DRAFT STUDY MATERIAL

AGRICULTURE (808)

CLASS – XII

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Contents

UNIT I : Advance Crop Production

1. Food Production Including Horticulture Crops and It's Importance in The Economy and Nutritional Security

Horticulture:- Horticulture is a branch of agriculture in which deal fruit crops, vegetable crops, ornamental plant, commercial flower, medicinal crops, arometics crops, spices crops, plantation crops, individual tree, shrub, climber and post-harvest management and processing.

Importance of Horticulture Crops:-

1. **Per Unit Area Yield is High:-** As compared to the field crops per hectare yield of horticulture crops is very high.

   From an fruit area of land more yield is obtained e.g. paddy gives a maximum yield of only 30 q/ha, while Banana gives 300 to 500 q/ha, Pine apple 450 q/ha and Grapes 90 - 150 q/ha. In present shortage of food and scarcity of land by growing fruits more food can be produced**.**

2. **High Returns per Unit Area:-** From one unit area of land more income will be obtained e.g. Well kept orchard of apple, grapes and sweet orange can give as much as Rs. 25,000 per ha as net income.
3. **High Employment Generation Per Unit Area:-**As per estimation, if agriculture crops are grown in one hector it gives 143 employment days per year but horticulture crops are far more ahead and it gives 870 employment days per year, and crops like has outstanding figure of employment with 2000 employment days per year.
4. **Best Utilization of Waste Land:** Some fruit crops can offer best utilization of waste land crops like wood apple, custard apple, karonda, litchi, cashew nut, coconut etc. can be grown in such areas.
5. **Raw Material for Industries:** Many industry like canning, wine processing, jam, jelly, preserve, candy, fruit beverage, pickle, drying & dehydration, flower processing etc. are depend on fruit, vegetable and flowers for row material.
6. **Use of Undulating Lands:** Fruit growing can be practiced in places where the gradient is uneven or where the land is undulating and agronomical crops cannot be cultivated. In Konkan region, mango and cashew are cultivated on large scales on hilly and hill back area.
7. **Religious Importance/ Aesthetic value:**-

- Coconut is known as *Kalpavriksha.*
- Banana is called as "Apple of paradise", "Kalpatharu" (plant of virtues) "Tree of paradise" and "Adam's Fig".
- Pipal (*Ficus religiosa*) is known as religious tree of India.
- God Shiva is associated with Beal.
- Goddess Sita is associated with Sita Ashok (*Saraca indica*).
- God Vishnu, Brahma and goddess Sarswati or Laxmi are associated with Lotus (*Nelumbo nucifera*).

- God Budha is associated with Pipal, Banyan (*Ficus benghalensis*) and Sita Ashok.

8. **Medicinal Importance:-** The parts like stem, leaf, flowers, roots and even the fruits of horticulture plants are used to make drugs, chemicals, insecticides, germicides etc. e.g. rose water is used to cure eyes ailments. Similarly saffron is important ingredient of many medicines. Papain is a digestive enzyme, citrus fruit like sweet lime is used for liver ailment, rind of pomegranate and pectin from guava used for stomach upset, bark of arjun trees for heart troubles, neem water for skin irritation and allergies etc.

   - **Triphala:-** It is make from Aonla, baheda and harad.

9. **Reputation generation:-** Crops of horticulture generate reputation of farmer by knowledge and high return value.
10. **Nutritive Value:-** Fruits and vegetables are important part of our dietary, which are rich source of nutrient (carbohydrates, protein, fat, vitamins, minerals, and dietary fiber). Carbohydrates, protein and fat are macronutrients, considered as energy sources. Vitamins and minerals are micro nutrient, play important role in body building. Fibers have several direct and indirect advantages. ICMR, New Delhi, recommends 125g of leafy vegetables, 100g of root and tuber vegetables and 75g of other vegetables (total 300g/day) and 120g of fruits per capita every day for balance diet.

1. Carbohydrates

- Carbohydrate is important and chief source of energy in human diet.
- Carbohydrates are classified in 3 groups.

Carbohydrates

Monosaccharides	Disaccharides	Polysaccharides
(Reducing Sugar)	(Non-Reducing Sugar)	
(Glucose, Fructose and Mannose)	(Sucrose, Lactose and Maltose)	(Starch, Cellulose and saccharin)

- 1g glucose liberates 4.0 calories of energy.
- Daily requirement of carbohydrate is 400-500g per capita.

Fruit Sources		**Vegetable sources**	
Raisins	77.3%	Cassava	38.1%
Apricot (dry)	72.8%	Sweet Potato	28.2%
Date	67.37%	Potato	22.6%
Karonda (dry)	67.1%		
Banana	36.4%		
Bael	30.6%		

2. Proteins

- Proteins are extremely complex nitrogen containing organic compounds. They constitute major part of protoplasm.
- Proteins, not considered to be primary body fuel, are also utilized for the production of organisms.
- Proteins made among 20 amino acids, in which 10 are essential amino acid as they are not synthesized in human body.
- 1 g protein liberates 4.0 calories of energy.
- Daily requirement of protein is 60-70g.

Fruit Sources		**Vegetable sources**	
Cashew nut	21.20%	Lima Bean	7.9 g/100g
Almond	20.88 %	Pea	7.2 g/100g
Walnut	15.60%	Cow Pea	4.3 g/100g

3. at

- Fat is stored energy sources of our body.
- 1 g fat liberates 9.0 calories of energy.

Fruit Sources		**Vegetable sources**	
Pecan nut	70.0%	Bengal Gram	1.40 g/100g
Walnut	64.5%	Potato	1.18 g/100g
Almond	58.9%	Small Bitter gourd	1.0 g/100g
Cashew nut	46.9%		
Avocado	22.8%		

4. Vitamins

- Vitamins classified in two group:-

1. Water soluble: Vitamin B complex and Vitamin C.
2. Fat soluble : Vitamin A, D, E and K.

Vitamin-A (Retnol, Carotene)

- Daily requirement is 1.2 mg/day.
- Deficiency symptoms: - Night blindness (Nyetalopia), Xeropthalmia for children, Keratnisation of epithelia cell of eyes.
- Vegetable are rich in 'Vitamin-A' than fruit.
- Carrot, muskmelon, winter squash and leafy vegetables are good source of vitamin-A.
- Carrot provide maximum vitamin-A per unit area.

- Precursor of vitamin-A is carotenoids.

Fruit Sources		Vegetable sources	
Mango	4800 IU	Bathua leaves	113000 IU
Papaya	2020 IU	Colocasia leaves	10278 IU
Persimmon	1710 IU	Turnip green	15000 IU
Date palm	600 IU	Beet leaves	9770 IU

Vitamin-B_1 (Thiamine)

- Daily requirement is 1.2 mg/day.
- Deficiency symptoms: - Beriberi, Muscular weakness, less of weight, Neuritis, loss of appetite and dilation of heart.

Fruit Sources		Vegetable sources	
Cashew nut	630 mg/100g	Palk	0.26 mg/100g
Walnut	450 mg/100g	Pea	0.25 mg/100g
Almond	240 mg/100g		

Vitamin-B_2 (Riboflavin)

- Daily requirement is 1.7 mg/day.
- Deficiency symptoms: - Dry scaly skin, crack in corners of mouth, cracking of lips etc.

Fruit Sources		Vegetable sources	
Bael	1191 mg/100g	Palak	0.56 mg/100g
Papaya	250 mg/100g	Chillies	0.39 mg/100g
Cashew nut	190 mg/100g	Fenugreek leaves	0.31 mg/100g
Pineapple	120 mg/100g		

Vitamin-C (Ascorbic acid)

- Daily requirement is 70 mg/day.
- Deficiency symptoms: - Scurvy.
- Approximately 90% vitamin-C is obtained from fruit and vegetable.

Fruit Sources **Vegetable sources**

Barbados cherry	1400 mg/100g	Drumstick leaves	250 mg/100g
Aonla	600 mg/100g	Coriander leaves	135 mg/100g
Guava	299 mg/100g	Chillies	111 mg/100g
		Broccoli	109 mg/100g

Vitamin-B_3 (Nicotinic Acid)

- Daily requirement is 19 mg/day.
- Deficiency symptoms: - Pellagra, nervous breakdown, stomach and intestinal disorder.

Fruit Sources		Vegetable sources	
Litchi	122.5 mg/100g	Palak	3.3 mg/100g
		Amaranths leaves	1.0 mg/100g

Vitamin-B_6 (Pyridoxine)

- Daily requirement is 1.3 mg/day.
- Deficiency symptoms: - Lack of Energy, Decrease in Brain Function, High Levels Of Homocysteine.
- Excellent sources of vitamin-B_6 include summer squash, bell peppers, turnip greens, shiitake mushrooms, and spinach.

Vitamin-B_{12} (Cyanocobalamin)

- Daily requirement is 2.4 µg/ day.
- Deficiency symptoms: - Pernicious anemia (Reduction in RBCs), Autoimmune disorders.
- Vitamin-B_{12} is providing by animal food. It is not found in vegetables and fruits.

Vitamin-D (Cholecalciferol)

- Deficiency symptoms: - Rickets, Pigeon chest in children, Ostcomalacia (adult).
- Vitamin-D is synthesized by the body through sunlight.

Vitamin-E (Tocopherol)

- Daily requirement is 5.0 mg/ day.
- Anti-sterility vitamin.
- Deficiency symptoms: - Degeneration of kidney, Necrosis of liver.
- Sweet corn is rich source of vitamin E.

Vitamin-K (Phylloquinone)

- Anti-morrhagic vitamin.
- Daily requirement is 0.015 mg/ day.
- Deficiency symptoms: - Delayed and faulty coagulation of blood.

5. Minerals

Calcium

- Daily requirement is 500-600 mg/ day.

Fruit Sources		**Vegetable sources**	
Litchi	0.21%	Agathi	1130 mg/100g
Karonda	0.16%	Cury leaf	813 mg/100g

Iodine

- Daily requirement is 500-600 mg/ day.
- Deficiency of Iodine leads to goiter.
- Onion, garlic, beet, agathi leaves are good source of iodine.

Iron

- Daily requirement is 20 mg/ day.

Fruit Sources		**Vegetable sources**	
Dry karonda	39.1%	Amaranths leaves	22.9%
Date (Pind)	10.6%		

Phosphorus

- Daily requirement is 20 mg/ day.

Fruit Sources		**Vegetable sources**	
Almond	0.49%	Amaranths leaves	800 mg/100g
Cashew nut	0.45%	Garlic	187 mg/100g
Walnut	0.38%		

Potassium

- Spinach (605 mg/100g) and amaranths leaves (230 mg/100g) are good source of potassium.

Sodium

- Daily requirement is 4000-6000 mg/ day.
- Celeug, green onion, Chinese cabbage etc. are good source of sodium.

Folic Acid

- Daily requirement is 0.1mg/ day.
- Deficiency symptoms: - Anamia, nervous breakdown and impaired growth.
- Importance for women.
- Green leafy vegetables are good source of folic acid.

6. Fibers

Fiber is comprised of components of plant materials (long chain glucose molecules) that are resistant to human digestive enzymes. Fiber plays an important role in digestion, providing bulk, decreasing bowel transit time, absorbing toxins and cleaning the colon of mucus and undigested food particles. Fiber acts to increase the thickness of the stomach contents which gives a feeling of fullness and slows down the emptying of the stomach.

- Fibers are in two forms — soluble and insoluble.

- Vegetables and fruits are an excellent source of fiber, especially potato (2.2g/100g), broccoli, cabbage, cauliflower, corn, green beans, tomatoes zucchini, fig, guava, apples, bananas, apricots, grapes, peaches, strawberries, etc.
- Maximum dietary fiber found in fig 7g/100g followed by guava (6.9%) in fruit and in vegetable potato have maximum dietary fiber 2.2g/100g.

Practice

1. Define the Horticulture?
2. Write down the per capita recommendation of ICMR for fruit and Vegetables.
3. Write down the deficiency symptoms of Ca, Vitamin-C and Vitamin-A.
4. Describe the role of fiber in our diet.
5. Write down the importance of horticulture.

Fill in the Blank-

1. Rickets diseases is due to……………..
2. Beriberi diseases is due to……………..
3. Per Capita per day Carbohydrate requirement……………
4. 1 g fat liberates ……………….. calories of energy
5. Iron content in Karonda fruit is…………………..

Objective Question

1. Per capita per day vegetable requirement is:-
a. 85g b. 125g c. 100g d. 300g
2. Which one is rich source of fat?
a. Walnut b. Pecannut c. Avacado d. Cashewnut
3. Which one is rich source of Fe?
a. Karonda b. Litchi c. Mango d. Date palm
4. Vegetable is poor source of:-
a. Vitamin b. Carbohydrate c. Fat d. Protean
5. Vit-C found in Barbandes Cherry is:-
a. 600mg/100g b. 1400-1600mg/100g c. 299mg/100g d. 150mg/100g

2. Soil Fertility and Productivity

Soil Fertility:

Soil fertility is the ability of the soil to provide all essential plant nutrients in available forms and in a suitable balance.

Soil productivity:

The capability of soil to produce specified crop yield under well-defined and specified systems of management of inputs and environmental conditions.

Factors Governing Soil Fertility

A. **Natural factors**

1. **Parent material:-** Fertility of a soil depends on the chemical composition of parent material from which it derived.
2. **Topography:-** Soils on the upper slope are less fertile than the soils on lower slope because high leaching and erosion on upper slope.
3. **Climate:-** In tropical climate decomposition of organic matter is faster than temperate climate. Thus soils of tropical regions are less fertile when compared to temperate region.
4. **Depth of Soil Profile:-** Deep soils are more fertile than the shallow soils and the roots are spread well enough in deep soils than the shallow soils.
5. **Physical Condition of Soil:-** The soil texture and soil structure influence the soil fertility.
6. **Soil Age:-** New soil is more fertile and good in structure than old soil because regular consumption of nutrient and degradation of soil structure by vegetation.
7. **Soil Erosion:-** With soil erosion, the top layer of soil is worn away due to factors such as water, wind and tillage of farmland, its lead to less fertility and poor structure.
8. **Nutrient status in Soil:-**

B. **Artificial Factors:-**

1. Waterlogging
2. Cropping System
3. Soil pH
4. Soil Microorganisms
5. Organic matter content in Soil
6. Method and time of ploughing

Factors Governing Soil Productivity

1. Soil Fertility
2. Soil Physical condition
3. Soil/Farm Location
4. Market demand of Crops
5. Transportation Facility
6. Weather condition
7. Insect-Pest and Disease Attack

Difference between Soil Fertility and Productivity:

Soil Fertility	**Soil Productivity**
1. It is an index of available nutrient to plants	1. It is used to indicate crop yields.
2. Influenced by the physical, chemical and biological factors of the soil.	2. Depends upon fertility and location.
3. It is the function of available nutrients of the soil.	3. It is the function of soil fertility, management and climate.
4. All fertile soils are not productive.	4. All productive soils are fertile.
5. It is an inherent property of the soil.	5. It is not the inherent property of the soil.
6. It is evaluated by soil testing in laboratory	6.It is evaluated by crop production.

Practice

1. Define the Soil Fertility and Soil Productivity?

2. Write down the difference between Soil Fertility and Productivity?

3. Which factor affect to soil fertility?

4. Which factor affect to soil productivity?

Fill in the Blank-

1. …………… is the ability of the soil to provide all essential plant nutrients in available forms and in a suitable balance.

2. Deep soils are ……………. fertile than the shallow soils and the roots are spread well enough in deep soils than the shallow soils.

3. Soil fertility determine in …………………

Objective Question

1. Capacity of nutrient supply to plant is known as?

a. Soil Productivity b. Soil Fertility c. a & b Both d. Production

2. Per unit production is known as?

a. Soil Productivity b. Soil Fertility c. a & b Both d. Production

3. Which is parental factor?

a. Soil Productivity b. Soil Fertility c. a & b Both d. Production

C. Essential Plant Nutrients, Classification of Plant Nutrients. Role of Function of Essential Plant Nutrients and their Important deficiency Symptoms.

The element is involved directly in the nutrition of the plant quite apart from its possible effects in correcting some unfavourable microbiological or chemical condition of the soil or other culture medium.

Essential plant nutrients:- A total of only 17 elements are essential for the growth and full development of higher green plants according to the criteria laid down by Arnon and Stout (1939). These criteria are:-

1. A deficiency of the given element makes it for the plant impossible to complete its life cycle.
2. The deficiency is specific for the given element and not replaceable by another element.
3. The element is a constituent of an essential metabolite or it is required for the action of an enzyme system.
    - According to Arnon had 16 elements are essential for the growth but Ni is also included in essential elements in 2009.

Classification of Plant Nutrients basis on quantity

1. **Frame work Nutrients/Structural Nutrients: -** Plant nutrient participated in structure development that are called as frame work nutrients.
2. **Macro Nutrient:-** Macro nutrient must be presented in plant tissue in concentration more than 1 mg per gram of dry weight.
    - **i.** **Primary Nutrients:-** Among macro nutrients, Nitrogen, Phosphorus and Potassium are known as primary nutrients which are required in a proper ratio for a successful crop.
    - **ii.** **Secondary Nutrients:-** Next to primary nutrients, there are three elements such as Calcium, Magnesium and Sulphur which are known as secondary nutrients.
3. **Micro Nutrients/Trace Nutrients**:- These are present in plant tissue in concentration of ≤ 1mg/gram are called as Micro Nutrients.
4. **Ultra-Micro Nutrients**:- These are present in plant tissue in concentration of < 1 ppb are called as Ultra-Micro Nutrients. Eg:- Mo and Co.
5. **Beneficial Plant Nutrients**:- They are not required by all plants but can promote plant growth and may be essential for several plant species. Eg.:- Sodium (Na), Vanadium (V), silicon (Si) and cobalt (Co)
6. **Quasi essential element:-** Silicon is considered a quasi-essential element for plants because its deficiency can cause various abnormalities with respect to plant growth and development. This term was introduced by Epstein (1999), Epstein & Bloom (2005).

Classification on the basis of mobility of nutrient in the soil:

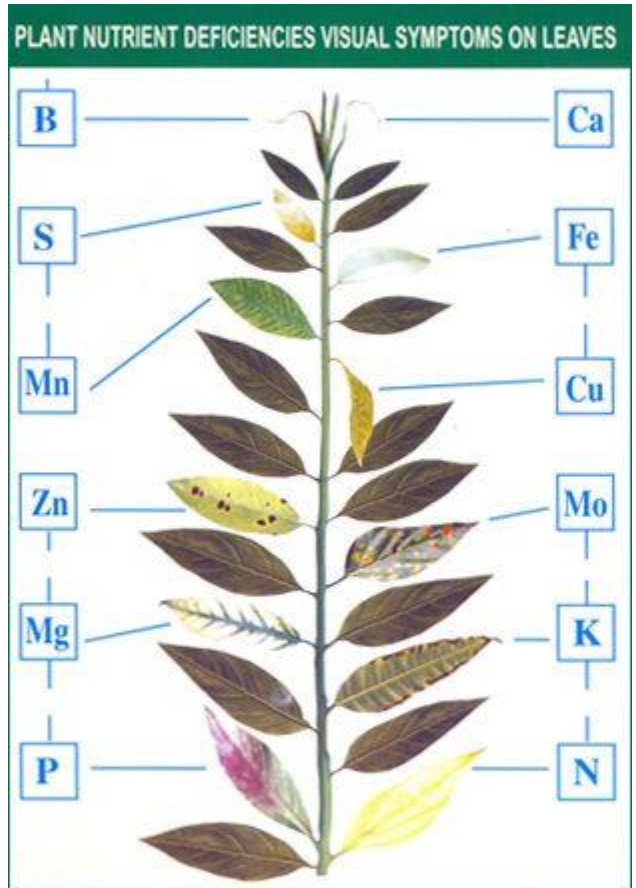
1. **Mobile nutrients:-** The nutrients are highly soluble and these are not adsorbed on clay complexes. Example: NO_3^-, SO_4^{2}-,BO_3^{2-}, Cl^- and Mn^{2+}
2. **Less mobile nutrients:-** They are soluble, but they are adsorbed on clay complex, so their mobility is reduced. Example: NH_4^+, K^+, Ca^+, Mg^{2+}, Cu^{2+}.
3. **Immobile nutrients:-** Nutrient ions are highly reactive and get fixed in the soil. Example: $H_2PO_4^-$, HPO_4^{2-}, Zn^{2+}.

