Paper 603: Unit V: B.Sc 3rd Year Botany Major (6th Semester)

Chapter: Plant Growth and Development:

Plant Growth Regulators

Plant Growth Regulators are defined as small, simple chemicals produced naturally by plants to regulate their growth and development.

- Characteristics

- ✓ Plant Growth Regulators can be of a diverse chemical composition such as gases (ethylene), terpenes (gibberellic acid) or carotenoid derivates (abscisic acid). They are also referred to as plant growth substances, phytohormones or plant hormones. Based on their action, they are broadly classified as follows:

- ✓ Plant Growth Promoters – They promote cell division, cell enlargement, flowering, fruiting and seed formation. Examples are auxins, gibberellins and cytokinins.

- ✓ Plant Growth Inhibitors – These chemicals inhibit growth and promote dormancy and abscission in plants. An example is an abscisic acid. Note: Ethylene can be a promoter or an inhibitor, but is largely a Plant Growth Inhibitor.

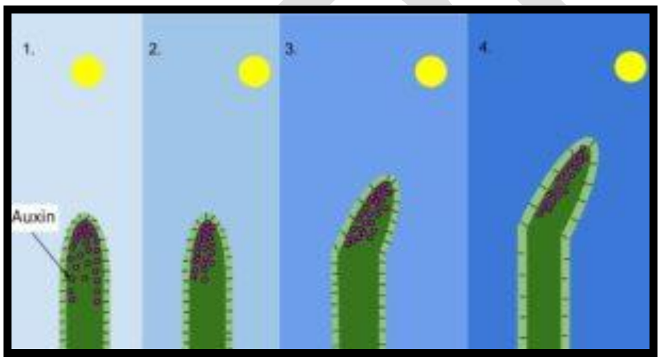
Plant Growth and Development

- Growth and its Phases
- Vernalisation
- Photoperiodism

All plant growth regulators were discovered accidentally. Let's take a detailed look at each regulator and learn about it more closely:

Auxins:

Discovery: **Auxins were the first growth hormone to be discovered. They were discovered due to the observations of Charles Darwin and his son, Francis Darwin. The Darwins observed that the coleoptile (protective sheath) in canary grass grows and bends towards the source of light. This phenomenon is 'phototropism'. In addition, their experiments showed that the coleoptile tip was the site responsible for the bending. Finally, this led to the isolation of the first auxin by F. W. Went from the coleoptile tip of oat seedlings.**



(Source: Wikimedia Commons)

- ✓ Types

First isolated from human urine, auxin is a term applied to natural and synthetic compounds that have growth regulating properties. Plants produce natural auxins such as Indole-3-acetic acid (IAA) and Indole butyric acid (IBA). Natural auxins are found in growing stems and roots from where they migrate to their site of action. Naphthalene acetic acid (NAA) and 2, 4-dichlorophenoxyacetic (2, 4-D) are examples of synthetic auxins.

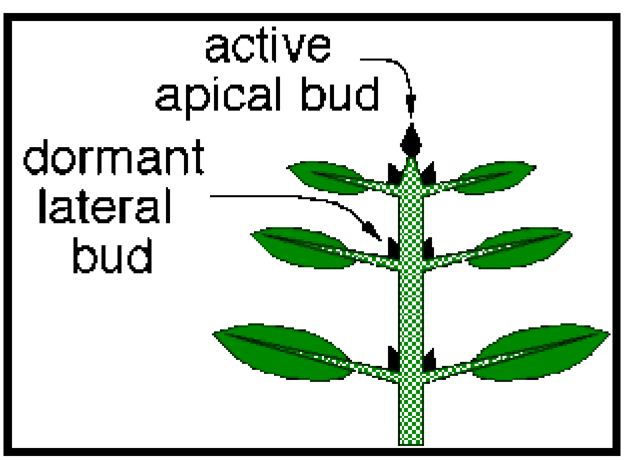
✓ Effects

- Promote flowering in plants like pineapple.
- Help to initiate rooting in stem cuttings.
- Prevent dropping of fruits and leaves too early.
- Promote natural detachment (abscission) of older leaves and fruits.
- Control xylem differentiation and help in cell division.

