M.Sc. AGRICULTURE LAB MANUAL

1st Semester

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SOIL FERTILITY AND NUTRIENT MANAGEMENT

EXERCISE-1

Object:-Collection and preparation of soil samples for analysis

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

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

The main purpose for which samples collected are:

a. Soil fertility evaluation and fertilizer recommendation.

b. Reclamation of problematic soils.

c. Plantation of orchards.

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

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

Tools and materials required :-

1. Soil auger, tube auger, spade, pick-axe, khurpi.
2. Bucket or tray.
3. Paper tages (Labels).
4. Information sheet

5. Cloth bags (alternatively polythene bags).
6. Ball point pen or copying pencil

Sampling for fertility evaluation and fertilizer recommendation

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

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

Sampling for soil reclamation

For reclamation purpose the samples should be drawn to the plough layer but thesalt crusts (visible or suspected) on the soil surface should be sampled separately. On saline and alkali soils, samples can be taken by either using a soil auger or digging a 90cm deep pit. The samples should be collected as follow:

1. Make one side of the pit vertical (sun facing side) and put mark on it at 15, 30, 60 and 90 cm depth from the surface.
2. Hold a suitable container at 15 cm mark and scrap a uniform slice of soil from the surface down to this mark and collect about 500 gram of the soil sample. Transfer the soil sample to a cloth bag and mark it as 0-15 cm. Similarly, collect 500 gram soil sample from each layer, i.e. 15-30, 30-60 and 60-90 cm and put them separately in three cloth bags and then after dry in shade.
3. Take a separate sample of the surface crust also, if any.
4. Prepare two labels for each sample showing the depth from samples has been taken, name of farmer, name of village, exact location of the field, conditions and growth of crop if any.
5. Put up one label inside the bag and the other on the bags. Label should be written with a copying pencil/ball pan.
6. Information sheet may also be prepared if necessary as given in soil sample information sheet.
7. Send the sample along with information sheet to be nearest soil testing laboratory.

Precautions

1. Do not draw any sample from the extreme corners of the field, area recently manured or fertilized, old bounds and marshy spots.
2. Avoid sampling from furrows, acidic or alkaline pockets.
3. Keep the sample in a bag and tag it properly.
4. Do not take less than 0.5 kg of a composite sample.
5. Sampling should be done from a uniform piece of land.
6. If there is a hard pan in the pit, it should be sampled separately and also note down its depth and thickness.

Sampling for orchard plantation

For horticultural plants, the samples may be taken from different depth or layer depending upon the root penetration of plants. The success of fruit tree plantation

depends upon the physico-chemical properties and fertility status of sub-soil layers. Therefore, it is necessary to test soil before fruit tree plantation. Soil samples for plantation are to be taken as follows:

1. Dig a pit 1.80 meter deep and make its one side vertical, put marks at 15, 30, 60, 90, 120, 150 and 180 cm depths from the surface.
2. Collect samples separately from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm depths in the same way that of saline alkali soils.
3. In case there is a hard pan in the pit, sample it separately and note down its depth and thickness.
4. Pack the soil samples depth wise in separate cloth bags.
5. Put up label on each cloth bags indicating the depth, name of farmers, name of village, location of the field etc.
6. Send the samples to nearest soil testing laboratory along with detailed information.

Preparation of samples for analysis

Drying: Wet soil sample should not be stored as changes may occur in the chemical nature of certain ions and organic matter. Samples are generally air dried at temperature (25-35 ^{0}C) and relative humidity (20-60%) then after are stored. Fresh samples from the field without any drying are required. For certain determinations such as ammonium and nitrate N, exchangeable K, acid extractable P and ferrous iron fresh sample from the field without any drying are required. Results of soil analysis are expressed on oven dry weight basis. This necessitates determination of moisture percentage by drying a small sample in an oven at 105 ^{0}C for 2 hours.

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

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

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

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

Soil sample information sheet

1. Name of farmer---------- Date----------
2. Address-_____

Village_____ P.O.-_____

Block_____- District_____-State_____

1. Sample No. ---------- 2. Depth of sampling (cms)----------
3. Area (in hectare)---------- 4. Slope or topography- level/sloping/undulating
5. Elevation ---------- Up land/ low land
6. Drainage---------- Well drained/ moderate/ impeded
7. Irrigation ---------- Irrigated/unirrigated (rain fed)
8. Source of irrigation---------- Well /tube well/ canal/ pond
9. Type of soil ---------- Sandy/loamy/ clayey
10. Special soil conditions---------- Hardpan layer/rocky subsoil/concentration
11. Cropping Details _____

Crop variety **Seed rate (kg/ha)** **Yield kg/haFor previous years**

1.

2.

For proposed years

1.

2.

14. Fertilizer and manuring history

Year Crop Manure/fertilizer Quantity /applied (kg/ha)20

20

15. Any other information to be furnished

16. Other remarks (if any)

Signature of teacher

EXERCISE – 2

Object : Mechanical analysis of soil by international pipette method

Principal : The analytical procedure by which the proportion of soil particles of different sizes is determined is called mechanical analysis. Before mechanical analysis, the complete dispersion of soil into ultimate particles is necessary. Then the coarse sand is separated by sieving, the silt and clay by their rates of settling in viscous medium and fine sand by decantation. This method is based on the principal that larger particles fall faster through water than do smaller particles. This principle is quantified in stoke's Low.

Stoke's Law

$$V = \frac{2}{9} \frac{g\ r^2}{n} (D-d)$$

Where,

v = Velocity of sedimentation

g = Acceleration due to gravity

r = Radius of the spherical particles

n = Coefficient of viscosity

D = Density of particles

d = Density of liquid

The limitations of Stoke's Law include that shape and density of soil particles vary from sample to sample. Also the maintenances of constant temperature during analysis time is one ofthe problems to be taken care of. Stoke's Law only permits the determination of the proportion of silt and clay in a soil sample.

The sample preparation consists of removing materials that are not to be considered in the analysis. Particles larger than 2 mm in diameter are removed by sieving. Precise results require that the organic matter present be removed, usually by oxidizing it with hydrogen peroxide.

Organic matter binds the clay particles together causing them to be measured as groups. Calcium carbonate in the soil which has a similar effect may be removed by treating the samples with dilute acids.

Table : 1 Sedimentation times for particles of silt and clay through water for the 10cm depth

Temperature (^{0}C)	Settling time			
	Clay particles (2□)		Silt particles (20□)	
	Hours	Minutes	Hours	Minutes
10	10	25	6	20
11	10	10	6	20
12	9	50	6	0
13	9	35	5	50
14	9	20	5	40
15	9	5	5	30
16	8	50	5	20
17	8	35	5	10
18	8	25	5	0
19	8	0	5	0
20	8	0	4	48
21	7	50	4	40
22	7	20	4	30
23	7	25	4	30
24	7	15	4	20
25	7	15	4	15
26	6	55	4	10
27	6	45	4	5
28	6	40	4	0
29	6	30	3	55
30	6	20	3	50

Apparatus :

(i) The pipette sampling apparatus.

(ii) An electric stirrer with a bowl.

(iii) Sieves

(iv) 600 ml beaker

(v) One liter – mark sedimentation cylinder.

(vi) A wide – mouthed glass funnel for holding the sieve.

(vii) Weighing beakers or weighing – dishes

(viii) A hot water-bath or a hot-plate.

Reagents :

(i) 30% hydrogen peroxide

(ii) 2 NHCl

(iii) N/10 NaOH

Procedure :

(i) Transfer 20 g of oven-dried soil to a 600 ml beaker.

(ii) Add 20 ml of H_2O_2 (20 volume) and swirl the contents well. Let the reaction proceed for 5-10 minutes.

(iii) Place the beaker over a hot water-bath or a hot plate. Continue digestion, stirring the contents all the time with a glass rod to minimize frothing, till the reaction completely subsides. In the case of severe frothing and prolonged reaction, a second lot of H_2O_2 should be added. Generally the Rajasthan soils do not contain high amounts of organic matter, a single treatment with H_2O_2 is usually sufficient.

(iv) Cool the beaker; wash its inner sides with distilled water.

(v) Add 25 ml of 2 N HCl and allow the contents to react.If more that 2% $CaCO_3$ is present, more HCl should be added at the rate of 2.5 ml for each per cent of

$CaCO_3$. Ensure that HCl reaction with the soil is complete. Therefore, allow the reaction to proceed for about an hour, with intermittent shaking at intervals.

(vi) Filter the contents through Whatman No. 50 filter paper. Discard the filtrate.

(vii) Give washing to the soil with distilled water till the filtrate coming out is free from chlorides. The test may be made by using silver nitrate solution.

(viii) Transfer the soil sample from the filter paper to the bowl of the electric stirrer with a jet of distilled water. Make the volume to about 400-500 ml. Add 5-6 drops of phenolphthalein indicator. Add N/10 NaOH till the whole suspension shows a pink colour, indicating its alkaline reaction. Stir the contents for 10 minutes.

(ix) Transfer the contents to a 70-mesh sieve placed in the funnel, which is held over the top of a one-litre cylinder. Wash the soil particles on the sieve with a jet of distilled water till only the coarser particles are retained on the sieve.

(x) Transfer these particles to a weighed dish. Dry at 105^0C in the oven to a constant weight and record this weight.

(xi) Make up the volume of the suspension in the cylinder to the one litre mark by adding more distilled water.

(xii) Place the cylinder upright on the table. Note down the temperature of the suspension.

(xiii) Stir the contents 20-25 times in one minute with the plunger so that nothing remains settled at the bottom of the cylinder. Remove the plunger gently.

(xiv) Find out the requisite time against the temperature for silt + clay and clay from the sedimentation table.

(xv) Pipette out a 25 ml sample of the suspension from 10 cm depth after the requisite time. Transfer the soil — water suspension to a weighed dish or beaker Dry at 105^0C to a constant weight and record the weight.

(xvi) In the same way as given above, remove 25 ml of the suspension from the 10 cm depth at the time required to sample for clay. Dry it in the oven.

(xvii) Record this weight as the weight of the dish and the amount of clay in 25 ml of the suspension.

(xviii) Decant the remaining suspension by washing repeatedly with distilled water. Remove the particles finally left, with a jet of distilled water to the weighing – dish.

(xix) Dry the weighing — dish with its contents in the oven. The weight of the soil particles in the dish is the amount of fine sand in the total sample.

(xx) Compare the weight of fine sand thus obtained with the weight calculated by subtracting the weight of coarse sand, slit and clay from the total weight of the sample taken.

Observations

W_1 = Weight of the container (beaker or weighing – dish used for coarse sand).

W_2 = Weight of the container + the weight of coarse sand.

W_3 = Weight of the container used for silt + clay.

W_4 = Weight of the container + the weight of silt + clay

W_5 = Weight of the container used for clay

W_6 = Weight of container + the weight of clay

W_7 = Weight of the container used for fine sand

W_8 = Weight of the container + the weight of the fine sand

Calculations: - The four fractions of soil obtained above are finally calculated as below :-

(a) Percentage coarse sand $= \dfrac{W_2 - W1}{20} \times 100$

(b) Percentage silt + clay $= \dfrac{W_4 - W_3}{20} \times \dfrac{1000}{25} \times 100$

(c) Percentage clay $= \dfrac{W_6 - W_5}{20} \times \dfrac{1000}{25} \times 100$

(d) Percentage fine sand $= \dfrac{W_8 - W_7}{20} \times 100$

(e) Percentage silt = b - c

(f) Percentage fine sand by subtraction = 100- (a+b) :

Precautions :

(i) The temperature of the suspension between two pipettings should not be allowed tovary too much.

(ii) While inserting the pipette, care should be taken that turbulence is not caused in thesuspension and pipetting is done uniformly at a moderate speed.

(iii) To avoid interference among the particles, the concentration of the suspension should not exceed 2%. This means that not more than 20g of soil should be used.

(iv) The diameter of the cylinder should be large enough to reduce the error due to the attraction of the walls of the vessel for soil particles. One-litre cylinder fulfils this conditions.

(v) The dispersion of the soil particles through mechanical action (shaking and stirring) should be thorough and enough to get an uniform dispersion of invidual particles.

(vi) Pipetting should be done slowly so that the soil suspension is not disturbed.

(vii) In both pipettings, start operation at least 20 seconds before the actual sampling time.

(viii) Adjust your time schedule in such a way that you prepare the suspension on the first day and the first pipetting during the next day.

The reporting of results: Results should be expressed as follows from the textural class triangle. The area of an equilateral triangle is divided into 12 parts. Each part represents the textural class of soil. Textural designation is based on the international soil- particle- fraction classifications (Fig. 1) While using the diagram the points corresponding to the percentage of siltand clay present in the soil under consideration are located on the silt and clay sides of the triangle respectively. Lines are then projected inwards from these points in the first case parallel to the sand side. The compartment in which the lines meet give the name of textural class of the soil.

Result: As per the mechanical analysis of the given soil the composition of the soil separates is

Sand = -----percent; Fine sand= ------percent ;Silt= ------percent ; Clay= ---------- perc entand accordingly from textural class triangle, the texture of the soil is ---------- .

EXERCISE – 3

Object: Determination of organic carbon in soil by Walkley and Black (1934) rapid titration method

Principle

A known weight of soil is treated with an excess volume of standard $K_2Cr_2O_7$ in the presence of conc. H_2SO_4. The soil is slowly digested at a low temperature by heat of dilution of H_2SO_4 and the organic carbon in the soil is thus oxidized to CO_2. The excess of $K_2Cr_2O_7$ not reduced (unused) by the organic matter is titrated back against a standard solution of ferrous ammonium sulphate in the presence of H_3PO_4 and diphenyl amine indicator. At the end point colour of suspension changes from violet to bright green.

Reactions:

(A) Oxidation of carbon

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

(B) During titration

$$K_2Cr_2O_7 + 4\ H_2SO_4 \rightarrow 2\ K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O2FeSO_4$$

$$+ H_2SO_4 + O \rightarrow Fe_2\ (SO_4)_3 + H_2O$$

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

Reagents

1. 1 N $K_2Cr_2O_7$ solution: Dissolve 49.04 g of A.R. grade $K_2Cr_2O_7$ in distilled water and dilute to 1 litre.
2. N/2 Fe $(NH_4)_2\ (SO_4)_2.6H_2O$: Dissolve 392 g F.A.S. in distilled water and add15 ml concentrate H_2SO_4 and make the volume to 2 litre.
3. Concentrate H_2SO_4 containing 1.25% silver sulphate.
4. Orthophosphoric acid (85%).
5. Diphenylamine indicator: Dissolve 0.5 g diphenylamine in a mixture of 20 ml water + 100 ml conc. H_2SO_4.

Procedure:

1. Take 2 g soil in a 500 ml conical flask
2. Add 10 ml 1 N $K_2Cr_2O_7$ solution with the help of pipette and shake to mix.
3. Add 20 ml conc. H_2SO_4 containing 1.25% Ag_2SO_4 and swirl the flask 20 to 30 times.
4. Allow the flask to stand for 30 minutes on an asbestos sheet for completereaction.
5. Pour 200 ml distilled water to the flask to dilute the suspension.
6. Add 10 ml 85% H_3PO_4 and 15-20 drops of diphenylamine indicator.
7. Titrate the solution with N/2 F.A.S. till the colour changes from violet to bright green.
8. Note the volume of ferrous ammonium sulphate (F.A.S.)
9. Carry out a blank titration (without soil) in a similar manner.

Observations

1. Weight of soil = ----------W (g)
2. Volume of N/2 Fe $(NH_4)_2$ $(SO_4)_2$ used in Blank titration (B) = ...ml.
3. Volume of N/2 Fe $(NH_4)^2$ $(SO_4)^2$ used in Soil sample titration (S) = ... ml.

Calculation:

1 ml of 1 N $K_2Cr_2O_7$ = 0.003 g of organic carbon

$$\% \text{ organic carbon in soil} = \frac{10\,(B - S) \times 0.003 \times 100}{B \times \text{Weight of soil}}$$

% Organic matter = % organic carbon x 1.724 (Since organic mater contains 58%carbon)

Interpretation of results for organic carbon :

(i) Below 0.50 % - Low

(ii) 0.50 to 0.75% - Medium

(iii) More than 0.75% - High

Result : The percent organic carbon of the soil is---------, therefore soil i --------- in organic carbon. The organic matter of the soil is ------- .

EXERCISE-4

Object : Determination of available nitrogen in soils (Subbiah and Asija, 1956).