Classification on the basis of mobility with in plant:-

1. **Highly mobile:-** N, P and K.
2. **Moderately mobile:-** Zn
3. **Less mobile:-** S, Fe, Mn, Cl, Mo and Cu
4. **Immobile:-** Ca and B

Plant Nutrient, Chemical Symbol, Uptake Form, Plant Tissue Concentration

Nutrient	Chemical Symbol	Principal forms for uptake	Source	Plant tissue concentration	Plant tissue concentration
1. Basic Nutrients/Frame Work Nutrients					
Carbon	C	CO_2	Air	45.0%	450000ppm
Hydrogen	H	H_2O	Water	6.0%	60000ppm
Oxygen	O	H_2O, O_2	Air/ Water	45.0%	450000ppm
2. **Macro Nutrients**					
a. Primary Nutrients					
Nitrogen	N	NH^+_4, NO^-_3	Soil	1.4%	14000ppm
Phosphorus	P	$H2PO^-_4$, HPO^{2-}_4	Soil	0.1%	1000ppm
Potassium	K	K^+	Soil	1.0%	10000ppm
b. Secondary Nutrients					
Calcium	Ca	Ca_2^+	Soil	0.5%	5000ppm
Magnesium	Mg	Mg_2^+	Soil	0.2%	2000ppm
Sulfur	S	SO^{2-}_4, SO_2	Soil	0.1%	1000ppm
Micro-Nutrients					
Iron	Fe	Fe^{2+}, Fe^{3+}	Soil	0.01%	100ppm
Manganese	Mn	Mn^{2+}	Soil	0.005%	50ppm
Boron	B	H_3BO_3	Soil	0.002%	20ppm
Zinc	Zn	Zn^{2+}	Soil	0.002%	20ppm
Copper	Cu	Cu^{2+}	Soil	0.0006%	6ppm
Molybdenum	Mo	MoO^{2-}_4	Soil	0.00001%	0.1ppm
Chlorine	Cl	Cl^-	Soil	0.01%	100ppm
Nickle	**Ni**	Ni_2^+	Soil		
3. **Beneficial Plant Nutrients**					
Cobalt	Co	Co^{2+}	Soil		
Vanadium	V	V^+	Soil		
Sodium	Na	Na^+	Soil		



Silicon	Si	$Si(OH)^4$	Soil		

Nutrient Deficiency Symptoms at Plant

- **Old Leaves:-** N, P, K, Mg, Mo
- **New Leaves:-** Fe, Cu, Cl, S, Mn
- **Old and New Leaves:-** Zn
- **Apical Bud:-** Ca, B

Nutrients function, deficiency and toxicity

Nutrient	Function	Deficiency	Toxicity
N	• N is biologically combined with C, H, O, and S to create amino acids, which are the	• Stunted growth may occur because of reduction in cell division.	• Vigorous vegetative growth coupled with dark green colour.

	building blocks of proteins. Amino acids are used in forming proto-plasm, the site for cell division and thus for plant growth and development. • Since all plant enzymes are made of proteins, N is needed for all of the enzymatic reactions in a plant. • N is a major part of the chlorophyll molecule and is therefore necessary for photosynthesis. • N is a necessary component of several vitamins. • N improves the quality and quantity of dry matter in leafy vegetables and protein in grain crops.	• Pale green to light yellow colour (chlorosis) appearing first on older leaves, usually starting at the tips. • Depending on the severity of deficiency, the chlorosis could result in the death and/or dropping of the older leaves. This is caused by the translocation of reduced yield. • Plants more susceptible to weather stress and disease. • N deficiency causes early maturity in some crops, which results in a significant reduction in yield and quality.	• The vegetative growth is prolonged and crop maturity is somewhat delayed. • Crop logging.
P	• Typically concentrated in the seeds of many plants as phytin. • Important for plant development including: − development of a healthy root system − normal seed development − uniform crop maturation − photosynthesis, respiration, cell division, and other processes • Essential component of Adenosine Triphosphate (ATP), which is directly responsible for energy transfer reactions in the plant. • Essential component of DNA and RNA, and phospholipids, which play critical roles in cell membranes.	• Because P is needed in large quantities during the early stages of cell division, the initial overall symptom is slow, weak, and stunted growth. • P is relatively mobile in plants and can be transferred to sites of new growth, causing symptoms of dark to blue-green coloration to appear on older leaves of some plants. Under severe deficiency, purpling of leaves and stems may appear. • Plants are stunted and show purple tints on their dark green leaves, veins and stems. • Lack of P can cause delayed maturity and poor seed and fruit development.	• The excess of phosphorus appears mainly in the form of micronutrient deficiency mostly for iron, zinc and manganese. • It is an interesting fact that excess phosphorus, however, may also cause typical calcium deficiency symptoms.
K	• Found in ionic form in the cell, rather than incorporated in structure of organic compounds.	• Commonly causes scorching or firing along leaf margins. • Deficient plants grow	As a result of excess potassium, plants show the typical symptoms of magnesium and possibly

	• Responsible for: − regulation of water usage in plants − disease resistance − stem strength • Involved in: − photosynthesis − drought tolerance − improved winter-hardiness − protein synthesis • Linked to improvement of overall crop quality, includinghandling and storage quality.	slowly, have poorly-developed root systems, weak stalks; lodging is common. • Seed and fruit are small and shrivelled. • Plants possess low resistance to disease. • Deficiencies most common on acid sandy soils and soils that have received large applications of Ca and/or Mg.	calcium deficiency due to a cation imbalance in the plant.
Ca	• Ca has a major role in the formation of the cell wall membrane and its plasticity, affecting normal cell division by maintaining cell integrity and membrane permeability. • Ca is an activator of several enzyme systems in pro-tein synthesis and carbohydrate transfer. • Ca combines with anions including organic acids, sulfates, and phosphates. It acts as a detoxifying agent by neutralizing organic acids in plants. • Ca is essential for seed production in peanuts. • Ca indirectly assists in improving crop yields by re-ducing soil acidity when soils are limed.	• Poor root growth: Ca deficient roots often turn black and rot. • Failure of terminal buds of shoots and apical tips of roots to develop, causing plant growth to cease. • Most often occurs on very acid soils where Ca levels are low. • Other deficiency effects such as high acidity usually limit growth before Ca deficiency apparent.	• Excessive calcium content will produce magnesium or potassium deficiency in plants, although this depends on the concentration of these elements. • Nevertheless, it should be mentioned here that so far calcium toxicity symptoms have not been reported for crops under field conditions.
Mg	• Primary component of chlorophyll and is therefore actively involved in photosynthesis. • Structural component of ribosomes, which are required for protein synthesis. • Involved in phosphate metabolism, respiration, and the activation of several enzyme systems.	• Leaves show a yellowish, bronze or reddish color while leaf veins remain green.	Magnesium toxicity are rare and not generally exhibited visibly.
S	• Required for the synthesis of the sulfur-containing amino acids *cystine*, *cysteine*, and *methionin*e, which are essential for protein formation.	• Chlorosis of the longer leaves. • If deficiency is severe, entire plant can be chlorotic and stunted. • Symptoms resemble those	Leaf size will be reduced and overall growth will be stunted. Leaves yellowing or scorched at edges.

	• Involved with: − Development of enzymes and vitamins (Vit-B). − Promotion of nodulation for N fixation by legumes − Seed production chlorophyll formation − Formation of several organic compounds that give characteristic odors to garlic, mustard, and onion. • It is increase oil content in oil seed crops.	of N deficiency; can lead to incorrect diagnoses.	
B	• Essential for: − germination of pollen grains and growth of pollen tubes − seed and cell wall formation − development and growth of new cells in meristematic tissue • Forms sugar/borate complexes associated with the translocation of sugars, starches, N, and P. • Important in protein synthesis.	• Reduced leaf size and deformation of new leaves. • Interveinal chlorosis if deficiency is severe. • May cause distorted branches and stems. • Related to flower and or fruit abortion, poor grain fill, and stunted growth. • May occur on very acid, sandy-textured soils or alkaline soils.	Yellowing of leaf tip followed by necrosis of the leaves beginning at tips or margins and progressing inward. Some plants are especially sensitive to boron accumulation.
Cu	• Cu is essential in several plant enzyme systems involved in photosynthesis. • Cu is part of the chloroplast protein plastocyanin, which forms part of the electron transport chain. • Cu may have a role in the synthesis and/or stability of chlorophyll and other plant pigments. • Cu is helpful in carotien.	• Reduced leaf size. • Uniformly pale yellow leaves. • Leaves may lack turgor and may develop a bluish-green cast, become chlorotic and curl. • Flower production fails to take place. • Organic soils are most likely to be Cu deficient.	Reduced growth followed by symptoms of iron chlorosis, stunting, reduced branching, abnormal darkening and thickening of roots. This element is essential but extremely toxic in excess.
Fe	• Serves as a catalyst in chlorophyll synthesis. • Involved in many oxidation-reduction reactions during respiration and photosynthesis. • Fe is oxygen the carrier	• Interveinal chlorosis that progresses over the entire leaf. • With severe deficiencies, leaves turn entirely white. • Factors contributing to Fe deficiency include imbalance with other metals, excessive soil P levels, high soil pH, wet, and cold soils.	Excess accumulation is rare but could cause bronzing or tiny brown spots on leaf surface.
Mn	• Functions primarily as a part of the enzyme systems in plants.	• Interveinal chlorosis. • Appearance of brownish-black specks. • Occurs most often on high	Chlorosis, or blotchy leaf tissue due to insufficient chlorophyll

	• Serves as a catalyst in chlorophyll synthesis along with iron. • Activates several important metabolic reactions (enzymes). • Plays a direct role in photosynthesis.	organic matter soils and soils with neutral to alkaline pH with low native Mn content.	synthesis. Growth rate will slow and vigor will decline.
Zn	• Aids in the synthesis of plant growth compounds and enzyme systems. • Zn is required in the synthesis of tryptophan, which in turn is necessary for the formation of indole ace-tic acid in plants. • Essential for promoting certain metabolic/enzymatic reactions. • Necessary for the production of chlorophyll, carbohydrates, and growth hormones.	• Shortened internodes between new leaves. • Death of meristematic tissue. • Deformed new leaves. • Interveinal chlorosis. • Occurs most often on alkaline (high pH) soils or soils with high available P levels.	Zinc in excess is extremely toxic and will cause rapid death. Excess zinc interferes with iron causing chlorosis from iron deficiency.
Mo	• Required for the synthesis and activity of nitrate reductase; the enzyme system that reduces NO_3^- to NH_4^+ in the plant. • Essential in the process of symbiotic N fixation by *Rhizobia* bacteria in legume root nodules.	• Interveinal chlorosis. • Wilting. • Marginal necrosis of upper leaves. • Occurs principally on very acid soils, since Mo becomes less available with low pH.	Excess may cause discoloration of leaves depending on plant species. This condition is rare but could occur from accumulation by continuous application. Used by the plant in very small quantities.
Cl	• Involved in: − energy reactions in the plant − breakdown of water − regulation of stomata guard cells − maintenance of turgor and rate of water loss − plant response to moisture stress and resistance to some diseases − Activates several enzyme systems. • Serves as a counter ion in the transport of several cations in the plant.	• Chlorosis in upper leaves. • Overall wilting of the plants. • Deficiencies may occur in well drained soils under high rainfall conditions.	Burning of leaf tip or margins. Bronzing, yellowing and leaf splitting. Reduced leaf size and lower growth rate.
Co	• Essential in the process of symbiotic N fixation by *Rhizobia* bacteria in legume root nodules. • Has not been proven to be essential for the growth of all	• Causes N deficiency: chlorotic leaves and stunted plants. • Occurs in areas with soils deficient in native Co.	

	higher plants.		
Ni	• Component of the urease enzyme. • Essential for plants supplied with urea and for those in which ureides are important in N metabolism.	• Symptoms and occurrence are not well documented but may include chlorosis and necrosis in young leaves and failure to produce viable seeds.	
V	• The role of vanadium in green plants. Vanadium, although essential for growth and chlorophyll formation in unicellular green algae, reveals toxic influences on cell division of Chlorella pyrenoidosa, these disturbances arising in the same range of V-concentrations as the known positive effects of the trace metal.		
Na	• Sodium is involved in osmotic (water movement) and ionic balance in plants. • It is helpful in tuberization of potato.		
Si	• Direct stimulation of plant growth and yield through more upright growth and plant rigidity. • Suppression of plant diseases caused by bacteria and fungi (such as powdery mildew on cucumber, pumpkin, wheat, barley; gray leaf spot on perennial ryegrass; leaf spot on Bermuda grass; rice blast) • Improved insect resistance (such as suppression of stem borers, leaf spider mites, and various hoppers) • Alleviating various environmental stresses (including lodging, drought, temperature extremes,		

	freezing, UV irradiation) and chemical stresses (including salt, heavy metals, and nutrient imbalances) • Silicon is an important element for animals where it strengthens bones and connective tissue		

Practice

Multiple Choice Question

1. Beneficial nutrient theory given by:-
a. Arnon) b. Satrtut c. Nicolsan d.DeCandoli
2. Ni considered as a essential plant nutrient in year:-
a. 2010 b. 2011 c. 1999 d. 2000
3. Yellowing diseases in tea is due to deficiency of:-
a. Ca b. Zn c. S d. B
4. Which plant nutrients deficiency seen on apical bud of plant?
a. N b. Fe c. Ca d. Mg
5. Which one is Secondary plant nutrients?
a. N b. C c. Mg d. Zn
6. Which one is beneficial plant nutrients?
a. N b. C c. Mg d. Zn
7. Which nutrients is oxygen carrier?
a. B b. Fe c. Ca d. Mg
8. Crop logging is due to toxicity of:-
a. N b. C c. Mg d. Zn

Fill in the Blank

1. ………………..nutrient is known as osmotic agents.
2. ……,…………and ……….are primary nutrients.
3. ………… has a major role in the formation of the cell wall membrane.
4. ……….. is essential component of DNA and RNA, and phospholipids.
5. ……….and …………….are major part of the chlorophyll molecule and is therefore necessary for photosynthesis.

Descriptive questions

1. Describe the essential plant nutrients theory.
2. Write down the deficiency symptoms of Nitrogen, Calcium and Iron.
3. Write down the function of Phosphorus, Magnesium and Zinc.
4. Write down the Classification of plant nutrients on the basis of mobility?
5. Write down the function, deficiency symptoms and toxicity of Potash in plant.

3 Soil Sampling and It's Processing. Introduction of Soil pH and Organic Carbon

1. **Introduction:** In present days everybody is talking about the soil testing and soil health card distribution. But if we see the common farmers, they have a very little idea about the soil sampling, testing and its profitable practical benefits in their field. Some of them are also wish to test their soils, but they have so many questions in mind likes where to take samples, how to take samples, how much number of samples should collect for a particular area, what should be the depth of sampling, period/interval of soil testing, where the soil can be tested etc. So, for the successful soil testing programme, there are four important phase likes collection of soil samples, analysis of soil samples, interpretation and recommendation, and should be followed strictly.
2. **Collection of Soil Samples:** Soil sampling is the most challengeable task, as a few grams of soil sample represents for a given area. Thus, the soil samples are required to be taken in such a manner that the collected sample should reflect the true fertility of soil for any targeted area. If the field is levelled and soil appears to be uniform, only one composite sample if taken properly could be enough for an area of 4-5 ha. Variation in slope, colour, texture, crop growth, unusual spots and management practice should be taken into account and separate sets of composite samples must be collected from each such area. Recently fertilized plots, bunds,

channels, marshy tracts and area near trees, wells, cattle dung and compost piles or other non-representative locations must be avoided during the sampling.

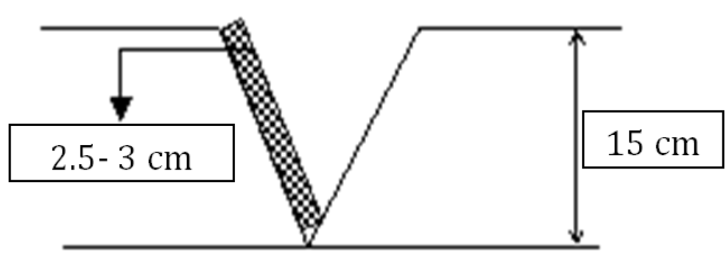
2.1. Sampling Tools: The equipment like; spade/khurpi, auger (tube and screw type), plastic bucket, plastic bag, scale and water proof marker are required for soil sampling. For sampling in the soft and moist soil, the tube auger, spade or khurpi is quite satisfactory. A screw type auger is more convenient on hard/dry land.

2.2. Sampling Depth: The root growth of most of the field crops is confined to 10-20 cm depth and hence sampling upto 15-20cm is enough for the field crops. For most of the pasture crop, 10cm sampling depth is normally sufficient. However, soil samples from the areas growing deep rooted crops like sugarcane, cotton, plantation and horticultural crops are to be collected upto 80-100 cm (90cm) depth.

2.3. Time of Sampling: Soil samples should be collected well before planting/sowing of the targeted crops, so that the soil can be tested in time. If one crop is cultivated in a year, then soil testing once in a three year is sufficient. But under intensive cultivation, say 2-3 crops in a year, then sampling should preferably be done every year prior to sowing of the first crop of the given cropping sequence.

2.4. Methods of Sampling: The greatest source of error in soil analysis is usually the soil sample itself. Consequently, soil samples should be taken in a zigzag manner to cover the entire field. At least 10-25 sub samples (cores) are taken randomly and mixed together to make a representative (composite) sample from a uniform field. First the sampling spot from where the sample is to be collected is cleaned with a spade. If a spade or khurpi is used for soil sampling, first a 'V' shaped cut is made up to the plough layer (0-15 cm) and then a uniform 2.5cm thick slice is taken out. Collected soil samples are thoroughly mixed on a clean piece of cloth/polythene sheet/ thick paper and the bulk is reduced by the quartering so that about 500g of composite sample is retained and kept in a clean polythene bag. The sample bags should be clean and fixed properly so as to avoid any mix ups during processing.

Process of sample size reduction or quartering method: Sample should be divided into 4 parts by drawing a '+' sign through it. Discard the soils from the opposite corners. Mix remaining soil, divide into 4 parts and again discard from corners.