✓ Applications

- Used for plant propagation.
- To induce parthenocarpy i.e. the production of fruit without prior fertilization.
- 2, 4-D is widely used as a herbicide to kill dicotyledonous weeds.
- Used by gardeners to keep lawns weed-free.

Note: The growing apical bud in higher plants inhibits the growth of the lateral buds. This phenomenon is '**Apical Dominance**'. Removal of the apical bud allows the lateral buds to grow. This technique is commonly used in tea plantations and hedge-making.



(Source: Wikimedia Commons)

- **Gibberellins**

- Discovery

It is the component responsible for the 'bakane' disease of rice seedlings. The disease is caused by the fungal pathogen *Gibberella fujikuroi.* E. Kurosawa treated uninfected rice seedlings with sterile filtrates of the fungus and reported the appearance of disease symptoms. Finally, the active substance causing the disease was identified as gibberellic acid.

- Types

There exist more than 100 gibberellins obtained from a variety of organisms from fungi to higher plants. They are all acidic and are denoted as follows – GA_1, GA_2, GA_3 etc. GA_3 (Gibberellic acid) is the most noteworthy since it was the first to be discovered and is the most studied.

- Effects

- Increase the axis length in plants such as grape stalks.
- Delay senescence (i.e. ageing) in fruits. As a result, their market period is extended.
- Help fruits like apples to elongate and improve their shape.

Applications

- The brewing industry uses GA_3 to speed the malting process.
- Spraying gibberellins increase sugarcane yield by lengthening the stem.
- Used to hasten the maturity period in young conifers and promote early seed production.

- Help to promote bolting (i.e. sudden growth of a plant just before flowering) in cabbages and beet.

➢ Cytokinins

- Discovery

F. Skoog and his co-workers observed a mass of cells called 'callus' in tobacco plants. These cells proliferated only when the nutrient medium contained auxins along with yeast extract or extracts of vascular tissue. Skoog and Miller later identified the active substance responsible for proliferation and called it kinetin.

- Types

Cytokinins were discovered as kinetin. Kinetin does not occur naturally but scientists later discovered several natural (example – zeatin) and synthetic cytokinins. Natural cytokinins exist in root apices and developing shoot buds – areas where rapid cell division takes place.

- Effects

- Help in the formation of new leaves and chloroplast.
- Promote lateral shoot growth and adventitious shoot formation.
- Help overcome apical dominance.
- Promote nutrient mobilisation which in turn helps delay leaf senescence.

➢ Abscisic Acid

- Discovery

Three independent researchers reported the purification and characterization of three different inhibitors – Inhibitor B, Abscission II and Dormin. Later, it was found that all three inhibitors were chemically identical and were, therefore, together were given the name abscisic acid. Abscisic acid mostly acts as an antagonist to Gibberellic acid.

- Effects
  - Regulate abscission and dormancy.
  - Inhibit plant growth, metabolism and seed germination.
  - Stimulates closure of stomata in the epidermis.
  - It increases the tolerance of plants to different kinds of stress and is, therefore, called 'stress hormone'.
  - Important for seed development and maturation.
  - It induces dormancy in seeds and helps them withstand desiccation and other unfavourable growth factors.

- **Ethylene**

- Discovery

  A group of cousins showed that a gaseous substance released from ripe oranges hastens the ripening of unripe oranges. Consequently, they found that the substance was ethylene – a simple gaseous Plant Growth Regulator. Ripening fruits and tissues undergoing senescence produce ethylene in large amounts.

- Effects
  - Affects horizontal growth of seedlings and swelling of the axis in dicot seedlings.
  - Promotes abscission and senescence, especially of leaves and flowers.

- Enhances respiration rate during ripening of fruits. This phenomenon is 'respiratory climactic'.
- Increases root growth and root hair formation, therefore helping plants to increase their absorption surface area.

- Application

  Ethylene regulates many physiological processes and is, therefore, widely used in agriculture. The most commonly used source of ethylene is Ethephon. Plants can easily absorb and transport an aqueous solution of ethephon and release ethylene slowly.

