EC	Rifit, Erase, Craze, Offset, Sureshot, Preet, Prettyherb, Profit, Prince, Nagpreticlor, Pretigan,Tatapreet,	
	Butachlor 50 EC	Machete, Finish,Dhanuchlor, Rasayanchlor, Hunter BilchlorNagclor,Dhanuchzor, Teer	1250
	Butachlor 5 G	Machete, Nagclor-G, Pedichlor	

	Butachlor 50 EW	Donmix, Kikout	
	Pyrazosulfuron Ethyl 10 WP	Saathi	30
	Bispyribac Sodium 10 SC	Nominee Gold	25
Sugarcane	Atrazine 50 WP+ Surfactant	Atrafil, Avert, Surya, Nagzine, Atrataf, Solaro,Atramex	2000
Pulse and Oilseeds	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Pendimethalin 30 EC	Stomp, Tatapanida,Pendigold, Pendigan, Pendiherb, Speed, Dhanutop, Pendisul	750
Jute and Cotton	Alachlor 50 EC	Lasso	100
Vegetables	Metribuzin 70 WP	Sencor, Krizin, Tata Metri, Barrier, Century, Chase, Nagmezin, Weedeclean, Metrigan	600
	Pendimethalin 30 EC	Stomp, Tatapanida,Pendigold, , Pendiherb, Speed, Dhanutop, Pendisul, Depend Pendigan	750
Potato	Metribuzin 70 WP	Sencor, Krizin, Tata Metri, Barrier, Century, Chase, Nagmezin, Weedeclean, Metrigan	600

	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Paraquat dichloride 24 SL	Gramoxone, Sweep,Weedol, Ozone, Filfuat, Kapiq, Paralac,Uniquat,Rhino, Chemspray, Nagat, Parashute, Peranax	2500
Onion	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Oryzalin 40 SC	Surflan	2000

D) During crop growing (After planting of desired crops):

(i) Use of POE low toxic selective organic chemical herbicide in appropriate time within CCWCP and avoiding the important critical physiological stages (nodule, bulb, tuber etc. formation of the desired crops) e.g. use of ready mixture of selective Almix 20 WP @ 4 g ha^{-1} at 30 DAT in paddy at 30 DAT.

(ii) One or two mechanical weeding (earthing up for groundnut, potato, brinjal, tomato, cabbage, cauliflower or other similar crops and fruit orchards etc.; paddy cono / rotary weeder for direct seeded puddled and transplanted paddy; wheel hoe for rapeseed – mustard, sesame etc.,) depending on the intensity of weed flora and time of POE organic herbicide application. The POE mechanical weeding helps the growth of desired crop plants by managing weed flora and improving crop health by creating more aeration in the crop field.

POE organic Chemical herbicides with doses

Crop	**Name of organic herbicides with active ingredient (a.i) and fomulation**	**Commercial name**	**Dose** (g ha^{-1})
Paddy	Azimsulfuron 50 DF	Gulliver	40
	Imazosulfuron10 SC	League	30
	Orthosulfamuron 50 WG	IR 5878, Strada, Kelion, Percutio	100
	Ethoxysulfuron 60 WG	Sunrice	15
Wheat and Millets	Isoproturon 75 WP	Arelon, Tolkan, Miracle, Bilron, Ngron,Nocilon, Ronak	750
	ClodinafopPropargyl 15 WP	Topic, Clodinagan, Rakshak Plus	80
	Sulfosulfuron 75 WG	Leader,Safari,Sutop,Nagsuron	25
Pulse and Oilseeds	Imazethapyr 10 SL	Persuit,Dinamaz,Passport, PI Glypho,Weedlock, Glyphogan SG	100

❖ **Selective and Systemic Grass Killer Organic Herbicides:** Apply only for weed management in **all Broadleaf field crops** like Jute, Cotton, all Oilseeds and Pulses, Vegetables, Fruits, Spices, and Plantation etc. (Except cereal crops like Paddy, Wheat, Sugarcane etc.) as Post emergence (POE).

Technical name	**Commercial name**	Dose (g ha^{-1})
Quizalofop Ethyl 5 EC	Targa Super	30
Fenoxaprop-P – Ethyl 9 EC	Whip Super	50
Propaquizafop 10 EC	Azil	100
Chlorimuron ethyl 25 WP	Kloban	10
Halosulfuron methyl 75 WDG/DF (*Cyperus spp*.)	Sempra	100

- **Selective and Systemic Broadleaf Killer Organic Herbicides:** Apply only for weed management in **all Cereal field crops** like Wheat, Sugarcane etc. (Except BL crops etc.)

Technical name	**Commercial name**	Dose (g ha^{-1})
Metsulfuron Methyl 20 WP	Algrip, Hook, Volt, Dot Mono, Niconin, Niconof, Pantera	**4**
Clodinafoppropargyl 15 WP	Topic, Clodinagan, Rakshak Plus	80
2,4- D Sodium salt 80 WP	Weedmar, Fernaxone, 24D Agan, Nagsal 2, Safaya, Herbocline	500
2,4-D Amine salt 58 SL	Champion, nagmine, 24D Main, Weedmar, Super, Kayam –M	750
2,4-D Ethyl ester 38 EC/20 WP	Slash, Weedmar, Nagester / Nagesterr P	750

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E) After crop harvesting: Taking care to avoid mixing of other weed seeds with crop seeds during threshing of harvested crop & storing of crop seeds. For storing of crop seeds it should be sun dried properly to make the moisture content of crop seeds around 10-12 %. To avoid mixing of weed seeds it is better to remove the young weed inflorescence by cutting before harvesting of crops. E,g. Removal of *Oryza rufipogon* or *Echinochloa spp.* during flowering of paddy crop.

Application of herbicide:

Herbicides should be applied in sufficient **moist soil and not in submerged or dry soil. If needed irrigation** may be given after three days of herbicide application. The spraying should be done **on weed flora but not on crop plant using proper nozzle**. If needed use **'Hood'** with nozzle for spraying herbicide within inter or intra rows space keeping safe to crop. Do not apply any fertilizer or other pesticides within two weeks of herbicide application. Generally, herbicides are applied towards the wind and in sunny day. Use musk & gloves for safety.

❖ **Method of Application**

- Sand mix: This is best for granular herbicide formulation (Coarse sand: herbicide: : 60:40)
- Soil or foliar with water: In general spray volume is 1 litre water for 20 m^{-2} area (500 litres water ha^{-1}) . During spraying water volume may increase (if moisture is less in soil) or decrease (if moisture is more in soil) but amount of herbicide should be fixed.

❖ For considering human health (herbicide residue in crop consumable parts), to retain environment (soil, air & water) safe and to avoid phytotoxicity to desirable plant crop it is always advisable to farmers to use environment safe, easily degradable & low persistence proper selective herbicide with proper dose (use injection syringe if needed) and in proper time (PE/EPOE/POE etc.).

