10. In a two year rotation sequence, three crops were grown on the entire farm area. Calculate the cropping intensity of the land.

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8. PLANT NUTRITION

8.1 INTRODUCTION:

Plants need food for their growth and development. All green plants are autotrophic or self-nourishing, i.e. they are able to manufacture carbohydrates. For this purpose they require inorganic raw materials or mineral elements, which are called plant nutrients or essential elements.

Plants cannot complete their life cycle in the absence of essential elements. They are directly involved in plant metabolic processes as an essential constituent of a biomolecule or required for the action of an enzyme system. Such activities are needed for the energy transformation and maintenance of cellular organization within the plants. Hence lack of essential elements causes characteristic deficiency symptoms. The supply of such elements and their absorption and utilization by the plants is referred to as plant nutrition.

8.2. ESSENTIAL NUTRIENTS:

There are several known essential plant nutrients. They have different functions at various stages of the growth and development of plants. Each element is required in different concentration by the plants. Accordingly they are classified as (i) macronutrients or the major elements and (ii) micronutrients or minor/trace elements.

I. MACRONUTRIENTS:

Plant nutrients that are needed in reletively large quantity (more than 1000 µg per kg dry matter) are known as macronutrients or major elements. These include: nitrogen (N), phosphorus (P), potassium (K). calcium (Ca), magnesium (Mg) and sulphur (S). The first three (NPK) are used by the plant in compratively larger quantity than the other three (Ca, Mg, S). Hence, NPK are catagorised as primary and the others as secondry macronutrients.

ii. MICRONUTRIENTS.

Some mineral elements are required by the plants in the smallest (minute/trace) amounts (100 µg/kg or less). They are called micronutrients or minor elements or trace elements. These include:zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), molybdenum (Mo), boron (B), and chloride (Cl). In addition, certain plant species have been shown to use cobalt (Co), sodium (Na), and silicon (Si). However, these are not considered essential for the growth, development and reproduction of plants.

8.3 NITROGEN (N)

Nitrogen plays a major role in plant physiology. It is an important constituent of chlorophyll, protoplasm, protein, amino acids, nucleic acids and growth hormones. It directly affects photosynthetic activity of the plants. Plants normally contain between 1.0 to 4.0% N in their dry matter. Nitrogen is taken up by the plants in the form of ammonium and nitrate ions. It is then converted to other compounds.

Nitrogen is most essential for: (i) leaf enlargement and thickness, (ii) branching / tillering, flowering, fruit setting and (iii) root development and expansion. For these reasons, nitrogen increased crop yield and improve quality. It makes leafy vegetables and fodder more succulent. It also enhanced the nutritive value of food and feed by increasing their protein content.

Nitrogen deficiency causes stunted growth, delayed maturity and pale green or yellow colour (chlorosis) of the leaves. The lower leaves die soon. Roots become thinner and redish

brown. An excess of nitrogen leads to more vegetative growth and cause lodging.

8.4 PHOSPHORUS (P)

It is a structural component of the membrane system of the cell, the chloroplasts and mitochondria. Phosphorus is a key element in the formation of high energy compounds, such as AMP, ADP and ATP (adenosine mono-di-, and triphosphate), which play essential role in photosynthesis and respiration. It is a vital component of nucleic acids and phospholipids and certain co-enzymes (e.g. NAD, i.e Nicotinamide adenosine dinucleotide, NADP, i.e. Nicotinamide adenosine dinucleotide phosphate).

Phosphorus is also involved in glycolysis, and fatty acid synthesis and N-metabolism. Plants take up phosphorus in the inorganic form, mainly as the orthophophate $(H_2PO)_4$ ion. It occurs in most plants in concentration between 0.1 and 0.4% on dry matter basis.

Phosphorus is essential for: (i). energy transformation in plant cells, (ii) cell division, (iii) development of meristem tissue (iv) early root development, (v) tillering and flowering, and (vi) seed/fruit development.

Phosphorus contributes to improve yield and quality of the crops. It increases the strength of cereal straw, and thus helps to prevent lodging in cereals. It also increases crop resistance to diseases. In legumes it induces rhizobial activity, nodule formation and thus N-fixation.

Deficiency symptoms of phosphorus are stunted growth, purple or reddish leaves, stems and branches, less number of tillers, small and fragile straw/stalks (in cereal, particularly maize). Low yield and poor quality of the crops are often observed in case of inadequate supply of phosphorus. In contrast to N, deficiency symptoms of P most often occur in seedlings and young plants.

Since P is mobile within the plant, symptoms appear on the lower leaves/parts of the plants.

8.5 POTASSIUM (K)

Potassium is not a constituent of the plant structural material but is essential for many plant processes, such as photosynthesis, formation of starch, sugar and cellulose, protein synthesis, and regulation of water balance. It activates enzymes, which act as catalyst in many metabolic reactions. It is also involved in the transport of other nutrients across cell membranes. The K content of many crop plants varied from 0.5 to 2.5% of the dry matter.

Potassium is essential for: (i) growth of meristematic tissue, (ii) strength of the stem/stalk, (iii) regulation of the opening and closing of stomata, (iv) transport of photosynthate from leaves (v) drought resistance (vi) salt tolerance and (vii) disease resistance of crops.

Plants absorb large quantities of potassium to maintain normal growth, and yield maximum. Potassium improves the keeping quality of fruits and vegetables, and the nutritional value (protein content) of grain crops.

