UNIT 9 APICAL DOMINANCE

Structure **Page No.**

9.1 INTRODUCTION

In the previous units of this course you have studied certain basic developmental processes like development of anther, ovule, pollination, fertilisation, endosperm, embryo, seed and fruit. These are developmental processes which are fundamental and basic for plant life. Now, we shall move forward to certain finer aspects of developmental biology (Plants). Apical dominance is a correlative phenomenon in the developmental biology of plants.

Branching of the main shoot into lateral branches is one of the main characteristics of the growth of most of the plants. More branches mean more leaves and more of photosynthesis. Branching also helps a tree to avoid crowding of leaves. Branches provide an opportunity for exposure of maximum number of leaves to sunlight.

Branching has a distinct evolutionary advantage, as it helps a plant to survive in a variety of habitats. A plant that does not branch finds it difficult to survive in crowded forests or in areas where the light intensity is low.

If you go around your place of stay or your place of work and start observing the big trees (flowering plants), you will come across two different types of tree growth. One, "monopodial" where the main trunk grows tall bearing a crown of leaves at the top without much of lateral branches such as the large majority of palms and the other- "sympodial" where lateral branches start spreading out leaving a gap from the apex. Plants which exhibit the second type of growth pattern are quite useful as they provide lot of shade from hot sunlight apart from providing economic benefits like timber and fruits.

Plants with a monopodial growth habit find it difficult to survive in temperate forests where light availability is poor. Palms mostly grow in tropical regions. Interestingly, bamboos have underground stems (rhizomes) like grasses which show both monopodial and sympodial branching pattern.

In those plants which exhibits sympodial growth, lateral branches always sprout a little distance away from the shoot apex and in the case of some plants this distance

is quite significant. Some of the questions that emerge in mind are: Why do not the lateral branches sprout immediately below the shoot apex? What is the advantage of this process to plants in terms of growth and viability? What are the physical and chemical factors involved in controlling this process apart from biological reasons at cellular level?

Apical dominance is well-known to plant physiologists for over two hundred years even though the mechanism that controls this process has become a matter of investigation more recently particularly after the discovery of phytohormones and their role in growth and development.

Objectives

After studying this unit you should be able to:

- define the terms related to the apical dominance,
- explain the role of chemical factors like phytohormones in controlling this process,
- correlate the role of factors like nutritional in the expression of apical dominance,
- determine the significance of this process in optimizing development and
- list the applications of modification of apical dominance in agriculture and horticulture.

9.2 SOME RELEVANT TERMS

Here are a few terms that will be used in discussing apical dominance. A clear understanding of these terms is needed for understanding the intricate mechanisms of physiological control of branching.

Apical Dominance

The inhibition of growth of lateral buds by the presence of active shoot apex of either the main stem or branches is called apical dominance.

Lateral Buds

Buds which are present in the axils of leaf primodia which are similar to main shoot apex in structure but generally remain dormant.

Dormancy

Arrested condition of growth.

Phytohormones

Specific chemical substances that are produced at one site in plants and travel to other areas (targets). At the target they regulate physiological responses.

Shoot Apex

The terminal tissue of main stem or of a branch. Very simple in structure consisting of just two different types of cells which are actively dividing to produce multiple number of cells which differentiate into various structures and tissues of the stem.

Root Apex

The terminal tissue of root consisting of actively dividing cells that differentiate into various tissues of root as the elongation of root takes place. A root apex does not generally give rise to other organs or structures.

Apical dominance can be recognized if we carefully observe the growth of plants. That the shoot apex is responsible for the inhibition of the growth of lateral buds can also be demonstrated "experimentally". You choose any actively growing plants in your courtyard and count the number of branches present immediately below the shoot apex. Take a fine blade and severe the shoot apex. Observe the growth pattern for a period of 10 or 15 days. Count the number of lateral branches sprouting below the cut.

