Chapter...

Problematic Soils and Testin...

2.1 Introduction to Problematic Soils :

The humid region soils are acidic in nature because of the formation of weak acid like carbonic acid, lactic acid, acetic acid etc. These acids replace basic cations like Ca, Mg^{++}, K^{+} through cation exchange sites with H^{+} and Al^{+++} ions. The replaced cations are leached into deep soil by water. The extent of the salt present in soil changes its nature. Excessive concentration of soluble salts or exchangeable Na or both makes the soil saline or alkaline. Excess of salt in soil is toxic to plants. Some of the problematic soils are acidic, saline, alkaline, calcareous, saline alkali and non-saline alkali.

2.2 Acid Soil :

2.2.1 Formation of Acid soil :

(i) **Acid soils are formed** under natural conditions as well as artificially by the continuous use of certain fertilisers. Soils developed in humid regions are mostly acidic. Under these conditions, the alkali and alkaline earth bases that are liberated during weathering are leached out leaving the soil deficient in bases. When all the soluble bases are lost, the H ions of carbonic and organic acids replace the basic cations of the colloidal complex. As the soil gets gradually depleted of its exchangeable bases through constant leaching it gets desaturated and becomes increasingly acidic. e.g brown soils, podsols, laterites etc.

(ii) **Acid soils** can also be **produced** through the accumulation of organic residues. The decomposition of organic matter in absence of O_2 gives rise to a product called **'Peat'** which is acidic in reaction and it is due to the accumulation of the humic acids.

(iii) **Acid soils are also produced** by continuous use of physiologically **acid fertilisers** on the soil that is poor in lime. When nitrogenous fertilisers like NH_4Cl, $(NH_4)_2SO_4$ are added to soil, they get nitrified and nitric acid is liberated which reacts with Ca and other bases to form nitrates. Nitrates are very soluble, so they are either absorbed by crops or lost in drainage. At the same time, a part of NH_4^{+} ions are absorbed by soil colloidal material by replacing Ca. Other metallic materials get nitrified and form nitric acid. Anions form sulphuric and hydrochloric acid which further deplete the soil solution and the colloidal complex of their bases. Thus, the clay gets desiderated, H^{+} ion concentration increases and the soil pH is lowered.

2.2.2 Effect of soil acidity of soil :

(i) The **soil acidity is also increased** by the use of materials like sulphur, molasses etc which liberate acids during the course of their decomposition. The increase in acidity decreases the soil production.

(ii) The soils that are predominant in alumino silicate clays are made up of alumina and silica layers. In acid soils, an equilibrium is maintained between H^{+} and Al^{+++} ions.

$$Al^{3+} + H_2O \longrightarrow Al(OH)^{2+} + H^{+}$$

$$Al(OH)^{2+} + H_2O \longrightarrow Al(OH)_2^{+} + H^{+}$$

$$Al(OH)_2^{+} + H_2O \longrightarrow Al(OH)_3 + H^{+}$$

In such soils poor growth of crop takes place.

Water holding capacity soil decreases
Soil erosion ↑.

(iii) **Slightly acidic soils are** quite suitable for growing crops without any treatment, but those that are strongly or even moderately acidic do not allow the normal growth of plants. So acidity has to be neutralised before the crops are grown. The lack of exchangeable bases is the main cause of unproductiveness, which can be restored by adding lime, dolomite etc.

$$CaO + H_2O \longrightarrow Ca(OH)_2$$ $CaCO_3 + MgCO_3$

$$Ca(OH)_2 + 2CO_2 \longrightarrow Ca(HCO_3)_2$$

As the concentration of CO_2 in soil is quite high, all these compounds are converted into soluble bicarbonates which then react with the soil colloids.

$$H_2 - clay + Ca(HCO_3)_2 \longrightarrow Ca - clay + 2H_2CO_3$$

The carbonic acid further reacts with lime and the series of changes repeats itself and turns colloidal clay into Ca- clay which increases the pH of the soil. As this reaction is reversible in nature, therefore additional quantities of lime are added from time to time to maintain the pH of soil.

(iv) **Gypsum** and **$CaCl_2$** cannot be used for improving acid soils because they are neutral salts with no alkaline effect. Their addition makes the soil more acidic.

2.2.3 Reclamation of acidic soil : Imp

The quantity of lime required to be added to a soil is also known as its **Lime Requirement (LR)**. It depends on the initial pH, base unsaturation and buffer capacity. Lime Requirement varies inversely as pH and buffer capacity. Lime Requirement also depends on the type of crop to be grown.

For determining LR, known weight of soil is mixed with varying quantities of standard $Ca(OH)_2$ or $Ba(OH)_2$ solution in a number of flasks and allowed to settle down. pH of each flask solution is determined electrometrically. Titration curves are drawn from the data so obtained and the quantity of lime needed to produce any particular pH is calculated from curve. Usually pH 6.5 or 7 is taken to represent the desired pH for most crops. The figure so obtained is multiplied by the liming factor gives the actual lime requirement.