- Used to break seed and bud dormancy and initiate germination in peanut seeds.
- To promote sprouting of potato tubers.
- Used to boost rapid petiole elongation in deep water rice plants.
- To initiate flowering and synchronising fruit-set in pineapples.
- To induce flowering in mango.

Ethephon hastens fruit ripening in apples and tomatoes and increases yield by promoting female flowering in cucumbers. It also accelerates abscission in cherry, walnut and cotton.

In summary, one or the other plant growth regulator influences every phase of growth or development in plants. These roles could be individualistic or synergistic; promoting or inhibiting. Additionally, more than one regulator can act on any given life event in a plant. Along with genes and extrinsic factors, plant growth regulators play critical roles in plant growth and development. Factors like temperature and light affect plant growth events (vernalisation) via plant growth regulators.

Plants Growth: Characteristics, Development, Phases and Factors

Characteristics of Plants Growth:

Growth is the manifestation of life. All organisms, the simplest as well as the most intricate, are slowly changing the whole time they are alive. They transform material into more of themselves.

From such ingredients as minerals, proteins, carbohydrates, fats, vitamins, hormones etc., organisms form additional protoplasm. The formation of protoplasm is called assimilation.

A large part of the food which a plant manufactures is used as a source of energy. Food may be consumed soon after it is produced, or it may be stored and used as a source of energy for the plant or its offspring weeks, months, or even years later.

A healthy plant, however, manufactures more food than is necessary to maintain the activities of its living substance, and the surplus may be built, more or less permanently, into its tissues, producing new protoplasm and new cell walls and thus promoting the growth of the plant body. Growth represents the excess of constructive over destructive metabolism.

Growth involves an irreversible increase in size which is usually, but not necessarily, accompanied by an increase in dry weight. The basic process of growth is the production of new protoplasm, which is clearly evident in the regions of active cell division.

The next stage in growth is increase in plant size, which is the result of absorption of water and the consequent stretching of the tissues, a process which in the strict sense is not growth at all, since it involves little or no increase in the characteristic material of the plant itself.

The third and the last stage in growth involves the entry of plenty of building materials, chiefly carbohydrates, into the expanded young tissues. This results in an increase in the dry weight but no visible increase in external size of the plant. Growth is, however, more than just an increasing amount of the plant. Differential growth of plant parts results in a characteristic shape. Each plant species has a distinctive form, development by growth patterns.

Differentiation:

Differentiation can be recognized at cell level, tissue level, organ level, and at the level of an organism. It becomes more obvious at the level of organ and organism. For instance, if we consider flower as an organ of plant, is bears sepals for photosynthesis and protection of inner floral parts; beautiful, coloured petals to attract insects for cross-pollination ; stamens for producing male gametes; and the carpels for bearing the ovules which after fertilization produce seeds.

Considering an angiosperm as an organism, we observe that it possesses the roots for absorption of water and minerals and fixation in the soil; the trunk and stem branches bear leaves for photosynthesis, flowers and fruits; the fruits for bearing the seeds which on germination form each a new plant.

Development:

Development implies a whole sequence of qualitative structural changes that a plant undergoes from the zygote stage to its death. The developmental changes may be gradual or abrupt. Examples of certain abrupt changes are germination, flowering and senescence (ageing leading to death).

Slow developmental changes include formation and maturation of tissues, formation of vegetative and floral buds and the formation of reproductive organs. Unlike growth, development is a qualitative change. It cannot be measured in quantitative terms, and is either described or illustrated with the help of photographs or drawings. Development includes growth (cell division, enlargement and differentiation), morphogenesis, maturation and senescence.

The growth cycle of annual, monocarpic, flowering plants (angiosperms) begins with the fertilized egg, the zygote. The zygote develops into an embryo following cell divisions and differentiation (embryonal stage). The embryo is enclosed within a seed where it undergoes a period of inactivity (dormancy). The resting embryo resumes growth during the germination of seed and develops into a seedling (seedling stage).

The seedling grows into a vegetative plant (vegetative phase). After some period of vegetative growth, the plant undergoes maturation and enters the reproductive phase. It develops flowers and fruits, the latter containing the seeds. Finally senescence sets in (senescence stage) leading to the death of the plant.