In many situations K- supplies in the soil are adequate for crop growth, but where high N and P fertilizer levels are used. K may become a limiting factor for plant growth. Potassium deficiency is evident from low growth rate, spotted, pale and curled (chloratic) leaves, and weak root system, and drying of leaves (necrosis). In plants like cotton limited potassium supply may cause premature loss of leaves and small knotty, poorly opened balls on plants. Likewise, small and shrivelled fruits can be found in orchards due to the lack of potash in the soil. In cereals, lodging and small grain size are often observed due to inadeqate supply of K.

8.6 CALCIUM (Ca)

Calcium is an essential constituent of the plant cell wall. It exists as calcium pectatate. It plays an important role in maintaining cell turgidity, membrane permeability, pollen germination and development of meristems. Its concentration in most crop plant ranges from 0.5 to 3.0% of the dry matter.

Calcium is required for: (i). cell division, (ii). cell elongation,(iii) uptake of NO_3-N, and (iv) neutralization of organic acids (such as citric, maleic and oxalic acid) which may become toxic for the plants..

Calcium is a structural component of chromosomes. It acts as a co-factor or activator in some enzyme systems e.g. lipase. It favours the assimilation of N in proteins. Hence it is essential to have adequate supplies of Ca to sustain normal growth.

Most soils have adequate quantities of Ca, but over a period of time leaching losses and removal by crops can cause deficiencies. Deficiency symptoms of Ca include: crinkled leaves impaired terminal buds and root tips, premature fall of buds and blossoms.

8.7 MAGNESIUM (Mg)

Magnesium is an integral part of chromosomes, polyribosomes and chlorophyll. It plays a catalytic role as an activator of a number of enzymes that are responsible for carbohydrate metabolism, phosphate transfer, decarboxyation and organic acid metabolism. Its concentration in crop plants varies from 0.1 to 0.4% of the dry matter. It is involved in: (i) photosynthesis, (ii) enzyme activation, (iii) uptake and transport of nutrients, and (iv) synthesis of fats/oils, vitamins and sugars.

Magnesium is needed for seed germination, growth and development of the plants.

Deficiency of magnesium results small-distorted leaves with dark-green spots, which are quite apparent in the pale yellow background of the leaf. Interveinal chlorosis (yellowing) of older leaves is caused by acute Mg-deficiency, particularly in dicots (e.g. beans, sugarbeet, potato and tomato). The leaves fall before maturity. Plants become prone to fungus attack due to the lack of Mg supply.

8.8 SULPHUR (S)

Sulphur is a component of the amino acids, cystine, cysteine, and methionine. It is also found in other bio-molecules, such as biotin and thiamin (vitamin B1), which act as co-enzymes in various bio-chemical reactions. Most crop plants contain 0.1 to 0.4% S in the dry matter.

Sulphur is needed by the plants for: (i) protein synthesis (ii) enzyme reactions (iii) energy transfer, and (iv) oil synthesis in seeds, and (v) nodule formation in legumes. It affects CO_2 fixation, and is involved in the synthesis of glucosides in Brassica species. For these reasons, S increases the chlorophyll content of leaves and impart characteristic flavour (or odour) in plants and their products (e.g. garlic, onion, raddish and mustard oil). Higher yield of crops can be maintained by adequate supply of S, particularly in case of legumes, and oil seed crops (e.g. rape and mustard).

Certain areas may be deficient in S, but in general this element is not a limiting factor to crop yields. Sulphur deficiency appears as chlorosis of the younger leaves first. In cereals chlorotic stripping appear between the veins. In Brassica species the lamina is restricted with cupping due to inward curling of the margins. The older foliage may develop orange or reddish tints and may shed permanently. The stem becomes weak, stiff and

woody with small diameter. Flowering is adversely affected in most crop plants. it is why the yield and quality of crops deteriorate if the supply of S is not sufficient.

8.9 MICRONUTRIENTS

Micronutrients are as essential for plant growth as major nutrients. However, they are required by the plants in very small quantities. This is because of their regulatory function as co-factor in various enzymes system involved in different physiological processes, such as photosynthesis and respiration. Soils usually contain sufficient total quantities of micronutrients, but their availability to plant roots is restricted under certain soil conditions, such as pH.

Most soils in Pakistan are alkaline and calcareous. In such soils solubility and availability of certain micronutrients (e.g. B, Zn, and Fe) can be a problem. In addition, intensive cropping and the use of pure fertilizers, high-yielding genotypes exhausted the micronutrients reserves of our soils. For these reasons some of our soils have become deficient in B, Zn and Fe. However, deficiency of other micronutrients is not widespread in Pakistan. The important functions and deficiency symptoms of micronutrients are outlined as follows:

i. BORON (B)

Boron is needed by the crop plants for cell division, nucleic acid synthesis, uptake of calcium, and transport of carbohydrates. In crop production B is important for pollen viability, flowering, seed set, fruit formation, yield and quality. Levels of B in mature leaves of most crops are usually adequate if over 20 to 100 μg /g of dry matter.

Boron deficiency affects the growing points of roots and youngest leaves. The leaves become wrinkled and curled with light green colour. In acute deficiency seed set is adversely affected in cereal crops. Flowering and fruit formation are reduced in horticultural plants. Dicot seeds are more susceptable to boron deficiency than monocot seed (with the exception of maize and sorghum crops). Brassica species and root crops are particularly sensitive to boron deficiency.