2.5. Sample Preparation: A sample is spread out on a plastic or a thick brown paper in the shade for drying, because the wet soil samples collected from the field cannot be stored as changes occur with time in storage condition. Sun drying is strictly prohibited and it is preferable to air dry soils at 20-25^{o}C and 20-60% relative. Coarse concretions, stones and pieces of roots, leaves and other under-composed organic residues are taken away. Large lumps of moist soil are broken by hand. After air drying soil samples are crushed gently with a wooden mortar and pestle, and sieved through a 2mm sieve. The material larger than 2 mm is discarded.

2.6. Sample Storage: Care should be taken to send the collected soil samples as soon as possible for analysis. However, until analyzed, processed samples should be stored in polythene bags or plastic containers properly tied and tagged with the sample label.

2.7. Relevant Information about the Sample: A tag should be attached with each sample includes: name of the farmer, address, date of sampling, sampling depth, previous crop(s) grown, etc. Any other relevant information such as intention of analysis, fertilization history, future crop/cropping plan, etc. should also be provided separately. This supporting information helps for precise fertilizer recommendations. Further, the details, crop and yield history, along with the amount and types of fertilizers applied can also be employed to refine the fertilizer recommendation.

3. Possible Benefits for Farmers:

- Alert about the deficiencies and toxic nutrients exist in their own field and get answers how to overcome.
- Identify the areas under problem soil (if any) which limits crop growth and gather knowledge for reclamation.
- Get an idea about fertilizer recommendation and develop their skill in the use of rational/efficient nutrient inputs.
- Practically observe the contribution in yield increase percent to the applied recommended nutrients.

Soil pH

Soil pH comes from a French term meaning the "Power of Hydrogen." It is a measure of hydrogen ion (H^+) and hydroxyl ion (OH^-) concentration in soil. It refers to the acidity (low pH) or alkalinity (high pH) of soil and is measured in pH units.

The pH scale goes from 0 to 14. A pH of seven is neutral. As the amount of H^+ ions in the soil increases, the soil pH decreases, and the soil becomes more acidic. As the amount of OH^- ions in the soil increases, the soil pH increases, and the soil becomes more alkaline. From pH 7 to 0, the soil is increasingly more acidic, and from pH 7 to 14, the soil is increasingly more alkaline or basic.

Using a strict definition, pH is the negative log of H^+ ion activity in a solution. This means the pH values are reported on a negative log scale. So, a one-unit change in soil pH value signifies a 10 fold change in the actual activity or concentration of H^+, and the H^+ activity increases as the pH level decreases.

To put this into perspective, a soil pH 6 has 10 times more H^+ ions than a soil pH 7, and a soil pH 5 has 100 times more H+ ions than a soil pH 7.

Measuring Soil pH:- Soil pH provides various clues about soil properties and is easily determined. The most accurate method of determining soil pH is by a pH meter. A second method which is simple and easy but less accurate then using a pH meter, consists of using certain indicators or dyes.

The Carbon Cycle and Soil Organic Carbon

Carbon and the Carbon Cycle:- Carbon (C) is one of the most common elements in the universe and found virtually everywhere on earth: in the air, the oceans, soil, and rock. Carbon is part of geologic history in rock and especially the ancient deposits that formed coal, oil and other energy sources we use today. Carbon is also an essential building block of life and a component of all plants and animals on the planet. It has unique bonding properties that allow it to combine with many other elements. These properties enable the formation of molecules that are useful and necessary to support life. The role of carbon in living systems is so significant that a whole branch of study is devoted to it: organic chemistry. Carbon that is not tied up in rock or deep in the oceans is constantly changing and moving. This process is called the carbon cycle (Figure 1). Soil holds the largest portion of active carbon on earth. Plants take carbon from the air and convert it to plant tissue, some of which returns to the soil as plant residue.

Agriculture's Role in the Carbon Cycle:- Carbon is critical to soil function and productivity, and a main component of and contributor to healthy soil conditions. Soil management plays a critical role in whether the carbon remains in the soil or is released to the atmosphere. Agricultural practices can impact both the amount and the composition of soil organic carbon and hence also the soil's physical, biological, and chemical condition, the combination of things that defines soil health. Farm practices that affect carbon therefore impact agricultural productivity and resilience (the soil's ability to deal with weather extremes) and the carbon cycle itself.

Importance of Soil Organic Carbon:- While the agricultural sector has the ability to impact the carbon cycle on a large scale, often through the release of carbon, farmers have a vested interest in retaining and increasing soil organic carbon for individual fields because soil and yield tend to improve when the soil organic carbon level increases. Higher soil organic carbon promotes soil structure or tilth meaning there is greater physical stability. This improves soil aeration (oxygen in the soil) and water drainage and retention, and reduces the risk of erosion and nutrient leaching. Soil organic carbon is also important to chemical composition and biological productivity, including fertility and nutrient holding capacity of a field. As carbon stores in the soil increase, carbon is "sequestered", and the risk of loss of other nutrients through erosion and leaching is reduced. An increase in soil organic carbon typically results in a more stable carbon cycle and enhanced overall agricultural productivity, while physical disturbances of the soil can lead to a net loss of carbon into the surrounding environment due to formation of carbon dioxide (CO2).

Management Practices for C Sequestration With agricultural productivity so dependent on soil organic carbon and carbon cycling, how can we best manage fields to enhance soil organic carbon levels while also reducing carbon loss into the atmosphere?

The ability of agricultural fields to sequester carbon (capture and storage of carbon that would otherwise be lost to the environment) depends on several factors including climate, soil type, type of crop or vegetation cover, and management practices. Employing farming practices that reduce disturbance of the soil (less aeration from tillage helps protect carbon), combined with practices that bring additional carbon to the soil, will allow for carbon sequestration over time. Such practices include implementation of conservation tillage (no-till, zone-till, minimum-till, shallow mixing or injection for manure applications), retaining crop residues, including cover crops in crop rotations, adding organic nutrient sources such as manure and compost, and including perennial crops in crop rotations (Table 1). Their implementation may slow or even reverse the loss of carbon from agricultural fields, improve nutrient cycling and reduce nutrient loss.

Management practices that can increase soil organic carbon and reduce carbon loss into the atmosphere.

Management practices	Functions and explanation
Conservation tillage practices	Conservation tillage practices including no-till management aid in storing soil organic carbon, keeping the physical stability of the soil intact. When reduced-till systems are combined with residue management and manure management, soil organic carbon can increase over time.
Crop residue management	Returning crop residue to the soil adds carbon and helps to maintain soil organic matter.
Cover crops	Cover crops can increase soil carbon pools by adding both root and above ground biomass. Covers also reduce the risk of soil erosion and the resulting loss of carbon with soil particles. Cover crops also enhance nutrient cycling and increase soil health over time.
Manure and compost	Adding organic amendments such as manure or compost can directly increase soil carbon, and also result in increased soil aggregate stability. This enhances the biological buffering capacity of the soil, resulting in greater yields and yield stability over time.

Crop selection	Perennial crops eliminate the need for yearly planting and increase soil organic carbon by root and litter decomposition post-harvest. Crops with greater root mass in general add to root decomposition and physically bond aggregates together. Using high residue annual crops can also help reduce net carbon loss from cropping systems.

Different between soil organic matter and soil organic carbon

Soil organic carbon (SOC) is different to organic matter because it refers only to the carbon component of organic compounds. Soil organic matter is difficult to measure directly, so laboratories tend to measure and report soil organic carbon. A conversion factor is available to report soil organic matter when required.

About 58% of the mass of organic matter exists as carbon. So if we know the organic carbon content in a soil we can estimate the amount of organic matter:

Organic matter (%) = total organic carbon (%) x 1.72

While this ratio can vary in different soils, using a conversion factor of 1.72 provides a reasonable estimate of soil organic matter and is suitable for most purposes.

C: N ratio

- The ratio between the nitrogen content in the microbes and in the organic residues and to the carbon content is called as C:N ratio.
- When fresh plant residues are added to the soil they are rich in carbon and poor in N.
- This results in wider C: N ratio (40:1) decomposition of the organic matter in the soil changes to humus resulting in a narrow C: N ratio (10:1).
- When materials high in carbon are added to the soil the microbial population increase due to the plentiful supply of food material.
- A lot of CO_2 is released.
- During this process the micro organisms utilize the soil N for their body build up and there is a temporary block of N.
- When the decomposition of fresh organic residues reaches to the stage where the C: N ratio is 20:1 there is an increase in the availability of N.
- The C: N ratio of cultivated soils ranges from 8:1 to 15:1.
- Average: 10:1 to 12:1.

Practice

Multiple Choice Question

1. Soil sample depth should be taken for agronomy crops?

a. 10 cm b. 15 cm c. 20 cm d. 25 cm

2. pH meter discover by:-

a. SPL Sorensen b. Arnold O. Beckman c. VV Dokuchaev d. All of theses

3. C:N ratio of Indian soil is:-

a. 10:1 b. 15:1 c. 20:1 d. 25:1

4. Soil sample should be dry at temperature?

a. 15-20^{o}C b. 20-25^{o}C c. 40-50^{o}C d. 100^{o}C

Fill in the Blank

1. Organic matter (%) = total organic carbon (%) x …………..

2. Soil pH comes from a French term meaning the……………….
3. About ………% of the mass of organic matter exists as carbon.
4. Soil samples from the areas growing deep rooted crops like sugarcane, cotton, plantation and horticultural crops are to be collected upto ……………cm depth.

Descriptive

1. Write down the process of preparation of soil sample?
2. Explain the pH?
3. Write the Carbon cycle?
4. What is C:N ratio.

5. Introduction of Manure, Fertilizer, Bio Fertilizer, Their Method of Application and Integrated Nutrients Management

Manures and Fertilizers

Manure: It is a well decomposed refuse from the stable and barn yards including both animal excreta and straw or other plant west.

The term manure implies to the any material with the exception of water which when added to the soil makes it productive and promotes plant growth.

Fertilizers:- These are industrially manufactured chemicals containing plant nutrients.

It is an artificial product containing the plant nutrients which when added to soil makes it productive and promotes plant growth.

Difference between Manures and Fertilizers:

Sr No	Characteristics	Manures	Fertilizer
1.	Origin	Plant or animal origin	Chemical synthesized or manufactured

2.	Nature	Organic in nature	Inorganic in nature
3.	Type	Natural product	artificial product
4.	Conc. Of nutrients	less concentrated	More concentrated
5.	Material	Supply organic matter	Supply inorganic matter
6.	Nutrient availability	slowly available	May or may not be readily available
7.	Nutrients	Supply all the primary nutrients including Micronutrient	Supply specific type of nutrients one, two or three. micro nutrients may or may not be present
8.	Effect on Soil Health	Improves physical condition of soil	Do not improve the physical condition of soil
9.	Effect on plant growth	No bad effect when applied in large quantities.	Adverse effect on plant whenever there is deficiency or excessive application

ADVANTAGES OF ORGANIC MANURES

(ii) Organic manure provides all the nutrients that are required by plants but in limited quantities.
(iii) It helps in maintaining C:N ratio in the soil and also increases the fertility and productivity of the soil.
(iv) It improves the physical, chemical and biological properties of the soil.
(v) It improves both the structure and texture of the soils.
(vi) It increases the water holding capacity of the soil.
(vii) Due to increase in the biological activity, the nutrients that are in the lower depths are made available to the plants.
(viii) It acts as much, thereby minimizing the evaporation losses of moisture from the soil.

List of Organic Manures

Manure	**Percentage content**		
	Nitrogen (N)	**Phosphoric acid P_2O5)**	**Potash (K_2O)**
Coir pith	1.20	1.20	1.20
Bird Guano	7-8	11-14	2-3
Blood meal	10-12	1.2	1.0
Press mud	1-1.5	4-5	2-7
Bone meal			
1)Raw bone meal	3-4	20-25	-
2)Steamed bone meal	1-2	25-30	-
Fish meal	4-10	3.9	0.3-1.5
Sheep and Goat Manure	3.0	1.0	2.0

Animal refuse	0.3-0.4	0.1-0.2	0.1-0.3
Cattle dung, fresh	0.4-0.5	0.3-0.4	0.3-0.4
Horse dung ,fresh	0.5 -0.5	0.4-0.6	0.3-1.0
Poultry manure, fresh	1.0-1.8	1.4-1.8	0.8-0.9
Sewage sludge, dry	2.0-3.5	1.0-5.0	0.2-0.5
Sewage sludge, activate dry	4.0-7.0	2.1-4.2	0.5-0.7
Cattle urine	0.9-1.2	trace	0.5-1.0
Horse urine	1.2-1.5	trace	1.3-1.5
Human urine	0.6-1.0	0.1-0.2	0.2-0.3
Sheep urine	1.5-1.7	trace	1.8-2.0
Ash, coal	0.73	0.45	0.53
Ash, household	0.5-1.9	1.6-4.2	2.3-12.0
Ash, wood	0.1-0.2	0.8-5.9	1.5-36.0
Rural compost ,dry	0.5-1.0	0.4-0.8	0.8-1.2
Urban compost ,dry	0.7-2.0	0.9-3.0	1.0-2.0
Farmyard manure ,dry	0.4-1.5	0.3-0.9	0.3-1.9
Filter-press cake	1.0-1.5	4.0-5.0	2.0-7.0
Rice hulls	0.3-0.5	0.2-0.5	0.3-0.5
Groundnut husks	1.6-1.8	0.3-0.5	1.1-1.7
Banana, dry	0.61	0.12	1.00
Cotton plant residues	0.44	0.10	0.66
Maize Husk	0.42	1.57	1.65
Paddy Husk	0.36	0.08	0.71
Tobacco residues	1.12	0.84	0.80
Pigeon pea residues	1.10	0.58	1.28
Wheat Husk	0.53	0.10	1.10
Sugarcane trash	0.35	0.10	0.60
Tobacco dust	1.10	0.31	0.93
Non edible Oil Cakes			
Castor cake	4.3	1.8	1.3
Cotton cake	3.9	1.8	1.6
Karanj cake	3.9	0.9	1.2
Mahua cake	2.5	0.8	1.8
Neem cake	5.2	1.0	1.4
Safflower cake	4.9	1.4	1.2
Edible Oil cakes			
Coconut cake	3.0	1.9	1.8
Groundnut cake	7.3	1.5	1.3
Niger cake	4.7	1.8	1.3
Rape seed cake	5.2	1.8	1.2
Sesame cake	6.2	2.0	1.2

Classification of Manure

Bulky Organic Manures

Concentrated Organic Manures

Farm Yard Manure (FYM)

Farm Yard Manure (FYM):- It refers to the decomposed mixture of dung and urine of farm animals along with litter (bedding material) and left over material from roughages or fodder fed to the cattle.

- FYM contains:- 0.5% N, 0.25% P_20_5 and 0.4% K_20.
- FYM is one of the most important agricultural by products.
- Nearly 50 per cent of the cattle dung production in India today is utilized as fuel and is thus lost to agriculture.

Compost

A mixture of decayed or decaying organic matter used to fertilize soil. Compost is usually made by gathering plant material, such as leaves, grass clippings, and vegetable peels, into a pile or bin and letting it decompose as a result of the action of aerobic bacteria, fungi, and other organisms.

Methods Of Composting:-

1. **The Indian Banglore Method**:- This method of composting was developed at Bangalore in India by Acharya (1939). The method is basically recommended when night soil and refuse are used for preparing the compost.

   The method overcomes many of the disadvantages of the Indore method such as problem of heap protection from adverse weather, nutrient losses due to high winds / strong sun rays, frequent turning requirements, fly nuisance etc. but the time involved in production of a finished compost is much longer. The method is suitable for areas with scanty rainfall.

   In this method, the disadvantages of Indore method are overcome by slowing down the rate of decomposition and avoiding the turnings. The substrates usually composted in this method are town refuse and night soil which are spread in alternate layers of 15 cm and 5 cm in trenches or pits. When the pit is filled to 15 cm above the ground level, it is sealed to prevent loss of moisture. After the initial aerobic decomposition for 8 - 10 days the material undergoes semi anaerobic decomposition. During this stage the rate of decomposition slows down taking about 6 - 8 months for the compost to be ready. Often, the composting period is more than eight months due to high carbon: nitrogen ratio. Loss of organic matter and nitrogen is negligible and percentage recovery of compost is more. But, this method is not adaptable to heavy rainfall areas.

2. **The Indian Indoor Method:-** Sir Albert Howard and Wad (1924-26) at Indore, Madhya Pradesh, developed this method in which the conservation of cattle urine is effected by getting it absorbed in rice straw, straw dust and other organic wastes used as bedding in cattle shed. The urine soaked material along with fresh cow dung serves as major source of nitrogen for the microorganisms involved in composting.

   Raw materials:- The raw materials used are mixed plant residues, animal dung and urine, earth, wood ash and water. All organic material wastes available on a farm, such as weeds, stalks, stems, fallen leaves, prunings, chaff and fodder leftovers, are collected and stacked in a pile. Hard woody material such as cotton and pigeon-pea stalks and stubble are first spread on the farm road and crushed under vehicles such as tractors or bullock carts before being piled. Such hard materials should not exceed 10 percent of the total plant residues. Green materials, which are soft and succulent, are allowed to wilt for two to three days in order to remove excess moisture before stacking; they tend to pack closely when stacked in the fresh state. The mixture of different kinds of organic material residues ensures a more efficient decomposition.

While stacking, each type of material is spread in layers about 15 cm thick until the heap is about 1.5 m high. The heap is then cut into vertical slices and about 20-25 kg are put under the feet of cattle in the shed as bedding for the night. The next morning, the bedding, along with the dung and urine and urine-earth, is taken to the pits where the composting is to be done.

Pit site and size:- The site of the compost pit should be at a level high enough to prevent rainwater from entering in the monsoon season; it should be near the cattle shed and a water source. A temporary shed may be constructed over it to protect the compost from heavy rainfall. The pit should be about 1 m deep, 1.5-2 m wide, and of a suitable length.

Filling the pit:- The material brought from the cattle shed is spread in the pit in even layers of 10-15 cm. A slurry made from 4.5 kg of dung, 3.5 kg of urine-earth and 4.5 kg of inoculum from a 15-day-old composting pit is spread on each layer. Sufficient water is sprinkled over the material in the pit to wet it. The pit is filled in this way, layer by layer, and it should not take longer than one week to fill. Care should be taken to avoid compacting the material in any way.

Turning:- The material is turned three times while in the pit during the whole period of composting: the first time 15 days after filling the pit; the second after another 15 days; and the third after another month. At each turning, the material is mixed thoroughly and moistened with water. It will be ready in four months.

3. **Indian Indore heap method**

Heap site and size:- During rainy seasons or in regions with heavy rainfall, the compost may be prepared in heaps above ground and protected by a shed. The pile is about 2 m wide at the base, 1.5 m high and 2 m long. The sides taper so that the top is about 0.5 m narrower than the base. A small bund is sometimes built around the pile to protect it from wind, which tends to dry the heap.

Forming the heap:- The heap is usually started with a 20 cm layer of carbonaceous material such as leaves, hay, straw, sawdust, wood chips and chopped corn stalks. This is covered with 10 cm of nitrogenous material such as fresh grass, weeds or garden plant residues, fresh or dry manure or digested sewage sludge. The pattern of 20 cm of carbonaceous material and 10 cm of nitrogenous material is repeated until the pile is 1.5 m high and the material is normally wetted until it feels damp but not soggy. The pile is sometimes covered with soil or hay to retain heat and it is turned at intervals of 6 and 12 weeks. In the Republic of Korea, the heaps are covered with thin plastic sheets to retain heat and prevent insect breeding.