Principle

A known weight of the soil is mixed with excess of alkaline $KMnO_4$ and distilled. Ammonia gas released by distillation is absorbed in a known volume of standard sulphuric acid excess of which is titrated with standard alkali using methyl red as an indicator.

$2KMnO_4 \rightarrow = K_2O + MnO_2 + 3O$

Organic matter + O $\rightarrow$ $= R\text{-}NH_2$

$R\text{-}NH_2 + H_2O \rightarrow = R\text{-}OH + NH_3$

$2NH_3 + H_2SO_4 \rightarrow = (NH_4)_2\ SO_4$

$H_2SO_4 + 2$ NaOH $\rightarrow = Na_2\ SO_4 +$ H_2O

Apparatus

Distillation apparatus, distillation flask, flask, glass beads, 250 ml beakers, conical flask, burette and pipette etc.

Reagent

1. 0.32% KMnO4 solution — Dissolve 3.2 g pure $KMnO_4$ in distilled water and dilute to one litre.
2. 2.5% NaOH solution – Dissolve 25 g NaOH in distilled water and dilute to one litre.
3. 0.02 N H_2SO_4 –Dissolve 0.56 ml of concentrated H_2SO_4 and make the volume one litre then standardize with 0.02 N Na_2CO_3 using phenolphthalein and methyl red indicator or 0.02 N NaOH using phenolphthalein indicator.
4. 0.02 N NaOH – Dissolve 0.8 g NaOH in distilled water and dilute to one litre.
5. Methyl red indicator

Procedure

1. Transfer 20 g of soil in a distillation flask. Add 20 ml water and 100 ml of 0.32 per cent $KMnO_4$ solution.
2. Take 20 ml of 0.02 N H_2SO_4 in a 250 ml conical flask and add two or three drops of methyl red indicator. Put the flask below the receiver tube. Keep the tip of the receiver tube well dipped into the H_2SO_4 solution.
3. Add 100 ml 0.32% $KMnO_4$ and 100 ml of 2.5% NaOH to the distillation flask containing soil and immediately connect the flask with the distillation apparatus.
4. Start heating the distillation flask. The free ammonia thus released will be absorbed in the H_2SO_4 solution. Continue the distillation till the evolution of ammonia from distillation flask takes place; test it by bringing a moist red litmus paper near the outlet of condenser, which will turn blue as long as ammonia is being evolved. No change in red litmus paper shows the completion of the ammonia distillation.
5. Titrate the excess of H_2SO_4 with N/50 NaOH and note the volume.

Observation and calculation

1. Weight of soil = 20 g
2. Volume of N/50 H_2SO_4 taken (X) = ---------- ml
3. Volume of N\50 NaOH used (Y) = ---------- ml
4. volume of N/50 H_2SO_4 used for NH_3 (X-Y) = ---------- ml
5. 1 ml of N/50 H_2SO_4 = 0.00028 g N
6. Per cent available nitrogen = (X-Y) x 0.00028 x 100/20
7. Available nitrogen in ppm = percent N x 10^4
8. Available nitrogen Kg/ha = (X-Y) x 0.00028/20 x 2240000 or = (X-Y) x 28 x 1.12 = **(X-Y) x 31.36**

Rating of soil based on available nitrogen status :

Low : Available nitrogen less than 250 kg / ha
Medium : Available nitrogen 250 – 500 kg / ha
High : Available nitrogen more than 500 kg / ha

Précautions

1. Dip the delivery tube end in the receiver containing standard acid before adding NaOH solution in the distillation flask.
2. Connect the distillation flask to the distillation apparatus immediately after the addition of NaOH to avoid the loss of ammonia.
3. During distillation, first remove the receiver flask and then off heater to avoid back suction of the distillate.
4. Collect about 100 ml of distillate in 30 minutes steady distillation.

Result : The available nitrogen status of the soil is---------- kg / ha , therefore soil is ----

--------in nitrogen .

EXERCISE-5

Object: Determination of available phosphorus in soil (Olsen et al., 1954)

Several methods are used for the determination of available phosphorus in soils. Generally two methods are common. Olsen's method is used for neutral and alkaline soil where as the Bray's method is used for acid soils.

Olsen's method

Principle

In Olsen's method available phosphorus in soil is extracted by shaking the soil with 0.5 M sodium bicarbonate solution adjusted at pH 8.5. Later on the method involved formation of chlorostannous reduced molybdophospheric blue colour.

Apparatus

Spectrophotometer, shaking machine, conical flask, volumetric flask, pipette, measuring cylinder, funnel etc.

Reagents

1. 0.5 M sodium bicarbonate : Take accurately 42 g of $NaHCO_3$ and dissolve in distilled water and make the volume one litre. Adjust the pH of this solution to 8.5 pH with 1 N NaOH.

2. Darco-G 60 or activated charcoal (phosphorus free).

3. ammonium molybdate 1.5% : Dissolve 15 g of ammonium molybdate in 300 ml of warm distilled water (about 50 ^{0}C). Filter the mixture, if necessary and allow it to cool. Then add 342 ml of concentrated HCl gradually by strring it. Dilute to one litre with distilled water.

4. Stannous chloride (stock solution): Dissolve 10 g of $SnCl_2$ in 25 ml concentrated HCl and add a piece of tin then heat it till it becomes clear. Store this solution in a amber colored bottle.
5. Working solution of Stannous chloride : Take 1.0 ml stock solution of $SnCl_2$ and make 66 ml with distilled water.
6. Standard solution of phosphorus : Take 0.439 g of A.R. KH_2PO_4 (oven dried at 40 0^C) and dissolve in about half a litre distilled water. Add to this 25 ml 7 N H_2SO_4 and make the volume one liter with distilled water. This gives 100 ppm P (100 mg P per litre).

Standard curve

Prepare a 1.0 ppm P solution by taking 2.5 ml of 100 ppm solution in 250 ml volumetric flask and make its volume with distilled water. To prepare the standard curve of different concentrationis of P, take 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ml of 1.0 ppm solution in 25 ml volumetric flask and follow the procedure for development of colour as given for sample and make the volume 25 ml. These will contain 0.04, 0.08, 0.12, 0.16, 0.20, 0.24, 0.28, 0.32, 0.36 and 0.40 ppm P, respectively. Also prepare a blank without adding KH_2PO_4 solution. The readings are taken on spectrophotometer at 660 nm. The curve is plotted taking the spectrophotometer reading on vertical axis and amount of Pin ppm on horizontal axis.

Procedure

1. Take 5 g of soil into a 250 ml conical flask and add a little amount of phosphorus free activated charcoal.
2. Add 100 ml of 0.5 M $NaHCO_3$ solution into the flask and shake the concial flask for 30 minutes on a mechanical shaker.
3. Filter the suspension through a Whatman No. 42 filter paper and take 5 ml aliquot of the extract in a 25 ml volumetric flask.
4. Add 5 ml of ammonium molybdate solution and a little quantity of distilledwater and shake the contents of the volumetric flask.
5. Add 1 ml of working $SnCl_2$ solution in each 25 ml volumetric flask and make the volume upto 25 ml with distilled water and shake well.

6. Measure the transmittance of the solution preferably within 5 to 20 minutes after the addition of $SnCl_2$ solution on 660 nm in a spectrophotometer .
7. Simultaneously run a blank without soil following the same procedure and take the reading.

Observations and calculation

1. Weight of soil taken = 5 g
2. Volume of 0.5 M $NaHCO_3$ taken = 100 ml
3. Aliquot of extract taken = 5 ml
4. Final volume of extract = 25 ml (After colour development)
5. spectrophotometer reading of soil sample = X
6. spectrophotometer reading of blank sample = Y
7. ppm P obtained from graph by using X = Z_1
8. ppm P obtained from graph by using Y = Z_2

Calculation

Avalable P (kg/ha) = Z_1-Z_2 X 100 (d.f.) X 2.24

Available P_2O_5 (kg/ha) = Z_1-Z_2 x 100 (d.f.) X 2.24 x 2.29

Whereas,

$$d.f. = \frac{\text{Volume of extractant taken}}{\text{Weight of soil}} \times \frac{\text{Final volume of extract}}{\text{Volume of extract taken}}$$

2.24 = Conversion factor for converting ppm into kg/ha

2.29 = Conversion factor for converting P in to P_2O_5

Precautions

1. Use phosphorus free activated charcoal and if not free then wash it with dilute HCl till it becomes P free, which can be tested by adding chloromolybdic acid and stannous chloride to the filtrate. Appearance of blue colour shows the presence of P.
2. If filtrate is not colourless then add more Darco G-60 shake and filter again.
3. Fresh working solution of $SnCl_2$ should be prepared at the time of development of colour in P extract.

4. Record the reading not before 5 minutes and not later than 20 minutes after development of color.
5. Reading should be taken at 660 nm or using red filter.

Rating of soil based on available phosphorus (P_2O_5) in soil

Low: Available phosphorus (P_2O_5) less than 20 kg/ha.

Medium: available phosphorus (P_2O_5) between 20 and 50 kg/ha

High: Available phosphorus (P_2O_5) more than 50 kg/ha.

Result: The available phosphorus status of the soil is---------- kg / ha, therefore soil is ----------in phosphorus.

EXERCISE-6

Object : Determination of available potassium in soil (Metson, 1956)

In general available potassium includes exchangeable and water soluble potassium in soils except that of saline or saline- sodic soils. Available K is determined by extracting the soil by shaking with N neutral ammonium acetate solution. The ammonium ions replace potassium ions absorbed on the soil colloids.

(Colloid) $K^+ + CH_3COONH_4$ - (colloid) $NH_4^+ + CH_3COOK$

The estimation of potassium in the extract is carried out with the help of flame photometer.

Apparatus

Flame photometer, shaking machine, conical flasks, volumetric flask, pipette, beaker, funnel etc.

Reagents

1. N neutral ammonium acetate solution : Take 700 ml of distilled water in a one litre volumetric flask. Add 57 ml of glacial acetic acid (99.5%) and then add 69 ml of concentrated ammonium hydroxide. Dilute it to about 900 ml and adjust the pH at 7.0 by adding 3 N NH_4OH or 3 N CH_3COOH and make up to one litre. It can also be prepared by dissolving 77.04 g of ammonium acetate in 900 ml of distilled water and adjust the pH at 7.0 by adding NH_4OH or CH_3COOH as required and make the volume one litre.
2. Standard solution: Dissolve 1.908 g AR grade KCl in distilled water and make the volume one litre. This solution contains 1000 mgK/L i.e. 1000 ppm K.
3. Working solution of K : Take 10 ml of 1000 ppm K solution in 100 ml volumetric flask and make the volume. This will contain 100 ppm K.

Procedure

1. Take 5 g soil in 150 ml conical flask
2. Add 25 ml N neutral ammonium acetate solution and shake for 5 minutes ona shaker.
3. Filter the contents through a Whatman No. 1 filter paper and reject first few drops of the filtrate.

4. Feed the filtrate to flame photometer after necessary setting and calibration ofthe instrument.
5. Also run a blank without soil using the same procedure.

Preparation of standard curve

From the 100 ppm solution take 10, 20, 30 and 40 ml of K in each 100 ml volumetric flask and make the volume. This will give 10, 20, 30 and 40 ppm of K. The concentration of K may be reduced according to the working range of flame photometer.The curve is obtained by plotting the readings of flame photometer against the various concentration of K by setting the reading at zero for the blank and 100 for the standard K solution having maximum concentration to be used.

Observation and calculation

1. Weight of soil taken = 5 g
2. Volume of extractant = 25 ml
3. Reading of flame photometer = X
4. ppm K as obtained from standard curve corresponding to X = (R) ---------- ppm
5. Available K kg/ha = R x 5 (dilution factor) X 2.24
6. Available K_2O kg/ha = R x 5 x 2.24 x 1.23

Here 1.23 is conversion factor for converting K into K_2O

Precautions

1. pH of the ammonium acetate solution should be adjusted at 7.0
2. In flame photometer gas and air pressure should not fluctuate to get steady reading.
3. Few ml of filtrate in the beginning should be rejected.
4. Use the proper filter of K and do not take the reading without filter.

Rating of soil based on available potassium (K_2O) in soil

Low : Available potassium (K_2O) less than 125 kg/ha

Medium : Available potassium (K_2O) between 125 and 250 kg/ha

High : Available potassium (K_2O) more than 250 kg/ha:

Result : The available potassium status of the soil is---------- kg / ha, therefore soil is --

----------in potassium .

EXERCISE-7

Object: Determination of available sulphur in soils

Principle

Soil is shaken with 0.15 % $CaCl_2$ solution. Chloride ions displace adsorbed sulphate during extraction. Calcium ions suppress the extraction of soil organic matter and hence eliminate the contamination caused by extractable organic S. The filtrate is analysed for S by the turbidimetric method of Chesnin and Yien (1950) in which the turbidity produced due to precipitation of sulphate as barium sulphate is measured on a spectrophotometer at a wavelength of 420 nm using a blue filter. Gum acacia solution is added to stabilize the turbidity so that the precipitate of barium sulphate does not settle down.

Reactions

$CaCl_2 \rightarrow Ca^{++} + 2\ Cl^-$

Micelle] $SO_4^{2-} + 2\ Cl \rightarrow$ Micelle] $Cl^- + SO_4$

$BaCl_2 \rightarrow Ba^{2+} + 2\ Cl$

$SO_4^{2-} + Ba^{2+} \rightarrow BaSO_4$

(Precipitate)

Reagents

1. Extracting solution: Dissolve 1.986 g of calcium chloride dehydrate ($CaCl_2 2H_2O$) in distilled water and dilute to one litre.
2. Barium chloride ($BaCl_2$): 30 to 60 mesh crystals: Grind barium chloride crystals until they pass through 30-mesh sieve and are retained on a 60-meshsieve.
3. Gum acacia solution (0.25%) : Dissolve 0.25 g gum acacia in distilled water and dilute to 100 ml.
4. Standard sulphur (100 ppm S) : Dissolve 0.5434 g of the reagent grade potassium sulphate (K_2SO_4) in distilled water and dilute to one litre.

Apparatus

150-ml Erlenmeyer flask, funnel, pipettes, 25 ml volumetric, flasks electricshaker, spectrophotometer and what man No. 42 filter paper.

Procedure

(a) Preparation of standard curve

Pipette out 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 5.0 ml of 100 ppm S solution in different 25-ml volumetric flasks. Thus series of standard S solutions of 1, 2, 4, 6, 8, 10, 12 and 20 ppm will be obtained, respectively after making final volume to 25 ml. In each flask add 1.0 g of 30-60 mesh $BaCl_2$ crystals. Swirl for one minute to dissolve the crystals and add 1 ml of 0.25% solution of acacia. Make up the volume in each flask with distilled water and shake well. Within 5 to 30 minutes after the development of turbidity ,read the standards on a spectrophotometer at 420nm .Plot a standard curve showing relationship between concentration of S and absorbance readings.

(b) Procedure

1. Weight 10 g air- dried soil and transfer it to a 150 ml conical flask.
2. Add 50 ml of 0.15 % $CaCl_2$ solution and shake for 30 minutes on a shaker.
3. Filter the suspension through what man no 42 filter paper.
4. Pipette out 20 ml of the filtrate in 25 ml volumetric flask.
5. Add one gram of 30-60 mesh $BaCl_2$ and shake for 1 minute
6. Thereafter add 1 ml of 0.25% gum acacia solution.
7. Finally make up the volume by adding distilled water and shake for 1 minute.
8. Within 5 to 30 minutes after development of turbidity take the reading on spectro photometer.

Calculation

Weight of soil = 10 g

Volume of extractant = 50 ml

First dilution = 5 times

Volume of aliquot taken	=	20 ml
Final volume	=	25 ml
Second dilution	=	1.25 times
Absorbance reading	=	A
ppm of S from standard curve against A value	=	Y
ppm of S in soil	=	Y x 6.25 (dilution factor)
Kg of S/ha	=	ppm x 2.24

Results: The soil contains available S ----------ppm and ----------kg /ha

The soil having available S less than 10 ppm are rated as deficient in sulphur

EXERCISE-8

Object: Estimation of available iron, manganese copper and zinc in soil (Lindsay and Norwell, 1978)

Principle

Diethylene tetramine penta acetic acid (DTPA) being a chelating agent is used in the determination of available Fe, Mn, Cu and Zn. When the soil is shaken with a solution of DTPA, it combines with metal ions in the solution and form soluble complexes of Fe^{++}, Mn^{++}, Cu^{++} and Zn^{++}. The $CaCl_2$ and triethanolamine (TEA) solution slightly raise and buffer the soil pH and mitigates the effect of Ca^{++} and Mg^{++}. From DTPA extract Fe^{++}, Mn^{++}, Cu^{++} and Zn^{++} are determined with the help of Atomic Absorption Spectrophotometer by using their respective hollow cathodes.