Effect of lime on acid soils :

a) Lime improves chemical and biological properties of acid soil without affecting its physical conditions.
b) It encourages the decomposition of organic matter producing excess of organic colloids. The Ca humus produced during the reaction acts as consenting agent in binding the soil particles.
c) It increases the availability of almost all the plant nutrients like N, P, K, Ca, Mg, B, Zn, Cu and Mo and reduces the toxicity caused by soluble Fe, Al and Mn.
d) It encourages the microbial activity of the soil by raising the pH.
e) It stimulates the activity of both symbiotic and about rapid decomposition of both native and added organic matter, resulting in increased microbial activity which increases the availability of N, P, and S.

Over liming of soil is toxic for crops, especially in case of sandy and organic matter deficient soils. It reduces the availability of major and minor essential nutrients like Fe, Mn, B, Cu, Zn, P, K etc. It also interferes with the absorption of certain elements like K, P, B etc. by plants thus hindering their utilisation. It also affects the very rapid decomposition of organic matter in the soils of arid and semi arid regions. Therefore, in order to make the acid soil fertile, a moderate quantity of lime should be added from time to time rather than to make a heavy application at a time.

2.3 Alkali Soils :

2.3.1 Formation of alkali soil :

(i) These soils have pH > 7. Calcareous soils give alkaline reactions mainly due to presence of $CaCO_3$ and $MgCO_3$ while alkaline soils are one whose alkalinity varies with the preponderance of sodium salts in soil solution or the presence of Na- clay or both. **They are formed in the low rainfall and high evaporation regions.** Due to low rainfall they have downward and upward movement of rain water which helps in the accumulation of salts in the surface layer soils of arid and semi arid regions.

(ii) These soils are **also available in semi humid and temperate regions** especially where drainage is defective or where the underground water table is high or close to the surface. Under humid conditions, the soluble salts formed by the weathering of rocks and minerals are carried down and removed with the drainage water into the stream and finally to ocean. In case of defective drainage they accumulate at lower layers and makes the soil alkaline. High water tevel also makes the soil alkaline. **Alkaline soils are also found** on sea coast, where tidal waters flood the land periodically and deposit their salts.

(iii) **Artificial alkaline soil is produced** where canal water is used for irrigation, due to movement of salts between the layers. Seepage irrigation water gets water logged in low lying tract or valley and produce alkaline soil.

(iv) In some cases, **alkaline soils result from irrigation water** itself having an excess of soluble salts as in the case of soil water wells or due to the canal water passing through saline regions.

2.3.2 Reclamation of Alkali soil :

This method depends on the type of alkalinity.

(i) **Reclamation of saline soils** is done by removing excess of salts either by scraping the salts from the surface or by washing them down into the lower layers beyond the root zone or by growing salt tolerant plants or by a combination of two or more of these methods. Reclamation is never complete in the soil in which the collodial complexes are sodiumised. The best method of leaching with water having low Na salt contents.

(ii) **Alkali soil cannot be reclaimed** by mere flooding the land. These soils contain free $CaCO_3$. The addition of substances which produce acidity reclaims the soil like FYM, green manure, sulphur, molasses, iron and aluminium sulphate and even sulphuric acid.

(iii) The acidity developed during the course of their decomposition in the soil neutralises alkalinity and at the same time brings $CaCO_3$ into solution which then reacts with the Na – clay and converts it into calcium clay.

(iv) The CO_2 liberated by the decaying organic matter and by the plant roots increases the solubility of $CaCO_3$ due to which the concentration of Ca^{2+} ions in the soil solution is increased. The H_2SO_4 also increases the concentration of Ca^{2+} ions by dissolving $CaCO_3$. The growing of salt tolerant crops which can also withstand water logging such as rice, berseem, etc. after the concentration of soluble salts has been sufficiently reduced to allow their growth further helps the reclamation process.

(v) **Use of Acidifying Fertilisers :** Superphosphate and ammonium sulphate, which increases acidity in soil and maintains fertility of soil, is impoverished (weakened) by

FYM = Farm Yard Manure

leaching and cropping. Suitable crop rotation including salt tolerant crops helps the reclamation process. The crop root helps to increase the permeability of the subsoil by exerting CO_2 pressure and developing cracks in it which allows easy percolation of water.

2.4 Classification of Alkali Soil :

These soils are mainly divided into three groups

(A) Saline Soil | **(B) Saline Alkali Soil** | **(C) Non-Saline Alkali Soil**

(A) Saline Soil :

The soils which contain excess of Na salts but the clay complex contain excess of exchangeable Ca are known as saline soils or **solonchak**. The process of accumulation of **salts leading to the formation of saline soils is known as Salinization.** The composition of soil depends on the composition of rock and nature of weathering process. These soils generally contain chlorides, sulphates, nitrates of Na, Ca and Mg. Some soils also contain K salts. Soluble carbonates are generally absent in such soils. This soil is also known as white soil due to the presence of NaCl and Na_2SO_4 which impart white colour to it. Sometimes the colour is brown due to the presence of $CaCl_2$ and $MgCl_2$. The pH of soil is between 7.5 and 8.5. ESP is very low.