SAQ 1

a) Complete the following sentences:

i) Apical dominance means.....
.....

ii) Apical dominance is regulated by....., ...
and..... plant hormones.

b) Differentiate between the following terms: Answer in about 5o words

i) Apical bud and lateral buds

ii) Monopodial and sympodial types of branching

iii) Shoot apex and root apex

9.3 ROLE OF CHEMICAL FACTORS IN CONTROLLING APICAL DOMINANCE

There were indications about the existence of plant hormones in the last part of 19th century. The plant hormones had been isolated and characterized in the third decade of this century. By the middle of this century we became aware of different types of plant hormones like auxins, gibberellins, cytokinins, abscisic acid and ethylene. The first four are chemical substances that influence growth in solutions and interestingly ethylene is a gas and perhaps the only hormone of its type. The first four plant hormones are isolated in crystal form from plant sources and their chemical structure is well characterised. Unlike the case of animal hormones, plant hormones exihibit a broad spectrum of effects on growth and development. Quite often same growth process may be regulated by more than one plant hormone. This applies to apical dominance also.

Prior to the discovery of plant hormones and their role in apical dominance it was thought that apical dominance is a kind of **struggle for existence and competition** between apical bud and lateral buds for nutrients from the root and leaves.

9.3.1 Auxins

The role of auxins in controlling the apical dominance was shown by the experiments done by Skoog and Thimann with the broad bean plant (see Fig. 9.1). They removed the terminal bud. This resulted in the development of lateral buds and branching occurred. If an agar block containing auxins was placed after the removal of apical bud, no growth of lateral buds occurred. This meant that the role of terminal bud in supressing the growth of lateral buds can be substituted by auxin. The agar blocks containing auxins is playing the same role as the apical bud. It was inferred that auxins present in the shoot apex might be playing a role in apical dominance.

As auxins could be isolated from the terminal bud, it was believed that shoot apex is also the site of synthesis of auxins. Experiments have also showed that terminal bud (shoot apex) contains a higher amount of auxins than lateral buds. A logical question that may arise in your minds is: If the auxins present in the main shoot

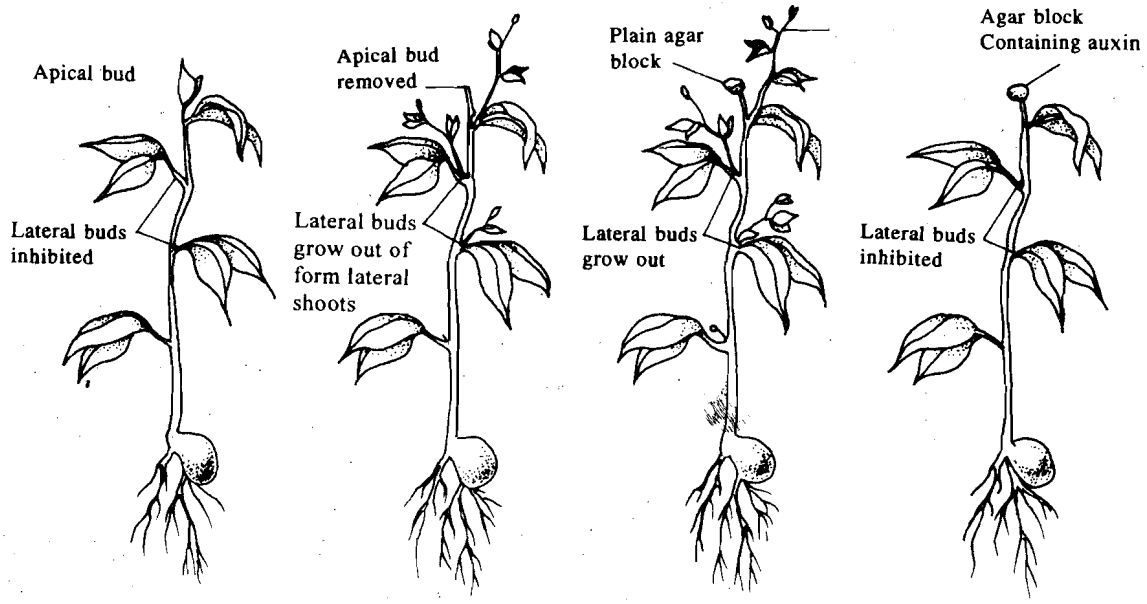

Fig. 9.1: Effect of apical bud removal and auxin on lateral bud growth in a leguminous plant.

apex promote its growth, why should the growth of lateral buds which contain lower amount of auxins be inhibited?