Boron deficiency also results in disorders such as 'heart-rot' of sugarbeet, 'browning or hollow stem, of cauliflower, and ' top sickness' of tobacco. Some soils of the Punjab and NWFP have been found deficient in their available or hot-water soluble boron content. It is due to the alkaline nature of the soil, which in the presence of excess Ca reduced B availability to the plants.

ii. ZINC (Zn)

Zinc is essential for the synthesis of plant growth regulators, also called auxins (e. g indole acetic acid, IAA). Such compounds regulate the growth and development of plants. Zinc also acts as a metal activator of several enzymes, involved in the synthesis of protein and nucleic acids and in the detoxification of superoxide radicals in plants. The amount of Zn in plants varies from 25 to 150 µg/g on dry matter basis.

Typical Zn deficiency symptoms are: short internodes (rosetting) and stunted leaf growth with prominent midrib, thick lamina and scattered yellow spots. In rice the leaves turn brown. These symptoms appear in crops grown on alkaline soil, where Zn is rendered unavailable due to the formation of zinc hydroxide and oxides. Liberal use of N and P also affect Zn uptake by the plants. Hence fertilizer enrichment with Zn is preferable for intensive farming system.

iii. IRON (Fe)

Iron is a constituent of cytochromes, which are involved in the plant respiratory mechanism. It mediates chlorophyll synthesis and thus accelerates photosynthesis. In plant tissues it is found in concentration between 50 to 250 µg/g of the dry matter.

Iron deficiency occurs when leaf Fe content is less than 50 µg/g of the dry matter. Such plants show typical interveinal chlorosis (yellowing) of leaves. Affected leaves are curved upward. Acute deficiency causes bleaching of leaves. These symptoms appear first on young leaves. It should be noted that Fe availability to plants is reduced by excess amount of P, Zn, Cu, Mn and Mo in the soil. This may promote Fe-deficiency.

iv. COPPER (Cu)

Copper is found in metalo-proteins. It acts as a co-factor in several enzyme systems, and thus participates in chlorophyll synthesis, respiration, lignifiction, and detoxification of superoxide radicals in plants. It promotes symbiotic N-fixation in legumes. It is also required for the synthsis of protein and vitamin A. Normal concentration in plant tissues ranges from 5 to 25 µg/g of the dry matter.

Deficiency of copper in cereals causes yellowing and curling of leaf blade, poor tillering and poor grain-set. In fruit trees fertilization and fruit-set are adversely affected by Cu deficiency. Higher concentration of Zn and Fe in the soil usually induce Cu deficiency. Alkaline calcarous soils with high pH induce Cu deficiency due to low solubility of Cu.

v. MANGANESE (Mn)

Manganese acts as a catalyst in several enzymatic and physiological reactions in plants. It activates enzymes involved in the synthesis of chlorophyll and protein, and respiratory mechanism of plants. Crop plants contain 20 to 500 µg/g Mn in their dry matter.

Manganese deficiency results small yellow spots on leaves and interveinal chlorosis. In Mn-deficient potato, the leaves near the shoot tips are small, and curled, with some chlorosis. In Mn sensitive crop, like oat deficiency symptoms appear in the basal leaf part as greenish gray spots and stripes. Grayish lesions then enlarge and become bright yellow or orange along the leaf edge. Tissue within the lesions die and become gray. This is known as 'gray speck' disease. Mn deficiency usually occur in alkaline soils.

vi. MOLYBDENUM (Mo)

Molybdenum (Mo) plays a key role in N-fixation by legumes. It is an essential constituent of the enzyme, nitrate reductase, which regulates the conversion of nitrates to ammonium. Mo also helps in the synthesis of protein and ascorbic acid (vitamin C) in plants. It is considered to be an antidote to excessive Cu, B, Ni, Ca, Mn and Zn in plants. Normally Mo content of plants is less than 1.0μg/g of the dry matter.

Molybdenum deficiency symptoms are similar to those of N-deficiency, because Mo is involve in N metabolism. Thus stunted growth, pale-green or yellow leaves (i.e chlorosis) can be observed in Mo deficient plants. In citrus fruits 'yellow spot' disease is due to Mo-deficiency.

vii. CHLORINE (Cl)

Chlorine is the latest element established as an essential micronutrient. It is important for the evolution of oxygen in photosynthesis, raising osmotic pressure and hydration of plant tissue. Plants usually contain 0.2 to 2.0% Cl in their dry matter.

Chlorine deficiency in plants displays a wilted appearance of the foliage and stuffy roots. Chorine deficiency in crops is rear. This is because of the high Cl, content in soils and its constant and rapid recycling in nature. In fact an excess of Cl in salt affected soils is a serious problem. Adequate quantities of Cl (50 Kg per annum) are deposited in the soil due to rainfall. Crops on such soils show symptoms of Cl-toxicity. These include burning of leaf tips or margins, and pre-mature yellowing and drop of leaves.

viii. COBALT (Co)

Cobalt is a structural component of vitamin B_{12} (cynocobaltamine), which is essential for the formation of leghaemoglobin. Thus it is needed by leguminous crops for atmospheric N-fixation by Rhizobia (nodule bacteria of legumes). Cobalt may also play a catalytic role by being an activator of certain enzymes.

No apparent deficiency symptom of Co is noticeable in plants, but reduced activity of biochemical N-fixation has been observed.