CEC = cation exchange capacity

$$ESP = \frac{100 \times \text{Exch. Na (meq. Percent)}}{\text{C.E.C.(meq. Percent)}}$$

where, ESP = Exchangeable Sodium Percentage

The clay particles of this soil are well granulated but do not have well developed structure. It has high salt concentration. It is permeable to water and air. High salt content is harmful to the crop.

(B)Saline Alkali Soil :

On accumulation of soluble salts in a soil over a prolonged period, Na, is the pre-dominant cation in soil solution while plants absorb Ca, Mg and K. Sodium doesn't serve as an essential nutrient except for a few crop plants. Due to evaporation of moisture of soil or absorption from plants, $CaCO_3$ and $MgCO_3$ or $CaSO_4$ gets precipitated, thus increasing the Na concentration considerably. When the concentration is above 50% of the total cations, Na^+ ions replace the exchangeable Ca^{++} and Mg^{++} ions of the clay complex due to high concentration. Ca – clay + Na- salts $\rightleftharpoons$ Na–clay + Ca – salts. Though the reaction is reversible, Ca salts are removed in drainage H_2O as soon as they are formed. Thus making the reaction unidirectional. The process of converting normal soils into alkali soils is called **alkalisation.** The soil may contain Na–clay and excess of salts or only Na – clay with no soluble salts. If the soluble salts are not leached out due to insufficient rains, then the soil contains sodium clay and excess of soluble salts in solution and it is known as **alkali soil.** This soil remains friable and possesses aggregate crumb structure because of the presence of Na salts that don't allow the Na clay to get dispersed. Its pH is less than 8.5 and ESP is more than 15%. Electrical conductivity is greater than 4 mmhos/cm.

(C) Non - Saline Alkali Soil :

When soluble salts are removed by leaching as a result of the increase in rainfall or due to the fall of the water table or by irrigation water washing them down or for any other reason, it gives rise to non-saline alkali soils. It contains colloidal complex saturated with exchangeable Na and insoluble salts. The soil changes depend on the presence or absence of free $CaCO_3$ in it.

$$Na\text{-clay} + CaCO_3 \rightarrow Ca\text{-clay} + Na_2CO_3.$$

Free Na_2CO_3 reconverts the exchange complex into Na-clay due to low concentration of soluble $CaCO_3$. Due to presence of Na_2CO_3, soil organic matter makes black solution which on drying forms black patches on the ground surface with black deposits on soil particles. This soil is known as **Black Alkali.** The clay gets deposited in the lower layers making them impervious having prismatic or columnar structure. These soils are called **Solonetz.** The process of development of these soils from saline soils is known as **Solonization.**

The soil reaction is strongly alkaline. The pH range from 8.5 to 10. ESP is greater than 15. But electrical conductivity is less than 4mmhos/cm. Drainage and aeration are poor because of deflocculating of colloidal material which swells the clay and chokes the soil pores. As a result, the soil loses the crumb structure. The presence of free Na_2CO_3 has a caustic effect on plant roots. The high pH, the impaired physical conditions of the soil and the toxic effect of free Na_2CO_3 and exchangeable Na adversely affect plant growth. These soils are therefore almost **barren**.

Degraded Alkali Soil :

The nature of changes during soil development is slightly different when it does not contain free $CaCO_3$ which results in the prolonged leaching. The Na clay hydrolyses and liberates free NaOH which combines with the CO_2 of the soil air and forms Na_2CO_3.

$$Na\text{-clay} + H_2O \longrightarrow H\text{-clay} + NaOH$$
$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

The **humus** gets dissolved in Na_2CO_3 and the solution passes down to lower layers which acquire black colour due to its deposition. A part of exchangeable Na^+ is also replaced by H^+ which breaks into silicic acid and sesquioxides which are also leached down along with humus. This process is known as **Solodization** and the soil so formed is called solod or soloth or **degraded alkali soil**.

$$\underset{\text{(H-clay)}}{H(R_2O_3, SiO_2.\ H_2O)} \longrightarrow \underset{\text{(Silicic acid)}}{H(SiO_2.H_2O)} + \underset{\text{(Sesquioxides)}}{R_2O_3}$$

It is acidic in nature. The soil pH is 6, ESP is greater than 15. It is very compact and has low permeability.

Tolerance by Plants :

Both saline and alkali soils are harmful to plants on account of the excessive concentration of soluble salts in soil solution in one case and of exchangeable Na or both in the other. The large amount of salt in solution increases the osmotic pressure and reduces the uptake of water which causes **Plasmolysis.** Plasmolysis increases with the concentration of solution until the all the functions of plant collapses completely and the plant finally dies.