Herbicide Nozzle:

Nozzle types commonly used in low-pressure agricultural sprayers include flat-fan, flat jet deflector, hollow-cone, full-cone and others. Normally WFN flat jet deflector 040 or 060 nozzles are better for herbicide application. The herbicides are used against the weed pests which exist in soil not on the crop plants. These can also be used for nematocides application against Nematode pest that exists in crop plant roots.

Economics:

1. Generally the cost involves for manual hand weeding (traditional weed control method) - ₹ 1500-2000 ha^{-1} (8-10 laboures each @ ₹ 200 only)

2. For chemical weed control it is almost 35 % of manual hand weeding - ₹ 500-600 ha^{-1}

3. For biological control 35% of chemical control (70% lesser cost to hand weeding) - ₹ 150-200 ha^{-1}

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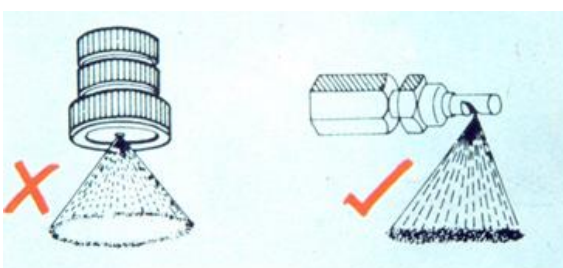
Sprayers and Nozzles






SOIL FERTILITY AND NUTRIENT MANAGEMENT

EXERCISE-1

Object:- Collection and preparation of soil samples for analysis

Introduction:- The importance of having a true representative sample can be very well realized from the fact that only a minute fraction of huge soil mass of the field is actually used for the analysis in the laboratory to find out the quantity of essential nutrients available to plants and other relevant physical and chemical characteristics. Therefore, while collecting soil samples the following aspects should be carefully considered.

The soil samples collected should be representative of the area. A field can betreated as single sampling unit if it is appreciably uniform in all respects. Variation in slope, colour, texture, crop growth and management practices should be taken in toaccount and separate set of composite soil samples should be collected from each unit of sucharea.

The main purpose for which samples collected are:

a. Soil fertility evaluation and fertilizer recommendation.
b. Reclamation of problem acidic soils.
c. Plant at ion of orchards.

The methods of sampling to be used and the amount of soil to be collected mainly depends on

1. The purpose for which sample is required
2. The nature of soil
3. The time available

Tools and materials required:-

1. Soil- auger, tube-auger, spade, pick-axe, khurpi.
2. Bucketortray.
3. Paper tages (Labels).
4. Information sheet
5. Cloth bags (alternative polythene bags).
6. Ball point pen and coping pencil

Sampling for ertility evaluation and fertilizer recommendation

For soil fertility point of view, normally the samples are taken from the plough layer i.e., 0-15 cm depth. This is applicable for the fields growing cereals and other crop. In case of deep-rooted crops and under dry farming conditions, it may be necessary to obtain samples from different depths (or layers) of soil. For collecting proper soil samples following steps should be kept in mind:

1. Divide the field into small areas so that each sample represents an area of approximately 1hectare.
2. A sample should be collected separately from areas which differ in soil colourorpastmanagement,e.g.,liming,manuring,fertilization,croppingpatternetc.
3. Scrap away the surface litter and insert soil auger or sampling root to a plough depth (about 15 cm). Take at least 15 samples randomly distributed over each area and place them in a clean bucket. A spade or khurpi can be very well use di-fauger is not available.
4. If a spade or khurpi is used for taking samples, then dig a V-shaped hole to a plough depth and cut 1.5 cm thick slice of soil from top to bottom of the exposed face of the V-shaped hole and collect soil in a clean bucket.
5. Thoroughly mix the soil samples collected from 15 or more spots in a bucket.
6. Collect only ½ to 1 kilogram soil and discard remaining soil samples by quartering.
7. Quartering is done by dividing the thoroughly mixed soil in to four equal parts and discarding two opposite quarters. Remix the remaining two quarters and again divide it into four parts and reject two of them, repeat this procedure until about one half kilogram of soil is left.

Sampling for soil reclamation

For reclamation purpose the samples should be drawn to the plough layer but thesaltcrusts(visibleorsuspected)onthesoilsurfaceshouldbesampledseparately.On

Saline and alkali soils, samples can be taken by either using a soil auger or digging a 90cm deep pit.

The samples should be collected as follow:

1. Make one side of the pit vertical (sun facing side) and put mark on it at 15,30, 60 and 90 cm depth from the surface.
2. Hold a suitable container at 15 cm mark and scrap a uniform slice of soil from

thesurfacedowntothismarkandcollectabout500gramofthesoilsample. Transfer the soil sample to a cloth bag and mark it as 0-15 cm. Similarly, collect500 gram soil sample from each layer, i.e. 15-30, 30-60 and 60-90 cm and put them separately in three cloth bags and then after dry in shade.

3. Take a separate sample of the surface crust also, if any.
4. Prepare two labels for each sample showing the depth from samples has been taken, name of farmer, name of village, exact location of the field, conditions and growth of crop if any.
5. Put up one label inside the bag and the other on the bags. Label should be written with a copying pencil/ball pen.
6. In formation sheet may also be prepared if necessary as given in soil sample in form at ion sheet.
7. Sendthesamplealongwithinformationsheettobenearestsoiltestinglaboratory.

Precautions

1. Do not draw any sample from the extreme corners of the field, area recently manured or fertilized, old bound sand marshy spots.
2. Avoid sampling from furrows, acidic or alkaline pockets.
3. Keep the sample in a bag and tag it properly.
4. Do not takelessthan0.5kgofacompositesample.
5. Sampling shuld be done from a uniform piece of land.
6. If the reisahard pan in the pit, it should be sampled separately and also not edown its depth and thickness.

Samplingfororchardplantation

Forhorticulturalplants,thesamplesmaybetakenfromdifferentdepthorlayerdependinguponthero otpenetrationofplants.Thesuccessoffruittreeplantationdepends upon the physico-chemical properties and fertility status of sub-soillayers.Therefore,itisnecessarytotestsoil beforefruittreeplantation.Soil samplesforplantationaretobetakenasfollows:

1. Dig a pit 1.80 meter deep and make its one side vertical, put marks at 15, 30, 60,90,120,150and180cmdepthsfromthesurface.

2.Collectsamplesseparatelyfrom0-15,15-30,30-60,60-90,90-120,120-150and 150-180cmdepthsinthesamewaythatofsalinealkalisoils.

3. Incasethereisahardpaninthepit,sampleitseparatelyandnotedownitsdepthandthickness.
4. Packthesoilsamplesdepthwiseinseparateclothbags.
5. Putuplabeloneachclothbagsindicatingthedepth,nameoffarmers,nameofvillage,locationofth efieldetc.
6. Sendthesamplestonearestsoiltesting laboratoryalong withdetailed information.