Thimann (1937) suggested that lateral buds respond to auxins in much the same manner as roots and stems but the optimum concentration for the promotion of shoot apex is much higher than that for lateral buds. The lateral buds need very low concentration of auxins for growth promotion. Hence the amount of auxin present

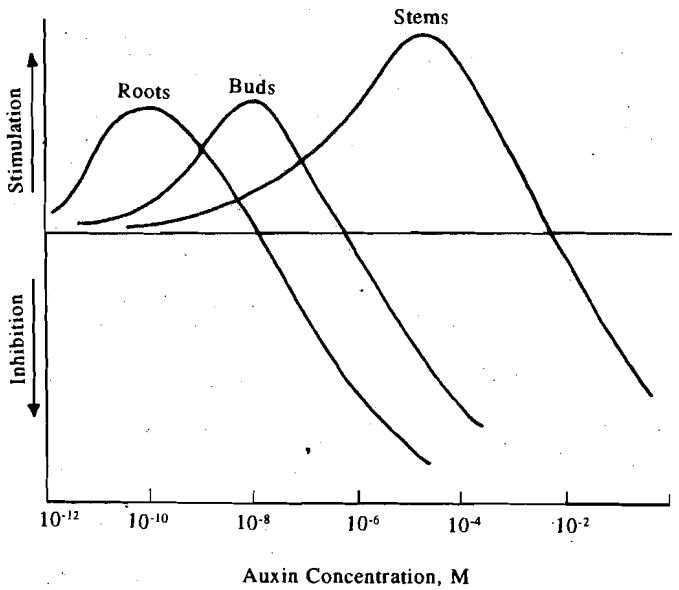

Fig. 9.2: Differential action of IAA on roots, buds, and stems as envisioned by K.V. Thimann.

in lateral buds and auxins transported from the apex, added together are sufficient enough to prevent the growth of lateral buds.

The transport of auxins is basipetal i.e., from top to bottom. Auxins synthesized in the shoot apex are transported downwards. In addition to this young leaves also produce auxins. The auxins transported from the shoort apex and from the young

leaves accumulate in excessive amounts to cause inhibition of the growth of lateral buds. There is a progressive decline in the concentration of auxin when you go down from the apex (see. Fig.9.3). This facilitates inhibition of growth of lateral buds immediately below the shoot apex (high concentrations of auxin inhibit growth of lateral buds). But at a distance from the apex growth is stimulated (low concentrations promotegrowth).

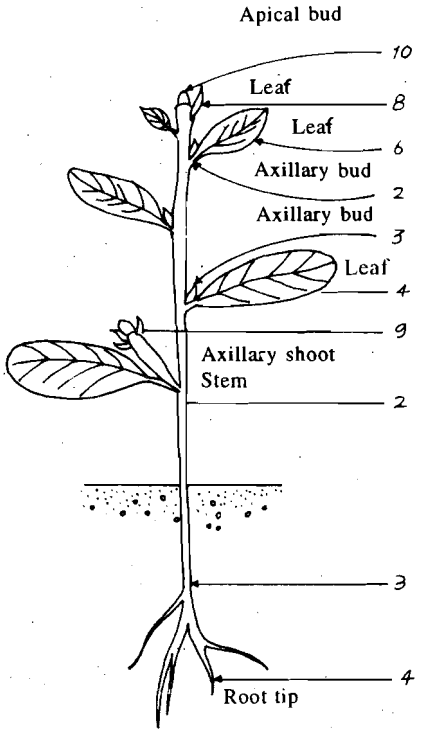

Fig. 9.3: The relative concentrations of auxin in different parts of seedling. Relative units of auxin: 10 = high, 1 = low.

9.3.2. Cytokinins

Cytokinins are also involved in the regulation of apical dominance. Wickson and Thimann studied the interaction of cytokinins and auxins in controlling the apical dominance. They isolated and cultured pea the stem sections in nutrient media containing auxins and no auxins. In the absence of auxins growth of lateral buds was not prevented. However, if cytokinins were added along with auxins, the inhibition of lateral buds was released.