In addition to the **total salt** concentration, the harmful effect of the salt depends also on the nature of salt present, the plant species, the nature of the soil especially its texture and the distribution of salts in the profile. Na_2CO_3 is the most harmful salt as compared to NaCl and Na_2SO_4.

In the case of **alkali soils,** the preponderance of exchangeable Na in the colloidal complex reduces the availability of Ca and thus, prevents its intake by the plants. Plants growing under such condition wilt (lose freshness) and die for want of sufficient water.

Salt tolerance varies also with the age of plants. Plants that have deep root systems are able to tolerate salinity better than others. Plants growing in sandy soils are able to tolerate a greater conc. of soluble salts than those in clayey or other fine textured soils. Climate also influences salt tolerance by crops. Plants growing in arid and semi-arid regions are able to tolerate greater salt concentrations than those in semi-humid and tropical regions.

2.5 Calcareous soils :

Calcareous soils are formed in warm temperate and semi acid region where rainfall is low and evaporation is high. Soil profile of those soils contain calcium carbonate and magnesium carbonate in varying proportions and precipitation is not sufficient to leach out all the basic products of weathering. Hence soil has high concentration of soluble salts of calcium and magnesium. Due to evaporation of water or absorption of water by plants, calcium is precipitated as $CaSO_4$ or $CaCO_3$ and magnesium as $MgCO_3$. Due to gradual precipitation, Ca and Mg salts get accumulated in soil. If the soil body (solum) is highly permiable these salts accumulate in parent material from which soil has formed. Sodium and potassium salts are either deposited in the lower depths or removed from the solum completely.

Calcareous soils are highly buffered. carbonate present in them get hydrolysed due to presence of water.

$$CaCO_3 + H_2O \longrightarrow Ca^{2+} + OH^-$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2 \longrightarrow Ca^{2+} + H^+ + HCO_3^{2+} + CO_3^{2-}$$

The pH of such soil depends on the concentration of CO_2 in soil air and its value lies between 7.5 to 8.5. The high pH and presence of calcium and magnesium carbonates in these soil, reduce the availability of some of the plant nutrients. Diseases like lime induced chlorosis are caused in crops due to this type of soil. The presence of excess amount of calcium imbalances the uptake of certain nutrients like potassium and magnesium properly managed. Calcereous soils are very productive and are suitable for a wide variety of crops.

2.6 Introduction to Soil Testing :

Soil testing is used for determining the soil fertility level. Soil fertility plays an important role in increasing the crop production in almost all the soils of the world. It provides the plant with proper nutrients in proper proportion at proper time. It is difficult for the farmers or cultivators to know the amount and type of fertiliser to be used by them for their land and to get the optimum results. The problem of fertiliser use, needs a quantitative assessment of the fertility status of the soils i.e. it can measure the –

1. Level of NPK in soil
2. pH of soil
3. Salt content
4. Salinity and bicarbonate content
5. Texture

On the basis of these informations, an agronomist can recommend the type of fertiliser and its proportion to be used to the farmer.

Different Methods of Soil Fertility Evaluation :

Soil testing has been done by soil scientists as an aid in determining the soil fertility level. It is a rapid chemical analysis to access the available nutrient status of soil and includes interpretation, evaluation and fertiliser recommendations. Soil scientists can guide the farmer in fertiliser use for different crops after knowing the chemical analysis results, soil type, crop history. Different methods applied for fertility evaluation are :-

1. Pot culture experiments
2. Field experiments
3. Biological tests
4. Deficiency symptoms
5. Plant tissue analysis
6. Soil testing

2.7 Objectives of Soil Testing :

1. Assessing nutrient status and grouping soils into classes relative to the nutrient levels.
2. Predicting the probability of getting profitable response.
3. Helping to evaluate soil productivity.
4. Determining specific soil conditions like alkalinity, salinity and acidity.

2.8 Phases of soil testing :

Soil testing is done in three phases :

A. Collection of soil sample from the field
B. Analysis of the sample in the laboratory
C. Interpretation of results and fertiliser recommendations.

A. Collection of soil sample from the field :

Collection of soil sample is the most important step in the soil testing. Its chemical analysis reveals the nutrient status of the soil and guides the scientist to profitable use of fertiliser. Soil sample cannot be collected at any time throughout the year. **Summer is the most appropriate time for collection of sample.** The sample may be collected after the harvest of crop as the soil is dry at that time. Wet sample have to be dried before being tested. The method of sampling depends largely on the purpose for which it is to be collected. When general fertility is to be found out, the number of samples to be collected varies according to the size of the plot. (Fig 2.1)