Preparation of samples for analysis

Drying: Wet soil sample should not be stored as changes may occur in the chemicalnatureofcertainionsandorganicmatter.Samplesaregenerallyairdriedattemperature (25-35 ^{0}C) and relativehumidity (20-60%) then after arestored. Fresh samples from the field without any drying are required. For certain determinations suchas ammonium and nitrate N, exchangeable K, acid extractable P and ferrous iron freshsamplefromthefieldwithout any drying are required. Resultsof soil analysis are expressed on ovendry weightbasis. This necessitates determination of moisture percentage by drying small sample in anovenat105^{0}C for 2 hours.

Sieving: Field moist samples prior to drying can be made to pass through a 6 mm sieve(about 4 mesh per inch) by rubbing with fingers. The practice seems of much advantage in case of heavy soils. Soil in the right moisture condition can be passed through a 2mm sieve (about 10 mesh per inch). The common practice of sieving a portion of the gross sample through a 2 mm sieve and discarding the rest is undesirable as it increase the concentration of most of the elements involved in soil fertility. When the gravels in the soil exceeds 2% limit over a 2 mm sieve their exact percentage should be recorded.

Grinding: A roller, rubber pestle in an agate mortar, or a motorized grinder is commonly used. Crushing of the gravel or primary sand particles should be avoided for heavy soils, it is better to pass these through a 2 mm sieve before allowing them to get completely air dried.

Mixing: Sample should be thoroughly mixed by rolling procedure. Place the dried ground and sieved sample on a piece of cloth. Hold all the four corners of the cloth and then up the one corner and down the other corner across the sample alternatively. Now repeat the process in the reverse direction to roll the soil from one corner to another. Continue this until thorough mixing is assured.

Storage: Store the soil in paper carton (soil sample box) using a polythene bag as in in nerlining. Label the cart on mentioning cultivators name, plot number, date of sampling and initials.

Soil sample in formation sheet

1. Name of farmer----------------------------------- Date-----------------

2. Address-________________________________

Village_________________________ P.O.-____________________

Block_________________________- District_________________-

State___________________________

1. Sample No.-------------- 2. Depth of sampling (cms)------------------

3. Area (inhectare)------------------- 4. Slope or topography-level/sloping/undulating

5. Elevation--------------------------- Upland/ low land

6. Drainage---------------------------- Well drained /moderate /impeded

7. Irrigation--------------------------- Irrigated/ un irrigated (rainfed)

8. Source of irrigation -------------------- Well/tube well/canal/pond

9. Type of soil----------------------------- Sandy/loamy/clayey

10. Specialsoilconditions----------------- Hardpan layer/rocky subsoil/concentration

11. CroppingDetails _______________________

Crop variety	Seed rate (kg/ha)	Yield kg/ha

For previous years

1.

2.

For proposed years

1.

2.

14. Fertilizer and manuring history

Year	Crop	Manure/fertilizer	Quantity/applied(kg/ha)

15. Any other information to be furnished
16. Other remarks (if any)

Signature of teacher

EXERCISE–2

Object: Determination of organic carbon in soil by Walkleyan Black (1934) rapid titrat ion method

Principle

A known weight of soil is treated with an excessvolume of standard $K_2Cr_2O_7$ inthe presence of conc. H_2SO_4. The soil is slowly digested at a low temperature by heat ofdilution of H_2SO_4 and the organic carbon in the soil is thus oxidized to CO_2. The excessof$K_2Cr_2O_7$notreduced(unused)by theorganicmatteristitratedbackagainstastandard solution of ferrous ammonium sulphate in the presence of H_3PO_4 and diphenylamine indicator. At the end point colour of suspension changes fromviolet to brightgreen.

Reactions:-

(A) Oxidationofcarbon

$K_2Cr_2O_7+8H_2SO_4+3C=2K_2SO_4+Cr_2(SO_4)_3+8H_2O+3CO_2$

(B) Duringtitration

$K_2Cr_2O_7+4H_2SO_4\rightarrow2K_2SO_4+Cr_2(SO_4)_3+4H_2O+3O2FeSO_4+H_2SO_4+O$

$\rightarrow Fe_2(SO_4)_3+H_2O$

$K_2Cr_2O_7+7H_2SO_4+6FeSO_4\rightarrow K_2SO_4+Cr_2(SO_4)_3+3Fe_2(SO_4)_3+7H_2O$

Reagents

1. 1N $K_2Cr_2O_7$ solution: Dissolve 49.04 g of A.R. grade $K_2Cr_2O_7$ in distilled water and diluteto1litre.

2. N/2Fe $(NH_4)_2(SO_4)_2.6H_2O$: Dissolve 392g F.A.S. in distilled water and add 15 ml concentrate H_2SO_4 and make the volume to 2 litre.
3. Concentrate H_2SO_4 containing1.25%silversulphate.
4. Ortho phosphoric acid(85%).
5. Diphenyl amineindicator:
   Dissolve0.5gdiphenylamineinamixtureof20mlwater+100mlconc.H_2SO_4.

Procedure:

1. Take2gsoilina500mlconicalflask
2. Add10ml1N$K_2Cr_2O_7$solutionwiththehelpofpipetteandshaketomix.
3. Add20ml conc.H_2SO_4containing1.25%Ag_2SO_4andswirl theflask20to30times.
4. Allowtheflasktostandfor 30minuteson an asbestossheet for completereaction.
5. Pour200mldistilledwatertotheflasktodilutethesuspension.
6. Add10ml 85%H_3PO_4and15-20dropsofdiphenylamineindicator.
7. TitratethesolutionwithN/2F.A.S.till thecolourchangesfromviolettobrightgreen.
8. Notethevolumeofferrousammoniumsulphate(F.A.S.)
9. Carryoutablanktitration(withoutsoil)inasimilarmanner.

Observations

1. Weightofsoil= -----------------------------W(g)
2. VolumeofN/2Fe$(NH_4)_2(SO_4)_2$usedinBlanktitration (B)= ....ml.
3. VolumeofN/2Fe$(NH_4)^2(SO_4)^2$usedinSoilsampletitration(S)= .... ml.

Calculation:

1mlof1N$K_2Cr_2O_7$ ≡ 0.003goforganiccarbon

$$\%\text{organiccarboninsoil} = \frac{10(B-S) \times 0.003 \times 100}{B \times \text{Weightofsoil}}$$

%Organicmatter= %organiccarbonx1.724(Sinceorganicmatercontains58%carbon)

Interpretationofresultsfororganiccarbon:

(i) Below0.50%-Low

(ii) 0.50to0.75%-Medium

(iii) Morethan0.75%-High

Result: Thepercentorganiccarbonofthesoilis---------,thereforesoilis ----------------------------------in organiccarbon.Theorganicmatterofthesoilis-------.

EXERCISE-3

Object:-Determinationofsoilreaction(pH)(Jackson,1973)

Principle: SoilpHhasbeendefinedasnegativelogarithmofthehydrogenionactivity

$$pH=\log_{10}I/a^{H+}=-\log_{10}a^{H+}$$

Soil pH is measured by pH meter containing glass and reference electrode andmarked pHscalefrom 0-14.The mid point 7.0of this scale isneutral, belowthisdenotes acidity and above this denotes alkalinity, pH meter is standardized with the helpofbuffersolutionsofknownpHandthenthepHofthesolutionisdetermined.