Apparatus

Atomic Absorption Spectrophotometer, shaking machi ne, Centrifuge, beaker, Pipette, volumetric flask, conical flask, funnel etc.

Reagents

1. DTPA 0.005 M solution
2. TEA 0.1 M (AR or extra pure)

solution3. $CaCl_2.2H_2O$ (AR) 0.01 M

4. Dilute HCl (1:1) AR diluted with double distilled water.

The extracting reagent is prepared by taking 1.967 g of DTPA, 1.470 g, Ca $Cl_2.2H_2O$ and 13.3 ml of TEA in 100 ml of glass or double distilled water and dilute approximately to 900 ml. With the help of pH paper adjust the pH of the solution to

7.3 by adding dilate HCl (1:1). While stiring make the volume of the extracting solution to one litre. The solution remains stable for several months.

Preparation of 100 ppm standard solutions

Element	Atomic weight	Micro nutrient salt	Molecular weight	Quantity of salt in g for 1litre solution
Zn	54.38	$ZnSO_4.7H2O$	287.56	0.4398

Cu	63.54	$CuSO_4.5H2O$	249.69	0.39259
Mn	57.94	$MnCl_2.4H2O$	197.69	0.3602
Fe	55.85	$FeSO_4.7H2O$	278.02	0.4977

From the above 100 ppm solution a 10 ppm working standard solutikon is prepared for Mn^{++}, Cu^{++} and Zn^{++} by taking 10 ml of 100 ppm solution in a 100 ml volumetric flask and making the volume 100 ml with the help of glass distilled water. From the 10 ppm solution take 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ml in 50 ml volumetric flask and make up the volume. This will give 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8 an d 2.0 ppm of respective micronutrient solution. For iron take direct 0, 1, 2, 3, 4, 5, 10 and 12 ml of 100 ppm solution in 50 ml volumetric flask and make up the volume with glass distilled water, this will give 0, 2, 4, 6, 8, 10, 16, 20 and 24ppm iron solution.

Procedure

1. Weight 10 g of soil and transfer it to a 150 ml polythene bottle and add 20 ml DTPA extracting solution to it and stopper it well.
2. Shake the contents of bottle on electric shaker for 120 minutes. Either centrifugeor filter the contents through Whatman No. 42.
3. Prepare a blank by adding all the solution except soil by shaking and filtration.
4. Insert the hollow cathode of the micronutrient which is to be determined in AAS and start the AAS.
5. Feed the blank solution of 0 ppm and adjust the zero in AAS then feed the lowest concentration standard and note the reading after that take the reading of standard in increasing order of concentration by running the blank in between tow standards to ensure that readings has not changed from zero. Note the readings of each working standard.
6. Absorbance verses concentration of standards is plotted on graph paper and prepare the standard curve.
7. Feed the sample extracts one by into AAS and note the readings.
8. Find out the concentration in ppm of the sample with the help of standard curve.

Observation and Calculation

1. Weight of soil = 10 g

2. Volume of extractant = 20 ml

$$\text{Dilution factor} = \frac{\text{Volume of extractant}}{\text{Weight of soil}} = \frac{20}{10} = 2$$

ppm of micronutrient in soil = ppm of sample reading x 2

Precautions

1. Use only glass distilled water or double distilled water for the determination of micronutrients
2. Soil sample should be either ground in wooden pastle and mortar or stainlesssteel grinder.
3. The glassware used should be of high quality i.e. either corning or Borosil.
4. The glassware should be washed thoroughly by chromic acid ($K_2Cr_2O_7$+ H_2SO_4) then with distilled and finally with double distilled water before use. If possible pipette etc. should be kept dipped into chromic acid.
5. All the reagents used for determination of micronutrients should be of AR grade.
6. The micronutrient laboratory should be kept dust free.
7. While determing micronutrients by AAS ensure about the hollow cathode lamp. The lamp should be of the respective element which is to be determined.

Results: The soil contains available zinc ----------ppm

soil having available zinc less than 0.6 ppm is rated as deficient in zinc

The soil contains available manganese ---------- ppm

soil having available manganese less than 2.0 ppm is rated as deficient in manganese

The soil contains available copper----------ppm

soil having available copper less than 0.65 ppm is rated as deficient in copper

The soil contains available iron ---------- ppm

soil having available iron less than 4.5 ppm is rated as deficient in iron

EXERCISE-9

Object : Determination of the cation exchange capacity (CEC) of soil

Principle :

It is the capacity of the soil to exchange cations for others on its exchange complex. It is usually expressed as meq per 100 gram of soil or Cmol (P^+) kg^{-1} of soil.

For CEC determination, soil is leached with suitable quantity of neutral N Ammonium acetate. Exchangeable cations are displaced by NH_4^+ ions. The excess of ammonium acetate (NH_4OAC) is washed with alcohol. The amount of NH_4^+ ions adsorbed is determined by distillation with MgO.

Apparatus

1. Beaker (400 ml)
2. Burette
3. Pipette
4. Conical flak
5. Funnel
6. Kjeldahl flask
7. Distillation apparatus etc.

Reagents

1. Neutral 1 N Ammonium acetate solution (pH 7.0) : Dissolve 154 g ammonium acetate in distilled water dilute it to 1.8 liters. Mix thoroughly. Adjust pH to 7.0 with dilute ammonium hydroxide or acetic acid as required and make volume to 2 litre.
2. 40% alcohol : Take 40 ml absolute alcohol (ethyl alcohol) and make up volume 100 ml with distilled water.
3. MgO powder
4. N/10 Sulphuric acid solution : Take 2.8 ml of concentrated H_2SO_4 (36N) with automatic pipette and dilute to one litre with distilled water.
5. N/10 Sodium hydroxide : Dissolve 4.0 gram sodium hydroxide (solid) in distilled water and make up volume to 1 litre.

6. Methyl red indicator.
7. Ammonium chloride (NH_4Cl) solution.

Procedure

1. Take 20 gram of soil in a 400 ml beaker and add 100 ml of 1 N ammonium acetate solution, stir well and let it stand over night, then filter the contents ofthe beaker through Whatman No. 44 filter paper.
2. After the solution has leached down, add a drop of NH_4Cl solution and washthe soil with 25 ml of 40% alcohol, at each washing.
3. Continue this washing till the filtrate becomes chloride free (which can be tested with $AgNO_3$ solution).
4. After complete washing, transfer the soil along with the filter paper in Kjeldahl flask.
5. Add about 2-3 gram of MgO powder and 250 ml of distilled water and connectthe flask to the distillation assembly.
6. Take 25 ml of N/10 sulphuric acid solution and 3-4 drops of methyl red indicator in a 250 ml conical flask, then put this conical flask below receiver ofthe distillation apparatus.
7. Collect distilled ammonia in this acid solution till the volume of distillate becomes 125 ml.
8. Titrate the excess acid with N/10 NaOH solution and calculate the C.E.C.

Observations

1. Weight of the soil taken = 20 g
2. Volume of N/10 H_2SO_4 solution taken (x) = ---------- ml.
3. Volume of N/10 NaOH solution used (y) =----------ml.
4. Volume of N/10 H_2SO_4 solution used (x-y) = ---------- ml.

Calculations

$$\text{Cation exchange capacity (CEC)} = \frac{(x-y) \times 0.018}{10} \times \frac{100}{20} \times \frac{1000}{18}$$

Result :Cation exchange capacity (CEC) of soil is---------- Cmol (P^+) kg^{-1} of soil.

EXERCISE-10

Object: Determination of exchangeable sodium by flame photometer

Apparatus Flame photometer, shaker, centrifuge and tubes etc.

Reagents

A. Ammonium acetate, approximately 1 N. To 700 or 800 ml of water add 57 ml of concentrate acetic acid and then 68 ml of concentrate ammonium hydroxide. Dilute to a volume of 1 liter and adjust the pH 7.0 to by the addition of more ammonium hydroxide or acetic acid.

B. Sodium chloride, 0.04 N in 1 N ammonium acetate. Dissolve 2.338 gm of dry sodium chloride in reagent A. Dilute to exactly 1 liter with additional A..

Take 5 g soil in a centrifuge tube and add 33 ml of reagent A to the tube, stopper, and shake for 5 min. remove the stopper and centrifuge at RCF= 1,000 until the supernatant liquid is clear. This usually requires 5 min. decant the supernatant liquid as completely as possible into a 100-ml volumetric flask. Extract the soil with a total of 3 times by this procedure, decanting into the same flask. Dilute to volume, mix and determine the amounts of the extracted sodium by flame photometer. Flame photometric analysis may be made directly upon aliquots of the extract.

Determine the saturation percentage. Obtain the saturation extract and determine the soluble sodium concentration by flame photometer.

The estimation of exchangeable sodium in ammonium acetate extract and soluble sodium in saturation extract with the help of flamephotometer can be determine by following the procedure given in Exercise No.15

Calculation

Ammonium acetate extractable sodium in meq/100 gm = sodium concentration in extract in meq./ L.x10) /Wt. of sample in gm). Soluble sodium in meq. /100 gm = sodium conc. of saturation extract in meq/L Xsaturation percentage /1,000. Exchangeable sodium in meq/100 gm=Ammonium acetate extractable sodium in meq /100 gm –soluble sodium in meq/100 gm.

Result : The exchangeable sodium in the soil is---------- meq/100 gm or Cmol (p^+) kg^{-1}

Computation of exchangeable sodium percentage (ESP)

$$ESP = \frac{\text{Exchangeable sodium (Cmol } (p^+)\ kg^{-1})}{\text{Cation exchange capacity (Cmol } (p^+)\ kg^{-1})} \times 100$$

Result : The exchangeable sodium percentage (ESP) of the given soil is ----------

EXERCISE-11

Object: Preparation of soil saturation paste and extraction of saturation extract

Apparatus China dish of 250-ml capacity or greater and spatula

Procedure

Take to 250 g soil in a china dish and add distilled water while stirring with a spatula. The soil-water mixture is consolidated from time to time during the stirring process by tapping the container on the workbench. **At saturation the soil paste glistens as it reflects light, flows slightly when the container is tipped and the paste slides freely and cleanly off the spatula for all soils but those with a high clay content.** After mixing, the sample should be allowed to stand for an hour or more, and then the criteria for saturation should be rechecked. Free water should not collect on the soil surface nor should the paste stiffen markedly or lose its glistening appearance on standing. If the paste does stiffen or lose its glisten, remix with more water.

Because soils puddle most readily when worked at moisture contents near field capacity, sufficient water should be added immediately to bring the sample nearly to saturation. If the paste is too wet, additional dry soil may be added.

Special precautions must be taken with peat and muck soils and with soils of very fine and very coarse texture.

Peat and muck soils: Dry peat and muck soils especially if coarse or woody in texture, require an overnight wetting period to obtain a definite endpoint of these soils usually stiffen and lose the glisten or standing. Adding water and remixing then gives a mixture that usually retains the characteristics of a saturated paste.

Fine textured soils: To minimize pudding and thus obtain a more definite endpoint with fine textured soils, the water should be added to the soils with a minimum of stirring, especially in the earlier stages of wetting.

Coarse textured soils: The saturated paste for coarse textured soils can be prepared in the same manner as for fine textured soils; however, a different moisture content is recommended for the salinity appraisal of such soils).

Extraction of saturation extract of soil

Apparatus :

Buechner funnels, filter paper, vacuum pump, extract containers such as test tubes or 1- oz. bottles.

Procedure :

Transfer the saturated soil paste, to Boehner funnel with a filter paper in place and apply vacuum. Collect the extract in a bottle or test tube, Pyrex should not be used if boron is to be determined. If the initial filtrate is turbid, it can be refiltered through the soil or discarded. Vacuum extraction should be terminated when air begins to pass through the filter. If carbonate and bicarbonate determination are to be made on the extract a solution containing 1,000 ppm of sodium hexametaphosphate should be added at the rate of one drop per 25ml. of extract prior to stoppering and storing. This prevents the precipitation of calcium carbonate on standing.

EXERCISE-12

Object:- Determination of soil reaction (pH) (Jackson, 1973)

Principle: Soil pH has been defined as negative logarithm of the hydrogen ion activity

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

Soil pH is measured by pH meter containing glass and reference electrode and marked pH scale from 0-14. The mid point 7.0 of this scale is neutral, below this denotes acidity and above this denotes alkalinity, pH meter is standardized with the help of buffer solutions of known pH and then the pH of the solution is determined.

Apparatus: pH meter, vacuum pump, beaker, pipette, glass rod, china dish, spatula etc.

Reagents: Buffer solutions of pH 4.0, 7.0 and 9.2: One buffer tablet of the respective pH is dissolved in water and the volume is made to 100 ml.

Procedure:

i. Saturation paste is prepared by adding distilled water to the soil and mixing till it starts glistening and slides on spatula as given in earlier exercise 11.

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

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

iv. Take the beaker of saturation paste and dip the electrodes into it andnote the pH reading.

v. After each determination the electrodes must be washed with distilled water and wiped out by ordinary filter paper.

Precautions:

i. Soil water suspension should be shaken well intermittently for 30 minutes.

ii. The glass and reference electrode of pH meter should always remain dippedin water.

iii. Buffer solutions should be prepared accurately and stored well in glass container. It is desirable to prepare fresh buffer solutions after few days.

iv. Connect the pH meter to the stabilizer to avoid the fluctuations in pHreadings.

v. Adjust the temperature knob of pH meter at room temperature for correct pH determination.

Interpretation of results of soil pH

pH (1:2 soil water suspension) Nature of the soil	
< 6.5	It is acidic soil
6.5 to 8.0	Soil is fit for all crops grown in the region and need no treatment
8.0 to 9.3	Soil is moderately alkaline and need small amount of amendmentsor even organic manures like green manuring and FYM
> 9.3	Gypsum requirement of soil sample should be determined andapplied according to the requirement of the soil on the hectare basis.

Observations: Reading of pH metre is----------

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

EXERCISE-13

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

Principle: A solution offers some resistance to the passage of electric current through it depending upon the concentration and type of ions present. Higher the salt content, lesser the resistance to the flow of current. The resistance (R) is defined by Ohm's law as the ratio of electrical potential in volts (E) and strength of current in ampere (I).

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

Electrical conductivity or conductance is the reverse of resistance.I/R
= I/Ohm = mho (reverse of ohm)
(At present mhos/cm is expressed in terms of dS/m).

Apparatus: Conductivity meter and a conductivity cell with known cell constant,vacuum pump, spatula, china dish, beakers, glass rod etc.

Reagents: i. Saturated solution of calcium sulphate (Reagent quality)

ii. 0.01 N KCl solution : Dissolve 0.7456 g of potassium chloride in distilled water and dilute to one litre.

Procedure :

1. The saturation extract of the soil is prepared by as per method given in exercise No. 11 and 1:2 soil water suspensions may be prepared as per method given in the procedure of pH determination.
2. Start the conductivity meter and adjust the temperature at 25 ^{0}C.
3. Check the instrument with saturated calcium sulphate solution (conductivity - 2.2 dS/m at 25 ^{0}C) or 0.01N KCl solution (conductivity – 1.41 dS/m at 25 ^{0}C)before proceeding for the samples.
4. Take the reading of the saturation extract by dipping the conductivity cell intoit. This will give ECe.

5. The same soil suspension prepared for determination of pH may also be used for EC. After recording the soil pH, allow the soil suspension in the beaker to settle for 30 minutes. Dip the conductivity cell and note the reading of conductivity meter. There should be no air bubble in conductivity tube.
6. Wash the conductivity cell after each determination and wipe with ordinary filter paper.

Observation and calculation :

$$\text{1. Cell constant} = \frac{\text{Actual conductivity of 0.01 N KCl solution}}{\text{Observed conductivity of 0.01 N KCl solution}}$$

$$\text{2. EC (dSm-1 at 25 } ^0\text{C) of 1:2 soil water suspension} = \frac{\text{Dial Reading x Knob Reading x Cell constant}}{10^3}$$

(The divisor 1000 is used to convert micromhos into millimhos)

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

Precautions:

a. The EC should be taken at 25 ^{0}C.
b. The EC reading of electrical conductivity of 0.1 N KCl solution should be 1.41 dS/m at 25 ^{0}C and that of saturated calcium sulphate should be 2.2 dS/m at 25 ^{0}C.
c. For each conductance cell its cell constant should be denoted or calculated.
d. No air bubble should remain in the conductivity tube.

