

Lecture-6

GROWTH AND DEVELOPMENT

6.1 MEASUREMENT OF GROWTH: Growth can be measured by a variety of parameters as follows

A. Fresh Weight

Determination of Fresh weight is an easy and convenient method of measuring growth. For measuring fresh weight, the entire plant is harvested, cleaned for dirt particles if any and then weighed.

B. Dry Weight

The dry weight of the plant organs is usually obtained by drying the materials for 21 to 48 h at 70 to 80°C and then weighing it. The measurements of dry weight may give a more valid and meaningful estimation of growth than fresh weight. However, in measuring the growth of dark grown seedling it is desirable to take fresh weight.

C. Length

Measurement of length is a suitable indication of growth for those organs which grow in one direction with almost uniform diameter such as roots and shoots. The length can be measured by a scale. The advantage of measuring length is that it can be done on the same organ over a period of time without destroying it.

D. Area

It is used for measuring growth of plant organs like leaf. The area can be measured by a graph paper or by a suitable mechanical device. Nowadays modern laboratories use a photoelectric device (digital leaf area meter) which reads leaf area directly as the individual leaves are fed into it.

6.2 GROWTH ANALYSIS:

Growth analysis is a mathematical expression of environmental effects on growth and development of crop plants. This is a useful tool in studying the complex interactions between the plant growth and the environment. Growth analysis in crop plants was first studied by British Scientists (Blackman 1919, Briggs, Kidd and West 1920, William 1964, Watson 1952 and Blackman, (1968). This analysis depends mainly on primary values (Dry weights) and they can be easily obtained without great demand on modern laboratory equipment.

The basic principle that underlie in growth analysis depends on two values (1) total dry weight of whole plant material per unit area of ground (w) and (2) the total leaf area of the plant per unit area of ground (A).

The total dry weight (w) is usually measured as the dry weight of various plant parts *Viz*, leaves, stems and reproductive structures. The measure of leaf area (A) includes the area of other organs *viz*, stem petioles, flower bracts, awns and

Pods that contain chlorophyll and contribute substantially to the overall photosynthesis of the plants

According to the purpose of the data, leaf area and dry weights of component plant parts have to be collected at weekly, fortnightly or monthly intervals. This data are to be used to calculate various indices and characteristics that describe the growth of plants and of their parts grown in different environments and the relationship between assimilatory apparatus and dry matter production. These indices and characteristics are together called as **growth parameters**. Some of the parameters that are usually calculated in growth analysis are crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), Leaf area ratio (LAR), Leaf weight ratio (LWR), Specific Leaf Area (SLA), Leaf area index (LAI) and Leaf area duration (LAD). Accuracy in calculations of these parameters and their correct interpretation are essential aspect in growth analysis.

6.2.1 Advantages of growth analysis

- a) We can study the growth of the population or plant community in a precise way with the availability of raw data on different growth parameters.
- b) These studies involve an assessment of the primary production of vegetation in the field i.e. at the ecosystem level (at crop level) of organization.
- c) The primary production plays an important role in the energetics of the whole ecosystem.
- d) The studies also provide precise information on the nature of the plant and environment interaction in a particular habitat.
- e) It provides accurate measurements of whole plant growth performance in an integrated manner at different intervals of time.

6.2.2 Drawbacks of Growth Analysis

In classical growth analysis sampling for primary values consist of harvesting (destructively) representative sets of plants or plots and it is impossible to follow the same plants or plots through out whole experiment.

6.3 Growth Characteristics – Definition and Mathematical Formulae

The following data are required to calculate different growth parameters in order to express the instantaneous values and mean values over a time interval. In the following discussion W , W_L , W_S and W_R are used to represent the dry weights of total plant (w), dry leaves (w_L), stem (w_S) and roots (w_R) respectively. Whereas A is the leaf area and P is the land area.

6.3.1 Crop Growth Rate (CGR):C

D.J. Watson coined the term Crop growth rate. It is defined as the increase of dry matter in grams per unit area per unit time. The mean CGR over an interval of time T_1 and T_2 is usually calculated as show in the following formula

$$\text{CGR} = \frac{I}{P} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ (g m}^{-2} \text{ day}^{-1}\text{)}$$

Where CGR is the mean crop growth rate, W_1 and W_2 are the dry weights at two sampling times T_1 and T_2 respectively.