Apparatus:pH meter,vacuum pump, beaker, pipette, glassrod, china dish, spatulaetc.

Reagents: BuffersolutionsofpH4.0,7.0and9.2:Onebuffertableoftherespective pHisdissolvedinwaterandthevolumeismadeto100ml.

Procedure:

i. Saturation paste is prepared by adding distilled water to the soil and mixing till it starts glistening and slides on spatula as given in earlierexercise11.

ii. 1:2 soil water suspension is prepared by taking 20 g of soil and 40 m ld is tilled water in 100 ml beaker. The suspension is shaken at regular intervals for half an hour.

iii. pH meter is set at room temperature and calibrated by immer singthe electrodes in different buffer solutions of pH 4.0, 7.0 and 9.2.

iv. TakethebeakerofsaturationpasteanddiptheelectrodesintoitandnotethepHreading.

v. After each determination the electrodes must be washed withd is tilled water and wiped out by ordinary filter paper.

Precautions:

i. Soilwatersuspensionshouldbeshakenwellintermittentlyfor30minutes.
ii. Theglassandreferenceelectrodeofp Hmetershouldalwaysremaindippedinwater.
iii. Buffer solutions should be prepared accurately and stored well in glass container. It is desirable to prepare fresh buffer solutions after few days.
iv. ConnectthepHmetertothestabilizertoavoidthefluctuationsinpHreadings.
v. Adjust the temperature knob of pH meter at room temperature for correct pH determination.

Interpretation of results of soil pH

pH(1:2soilwater suspension)	Nature of the soil
<6.5	It is acidic soil
6.5to8.0	Soil is fit for all crops grown in the region and need not reatment
8.0to9.3	Soilismoderatelyalkalineandneedsmallamountofamendmentsorevenorganicmanureslikegreenmanuringand FYM
>9.3	Gypsum requirement of soil sample should be determined and applied according to the requirement of the soil on the hectare basis.

Observations: Reading of pH metreis--------------------------------------

Result: pH of saturation paste/ 1:2 soil water suspension is------------------------------------ --.

EXERCISE-4

Object: Determination of electrical conductivity of soil (Jackson,1973)

Principle: A solution offers some resistance to the passage of electric current through it depending upon the concentration and type of ions present. Higher the salt content,lesser the resistance to the flow of current. The resistance (R) is defined by Ohm's lawastheratioofelectricalpotentialinvolts(E)andstrengthofcurrentinampere(I).

$$E/I = \frac{\text{Volt}}{\text{Current}} = R \text{ in ohm}$$

Electrical conductivity or conductance is the reverse of resistance.I/R=I/Ohm=mho(reverseofohm) (Atpresentmhos/cmisexpressedintermsofdS/m).

Apparatus: Conductivity meter and a conductivity cell with known cell constant,vacuumpump,spatula,chinadish,beakers,glassrodetc.

Reagents: i.Saturatedsolutionofcalciumsulphate (Reagentquality)

ii. 0.01NKClsolution: Dissolve0.7456gof potassium chloride in distilled water and dilute to one litre.

Procedure:

1. The saturation extract of the soil is prepared by as per method given in exercise No. 11 and 1:2 soil water suspensions may be prepared asper method given in the procedure of pH determination.
2. Starttheconductivitymeterandadjustthetemperatureat25^{0}C.
3. Checktheinstrumentwithsaturatedcalciumsulphatesolution(conductivity-2.2 dS/m at 25 ^{0}C) or 0.01NKCl solution (conductivity – 1.41 dS/m at25^{0}C) before proceeding for the samples.
4. Takethereadingofthesaturationextractbydippingtheconductivitycellintoit.Thiswillgive ECe.

5. The same soil suspension prepared for determination of pH may also be used for EC. After recording the soil pH, allow the soil suspension in the beaker tosettlefor30minutes.Diptheconductivitycellandnotethereadingofconductivitymeter.Thereshouldbenoairbubbleinconductivitytube.
6. Wash the conductivity cell after each determination and wipe with ordinary filter paper.

Observation and calculation:

1. Cell constant = $\dfrac{\text{Actualconductivityof0.01NKClsolution}}{\text{Observed conductivity of 0.01NK Clsolution}}$

Dial Readingx Knob Readingx Cell constant2.EC

(dSm-1at25^{0}C)=---

of1:2soilwatersuspension 10^{3}

(Thedivisor1000isusedtoconvertmicromhosintomillimhos)

Results: EC of saturation extract/1:2 soil water extract of given soil is---------------dS/m.

Precautions:

a. The ECshouldbetakenat25^{0}C.
b. The EC reading of electrical conductivity of 0.1 N KCl solution should be 1.41dS/mat25^{0}Candthatofsaturatedcalciumsulphateshouldbe2.2dS/mat25 ^{0}C.
c. Foreachconductancecellitscellconstantshouldbedenotedorcalculated.
d. Noairbubbleshouldremainintheconductivitytube.

Table1: InterpretationofresultsforECeofsaturationextract

Ceofsaturation tract(dSm^{-1}at25^{0}C)	**tureofthesoil**
	linityeffectsmostlynegligible
4	eldofverysensitivecropsmayberestricted
8	eldofmanycropsrestricted
16	lytolerantcropsyieldsatisfactorily
6	lyfewtolerantcropsyieldsatisfactorily

Table2: InterpretationofresultsofECof1:2soilwatersuspension

Ceofsaturationextract Sm^{-1}at25^{0}C)	**tureofthesoil**
.8	rmal
3-1.6	iticalforsaltsensitivecrops
5-2.5	lttolerantcropscan be grown
.5	urioustoallcrops

Result:ECofsaturationextract/1:2 soilwater suspensionis -- --.

Accordingly the natureof soilis -------------------------- --

Sl. No.	HORTICULTURE-GARDEN-TOOLS	
1.	For lopping of branches, cutting of shrubs and other hard vegetative material.	 **BILL HOOK**
2.	For the budding operation, cutting of scion stick, defoliation of leaves and removing or cutting of unwanted thin twigs of the plants.	 **BUDDING KNIFE**
3.	For the patch, flute and ring budding operation especially for removing the bud patches of same size from stock and scion	 **PATCH BUDDING KNIFE**

4.	For cutting and defoliation of scion stick, making of chisel point and 'V' grooves for grafting and slashing of thin twigs and for general-purpose cutting.	 **GRAFTING KNIFE**
5.	For budding and grafting in vegetables and fruit gardens. The knife is also used for cutting of thin unwanted twigs, defoliation of leaves and general cutting works in nurseries and orchards.	 **BUDDING & GRAFTING KNIFE**
6.	For cutting of the unwanted branches or twigs of the orchard tree, vines, scion sticks, defoliation etc.	 **SECATEUR**