Table 1: Interpretation of results for ECe of saturation extract

ECe of saturation extract (dSm^{-1} at 25 ^{0} C)	**Nature of the soil**
< 2	Salinity effects mostly negligible
2-4	Yield of very sensitive crops may be restricted
4-8	Yield of many crops restricted
8-16	Only tolerant crops yield satisfactorily
> 16	Only few tolerant crops yield satisfactorily

Table 2: Interpretation of results of EC of 1:2 soil water suspension

ECe of saturation extract (dSm^{-1} at 25 ^{0} C)	**Nature of the soil**
< 0.8	Normal
0.8-1.6	Critical for salt sensitive crops
1.6-2.5	Salt tolerant crops can be grown
> 2.5	Injurious to all crops

Result: E C of saturation extract/ 1:2 soil water suspension is ---------- --.

Accordingly the nature of soil is ---------- .

EXERCISE-14

Object: Determination of Ca^{2+} + Mg^{2+} in saturation extract of soil by versenate (EDTA) method

Principle

Ca + Mg in solution can be titrated with 0.01 N EDTA using Erichhrome black T dye as indicator at pH 10 in the presence of ammonium chloride and ammonium hydroxide buffer. At the end point colour changes from wine red to blue or green. This titration will estimate both calcium and magnesium. Beyond pH 10 magnesium is not bound strongly to Eriochrome black T indicator to give a distinct end point.

Reagents

1. EDTA or versenate solution (0.01 N): EDTA solution (0.01 N) : Take 2.0 gm of EDTA, dissolve in distilled water and make volume to 1 litre. Titrate with 0.01 N calcium solution by the procedure discussed below and make necessary dilution so that its normality is exactly equal to 0.01 N.
2. Ammonium chloride + ammonium hydroxide buffer: Dissolved 67.5 g and ammonium chloride in 750 mL of concentrated ammonia and make to 1 litre volume.
3. Erichorme black T indicator : Take 100 mL ethanol and dissolve 4.5 g of hydroxyl amine hydrochloride and 0.5 g of the eriochrome black T. indictor. Hydroxylamine hydrochloride removes the interference of manganese by keeping it in lower velency state (Mn++), or mix thoroughly 0.5 gram of the indicator with 50 g ammonium chloride.
4. Sodium cyanide solution (2%) or sodium diethyl dithiocarbamate crystals. This is used to remove the interference of copper, cobalt and nickel.

Method

1. Pipette out 10 mL of aliquot (saturation extract) in porcelain dish containing not more than 0.1 meL^{-1} of Ca plus Mg. If the solution has a higher concentration, it should be diluted.

2. Add 0.5 mL of ammonium chloride-ammonium hydroxide buffer. Now add 3-4 drops of Erichrome black T indicator.
3. Titrate this solution with 0.01 N versenate till the colour changes to bright blue or green and no tinge of wine red colour remains behind.

Observations

S.No.	Volume of aliquot taken (mL)	Burette readings		Volume of EDTA used(mL)
		Initial	Final	
1				
2				
3				
4				

Calculations

If N_1 and V_1 are normality and volume of aliquot (Ca^{2+} + Mg^{2+}) taken and N_2V_2 are the normally and volume of EDTA used, respectively, then $N_1,V_1 = N_2V_2$

N_2V_2 Vol. of EDTA x Normal of

EDTAOr N1 = -_____- = ----------

V1 mL of aliquot taken

Here, N_1, Normality = gram equivalents of Ca^{2+} plus Mg^{2+} present in one litre of aliquot.Hence,

Normality of EDTA x Vol EDTA

$Ca^{2+} + Mg^{2+}$ (meL^{-1}) =_____x 1000 =_____-

Volume of aliquot taken

$Ca^{2+} + Mg^{2+}$ (ppm) = $Ca^{2+} + Mg^{2+}$ (meL^{-1}) x equivalent weight (32) = ----------

Results

The concentration of $Ca^{2+} + Mg^{2+}$ in soil extract = ---------- MeL-1The concentration of Ca + Mg^{2+} in soil extract = ppm

EXERCISE-15

Object: Determination of Na in saturation extract of soil by flame photometer

Principle

Sodium is determined by flame photometer. Analysis through flame photometer is based on the measurement of the intensity of characteristics line emission given by the element to be determined. When a solution of salt is sprayed into a flame, the salt get separated into its component atoms because of the high temperature. The energy provided by flame excites the atoms to higher energy levels (the electrons of atoms go to high energy level). When the electrons return back to the ground or unexcited state, they emit radiation of characteristics wave length (line emission spectrum). The intensity of these radiations is proportional to the concentration of particular elements in solution which is measured through a photo cell in the flam photometer.

Equipment and reagents

1. Flame photometer with Na filter
2. Volumetric flask (100 mL)
3. Sodium chloride standard solution. Dissolve 5.845 of A.R. grade NaCl in distilled water and make volume to one litre. It will give 100 meL^{-1} of sodium. This solutionis treated as stock solution.
4. From this solution take, 0, 1, 2.5, 5.0, 7.5 and 10 mL in volumetric flasks of 100 mL capacity and make the volume by further adding distilled water. This will give a series of standard solution having 1, 2.5, 5.0, 7.5 and 10.0 meL^{-1} Na.

Method

1. Read the operation manual of flame photometer. Set the Na filter. Start the compressor and light the burner of flame photometer. Keep air pressure at 0.5 kg/cm^2 and adjust the gas feeder so as to have a blue sharp flame cones.
2. Adjust the zero reading of the meter by feeding distilled water. Now feed standard sodium solution of highest value in the standard series (10 meL^{-1}) and adjust the flame photometer to feed full value of emission in the scale i..e 100 reading.
3. Feed different standard sodium solutions one by and record the emission value (reading) for each.

4. If concentration of Na is high in extract than dilute it by taking 10 mL extract (aliquot) of sample in a 100 mL volumetric flask and make volume 100 mL by distilled water.
5. Feed the diluted extract at flame photometer and note the reading.

Note: If flame photometer does not show reading of unknown, it indicates that concentration of Na in unknown solution is higher and is out of the range of flame photometer scale. In such situation, further dilute the extract (unknown solution) and take the reading.

Observations

S.No.	Concentration of Na in known solution (meL^{-1})	Reading on flame photometer
1	1.0	
2	2.5	
3	5.0	
4	7.5	
5	10.0	

Reading of unknown solution =

Plot a standard curve between concentration and readings of standard sodium solutions. Obtain concentration of Na in unknown solution from the standard curve.

Calculations

Na (meL-1) in saturation extract = Na (meL^{-1}) as obtained from curve x dilution factor if any,

Na (ppm) = meL^{-1} x equivalent weight of Na (23) =

Results : Concentration of Na^+ (MeL^{-1}) = ----------in soil extract

Computation of Sodium adsorption ratio (SAR)

$$SAR = \frac{Na}{\sqrt{Ca + Mg / 2}}$$

Whereas:- Na, Ca, Mg are in meL^{-1}

EXERCISE-16

Object: Determination of CO_3^{2-} and HCO_3^- in saturation extract of soil

Principle

Carbonate and bicarbonate in a solution can be determined by titrating the solution against standard acid using phenolphthalein and methyl red respectively as indicators. When the colour of phenolphthalein is disappeared, it indicates half the neutralization of carbonate. At this stage methyl red indicator is added and the titration continued. When the colour changes from yellow to rose red , it is the end point for the complete neutralization of bicarbonate. The following equations illustrate these changes.

$2Na_2CO_3 + H_2SO_4 = 2NaHCO_3 + Na_2SO_4$

(phenolphthalein = pink) (phenolphthalein = colourness)

$2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2H_2O + 2CO_2$

(methyl red = yellow) (methyl red = rose red)

Reagents

1. Standard H_2SO_4 (0.01 N) : Take 2.8 mL of concentrated H_2SO_4 (36 N) with automatic pipette and dilute to one liter with distilled water, it will give 0.1 N H_2SO_4 further dilute this solution 10 times to get 0.01 N H_2SO_4
2. Methyl red indicator (0.5%) : Dissolve 0.5 g of pure methyl red powder in 100 mL of 60% ethanol .
3. Phenolphthalein indicator (0.25%) : Dissolve 0.25 g of pure phenolphthalein powder in 100 mL of 60% ethanol.

Method

1. Pipette out 10 mL of saturation extract in a conical flask or in porcelain dish andadd 2-5 drops of Phenolphthalein. Appearance of pink colour indicates the presence of carbonates. Initial reading designate as I.
2. If carbonate is present, add 0.01 N H_2SO_4 from burette till the solution becomes colourless. Record this reading (designate as II)
3. Add a few drops of methyl red indicator and titrate till the colour changes from yellow to rose red.
4. Record this reading also (designate as III). Repeat this process a number of times so as to get two concordant readings.

Observations

Volume of aliquot taken (mL)	Burette Readings			Vol. (mL) of H_2SO_4 usedfor half neutralization of CO_3 (II-I)= x	Vol. (mL) of H_2SO_4 usedfor complete neutralization of CO_3 = 2x	Vol. (mL) of H_2SO_4 used for complete neutralization ofCO_3 andHCO_3 (III-I) = Y	Vol. (mL) of H_2SO_4 usedfor neutralization of HCO_3 = Y-2x
	I	II	III				
1							
2							
3							

Calculation CO^{2-} in me L^{-1}

If N_1 and V_1 are normality and volume of aliquot (CO_3^{2-}) taken and N_2V_2 are the normality and volume of H_2SO_4 used respectively, then,

$$N_1V_1 = N_2V_2 \quad \text{or} \quad N1 = \frac{N_2V_2}{V_1}$$

Here, N_1 = normality = gram equivalents of CO_3^{-} present in one litre of aliquot

Hence, meL^{-1} of CO_3^{2-} is :

$$CO_3\ (meL^{-1}) = \frac{\text{Vol. of } H_2SO_4 \text{ used} \times \text{Normality of } H_2SO_4}{\text{Volume of aliquot taken}} \times 1000 = \frac{2x \times 0.01 \times 1000}{\text{Volume of aliquot taken}}$$

HCO_3^{-} in meL^{-1}

$$HCO_3\ (meL^{-1}) = \frac{\text{Vol. of } H_2SO_4 \text{ used} \times \text{Normality of } H_2SO_4}{\text{Volume of aliquot taken}} \times 100 = \frac{(Y-2x) \times 0.01 \times 1000}{\text{Volume of aliquot taken}}$$

Results

The concentration of CO_3 in saturation extract is = ---------- meL^{-1}

The concentration of HCO_3 in saturation extract is = ---------- meL^{-1}

EXERCISE-17

Object: Determination of nitrogen in plant (Snell and Snell, 1949).

Principle

Plant sample are digested with H_2SO_4 alongwith H_2O_2 till it become colourless. The intensity of the colour developed by Nessler's reagent in the presence of NaOH and sodium silicates is measured colorimetrically.

Apparatus

Kjeldahl flask 100 ml, measuring cylinder, volumetric flask 50 and 100 ml, pipette, beaker, digestion assembly, spectrophotometer etc.

Reagents

1. Sulphuric acid (concentrated)
2. Hydrogen peroxide 30%
3. Nessler reagent : Dissolve 45.5 g mercuric iodide and 35.0 g potassium iodide in about 70 ml distilled water. Then dissolve 112 g potassium hydroxide in another beaker in 100 ml distilled water. Mix both the solution in one litre volumetric flask and add 600 ml of water. Shake the contents of flask thoroughly, cool it and make the volume up to the mark. The solution is allowed to stand for few days and the clear supernatant liquid is stored into an umber colored bottle for use. Working solution of Nessler reagent is prepared by diluting the stock solution four times i.e. by diluting 100 ml to 400 ml.
4. Sodium silicate 10% solution: Dissolve 10 g sodium silicate in 100 ml of water. Boil it till it becomes clear. This solution is used to prevent turbidity.
5. Sodium hydroxide 10% solution: Dissolve 10 g sodium hydroxide pellets in 100 ml of distilled water. Freshly prepared solution is used to neutralize the excess of acid.
6. Nitrogen standard solution: Dissolve 0.1179 g of $(NH_4)_2SO_4$ AR grade in water and make the volume one litre in volumetric flask. This solution contains 25 ppm N. For working standards take 1, 2, 3, 4, 5, 6, 7, 8 ml of 25 ppm N solution in 50 ml volumetric flasks. Add 2 ml 10% NaOH and 1 ml 10% sodium silicate solution in 50 ml volumetric flasks. Add some water and shake the contents. Now add 1.6 ml Nessler's reagent slowly drop while shaking

and make the volume. The flasks will contain 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 ppm N, respectively.

Procedure

1. Take 0.1 g well ground and dried plant sample and transfer into a 100 ml dry kjeldahl flask carefully so that it should not stick to the neck.
2. Add 2 ml concentrated H_2SO_4 to the Kjeldahl flask, mix the contents of the flask, place on the digestion assembly and heat it till the plant material is digested.
3. Cool the flask and add 0.5 ml (10 drops) of 30% H_2O_2 and again heat the contents till it becomes clear and colourless.
4. Transfer the digested contents of the Kjeldahl flask into a 100 ml volumetric flask by washing it 2-3 times with distilled water and make the volume.
5. Take 5 ml of digested solution into a 50 ml volumetric flask and add few ml of water. Then add 2 ml of 10% NaOH and 1 ml of 10% sodium silicate solutionsand then add some water. Mix the contents and add 1.6 ml Nessler's reagent to the flask while shaking. After this, make its volume.
6. Take the reading of standard working solutions using blue filter or adjusting the spectrophotometer at a wave length of 420 nm. Plot the concentration ofN on X-axis and the spectrophotometer reading on Y-axis and prepare a standard curve.
7. Now take the reading of plant sample and calculate the ppm N with the help of standard curve.

Observation and calculation

1. Weight of plant sample = 0.1 g
2. Volume of digested material = 100 ml
3. Volume of extract taken = 5 ml
4. Final volume prepared = 50 ml

Dilution factor = 100/0.1 X 50/5 =
10,000ppm N from standard curve =R
Concentration of N in ppm = RX 10000
%N in plant sample = R x 10000/10000 = R

Precautions

1. The plant material should not stick to the Kjeldhal flask. It should be transferred in dry flask pouring the material in the centre.
2. Hydrogen peroxide should be added to the digested material when it is completely cooled.
3. Freshly prepared or turbid Nessler reagent should not be used.
4. After each addition of NaOH and sodium silicate few ml of distilled watershould be added.
5. Nessler's reagent should be added drop by drop while shaking the flask to avoid turbidity.
6. Freshly prepared NaOH solution should be used.

Questions

1. How Nessler's reagent is prepared ?
2. What is the function of sodium silicate in N determination ?
3. Why fresh solution of NaOH is required ?
4. Why colorimeteric method is generally adopted for N determination in plant sample ?
5. How will you calculate the ppm of N and per cent of N from standard curve readings?
6. How will you judge that the plant material has been digested completely ?

EXERCISE-18

Object: Determination of Phosphorus in plant (Jackson, 1973).

Principle

Orthophosphates obtained in triacid digest react with ammonium molybdate ammonium vanadate in HNO_3 medium and gives a yellow colour complex. The colour develops in about 30 minutes and remains stable for 2 to 8 weeks. Intensity of colour is measured at 470 nm in a Spectrophotometer.

Apparatus

Spectrophotometer, volumetric flask, pipette, conical flasks, digestion flask, 1 litreand 50 ml beakers.

Reagents

1. Triacid: First take 100 ml of HNO_3 add 10 ml of concentrated H_2SO_4, mix it and then add 40 ml of 60% $HClO_4$ i.e. in the ratio of 10:1:4 of HNO_3 : H_2SO_4 : $HClO_4$.
2. Ammonium molybdate ammonium vanadate solution : Dissolve 22.5 g of $(NH_4)_6$ MO_3O_7 .$4H_2O$ in 400 ml of distilled water in a beaker. Take 1.25 g of ammonium vanadate in another beaker, add 300 ml distilled water and boil it. Add ammonium vanadate solution to the ammonium molybdate solution and cool the contents. Add 250 ml of concentrated HNO_3 and dilute it to 1 litre.
3. Phosphate standard solution: Take 0.2195 g of AR grade KH_2PO_4 in a beaker and dissolve in distilled water, transfer the solution to a 1 litre volumetric flask and make up the volume. This solution contains 50 ppm of P.