In unicellular organisms, growth consists of an increase in the size or volume (enlargement) of the cell. This increase is due to the synthesis of new protoplasm. Growth in unicellular organisms thus consists of single phase or step. Growth leads to maturation ("adults") or full grown individuals. Cell division in unicellular organisms results in their multiplication or reproduction.

In simple multicellular organisms like Spirogyra, growth involves two phases or steps, cell division and enlargement. Cell division results in increase in the number of cells in the filamentous alga. The newly formed cells enlarge or increase in size. As a result, the filament of Spirogyra grows. In, flowering plants, however, growth involves three phases cell division, enlargement and differentiation.

Growth Regions in Animals and Plants:

Cell division and differentiation are important aspects of growth and development in both animals and plants. In mammals, the growth is diffuse and it is very difficult to specify the regions where the growth occurs. In animals, the growth of the embryo is completed quite early, although the mature size may be gained at specific periods.

In plants, the growth may be diffuse or localized. Diffuse growth occurs in lower forms of life i.e., filamentous algae. Here each cell of the multicellular plant body can divide and enlarge. The higher plants, especially, the trees are built up in a modular fashion i.e. their development is relatively open-ended and their structure never complete.

In such plants, the growth continues throughout with the new organs forming, replacing the old ones. Here the growth is localized i.e. growth is confined to certain specific regions, the growing points. Localized growth occurs due to the activity of a group of cells called the meristems. Depending upon the location of the meristems, the growth may be apical, intercalary and lateral.

Phases of Plant Growth:

As a plant is made up of cells, its growth will be the sum total of the growth of its cells.

The growth of cells involves three main phases:

(1) The phase of cell division (formative phase),

(2) Cell enlargement and cell differentiation.

(3) Cell Differentiation or Cell Maturation.

1. Phase of Cell Division (Formative Phase):

Cell division is the basic event for the growth of multicellular plants. All cells in an organism result from the division of pre-existing cells. The type of cell division that occurs during the growth of an organism is mitosis. It is a quantitative as well as qualitative division that is generally completed in two stages: the division of the nucleus (karyokinesis), followed by the division of the cytoplasm (cytokinesis).

During mitosis, the cell passes through prophase, metaphase, anaphase and telophase, resulting in equal distribution of the genetical material and the cytoplasm in each of the two daughter cells thus formed. Further, the daughter cells are genetically similar to the parent cell. As a result of this process, cells having the same genetic constitution get multiplied.

In higher plants, cell divisions continuously occur in the meristematic regions, such as apical meristem. As a result, an increase in the number of cells takes place in the meristematic region. Some of the daughter cells retain the meristematic activity, while others enter the next phase of growth— the phase of cell enlargement.

2. Phase of Cell Enlargement:

The cell enlargement plays an important role in contributing to the size of the tissue and organs. The enlargement occurs by synthesizing protoplasm, absorbing water (hydration), developing vacuoles and adding new cell wall material to the stretched, thin elastic walls to make them slightly thicker and permanent. Cell enlargement may be linear or in all directions.

3. Phase of Cell Differentiation or Cell Maturation:

During the last phase, the enlarged cells eventually acquire a specific size and form according to their location and role following biochemical, physiological and morphological changes, i.e., the cells undergo specialization or transformation. As a result, various kinds of cells get differentiated. These differentiated cells form different kinds of simple and complex tissues which perform different functions.

Experiment to Study Phases of Growth:

Germinate a few seeds of Pea or Bean in moist saw dust. Pick up a couple of seedlings with straight radicle of 2-3 cm length. Wash the seedlings. Blot the surface water. Mark the radicles from tip to base with 10-15 points at intervals of 2 mm with the help of water proof or India ink. As soon as the ink dries up, place the seedlings on moist blotting paper in a petri dish. Allow the seedling to grow for 1-2 days. Measure the intervals between the marks.