Wickson and Thimann also demonstrated the effect of cytokinins on entire shoots. When the intact shoot was soaked in a solution of kinetin, growth of lateral buds occurred even in the presence of shoot apical buds. From this observation it was inferred that apical dominance exhibited by the shoot apex was overcome by the application of cytokinins.

The present concept is that apical dominance is controlled by a balance between cytokinin and auxin concentrations. Some investigators suggest the possible inhibitory influence of cytokinins on auxin production. The cytokinin application to the lateral buds may inhibit the synthesis of certain forms of IAA oxidase, normally induced by IAA translocated from the terminal bud. With the repression of IAA oxidase, the spared auxin may stimulate lateral bud growth and shoot development. In addition to the possible inhibition of IAA degradation, cytokinins may initiate a sink effect at the site of lateral buds to attract diversion of nutrients from other regions (Fig. 9.4).

9.3.3 Ethylene

Ethylene also plays a role in the inhibition of lateral bud growth. It is present in those tissues like shoot apex where auxins are also present. In normal mature

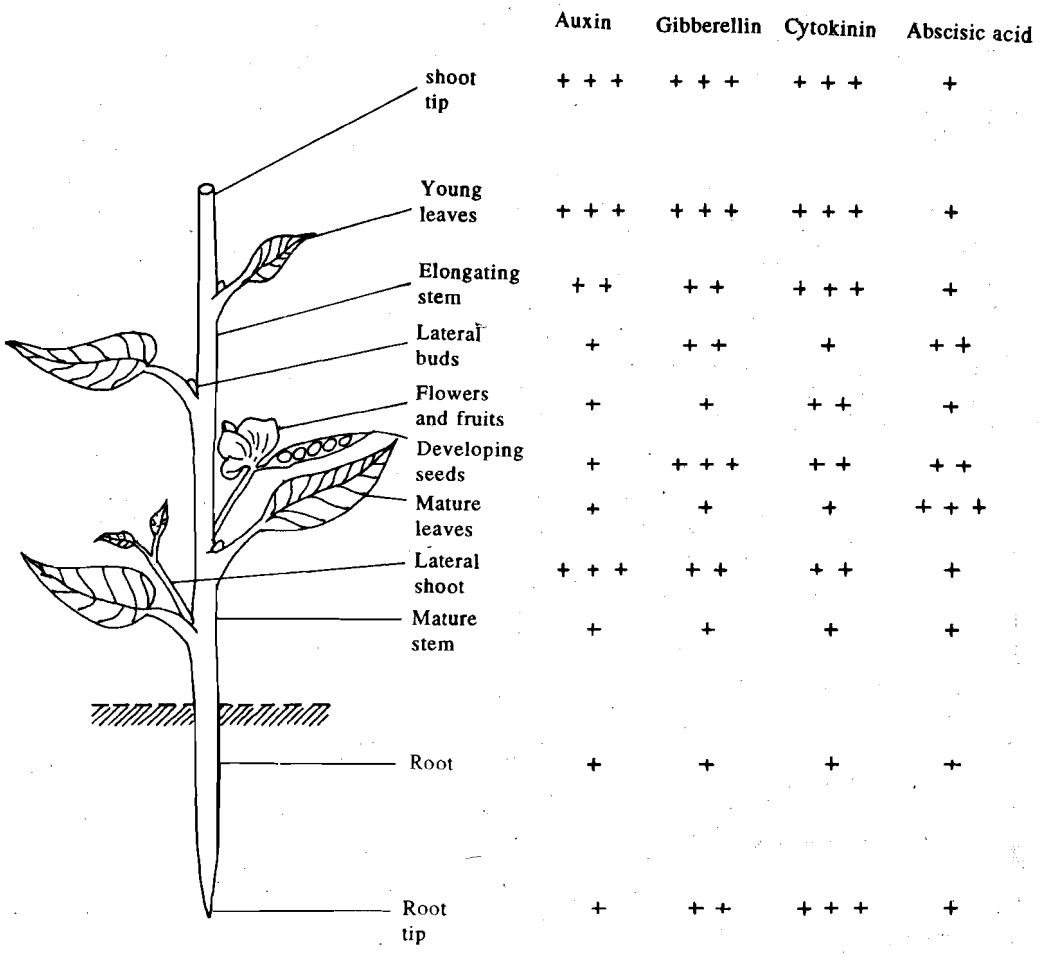

Fig. 9.4: Relative concentrations of some plant growth substances in various parts of the plant. +++ high concentration, ++ medium concentration, + low concentration.