Where materials are in short supply, the alternate layers can be added as they become available. Moreover, all the materials can be mixed together in the pile provided that the proper proportions are maintained. Shredding the material speeds up decomposition considerably. Most materials can be shredded by running a rotary mower over them several times. Where sufficient nitrogenous material is not available, a green manure or leguminous crop such as sun hemp is grown on the fermenting heap by sowing seeds after the first turning. The green matter is then turned in at the time of the second mixing. The process takes about four months to complete.

4. **Indian Coimbatore method:-** This method (Manickam, 1967) involves digging a pit (360 cm long × 180 cm wide × 90 cm deep) in a shaded area (length can vary according to the volume of waste materials available). Farm wastes such as straw, vegetable refuse, weeds and leaves are spread to a thickness of 15-20 cm. Wet animal dung is spread over this layer to a thickness of 5 cm. Water is sprinkled to moisten the material (50-60 percent of mass). This procedure is repeated until the whole mass

reaches a height of 60 cm above ground. It is then plastered with mud, and anaerobic decomposition commences. In four weeks, the mass becomes reduced and the heap flattens. The mud plaster is removed and the entire mass is turned. Aerobic decomposition commences in at this stage. Water is sprinkled to keep the material moist. The compost is ready for use after four months.

5. **NADEP method:-** NADEP method of compost making has been developed by a farmer, Narayan Rao Pandhari Pande, in Maharastra, India. This method is based on the principle of aerobic decomposition with natural flow of optimum air. The substrate is converted at the top by plastering with dung and soil to minimise the loss of moisture.
6. **ADCO Method:-** This method of compost making has been developed by Hutchinson and Richards in 1921 in England. In such method ADCO powder use as a starter.
7. **Activated method:-**

Oil Cakes Manure

Many oil cakes such as the castor, neem, madhuca, karanja, linseed, rape seed and cotton seed which are non-edible oil cakes may serve as useful organic manure as these contain high amounts of plant nutrients.

- Most of the non-edible oil cakes are valued much for their alkaloid contents which inhibit the nitrification process in soils.
- Neem cake contains the alkaloids - nimbin and nimbicidine which effectively inhibit the nitrification process.
- Karanjin (Pongamia pinnata) and (*Madhuca butyracea*) is a potent nitrification inhibitor equal in efficiency to nitropyrin inretarding the nitrification process of ammoniacal nitrogen and increasing the yield, nitrogen uptake and grain protein content of rice .
- Madhuca cake has been successfully used in coastal saline soils for cultivatiion of rice.
- Oil cake powder manure use 15 days before sowing.
- Mahua oil cake contains saponin, it is decomposed slowly so 2 months before sowing.

Green Manuring

Green Manuring:- It can be defined as a practice of ploughing or turning into the soil, undecomposed green plant tissues for the purpose of improving the soil fertility. Green manure plant should be turning into soil at flowering stage and 45 days before crop sowing.

- Dhaincha and Sun hemp are mostly used for green manuring.
- Dhaincha can be grown in highly alkali soil.
- Dhaincha plant pH is 5.0-5.2 and Dhaincha juice pH is 4. It is use as a Soil improvers in saline and alkaline soil.
- It is obtained in two ways: by growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest.
- Green manuring is growing in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth.
- The plants that are grown for green manure known as green manure crops.

Sr.	Green manure	Botanical Name	N%	N Kg/ha	Organic

No.					Matter (t/ha)
1.	Sunhemp	*Crotalaria juncea*	0.43	84	30
2.	Dhaincha	*Sesbania aculeata*	0.42	77	23.2
3.	Sweet clover	*Melilotus indica*	0.51	134	
4.	Black gram	*Vigna mungo*	0.41	38	
5.	Mung bean	*Vigna radiata*	0.53	38	
6.	Cluster bean	*Cyamopsis tetragonoloba*	0.34	62	
7.	Cowpea	*Vigna sinensis*	0.49	56	
8.	Pea	*Pisum sativum*	0.36	66.5	
9.	Lentil	*Lens culinaris*	0.70	36.5	
10	Moth bean	*Vigna aconitifolia*	0.41	42	

Nutrient content of green leaf manure

Plant	**Scientific name**	**Nutrient content (%) on air dry basis**		
		N	**P2O5**	**K**
Gliricidia	*Gliricidia sepium*	2.76	0.28	4.60
Pongania	*Pongamia glabra*	3.31	0.44	2.39
Neem	*Azadirachta indica*	2.83	0.28	0.35
Gulmohur	*Delonix regia*	2.76	0.46	0.50
Peltophorum	*Peltophorum ferrugenum*	2.63	0.37	0.50
Weeds				
Parthenium	*Parthenium hysterophorus*	2.68	0.68	1.45
Water hyacinth	*Eichhornia crassipes*	3.01	0.90	0.15
Trianthema	*Trianthema portulacastrum*	2.64	0.43	1.30
Ipomoea	*Ipomoea*	2.01	0.33	0.40
Calotrophis	*Calotropis gigantea*	2.06	0.54	0.31
Cassia	*Cassia fistula*	1.60	0.24	1.20

Bio-Fertilizer

Biofertilizer are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants for the uptake of nutrients by their interactions in the rhizosphere.

Role of Biofertilizers in soil fertility and Agriculture:-

1. They supplement chemical fertilizers for meeting the integrated nutrient demand of the crops.
2. They can add 20-200 kg N/ha year under optimum soil conditions and thereby increases 15-30 percent of total crop yield.
3. They can at best minimize the use of chemical fertilizers not exceeding 40-50 kg N/ha under ideal agronomic and pest-free conditions.
4. Application of Biofertilizers results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation.

5. Some Biofertilizers (eg, *Rhizobium* BGA, *Azotobacter sp*) stimulate production of growth promoting substance like vitamin- B complex, Indole acetic acid (IAA) and Gibberellic acids etc.
6.Phosphate mobilizing or phosphorus solubilizing Biofertilizers / microorganisms (bacteria, fungi, mycorrhiza etc.) converts insoluble soil phosphate into soluble forms by secreting several organic acids and under optimum conditions they can solubilize / mobilize about 30-50 kg P2O5/ha due to which crop yield may increase by 10 to 20%.
7.Mycorrhiza or VA-mycorrhiza (VAM fungi) when used as Biofertilizers enhance uptake of P, Zn, S and water, leading to uniform crop growth and increased yield and also enhance resistance to root diseases and improve hardiness of transplant stock. They liberate growth promoting substances and vitamins and help to maintain soil fertility.
8. They act as antagonists and suppress the incidence of soil borne plant pathogens and thus, help in the bio-control of diseases.
9. Nitrogen fixing, phosphate mobilizing and cellulolytic microorganisms in bio- fertilizer enhance the availability of plant nutrients in the soil and thus, sustain the agricultural production and farming system.
10. They are cheaper, pollution free and renewable energy sources.
11. They improve physical properties of soil, soil tilth and soil health in general.
12. They improve soil fertility and soil productivity.
13. Blue green algae like Nostoc, Anabaena, and Scytonema are often employed in the reclamation of alkaline soils.
14. Bio-inoculants containing cellulolytic and lignolytic microorganisms enhance the degradation/ decomposition of organic matter in soil, as well as enhance the rate of decomposition in compost pit.
15. BGA plays a vital role in the nitrogen economy of rice fields in tropical regions. *Azotobacter* inoculants when applied to many non-leguminous crop plants, promote seed germination and initial vigor of plants by producing growth promoting substances.
16. Azolla-Anabaena grows profusely as a floating plant in the flooded rice fields and can fix 40-80 kg N/ha /year in approximately 40-60 tones of biomass produced, Plays important role in the recycling of plant nutrients.

Sr. No.	Examples	Remarks
Symbiotic N_2 Fixing Bio fertilizer		
1.	*Rhizobium*	Symbiosis with Pulses
2.	*Frankia* and *Casuarina sp*	Symbiosis with Non-legume crops like Casuarina
3.	*Anabaena azollae* and *Azolla pinnata*	Symbiosis with Azolla
Associative Symbiotic N_2 Fixing Bio fertilizer		
4.	*Azospirillum*	
Free living N_2 Fixing Bio fertilizer		
5.	*Azotobacter chroccum, Azotobacter vinefandi, Beijernckia, Klebsiella, Anabaena, Nostoc,*	Aerobic Bacteria
6.	*Clostridium*	Anaerobic Bacteria

Sr. No.	Group	Examples
P Solubilizing Biofertilizers		
1.	Bacteria	*Bacillus megaterium* var. *phosphaticum, Bacillus subtili, Bacillus circulans, Pseudomonas striata*

2.	Fungi	*Penicillium sp, Aspergillus awamori*
P Mobilizing Biofertilizers		
1.	Arbuscular mycorrhiza	*Glomus sp.,Gigaspora sp., Acaulospora sp., Scutellospora sp. & Sclerocystis sp.*
2.	Ectomycorrhiza	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
3.	Ericoid mycorrhizae	*Pezizella ericae*
4.	Orchid mycorrhiza	*Rhizoctonia solani*
Biofertilizers for Micro nutrients		
1.	Silicate and Zinc solubilizers	*Bacillus* sp.
Plant Growth Promoting Rhizobacteria		
1.	Pseudomonas	*Pseudomonas fluorescens*

Bio-fertilizer:-

Name of Bio fertilizer	Contribution	Beneficiaries
Rhizobium (Symbiotic)	Fix 30-100kg N/ha Leaves residues nitrogen Increase yield by 10-30% Maintains soil fertility	All legume exception Rajamma
Azotobacter	A free living bacteria mostly found in neutral to alkaline soils. Supplies 20-40mg/g of carbon source Performance of growth substance like vitamins 10-15 increase in yield Maintains soil fertility Biological control of plant disease, suppresses plant pathogen	Mustard, sunflower, banana, sugarcane, grapes, papaya, watermelon, tomato, chilli, okra, coconut, spices, flower plants etc.
Azospirillum	Fixes 20-40 kg N/ha Result in increased minerals and water uptake Root development PGRs production (IAA), disease resistance and drought tolerance are some of the additional benefits	Rice, Sugarcane, Pearmillet, wheat, sorghum etc
Blue Green Algae	Fix 20-30kg/N/ha Result in increased minerals and water uptake Produce substance like Auxin and GA_3	Rice
Azolla	Fix 40-80kg/N/ha Play role as a green manure	Rice

	because it produce large mass	

Phosphate solubilizing Biofertilizer

- Group of beneficial bacteria capable of hydrolyzing organic and inorganic phosphorus from insoluble compounds
- Pseudomonas, Bacillus and Rhizobium are among the most powerful inoculation of PSB- 30 kg P_2O_5 /ha

Mycorrhiza

- A symbiotic generally mutualistic association between a fungus and the roots of a vascular plant.
- The fungus colonizes the host plant's roots, either intracellularly or extracellularly.
- This association provides the fungus with access to carbohydrates.
- In return, the plant gains the benefits of the mycelium's higher absorptive capacity for water and mineral.
- Plant roots alone may be incapable of taking up phosphate ions that are demineralized in soils with a basic pH.
- The mycelium of the mycorrhizal fungus can make them available to the plants they colonize. Mycorrhizal and non-mycorrhizal barley plants after colonization with *Cochliobolus sativus* (Kogel, Giessen) nutrients carbohydrates Stress resistance Benefit for both partners

Silicate and Zinc solubilizing Biofertilizer

- Microorganisms are capable of degrading silicates and aluminum silicates.
- Bacillus sp can be used as bio-fertilizer for zinc or aluminum silicates because these organisms solubilize the zinc present in the soil and make it available to the plants.
- Plant Growth Promoting Rhizobacteria (PGPR).
- Species of Pseudomonas and Bacillus can produce phytohormones or growth promoters.
- They produce include indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production

Methods of Bio fertilizer Application:-

1. **BGA(Rice):-** Soil Application @4kg algal culture/ac at 7DAT
2. **Azolla(Rice):-** As Green Manure (4t/ac) at planting. As Dual Crop/inter crop (400-500kg/ac) at 7DAT
3. ***Rhizobium* (all legumes):-**
    - Treatment Seed
    - Soil Application
4. ***Azotobacter* and *Azospirillum* (all non-legumes):-**
    - Seed treatment
    - Seed material treatments (potato/sugarcane/sweet potato etc.)
    - Seedling Root dipping (vegetables/flowers those are transplanted)
    - Soil application
5. **PSM/ Phosphorus Solubilizer Microorganism (all legumes and non-legumes):-**
    - Seed treatment
    - Seed material treatment(potato/sugarcane/sweetpotato etc.)
    - Seedling Root dipping (vegetables/flowers those are transplanted)
    - Soil application
6. **VAM (Vescicular Arbuscular Mycorrhiza):-**
    - Inoculation of seedlings on the seedbed
    - Inoculation of potted soil Waste Decomposers

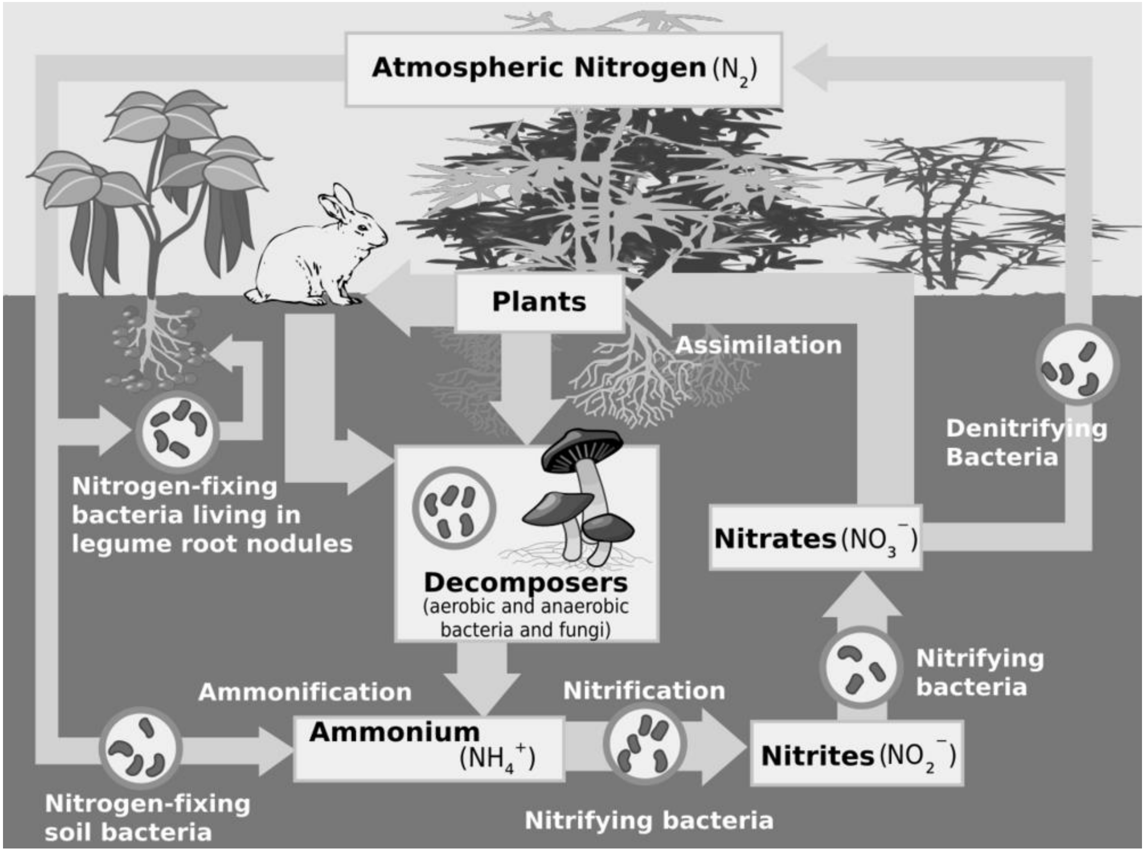
- ➢ Compost pit decomposition
- ➢ Field(in situ) decomposition

- ✓ The name Rhizobium was established by Frank in 1889.

Rhizobium bacteria and its groups

Host Group	***Rhizobium* Species**	**Crops**	**N fix kg/ha**
Pea group	*Rhizobium leguminosarum*	Pea, Lentil, Vicia (Vetch), Lathyrus (sweet pea)	62- 132
Soybean group	*R.japonicum*	Soybean, Cowpea, Groundnut, Sunhemp, Moong	57- 105
Lupini Group	*R. lupine orinthopus*	Lupinus, Ornithopus	70- 90
Alfafa grp.Group	*R.melliloti*	Melilotus (Sweet Clover), Medicago (Alfa-Alfa), Trigonella (Fenugreek)	100- 150
Beans group	*R. phaseoli*	Phaseoli	80- 110
Clover group	*R. trifoli*	Trifolium	130

Nitrogen fixation:- The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into various chemical forms as it circulates among the atmosphere and terrestrial and marine ecosystems. The conversion of nitrogen can be carried out through both biological and physical processes.



Nitrifying bacterium, plural Nitrifying Bacteria, any of a small group of aerobic bacteria (family Nitrobacteraceae) that use inorganic chemicals as an energy source. They are microorganisms that are important in the nitrogen cycle as converters of soil ammonia to nitrates, compounds usable by plants. The nitrification process requires the mediation of two distinct groups: bacteria that convert ammonia to nitrites (*Nitrosomonas, Nitrosospira, Nitrosococcus, and Nitrosolobus*) and bacteria that convert nitrites (toxic to plants) to nitrates (*Nitrobacter, Nitrospina, and Nitrococcus*).

Denitrifying bacteria, microorganisms whose action results in the conversion of nitrates in soil to free atmospheric nitrogen, thus depleting soil fertility and reducing agricultural productivity. *Thiobacillus denitrificans*, *Micrococcus denitrificans*, and some species of *Serratia, Pseudomonas*, and *Achromobacter* are implicated as denitrifiers. *Pseudomonas aeruginosa* can, under anaerobic conditions (as in swampy or water-logged soils), reduce the amount of fixed nitrogen (as fertilizer) by up to 50 percent.

Sr.No.	Crops	Fix N/kg/ha
1.	Alfalfa	194
2.	Ladino Clover	179
3.	Sweet clover	119
4.	Red clover	114
5.	Kudzu	107
6.	White clover	103
7.	Cowpea	90
8.	Vetch	80
9.	Peas	72
10.	Soya been	58

11.	Peanuts	42
12.	Beans	40

Integrated nutrient management (INM)

1. Introduction:- Integrated nutrient management (INM) is not a new concept. It is an age-old practice when almost all the nutrient needs were met through organic sources to supply secondary and micronutrients besides primary nutrients. In scientific literature, a few terminology variants like integrated plant nutrient supply (IPNS) and integrated nutrient supply and management (INSAM) are also used to convey almost similar meaning as that of INM.

2. INM/IPNS Definitions:- INM or IPNS has been defined by different researchers as follows: IPNS is defined as maintenance or adjustment of soil fertility and supply of plant nutrient to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible resources of plant nutrients in an integrated manner. IPNS is used to maintain or adjust soil fertility and plant nutrient supply to achieve a given level of crop production. This is done by optimizing the benefits from all possible sources of plant nutrients. The basic concept of INM is the maintenance and improvement of soil fertility through integrating various nutrient resources along with fertilizers for sustaining crop productivity on long-term basis.