8.10 NUTRIENTS STORE-HOUSE

Soil is the store-house of plant nutrients. There are always in-and-out flows of these nutrients from this store-house. The inflow or supply of nutrients to the soil is mainly through commercial fertilizers and manures, which will be discussed in the next two chapters.

The outflow or loss of nutrients from the soil occurs mainly through: (i) removal by crops and weeds (ii) leaching (downflow), (iii) erosion or run-off (loss of surface soil by rains and winds), and (iv) transfomation to gaseous form.

Plants take-up nutrients from the soil in the soluble ionic or available form. For instance, N as $NH4^{+}$ and / or $NO3^{+}$ and P as $HPO4^{-}$ and /or $HPO4^{-}$ The soil must supply all essential nutrients in a readily available form to fulfil the plant requirements at various stages of their growth and development.

Nutrient solubility and availability depend on various adaptic, climatic and biotic factrors. Nutrient uptake by plants requires an intimate root-soil contact. It is accentuated by root exudates and microbial activity in the soil. Such biochemical phenomena greatly increase the rate and ease of transfer of nutrients from the soil to the plant.

Soil fertility is of prime importance to increae productivity of field crops. It refers to the ability of a soil to supply all the essential nutrients in an optimum amount in a readily available form to the plants. Sometimes, the store-house or soil is full of nutrients, but soil conditions restrict their supply to the plants. Such conditions could be (i) excessive acidity or alkalinity, (ii) the presence of toxic substances, (iii) poor physical properties, and/or (iv) excess or deficiency of water. These factors affect soil productivity, i.e. the capacity of soil to produce crops per unit area. Farmers must consider such factors in the selction and production of field crops.

SELF-CHECK EXERCISE.

1. Define and classify plant nutrients with examples.
2. Why nitrogen is essential for plant growth?How you will recognized its deficiency?
3. What are the biochemical functions of phophorous. What particular aspects of plants are affected by phosphorus?
4. Describe the role of potassium in plants. How you will recognized its deficiency in cotton and cereals?
5. Where you can find calcium in the plant cell? In which form it exist?. Which particular aspects of the cell are affected by the absence of calcium?
6. Why you can not think about life on the earth without magnesium?
7. Name atleast two bio-molecules, which contain sulphur. Why sulphur is more important for legumes?
8. Why micronutrients are required by the plants in very small quantity? Why our soils need micronutrients to produce a good crop.
9. Which particular micronutrients are deficient in alkaline soils? Describe their role and deficiency symptoms.

10. What is the role of chloride in plants? Why we don't need applications of this nutrient in crop production?
11. Which microelement is an integral part of vitamin B_{12}? What is the function of this vitamin in the production of legumes?.
12. What are the common sources of essential plant nutrients?. Under what condition the supply of nutrients is restricted from the soil to the plants?.

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9. FERTILIZERS

9.1 INTRODUCTION

The term fertilizer refers to any substance, which supply one or more of the mineral elements essential for plant growth. In other words, it is any artificial or natural material, which make the soil fertile for profitable crop production. Generally the artificially produced concentrated sources of nutrients are called fertilizers, or commercial fertilizer, and the natural organic sources of plant nutrients are known as manures.

Fertilizers play a significant role in modern crop production. They are key inputs contributing about 30 to 70% increase in crop yield. Besides, increasing yield per unit area, fertilizers improve the nutritional and storage quality of many crops, particularly of the grain, fruit and vegetable crops. This is because fertilizers increase plant resistance to certain diseases, insects, and weather injury. Fertilizers are used in intensive farming to supplement the soil supply of the essential plant nutrients.

Commercial fertilizers unlike manures are less bulky and easier to transport, handle and store. These merits made commercial fertilizers more popular among our farming community. Thus fertilizer off-take in Pakistan has been increasing in the past few years. During 1999-2000 the overall consumption of commercial fertilizers in the country was 2.83 million tonnes of nutrients as compared to 2.59 million tonnes of nutrients in 1998-99, showing an increase of about 9.5 %. In NWFP about 0.18 million tonnes of NPK fertilizer was consumed in 1999-2000, which was 8.1% higher than the previous year.

Pakistan produced a large quantity of fertilizer for domestic use. There are 11 fertilizer units operating in the country, 6 in Punjab, 3 in Sindh and 2 in NWFP. The installed

capacity of these units is 5.2 million tonnes. During 2000-01 fertilizer production in Pakistan has increased by 10.7% and stood at 3.81 million tonnes. There are many grades of fertilizers used in Pakistan. Those containing more than 25% of the major plant nutrients (e.g urea) are called **'high analysis',** while others, like ammunium sulphate, with lower amount (less than 25%) are known as low analysis. Some of the important fertilizers with their nutrient content are listed in Table 9.1. Government of Pakistan has deregulated the trade and price of NPK fertilizer. These are now freely importable and their sale price is determined by free market mechanism. We import phosphate fertilizer from Maraco and Jordan, and Potash fertilizer from Canada.