light-grown plants the inhibition of lateral buds seems to result from the action of ethylene stimulated by auxins translocated there from the apical buds and leaves. This inhibitory effect of ethylene on lateral buds is released by the application of cytokinins.

9.3.4 How do Hormones Regulate Apical Dominance?

Auxins promote cell expansion and differentiation. Cytokinins accelerate cell division. A proper balance of these two hormones stimulates the production and differentiation of a variety of tissues in the stem. This rapid growth turns the shoot apex into a sink to draw nutrients from roots and adjacent leaves. As the main shoot apex generally draws most of the nutrients, lateral buds are starved resulting in the inhibition of their growth.

9.4 NUTRIENT DIVERSION THEORY

It has been repeatedly observed that if labelled nutrients like C^{14} sugars, S^{35} amino acids are applied leaves lowerdown the shoot are translocated towards the shoot apex. Application of cytokinins that break lateral bud dormancy reverts this process It is suggested that growth promoting hormones can enhance the transport of nutrients by increasing the rate of metabolism at the site of their application.

9.5 APICAL DOMINANCE AND PHYTOCHROME

We do not know the exact role of phytochromes in apical dominance. However short day induce lateral bud dormancy, suggesting the involvement of phytochromes. In those plant varieties in which phytochrome is genetically over expressed, apical dominance is poorly expressed.

9.6 APICAL DOMINANCE AND GENETIC STUDIES

In plants genetically programmed to over produce IAA, extreme cases of apical dominance is observed. If a genotype with a characteristic phenotype of over production of IAA is crossed with a genotype causing over production of cytokinins, apical dominance decreases phenotypically. This suggests that the balance between levels of cytokinins may be genetically regulated.

9.7 APPLICATIONS IN HORTICULTURE AND AGRICULTURE

While going round in public parks, you might have observed plants trimmed in such a way giving appearances of animals like camel, elephant, horse, and lion. This art traditionally used by gardeners, called topiary involves cutting of shoot apical buds, and force lateral branches such that they take on the shapes of animals.

Coniferous trees such as *Thuja* and *Biota* are also trimmed to produce globuler shapes. Another interesting case is that of *Picea (abies)* which grows straight, producing numerous lateral branches at equal intervals. It is commonly used as Christmas tree.In India *Araucaria* is commercially grown to serve as the Christmas tree. In *Araucaria* if you cut the terminal portion of a horizontally growing branch and plant it in a pot, it keeps growing horizontally after rooting. The plant appears to have "forgotten" to grow vertically (topophysis).

Another plant in which apical bud removal is being practised since times immemorial is the tea. Here, the commercial interest is in the production of new twigs bearing fewer leaves. Apical buds of the main axis and the branches are

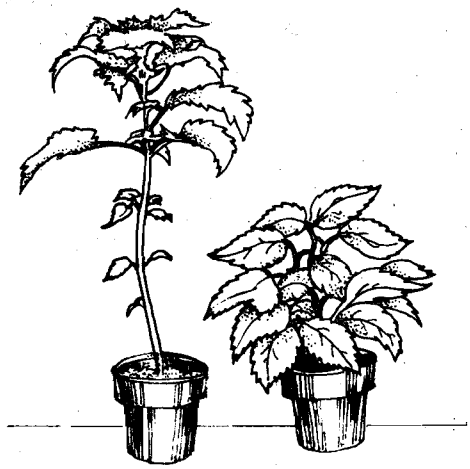

Fig. 7.5: The strong influence of the apical bud on the growth of lateral buds is easily demonstrated by removing it from the plant. In the absence of the apical bud, active growth begins in the lateral buds. However, in a short time the lateral bud nearest the apex will establish dominance over the other lateral bud and causes them to become inactive again. Of course, the response to removal of apical bud on the growth of lateral buds follows different patterns in different plants. In Bryophyllum and Kalanchoe, for example, the lateral bud closest to the apical bud grows out first, not the buds far-

removed seasonally so that the tea bush table is maintained at a convenient height to low picking of two leaves and a bud periodically.