7.	The hedge shear is used for pruning and trimming of hedge and giving it desired shape. It is also used for cutting of shrubs and removing of haphazard growth in gardens and lawns.	 **HEDGE SHEAR**
8.	For pruning and cutting of branches and twigs of the orchard trees in standing position, which are beyond the reach, and capacity of pruning secateur	 **LOPPING SHEAR**

9.	To prune the medium sized branches (4 - 8cm) which are at higher height on the trees	 **FORESTER'S SHEAR**
10.	For trimming of the grass in the lawn. It is also used for side dressing of the lawn and cutting of the soft vegetative material	 **GRASS SHEAR**
11.	For cutting flowers with stems and other soft vegetative materials	 **FLOWER SCISSORS**

12.	For cutting grass in lawns and fields	 **LAWN MOWER**
13.	For digging holes or pits for planting and fencing	 **CROW BAR**
14.	For intercultural practices in row crops / vegetables	**HAND**  **WHEEL HOE WITH THREE TINES**

15.	For hoeing, weeding, aerating and levelling the soil.	 **GARDEN HOE**
16.	For hoeing between seedlings, plants & shrubs	 **DUTCH HOE**

17.	Round point used primarily for digging holes Square point used for picking up trash and debris	 **SHOVELS**
18.	For uplifting the seedlings from beds along with root ball and transplanting	 **TROWEL**
19.	For Loosening soil in beds and flower boxes	 **HAND CULTIVATOR**

20.	For removing weeds from the field from the field and also used for digging bulb crop.	 **WEEDING FORK**
21.	For digging unprepared ground and turning of soil	 **DIGGING FORK**
22.	For raking dry leaves, weeds & grass cuttings	**WIRE HAND RAKE** 

23.	To dig or loosen ground, or to break up lumps in the soil also used for lifting, and moving bulk materials, such as soil, manures	 **SPADE**
24.	For weeding and cutting the grasses Harvest of leafy vegetables	 **SICKLE**

25.	Loosening of soil of nursery beds, collection of stubbles	 **GARDEN RAKE**
26.	To transport manures, soil, seedlings, garden waste, etc.	 **WHEEL BARROW**

27.	For watering the plants and nursery beds	 **WATER CAN**
28.	Spraying of agrochemicals	 **KNAPSACK SPRAYER**

29.	Weeding and stirring the soil in the pots and beds	 **KHURPI**
30.	Harvesting mangoes from trees	 **MANGO HARVESTER**

STUDY ON AGRICULTURAL TILLAGE IMPLEMENTS

Introduction

The implements are used for different agricultural operation in order to raise crops within a farm are termed as agricultural implements. The different agricultural operation includes all the works done in the field from ploughing to harvesting, threshing, winnowing, cleaning and storing of the agriculture produce.

Some terminologies

Tillage: Tillage refers to mechanical manipulation of the soil that are used to provide necessary soil conditions favorable for the growth of crops.

Intercultural operations: The operations or cultural practices which are done between the periods of seed sowing and harvest of crops are called intercultural operations. e.g. weeding, mulching etc.

Pest: Any agents, which are directly or indirectly harmful to human being are known as pest. e.g. weeds, insects etc.

Ploughing: Ploughing is the process of opening the soil with the help of plough. It is the most important operation for seed bed preparation as well crop production. The depth of ploughing varies from 10 to 30 cm.

Furrow: The 'V'-shaped opening by the country plough at the time of ploughing is known as furrow.

Furrow slice: The soil which comes from the creation of 'V'-shaped furrow by country plough is known as furrow slice.

Ridge: The raised portion of soil between the two 'V' shaped furrow is called ridge.

Plough pan: The hard layer formed under the certain depth of soil surface due to continuous ploughing by a same plough in the same land for several years is known as plough pan.

IMPLEMENTS FOR PLOUGHING

The implements which are used in ploughing operation are known as ploughing implements.

Functions of ploughing:

1. It cuts the soil
2. It inverts the soil partially or completely
3. It sometimes pulverizes the soil
4. It control weeds and insects
5. It helps in mixing manures and fertilizers.

Types of ploughs:

A. Country plough
B. Mouldbourd plough

i. Standard plough
ii. Sub-cum plough
iii. Kishan plough
iv. Chashi plough

C. Disc plough
D. Rotary plough/Rotavator

A. Country plough

A country plough is commonly used ploughing implement in our country and also performed tillage operation. It is made of wood except share. Share is used for making furrows. Its grooves are used to join the plough with the yoke and to maintain the depth of ploughing.

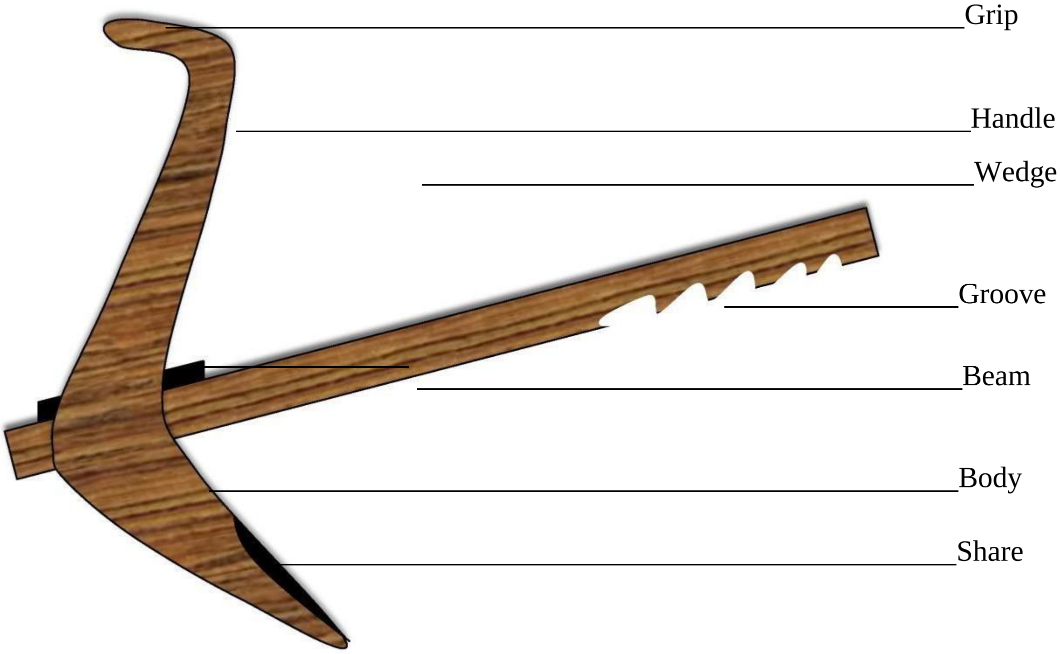


Fig. Country plough and its different parts

Characteristics of ploughing by country plough:

1. The depth of ploughing is about 0–15 cm.
2. It has no mouldboard hence there is no inversion of soil.
3. 'V' shaped furrow is made remaining the unploughed land between the two furrows.
4. When increase the length of the beam the depth of furrow is increased and vise-versa.

Efficiency: 0.135 ha /working day (8 hours).

