



Handwritten Notes

Course No.: NEMA-231 (New)

Course Title: Fundamentals of Nematology

-
- All the questions in this PDF file are based on the new 6th Dean Committee Syllabus.
 - Students are required to take a print of this file to study at the time of exam.
 - Join our Telegram Channel: [@AgroMind](#) (Click the Blue link to join the Channel.)
-

AgroMind

[CLICK HERE to Join AgroMind Telegram Channel](#)

Topic 1 Propagation-need and potentialities, sexual and asexual methods of propagation and their advantages and disadvantages

Introduction

The progress in plant improvement would have been of little significance, without methods whereby improved forms could have been maintained in cultivation. Most cultivated plants either would have lost or reverted to less desirable forms unless they are propagated under controlled conditions that preserve the unique characteristics which make them useful. Plant propagation means multiplication of plants with the aim to achieve increase in number and preserve the essential characteristics of the mother plant. It is essentially of two types:

- A. Sexual Propagation
- B. Asexual Propagation

Sexual Propagation

- Sexual reproduction refers to multiplication of plants by seeds. Seeds are formed after successful pollination and fertilization (Fig.1.1) by the union of male and female gametes.
- Meiosis division takes place in the course of fusion and the chromosome numbers are reduced to half, which after fertilization becomes normal.
- The plants raised through seed are called seedling plants.
- Propagation of plants by seeds offers many advantages however several have disadvantages too.
- Sexual propagation involves careful management of germination conditions and facilities and knowledge of the requirements of individual kind of seeds.

Success of seed propagation depends upon fulfilling the following conditions:

- Using seed of proper genetic characteristics to produce the cultivar or species, of provenance desired. This can be accomplished by obtaining seed from a reliable source or dealer.
- Using good quality seeds which germinate rapidly and vigorously to withstand possible adverse environmental conditions in the seed bed and provide a high percentage of usable seedlings.

- Manipulating the seed dormancy by applying pre-germination treatments or proper timing of planting.
- Providing proper environment for seed germination i.e., supplying sufficient water, proper temperature, adequate oxygen and either light or darkness (depending upon kind of seed) to the seeds and resulting seedlings until they are well established.

Advantages:

Sexual method of propagation has several advantages, like □
 Propagation by seeds is simple and easy.

- Seed propagation is only mean of diversity particularly in the selection of chance seedlings.
- Seedling plants are long lived, productive and have greater tolerance to adverse soil and climatic conditions and diseases.
- Seed propagation makes feasible to propagate plants like papaya and coconut in which asexual means of propagation is not common.
- Hybrids can only be developed by sexual means.
- Sexual propagation offers opportunities of polyembryony (citrus, mango or jamun) and apomixis (*Malus sikkimensis*, *Malus hupehensis*, *Malus sargentii*), which produces true- to - type plants.
- Seed is the source for production of rootstocks for asexual propagation.
- Seeds, if stored properly can be kept for longer duration /period for future use.

Disadvantages:

Sexual method of propagation has some disadvantages, like

- Seedling plants are not true to type to the mother plants due to heterozygous nature of fruit plants.
- Seedling plants have long juvenile phase (6-10 years) and hence flowering and fruiting commences very late.
- Sexually raised plants are generally tall and spreading type and thus are cumbersome for carrying out various management practices like pruning, spraying, harvesting etc.
- Seeds of many fruits are to be sown immediately after extraction from the fruits as they lose their viability very soon e.g. cashew nut, *jamun*, jackfruit, citrus, mango and papaya.
- The beneficial influences of rootstocks on scion variety cannot be exploited in sexual propagation.
- Seedling plants usually produce fruits of inferior quality.

Asexual Propagation

- It is independent of sexual propagation process as there is no involvement of sex organs.
- It takes place due to mitotic division. Mitotic division continues in shoot tip, root tip and cambium.
- When some portion of plant is wounded, mitotic division takes place.
- Under mitotic division, chromosomes divide longitudinally to form two daughter cells. This forms the basis of asexual propagation.
- The plants raised through asexual process are identical to mother plants. Cutting, division, layering, budding and grafting are main techniques of asexual propagation.