9.8 SUMMARY

What we have studied in this unit could be summarised as follows:

1. Apical dominance has a great eco-Physiological significance and adds to survival value of plants.
2. Auxins play a role in association with cytokinins and ethylene in controlling the nature and extent of apical dominance.
3. Competition for nutrients between apical and lateral buds also decides the influence of apical bud.
4. Hormones activate synthetic machinery and create as 'Sink' to draw nutrients from other parts of the plant resulting in stimulated growth.
5. Recent Genetic studies indicate a role of phytochrome and confirm the earlier findings of the role of hormones in apical dominance.

9.9 TERMINAL QUESTIONS

1 Name some plants that exhibit monopodial branching and sympodial branching.

2. Mention the contributions of the following scientists in our understanding of apical dominance:
   i) Wickson & Thimann
   ii) Skoog
3. Does branching provide any extra survival value to plants? If so, explain
4. What is the nature of competition in the apical dominance?
5. What is the nutrient diversion theory? Explain with reference to phytohormones.
6. What is the effect of red light on apical dominance?
7. What is the contribution of recent genetic studies to our knowledge on apical dominance?
8. Describe briefly the application of techniques based on apical dominance in horticulture and agriculture.

9.10 ANSWERS

Self Assesment Questions:

a. i) Suppression of growth of lateral buds by the presence of shoot apex (apical bud).
   ii) Auxins, cytokinins and ABA.

b. i) The apical bud is the topmost meristematic tissue of main shoot or branch that contributes to the growth of main shoot/axis. Lateral buds are meristematic tissues that arise in the axils of leaves and that give rise to lateral branches.
   ii) Monopodial is a type of branching where the main axis grows continuously with less and little of lateral branching, bearing a crown of

leaves. (E.g. Palms). Sympodial type of branching is marked by a number of lateral branches, giving a bushy appearance to the tree (mango, lemon etc.).

iii) Shoot apex consists of meristematic tissue whose division and differentiation lead to the formation of all tissues and most organs of shoot. Slightly large in size and prominant, it is often protected by scaly leaves.

Root apex consists of actively dividing cells leading to the differentiation of tissues in root. It is protected by a layer of cells called as root cap. Root apex is relatively small in size.

Terminal Questions

1. Monopodialgrowth: Palms such as coconut, *Bonassus*,
   Sympodial growth: Neem (*Azadirachta indica*)
   Mango (*Mangifera indica*)

   Sisham (*Dalbergia sissoo*)

2. Wickson and Thimann Confirmed the role of auxins in apical dominance, through surgical removal of apex. Demonstrated the role of cytokinins in apical dominance.

3. Yes, because plants with more branches bear more leaves and can conduct more photosynthesis: spreading of branches helps in optimum utilisation of solar radiation.

4. The nature of "Struggle for existence" competition is as follows: The growing shoot apex functions as a sink in drawing nutrients from leaves and hormones from roots while lateral buds fail to get enough of nutrients.

5. Nutrients are diverted towards growing shoot apex from leaves thus depriving lateral buds from the supply of nutrients. Phytohormones are also produced in leaves and roots (like cytokinins, Gibberellins etc.) so along with nutrients, phytohormones supply is also mainly towards shoot apex. Cytokinins can break bud dormancy. Lack of supply of cytokinins to lateral buds induces bud dormancy.

6. Red light breaks apical dormancy. This effect is mediated through phytochrome that perceives red light and further mediates this process through production of phytohormones, like cytokinins that are needed to break dormancy.

7. The earlier observations on phytohormone interactions have now been confirmed by studying mutants that produce relatively high amounts of auxins and low amounts of cytokinins or relatively more cytokinins and less auxins.