The concept includes key areas like, maintenance/adjustment of soil fertility, optimum plant nutrient supply, sustaining desired level of productivity, optimization of benefits from all possible sources of nutrients and addressing environmental concerns. This may be achieved through combined use of all possible sources of nutrients and their scientific management for optimum growth, yield and quality of different crops and cropping systems.

This concept of nutrient management assumed greater significance in recent years because of two reasons. First, the need for continued increase in agricultural production and productivity requires growing application of nutrients and the present level of fertiliser production in India is not enough to meet the entire plant nutrient requirement. The impending demand-supply gap of about 10 million tonnes of plant nutrients is likely to widen further in view of steep hike in the prices of P&K fertilisers and raw materials. Second, a large number of experiments on INM, particularly long-term experiments (LTEs) conducted in India or elsewhere reveal that neither the fertilisers nor the organic sources in isolation can achieve sustained production under intensive cropping. Even the so called balanced use of fertilisers will not be able to sustain high productivity due to emergence of secondary or micronutrient deficiencies over time. The interactive advantages of combining organic and inorganic sources of nutrients in INM have proved superior to the sole use of these sources.

3. Components of INM:- Fertilisers, organic manures, legumes, crop residues, and bio-fertilisers are the main ingredients of INM**.**

3.1. Fertilisers:- Fertilisers continued to be the most important ingredient of INM. The dependence on fertilisers has been increasing constantly because of the need to supply large amounts of nutrients in intensive cropping with high productivity. Nonetheless, fertiliser consumption is not only inadequate but also imbalanced.

The $N:P_2O_5:K_2O$ use ratio is quite wide whereas application of K, S and micronutrients is often ignored. Domestic fertilizer production is inadequate to meet the requirements and the situation is not likely to improve in the near future. On the other hand, constraints like global price hike of fertilisers and raw materials would not permit fertiliser import in large quantities leading to a big gap between fertiliser supply and consumption. While organics and biofertilisers are expected to bridge a part of this gap, efficient use of fertilisers in narrowing the nutrient supply gap also needs greater emphasis. Utilization of fertiliser nutrients by the crops vary from 30-50% in case of N, 15- 20% in case of P and less than 5% in case of micronutrients. Thus substantial amount of applied nutrients is lost through various pathways. Enhancing nutrient use efficiency should, therefore, be a prioritized area of research for restoration and improvement of soil health and minimising the cost of crop production.

3.2. Organic Manures:- Organic manures like urban compost, FYM, crop residues, human excreta, city refuse, rural compost, sewage-sludge, pressmud and other agroindustrial wastes have large nutrient potential. Compost and FYM have traditionally been the important manures for maintaining soil fertility and ensuring yield stability. Other potential organic sources of nutrients such as non-edible oilcakes and wastes from food processing industry are also there. Moreover, there are several industrial by-products and municipal wastes with fair nutrient potential. However, these nutrient-carriers have not been properly evaluated to establish their fertiliser equivalents. There is need to integrate these sources depending on their availability in different crops and cropping systems. The industrial byproducts like spent-wash from distillery, molasses, pressmud, etc., from sugar industry and wastes from other food processing industries have good manorial value. Sulphitation pressmud (SPM) has a great potential to supply nutrients in addition to favourable effects on soil properties. During the last three decades, SPM has assumed great importance as a nutrient supplement in sugarcaneratoon- wheat and other intensive cropping systems of the sugarcane growing areas. Municipal solid wastes (MSW) and sewage-sludge are the other important nutrient sources available for integration with fertiliser inputs, though these have to be used with caution to avoid any potential threat of pathogens and heavy metal load. These nutrient sources are bulky in nature with low nutrient content and short in supply; hence, have lost their relative importance over time in crop production. However, cost of fertilisers and their limited supply made it necessary to search for alternative and renewable sources of plant nutrients leading to major interest in organic recycling. Less than 50% of the manurial potential of cattle dung is utilized at present, as large proportion is lost as fuel and droppings in non-agricultural areas. Out of the cattle dung and other farmyard wastes recycled lack to the soil as manure, substantial nutrients are lost due to faulty methods of manure preparation and its amount of application. Organic manures not only supply macro and micronutrients, but also help improving the physical, chemical and biological properties of the soils. These manures, besides supplying nutrients to the first crop, also leave substantial residual effect on succeeding crops in the system.

3.3. Legumes:- Legumes have a long-standing history of being soil fertility restorers due to their ability to obtain N from the atmosphere in symbiosis with Rhizobia. Legumes could prove an important ingredient of INM when grown for grain or fodder in a cropping system, or when introduced for green manuring. Legumes grown as green manure, forage or grain crops improved the productivity of rice-wheat cropping system (RWCS) and rejuvenated soil fertility.

3.4. Crop Residues:- Crop residues have several competitive uses and may not be always available as an ingredient of INM, yet in the regions like North-West India where mechanical harvesting is practiced, a sizeable quantity of residues is left in the field, which can form a part of nutrient supply. There are large amounts of residues of other crops like, potato, sugarcane, vegetables, etc., which are practically wasted in most cases.Although cereal crop residues are valuable cattle-feed, these could be used to supplement the fertilisers wherever available in excess of the local needs.Disposal of rice straw in Trans- and Upper Gangetic Plains has emerged as a great problem. In these combine-harvested areas farmers opt to burn the residues in situ, losing precious nutrients on one hand and polluting environment on the other. Recycling of these residues back to fields helps to build stable organic matter in the soil, as also to sustain crop yield levels. Stubbles left in the field even in traditional harvesting methods range from 0.5 to 1.5 t/ha in case of different crops. When mechanical harvesting is done, this amount is much greater. Stubbles of coarse cereals such as sorghum, maize, pearl millet, etc., which are difficult to decompose are normally collected and burnt during land preparation causing significant loss of plant nutrients.

3.5. Biofertilisers:- Biofertilisers are the materials containing living or latent cells of agriculturally beneficial microorganisms that play an important role in improving soil fertility and crop productivity due to their capability to fix atmospheric N, solublize/mobilize P and decompose farm waste resulting in the release of plant nutrients. The extent of benefit from these microorganisms depends on their number and efficiency which, however, is governed by a large number of soil and environmental factors. Bacterial cultures like *Rhizobium, Azospirillium* and *Azotobacter* have the ability to fix atmospheric N which in turn increase N supply to the crops. Bacterial cultures of *Pseudomonas* and *Bacillus* species and fungal culture of *Aspergillus* species help to convert insoluble P into plant usable forms and thus improve phosphate availability to the crops. Similarly, fungi like Vesicular Arbuscular Mycorrhizae (VAM) increase nutrient uptake particularly that of P due to increased contact of roots with larger soil volume. *Rhizobium* is the most well-known bacterial species that acts as the primary symbiotic fixer of N. These bacteria can infect the roots of leguminous plants, leading to the formation of lumps or nodules where the N fixation takes place. The bacterium's enzyme system supplies a constant source of reduced N to the host plant and the plant furnishes nutrients and energy for the activities of the bacterium. The Rhizobium-legume association can fix up to 100-300 kg N/ha in one crop season and in certain situations leave substantial N for the following crop. This symbiosis can meet more than 80% of the N requirement of the legume crop.

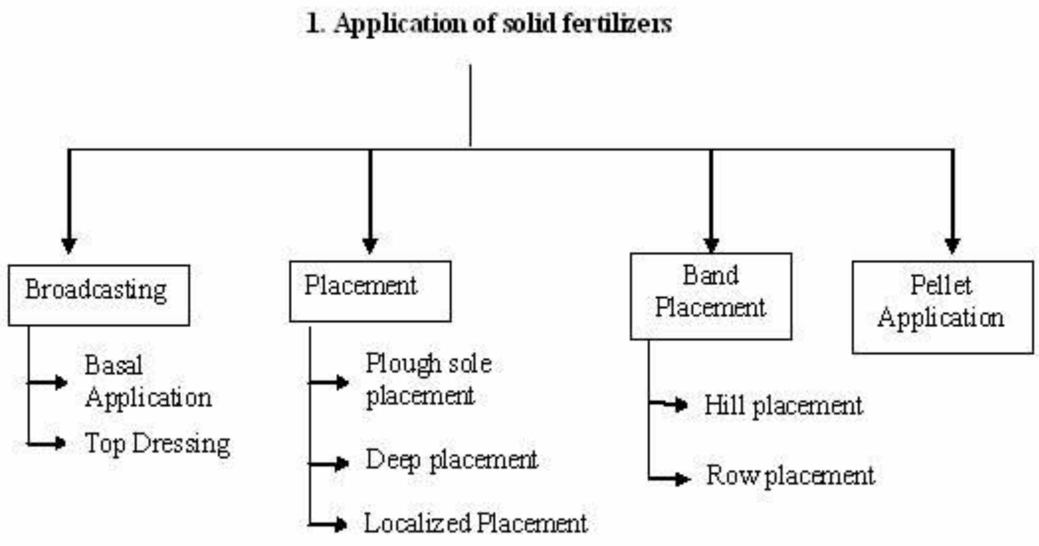
The free-living N-fixer, *Azotobacter* imparts positive benefits to the crops through small increase in N input from BNF, development and branching of roots, production of plant growth hormones, enhancement in uptake of NO_3-, NH_4+, H_2PO_4-, K+ and Fe_2+, improved water status of the plants, increased nitrate-reductase activity and production of antifungal compounds. In irrigated wheat, significant response to *Azotobactor* inoculation was recorded in large number of onfarm trials. *Azotobacter* has been found to contribute, in general, 20- 25 kg N/ha. *Azospirillum* colonises the root mass fixes N in loose association with plants. It has shown positive interaction with applied N in several field crops with an average response equivalent to 15-20 kg/ha of applied N. Several strains of P solubilizing bacteria and fungi have been isolated and inoculation with *Psolubilizing* microbial cultures is known to increase the dissolution of sparingly soluble P in the soil. Integrated use of the microbial cultures along with low-grade rock phosphate might add about 30-35 kg P_2O_5/ha. Soil inoculation with *Pseudomonas striata*, besides increasing grain yield of wheat, showed residual effect in succeeding maize on alluvial soil of Delhi. In a 3-year field study on sandy loam alluvial soils of *Modipuram*, however, PSM (*Psolubilizing* microbial culture containing *Aspergillus awamori*) inoculation of wheat seed did increase crop response to P and soil available P content over the noninoculated treatments, but the magnitude of increase in these parameters was generally too small to attain statistical significance. In recent years, K mobilising biofertilisers (KMB) and Zn solubilizing biofertilisers (ZnSB) have been introduced to augment the solubility of K and Zn in soil, respectively. The need of such bacteria to be evaluated extensively. Also, liquid biofertilizers have proved superior to the conventional (solid) carrier based ones. Blue-Green Algae (BGA) is another csimportant source of N to wetland rice. The most frequently mentioned estimates of N fixed by BGA inoculation are in the range of 20-30 kg N ha-1. Extensive field studies have shown that the incorporation of Azolla would allow N applications to be reduced by at least 30-40 kg/ha.

The advantages of INM can be broadly enumerated as:-

i) Restoration and sustenance of soil fertility and crop productivity,
ii) Prevention of secondary and micronutrient deficiencies,
iii) Economizing in fertiliser use and improvement in nutrient useefficiency and
iv) Favourable effect on the physical, chemical and biological health of soils

Methods of fertilizer application

The different methods of fertilizer application are as follows:



a) Broadcasting

1. It refers to spreading fertilizers uniformly all over the field.
2. Suitable for crops with dense stand, the plant roots permeate the whole volume of the soil, large doses of fertilizers are applied and insoluble phosphatic fertilizers such as rock phosphate are used.

Broadcasting of fertilizers is of two types.

i) Broadcasting at sowing or planting (Basal application):- The main objectives of broadcasting the fertilizers at sowing time are to uniformly distribute the fertilizer over the entire field and to mix it with soil.

ii) Top dressing:- It is the broadcasting of fertilizers particularly nitrogenous fertilizers in closely sown crops like paddy and wheat, with the objective of supplying nitrogen in readily available form to growing plants.

Disadvantages of broadcasting

The main disadvantages of application of fertilizers through broadcasting are:
i) Nutrients cannot be fully utilized by plant roots as they move laterally over long distances.
ii) The weed growth is stimulated all over the field.
iii) Nutrients are fixed in the soil as they come in contact with a large mass of soil.

b) Placement

1. It refers to the placement of fertilizers in soil at a specific place with or without reference to the position of the seed.
2. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soil have a low level of fertility and to apply phosphatic and potassic fertilizer.

The most common methods of placement are as follows:

i) Plough sole placement:- In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing. Every band is covered as the next furrow is turned. This method is suitable for areas where soil becomes quite dry upto few cm below the soil surface and soils having a heavy clay pan just below the plough sole layer.

ii) Deep placement:- It is the placement of ammoniacal nitrogenous fertilizers in the reduction zone of soil particularly in paddy fields, where ammoniacal nitrogen remains available to the crop. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off.

iii) Localized placement:- It refers to the application of fertilizers into the soil close to the seed or plant in order to supply the nutrients in adequate amounts to the roots of growing plants.

- The common methods to place fertilizers close to the seed or plant are as follows:

a) Drilling:- In this method, the fertilizer is applied at the time of sowing by means of a seed-cum-fertilizer drill. This places fertilizer and the seed in the same row but at different depths. Although this method has been found suitable for the application of phosphatic and potassic fertilizers in cereal crops, but sometimes germination of seeds and young plants may get damaged due to higher concentration of soluble salts.

b) Side dressing:- It refers to the spread of fertilizer in between the rows and around the plants. The common methods of side-dressing are

1. Placement of nitrogenous fertilizers by hand in between the rows of crops like maize, sugarcane, cotton etc., to apply additional doses of nitrogen to the growing crops and
2. Placement of fertilizers around the trees like mango, apple, grapes, papaya etc.

c) Band placement:- If refers to the placement of fertilizer in bands.

Band placement is of two types:-

i) Hill placement:- It is practiced for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of the crop.

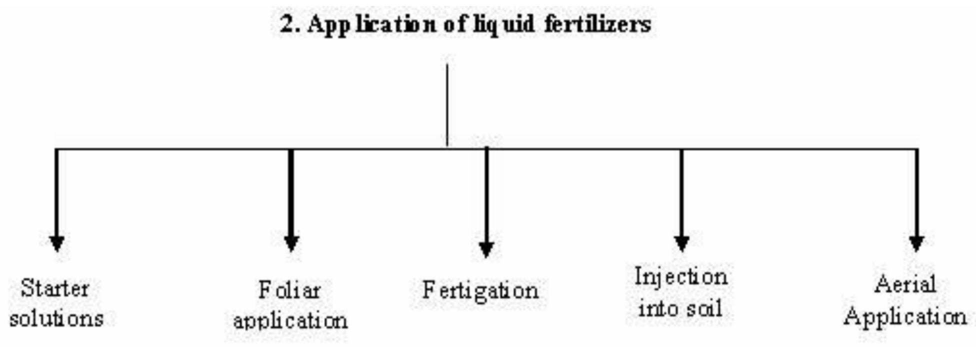
ii) Row placement:- When the crops like sugarcane, potato, maize, cereals etc., are sown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row, which is known as row placement.

d) Pellet application

1. It refers to the placement of nitrogenous fertilizer in the form of pellets 2.5 to 5 cm deep between the rows of the paddy crop.
2. The fertilizer is mixed with the soil in the ratio of 1:10 and made small pellets of convenient size to deposit in the mud of paddy fields.

Advantages of placement of fertilizers

The main advantages are as follows:
i) When the fertilizer is placed, there is minimum contact between the soil and the fertilizer, and thus fixation of nutrients is greatly reduced.
ii) The weeds all over the field can not make use of the fertilizers.
iii) Residual response of fertilizers is usually higher.
iv) Utilization of fertilizers by the plants is higher.
v) Loss of nitrogen by leaching is reduced.
vi) Being immobile, phosphates are better utilized when placed.



Following are the common methods of applying liquid fertilizers:-

a) Starter solutions:- It refers to the application of solution of N, P_2O_5 and K_2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings.
The disadvantages of starter solutions are:-
(i) Extra labour is required, and
(ii) the fixation of phosphate is higher.

b) Foliar application:- It refers to the spraying of fertilizer solutions containing one or more nutrients on the foliage of growing plants.

- Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them.
- The concentration of the spray solution has to be controlled, otherwise serious damage may result due to scorching of the leaves.
- Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.
- Mostly urea is used for foliar application (2-6%).
- Biuret shouldn't be more than 1.5%.

Application through irrigation water (Fertigation):- It refers to the application of water soluble fertilizers through irrigation water.

- The nutrients are thus carried into the soil in solution.
- Generally nitrogenous fertilizers are applied through irrigation water.

d) Injection into soil

- Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types.
- Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions.
- Anhydrous ammonia must be placed in narrow furrows at a depth of 12-15 cm and covered immediately to prevent loss of ammonia.

e) Aerial application:- In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands or in sugarcane fields etc.

Practice

Multiple Choice Question

1. Best earthworm for vermicomposting in Rajasthan is:-
a. *Eisenia fetida* b. *Pheretima posthuman* c. *Pheretima enlongata* d. All of these
2. Oil cake manure should be mix in soil before sowing:-
a. 10-15 Days b. 30 Days c. 45 Days 10. 60 Days

3. Who discover Indian Indore composting method?
a. L. N. Acharya (1939) b. Sir Albert Howard and Wade (1924-26)
c. Manikam (1967) d. Narayan Rao Pandheri Pandey
4. Fertilizers which are contain two or three primary plant nutrients, known as:-
a. Mixed manure b. Mixed Fertilizer c. Compound Manure d. Compound Fertilzer
5. Completely chlorosis on younger leaves occur due to deficiency of:-
a. Fe,S b. S,Mn c. S,Cu d. Mn,Fe
6. Which one an organic manure:-
a. Urea b. DAP c. SSP d. None of these
7. Nitrate and Nitrite are results of:-
a. Nitrosomonas, Nitrobacter b. Nitrobacter, Nitrosomonas
c. Bacillus, Pseudomonas d. Rhizobium, Bacillus
8. Rock phosphate is best suitable for the……………. soil.)
a. Acidic Soil) b. Neutral Soil c. Alkaline Soil d. Saline Soil
9. Which fertilizer totally manufactured in India:-
a. Muret of Potash b. Sulphate of Potash c. Di Ammonium Phosphate d. a & b
10. What should be concentration of urea in foliar spray?
a. 2% b. 3% c. 4% d. 6%.
11. Which one of them best suitable nitrogenous fertilizer in sub-merged soils:-
a. Ammonium Sulphate b. CAN c. Urea d. All
12. Nitrogenous fertilizers are applied into crops:-
a. After Sowing b. Split doze c. at sowong time d. None of these

Fill in the Blank

1. The name Rhizobium was established by ………….. in 1889.
2. Rhizobium fix …………….kg nitrogen per hector.
3. ………. and Sun hemp are mostly used for green manuring.
4. The Indian Indoor Method of manuring developed by……………..
5. Urea content ………………% N.
6. SSP content …………………% P.
7. MOP Content ………………..% K.
8. Gypsum Content …………% Ca and ………..% S.