Advantages

- Asexually propagated plants are true to type to their mother plants.
- Asexually propagated plants have short juvenile phase and bear flowers and fruits in the early age (3-4 years) than seedling plants.
- The vegetatively propagated plants are smaller in stature and hence management operations like spraying, pruning and harvesting etc. become easy.
- Plants in which seed setting does not take place (e.g. pineapple and banana), asexual propagation serves as a substitute for sexual propagation.
- Using asexual methods, desirable characters of a mother plant can be perpetuated/multiplied easily.
- The benefits of rootstocks and scion are usually exploited through asexual propagation.
- Repairing of damaged portion of plant is possible through asexual propagation as in case of bridge grafting.
- It is possible to convert a non-productive local variety into productive improved variety by using asexual methods.
- It is possible to grow several varieties on one plant or change variety of existing plant by top working.

Disadvantages

- Asexual propagated plants have shorter life-span.

Topic 2

Seed Dormancy: Causes and Types

Introduction

Dormancy is a condition where seeds will not germinate even when the environmental conditions such as water, temperature and air are favourable for germination.

- It is observed that seeds of some fruit plants (mango, citrus) germinate immediately after extraction from the fruit under favourable conditions of moisture, temperature and aeration.
- However, in others (apple, pear, cherry) germination does not take place even under favourable conditions. This phenomenon is called as 'dormancy'.
- This is an important survival mechanism for some species because these species do not germinate unless adverse climatic conditions end.
- In some species, chilling temperature for certain period helps in the termination of dormancy. Often dormancy is due to several factors and may persist indefinitely unless certain specific treatments are given.

Types of Dormancy

1. Exogenous Dormancy

- This type of dormancy is imposed by factors outside the embryo.
- In exogenous dormancy, the tissues enclosing the embryo can affect germination by inhibiting water uptake, providing mechanical resistance to embryo expansion and radicle emergence, modifying gaseous exchange (limit oxygen to embryo), preventing leaching of inhibitor from the embryo and supplying inhibitor to the embryo. It is of three types:
 - a) **Physical dormancy (seed coat dormancy):** Seed coat or seed covering may become hard, fibrous or mucilaginous (adhesives gum) during dehydration and ripening as a result they become impermeable to water and gases, which prevents the physiological processes initiating germination. This type of dormancy is very common in drupe fruits i.e. olive, peach, plum, apricot, cherry etc. (hardened endocarp), walnut and pecan nut (surrounding shell). In various

plant families, such as, Leguminosae, the outer seed coat gets hardened and becomes suberized and impervious to water.

- b) **Mechanical dormancy:** In some fruits seed covering restricts radicle growth, resulting in dormancy of seeds. Some seed covering structures, such as shells of walnut, pits of stone fruits and stones of olive are too strong to allow the dormant embryo to expand during germination. The water may be absorbed but the difficulty arises in the cementing material as in walnut. Germination in such seeds does not occur until and unless the seed coats are softened either by creating moist and warm conditions during storage or by microbial activity.
- c) **Chemical dormancy:** In seeds of some fruits chemicals that accumulate in fruit and seed covering tissues during development and remain with the seed after harvest. It is quite common in fleshy fruits or fruits whose seeds remain in juice as in citrus, cucurbits, stone fruits, pear, grapes and tomatoes. Some of the substances associated with inhibition are various phenols, coumarin and abscisic acid. These substances can strongly inhibit seed germination.

2. Endogenous Dormancy

This type of dormancy is imposed by rudimentary or undeveloped embryo at the time of ripening or maturity. This can be of different types such as morphological, physiological, double dormancy and secondary dormancy.