8, IMP

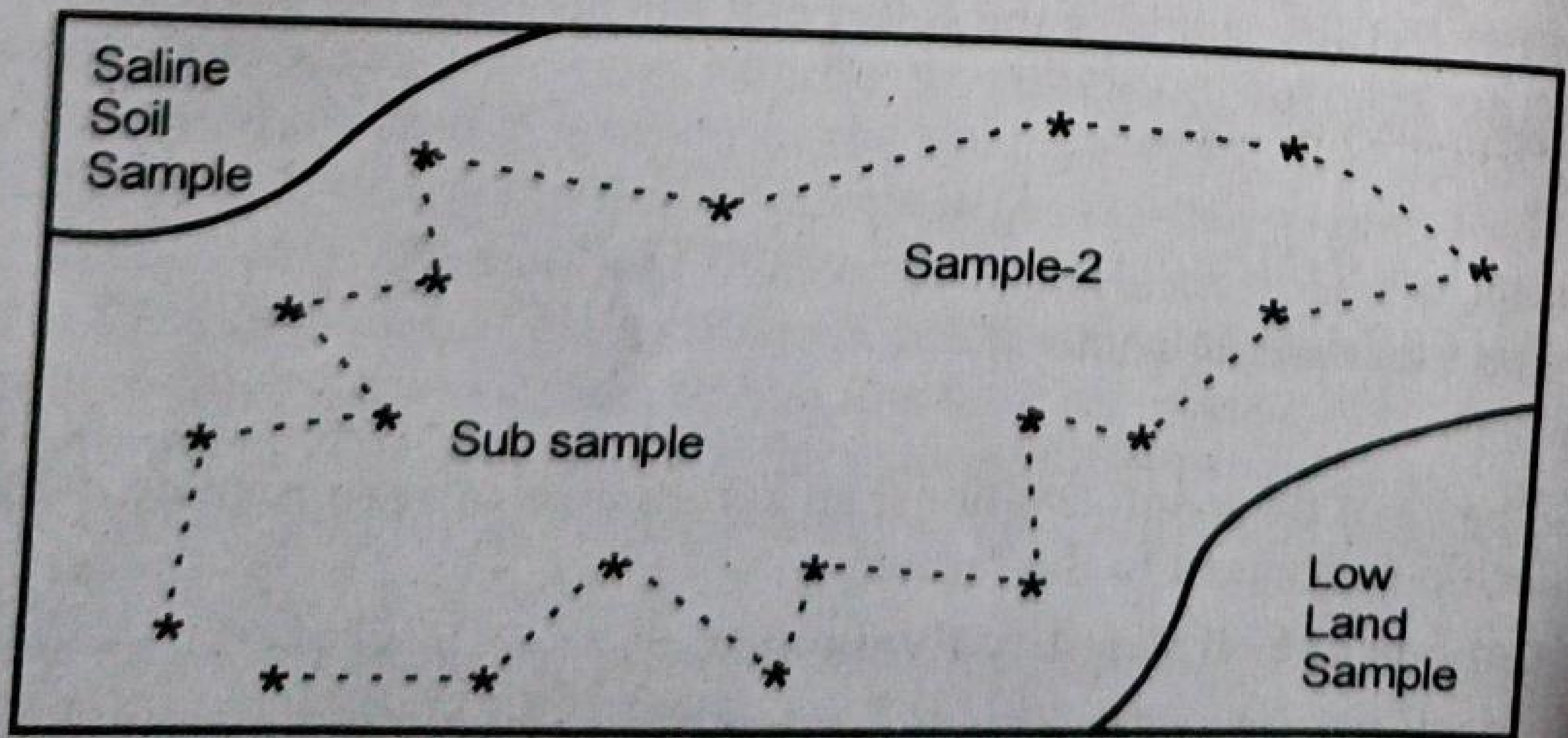

Fig. 2.1 : Collection of Soil Sample From the Field.