6.3.2 Relative Growth Rate (RGR):R

The term RGR was coined by Blackman. It is defined as the rate of increase in dry matter per unit of dry matter already present. This is also referred as **Efficiency index** since the rate of growth is expressed as the rate of interest on the capital. It provides a valuable overall index of plant growth. The mean relative growth rate over a time interval is given below.

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \text{ (g g}^{-1} \text{ day}^{-1}\text{)}$$

6.3.3 Net Assimilation Rate (NAR):E:

The NAR is a measure of the amount of photosynthetic product going into plant material i.e. it is the estimate of net photosynthetic carbon assimilated by photosynthesis minus the carbon lost by respiration. The NAR can be determined by measuring plant dry weight and leaf area periodically during growth and is commonly reported as grams of dry weight increase per square centimeter of leaf surface per week. This is also called as **Unit leaf rate** because the assimilatory area includes only the active leaf area in measuring the rate of dry matter production.

The mean NAR over a time interval from T_1 to T_2 is given by

$$\text{NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{Log}_e A_2 - \text{Log}_e A_1}{A_2 - A_1} \text{ (g cm}^{-2} \text{ wk}^{-1}\text{)}$$

6.3.4 Leaf Area Ratio (LAR)

The LAR is a measure of the proportion of the plant which is engaged in photosynthetic process. It gives the relative size of the assimilatory apparatus. It is also called as capacity factor. It is defined as the ratio between leaf area in square centimeters and total plant dry weight. It represents **leafiness character** of crop plants on area basis.

$$\text{LAR} = \frac{A}{W} \text{ (cm}^2 \text{ g}^{-1}\text{)}$$

6.3.5 Leaf Weight Ratio (LWR)

It is one of the components of LAR and is defined as the ratio between grams of dry matter in leaves and total dry matter in plants (g). Since the numerator and denominator are on dry weight basis LWR is dimensionless. It is **the index of leafiness** of the plant on weight basis.

$$\text{LWR} = \frac{W_L}{W}$$

6.3.6 Specific Leaf Area (SLA)

It is another component of LAR and defined as the ratio between leaf area in cm² and total leaf dry weight in grams. This is used as a measure of **leaf density**. The mean SLA can be calculated as

$$\text{SLA} = \frac{A}{W_L} \text{ (cm}^2\text{g}^{-1}\text{)}$$

6.3.7 Specific Leaf Weight (SLW)

The reversal of SLA is called as SLW. It is defined as the ratio between total leaf dry weight in gms and leaf area in cm². It indicates the **relative thickness** of the leaf of different genotypes.

$$\text{SLW} = \frac{W_L}{A} \text{ (g cm}^{-2}\text{)}$$

6.3.8 Leaf area index (LAI):

D.J. Watson coined this term. It is defined as the functional leaf area over unit land area. It represents the leafiness in relation to land area. At an instant time (T) the LAI can be calculated as

$$\text{LAI} = A/P \text{ unit less}$$

For maximum production of dry matter of most crops, LAI of 4-6 is usually necessary. The leaf area index at which the maximum CGR is recorded is called as 'optimum leaf area index'.

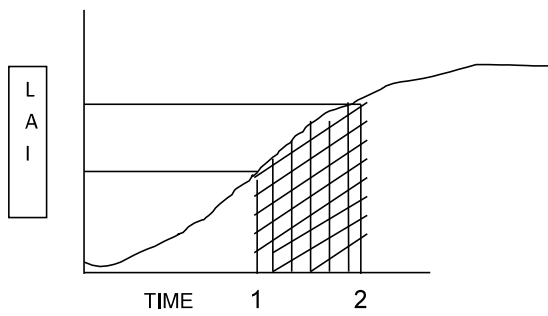
6.3.9 Leaf Area Duration (LAD): d: It is usually expressed as a measure of leaf area integrated over a time period. Some takes into account both the magnitude of leaf area and its persistence in time;

it represents the leafiness of the crop growing period. Thus the unit of measurement of LAD may be in days or weeks or months.

$$T_1) \text{ LAD (Leaf area basis) = } \frac{LA_1 + LA_2(T_2 - T_1)}{2}$$

$$\text{LAD (LAI basis) = } \frac{LA_1 + LA_2(T_2 - T_1)}{2}$$

This is expressed as $\text{cm}^2 \text{ d}^{-1}$



Leaf area duration (Shaded area)

For how many days/weeks functional leaf area is present on the plant can be estimated by this LAD.