Descriptive

1. Write down the difference between Manure and Fertilizer?
2. Describe the process of vermicomposting.
3. Write down the classification of Phosphatic fertilizer.
4. What is green manure.?
5. Describe the method of preparation of FYM.
6. What is the biofertilizer. Type of biofertilizer?
7. Explain the nitrogen cycle.

6. Concept of Soil Moisture Availability, Various Irrigation Method. Concept of Precision and Pressure Irrigation. Drip and Sprinkler Irrigation.

Soil water

Water contained in soil is called soil moisture. The water is held within the soil pores. Soil water is the major component of the soil in relation to plant growth.

Physical Classification of Soil Water:-

1. Hygroscopic water: This water forms very thin films around soil particles and is not available to the plant. The water is held so tightly by the soil that it cannot be taken up by roots. Hygroscopic water held so tenaciously (-31 to -10000 bar/-449.6 psi to -145037.738 psi) by soil particles that plants cannot absorb it.

2. Capillary water: Capillary water is held in the capillary pores (micro pores). Capillary water is retained on the soil particles by surface forces. It is held so strongly that gravity cannot remove it from the soil particles. The molecules of capillary water are free and mobile and are present in a liquid state. Due to this reason, it evaporates easily at ordinary temperature though it is held firmly by the soil particle; plant roots are able to absorb it. Capillary water is, therefore, known as available water. The capillary water is held between -1/3 and -31 bar (-4.8 psi to -449.6 psi).

3. Gravitational water:- Gravitational water occupies the larger soil pores (macro pores) and moves down readily under the force of gravity. Water in excess of the field capacity is termed gravitational water. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its removal from soil is a requisite for optimum plant growth. Soil moisture tension at gravitational state is less than -1/3 bar (less than -4.8 psi).

B. Biological Classification of Soil Water:- There is a definite relationship between moisture retention and its utilization by plants. This classification based on the availability of water to the plant. Soil moisture can be divided into three parts.

i. Available water:- The water which lies between wilting coefficient (-15 bar) and field capacity (-1/3 bar). It is obtained by subtracting wilting coefficient from moisture equivalent.

ii. Unavailable water:- This includes the whole of the hygroscopic water (-10000) plus a part of the capillary water below the wilting point (-15 bar).

iii. Super available or superfluous water:- The water beyond the field capacity stage is said to be super available. It includes gravitational water plus a part of the capillary water removed from larger interstices. This water is unavailable for the use of plants. The presence of super-available water in a soil for any extended period is harmful to plant growth because of the lack of air.

- **Field Capacity :-** The maximum quantity of water which a soil can retain against the force of gravity is known as field capacity. Value of field capacity is -1/3 bar.
- **Wilting point:-** Soil moisture content when the rate of absorption of water by plant roots is too slow to maintain plant turgidity and wilting occurs. The value of wilting point is -15 bar (220 psi). Type of wilting:-
  - i. **Temporary Wilting:-** Wilting from which a plant will recover by reduction of the transpiration rate and without addition of water to the soil. The value of temporary wilting is -15 bar.

ii. **Permanent Wilting Point:-** As moisture is lost from the soil, the point at which the force with which the remaining moisture adheres to soil particles exceeds that exerted by plant roots. Plants are therefore unable to absorb moisture and wilting results. Since this condition arises from the amount of water present in the soil, plants will not recover unless water is added to the soil, i.e. the wilting is permanent.

- **Saturation:-** All soil pores are filled with water. This condition occurs right after a rain. This represents 0 bars.
- **Hygroscopic coefficient:-** The hygroscopic coefficient is the maximum amount of hygroscopic water absorbed by 100 g of dry soil under standard conditions of humidity (50% relative humidity) and temperature (15°C). This tension is equal to a force of -31 bar. Water at this tension is not available to plant but may be available to certain bacteria.

S.No.	Moisture Class	Tension (bar)	pF
1.	Chemically Combined	Very High	-
2.	Water Vapour	Held at saturation point in the soil air	-
3.	Hygroscopic	-31 to -10000	4.5 to 7.00
4.	Hygroscopic Coefficient	-31	4.50
5.	Wilting Point	-15	4.20
6.	Capillary	-1/3 to -31	2.54 to 4.50
7.	Moisture equivalent	-1/3 to 1	2.70 to 3.00
8.	Field Capacity	-1/3	2.54
9.	Sticky Point	-1/3	2.54
10.	Gravitational	-1/3-0	<2.54
11.	Maximum water holding Capacity	Almost Zero	-

Forces on Soil Water

1. **Adhesion:-** The attraction o f soil water to soil particles.
2. **Cohesion:-** The attraction of water molecules to other water molecules.
3. **Capillarity:-** A capilary is a very thin tube in which a liquid can move against the force of gravity. The narrower the tube the higher the liquid rises due to the forces of adhesion and cohesion.

Water movement in Soil:-

1. **Infiltration:-** Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated.
2. **Percolation:-** Percolation is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation occurs when water is under pressure or when the tension is smaller than about ½ atmosphere. Percolation rate is synonymous with infiltration rate with the qualitative provision of saturated or near saturated conditions.
3. **Interflow**:- Interflow is the lateral seepage of water in a relatively pervious soil above a less pervious layer. Such water usually reappears on the surface of the soil at a lower elevation.

4. **Leaching**:- **L**eaching reference to a soluble chemical or mineral) drain away from soil, ash, or similar material by the action of percolating liquid, especially rainwater or irrigation water.
5. **Saturated flow:-** The movement of water through a soil that is temporarily saturated. Most of the loosely held water moves downward, and some moves more slowly laterally.
6. **Unsaturated flow:-** The movement of water through a soil that is unsaturated.

Water Requirement and Irrigation Requirement

Water Requirement of Crop:- Water requirement of crop is the quantity of water regardless of source, needed for normal crop growth and yield in a period of time at a place and may be supplied by precipitation or by irrigation or by both.

Water is needed mainly to meet the demands of evaporation (E), transpiration (T) and metabolic needs of the plants, all together is known as consumptive use (CU). Since water used in the metabolic activities of plant is negligible, being only less than one percent of quantity of water passing through the plant, evaporation (E) and transpiration (T), i.e. ET is directly considered as equal to consumptive use (CU). In addition to ET, water requirement (WR) includes losses during the application of irrigation water to field (percolation, seepage, and run off) and water required for special operation such as land preparation, transplanting, leaching etc.

WR = CU + application losses + water needed for special operations.

Water requirement (WR) is therefore, demand and the supply would consist of contribution from irrigation, effective rainfall and soil profile contribution including that from shallow water tables (S)

$$WR = IR + ER + S$$

Under field conditions, it is difficult to determine evaporation and transpiration separately. They are estimated together as evaportranspiration (ET). IR is the irrigation requirement.

Factors influencing Evapotranspiration (ET):-

ET is influenced by atmospheric, soil, plant and water factors.

A) Atmospheric factors:

1) Precipitation
2) Sunshine
3) Wind velocity
4) Temperature
5) Relative humidity

B) **Soil factors:**

1) Depth of water table
2) Available soil moisture
3) Amount of vegetative cover on soil surface.

C) **Plant factors:**

1) Plant morphology
2) Crop geometry
3) Plant cover
4) Stomatal destiny
5) Root depth

D) **Water factors:**

1) Frequency of irrigation
2) Quality of water ET.

Water requirement of any crop depends on crop factors such as variety, growth stage, and duration of plant, plant population and growing season. Soil factors such as temperature, relative humidity, wind velocity and crop management practices such as tillage, fertilization, weeding, etc. Water requirement of crops vary from area to area and even field to field in a farm depending on the above-mentioned factors.

Estimation of Evapotranspiration (ET):

Climate is the most important decides the rate of ET. Several empirical formulas are available to estimate ET from climate date. FAO expert group of scientists has recommended four methods for adoption of different regions of world.

1) Blaney and Criddle method
2) Radiation method
3) Pan evaporation method
4) Modified penman method

Estimation of ET Involves Three Important Steps:

a) Estimation of PET or evapotranspiration (ET) by any four above methods.
b) Estimation of crop co-efficient (KC) and
c) Making suitable adjustments to local growing conditions.

a) **Reference Evapotranspiration (ETO):** ETO can be defined as the rate of evapotranspiration of an extended surface of an 8 to 15 cm tall, green cover, actively growing completely shading the ground and not short of water.

Selection of a method for estimation of ETO depends on availability of metrological data and amount of accuracy needed. Among four methods for estimation of ETO, modified Blaney-Criddle method is simple, easy to calculate and requires data on sunshine (S.S.) hours, wind velocity (WV), relative humidity (RH) in addition to temperature (T).

Among these methods, modified penman method is more reliable with a possible error of 10% only. The possible errors for other methods are 15, 20 and 25% of pan evaporation, radiation and modified Blaney-Criddle methods respectively.

Modified Blaney method:

$$ETO = C [P (0.46 T + 8)] \text{ mm/day}$$

Where ETO = Reference crop ET in mm/day for the month considered
T = Mean daily temperature in oC over the month considered
P = Mean daily percentage of total annual day time hours of a given month and latitude (from standard table)
C = Adjustment factor depends on minimum R.H., Sunshine hours and day time wind estimates.

Pan evaporation method:

$$ETO = Kp/Epan$$

Where Kp = Crop factor
Epan = mean pan evaporation (Epan pan evaporation)

Modified penman method:

$$ETO = C [W.Rn + (1-w). f (U). (ea – ed)]$$

Where Rn = Net radiation in equivalent evaporation expressed as mm/day
W = temperature of altitude related factor
F (U) = Wind related function
Ea – ed= Vapour pressure deficit (mili bar)
C = the adjustment factor (ratio of U day to U night)
Rn (0.75-Rns)
Ea =Saturated vapour pressure (m.bar)
Ed = Mean actual vapour pressure of the air (m. bar)

Crop Coefficient:

Crop co-efficient is the ratio between evapotranspiration of crop (Etc) and potential evapotranspiration and expressed as T (crop) = Kc X ETo

Irrigation requirement:

Irrigation requirement is the total quantity of water applied to the land surface in supplement to the water supplied through rainfall and soil profile to meet the water needs of crops for optimum growth.

$$IR = WR – (ER + S)$$

Net irrigation requirement:

The net irrigation requirement is the amount of irrigation water just required to bring the soil moisture content in the root zone depth of the crops to field capacity. Thus, net irrigation requirement is the difference between the field capacity and soil moisture content in the root zone before application of irrigation water.

Gross irrigation requirement:

The total amount of water inclusive of water in the field applied through irrigation is termed as gross irrigation requirement, which in other words is net irrigation requirement plus application and other losses.

Methods of irrigation:-Irrigation water can be applied to crop lands using one of the following irrigation methods :

(i)Surface irrigation

(a)Uncontrolled (or wild or free) flooding method,

(b)Border strip method,

(c)Check method,

(d)Basin method,

(e) Ring method and

(f)Furrow method.

(ii)Subsurface irrigation

(iii)Sprinkler irrigation

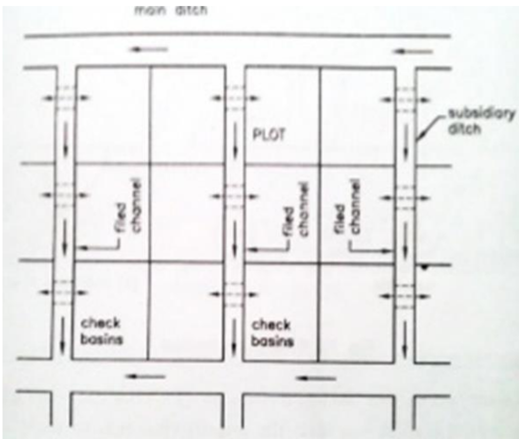
(iv)Trickle (Drip) irrigation

(V) Matka Irrigation Method

Each of the above methods has some advantages and disadvantages, and the choice of the method depends on the following factors:

- Size, shape, and slope of the field,
- Soil characteristics,
- Nature and availability of the water supply subsystem,
- Types of crops being grown,
- Initial development costs and availability of funds, and
- Preferences and past experience of the farmer

(i) **Surface Irrigation:-** In all the surface methods of irrigation, water is either ponded on the soil or alloed to flow continuously over the soil surface for the duration of irrigation. Although surface irrigation is the oldest and most common method of irrigation (90% adopted in worldwide) , it does not result in high levels of performance. This is mainly because of



uncertain infiltration rates which are affected by year-to-year changes in the cropping pattern, cultivation practices, climatic factors, and many other factors. As a result, correct estimation of irrigation efficiency of surface irrigation is difficult. Application efficiencies for surface methods may range from about 40 to 80 per cent.

(a) Uncontrolled Flooding:-When water is applied to the cropland without any preparation of land and without any levees to guide or restrict the flow of water on the field, the method is called 'uncontrolled', wild or 'free' flooding. In this method of flooding, water is brought to field ditches and then admitted at one end of the field thus letting it flood the entire field without any control. Uncontrolled flooding generally results in excess irrigation at the inlet region of the field and insufficient irrigation at the outlet end. Application efficiency is reduced because of either deep percolation (in case of longer duration of flooding) or flowing away of water (in case of shorter flooding duration) from the field. The application efficiency would also depend on the depth of flooding, the rate of intake of water into the soil, the size of the stream, and topography of the field.

Obviously, this method is suitable when water is available in large quantities, the land surface is irregular, and the crop being grown is unaffected because of excess water.

- The advantage of this method is the low initial cost of land preparation.
- This method is the cheapest method.
- This method is sutable fore paddy, jute, bursum.
- There is a lot of water loss in this method.
- This method is inappropriate in undulated land.
- In this method water does not spread uniformly

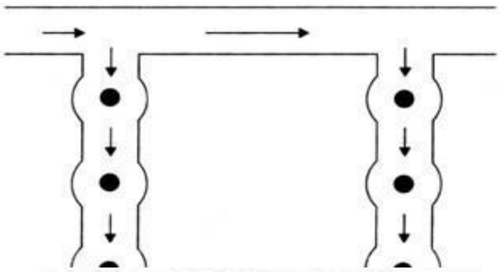
(b) Border Strip Method:-Border strip irrigation (or simply 'border irrigation') is a controlled surface flooding method of applying irrigation water. In this method, the farm is divided into a number of strips. These strips are separated by low levees (or borders

Water from the supply ditch is diverted to these strips along which it flows slowly towards the downstream end and in the process it wets and irrigates the soil. When the water supply is stopped, it recedes from the upstream end to the downsteam end. The border strip method is suited to soils of moderately low to moderately high intake rates and low erodibility. This method, however, requires preparation of land involving high initial cost

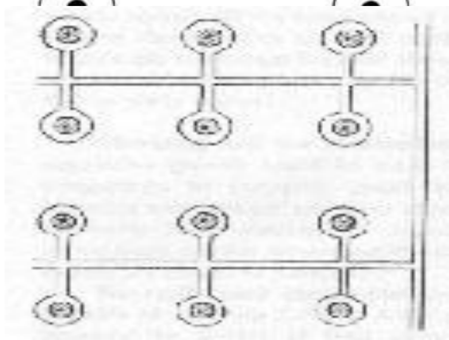
c) Check Basin Method:-The check Basin method of irrigation is based on rapid application of irrigation water to a level or nearly level area completely enclosed by dikes. In this method, the entire field is divided into a number of almost levelled plots (compartments or 'Kiaries') surrounded by levees. Water is admitted from the farmer's watercourse to these plots turn by turn.

- This method is suitable for a wide range of soils ranging from very permeable to heavy soils.
- The farmer has very good control over the distribution of water in different areas of his farm.
- Loss of water through deep percolation (near the supply ditch) and surface runoff can be minimised and adequate irrigation of the entire farm can be achieved.
- Thus, application efficiency is higher for this method.
- However, this method requires constant attendance and work (allowing and closing the supplies to the levelled plots).
- Besides, there is some loss of cultivable area which is occupied by the levees.

- Sometimes, levees are made sufficiently wide so that some 'row' crops can be grown over the levee surface.
- It is most popular method in India.
- This method is mostly adopted in wheat, barley, chick pea and vegetables.



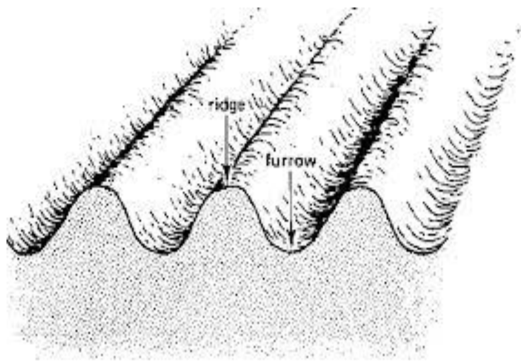
(d) Basin Method:- This method is frequently used to irrigate orchards. Generally, one basin is made for one tree. However, where conditions are favourable, two or more trees can be included in one basin. In this method there is a possibility of infections of diseases.



(e) Ring Method:- This is the most suitable method of irrigation for fruit trees. In this method diseases are not transmitted one plant to another. In this method no chance of damping off.

(e) Furrow Method:- In the surface irrigation methods, the entire land surface is flooded during each irrigation. An alternative to flooding the entire land surface is to construct small channels along the primary direction of the movement of water and letting the water flow through these channels which are termed 'furrows', 'creases' or 'corrugation'. Furrows are small channels having a continuous and almost uniform slope in the direction of irrigation. Water infiltrates through the wetted perimeter of the furrows and moves vertically and then laterally to saturate the soil. Furrows are used to irrigate crops planted in rows.

Furrows necessitate the wetting of only about half to one-fifth of the field surface. This reduces the evaporation loss considerably. Furrows provide better on-farm water management capabilities for most of the surface irrigation conditions, and variable and severe topographical conditions. For example, with the change in supply conditions, number of simultaneously supplied furrows can be easily changed. In this manner, very high irrigation efficiency can be achieved.



The following are the disadvantages of furrow irrigation:-

- Loss of water at the downstream end unless end dikes are used,
- The necessity of furrow construction,
- Possibility of increased erosion, and
- Furrow irrigation requires more labour than any other surface irrigation method.