Sampling pattern for collecting a representative soil sample is shown in Fig 2.2

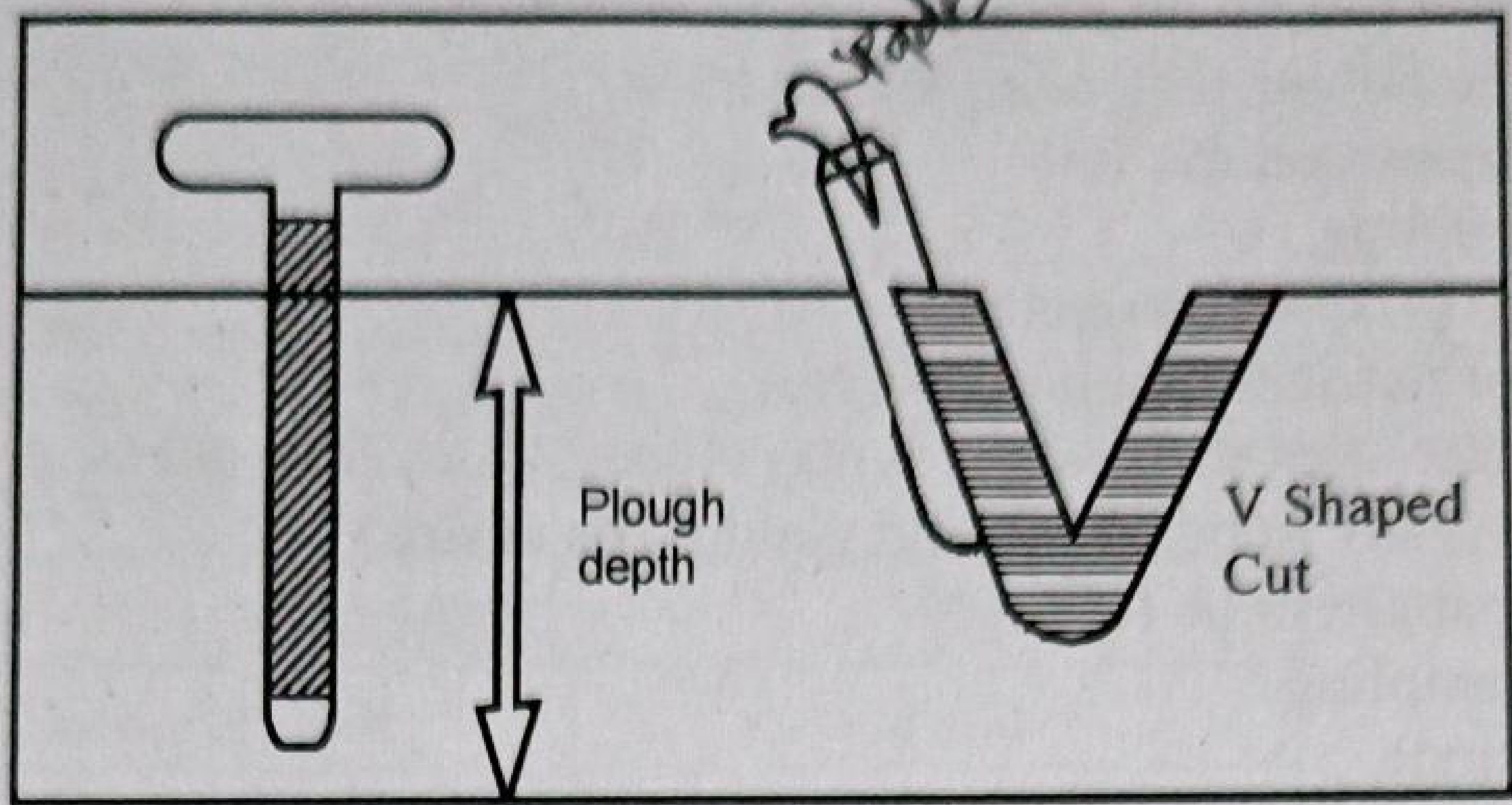

Fig. 2.2 : Sampling Pattern.

(i) Soil sampling tools and sampling depths :

To obtain a representative sample, a composite sample should be collected consisting of small portions of soil from approx. 12 locations with the help of any of the tools like auger, spade, khurpi or travel. Before collecting the sample, organic debris, rocks and trash from the surface of sampling area are removed. The field is divided according to the slope, colour, depth, texture, management and cropping pattern. Each unit is divided into two parts and zigzag line is drawn so that it covers whole area. A V-shaped cut is made in the soil to the depth of sampling. Next 2-3 cm. thick vertical slice of the same depth is removed from the smoothest side of the cut. The collected samples are mixed thoroughly from the bucket is poured on a piece of clear paper or cloth and mixed thoroughly. It is divided into four equal parts and opposite portions are discarded. Remaining two portions are mixed thoroughly and the procedure is repeated to get desired quantity of soil sample. (fig. 2.3)