Procedure

1. Take 0.5 to 2.0 g of dried and ground plant sample in a 500 ml conical flask and add 5 ml of concentrated HNO_3 for each 1 g of plant sample. Keep it for overnight.
2. To the pre-digested samples add 5 ml of triacid mixture (add 4 ml for each additional g if plant sample taken for digestion is more than 5 g).
3. Digestion of sample is carried out at 180 to 200 ^{0}C till it gives white fumes andthe liquid content is largely volatilized. At the stage of complete digestion the residue remained in the flask become clear and white. If the digested residues brown due to organic matter then again add 0.5 ml of triacid mixture and digest the material.

4. Transfer the digested material into a 100 ml volumetric flask, dilute it with distilled water upto the mark.
5. Take 10 ml plant extract into a 50 ml volumetric flask. Add 10 ml ammonium molybdate-ammonium vanadate solution and make the volume to 50 ml with distilled water. Yellow colour will develop after 15-20 minutes.
6. From the 50 ppm standard solution of P pipette out 0, 2, 4, 6, 8 and 10 ml and transfer in 50 ml volumetric flaks then add 10 ml of ammonium molybdate ammonium vanadate solution and make the volume. This will contain 0, 2, 4, 6, 8 and 10 ppm P.
7. Measure the colour intensity of standard solutions at a wave length of 470 nm or by using blue filter in a Spectrophotometer. Prepare the standard curve by plotting concentration of P on X-axis and Spectrophotometer readings on Y- axis on a graph paper.
8. Take readings of plant samples in the similar manner that of standard. Workout the ppm content of P with help of standard curve.

Observations and calculation

1. Weight of plant sample = X g
2. Volume of digested extract prepared = 100 ml
3. Volume of digested extract taken = 10 ml
4. Volume of final coloured extract prepared = 50 ml

Concentration of P in ppm in plant sample = ppm reading of plant from standard curve X Digested volume of plant sample /Weight of plant sample X Final volume prepare/volume of aliquot taken = R x 100/ X x 50/10 = R x 500/ X

Per cent P in plant sample = R x 500/X 1/10000 = R/20 X

Precautions

1. While making triacid mixture concentrated HNO_3 and $HClO_4$ should not be mixed directly. First the H_2SO_4 should be added to HNO_3 and then $HClO_4$ should be added to avoid explosion.
2. The temperature of the digestion mixture during digestion should not exceed 230 ^{0}C.

3. The reading of the P in solution should be taken after 30 minutes from the development of yellow colour.
4. Ammonium molybdate-ammonium vanadate solution should be stored in acoloured bottle to prevent oxidation.
5. A clear and white residues in flask should remain after digestion. In case of incomplete digestion the material should be again digested after addition of 5 mlof triacid.

Questions

1. How triacid extract is prepared ?
2. How yellow colour of phosphorus develops in plant extract.
3. Why HNO_3 is not mixed with $HClO_4$ directly ?
4. What happens when, plant sample is digested with acid mixture at more than230 ^0C.
5. Why ammonium molybdate ammonium vanadate solution is stored in acoloured bottle?

EXERCISE-19

Object: Determination of Potassium in plant (Bhargava and Raghupathi, 1993)

Principle

Potassium content in plant extract is determined by flame photometer i.e. when atoms of potassium are excited in flame emit a flame of specific wave length, the intensity of emission is proportional to the concentration of K which is determined in flame photometer using K filter.

Apparatus

Flame photometer, volumetric flask, pipette, beaker, conical flask 50 ml, hot plate etc.

Reagents

1. Triacid as described in P determination.
2. Potassium standard solution: Dissolve 1.9103 g of AR grade KCl in distilled water. Transfer it to 1 litre volumetric flask and make the volume. This solution contains 1000 ppm of K. To prepare 100 ppm solution take 10 ml of 100 ppm K solution in a 100 ml volumetric flask and make up its volume.

Procedure

1. Digest the plant sample with triacid as per the method given in P determination in plant sample and make the volume in 100 ml volumetric flask.
2. Prepare 0, 2, 4, 6, 8 and 10 ppm K solution by taking 0, 2, 4, 6, 8 and 10 ml of 100 ppm K solution in 100 ml flask respectively and making up their volume.
3. Feed the standard in flame photometer and take the reading. Plot the concentration on X-axis and flame photometer reading on Y-axis on graph paper and prepare a standard curve.
4. Feed the unknown sample in the flame photometer, note the readings and find out the concentration with the help of standard curve. If the readings of sample go above the standard then dilute the extract 5 to 10 times or more as required.

Observations and calculation

Weight of plant sample = X g Volume of extract prepared = 100 ml

Concentration of K in plant sample = ppm K in plant sample from standard curve (R) x Volume of extract prepared / Weight of sample

= R x 100 / X

$$\text{Per cent K} = R \times \frac{100}{X} \times \frac{1}{10000} = \frac{1}{100\,X}$$

Precautions

1. Extract should be clear and it should be prepared from double distilled water otherwise it clogs the sucking capillary.
2. The air pressure should be maintained steadily at 0.6 kg/cm2 to get uniformflame and proper atomization.
3. Do not feed K solutions having higher concentration than that prescribed forthe instrument.
4. Be sure that the filter used in flame photometer is of potassium.
5. After taking 8-10 readings feed distilled water and then again take the sample readings.
6. For preparing standard curve first feed the highest concentration solution andthen feed the standards of decreasing concentration of K.
7. After completion of reading close the gas then after some time stop the air supply.

Questions

1. Why potassium is determined with the help of flame photometer ?
2. How potassium standard curve is prepared ?
3. What type of gas is used in flame photometer and at what pressure it is mixedwith air?
4. How percentage of K in plant sample is calculated ?
5. Why turbid solution is not flame photometer determination?
6. Can you determine K from the same solution prepared from digested materialfor P?

EXECISE – 20

Object :- Rapid plant tissue test for NPK (Cook and Wheeler, 1978)

Principle :- Rapid plant tissue tests are performed in the standing crops on above ground portions to find out deficiency of particular element before the plant become acute deficient and help to correct the nutritional level by applying deficient elements through fertilizers. Plants accumulate in their tissues nitrate phosphate and potassium ininorganic form as ions which can be determined by chemical tests. These tests are essentially rapid qualitative tests in which the nutrients are extracted from leaf parts withthe help of chemical reagents and the concentration of a particular nutrient is estimated by the difference in intensity of colour, the results are classified as low, medium, high and very high.

Tests for nitrates : In most of the crops like wheat, corm, sorghum, potato etc. except

paddy nitrogen accumulates in nitrate form that represents the chief inorganic nitrogen reserve of the plant tissues hence plant supply of nitrogen can be related to the ni trate content of the plant tissue. These tests are useful from the early growth period to the grand growth period. As nitrogenous fertilizers can be applied to standing crops, the plant tissue test for nitrate nitrogen is of practical importance.

Diphenyl amine test : This is the most common field test used for determining the relative abundance of nitrates in plant tissues.

Reagents

1. Diphenyl amine
2. Concentrate sulphuric acid

   Dissolve 1 g of diphenyl amine in 100 ml of concentrated sulphuric acid.This solution is very corrosive hence handle it with care.

Procedure :

1. In case of thick stalk plants like maize, sorghum etc. nitrate test is made at the base of the leaf midrib without destroying the entire plant. Cut a thin vertical section at the plant node and add a drop of the diphenyl amine reagent. In about 30 seconds blue colour develops if plant sap contains nitrate nitrogen.

2. In case of thin stalk plants like wheat, barley, pearl millet etc. Uproot the plant and cut the stem near the lower node in slanting manner. Add 2-3 drops of diphenyl amine reagent. A dark blue colour will develop if plant sap contains abundance of nitrates.

Observation and interpretation

The intensity of blue colour indicates the concentration of nitrate nitrogen in thesap. The inference of colour is interpreted in the following manner.

1. No colour –Plant is severely deficient in nitrogen (urgent need to apply nitrogenous fertilizers).
2. Slightly blue-plant is deficient in nitrogen (need to apply nitrogenous fertilizers).
3. medium blue-plant is slightly deficient in nitrogen (application of nitrogenous fertilizers will give a slight increase in crop yield, but will increase the protein in cereal grains).
4. Dark blue- plant is adequately supplied with nitrogen (no need to apply nitrogen fertilizers).

Test for phosphate:Inorganic phosphate ($H_2PO_4^-$, HPO_4^{--}) are present in the cell saphence the test is carried out with the leaf tissue

Reagent 1: Dissolve 8 g of ammonium molybdate in 200 ml of distilled water in a beaker. In another beaker take 74 ml of distilled water and add 126 ml of concentrated hydrochloric acid and shake well. Now add this dilute solution of HCl to the solution of ammonium molybdate slowly with constant stirring.

The concentrated phosphate reagent 1 should be diluted with four volumes ofdistilled water just before use. The diluted reagent become unsuitable for use after afew weeks hence fresh working solution should be prepared while determining phosphate in plant tissue.

Reagent 2: Dry stannous oxalate or stannous chloride.

Procedure

1. Cut leaf blade into fine pieces after removing thick mid rib.
2. Place a tea spoonful of the finely cut tissue in a flat bottomed vial, which has10 ml graduation.

3. Now fill the vial up to the 10 ml mark with the phosphate reagent 1 and shakethe contents vigorously for a minute to remove most readily soluble phosphates.
4. After shaking, add a small amount of stannous oxalate (approximately thesize of a pin head).
5. Mix the contents and observe the colour.
6. Add another small portion of the powder to make certain that sufficientquantity has been added.
7. The amount of inorganic phosphate present in the plant tissue is indicated bythe intensity of blue colour, which may range from light blue to dark blue.

Observation and interpretation

The intensity of colour noted from the test is interpreted as follows:

1. No colour or yellow colour : Plant is highly deficient in phosphorus (need toapply phosphatic fertilizers for increasing crop yield)
2. Green or bluish green-plant is deficient in phosphorus (need to applyphosphatic fertilizers).
3. Light blue: Plant has medium phosphorus supply (Slight increase in yield isexpected with application of phosphatic fertilizer).
4. Medium blue: Plant is adequately supplied with phosphorus (no need to apply phosphatic fertilizers).
5. Dark blue: Plant is abundantly supplied with phosphorus (no need to apply phosphatic fertilizers).

When the test indicates need to apply phosphatic fertilizers, a phosphatic fertilizer like super phosphate which contains water soluble P_2O_5 should be applied as to enable the growing plants to utilize the phosphorus immediately. During the growthperiod, foliar application of phosphatic fertilizers of suitable concentration is more effective than soil application.

Test for potassium : Potassium is not known to be a definite part of any plant structure or tissue, but it exists in soluble form in the cell sap

Reagent 1 : Dissolve 5 g of sodium cobaltinitrite and 30 g sodium nitrite in 50 to 70ml distilled water, add 5 ml of glacial acetic acid, make it to 100 ml in a volumetric

flask and allow to stand for several days. Add 5 ml of this solution to a solution of 15 g of sodium nitrite in 100 ml of distilled water and adjust the pH 5.0 with acetic acid. Since the sodium cobaltinitrite concentration is an important factor in determining

the sensitivity of the test, use this chemical in pure form.

Reagent 2: Ethyl alcohol (95%)

Procedure

1. Cut leaf tissue into fine pieces with scissor
2. Place 1/4th tea spoon of the finely cut leaf tissue in a glass vial and add 10 ml of potassium reagent 1 at 21 ^{0}C.
3. Maintain the temperature 21 ^{0}Cwith the use of ice water.
4. Shake the contents of vial vigorously for a minute carefully.
5. Then add 5 ml of 95% ethyl alcohol (potassium reagent) and mix.
6. After 2-3 minutes, observe the turbidity formed.

Observation and interpretation

1. Only a trace of turbidity –Plant is deficient in potassium supply (need to apply potassic fertilizers as top dressing or in the form of foliar spray).
2. Medium turbidity- Doubtful potassium supply in plant (no need to apply potassic fertilizer).
3. Very high turbidity-Plant is adequate in potassium supply (no need to applypotassic fertilizer).

Precautions

1. For rapid plant tissue test the stage of growth and plant part to be takenshould be considered first.
2. Intensity of turbidity developed by various reagents for an element in a non deficient plant should be compared with a deficient plant for comparison.
3. The knife and other equipments used for plant tissue test should be cleanedand washed with distilled water.
4. Do not use reagents which has been kept for longer period.
5. Do not use oxidized stannous oxalate powder.
6. Use AR grade sodium cobaltinitrite for the rapid tissue test of K.

EXERCISE – 21

Object : Determination of pH and EC of irrigation water

Principal : Same as given in exercise No. 12(pH) and 13(EC.).

Procedure : Same procedure is followed as for pH and EC of 1:2 soil watersuspension given in the earlier exercise No. 12(pH) and 13(EC.).

Result :

The pH of the irrigation water is ..... The irrigation water having pH between 6.5 and 8.4 can safely be used

The EC of the irrigation water is.....dSm^{-1} , hence on the basis of salinity (EC) the water is.....-

Classification of irrigation water on the basis of EC (salinity)

S.No.	Name of quality water	Symbol	EC dS/m
A.	Salinity		
1	Non saline water	C-0	<0.2
2	Normal water	C-1	0.2-1.5
3	Low salinity water	C-2	1.5-3.0
4	Medium salinity water	C-3	3.0-5.0
5	High salinity water	C-4	5.0-10.0
6	Very high salinity water	C-5	>10.0

EXERCISE-22

Object: Determination of Ca^{2+} + Mg^{2+} in irrigation water by versenate (EDTA)method

Principle

Ca + Mg in solution can be titrated with 0.01 N EDTA using Erichhrome black T dye as indicator at pH 10 in the presence of ammonium chloride and ammonium hydroxide buffer. At the end point colour changes from wine red to blue or green. This titration will estimate both calcium and magnesium. Beyond pH 10 magnesium is not bound strongly to Eriochrome black T indicator to give a distinct end point.

Reagents

1. EDTA or versenate solution (0.01 N): EDTA solution (0.01 N) : Take 2.0g of EDTA, dissolve in distilled water and make volume to 1 litre. Titrate with 0.01 N calcium solution by the procedure discussed below and make necessary dilution so that its normality is exactly equal to 0.01 N.
2. Ammonium chloride ammonium hydroxide buffer dissolved 67.5g ammonium chloride in 750 mL of concentrated ammonia and make the volume one litre.
3. Erichorme black T indicator : Take 100 mL ethanol and dissolve 4.5 g of hydroxyl amine hydrochloride and 0.5 g of the eriochrome black T. indicator. Hydroxylamine hydrochloride removes the interference of manganese by keeping it in lower velency state (Mn++).
4. Sodium cyanide solution (2%) or sodium diethyl dithiocarbamate crystals. This is used to remove the interference of copper, cobalt and nickel.

Method

1. Pipette out 10 mL of aliquot (Irrigation water) in porcelain dish containing not more than 0.1 meL^{-1} of Ca plus Mg. If the solution has a higher concentration, it should be diluted.
2. Add 0.5 mL of ammonium chloride-ammonium hydroxide buffer. Now add 3-4 drops of Erichrome black T indicator.
3. Titrate this solution with 0.01 N versenate till the colour changes to bright blue orgreen and no tinge of wine red colour remains behind.

Observations

S.No.	Volume of aliquot taken (mL)	Burette readings		Volume of EDTA used (mL)
		Initial	Final	
1				
2				
3				
4				

Calculations

$$Ca^{2+} + Mg^{2+} (MeL^{-1}) = \frac{\text{Normality of EDTA x Vol. of EDTA}}{\text{Volume of aliquot taken}} \times 1000 = \_\_\_\_\_$$

$Ca^{2+} + Mg^{2+}$ (ppm) = $Ca^{2+} + Mg^{2+}$ (meL^{-1}) x equivalent weight (32) = ------

Results :

(I) The concentration of Ca^{2+}+ Mg^{2+} in irrigation water is ----------MeL^{-1} -

(II) The concentration of Ca^{2+} Mg^{2+} in irrigation water is ---------- ppm.

EXERCISE-23

Object: Determination of Na+ in irrigation water by flame photometer

Principle

Sodium is determined by flame photometer. Analysis through flame photometer used based on the measurement of the intensity of characteristics line emission give n by the element to be determined. When a solution of salt is sprayed into a flame, the salt get separated into its component atoms because of the high temperature. The energy provided by flame excites the atoms to higher energy levels (the electrons of atom go to high energy level). When the electrons return back to the ground or unexecuted state, they emit radiation of characteristics wave length (line emission spectrum). The intensity of these radiations is proportional to the concentration of particular elements in solution which is measured through a photo cell in the flam photometer.