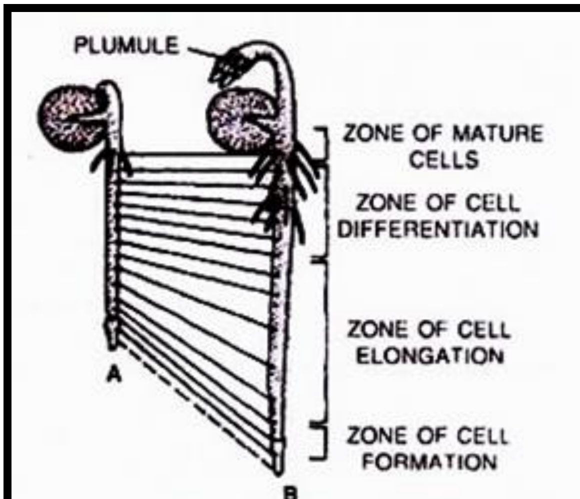


Fig. 2.1 Regions or phases of growth in root. A, marked radicle of the seedling at the beginning of experiment. B, marked radicle after 48 hours.

Growth Rates:

The increased growth per unit time is termed as growth rate. Thus, rate of growth can be expressed mathematically. An organism, or a part of the organism can produce more cells in a variety of ways. The growth rate shows an increase that may be arithmetic or geometrical (Figure 2.2).

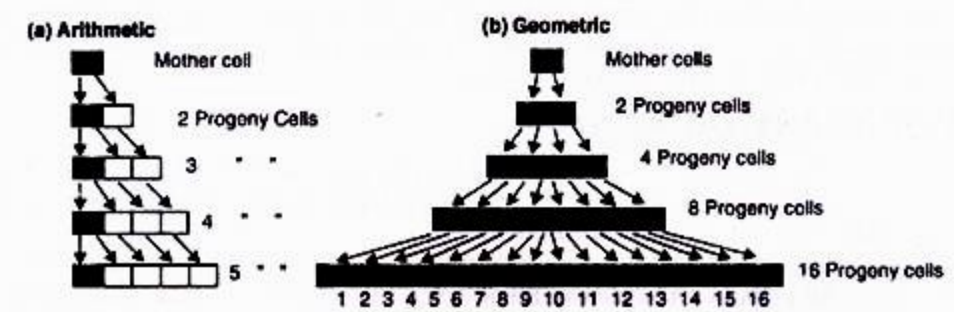


Fig. 2.2. Diagrammatic representation of : (a) Arithmetic and (b) Geometric growth.

In arithmetic growth, following mitotic cell division, only one daughter cell continues to divide while the other differentiates and matures. The simplest expression of arithmetic growth is exemplified by a root elongating at a constant rate. Look at (Fig. 2.3). On plotting the length of the organ against time, a linear curve is obtained.

Mathematically, it is expressed as:

$L_t = L_0 + rt$

L_t = length at time 't'

L_0 = length at time 'zero'

r = growth rate/elongation per unit time.

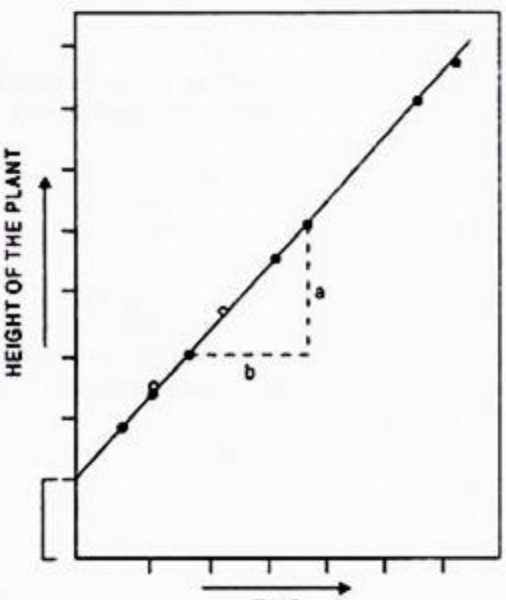


Fig. 2.3. Constant linear growth, a plot of length L against time t

Let us now see what happens in geometrical growth. In most systems, the initial growth is slow (lag phase), and it increases rapidly thereafter – at an exponential rate. Here, both the progeny cells following mitotic division retain the ability to divide and continue to do so (Fig. 2.4). Geometrical growth can be expressed by "Grand Period of Growth" (Fig. 2.5).