Table-9.1 Fertilizer Available in Pakistan

Common Name	Grade or Analysis		
	N	P_2O_5	K_20
Nitrogenous Fertilizers			
Urea	46	0	0
Ammonium Sulphate	21	0	0
Ammonium Nitrate	35	0	0
Phosphate Fertilizers			
Single Superphosphate (SSP)	0	18	0
Triple Superphosphate(TSP)	0	46	0
Diammonium Phosphate (DAP)	18	46	0
MonoammoniumPhosphate (MAP)	11	52	0
Potash Fertilizers			
Sulphate of Potash (SOP)	0	0	50
Muriate of Potash (MOP)	0	0	60
Complex Fertilizers			
Nitrophosphate (Nitrphos)	23	23	0
Complex fertilizers:			
(i) NPK	15	15	15
(ii) NPK	10	20	20
(iii) NPK	13	13	21

9.2 TYPES OF FERTILIZERS:

Commercial fertilizers may contain one or more primary nutrients. Accordingly they may be simple or compound fertilizers:

i **Simple or Straight Fertilizers**: which contain only one of the primary macronutrients, N, P or K. Common examples are urea and single superphosphate (SSP).

ii. **Compound or Mixed Fertilizers**: which contain two or three primary nutrients. For example, diammonium phosphate (DAP), nitrophos, and NPK complexes.

In Pakistan, these two types of fertilizers are sold in 50 kg bag. The composition of nutrients is printed on the bag. It is a standard practice to state nutrients in the sequence as NPK. For example 20-20-20 means that the ratio of N: P_20_5, K_20 is 1:1:1 and the concentration of these nutrients in compound is 20% N, 20% P_20_5 and 20% K_20.

9.3 NITROGENOUS FERTILIZER

Nitrogenous fertilizers are used in much larger quantity than any other fertilizer. This is because N is required by the crop plants in greater amount than any other nutrient. Moreover , our soils are most deficient in this most demanding nutrient. During 1999-2000 about 2.22 million tonnes N was used by the farmers in Pakistan. This amount was 5.6% higher than the previous year. The three most important nitrogenous fertilizers are urea, ammonium sulphate and ammonium nitrate.

i. UREA

This is the most concentrated solid straight nitrogen fertilizer. It is colourless and readily soluble in water. It contains 46% N in amide (NH_2) form, which is converted to ammonium (NH^+_4) in the soil. It is well suited for use in solution for foliar

sprays because of its high water solubility. Urea leaves behind a slightly acidic effect in soil. Sometimes it contains small amounts of biuret, a toxic impurity. Commercial supplies are usually monitored to ensure that the biuret content is below the toxic level.

ii. AMMONIUM SULPHATE (AS)

Ammonium sulphate was one of the most important N-fertilizer, but because of its low nutrient content and relatively high manufacturing cost it lost popularity. It contains 21% N and 24% S. It is a white or grey crystalline salt, soluble in water. Its nitrogen is readily available to crops. Ammonium sulphate has an acidifying effect on soils. It is therefore useful under our alkaline or calcareous soil conditions.

iii. AMMONIUM NITRATE (AN)

This product contains 35% N, in the form of ammonium and nitrate. It is a white, water-soluble compound. It is popular among our farmers. Most of the field crops (except rice) take up N in the form of nitrate in their early stage of growth. So ammonium nitrate is better than other forms of N-fertilizers, particularly in dry soils. Its residual effect in the soil is acidic.

9.4 PHOSPHATIC FERTILIZER

These fertilizers are also used by some of the farmers in Pakistan. However, it is consumed in much less quantity as compared to nitrogenous fertilizer. The N-P consumption ratio in the country was 4.5:1 during 1998-99, which decreased to 3.7:1 in 1999-2000. This indicates that the use of phosphatic fertlizer increased to a significant extent. In fact the consumption of phosphate fertilizers in 1999-2000 was about 0.60 million tonne, which was 28.2% higher than the previous year. Two important straight phosphate fertilizers are Single superphosphate (SSP) and Triple superphasphate (TSP).

i. SINGLE SUPERPHOSPHATE (SSP)

SSP fertilizer is available in powder as well as in granular form. It is of grey or brown colour, and contains 18% P_2O_5. It consists of monocalcium phosphate and calcium sulphate (gypsum) in almost equal proportions. The phophorus in this fertilizer is readily soluble. It also contains a small amount of free acid and sulphur.

ii. TRIPLE SUPERPHOSPHATE (TSP)

This is a concentrated phosphatic fertilizer which contains 46% P_2O_5 and almost all of this phosphorus is in water soluble form. TSP could be in powder as well as in granular form, but the granulated product has better storage and handling qualities. This material also contains small amounts of free phosphoric acid. In Pakistan more than 0.25 million tonne TSP is used in crop production each year.

9.5 POTASH FERTILIZERS

Potash fertilizer are rearly used by the farmers in Pakistan. This is because our soils are not much deficient in potash. However, the positive response of crops to potash fertilizers has been recorded in the country. It has been observed that the application of potash is more profitable and economical than doubling the rate of nitrogen for wheat crop grown in NWFP. Realising this fact, some of our farmers are now using small quantity of potash with other fertilizers. About 0.02 million tonne of potash is used in Pakistan each year. The two important such fertilizers are Sulphate of Potash (SOP) and Muriate of Potash (Potassium Chloride).

i. SULPHATE OF POTASH (SOP)

Sulphate of Potash is available as a white crystalline salt or in granular form. It contains 48 to 52% K_2O, and 18% S. It is soluble in water. In Pakistan this is the only potassium fertilizer, which is recommended for all crop. More than 27,000 tonnes SOP is used per annum in Pakistan.

ii. MURIATE OF POTASH (POTASSIUM CHLORIDE)

This fertilizer contains 50 to 60% K_2O. Although it is cheaper than SOP, it is not recommended for use in Pakistan. This is because of its chloride content, which may raise the chloride levels of our soils to toxicity limit. Certain crops are sensitve to chloride. Our soils already contain more chloride.