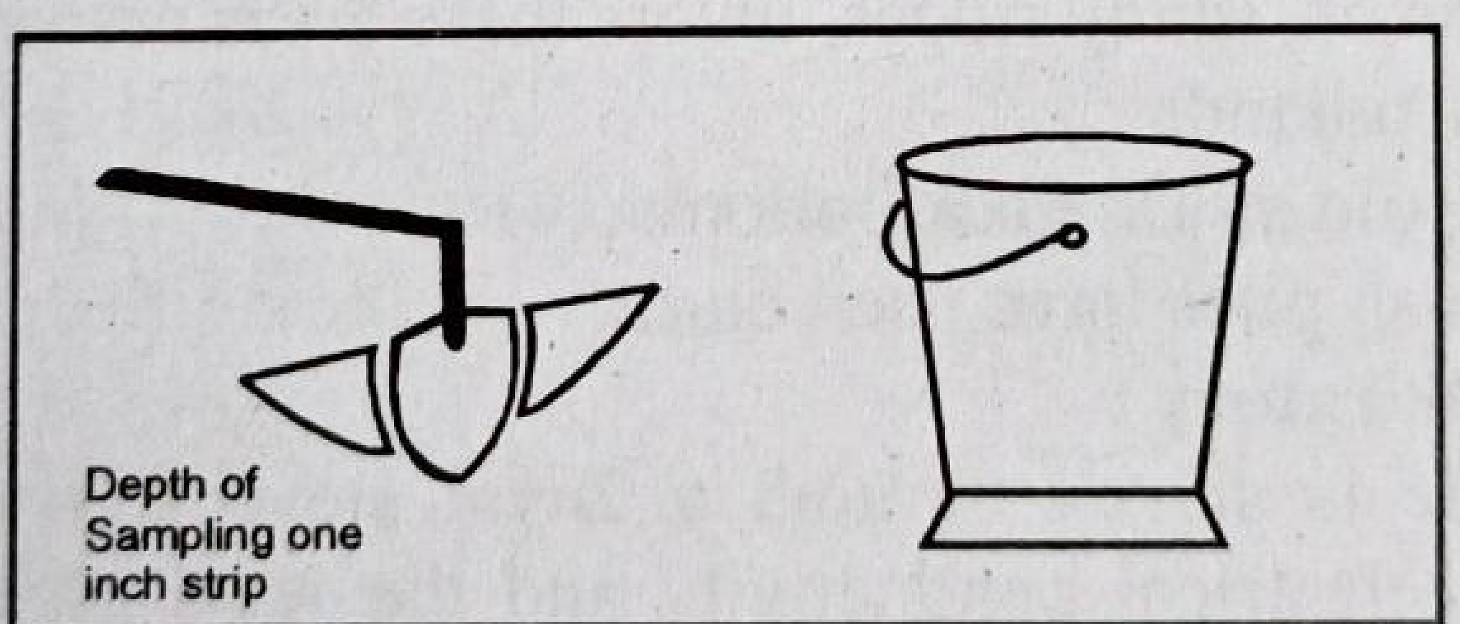

Fig 2.3 Removing a portion of soil from a soil slice.

(ii) Sampling Tools :

Proper sampling tools are essential for collection of good soil samples. Screw type and post-hole augers are generally used for this purpose. Screw-type auger is used for harder soils. For soft moist soil, soil tube or prove is used which allows a uniform portion of the soil to be collected rapidly and accurately by pushing the tube into the ground to the desired depth and removing a soil core. The other tools used for this purpose are shovel, spade, khurpi, etc. (Fig 2.4)

Sample generally, soil from all the fields, should be tested atleast once in every three to four years. More soil testing is required for the soils on which vegetables and other cash crops are grown. The frequency may vary depending upon the cropping intensity, soil type, fertilisation rate, tillage methods, weather conditions and new research findings. The test for P and K is needed only once in 3-4 years while the test for available N_2 is done annually and the organic matter levels are tested once in every 5 years.

A complete soil **sample information sheet** is required with each soil sam submitted for soil testing information required includes :-

1. Name of the farmer with complete address
2. Last crop grown on the soil
3. Date of sampling
4. Whether crop is to be irrigated
5. Amounts of nutrients applied last year
6. Soil characteristics such as low lying, upland, stonyness and topography.
7. Crop and variety to be grown and yield goals desired.
8. Cropping pattern to be followed.
9. Depth of sampling.
10. Drainage slope.

(iii) Use of proper tools for soil sampling :