Merits:

1. Low cost of making.
2. It can be made easily.
3. It is easy to operate.
4. It can be transferred easily from one location to another.
5. It is light in weight. So, our country bullocks can draw it easily.

Demerits:

1. Depth of ploughing is low.
2. It can not invert and pulverize the soil properly.
3. It makes plough pan.
4. Unploughed land remains between two furrows.

B. Mouldboard plough

In Indian sub-continent, a more improved plough that had the specialty of having mouldboard wasdeveloped. This special type of plough is known as mouldboard plough.

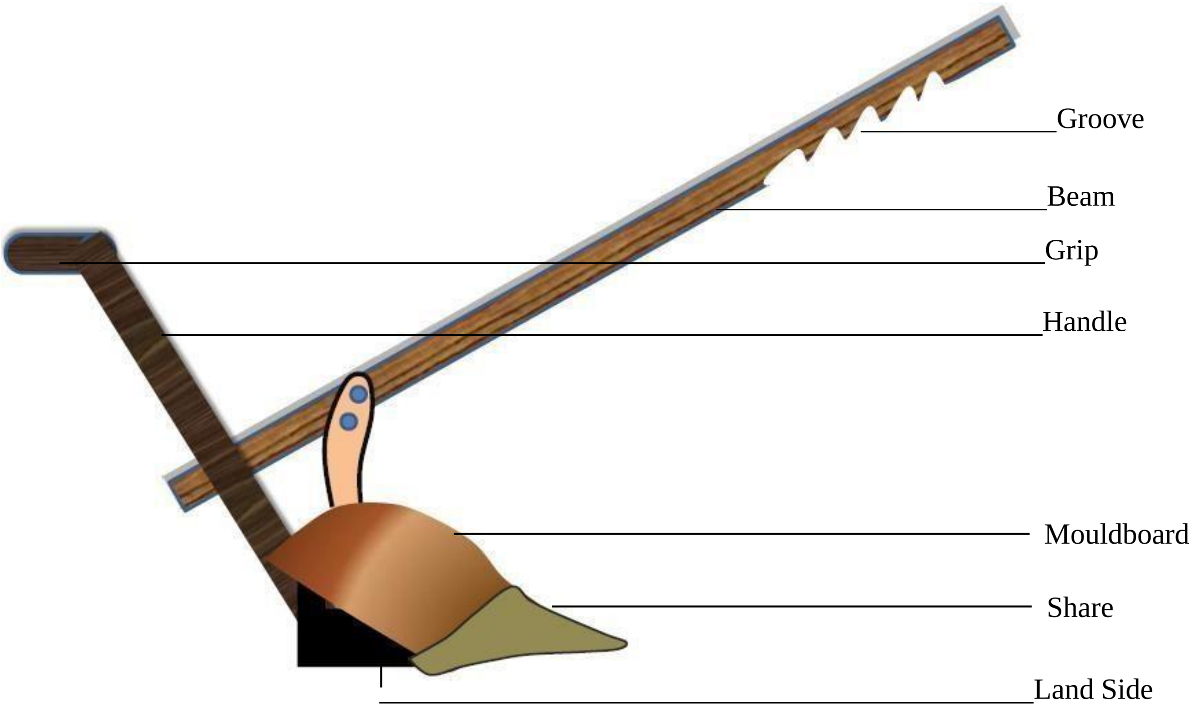


Fig. Mouldboard plough and its different parts

Characteristics of ploughing by mouldboard plough:

1. It can invert the soil completely due to presence of mouldboard.
2. Depth of ploughing is more than country plough (0- 25 cm).
3. ‘U’ shaped or ‘L’ shaped furrow is made, so there is no unploughed land between two furrows.
4. It can pulverize the soil properly.

Efficiency: 0.404 ha/ working day.

Merits:

1. Deep ploughing is possible.
2. Complete inversion of soil.
3. Absence of unploughed land between two furrows.
4. It can be suitably used in weed infested and hard land.

Demerits:

1. It is more costly than country plough.

2. Sometimes difficult to drawn by our country bullock.
3. It is heavier than country plough.
4. Repairing is difficult.
5. Requires experienced labors to operate.

c. Disc plough

Disc plough does not bear any resemblance to the other plough. The plough bottom consists of one toeight large concave discs set at angle to the line of draught. The discs are mounted on a frame, which supported on the wheels. The discs enter the soil under the heavy weight of the frame aided by the scarping action of the discs.

Fig. Disc plough

Efficiency:

Tractor drawn : 2.8-3.2 ha/ working day. Power tiller drawn : 1.0- 1.25 ha/ working day.

Merits:

1. It is suitable for clay soil where mould board plough cannot be used.
2. It is suitable for clay and hard soils where mould board plough cannot be penetrate.
3. It is suitable for land having hard plant roots, stubble and concrete mould board plough canwork properly.

Demerits:

1. It requires heavy power to operate.

2. Maintaining and repairing is expensive.
3. It unsuitable for small areas.
4. It is not available.

D. **Rotary plough/Rotavator**

It is a power operated plough. It consists of a rotating shaft having
several ti

Fig. Rotary plough/Rotavator

Merits:

1. It can be used in wet land.
2. It is used to soften the soil.
3. Efficiency is high.

Demerits:

1. It cannot be used in dry land.
2. It requires high power to operate.

IMPLEMENTS OF LADDERING

The implements, which are used to level the land, break the clods after ploughing and collect the weeds, are known as laddering implements.

Functions of a ladder:

1. It is used to break the clods after ploughing.
2. It is used to level the surface of the field.
3. It is used to collect weeds.

Merits:

1. Construction is very simple.
2. Price is very low.
3. It is light in weight. So, our country bullock can pull it easily.
4. It can be made locally.

Demerits:

1. It is not suitable for breaking the larger clods.
2. Ladder may be broken easily.

There are different types of ladder, such as i) Triple bar ladder ii) Double bar ladder ii) wooden ladder.