9.6 MULTINUTRIENT (COMPOUND) FERTILIZERS

Compound or mixed fertilizers containing two or more primary nutrients are available in Pakistan. Such fertilizers are preferable to reduce the extra cost of transportation, and application in the field. Some important compound fertilizers are diammonium phosphate (DAP) and nitrophosphates. In addition to these fertilizer blends or mixtures containing all the three primary nutrients (NPK) in definite ratio are also produced for use in crop production. Such blends/mixtures are also called **complete fertilizers.**

i. DIAMMONIUM PHOSPHATE (DAP)

DAP is a bright greyish granular fertilizer, containing 18% N, and 46% P_2O_5. It is readily soluble in water. Its initial reaction is alkaline (PH >.7). Most of the soils in Pakistan are also alkaline. So it is logical to think about the suitability of DAP for our soils. Research data available in the country have shown that DAP is as good as other phophatic fertilizers (SSP and TSP) in increasing yield of the crop. No deleterious effect on soil or crop has been observed due to its use. However, its direct contact with seed and young seedlings should be avoided as ammonia may cause injury. More than five thousand tonnes of DAP is used in Pakistan each year.

ii. NITROPHOSPHATES (NITORPHOS)

These fertilizers are also called ammonium nitrate phosphates. In Pakistan they are known as nitrophos. The nutrients composition is usually 23% N and 23% P_2O_5. Half of the nitrogen is in ammonium form and the other half in nitrate form. The water solubility of phosphorus is normally 80 to 85%, but nitrophos manufacture by certain factories in Pakistan have water solubility of less than 80%.

iii. FERTILIZER MIXTURES

Fertilizer mixtures can be prepared by blending the straight or compound fertilizers. Such mixtures are commercially produced for the market. They can also be prepared at home or farm. In doing so care must be taken to avoid the uneven mixing of incompatible fertilizers. Such mixing may induce caking and convert soluble nutrients into insoluble form. It may also leads to loss of some nutrients in the form of gas. Hence the following combination should be avoided in preparing fertilizer mixture at the farm / home:

a). urea with superphosphate, (SSP or TSP)
b). sodium / potassium nitrate with superphosphate,
c). ammonium sulphate / chloride / nitrate with lime
d). superphosphate with lime (calcium ox cide).

9.7 SPECIAL FERTILIZERS

i. SLOW-RELEASE FERTILIZERS

Crops can not recover all the applied N. Some of it is lost due to its volatilization as NH_3. This loss has prompted a search for fertilizer material that releases their N slowly, and over a long period of time so that nitrates are available to the plants during the entire period of their growth season. Such a fertilizer should be economical for crops, which require frequent fertilizer application.

Sulphur coated urea (SCU) is a slow release fertilizer, containing 30 to 40% N. It has proved quite good in paddy fields. **Urea supergranules (USG)**, which are simply large (about 1 cm) granules of ordinary urea, also release N slowly when placed 5 to 6 cm below the surface of the soil, particularly in paddy field. This has proved much better than ordinary split application of urea. Some new slow release products, which are still in experimental stage include: urea-formaldehyde, metal ammonium phosphate, and oxamide.

ii. LIQUID FERTILIZERS

In some industrialized countries, liquid fertilizers are used. The most important liquids available for direct application are anhydrous ammonia, aqueous ammonia and aqueous N solutions. Such products have the advantage of low cost of production, distribution and application. Anhydrous ammonia is NH_3 gas liquefied under high pressure. It contains 82% N. Aqueous ammonia contains about 28% N. These liquids are applied about 10 to 16 cm into the soil from pressurized tanks through tubes. An aqueous N solution contains 26 to 30% N, and are mixtures of ammonium nitrate and urea. The effects of liquids are comparable to those of ordinary fertilizers.

iii. POLYPHOSPHATES

They are more concentrated phosphatic fertilizer materials. They have some advantages in the manufacturing stage, especially for mixed products. However, their agronomic effectiveness is not better than ordinary phosphates

iv. FERTILIZER PESTICIDE MIXTURES

One of the recent developments in fertilizers involves their use as pesticide carriers. Pesticides (both herbicides and insecticides) are mixed with fertilizers, and applied simultaneously. The economic advantages of such mixtures in terms of cost and labour saving are obvious.

Note: Bio-fertilizers or so-called magic fertilizers are being marketed in Pakistan. They are probably derived from animal by-products or decayed organic matter. The authenticity of such products is questionable. They should not be used unless approved by concerned authorities in Pakistan, the Pakistan Agriculture Research Council (PARC).

9.8 FERTILIZER USE EFFICIENCY

Fertilizer is a costly input. It must be used judiciously to gain much higher yield per unit quantity of nutrients. This will compensate the farmers for the extra cost of fertilizers. Fertilizer use efficiency (FUE) is an index of extra gain in yield by the effective utilization of fertilizers. It may be defined as the amount of increase in yield per unit weight of fertilizer nutrients.

In case of cereals, FUE is measured by the grain: nutrient ratio (GNR) or productivity index. This is the direct indicator of FUE, employed in the economic use of fertilizers. Sometimes, FUE is also expressed in terms of the recovery of the applied

nutrients. This is done by plant/leaf analysis for its nutrient content.