Subsurface Irrigation:- Subsurface irrigation (or simply sub irrigation) is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. The conditions which favor sub irrigation are as follows:-

(i)Impervious subsoil at a depth of 2 meters or more, (ii)A very permeable subsoil,

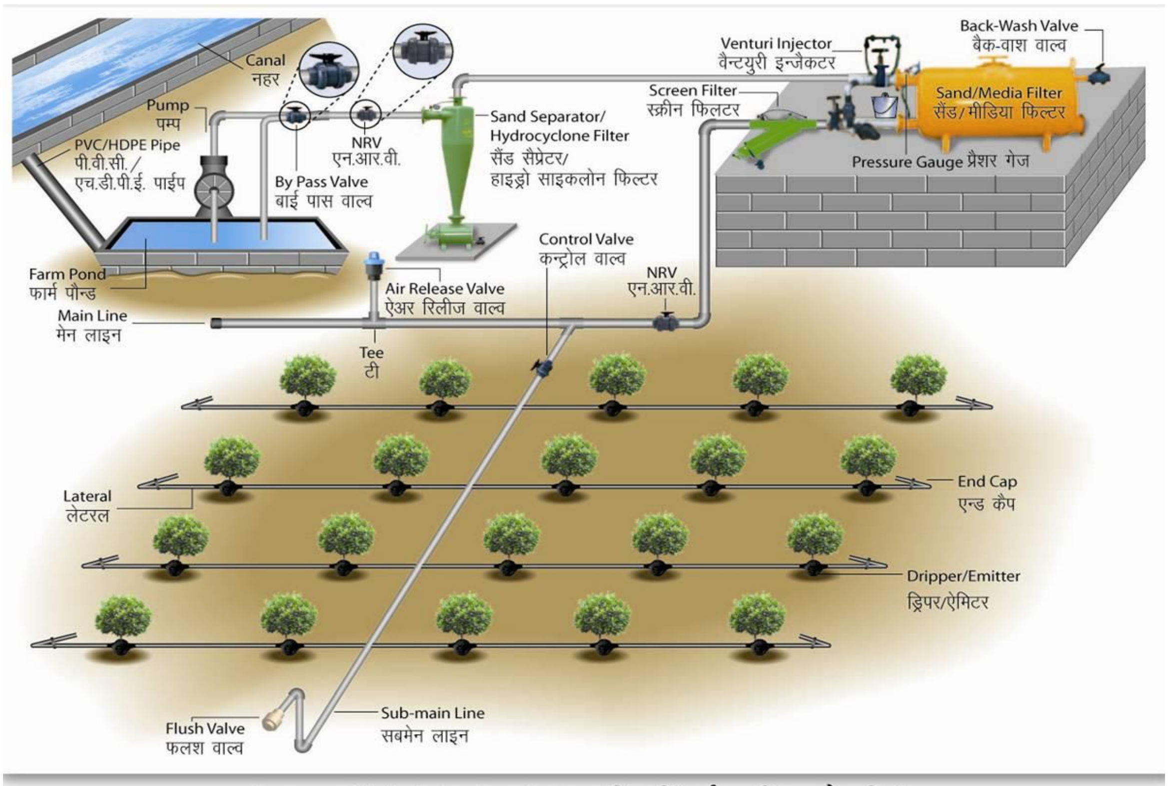
(iii)A permeable loam or sandy loam surface soil,

(iv)Uniform topographic conditions, and

(v)Moderate ground slopes.

In natural sub irrigation, water is distributed in a series of ditches about 0.6 to 0.9 meter deep and 0.3 meter wide having vertical sides. These ditches are spaced 45 to 90 meters apart. Sometimes, when soil conditions are favorable for the production of cash crops (i.e., high-priced crops) on small areas, a pipe distribution system is placed in the soil well below the surface. This method of applying water is known as artificial sub-irrigation. Soils which permit free lateral movement of water, rapid capillary movement in the root-zone soil, and very slow downward movement of water in the subsoil are very suitable for artificial sub-irrigation. The cost of such methods is very high. However, the water consumption is as low as one-third of the surface irrigation methods. The yield also improves.

Sprinkler Irrigation:- Sprinkling is the method of applying water to the soil surface in the form of a spray which is somewhat similar to rain. In this method, water is sprayed into the air and allowed to fall on the soil surface in a uniform pattern at a rate less than the infiltration rate of the soil. This method started in the beginning of this century and was initially limited to nurseries and orchards. In the beginning, it was used in humid regions as a supplemental method of irrigation. This method is popular in the developed countries and is gaining popularity in the developing countries too.



Layout of Drip Irrigation System (ड्रिप सिंचाई पद्धति का रेखाचित्र)

Rotating sprinkler-head systems are commonly used for sprinkler irrigation. Each rotating sprinkler head applies water to a given area, size of which is governed by the nozzle size and the water pressure. Alternatively, perforated pipe can be used to deliver water through very small holes which are drilled at close intervals along a segment of the circumference of a pipe. The trajectories of these jets provide fairly uniform application of water over a strip of cropland along both sides of the pipe. With the availability of flexible PVC pipes, the sprinkler systems can be made portable too.

Sprinklers have been used on all types of soils on lands of different topography and slopes, and for many crops.

The following conditions are favourable for sprinkler irrigation:-

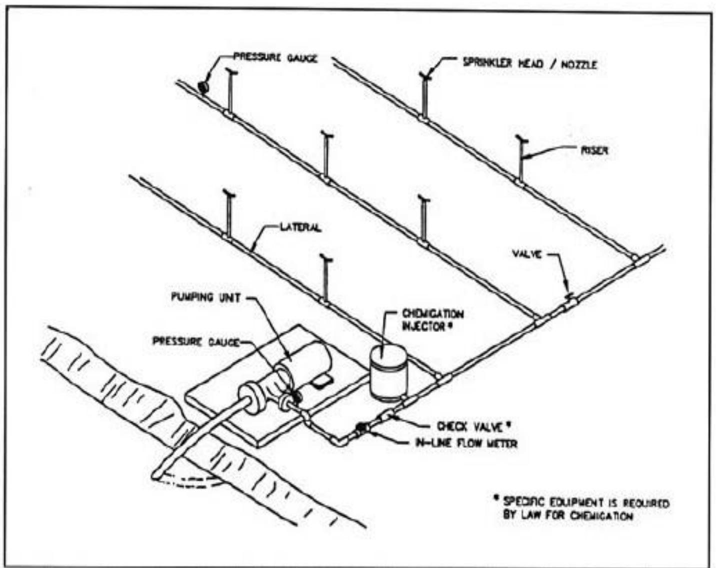
- Very previous soils which do not permit good distribution of water by surface methods,
- Lands which have steep slopes and easily erodible soils,
- Irrigation channels which are too small to distribute water efficiently by surface irrigation, and
- Lands with shallow soils and undulating lands which prevent proper leveling required for surface methods of irrigation.

Advantages:-

- In the method, approximately 80 percent of the water is consumed by plants, whereas in conventional method only 30 percent of the water is used.
- In this method save 30-50% water.
- In this method the pressure is kept 2-2.5kg / cm^2.
- Saving in fertilizer
- Suitable for any topography
- No soil erosion
- Better seed germination, free aeration of root zone.
- Uniform application of water.

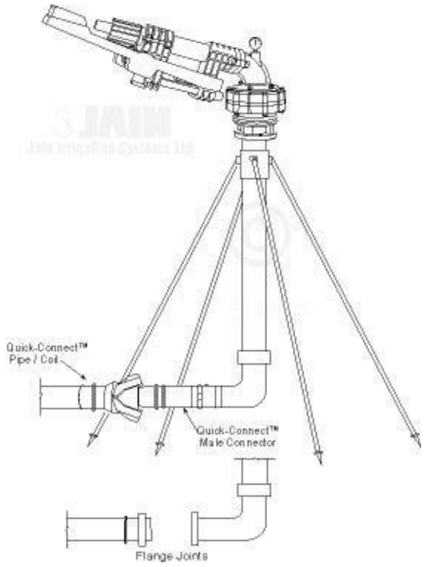
Disadvantages:-

- High initial cost, cannot adopt by ordinary farmers
- Poor application efficiency in windy weather and high temperature
- High evaporation losses
- Water should be free of debris
- Equipments need careful handling
- Physical damage to crops by application of high intensity spray
- Power requires for running pumping unit.
- It is not suitable for tree.



Trickle (Drip) Irrigation:-

Trickle irrigation (also known as drip irrigation) system comprises main line, sub mains, laterals, valves (to control the flow), drippers or emitters (to supply water to the plants), pressure gauges, water meters, filters (to remove all debris, sand and clay to reduce clogging of the emitters), pumps, fertilizer tanks, vacuum breakers, and pressure regulators. The drippers are designed to supply water at the desired rate (1 to 10 liters per hour) directly to the soil. Low pressure heads at the emitters are considered adequate as the soil capillary forces causes the emitted water to spread laterally and vertically. Flow is controlled manually or set to automatically either deliver desired amount of water for a predetermined time, or supply water whenever soil moisture decreases to a predetermined amount.



Advantages:-

- Low water loss and hence saves water
- Enhances plant growth and plant yield
- Saves labor and energy
- Control weed growth
- No soil erosion
- Improves fertilizer application efficiency.
- With this method water saving is 50-70%.
- By this method, fertilizer savings are 30-60%.
- Production increases by 20-40%.
- The most useful method for saline and alkaline soil is.
- In this method, the water from which water is drip is called a dripper or a meter.
- Rajasthan remains the most problem in this method.
- In this method the pressure is kept 2.5kg / cm2.

Disadvantages:-

- High skill in design, installation, and subsequent operation
- Clogging of small conduits and openings in emitters due to sand, clay particles, debris, chemical precipitates and organic growth
- Not suitable for closely planted crops such as wheat and other cereal grains.

Rain gun Irrigation Method:- Rainguns are available with operating pressure of 2.0 to 7.5 kg/cm2 and flows of 3 to 30lps usually with nozzle diameters ranging from 10 to 30 mm and with a wetting radius of 27 to 60 metre.

Matka Irrigation Method: - The conditions of the clocks in the farm should be determined. This distance is kept low for more and direct stagnant crops for the crops that are cultivated. In order to place the pitcher, it should be kept separately by digging the pits of 60 cm deep and 90 centimeters in diameter. Mix the dirt of the soil (less than one centimeter) and add the basic amount of fertilizer and fertilizers (phosphorus and potash) in it. If necessary, land treatment medication should also be provided. Mix the nitrogen with soil in the first 30 centimeter layer in the pits for irrigation through the clay. After this, placing the pitcher in the pits and clogging the clay around the pitcher. Through which the plow will go completely inside the ground. A heavy layer of sand is kept around the pitcher in a heavy soil farm. In the absence of good contact, the water will either not get out of the pitcher or the drift will be irregular. The pitcher should be filled with clean water. To fill the pitcher, apply two to three days after 6 to 8 plants or seeds around the pitcher. These plants or seeds must be around four distances similar to the pitcher. In fact, plants will develop from water and moisture emanating from the pitcher.

Water Requirement

Crops	**Water requirement (mm)**
Rice	900-2500
Wheat	450-650
Sorghum	450-650
Maize	500-800
Sugarcane	1500-2500
Groundnut	500-700
Cotton	700-1300
Soybean	450-700
Tobacco	400-600
Tomato	600-800
Potato	500-700
Onion	350-550
Chilli	500
Sunflower	350-500
Castor	500
Dolichus been	300-500
Cabbage	380-500
Pea	350-500
Banana	1200-2200
Citrus	900-1200
Pineapple	700-1000
Ray	400-450
Grapes	500-1200

Critical Stage for Irrigation of different crops

Crops	Critical Stages
Rice	Initial tillering, flowering
Wheat	Most critical stage: Crown root initiation, tillering, jointing,. booting, flowering, milk and dough stages
Pulses	Flowering and podding.
Peas	Pre bloom stage.
Berseem	After each cutting.
Gram	Pre flowering and flowering.
Pigeonpea	Flower initiation, pod filling.
Sorghum	Initial seedling, pre flowering, flowering, grain formation.
Barley	Boot stage, dough stage
Maize	Early vegetative, taselling and silking stage.
Groundnut	Flowering, Pegging, and Pod filling
Sesames	Flowering and Ripening
Sun flower	Before flowering and after flowering
Soybean	Flowering stage, Dough Stage
Mustered	Before Flowering, pod filling
Linseed	Before Flowering, pod filling
Sugarcane	Germination, Tailoring Stage, growth stage
Cotton	Sympodial branching and square formation stage, Flowering and fruiting stage, Peak boll formation, Boll development and boll opening stage
Tobacco	Immediately after transplanting and knee stage.
Citrus	Fruit setting and enlargement stage.
Banana	Early vegetative period, flowering and yield formation.
Tomato	From the commencement of fruit set.
Potato	Tuber initiation to tuber maturity.
Cabbage	Head formation until become firm.
Carrot	Root enlargement.

Practice

Multiple Choice Question

1. CRI is related to:-
a. Wheat b. Rice c. Maize d. Sugarcane
2. Field capacity is:-
a. -31 atm b. -15 atm c. -1/3 atm d. 0 atm
3. Maximum water requirement crop is:-
a. Wheat b. Rice c. Maize d. Sugarcane
4. Which one is available water for plant?
a. Capillary water b. Hygroscopic water c. Gravitational Water d. All of theses
5. Water requirement of wheat is?
a. 400-500mm b. 450-650mm c. 600-800mm d. 1200 mm

Fill in the blank

1. ……………… is the process by which water on the ground surface enters the soil.
2. WR = ……………. + application losses + water needed for special operations.
3. In drip irrigation pressure is kept …………………kg / cm2.
4. All soil pores are filled with water is known as…………………
5. Taselling and silking stage of irrigation is………………..

Descriptive

1. Describe the Drip Irrigation?
2. Write down the biological classification of soil water?
3. Write down the advantage and disadvantage of sprinkler irrigation?
4. Write down the critical irrigation stage of Wheat, Maize, Sugarcane and Groundnut.
5. Write a summery on rain gun.

7. Method of Insect-Pest Management Chemical, Biological and Mechanical. Concept of Integrated Pest Management.

Insect-Pest Management

Introduction

Insects are found in all types of environment and they occupy little more than two thirds of the known species of animals in the world. Insects affect human beings in a number of ways. Many of them fed on all kinds of plants including crop plants, forest trees, medicinal plants and weeds. They also infest the food and other stored products in godowns, bins, storage structures and packages causing huge amount of loss to the stored food and also deterioration of food quality. Insects inflict injury to plants and stored products either directly or indirectly in their attempts to secure food. Insects that cause less than 5 % damage are not considered as pests. The insects which cause damage between 5 - 10% are called minor pests and those that cause damage above 10% are considered as major pests. Insects that cause injury to plants and stored products are grouped into two major groups namely chewing insects and sucking insects. The former group chews off plant parts and swallow them thereby causing damage to the crops. Sucking insects pierce through the epidermis and suck the sap. Many of the sucking insects serve as vectors of plant diseases and also inject their salivary secretions containing toxins that cause severe damage to the crop.

Introduction of high yielding varieties, expansion in irrigation facilities and indiscriminate use of increased rates of agrochemicals such as fertilizers and pesticides in recent years with a view to increase productivity has resulted in heavy crop losses due to insect pests in certain crops. This situation has risen mainly due to elimination of natural enemies, resurgence of pests, and development of insecticide resistance and out-break of secondary pests.

Insect-Pest Control Method

A. Cultural Control

Surprisingly simple modifications of a pest's environment or habitat often prove to be effective methods of pest control. As a group, these tactics are usually known as cultural control practices because they frequently involve variations of standard horticultural, silvicultural, or animal husbandry practices. Since these control tactics usually modify the relationships between a pest population and its natural environment, they are also known, less commonly, as ecological control methods. Simplicity and low cost are the primary advantages of cultural control tactics, and disadvantages are few as long as these tactics are compatible with a farmer's other management objectives (high yields, mechanization, etc.). Unfortunately, there are still a wide variety of insect pests that cannot be suppressed by cultural methods alone. There are following practice done for cultural control:-

1. Crop Rotation:- Certain pests are more common in some crops than in others. Rotating crops to different sites can isolate pests form their food source or can change the conditions pests must tolerate. If another site is not available, change the type of crops grown in the garden plot. Do not put members of the same plant family in the same location in consecutive seasons. For example, do not follow melons with cucumbers or squash. This is also true for rotations using green manure crops, which add organic matter to the soil when they are tiled in before they produce flowers or seeds. Waiting two years to plant the same family of vegetable in the same location is the most effective rotation practice; however, yearly rotations can also be beneficial. Rotating annual flower plantings is also a good practice.

2. Sanitation:- Sanitation is another cultural control strategy that may be highly effective for some pests. Removing crop debris from cotton fields after harvest eliminates overwintering populations of pink bollworms (*Pectinophora gossypiella*), European corn borers (*Ostrinia nubilalis*), and sugarcane borers (*Diatraea saccharalis*). Collecting dropped fruit from beneath an apple tree reduces the next season's population of apple maggots (*Rhagoletis pomonella*), codling moths (*Cydia pomonella*), and plum curculio (*Conotrachelus nenuphar*). Shredding or burning the pruning wood from a peach orchard kills shothole borers (*Scolytus rugulosus*) and lesser peach tree borers (*Synanthedon pictipes*) that would otherwise emerge and rein fest the orchard. Clean cultivation is often recommended as a way to eliminate shelter and/or overwintering sites for pest populations. Simply tilling or ploughing a corn field before winter may disrupt a pest's life cycle by causing mechanical injury, by increasing exposure to lethal cold temperatures, by intensifying predation by birds or small mammals, or by burying the pests deep beneath the soil surface. Populations of corn earworms and European corn borers have been greatly reduced in recent years by community-wide efforts to plough under corn stubble after harvest.

3. Soil Solarization:- A clear plastic sheet spread over the soil traps solar heat, which kills soil borne diseases, insects, nematodes, and many weed seeds. The treatment should occur during summer’s high air temperatures and intense solar radiation. Keep the soil damp during the solarization process, and keep the plastic in place for several weeks.

4. Timed Plantings and Harvests:- Many crops may be planted or harvested early to miss heavy pest infestations, while still achieving a full yield. Planting earlier than normal may involve the use of cold frames or hot caps to protect seedlings form the weather while they get a head start growing. The crop then has a competitive edge over pests. Early planting depends upon the gardener knowing the emergence times and life cycles of the pests to be controlled.

5. Resistant Varieties:- When buying seeds or plants, try to choose those with built-in resistance to diseases and nematodes.

6. Intercropping:- Intercropping (also known as mixed cropping) is another way to reduce pest populations by increasing environmental diversity. In some cases, intercropping lowers the overall attractiveness of the environment, as when host and non-host plants are mixed together in a single planting. But in other cases, intercropping may concentrate the pest in a smaller, more manageable area so it can be controlled by some other tactic. Strips of alfalfa, for example, are sometimes interplanted with cotton as a trap crop for lygus bugs (Miridae). The alfalfa, which attracts lygus bugs more strongly than cotton, is usually treated with an insecticide to kill the bugs before they move into adjacent fields of cotton.

7. Certified Plants:- When they are available, consider buying plants labelled as “certified” or grown and inspected under sterile or quarantined conditions. Certified plants may cost more than others, but the certification guarantees they are free of diseases. Strawberries and potatoes are among crops which may be offered as certified plants.

8. Allelopathy:- Allelopathy, a natural chemical interaction among plants, has been the subject of much research recently. Allelopathy refers to stimulatory as well as inhibitory properties. A living plant may release toxins, or in the case of decaying plant tissues, microorganisms may play a role in the release of the toxin. The microbes may also modify nontoxic compounds into toxic compounds. Black walnut trees and Johnson grass are among plants that have been shown to inhibit the growth of winter annual weeds and may offer some control of root knot nematode.

B. Mechanical Control

Destruction of the pest by mechanical means such as burning, trapping, protective screens and barriers or use of temperature and humidity is often useful.

1. Handpicking:- When the infestation is low, the pest is conspicuous and labor is cheap, the pest stages can be destroyed by mechanical means. Eggs of grasshoppers can be destroyed by hand. Alfalfa aphids can be killed by using chain drags on plants less than 10 inches long. Locust nymphs which are congregating can be beaten by sticks and brooms. European corn borer in the stalk can be killed by running the corn stalks through the stalk shredder. Handpicking of sugarcane borer eggs, cabbage butterfly eggs, sawfly larvae on mustard, *Papilio* larvae from citrus plants and stages of *Epilachna*beetle is very effective, especially in small areas.