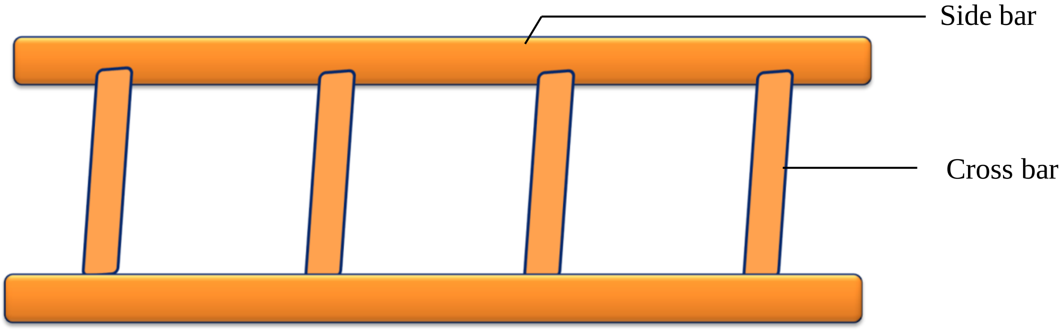


Fig. Double Bar Ladder

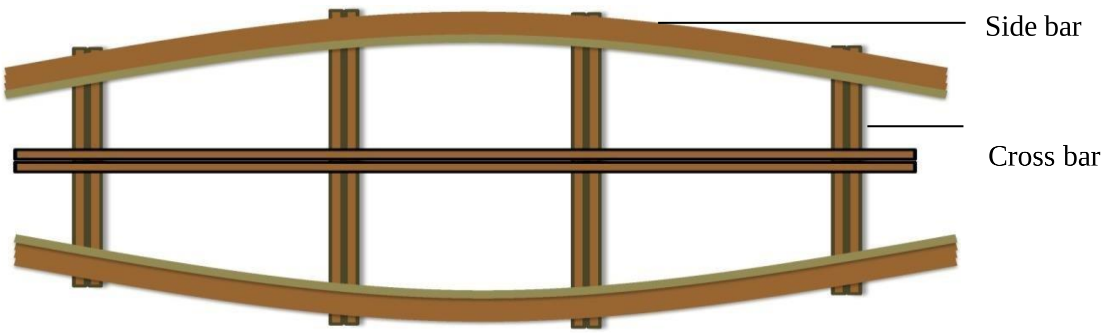


Fig. Triple Bar Ladder

Fig. Wooden Ladder

IMPLEMENTS OF INTERCULTURAL OPERATIONS

The operations, which are done after seed sowing/seedling transplanting until crop harvest in the cropfield for successful crop production, are known as intercultural operations. The implements, which are used in different intercultural operations, are grouped into the following classes:

a. Raking implements

The operation, by which the upper crust of the soil is broken, is known as raking. The implements, which are used in raking operation, are known as raking implements.

Functions of a rake:

1. The main function of rake is to break the upper crust of the soil.
2. It is used to loosen the soil.
3. It maintains plant population in the field.
4. It controls weeds.

There are different types of ladder, such as:

i) Field rake ii) Hand rake iii) Garden rake

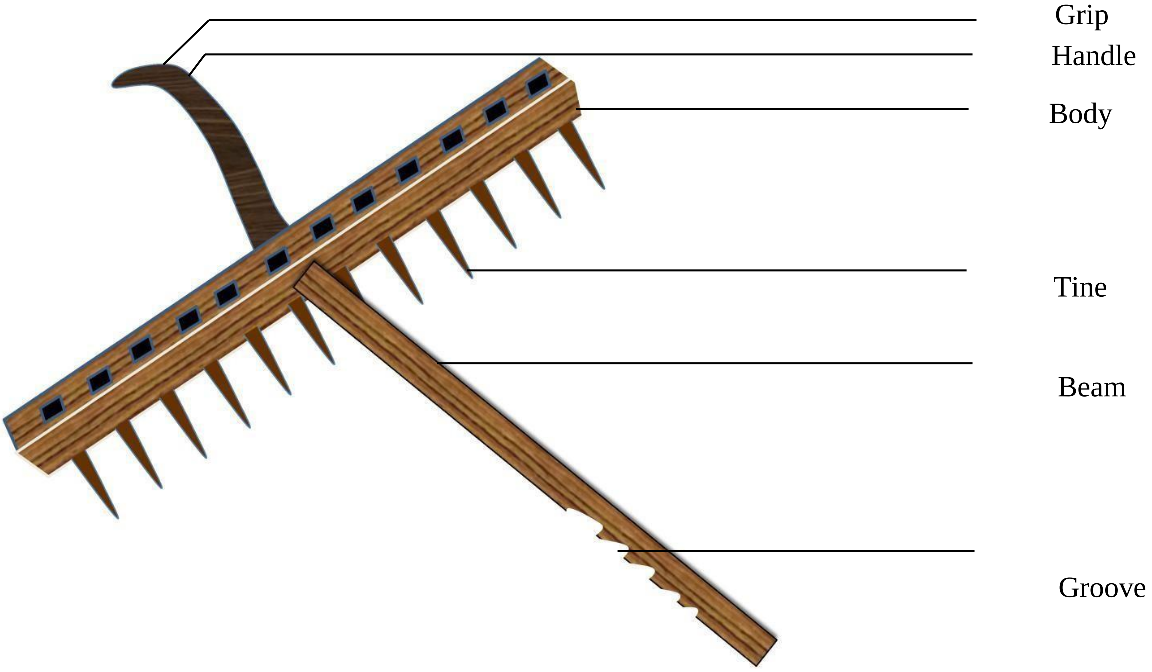


Fig. Field rake and its different part

Fig. Hand rake

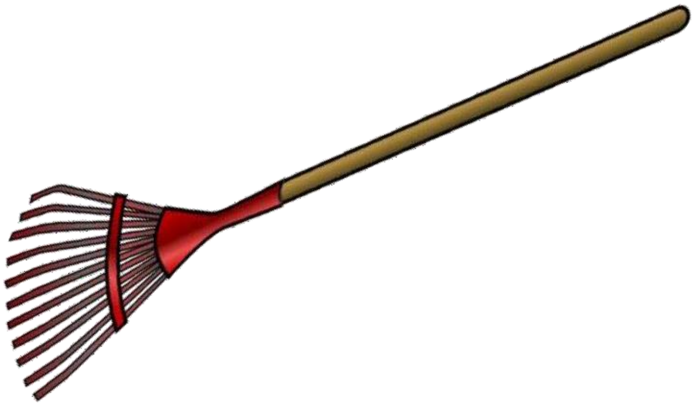


Fig. Garden rake

Difference between field rake and hand rake:

Field rake	Hand rake
1. It has beam. 2. It has groove on beam. 3. It has grip on handle. 4. It is used in large area.	1. It has no beam. 2. It has no groove. 3. It has no grip on handle. 4. It is used in small area.

SEEDING IMPLEMENTS

The implements which are used to sowing seeds or transplanting seedling are known as seeding ortransplanting implements. These are:

i. Seed drill
ii. Furrower
iii. Rice transplanter
iv. Drum seeder

Seed Drill

The equipment is used to drill seed in line in the optimum depth of soil to ensure proper germinationof seed with optimum moisture for optimum growth, development and yield of crop. The equipment contains the following parts.