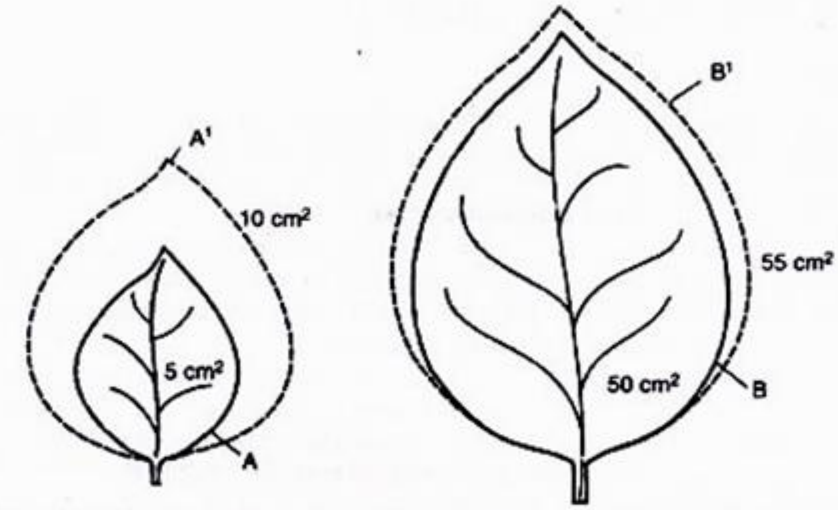


Fig. 2.4. Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm^2 in a given time to produce A_1, B_1 leaves.

Quantitative comparisons between the growth of living system can also be made in two ways:

(i) Measurement and the comparison of total growth per unit time is called the absolute growth rate,

(ii) The growth of the given system per unit time expressed on a common basis, e.g., per unit initial parameter is called the relative growth rate.

In Figure 2.6 two leaves, A and B, are drawn that are of different sizes but shows absolute increase in area in the given time to give leaves, A, and B'. However, one of them shows much higher relative growth rate. Which one and why?

The Grand Period of Growth:

The vegetative growth of most plants in general shows three phases, starting slowly, becoming gradually faster and finally slowing again. These three phases, which are together known as “grand period of growth”, cover the whole of the vegetative history of an annual plant. In a perennial plant such a grand period of growth is repeated annually with periods of dormancy between the repetitions.

In order to explain the grand period of growth, a graph may be drawn between the duration of growth and increase in the dry weight of the plant. It is graphically represented by a ‘S’-shaped curve (a sigmoid curve) (Fig. 2.5). These variations in growth occur due to several external and internal factors.

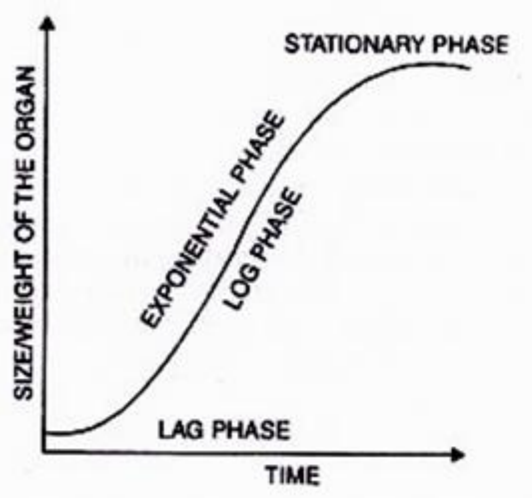


Fig. 2.5. Graphical representation of **‘grand period of growth’** (a sigmoid curve) in maize plant.

The sigmoid curve shows following three distinct phases:

(1) The lag phase or initial phase:

It represents initial stages of growth. The rate of growth is naturally slow during this phase.

(2) Log phase or exponential phase:

It is the period of maximum and rapid growth. Physiological activities of cells are at their maximum.