2. Burning:- Controlled burning is sometimes recommended to control certain pests. Weedy fallows harboring European corn borers are burnt to destroy overwintering pest stages. To eradicate the pink bollworm dried cotton stalks are piled and dried. Trash and garbage, weeds etc. are collected and burnt to destroy pest stages. Flamethrowers are used to burn locust hoppers and adults that are congregating and marching.

3. Trapping:- Trapping is popular method to lure insects to bait, light etc. to kill them. Traps usually fail to give adequate crop protection but prove useful to know population build up and are convenient to collect insect samples. Many trap designs have been developed room time to time to suit different insect species. Hopper-dozers were formerly used to collect grasshoppers. In these the insects after hitting the back of the machine fall to the bottom and then through a narrow opening collect into a box. Yellow-pan traps containing water and few drops of oil were proved useful in killing hopper adults on paddy, sugarcane and wheat crops. Sticky traps are boards of yellow color smeared with sticky substance, which trap and kill the flying insects that are attracted to and try to rest on it. Pitfall traps are pan-like containers bearing insecticide and embedded below the ground level. Crawling and fast-running insects often fall into them and die. Light traps attract night-flying insects, which fall into a container having insecticide, water or oil, or hit an electric grid. Light source emitting UV light is most attractive to insects. Pheromoe traps are particularly effective against the lepidopterous pests. Females release specific pheromone to which males are attracted from considerable distance.

4. Barriers:- In certain instances, barriers may prevent insects from infesting the crop. Cloth screens over seedbeds protect the younger plants from insects, like flea beetles, hoppers, armyworms etc. Metal collars around young plants protect them from cutworms. Trench barriers are used to stop chinch bugs, armyworms, locusts etc. Metal or concrete barriers are used against termites. Barrier spraying of residual insecticides has become more popular against termites, locusts and several other insects. Sticky bands applied around mango tree-trunks during December-January prevent the upward movement of mango mealy bugs, which upon hatching begin to crawl up the trunk to reach the leaves.

5. Temperature control:- Temperature extremes are fatal to insects. This method is used against stored grain pests. Low temperatures that are enough to dormancy can prevent damage. Low temperatures are utilized for the control of insects in flourmills and warehouses. Exposure to subzero temperature for 24 hours is lethal to most of the insects.

6. Drying:- Insects infesting stored grains require certain amount of moisture to develop. Neither the rice weevils nor the granary weevils can survive moisture contents as low as 8.0%. Drying the grains either in the sun or by heat blowers reduces infestation of majority of stored grain insects.

7. Radiation:- Gamma radiation kills all stages of the pests in storage conditions. This is a common method employed to kill insect stages during export or imports of huge quantities of grains, fruits and vegetables.

8. Ultrasonic vibrations:- Moths are often sensitive to bats' ultrasonic signals and quickly escape from the area. Imitation of the bat's echolocation system helps in scaring away the lepidopterous insect pests from the area.

C. **Biological Control**

Regulation of pest abundance below the level of economic injury is the target of biological control, which is usually done by study, importation, augmentation and conservation of beneficial organisms for the regulation of harmful animal's population. Most of the agricultural pests are insects and these have natural enemies, which are also mostly insects. Therefore most of the examples of biological control come from insects.

Definition:- Biological control is the action of natural enemies (parasites, predators and pathogens) in maintaining another organism's population density at a lower level than would occur in their absence.

The importance of biological control has lately been enhanced due to the fact that overwhelming use of insecticides has led to the resurgence of the pests and resistance to insecticides by the pests like mosquitoes, houseflies and stored grain pests. Biological control is based on the utilization of ecological principles; hence it is frequently called Applied Ecology. Maintenance of the balance of nature is an important aspect of biological control.

Natural Biological Control:- includes role of natural enemies to contain pest populations in an undisturbed environment.

Applied Biological Control:- includes manipulation of biotic factors (natural enemies) by man to reduce the population of a pest species.

Pests of foreign origin usually do not cause serious damage in their native country because there they are kept under check by natural enemies. But when accidentally introduced into a new country they multiply unchecked and become serious pests. Role of biological control is to find out natural enemies of such pests and introduce them in the areas of pest outbreak. Against pests of domestic origin also exotic natural enemies of species closely related to the indigenous pest are imported and released.

Examples: Control of cottony cushion scale (*Icerya purchasi*) by using vedalia beetle (*Rodolia cardinalis*) in California in 1988 is an outstanding success story. In 1887, citrus industry in California suffered massive destruction by the cottony cushion scale. Chemical control had failed.

A German scholar, Albert Koebele, was assigned the job to find out natural enemies of this pest in its native home, Australia and New Zealand. In Australia, Koebele found a ladybird beetle, *Rodolia cardinalis* and a dipteran fly, Chryptochaetum feeding on the pest stages. He dispatched many consignments of the two species to USA for release in the orchards. Chryptochaetum failed to establish but Rodolia multiplied so fast that by July, 1889 the scale was virtually wiped out from the valley.

Another outstanding example is the control of cactus, *Opuntia stricta* by the Argentine moth, *Cactoblastis cactorum* in Australian grasslands in 1927-30.

Bacillus thuringiensis is a pathogen which is widely used to control caterpillars of many pest species commercially.

Many outstanding works on biological control have been done in Australia, Canada, Chile, Fiji, Hawaii, Japan, New Zealand, and India. Successes have been reported in over 60 countries. Commonwealth Institute of Biological Control, with headquarters in London and Indian station at Bangalore, is noteworthy for its contribution.

Some terms and definitions

Parasite:- An organism that derives its nutritional requirements from another organism, killing it slowly or not killing it at all.

Predator:- When one organism kills another instantly for food.

Ectoparasite:- Parasites which feed on the host from outside their bodies. Examples are larvae of parasitic Hymenoptera and Diptera.

Endoparasite:- Parasites which live inside the body of the host and derive their nutrition from it.

Parasitoid:- Larvae of Diptera and Hymenoptera which live as parasites in early stages but behave like predators when nearing maturity and kill the host before emergence.

Protelian parasites:- Insects in which only the immature stage is parasitic and not the adult. Examples are parasitic Hymenoptera and Diptera.

Superparasitism:- When a parasite oviposits in a host, which is already parasitized by the parasite of the same species.

Hyperparasitism:- When a parasite develops on another parasite, which is on the host. The parasite that attacks the host is called primary parasite and the one that attacks the primary parasite is calledsecondary parasite.

Multiple parasitism:- When two or more species of parasites oviposit in the same host. Normally only one parasite manages to develop to maturity.

Applied biological control is practiced in the following three ways:

1) Importation and colonization of exotic natural enemies:- When the target pest is of foreign origin, it is always advantageous to search for its natural enemies in the country of its origin. It is taken as a general rule that the predominant natural enemy occurring at relatively low host densities in the native home offers greatest promise for introduction to new environment. Usually the dormant stage of the parasite (eggs or pupae), or the dormant stages of the parasitized host are shipped. Releases should be timed with the availability of the host stages to be parasitized. To evaluate the effectiveness of the natural enemy introduced, samples are collected at regular intervals and analyzed as life-table data.

2) Conservation and inundative releases of indigenous natural enemies:- Conservation of natural enemies demands judicious and minimal use of insecticides on crops, so that parasites and predators are not unnecessarily killed. Selective insecticides which are not harmful to the natural enemies are used, such as organophosphates and methyl esters. Use of favorable application technique, e.g. soil application of systemic insecticides, seed treatment and use of baits, helps to conserve the natural enemies. Sometimes natural enemies are collected from the field, mass-bred in labs and then released in the field, much like biological insecticides, e.g. use of Trichogramma and Bacillus thuringiensis.

3) Manipulation of natural enemies:- When a parasite or predator fails to become effective, ecological, biological and physiological studies are conducted to find out reasons for failure. There are various possible ways of enhancing the effectiveness of natural enemies as follows:

- Development of resistant strains of parasites by artificial selection under controlled conditions.
- Provision for supplementary food for adults.
- Use of behavior modifying chemicals (semiochemicals) is sometimes helpful. Extracts of tomato sprayed on corn increases parasitization of *Heiothis zea*. The predator Chrysopa is strongly attracted to honey dew of aphids. Synomones are chemicals produced by plants which attract natural enemies and Kairomones are chemicals released by host insects that attract natural enemies.
- Genetic improvement of natural enemies by hybridization and artificial selection of different strains, which increases vigour and effectiveness of

parasites and sometimes even resistance to insecticides. Intercropping is known to augment parasitic activity.

Advantages and disadvantages of biological control

Advantages:- It is a long-time self-perpetuating control of the target pest. Unlike insecticides, there is no fear of pest developing resistance. There is no fear of environmental pollution. In this method balance of nature in the ecosystem is not disturbed. This is a long-term control method and cost of controlling the pest is economical. There is no fear of pest resurgence, as normally happens by the application of insecticides.

Disadvantages:- Biological control is a long-term process and takes years before natural enemies could be established and during this period the pest can cause immense damage. Often natural enemies fail to establish, leading to failure of the entire programme. In case of pest outbreak, biocontrol fails to provide immediate relief. In some cases a natural enemy also damages some useful animals or plants. Biocontrol doesn't provide surety. The projects usually have equal chances of failure or success.

Some Indian examples of biological control

1. Biological control of cottony cushion scale in southern India by the introduction and release of *Rodolia cardinalis* from USA in 1928.
2. Control of woolly apple aphid, *Eriosoma lanigerum*, by *Aphelinus mali* introduced from USA in 1941.
3. Partial control of San Jose scale by the introduction and release of *Prospaltella perniciosi* and *Aphytis diaspiditis* from USA in 1961.
4. Control of sugarcane stem borers in some states of India by inundative releases of *Trichogramma minutum, T. japonicum* and *T. australicum*.
5. Control of Lantana weed by the anthocorid bug, *Teleonemia scrupulosa* along the foothills of Himalaya.
6. Biological control of mosquito larvae by the fish *Gambusia* and *Nothobranchius guntheri*.
7. Partial control of *Opuntia spp*. by the cochineal insect, *Dactylopius tomentosus* introduced from South America in 1900.

D. Chemical control of pests

It is the pest control using the chemical pesticides. A pesticide is a chemical used to prevent, destroy, or repel pests. They combat pests and deseases occuring on our crops, livestock and our possessions.

Classifications of pesticides

1. **Sphere of activity:-** They are classifies according to the usefulness
- **Acaricides-** used to control ticks and mites Eg:carbophenothion
- **Insecticides-**Used to control insects Eg:Carbofuron
- **Fungicides-** used to control fungal diseases in plants Eg:Menab
- **Herbicides-** Used to control weeds Eg: MCPA
- **Nematicides-** Chemicals used to control nematodes Eg:Phenamiphos
- **Rodenticides-** Chemicals used to control rats Eg:Coumarin
2. **Mode of action Contact poison:-**
    - **Systematic Pesticide:-** Systemic pesticides are chemicals that are actually absorbed by a plant when applied to seeds, soil, or leaves. The chemicals then circulate through the plant's tissues, killing the insects that feed on them.
    - **Non- Systematic Pesticide:-** Non-systematic pesticide are chemical that are kill any pest when they are contacted with pest.
3. **Chemical constituents:-**
    - **Botanical compounds:-** Eg: Pyrethroids-produced by the ground flowers of daisy *Chysanthemum cinerariaefolum*.
    - **Synthetic organic compounds:-** Organochlorines-insecticides containing C,H, and O. Eg:DDT, Aldrin.
    - **Organophosphorus:-** They are made up of organic molecules containing phosphorus. Carbomates-Structurally esters of unstable carbonic acid.
    - **Microbial compounds:-** Commercially produced insecticides from the natural pathogens of insect .Eg. Bacillus thurengiensis.
    - **Growth regulator compounds:-** Novel compounds which inhibit synthesis in insects. Eg: Atabrai-cabbage caterpillar control, Applaud-brown plant hopper control.
    - **Synthetic pyrethroids:-** They are synthesized from petroleum based chemicals
4. **Types of pesticide formulation:-**
    - Dusts
    - Granules
    - Emulsifiable concentrate (EC)
    - Flowables
    - Wettable powders
    - Poisonous baits

Application of pesticides:- There numerous ways,but knapsack sprayer is the post popular spray equipment.

Advantages and disadvantages of chemical pest control

Advantages

- Cost effectiveness
- Timeliness and flexibility
- Quality, quantity and price of produce
- Prevention of problems
- Protection of the environment

Disadvantages:-

- Reduction of beneficial species. Non-target organisms, including predators and parasites of pests
- Drift of sprays and vapour during application can cause severe damage and residue problems in crops
- Residues in food for humans and feed for livestock
- Ground water contamination by leached chemicals
- Resistance to the pesticide used can develop in target pests due to overuse and incorrect use of the chemical.
- Poisoning hazards and other health effects Poisoning hazards and other health effects

Integrated Pest Management

Integrated Pest Management (IPM) is that method of pest control, which utilizes all suitable techniques of pest control to reduce pest populations and maintain them below economic injury level.

IPM is also defined as a stable system of crop protection, which based on the ecological relations within the crop and the environment, combines several methods of pest control in such a way that the pest is prevented from causing economic injury.

The idea of integrated control emerged independently in California and in Netherlands, where it was first known as harmonic control. The term pest management arose in Canada and Australia. It is also called protective management and was originally coined to define the blending of biological control agents with chemical control because these techniques used independently, either failed to produce satisfactory results or caused environmental problems. Therefore, need arose to consolidate these two methods and also other possible means into a unified programme to manage pest population so that economic injury is avoided.

Components of Integrated Pest Management

Various components and techniques that can be utilized in Integrated Pest Management programmes are as follows:

1. Cultural control: Use of resistant varieties of crops is a promising technique in IPM. Moderately to low level of resistance is best integrated with chemical and biocontrol agents. Crop rotation and sanitation are also used to reduce the pest population to lower levels.

2. Mechanical control: Use of screens or barriers or handpicking in nursery stage of the crops and use of light traps to kill egg-laying adults can bring down the population for the other methods to be effective.

3. Biological control: Natural enemies are commonly utilized in IPM programmes. Emphasis is given to protection and augmentation of indigenous natural enemies and recolonisation of those that have been wiped out due to indiscriminate use of insecticides.

4. Chemical control: Minimal use of insecticides is recommended in IPM. Rule of the thumb is not to use insecticides unless absolutely necessary. Application methods that do not bring insecticides in contact with natural enemies are favoured in IPM programmes

5. Regulatory methods: Plant and animal quarantines by the government and collective eradication and suppression in large areas help in providing long-lasting management. International efforts to suppress noxious pests like locusts have proved fruitful.

In most of the cases, chemical, biological and varietal resistances are combined to manage the population of pest species.

Role of biological control in IPM

Being safe, permanent and economical, biocontrol should be of primary consideration in any IPM programme and should not be taken up only when other methods fail. In IPM biological control need not achieve complete success, since other methods combined also contribute in achieving the goal.

There are three major ways to integrate biological control in IPM programmes:

1. Conservation and augmentation of natural enemies already available,

2. Importation and colonization of exotic natural enemies and

3. Mass culture and release of indigenous as well as exotic natural enemies.

Conservation is done by using selective insecticides to which natural enemies are resistant or use of soil application methods or habitat management like planting of nectar producing flowering plants in the vicinity of the crop. Cultural practices which maintain diversity of crops in the area are usually beneficial for the natural enemies. Intercropping of selected crops is known to augment parasitic activity. Integration of moderately resistant crop varieties with natural enemies is currently a popular component of pest management.

Role of insecticides in IPM

When pest populations reach above tolerable levels, insecticides provide immediate control. But great majority of insecticides are broadly toxic and therefore ecologically disruptive. Great need for IPM is to develop selective or even specific insecticides which will have negligible effect on non-target species. Modification of dosage, times of application, formulations and placement of material can be utilized to increase selectivity of chemicals. Successful use of pesticides of mites illustrates bright future for selectivity. Use of pheromones, hormones, repellents, antifeedants and sterilants are selelective in their action and hence must be encouraged.

An elementary integration is the application of insecticides and pheromone traps to reduce male population of the pest before undertaking control through sterile male technique, since the latter is more successful at lower pest densities. An example is the control of Mediterranean fruit fly *(Ceratitis capitata)* onProcida Island in Italy.

Role of varietal resistance in IPM

Use of resistant varieties is a less utilized concept. A low plant resistance is better since it does not impose too much stress on the pest species to change its behavior and develop biotypes. It also harbors natural enemies at low pest densities. A highly resistant crop, on the other hand, wipes out not only the pest species but also the specific natural enemy fauna from the area.

An interesting integration of resistance, cultural practice and chemical control is the planting of trap crop of a susceptible variety or attractive crop on the borders and main crop in the middle, and then spraying only on the susceptible variety where the pest would naturally congregate.

An integration of resistance and biocontrol was shown in California by planting moderately resistant variety of barley and sorghum which complemented the activity of the parasite *Lysiphlebus testaceipes* in reducing green bug (*Schizaphis graminum)* population. Advantages of varietal resistance in IPM programmes include: its specificity, easy compatibility with other methods, cumulative effect is carried through generations over a long period and non-disturbance of ecosystem.

Examples of Integrated Pest Management

1. Cotton pest control in Peru: Developed by Wille (1951) in Canete Valley which is a self-contained ecosystem surrounded by arid areas. Due to extensive use of organic insecticides and subsequent resistance developed by the cotton pests, the valley was led to the brink of disaster. The following steps were taken to save the crops:

- Prohibition of ratooning.
- Prohibition of synthetic organic insecticides and return to the old calcium and lead arsenates and nicotine sulphates.
- Repopulation of the area with; natural enemies introduced from the surrounding regions.
- Establishment of deadlines for planting, ploughing, irrigation, pruning and harvesting.
- Employment of cultural practices, which led to the establishment of healthy, uniform stands.

As a result of this IPM programme, the pest problem was solved and the whole agro-ecosystem twined into a self-balanced system.

2. Integrated Pest Management in Paddy: FAO developed an intercountry programme for IPM in South andSoutheast Asia by integrating biological, chemical and cultural control methods.

3. Integrated Pest Management in Sugarcane: Chemical control is not successful in sugarcane fields because of technical and mechanical problems of insecticide applications and also insecticide contamination eventually reaching humans. Integration of biological contraol, particularly the egg parasite, *Trichogramma*species and modification of cultural practices has been found to keep the pest densities below economic injury levels.

4. Integrated control of locusts: FAO undertakes constant surveillance throughout the breeding areas and follows the following IPM programme: Eggs are destroyed by ploughing or flooding (mechanical control). Nymphs are controlled either by direct spraying by aircrafts or by barrier spraying, baiting, trenching or burning by flame-throwers. Repellents like neem-oil are sprayed on crop at the time of swarming. Swarms are either sprayed while resting on ground or by aircrafts while migrating. Some biological control is achieved by conserving predators in the breeding grounds.

Practice

Define the below mentions

1. IPM
2. Soil Solarization
3. Systematic Pesticide
4. Pesticide
5. Fungicide
6. Biological control of Insect-Pest
7. Parasitoid
8. Protelian parasites
9. Superparasitism
10. Hyperparasitism

Descriptive

1. Describe the IPM.
2. Write down the advantage and disadvantage of Biological control.
3. Draw the flow chart of IPM.