A. Morphological dormancy (Rudimentary and linear embryo): Dormancy occurs in some seeds in which the embryo is not fully developed at the time of seed dissemination. Such seeds do not germinate, if planted immediately after harvesting. Plants with rudimentary embryos produce seeds with little more than a pro-embryo embedded in a massive endosperm at the time of fruit maturation. Enlargement of the embryo occurs after the seeds have imbibed water but, before germination begins. Formation of rudimentary embryo is common in various plant families such as Ranunculaceae (*Ranunculus*), Papavaraceae (poppy). Some plants of temperate zone like holly and snowberry have also rudimentary embryos.

B. Physiological dormancy

a) **Non-deep physiological dormancy:** After ripening time is required for seeds in dry storage to lose dormancy. This type of dormancy is often transitory and disappears during dry storage. Temperate fruits such as apple, pear, cherry, peach,

plum and apricot, cultivated cereals, vegetables and flower crops, have this type of physiological dormancy which may last for one to six months and disappears with dry storage.

b) Photo dormancy: Seeds that either require light or dark condition to germinate are termed as photo-dormant seeds. It is due to photo-chemically reactive pigment called phytochrome widely present in some plants. When imbibed seeds are exposed to red light (660-760 nm), the phytochrome changes to red form (P_{fr}), thereby substituting the germination process. However, when seeds are exposed to far-red light (760-800), P_{fr} is changed to P_f which inhibits germination process.

c) Thermo dormancy: Some seeds have specific temperature requirement for their germination, otherwise they remain dormant. Such seeds are called as thermo dormant. For example seeds of lettuce, celery and pansy do not germinate if the temperature is below 25°C.

Physiological dormancy is of 3 types:

- a) Intermediate physiological dormancy:** The seeds of some species require a specific period of one-to-three months of chilling, while in an imbibed and aerated state, commonly called as moist chilling. For example, most of temperate fruit seeds require moist chilling to overcome seed dormancy. This requirement led to the standardization of world famous, horticultural practice of stratification. In this process, the seeds are placed between layers of moist sand in boxes and exposed to chilling temperatures (2 to 7°C) for the period varying from 3-6 months to overcome dormancy.
- b) Deep physiological dormancy:** Seeds, which usually require a relatively long (>8 weeks) period of moist chilling stratification to relieve dormancy as in peach.
- c) Epicotyl dormancy:** Seeds having separate dormancy conditions for the radicle hypocotyl and epicotyl, is called as epicotyl dormancy e.g. *Lilium*, *Hepatica antiloba* and *Trillium*.

C. Double dormancy

- In some species, seeds have dormancy due to hard seed coats and dormant embryos.
- For instance, some tree legumes seed coats are impervious and at the same time their embryo are also dormant.
- Such seeds require two years for breaking of dormancy in nature. In the first spring, the microorganisms act upon the seed making it weak and soft and

then embryo dormancy is broken by chilling temperature in the winter next year.

- Combination of two or more types of dormancy is known as ‘double dormancy’. It can be morpho-physiological i.e. combination of under developed embryo and physiological dormancy or exo-endodormancy i.e. combination of exogenous and endogenous dormancy conditions i.e. hard seed coat (physical plus intermediate physiological dormancy).

D. Secondary dormancy

Secondary dormancy is due to germination conditions. It is a further adaptation to prevent germination of an imbibed seed if other environmental conditions are not favorable. These conditions can include unfavorably high or low temperature, prolonged darkness and water stress. It is of two types:

Thermo dormancy: High temperature induced dormancy.

Conditional dormancy: Change in ability to germinate related to time of the year.

Advantages:

1. Permitting germination only when environmental conditions favour seedling survival as in fruit plants of temperate region.
2. Helpful in creation of a “seed bank”
3. Dormancy can also synchronize germination to a particular time of the year.
4. Seed disposal can be facilitated by specialized dormancy conditions. For example modification of seed covering through digestive tract of a bird or other animals.

- i.
- ii.