Equipment and reagents

1. Flame photometer with Na filter
2. Volumetric flask (100 mL)
3. Sodium chloride standard solution. Dissolve 5.845 of A.R. grade NaCl in distilled water and make volume to one litre. It will give 100 meL^{-1} of sodium. This solution is treated as stock solution.
4. From this solution take, 0, 1, 2.5, 5.0, 7.5 and 10 mL in volumetric flasks of 100 mL capacity and make the volume by further adding distilled water. This will give a series of standard solution having 1, 2.5, 5.0, 7.5 and 10.0 meL^{-1} Na.

Method

1. Read the operation manual of flame photometer. Set the Na filter. Start the compressor and light the burner of flame photometer. Keep air pressure at 0.5 kg/cm^2 and adjust the gas feeder so as to have a blue sharp flame cones.
2. Adjust the zero reading of the meter by feeding distilled water. Now feed standard sodium solution of highest value in the standard series (10 meL^{-1}) and

adjust the flame photometer to feed full value of emission in the scale i..e 100 reading.

3. Feed different standard sodium solutions one by and record the emission value (reading) for each.
4. If concentration of Na is high in extract than dilute it by taking 10 mL extract (aliquot) of sample in a 100 mL volumetric flask and make volume 100 mL by distilled water.
5. Feed the diluted extract at flame photometer and note the read

Observations

S.No.	Concentration of Na in known solution (meL^{-1})	Reading on flame photometer
1	1.0	
2	2.5	
3	5.0	
4	7.5	
5	10.0	

Reading of unknown solution =

Plot a standard curve between concentration and readings of standard sodium solutions. Obtain concentration of Na in unknown solution from the standard curve.

Calculations

Na (meL^{-1}) in irrigation water = Na (meL^{-1}) as obtained from curve x dilution factor if any,

Na (ppm) = meL^{-1} x equivalent weight of Na (23) = ---------- --.

Results

The concentration of Na^+ in irrigation water is ----------meL^{-1} or ----------ppm.

Computation of SAR

$$SAR = \frac{Na}{\sqrt{Ca + Mg / 2}}$$

Whereas:- Na, Ca, Mg are in meL^{-1}

Classification of irrigation water on the basis of SAR (sodicity)

B	Sodicity	Symbol	SAR
1	Non sodicity water	S-0	< 5
2	Normal water	S-1	5-10
3	Low sodicity water	S-2	10-20
4	Medium sodicity water	S-3	20-30
5	High sodicity water	S-4	30-40
6	Very high sodicity water	S-5	>40

EXERCISE-24

Object: Determination of CO^{-}_{3} and HCO_3 in irrigation water

Principle

Carbonate and bicarbonate in a solution can be determined by titrating the solution against standard acid using phenolphthalein and methyl red respectively as indicators. When the colour of phenolphthalein is disappeared, it indicates half the neutralization of carbonate. At this stage methyl red indicator is added and the titration continued. When the colour changes from yellow to rose red , it is the end point for the complete neutralization of bicarbonate. The following equations illustrate these changes.

$2Na_2CO_3 + H_2SO_4 = 2NaHCO_3 + Na_2SO_4$

(phenolphthalein = pink) (phenolphthalein = colourness)

$2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2H_2O + 2CO_2$

(methyl red = yellow) (methyl red = rose red)

Reagents

1. Standard H_2SO_4 (0.01 N) : Take 2.8 mL of concentrated H_2SO_4 (36 N) with automatic pipette and dilute to one liter with distilled water, it will give 0.1 N H_2SO_4 further dilute this solution 10 times to get 0.01 N H_2SO_4
2. Methyl red indicator (0.5%) : Dissolve 0.5 g of pure methyl red powder in 100 mL of 60% ethanol . Phenolphthalein indicator (0.25%) : Dissolve 0.25 g of pure phenolphthalein powder in 100 mL of 60% ethanol.

Method

1. Piptte out 10 mL of soil extract in a conical flask or in porcelain dish and add 2- 5 drops of Phenolphthalein. Appearance of pink colour indicates the presence of carbonates. Initial reading designate as I.
2. If carbonate is present, add 0.01 N H_2SO_4 from burette till the solution becomes colourless. Record this reading (designate as II)
3. Add a few drops of methyl red indicator and titrate till the colour changes from yellow to rose red.
4. Record this reading also (designate as III). Repeat this process a number of times so as to get two concordant readings.

Observations

Volume of aliquot taken (mL)	Burette Readings			Vol. (mL) of H_2SO_4 used for half neutralization of CO_3 (II-I)= x	Vol. (mL) of H_2SO_4 complete neutralization of CO_3 = 2x	Vol. (mL) of H_2SO_4 used for complete neutralization of CO_3 and HCO_3 (III-I) = Y	Vol. (mL) of H_2SO_4 used for neutralization of HCO_3 = Y-2x
	I	II	III				
1							
2							
3							

Calculation CO^{2-} in meL^{-1}

If N_1 and V_1 are normality (concentration of CO_3^{2-}) and volume of aliquot taken and N_2V_2 are the normality and volume of H_2SO_4 used respectively, then,

$$N_1V_1 = N_2V_2 \quad \text{or } N1 = \frac{N_2V_2}{V_1}$$

Here, N_1 = normality = gram equivalents of CO_3^{-} present in one litre of aliquotHence, meL^{-1} of CO_3^{2-} is :

$$CO_3\ (meL^{-1}) = \frac{\text{Vol. of } H_2SO_4 \text{ used x Normality of } H_2SO_4}{\text{Volume of aliquot taken}} \times 1000 = \frac{2x \times 0.01 \times 1000}{\text{Volume of aliquot taken}}$$

HCO_3^- in meL^{-1}

$$HCO_3\ (meL^{-1}) = \frac{\text{Vol. of } H_2SO_4 \text{ used x Normality of } H_2SO_4 (Y-2\ x) \times 0.01 \times 1000}{\text{Volume of aliquot taken}} \times 100\ 0 = \frac{}{\text{Volume of aliquot taken}}$$

Results

The Concentration of CO_3 in irrigation water = ---------- meL^{-1}

The Concentration of HCO_3 in irrigation water = ----------meL^{-1}

Computation of residual sodium carbonate (RSC)

$$RSC = (CO_3 + HCO_3\ meL^{-1}) - (Ca^{++} + Mg^{++}\ meL^{-1})$$

Whereas : Ca + Mg and CO_3 + HCO_3 are in meL^{-1}

Classification of irrigation water on the basis alkalinity (RSC)

C.	Alkaline	Symbol	RSC (me L^{-1})
1	Non-alkaline water	A-0	Negative
2	Normal water	A-1	0
3	Low alkalinity water	A-2	<2.5
4	Medium alkalinity water	A-3	2.5-5.0
5.	High alkalinity water	A-4	5.0-10.0
6.	Very high alkalinity water	A-5	>10

EXERCISE-25

Object: Determination of Cl^- in irrigation water

Principle

Chloride in irrigation water can be determined by titrating the irrigation water against standard $AgNO_3$ solution using potassium chromate as indicator. There is a formation of sparingly soluble brick red silver chromate precipitate at the end point. Initially the Cl- ions are precipitation as AgCl. The dark brick red precipitate as Ag_2CrO_4 formed just after the precipitation of AgCl is over. The chomate reactions takes place are given as under.

$NaCl + AgNO_3 = AgCl + NaNO_3$

(White ppt) $K2CrO4 + 2AgNO3 = Ag_2CrO_4 + 2KNO_3$

(brick red ppt)

Reagents

1. 0.01 N sodium chloride : 0.585 g of NaCl (AR grade, drived at 80 ^{0}C for 1 hour) is dissolved in distilled water and made to one litre volume.
2. 0.01 N sliver nitrate: Dissolve 1.6989 g of $AgNO_3$ in distilled water and make the volume upto 1 litre standardize it against standard NaCl solution (0.01 N) and keep in amber coloured bottle away from light.
3. Potassium chromate (K_2CrO_4) indicator solution (5%) :Dissolve 5 g of K_2CrO_4 in about 75 mL distilled water and add saturated solution of $AgNO_3$ drop wise until a slight permanent red precipitate is formed. Filter and dilute to100 ml.

Method

1 In a clean titration flask or in porcelain dish take 10 mL of the irrigation water by pipette.

2 Add 1-2 drops of potassium chromate indicator in irrigation water taken.

3 Titrate with 0.01 N $AgNO_3$ solution till a permanent brick red precipitate persists. Take three concordant readi

Observations

Record observation in following manner

S.No.	Volume aliquot taken (mL)	Burette reading		Volume of $AgNO_3$ used (mL)
		Initial	Final	
1				
2				
3				

Calculations

Cl^- (meL^{-1}) = - ----------

Normality of $AgNO_3$ x volume $AgNO_3$ x 1000Volume of aliquot taken

Cl^- (ppm) = meL^{-1} of Cl x eq. Wt. of Cl^- (35.5) = ----------

Results Chloride (Cl^-) concentration in irrigation water is meL^{-1} ----------or -------ppm.

CROPS

GROWTH ANALYSIS

Growth analysis can be used to account for growth in terms that have functional or structural significance. The type of growth analysis requires measurement of plant biomass and assimilatory area (leaf area) and methods of computing certain parameters that describe growth. The growth parameters that are commonly used in agricultural research and the name of the scientists who proposed the parameters are given below.

- LAI - Williams (1946)
- LAR - Radford (1967)
- LAD - Power et al. (1967)
- NAR - Williams (1946)
- CGR - Watson (1956)
- RGR - Williams (1946)
- HI - Nichiporovich (1951)

i. Leaf Area

This is the area of photosynthetic surface produced by the individual plant over a period of interval of time and expressed in cm^2 $plant^{-1}$.

***ii. Leaf Area Index (LAI)**

Williams (1946) proposed the term, Leaf Area Index (LAI). It is the ratio of the leaf of the crop to the ground area over a period of interval of time. The value of LAI should be optimum at the maximum ground cover area at which crop canopy receives maximum solar radiation and hence, the TDMA will be high.

$$LAI = \frac{\text{Total leaf area of a plant}}{\text{Ground area occupied by the plant}}$$

Total dry matter production (TDMP) and its distribution:- The TDMP is the biomass accumulated by the whole plant over a period of interval of time and its distribution (allocation) to different parts of the plant such as roots, stems, leaves and the economic parts which controls the sink potential.

iii. Leaf Area Ratio (LAR)

The term, Leaf Area Ratio (LAR) was suggested by Radford (1967), expresses the ratio between the area of leaf lamina to the total plant biomass or the LAR reflects the leafiness of a plant or amount of leaf area formed per unit of biomass and expressed in cm^{-2} g^{-1} of plant dry weight.

$$LAR = \frac{\text{Leaf area per plant}}{\text{Plant dry weight}}$$

iv. Leaf Weight Ratio (LWR)

It was coined by (Kvet *et al.*, 1971) Leaf weight ratio is expressed as the dry weight of leaves to whole plant dry weight and is expressed in g g^{-1}.

$$LWR = \frac{\text{Leaf dry weight}}{\text{Plant dry weight}}$$

v. Leaf Area Duration (LAD)

To correlate dry matter yield with LAI, Power *et al.* (1967) integrated the LAI with time and called as Leaf Area Duration. LAD takes into account, both the duration and extent of photosynthetic tissue of the crop canopy. The LAD is expressed in days.

$$LAD = \frac{(L1 + L2)}{2} \times (t_2 - t_1)$$

L_1 = LAI at the first stage

L_2 = LAI at the second stage, $(t_2 - t_1)$ = Time interval in days.

***vi. Absolute Growth Rate (AGR)**

AGR is the function of amount of growing material present and is influenced by the environment. It gives Absolute values of biomass between two intervals. **It is mainly used for a single plant or single plant organ** e.g. Leaf growth, plant weight etc.

$$AGR = \frac{W2 - W1}{t2 - t1} \quad g\ day^{-1}$$

Where, W1 and W2 are the plant height at t_1 and t_2 times respectively.

***vii. Net Assimilation Rate (NAR)**

The term, NAR was used by Williams (1946). NAR is defined as dry matter increment per unit leaf area or per unit leaf dry weight per unit of time. The NAR is a measure of the average photosynthetic efficiency of leaves in a crop community.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)}$$

Where, W_1 and W_2 is dry weight of whole plant at time t_1 and t_2 respectively

L_1 and L_2 are leaf area at t_1 and t_2 respectively

$t_1 - t_2$ are time interval in days

NAR is expressed as the grams of dry weight increase per unit dry weight or area per unit time ***(g g $^{-1}$day^{-1})(Leaf Area)***

***viii. Relative Growth Rate (RGR)**

The term was coined by Williams (1946). Relative Growth Rate (RGR) expresses the total plant dry weight increase in a time interval in relation to the initial weight or Dry matter increment per unit biomass per unit time or grams of dry weight increase per gram of dry weight and expressed as unit dry weight / unit dry weight / unit time ***(g g $^{-1}$day^{-1})(Leaf Weight)***

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are whole plant dry weight at t_1 and t_2 respectively

t_1 and t_2 are time interval in days

***ix. Crop Growth Rate (CGR)**

The method was suggested by Watson (1956). The CGR explains the dry matter accumulated per unit land area per unit time **(g m^{-2} day^{-1})**

$$CGR = \frac{(W_2 - W_1)}{\rho\,(t_2 - t_1)}$$

Where, W1 and W2 are whole plant dry weight at time $t^1 - t^2$ respectively

ρ is the ground area on which W1 and W2 are recorded.

CGR of a species are usually closely related to interception of solar radiation.

***x. Harvest Index**

The harvest index is expressed as the percent ratio between the economic yield and total biological yield and was suggested by Nichiporovich (1951) / C.M. DONALD (1967).

$$HI = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

AGRO-BIOLOGICAL LAWS

Law of Minimum (Justus Von Liebig, 1840)

Liebig stages that the deficiency or absence of one necessary constituent all others being presents, the soil rendered barren for all these crops of the life of which one constituent is indispensable. It is sometimes referred to as the barrel concept.

Blackman's Law of Optimum and Limiting Factors (1905)

Blackman in 1905 proposed law of optima and limiting factors. It states that when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor.

Mitscherlich,s Law of Diminishing Returns (1909)

Mitscherlich in 1909 developed an equation relating growth with the supply of plants nutrients. When plants are supplied with adequate amounts of all but one limiting element, their growth is proportional to the amount of this one limiting element. Plant growth increases as more of this element is applied; but not in direct proportion to the amount of the growth factor added. Increase in growth with each successive addition of the limiting element is progressively smaller.

Inverse Yield- Nitrogen Law (1929)

Wilcox (1929) propose inverse yield – nitrogen law which state that the power of growth or yielding ability of any crop plant is inversely proportional to the mean N content in the dry matter.

Agriculture Meteorology and Weather Forecasting

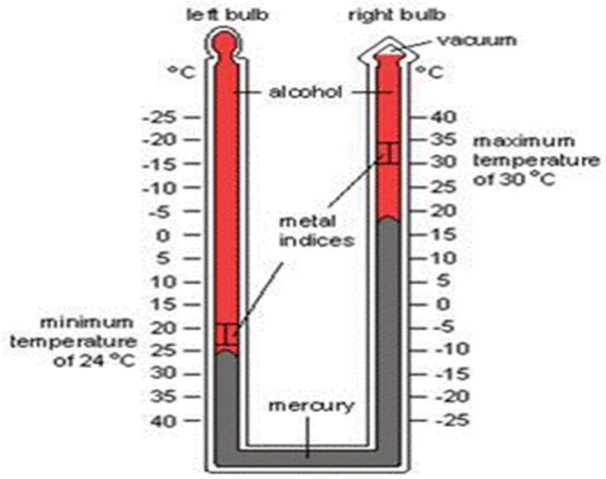
The agro met observatory with the following instruments to record the weather parameters:-

- Max. & Min. Thermometer
- Soil thermometer for 5, 10, 20 cm depth
- Thermograph
- Hygrograph
- Wind vane
- Anemometer
- Rain gauge
- Sunshine Recorder
- USWB Open pan Evaporimeter

MAX & MIN THERMOMETER:-

Six's Maximum and Minimum thermometer is a U shaped parallel tube made up of glass. One side registers the maximum temperature and the other side records the minimum temperature. The bend at the bottom of the thermometer contains mercury which moves up or down based on the expansion and contraction of alcohol. When the temperature rises, the alcohol expands and pushes the mercury up the maximum column. This also pushes the mercury down in the minimum column. Similarly, when the temperature falls, the alcohol contracts and pulls the mercury up in the minimum column resulting in a fall of mercury in the maximum column. The steel indexes are located on the surface of mercury. They move along with the flow of mercury up and down. When

the temperature reaches its maximum and minimum limits, the metal indexes remain at that place. This helps in recording the maximum and minimum temperatures of the day.