Here, both the progeny cells following mitotic cell division retain the ability to divide and continue to do so. However, with limited nutrient supply, the growth slows down leading to a stationary phase_

The exponential growth can be expressed as

$W_1 = W_0 e^{rt}$
W_1 = final size (weight, height, number etc.)
W_0 = initial size at the beginning of the period
r = growth rate

t = time of growth

e = base of natural logarithms

Here, r is the relative growth rate and is also the measure of the ability of the plant to produce new plant material, referred to as efficiency index. Hence, the final size of W_1 depends on the initial size, W_0.

(3) Adult phase or stationary phase:

This phase is characterized by a decreasing growth rate. The plant reaches maturity, hence the physiological activity of cells also slows down and plant begins to senesce.

Factors Affecting Plant Growth:

(I) External Factors:

Regardless of the habitat in which a plant is growing, it is continuously subjected to the variability's of a complex set of environmental factors. Environmental factors play an important role in the growth and development of any plant. Important among these environmental factors are temperature, light, oxygen, water and nutrients.

(1) Temperature:

Temperature is one of the most important environmental factors that effect the growth of any plant. However, the minimum, optimum and maximum limits of temperature for growth vary from species to species. For instance, the winter cereals make some growth at temperatures of 34° to 40°F, whereas in that temperature range pumpkins and melons do not grow ,it all.

As the temperature increases above the minimum, growth is accelerated until a certain optimum temperature is attained, above which it becomes slower and ultimately completely retarded. The optimum temperature greatly varies with the species of plant; it also varies with the age of the plant. The optimum temperatures for the growth of tropical plants are higher than the temperate ones.

Arctic and alpine species may grow at the freezing point or even at a temperature slightly below the freezing point. Their optimum temperature is usually no higher than 10°C. The optimum temperature for most of the tropical species varies from 30° to 35°C, and for temperate species it usually varies from 25° to 30°C.

Effect of duration for which a plant is exposed to a particular temperature also varies with the species. For instance, a plant may make considerable growth if exposed to a temperature of 86°F for a short duration—the same temperature has deleterious effects on growth if maintained for a longer duration.

Soil temperature also greatly influences the growth of roots and shoots. Under natural conditions, temperature is a cyclic environmental factor. Normally the temperatures of day and night greatly vary and with only few exceptions plants grow better when night temperatures are lower than day temperatures. Sometimes, the term thermo-periodicity is used to designate the effects of an alternation of temperature between the day and night upon the growth and other reactions of the plants.

(2) Light:
Light is another important factor that variously effects the growth and development of all plants. Light intensity, quality of light and duration of light affect growth through several ways. It greatly influences several

important physiological processes like chlorophyll synthesis, stomata movements, photosynthesis, formation of anthocyanin, temperature of aerial organs, absorption of minerals, permeability, rate of transpiration, streaming of protoplasm etc.

(i) Intensity of light:

The intensity of light greatly influences plant growth. Variations in the intensity of sunlight are always invariably associated with changes in the quality of light, and under natural conditions, variations in light intensity have more significant effects upon growth pattern of plants than changes in the quality of light. Most crops and ornamental plants, for instance, wheat, corn, peas, tobacco make vigorous and stocky growth and flower profusely with full sun. Such plants are called "sun plant".

When grown with intermediate light intensities, sun plants become taller and have larger, thinner leaves, but fewer flowers. They make very poor growth in low light intensity. Shirley (1929, 1935), however, observed in a number of plant species that the absolute weight, percentage of dry matter in the tops, thickness and rigidity of the stem and leaf thickness all increase with increase in the light intensity up to full sun light, provided no other factor is limiting. Low light intensity results in poor flower development and consequently very poor fruit setting.

(ii) Quality of light:

Different wave lengths of sun light have significant effects upon the growth of plants. Most of the experiments conducted in this direction indicate that overall development of a plant and increase in its dry weight take place most effectively in the full spectrum of visible light. Plants grown in blue and violet light tend to be dwarf, those in red light, tall and spindly. The ultraviolet and infra red radiations of sunlight do not promote growth.

Overall growth of plant in green light is much less than in either blue-violet or orange red portions of the spectrum. This effect of green light is partly due to lower efficiency of photosynthesis in the green light. Different wave lengths of sun light do not have uniform effects on different organs of a plant. For instance, orange-red light generally results in poor development of stems and hypocotyls.