Fertilizer use efficiency can be improved by cultural and management practices, such as (i) the use of high-yielding cultivars (ii) sowing by drill at proper time with recommended seed rate, (iii) applying the optimum fertilizer dose by drill or placement near the root zone at approperiate time (iv) irrigating the crop to dissolve nutrients and facilitate their uptake by the plants (v) maintaining optimum plant density by thining, and (vi) controlling weeds, insects-pests and diseases.

9.9 FERTILIZER APPLICATION

Fertilizers are most commonly applied to fully exploit the yield potential of crops. Economic use of fertilizers involves:

(i). The selection of proper fertilizers materials.
(ii) Application of the correct quantities of nutrients.
(iii). Application at proper time, and
(iv). Proper method of application.

i. SELECTION OF FERTILIZERS:

Different types of fertilizers have been discussed in the previous sections of this chapter. Besides considering their merits, the cost per unit of nutrient should also be assessed. If various sources of the same nutrient have equal merit, a cheaper source should be selected.

ii. OPTIMUM QUANTITIES OF NUTRIENTS:

After selection of the suitable fertilizer materials their application rates need consideration. The optimum quantities of nutrients should be applied to each crop. The recommended dose should be economical. In Pakistan most farmers use nitrogenous fertilizers and ignore other nutrients such as P_2O_5. This imbalance in the use of N and P_2O_5 , is one of the major factors of the low yield of our crops. Research data available in the country have shown that the optimum N: P_2O_5 ratio for most crops ranges from 1 : 1 to 2: 1. Trials on wheat, rice, maize and oil seed crops during 1987-90 have demonstrated that balanced use of N and P_2O_5 on the average increased yield by 50% over N alone. It is why all nutrients must be applied in balance quantities.

iii. TIME OF APPLICATION:

The time of fertilizer application depends on the type of crop, kind of nutrient, soil and moisture conditions. Fertilizers are usually applied at the time of sowing in case of (i) short duration and fast growing crops, (ii) rabi crops in barani areas, and (iii) rabi pulses (legumes), which require low nitrogen dose. For long duration crops (e.g sugar cane) nitrogen is applied in two or three splits. For vegetable crops in which produce is harvested in many pickings, N fertilizer is usually applied in 3 to 4 splits.

For many crops both P and K fertilizers are mostly applied at the time of sowing. While N is split into two or three doses. The first dose applied at the time of sowing with P&K application. However, in barani areas all NPK should be applied at the time of planting.

iv. METHODS OF APPLICATION:

Applying fertilizer at the proper place is as important as applying the correct amount at the right time. A good method of application will distribute fertilizer at a place from where plant roots can take up nutrients easily. The three common methods of fertilizer application are: (a) Broadcasting, (b) Placement, and (c) Top dressing.

a. **Broadcasting.** This method involves the surface spreading of fertilizer and its incorporation into the soil by ploughing and planking. This is done at or before sowing time. Fertilizers can be spread in the field by hand or by mechanical distributors. For very large farm area aircraft can also be used.

b. **Placement:** In this method fertilizer is placed in bands or in rows (side-dressing).

Band placement: In this case fertilizer is applied in strips or bands 5 to 7 cm to the side, and 3 to 5 cm below the rows of seeds.

Row Placement (Side-Dressing): In standing wide-row crops split application of fertilizer is usually done by side-dressing. This involves placing fertilizer along the side of each row, and mixing it in the soil by hoeing. Side-dressing is followed by irrigation.

Placement in bands or as side-dressing is preferable for phosphate fertilizers. This is because less soil is in contact with phosphate, which reduces its fixation into the soil and thereby increased its availability to the plants.

c. **Top-Dressing.** This involves the scattering of fertilizer by hand or air-craft on top of the standing crops. The field is irrigated immediately after top-dressing. This method is used for split application of fertilizer. It is particularly useful for narrow row or densely populated crops, like cereals.

Note: In addition to these methods, fertilizer can also be applied as foliar spray. This method is not common in Pakistan because it is laborious and costly. It can only be used for experimental purpose.

SELF-CHECK EXCERCISE:

1. Differentiate between:
   a) Fertilizer and manure.
   b) Straight and compound fertilizer.
2. Name different fertilizers with their nutrient contents.
3. What factors should be kept in mind for the economic use of fertilizer?

4. In which particular cases you will apply fertilizer to the soil before seeding?
5. What are the different methods of fertilizer application? Which method you will prefer for sugar cane crop?
6. Which method of application is suitable for phosphate fertilizer? Support your answer with reason.

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10. MANURE

10.1 INTRODUCTION:

Manures are bulky organic materials derived from plant residues and animal wastes and excreta. They are the natural sources of plant nutrients. In contrast to artificial/commercial fertilizers the nutrients concentration of manures is very low. For this reason, they are applied in large quantities to supply an appreciable amount of nutrients to plants.

Manures supplement the organic matter content of the soil and make it fertile. Most of the organic matter is converted to humus, a black or dark-brown organic substance, which persists in the soil. It improves the tilth or physical characters of the soil, increasing its porosity, aeration and water-holding capacity. This promotes soil microbial activities, and thus increase, nutrient availability to plants.

The use of manures decline in the past few decades due to commercial fertilizers, which are more concentrated in their nutrient contents, less bulky, easier to transport and apply in the field. Organic farming is now receiving much attention because artificial fertilizers have become expensive. Moreover, environmental concerns necessitated the use of manure. Organic farming avoid the use of artificial fertilizers and crop protecting chemicals. In this system manures are used as a slow release source of nutrients. The most important organic manures are the (i) farmyard manures (FYM), (ii) compost, and (iii) green manure.