SOIL THERMOMETER:-

(*Also called* earth thermometer) A thermometer used to measure the temperature of the soil.
Two forms of the mercury-in-glass thermometer are used for this purpose. For measurement at small depths, a thermometer with a right-angle bend in the stem is used. The bulb is inserted into a hole in the ground with the stem lying along the surface. A thermometer that has been fused into an outer protecting glass shield is used for measurement at greater depths. Wax is inserted between the bulb and the shield to increase the time constant. To obtain a measurement, the instrument is lowered into a steel tube that has been driven into the soil to the desired depth.

THERMO-HYGROGRAPH:-

A **thermo-hygrograph** or **hygrothermograph** is a chart recorder that measures and records both temperature and humidity (or dew point). Similar devices that record only one parameter are a **thermograph** for temperature and **hygrograph** for humidity.

WIND VANE:-

A wind vane, weather vane, or weathercock is an instrument used for showing the direction of the wind. It is typically used as an architectural ornament to the highest point of a building.

ANEMOMETER:-

An anemometer is **a device used for measuring wind speed and direction**. It is also a common weather station instrument. The term is derived from the Greek word anemos, which means wind, and is used to describe any wind speed instrument used in meteorology.

RAINGAUGE:-

A **raingauge** (also known as an **udometer** ,**pluviametior**, **pluviometer**, **ombrometer**, and **hyetometer**) is an instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over an area in a predefined area, over a period of time. It is used for determining the depth of precipitation (usually in mm) that occurs over a unit area and thus measuring rainfall amount.

SUNSHINE RECORDER:-

A sunshine recorder is **a meteorological instrument used for recording the amount of sunlight that a particular location receives throughout a** day.

OPEN PAN EVAPORIMETR:-

Evaporimeter, **instrument that measures the rate of evaporation of water into the atmosphere**, sometimes called an atmometer.

The standard USWB Class-A pan evaporimeter is the most widely used evaporimetr in the world for finding evaporation from the free water surface. It consists of a 121.5 cm diameter and 25.4 cm deep pan made of 20 gauge galvanized iron sheet with a stilling well. A vertical pointer is provided in the stilling well to show the level of water maintained in the pan. The pan is painted white and is placed on a wooden frame so that air may circulate beneath the pan. Daily evaporation rate is given by the fall of water level in the stilling well during 24-hour period.

Measurements of the fall of water level may be made at closer intervals to know the evaporation rate during different parts of a day. Water levels in the stilling well are measured by hook gauge. Adjustments are made to the evaporation values if rain occurs during a period of measurement. The rainfall is measured by standard rain gauge. Evaporation loss may also be computed from the measured quantity of water added to bring the water level to the tip of the pointer in the stilling well. The amount of water added is divided by the surface areas of pan and stilling well together to find out the depth of water added which is taken as the daily evaporation rate. After measuring the fall in water level each time, water is added to the pan to bring back the water level to the original position of pointer tip level. As the rate of evaporation from pan evaporimeter is higher than that over a large free water surface, the pan evaporation value is multiplied by 0.7 to obtain the evaporation rate over the large free water surface (Eo).

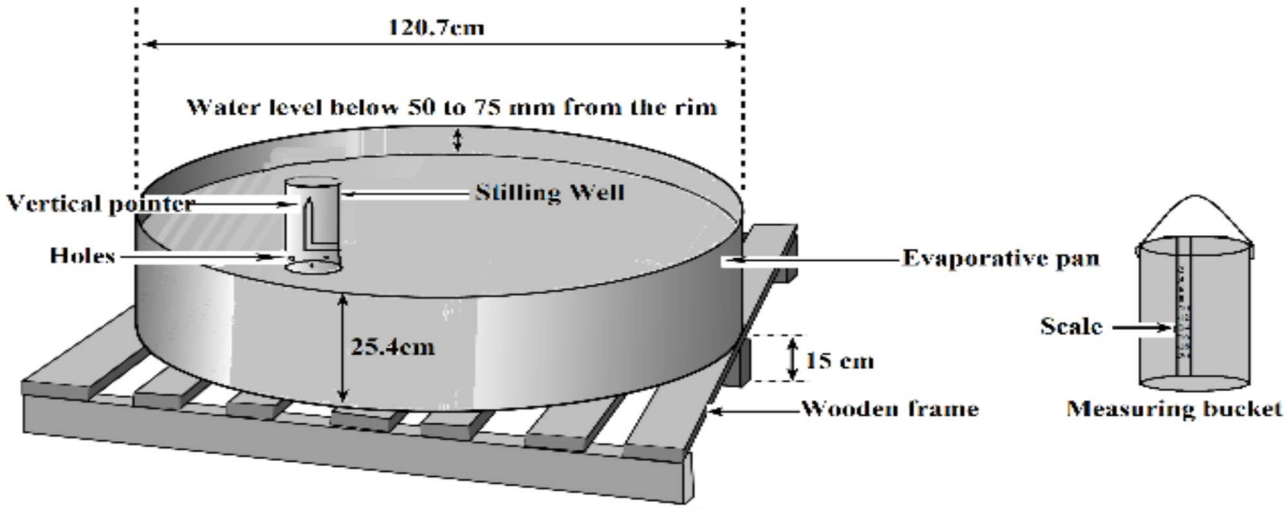
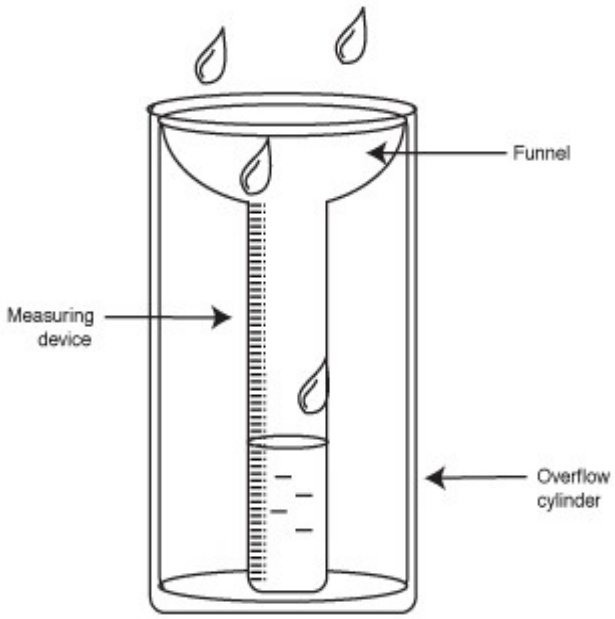
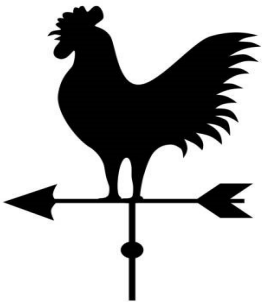
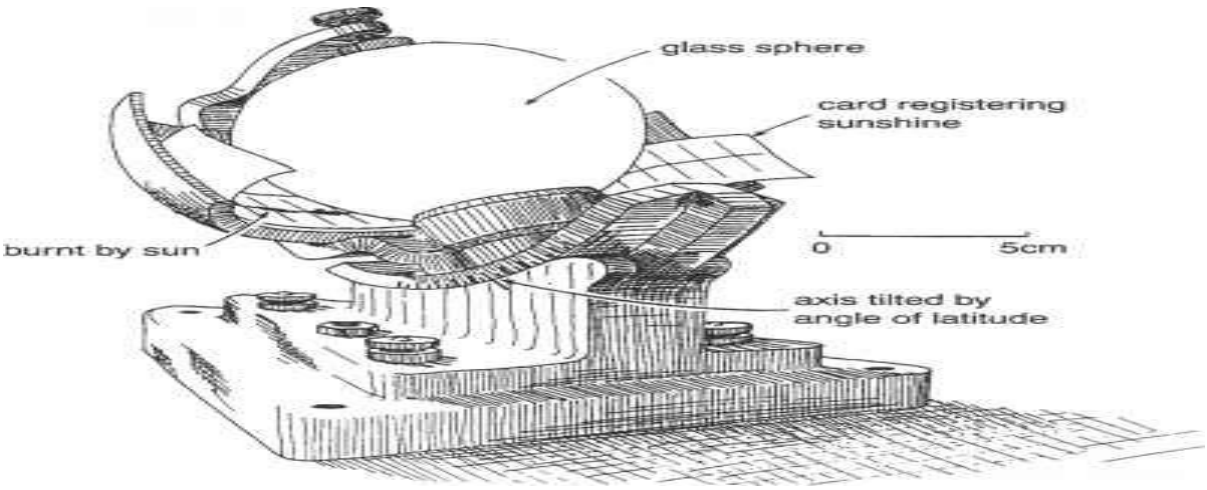


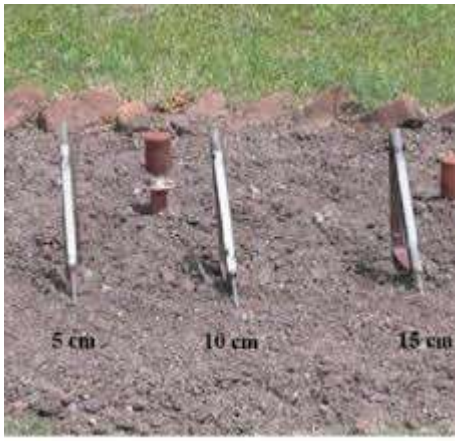
Fig: Components of Class A pan Evaporimeter







SUNSHINE RECORDER



SOIL TERMOMETER

PRINCIPLES AND PRACTICES OF WATER MANAGEMENT

Irrigation Efficiency

The term irrigation efficiency expresses the performance of a complete irrigation system or components of the system. Irrigation efficiency is defined as the ratio between the amount of water used to meet the consumptive use requirement of crop plus that necessary to maintain a favourable salt balance in the crop root zone to the total volume of water diverted, stored or pumped for irrigation. Thus, water applied by the irrigation system and not being made available to be taken up by plant roots is wasted and reduces irrigation efficiency. Fig. 28.1 shows components of water loss from source to point of application. In addition, losses can also occur during storage in case of pond, tank, or reservoirs. The major causes for reduced irrigation efficiency include storage losses, conveyance losses and field application losses. In India, overall irrigation efficiency of major irrigation projects ranges between 35-40%. This is one of the reasons for increasing gap between irrigation potential created (102.77 M ha till end of 10^{th} plan 2007) and utilized (87.23 M ha). This gap of about 16%, is same as the irrigation potential created between 1951 and 1970. At the end of eighth plan, Planning commission estimated that with a 10% increase in the present level of water use efficiency in irrigation systems, an additional 14 Mha area can be brought under irrigation from the existing irrigation capacities. In order to meet

the growing demands of water for food, environment, urban and industry, it is necessary to improve irrigation efficiency at all levels.

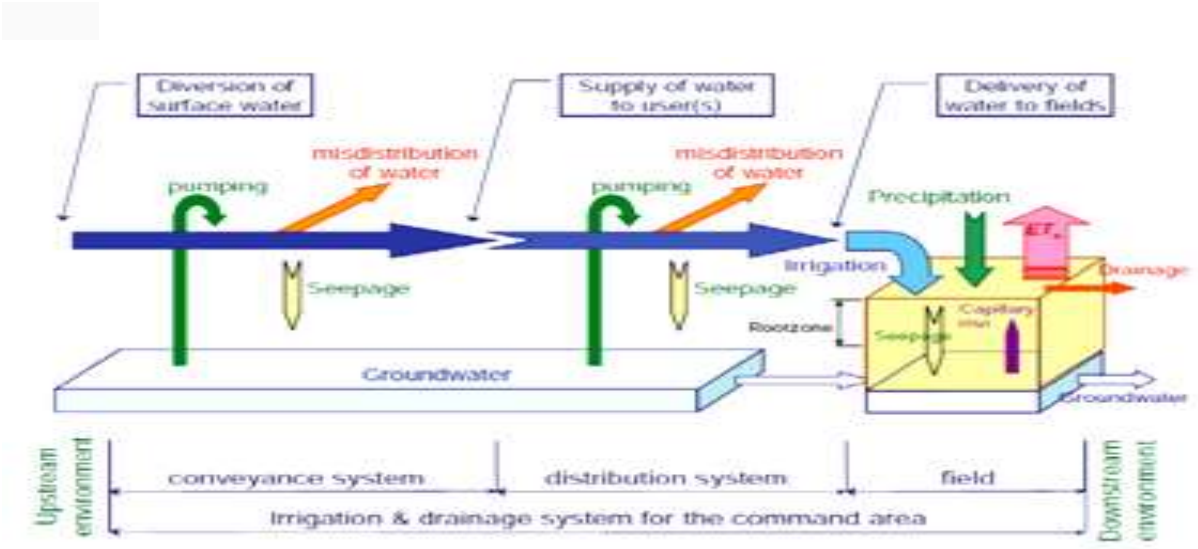


Fig: - Schematic water flow in irrigation drainage system

Definition of Various Efficiencies

Reservoir Storage Efficiency

It is the efficiency with which water is stored in the reservoir. It is expressed as follows,

$$E_r = 100 \times \left(1 - \frac{V_e + V_s}{V_i}\right) = 100 \left(\frac{V_o + \Delta S}{V_i}\right)$$

Where,

V_e = evaporation volume from the reservoir

V_s = seepage volume from the reservoir

V_t = inflow to the reservoir

V_o= volume of out flow from the reservoir

ΔS = change in reservoir storage

Water Conveyance Efficiency

The conveyance efficiency is used to measure the efficiency of water conveyance systems associated with the canal network, water courses and field channels. It isdefined as the ratio between the water that reaches a farm or field and that diverted from the irrigation water source. Mathematically it is represented as follows:

$$E_c=100(V_f/V_d)$$

Where,

E_c= the conveyance efficiency (%),

V_f = the volume of water that reaches the farm or field (m^3),

V_d= the volume of water diverted ($m^{3)}$ from the source.

Application Efficiency

Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. It might be defined for individual irrigation or parts of irrigations or irrigation sets.Application efficiency includes any application losses to evaporation or seepage from surface water channels or furrows, any leaks from sprinkler or drip pipelines, percolation beneath the root zone, drift from sprinklers, evaporation of droplets in the air, or runoff from the field. In case of surface irrigation evaporation losses are generally small but runoff and deep percolation are substantial. However, air losses (droplet evaporation and drift) can be very large if the sprinkler design or excessive pressure produces a high percentage of very fine droplets. Application efficiency is defined as:

$$\mathbf{E_a = 100(V_s/V_f)}$$

Where,

E_a= the application efficiency (%),

V_s= the volume of water stored in root zone (m^3),

V_f = the water delivered to the field or farm (m^3).

Storage Efficiency

The water storage efficiency evaluates the storage of water in the root zone after the irrigation in relation to the need of water prior to irrigation.

$$E_s = 100 (V_s/V_{rz})$$

Where,

E_s= the storage efficiency (%)

V_{rz}= the root zone storage capacity (m^3).

The root zone depth and the water-holding capacity of the root zone determine V_{rz}. The storage efficiency has little utility for sprinkler ormicro irrigation because these irrigation methods seldom completely refill the root zone.

Water Distribution Efficiency

It is the ratio between the mean of numerical deviations from the average depth of water storedduring irrigation (Y) and the average depth stored during irrigation (d). It is mathematically expressed as:

Where,

Y= Average numerical deviation in depth of water stored from average depthstored during irrigation

d = Average depth of water stored during irrigation.

It is a measure of water distribution within the field. A low distribution efficiencymeans non-uniformity in the distribution of irrigation water. This may be due to uneven landlevelling. There may beexisting low patcheswhere water will penetrate more and high patches where water cannot reach. This leaves some spots unirrigated unless excess irrigation water is applied. Excess waterapplication lowers irrigation efficiency.It may be noted that water distribution efficiency is identical to Christiansen's Uniformity Coefficient which is discussed later.

Water Use Efficiency

The term water use efficiency denotes the production of crops per unit water applied. It is expressed as the weight of crop produce per unit depth of water over a unit area. i.e., kg/cm/ha.