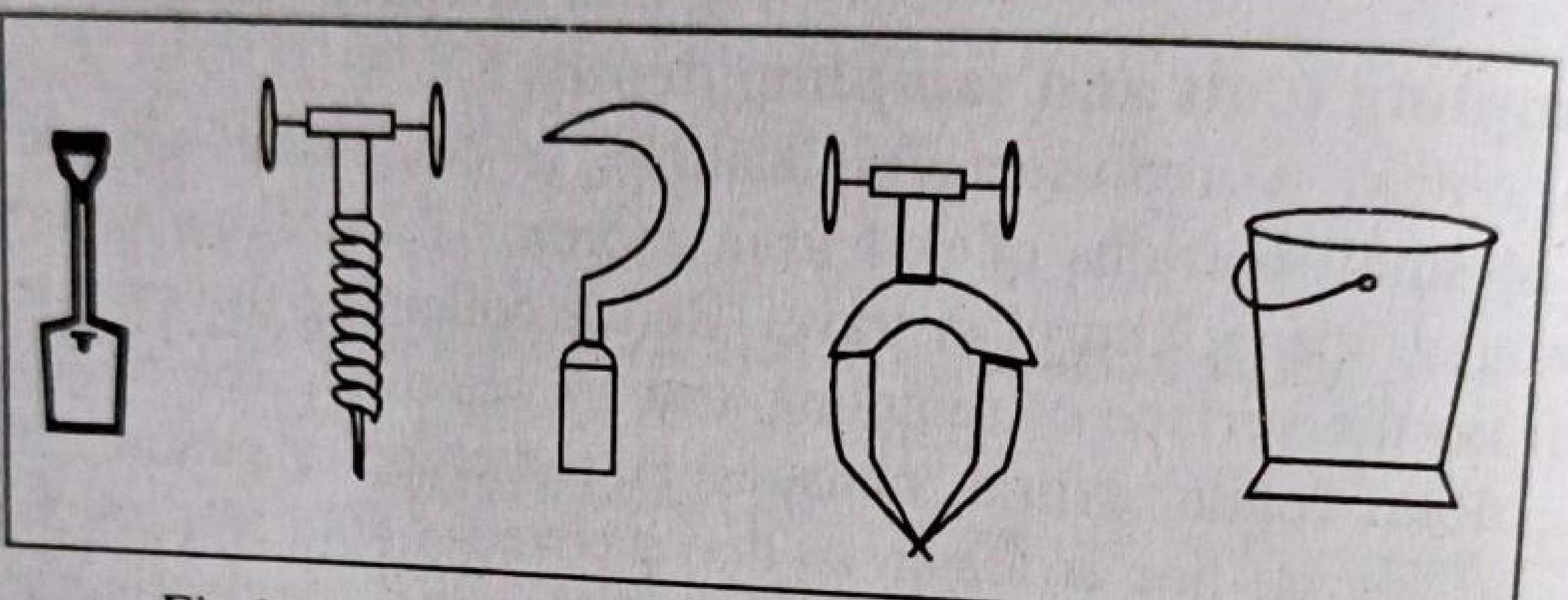

Fig 2.4 Proper tools for soil Sampling.

Sampling should not be done from –

1. Farm lanes and field boarders.
2. Fertilisers bands in row crops.
3. Any areas which are distinct from the dominant soil type in the field such as eroded spots, small saline areas, sandy ridges, unless these areas are sampled separately.
4. Dead furrows and headlands.
5. Old manure piles or old straw stack bottoms.
6. Locations where brush piles have been burnt.

(B) Analysis in the Laboratory :

The soil sample is sieved through a 2mm. sieve and then analysed for texture, carbonate content, pH, electrical conductivity and the level of available nutrients i.e. the chemical forms of an essential plant nutrient in the soil whose variation in amount is reflected in the differential growth of plant and yield. The basic principle of soil testing is that simple rapid chemical analytical procedures should be designed for accurate measurement of the level of available nutrients in the soil.

(i) Classification Chart For Soil Test Data :

From the soil testing results, the soils may be classified into different categories i.e. low, medium or high, acidic, alkaline or neutral.

Nutrient	Low	Medium	High
Organic Carbon (%)	$\leq$0.50	0.50 – 0.75	> 0.75
Available N (kg/ha)	<250	250-500	>500
Available P (kg/ha)	<10	10-25	>25
Available K (kg/ha)	<125	210-25	>210

(ii) Classification Chart for soil pH

EC range	Rating
< 1mmho/cm	Good soil
1-2 mmho/cm	Poor seed emergence
2-3 mmho/cm	Harmful for some crops e.g. Pulses
>3 mmho/cm	Harmful for most of the crops

(iii) Classification Chart for soil test data

pH range	Rating
Soil pH <6.0	Acid soil
Soil pH 6.0 – 8.5	Good soil
Soil pH > 8.5	Alkali soil

(C) Interpretation of Results and Fertiliser Recommendations :

On the basis of soil testing results fertiliser doses are recommended for better yield of crops. If the level of nutrient in soil is very low, the fertiliser dose for the crop is increased by 50%; if low by 25% and for moderate to moderately high, the dose is reduced by 25% and for very high, by 50%.

'Target yields' can be made for the recommended fertilisers. The fertilisers requirement for any crop is the total amount of nutrient needed by the crop minus the amount that the soil can supply. Thus farmer can give balanced fertiliser to the crop and achieve his target of the season. The target yield can be calculated as per the equations given below :

i) Kharif Sorghum (irrigated) :

FN = 4.04 T-.22SN

FP_2O_5 =2.72 T-8.26SP

FK_2O =3.82 T-0.17SK

ii) Kharif Soghurm (rainfed, under assured rainfall area) :

FN = 4.58 T-0.96SN

FP_2O_5 =2.21 T-6.94SP

FK_2O =3.34 T-0.22SK

iii) Wheat :

FN = 7.54 T-0.74SN

FP_2O_5 =1.90 T-2.88SP

FK_2O =2.49 T-0.22SK

Kharif groundnut :

FN = 2.5 T-0.135N

FP_2O_5 =15.14 T-24.15SP

FK_2O =6.96 T-0.31SK

Cotton :

FN = 13.1 T-0.75SN

FP_2O_5 =2.6 T-6.51SP

FK_2O =1.9 T-0.15SK

Where FN is Nitrogen in kg/ha

FN = 2.5 T-0.135N

FP_2O_5 is P_2O_5 in kg/ha