One tonne of fresh manure supplies 227 kg of organic matter. 4.5 kg of N, 2.5 kg P_2O_5 and 4.5 kg of K_2O.

10.2 FARMYARD MANURES (FYM)

Farmyard manure is the most important of the organic manures. It is a decomposed mixture of dung and urine of cattle and other animals, with straw and litter used for bedding and residues from fodder. Animal dung is the major component. It is collected along with other waste materials, and stored in covered pits to accelerate the decomposition process, or rotting of the mixture. On rotting the total weight of the manure is reduced and the complex organic substances are converted to humus. Much of the effects of FYM on soil and crop yield are due to its humus content, which serves as a slow release source of plant nutrients.

The composition of FYM varies and depends on (i) animal species of the farm, (ii) kind and amount of straw used, and (ii) the storage method. Excreta of cattle, buffalo and horses contain less NPK than those of sheep and goat. Likewise, cereal straw contributes less nitrogen than legume straw. Moreover, nutrients concentration decreased with increasing amount of straw.

Storage method significantly affect the nitrogen content of FYM Most farmers store FYM on the open ground or in uncemented open pits. This causes nitrogen losses by volatilization and leaching. A covered concrete pit reduces such losses and thus supply FYM rich in nitrogen.

Although FYM is not a standardized product, generally it contains 10 kg of N, 16 Kg P_2O_5 and 23 Kg K_2O per tonne. It also supplies small amounts of other nutrients. The efficiency of FYM can be increased by the addition of phosphate fertilizers. Mixing FYM with phosphate fertilizer is also recommended because this increases P_2O_5 availability to plants. FYM solubilize granular phosphate fertilizer, and provide an organic coating to prevent phosphate fixation in the soil.

FYM should be applied well before planting. The application of well-decomposed or rotten FYM is more desirable than using fresh materials. Fresh FYM loses N by volatilization on

the open soil. To control such losses fresh FYM must be incorporated into the soil soon after its application.

10.3 COMPOST

Compost is a mixture of organic residues and soil that has been piled, moistened, and allowed to decompose in a pit or heap. It differs from FYM in that it is mixed with soil prior to decay process. Like FYM it may also contain animal dung and urine along with other residues, such as fodder reminants, stubble, weeds and leaves. All materials are collected in specially designed cemented pits. These are mixed with the soil and then moistened. The pit is covered for some time so that the materials are decomposed by the action of microorganisms. The complex mixture degrades to simpler substances, also called humic substances. Two such products are humic and fulvic acids. This process of biodegradation is known as composting.

Composting occur in two to three months. For this purpose three or more pits of 300 cubic feet each should be used, the depth, width, and length of each pit should be 3′, x 6′,x 7′. These pits are filled one after the other. It will take some time to fill all the pits. During this time compost will be ready for soil application in the first pit. This rotation should continue for the constant supply of compost. Phosphate fertilizers (SSP, TSP) can be added to the compost to enrich it.

Rural compost is mainly derived from farm wastes and animal excreta. The urban or municipal compost is mainly comprised of town refuse and human excreta. Large scale preparation of urban compost require sophisticated machinery. Such plants are used in most of the developed countries. In the rural areas of Pakistan 50% of the collected cattle dung is used for manuring, and the rest is burnt as fuel in the form of dried cakes.

10.4 GREEN MANURES (G.M)

Green plants buried under the soil in their pre-mature stage are known as green manure. Green manuring refers to the practice of growing crops (mostly legumes) and ploughing them under the soil when their tops are green. Legumes are the best green manuring crops because they have the ability to fix atmospheric nitrogen into the soil. The amount of N fixed varies from crop to crop and may be about 40-60 kg/ ha under field conditions. Some important green manuring crops are Sesbania, Dhaincha, Berseem and Sannhemp.

Green manuring supplement the N and organic matter content of the soil and makes it more fertile. In Pakistan, sufficient time is available for green manuring between the rabi and kharif crops (particularly in the wheat-rice sequence). The months of May and June are ideal for growing any summer legume as green manure. It has been reported that **sesbania** as green manure contributed 60 kg N/ha in a rice-wheat cropping system.

The green manure crop should be of short duration. Moreover, it should take less time for its decomposition in the soil. Green manuring is preferable in kharif season as hot weather in the presence of moisture readily decomposes the material in the soil. In such conditions complete decomposition may occur in less than six week. It should also be noted that young succulent material decomposes much more readily than older or mature plants. These considerations are important to avoid any problem that may affect the next regular crop.

Increases in the yield of various crops for 2 to 3 years, have been recorded due to green manuring once in a 3 year rotation sequence. This shows the residual effect of green manures that last for 2 to 4 years. In intensive farming green manures should be supplemented with commercial fertilizers in order to keep the soil more fertile and productive.

SELF-CHECK EXCERCISE:

1. Why interest in the use of manure is regenerating?
2. How much NPK will be present in one metric tonne (1000 kg) of FYM?
3. Why phosphate should be applied mixed with FYM?
4. What is humus? How it is beneficial for crops?
5. What do you mean by composting? How much time is required to complete this process? How you will proceed to make compost.
6. Differentiate between FYM and compost. Which one is preferable for application to a crop just before its seeding?
7. Define green manuring. What should be the characteristic of a green manure crop?
8. Name few green manure crops. After how long green manuring should be repeated?

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