Crop Water Use Efficiency

It is the ratio of crop yield per amount of water depleted by the crop in the process of evapotranspiration (ET).

Crop water use efficiency = Y/ET

Field Water Use Efficiency

It is the ratio of crop yield (Y) to the total amount of water used in the field (WR).

Field water use efficiency = Y/WR

WEED MANAGEMENT

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

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

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

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

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

Modern Concept of Weed Pest Management

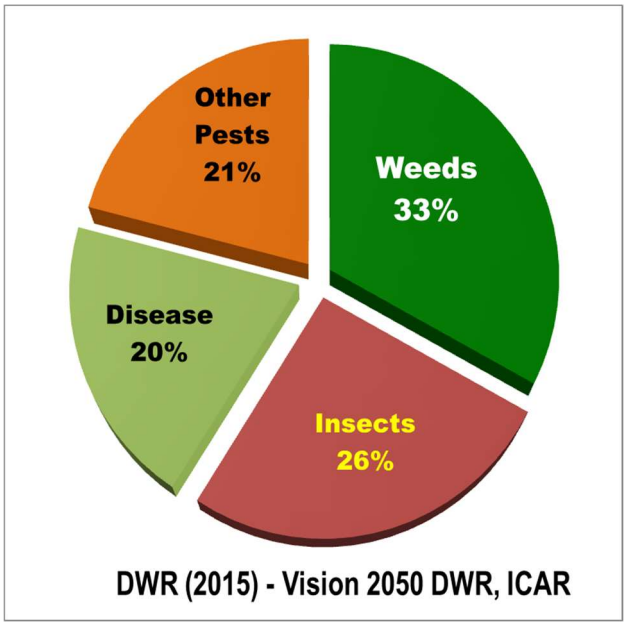
***Weed* – Definition and Importance:**

In the beginning of agriculture, there was no weed. The violet flowers *of Digera, Allium (*wild onion), *Chicorium* or even bluish *Eichhornia* (water hyacinth) or *Monochoria* (pana kachu) are beautiful and worthy of artistic praise for symmetry and colour. *Opuntia* is an effective fence plant as well a valuable plant in desert as it holds sand; *Amaranthus* (note), *Chenopodium* (Beta), *Ipomoea* (kalmi), *Nasturtium* (sarse)*, Trapa* (panifal)*, Alternanthera* (sechi), *Nymphaea* (saluk) ,

Melilotus (senji methi) or Ne*lumbo* (padma) all are cultivated in many areas for their economic uses as vegetables. I*mperata, Cynodon, Agropyron, Elensine* etc. act very good soil binding plants. Why we humans call such plants as "Weeds"? Who has the right to say some plants are unwanted in nature. The question still lies by what authority do we so easily assign the derogatory term "Weed" to a plant and say it interferes with agriculture, increases cost of production, reduces yields and may even detract from quality of life. Nature knows no such category of plant "Weed". It is the human who attempt to modify nature to grow high value crops for food, fodder, fibre, oil, medicinal, paper pulp and other purposes. Therefore, you decide what plants are weeds and when, whereas by which way they will be managed.

Thus, **Weeds are plants where it is not desired for any period of time**- Desire is purely a human trait and only for this reason any plant in nature is a weed only in terms of a human, attitude. People say that a plant in a certain place is not desirable and therefore assign it the derogatory term "Weed". We make it the lowest of plant kingdom not because it is naturally harmful but because it is harmful to us.

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



PEST (33 % National Production Loss)

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

Production loss in India

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

Weed Science

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

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

Weed Ecology:

Classification of Weeds:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(3) According to Cotyledon (Seed):

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

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

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

(4) According to Origin:

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

B. Exotic or Invasive: Weeds are originated from other parts of the region, country and world and invaded in new places, called Invasive or **Alien Weeds or Anthrophytes.** The invasive alien weeds which are introduced from outside India are *Eichhornia crassipes* (Tropical America), *Lantana camera* (Central America), *Alternanthera philoxeroides* (South America),

Parthenium hysterophorus (Mexico) etc. Quarantine people should need to identify Alien weeds to prevent their movement from one country to another.

5. According to Habitat:

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

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

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

Diversity of weed flora in anaerobic ecosystem

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

Diversity of weed flora in aerobic ecosystem

Monocots	Dicots (Broadleaf)	
Grass	*Alternanthera sessilis*	*Melilotus alba / indica*
Avena fatua	*Amaranthus viridis*	*Melochia corchorifolia*
Brachiaria mutica	*Anagallis arvensis*	*Nicotiana plumbiginifolia*
Dactyloctaneum aegyptium	*Argemone mexicana*	*Oxalis corymbosa / corniculata*
Digitaria sanguinalis	*Blumea lacera*	*Parthenium hysterophorus*
Eleusine indica	*Borreria hispida / alata*	*Phyllanthus niruri*
Echinochloa colona	*Chenopodium album*	*Physalis minima*
Leersia hexendra	*Chicorium intybus*	*Portulaca oleracea*
Phalaris minor	*Cleome viscosa*	*Scoparia dulcis*
Sedge	*Commelina nudiflora / benghalensis*	*Solanum nigram*
Cyperus rotundus	*Corchorus acutangulas*	*Sonchus oleraceus*
Cyperus arometicus	*Digera arvensis*	*Spilanthes paniculata*
Cyperus compressus	*Desmodium triflorum*	*Spermacoce ocymoides*
Cyperus halpan	*Euphorbia hirta / tenella*	*Tithonia rotundifolia*
Cyperus digitatus	*Fumaria purviflora*	*Trianthema portulacastrum / monogyne*
	Gnaphalium indicum/ luteoalbum	*Vicia sativa / indica*

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

<table>
<tr><th colspan="2">Monocots</th><th colspan="2">Dicots (Broadleaf)</th></tr>
<tr><td>Grass
Axonopus compressus
Cynodon dactylon
Dactyloctaneum aegyptium
Digitaria sanguinalis
Eleusine indica
Paspalum conjugatum / distichum / dilatatum
Phalaris minor
Sporobolus diander</td><td>Sedge
Cyperus rotundus
Cyperus arometicus
Cyperus compressus
Cyperus esculentus
Cyperus flavidus
Cyperus polystachyos
Cyperus pumilus</td><td rowspan="3">Abutilon indicum
Acalypha indica
Aeschynomene indica
Ageratum conyzoides
Alternanthera tenella / sessilis
Amaranthus viridis
Argemone mexicana
Blumea lacera
Borreria alata
Boerhavia erecta/ diffusa
Calotropis gigantea / procera
Cannabis sativa
Cleome viscosa / rutidosperma
Commelina subulata
Cyanotis axillaris
Desmodium triflorum
Eupatorium odoratum
Euphorbia hirta/tenella
Hydrocrotyle rotundifolia</td><td rowspan="2">Leucas linifolia / aspera
Oxalis corymbosa / corniculata
Parthenium hysterophorus
Piperomia pellucida
Phyllanthus niruri
Physalis minima
Pteridium aquilinum
Rungia repens
Scoparia dulcis
Solanum torvum / incanum / sisybrifolia/ myriacanthum
Spilanthes paniculata
Spermacoce ocymoides
Tephrosia purpuria
Torenia bicolor
Tridax procumbans</td></tr>
<tr><td>Aquatic
Eichhornia crassipes
Ipomoea aquatica
Lemna minor
Monochoria haestifolia / vaginalis
Polygonum hydropiper / glabrum
Pistia stratiotes</td><td>Climbers
Argyreia speciosa
Coccinea grandis
Convolvulus tridentata
Cuscuta chinensis/reflexa
Cucumis maderaspatana
Dioscorea deltoida / pentaphylla
Ipomoea linifolia / pes-tigridis
Mikania micrantha
Phaseolus adenanthus
Stephania hernandifilia
Trichosanthes cucumerina
Vitis trifolia</td></tr>
<tr><td>Green algae
Euglena spp.
Chaetomorpha indica / allichii
Chara coralline
Pithophora spp.
Ulothrix zonata
Fresh water algae
Hydrodictyon indicum</td><td></td></tr>
</table>

Important Associate weed (Phenotypic Mimicry) of cultivated crops

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

Merits and demerits of various weed management practices

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

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

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

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

It continues since inception of agriculture. Jhum cultivation is an example. Stale seed bed technique and Soil solarization limit only in summer months and limitations of additional investment. Cover legumes like green gram (*Vigna radiata*), black gram (*Vigna mungo*), cowpea

(*Vigna sinensis*) either as sole or intercrop in summer and bengal gram (*Cicer arietinum*), horse gram (*Dolichos biflorus*), lentil (*Lens esculenta*), field pea (*Pisum sativum*), butterfly pea (*Clitoria ternatea*), chikling pea or khesari (*Lathyrus sativus*); Senji methi (*Melilotus parviflora*) besides *Azolla* & *Lemna* mat in lowland during kharif season, may be advocated for better soil health management and reducing weed seed bank. Ecological management has the advantage of improving soil health, reducing weed seed bank and additional income but the limitations are farmers' willingness because of additional expenditure and diversified management practices.

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

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

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

Important Bioherbicides including Botanicals

Name of the bioherbicides	Name of plant/ pathogen	Name of the weed pest to control	Country originate

Botanicals	*Parthenium hysterophorus*	Most grassy weeds	India
	(young plants)	Most grassy weeds	India
	Calotropis procera (twigs)	Most grassy weeds	India
	Bambusa vulgaris (root & leaf)	Most grassy weeds	India
	Tectona grandis (leaf)	*Echinochloa spp*	Japan
	Some wild rice cultivars (root & leaf)		
Bialaphos	***Streptomyces hygroscopicus***	**General vegetation**	**USA**
Collego	*Colletotrichum gloiosporioides*	*Aeschynomene virginica*	USA
Casst	*Alternaria cassiae*	*Cassia occidentalis*	USA
Devine	*Phytophthora palmivora*	*Morrenia adorata*	USA
Dr. Biosedge	*Puccinia canaliculata*	*Cyperus esculentus*	Georgia

❖ **Chemical control:**

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

Classification of Herbicides

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

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

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

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

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

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

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

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

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

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

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

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

(i) **Soil applied herbicides**: The herbicides that are applied on soil and kill germinating or sprouting weed seeds, corms, bulbs, rhizome, etc and thereby eliminate the chance of early weed competition in the field are called soil applied herbicides e.g. (a) PP & PE herbicides like Pretilachlor, Alachlor, Atrazine, Fluchloralin, Metribuzin, Pendimethalin, Trifluralin etc. (b) EPOE or POE herbicides: Butachlor, Almix, Sulfosulfuron, Quizalofop ethyl etc.

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

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

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

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

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

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

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

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

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

Surfactants, Safener and Formulation:

Surfactants: In the advance weed management for controlling weed pest the ecosafe criteria (the air, soil, water & consumable food products) is the topmost priority and for this the doses of the synthetic chemicals is gradually becoming decrease, thus safer herbicides are using with lower doses e.g. Dalapon was used @ 15 kg ha^{-1} (1970) and now (2010) Trifloxysulfuron is used @ 2 g ha^{-1} or Almix 4 g ha^{-1} etc. But while herbicide doses are reduced there may be a chance of reducing the activity of chemicals. To increase the activity of botanicals & synthetic chemicals for better controlling the weed plants various surfactants are mostly used along with changing

formulation considering the polarity of herbicides (Ionic position – electrically positive or negative)**. Dose@ 1 lit. ha^{-1}.** e. g. Anionic – Vatsol-Ot Cationic- Aliquat-4 Non-ionic- S-145, Tween 20 etc.

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

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

e.g. Fenchlorin, Furilazole, Flurazole etc.

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

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

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

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

Annual Planning of Weed Pest Management (APWPM)

Basic concepts of APWPM:

I. *To reduce the weed bank in soil before planting of any desired crop so that the initial weed competition*

to crop could be minimized

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

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

Crop	Name of organic	Commercial name	Dose

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

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

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

List of important selective organic herbicides with dose

- **Time of application: Pre-emergence of weed flora (0-1 DAS/DAT/DAP)**
- **Major criteria: Soil should be adequately moist**
- ❖ **Organic botanical herbicides: Apply in any crop**
- ✓ Allelopathic effect through natural chemical compounds

✓ Raw, Aqueous or Methanol extracts dose - @ 100 ml/litre of water

List of organic botanical herbicides

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

❖ **Organic Synthetic chemical herbicides:**

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

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

Crop	Name of organic herbicides with active ingredient (a.i) and fomulation	Commercial name	Dose ($g\ ha^{-1}$)
Paddy	Pretilachlor 30.7 EC Pretilachlor 50 EC	Sofit, Erase N, Petigan-S Rifit, Erase, Craze, Offset, Sureshot, Preet, Prettyherb, Profit, Prince, Nagpreticlor, Pretigan,Tatapreet,	500
	Butachlor 50 EC Butachlor 5 G Butachlor 50 EW	Machete, Finish,Dhanuchlor, Rasayanchlor, Hunter BilchlorNagclor,Dhanuchzor, Teer Machete, Nagclor-G, Pedichlor Donmix, Kikout	1250
	Pyrazosulfuron Ethyl 10 WP	Saathi	30
	Bispyribac Sodium 10 SC	Nominee Gold	25
Sugarcane	Atrazine 50 WP+ Surfactant	Atrafil, Avert, Surya, Nagzine, Atrataf, Solaro,Atramex	2000
Pulse and Oilseeds	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Pendimethalin 30 EC	Stomp, Tatapanida,Pendigold, Pendigan, Pendiherb, Speed, Dhanutop, Pendisul	750

Jute and Cotton	Alachlor 50 EC	Lasso	100
Vegetables	Metribuzin 70 WP	Sencor, Krizin, Tata Metri, Barrier, Century, Chase, Nagmezin, Weedeclean, Metrigan	600
	Pendimethalin 30 EC	Stomp, Tatapanida,Pendigold, , Pendiherb, Speed, Dhanutop, Pendisul, Depend Pendigan	750
Potato	Metribuzin 70 WP	Sencor, Krizin, Tata Metri, Barrier, Century, Chase, Nagmezin, Weedeclean, Metrigan	600
	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Paraquat dichloride 24 SL	Gramoxone, Sweep,Weedol, Ozone, Filfuat, Kapiq, Paralac,Uniquat,Rhino, Chemspray, Nagat, Parashute, Peranax	2500
Onion	Oxyfluorfen 23.5 EC	Goal, Alto, Oyester, Kroll, Galigan, Oxygold, Zargon, Herbucsone	100
	Oryzalin 40 SC	Surflan	2000

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

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

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

POE organic Chemical herbicides with doses

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

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

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

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

Technical name	Commercial name	Dose (g ha^{-1})
Metsulfuron Methyl 20 WP	Algrip, Hook, Volt, Dot Mono, Niconin, Niconof, Pantera	**4**
Clodinafoppropargyl 15 WP	Topic, Clodinagan, Rakshak Plus	80

2,4- D Sodium salt 80 WP	Weedmar, Fernaxone, 24D Agan, Nagsal 2, Safaya, Herbocline	500
2,4-D Amine salt 58 SL	Champion, nagmine, 24D Main, Weedmar, Super, Kayam –M	750
2,4-D Ethyl ester 38 EC/20 WP	Slash, Weedmar, Nagester / Nagesterr P	750

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

Application of herbicide:

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

❖ **Method of Application**

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

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

Herbicide Nozzle:

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

Economics:

1. Generally the cost involves for manual hand weeding (traditional weed control method) - ₹ 1500-2000 ha^{-1} (8-10 laboures each @ ₹ 200 only)
2. For chemical weed control it is almost 35 % of manual hand weeding - ₹ 500-600 ha^{-1}
3. For biological control 35% of chemical control (70% lesser cost to hand weeding) - ₹ 150-200 ha^{-1}

References:

- ✓ Principles of Weed Science- V.S.Rao- Oxford & IBH Publishing Co.Pvt. Ltd., New Delhi, 2002
- ✓ Modern Weed Management- O.P.Gupta, Agrobios Publishers, Rajasthan, 2002
- ✓ Weeds and their Control- R.K.Ghosh and P.C.Das, Kalyani Publishers, Ludhiana, 2004
- ✓ Plant Protection Schedule -Weed Management Chapter (Prof. R.K.Ghosh); Published by Directorate of Agriculture, Government of West Bengal- 2010
- ✓ Annual Planning of Weed Pest Management in System Agriculture - R. K.Ghosh, A. Ghosh, D. Mondal and P. Bandopadhyay- Published from BCKV, ICAR Fund, 2017

Sprayers and Nozzles