Greatest elongation of stems and hypocotyls in most of the plants takes place in blue-violet portion of the spectrum, less in the green and still less in the orange-red and least in the complete spectrum of visible light. On the other hand maximum expansion of leaf blades occurs in the full spectrum of visible light and least in the green.

(iii) Duration of light:

Duration, intensity and quality of light have marked influence on the rate of photosynthesis and hence the rate of growth. During winters, when the days are short, plants grow slowly; as the days get longer toward spring, growth is accelerated.

Duration of light not only affects photosynthesis but also greatly influences dormancy and flowering in plants. The short days of autumn bring about retardation of growth in many plants, a phenomenon not related to photosynthesis. A number of trees respond to the short days of autumn by ceasing to grow and becoming dormant.

The length of day has a marked influence on flowering. Plants, according to their requirement of light for flowering, are classified as-long-day plants, short-day plants and day-neutral plants. The long-day plants in general flower when the days are longer than 13 or 14 hour (depending upon the species), while the short-day plants produce flowers when the days are shorter than 13 or 14 hours. Flowering in the day-neutral plants is not affected by the length of the day. They can very well flower under both short and long day conditions.

(3) Oxygen supply:

With the exception of only those plants which are native to marshy and boggy terrains, the growth of all terrestrial plants is greatly retarded in poorly aerated soils. Usually the shoots of plants receive an ample supply of oxygen, but the roots may or may not get sufficient oxygen to grow and function normally. Plants in flooded fields or in water logged pots do not thrive due to marked deficiencies in soil aeration. The retarded growth of plants in poorly aerated soils is chiefly due to reduced absorption of minerals and water.

(4) Water:

Water is one of the most essential requirements for growth of a plant. With an inadequate water supply, growth is poor and yields low. Plants grow well when ample but not excessive moisture is available. For most of the plants a soil-water content in the capacity to just above the wilting percentage is most favorable tor good growth. With a decrease in the soil-water content, marked effects on growth do not appear until the permanent wilting percentage is reached. At the permanent wilting percentage all growth ceases. If the soil is continuously above field capacity, as it may be in poorly drained fields, plants grow slowly because roots are deprived of oxygen.

Plants vary in their response to moisture deficiency. For instance, radishes, spinach and peppers wilt and cease to grow when soil-water percentage is low. Cucurbits and tomatoes in the field stop growing and their lower leaves respond by changing from a light green colour to a darker green or bluish colour. The leaves of corn and many grasses curl when the water supply is inadequate.

Deficient soil-water supply may affect the growth of a plant more at certain stages in its development than others. Vegetative growth in many plants is checked but the development of reproductive organs is not affected under deficient soil-water supply.

(5) Soil Nutrients: The quantity and nature of soil nutrients have marked influence on the growth and development of plants. For luxuriant growth of any crop, field should be adequately rich in nutrients (both micro and macronutrients). Furthermore, these mineral nutrients do not effect the growth as such, but only when present in the form of ions, or as constituents of molecules.

II. Internal Factors:

(1) Growth Regulators: Several classes of growth regulators are known. While some growth regulators are growth promoting (e.g., auxins, gibberellins, cytokinins, florigen etc.), others are growth inhibitors (e.g., abscisic acid, ethylene, chlorocholine chloride). Many of them are synthesized by the plants, while few of them are synthetic.

(2) C/N Ratio: The ratio of carbohydrates and nitrogenous compounds governs the pattern of growth. Presence of more carbohydrates compared to nitrogenous compounds favours good vegetative growth, flowering and fruiting. On the contrary, presence of more nitrogenous compounds compared to carbohydrates results in poor vegetative growth, flowering and fruiting.

(3) Genotype and Genetic Factor: All metabolic activities, growth and development are under the control of genetic complement (genotype), nuclear, as well as extra nuclear, of the cell. Expression of appropriate genes in an appropriate sequence is controlled both by genes and the environment. The genes, located in chromosomes, transcribe information to m-RNA which translates it into structural and enzymic proteins.