Handle: To hold the equipment firmly and make it functional
Hopper: To receive seeds and lets the seeds to be canalized **Tube:** To facilitate seeds to enter in the metering device **Metering device:** To keep line to line distanced fixed as required
Line marker: To facilitate seeds to be drilled with required plant spacing
Furrow opener: To open the furrows to be drilled with seeds
Furrow closer: To close the furrows with loose soil
Press wheel: To ensure light compaction of soil of closed sown furrows
Front Wheel: To keep the equipment moveable

Advantages:

i. It maintain proper seed rate of crop
ii. It maintains proper plant spacing to ensure required plant population of crop per unit area ofland
iii. It drills seed in optimum moisture zone of soil to ensure maximum germination of crop.
iv. The sown furrows are covered with loose soil followed by light compaction of soil thus havingproper germination of soil
v. It converses soil moisture during drilling seeds
vi. It controls weed in the sown furrows
vii. It facilitates intercultural operation for grown crops
viii. It requires less time to complete sowing

Limitations:

i. It is costly to prepare
ii. It needs graded seeds
iii. It is not ideal for hard and wet soils
iv. It is not suitable for uneven soils

IMPLEMENTS OF INTERCULTURAL OPERATIONS

Weeding and mulching implements:

Weeding is the removal of unexpected plant from the land and mulching is the making of artificial layer on the soil surface to conserve soil moisture. The implements, which are used to carry out these operations, are known as weeding and mulching implements. T he implements are as follows:

i. Nirani
ii. Khurpi
iii. Hand hoe or wheel hoe
iv. Japanese rice weeder

Nirani:

It is small sized weeding and mulching implements and consists of iron blade & wooden handle.

Fig. Nirani

Functions :

It controls weeds
i. It breaks the upper crust of the soil
ii. It makes the soil loosen

Merits:
i. It can be made locally
ii. It can be used in broadcast crops

Limitations:
i. Weeding efficiency is low
ii. It is not suitable for large area

Khurpi

It is a small sized implement used for weeding and mulching. It consists of iron blade and wooden orbamboo handle.

Fig. Khurpi

Functions of a khurpi:

i. It breaks the upper crust of the soil
ii. It controls weeds of fallow land
iii. It is used to loosen the soil

Merits:

i. It is light in weight
ii. It can be made locally

Limitations:

i. It is not suitable for large area
ii. Weeding efficiency is low

Hand hoe/ Wheel hoe:

It is an implement, which is used for weeding and mulching of row crops in dry condition. It is made ofiron & wood and consists of the different parts, which has been sown in the figure.

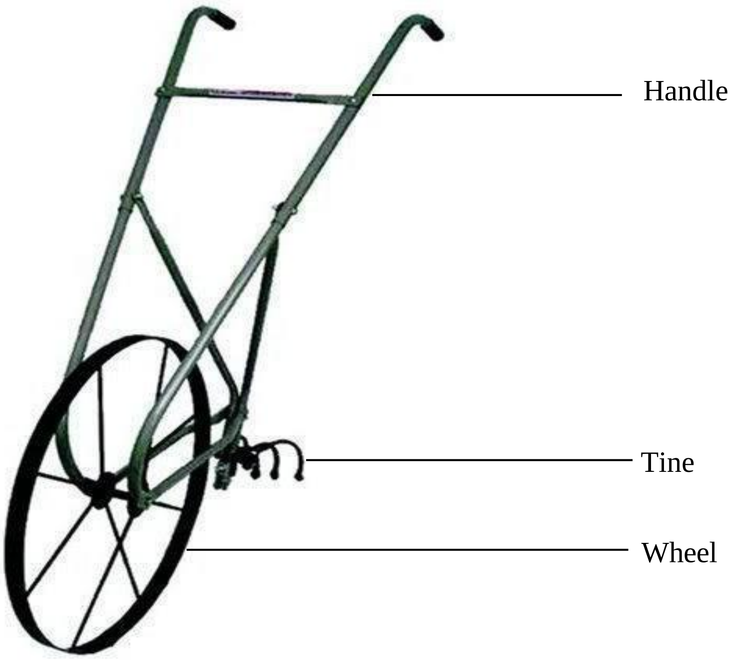


Fig. Hand hoe/ Wheel hoe

Functions of hand hoe:

i. It is used to control weeds
ii. It is needed to loose the soil for mulching.

Advantages:

i. It is suitable for dry land when Japanese rice weeder can not be used
ii. Weeding efficiency is higher than other manual operated implements like nirani, khurpi etc.

Limitations:

i. It cannot be used in clay soil
ii. It is heavy in weight (about 8 kg)

Efficiency: 0.4-0.8 ha/ working day

Japanese rice weeder:

It is an important weeding implements in rice field having 10-12 cm water. The different parts of aJapanese rice weeder have been sown in the figure.

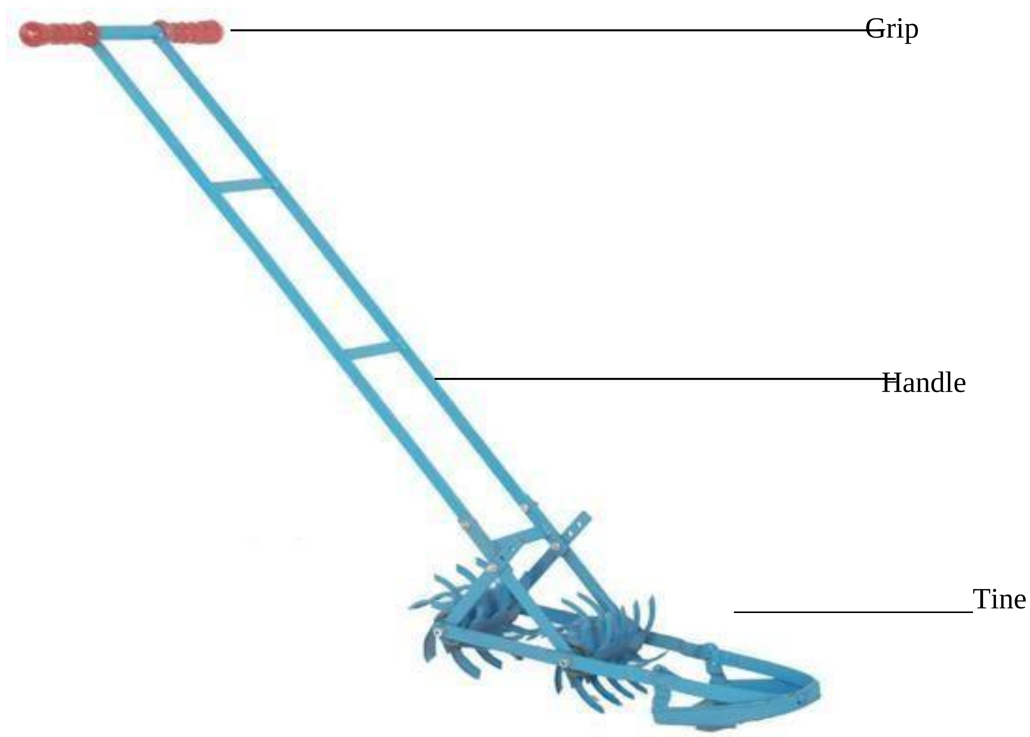


Fig. Japanese Rice Weeder

Functions of Japanese rice weeder:

i. It is used to control weeds of transplanted rice field
ii. It is also used to loosen the soil for mulching.

Merits:

i. It can be used when land is wet where hand hoe cannot be used.
ii. Efficiency is higher than nirani, khurpi etc.

Limitations:

i. It cannot be used in dry soil.
ii. It can used only in row spaced rice field

Efficiency:

0.4-0.5 ha/ working day.