Topic 3

Seed Dormancy: Methods of breaking seed dormancy

Several methods are used for breaking seed dormancy of horticultural crops. These are briefly described hereunder

1. Softening seed coat and other seed coverings: This helps in better absorption of water and gases, which ultimately leads to better germination of the seeds. This can be achieved by scarification.

a) Scarification: Scarification is the process of breaking, scratching, mechanically altering or softening the seed covering to make it permeable to water and gases. Three types of treatments are commonly used as scarification treatments. These include mechanical, chemical and hot water treatments.

i. Mechanical scarification

- It is simple and effective if suitable equipment is available.
- Chipping hard seed coat by rubbing with sand paper, cutting with a file or cracking with a hammer are simple methods useful for small amount of relatively large seeds.
- For large scale, mechanical scarifiers are used. Seeds can be tumbled in drums lined with sand paper or in concrete mixers containing coarse sand or gravel. The sand gravel should be of a different size than the seed to facilitate subsequent separation.
- Scarification should not proceed to the point at which the seeds are injured and inner parts of seed are exposed.

ii. Acid scarification

- Dry seeds are placed in containers and covered with concentrated Sulphuric acid (H_2SO_4) or HCl in the ratio of one part of seed to two parts of acid.
- The amount of seed treated at any time should be restricted to not more than 10kg to avoid uncontrollable heating.

- The containers should be of glass, earthenware or wood, non-metal or plastic. The mixture should be stirred cautiously at intervals during the treatment to produce uniform results.
- The time may vary from 10 minutes to 6 hours depending upon the species.
- With thick-coated seeds that require long periods, the process of scarification may be judged by drawing out samples at intervals and checking the thickness of the seed coat. When it becomes paper thin, the treatment should be terminated immediately.
- At the end of the treatment period, the acid is poured off and the seeds are washed to remove the acid.
- The acid treated seeds can either be planted immediately when wet or dried and stored for later planting. Large seeds of most legume species, brinjal and tomatoes are reported to respond simple sulphuric acid treatment.

iii. Hot water scarification

- Drop the seeds into 4-5 times their volume of hot water with temperature ranging from 77 to 100°C.
- The heat source is immediately removed, and the seeds soaked in the gradually cooking water for 12 to 24 hours. Following this the unswollen seeds may be separated from the swollen seeds by suitable screens.
- The seed should be sown immediately after hot water treatment.

iv. Warm moist scarification

The seeds are placed in moist warm medium for many months to soften the seed coat and other seed coverings through microbial activity. This treatment is highly beneficial in seeds having double seed dormancy.

- The hard seeds are planted in summer or early fall when the soil temperature is still higher, that usually facilitates germination.

- For instance the stone fruit including cherry, plum ,apricot and peaches) show increased germination if planted early enough in the summer or fall to provide one to two months of warm temperature prior to the onset of chilling.

b) Stratification:

- Stratification is a method of handling dormant seed in which the imbibed seeds are subjected to a period of chilling to after ripen the embryo in alternate layers of sand or soil for a specific period. It is also known as moist chilling.
- However, temperate species displaying epicotyl dormancy (like fringed tree) or under developed embryo (like hollies) a warm stratification of several months followed by a moist chilling stratification is required.
- Several tropical and subtropical species (like palms) require a period of warm stratification prior to germination to allow the embryo to continue development after fruit drop.
- The seeds can be sown after fruit drop. The seeds can be sown immediately after stratification in the field.
- Seeds with a hard endocarp, such as *Prunus* spp. (the stone fruit including cherry, plum, apricot and peaches) show increased germination if planted early in the summer or fall to provide one to two months of warm temperature prior to the onset of chilling.

i. Outdoor stratification

- If refrigerated storage facilities are not available, outdoor stratification may be done either by storing seeds in open field conditions in deep pits or in raised beds enclosed on wooden frames.
- However it is likely that seeds are destroyed in outdoors by excessive rains, freezing, drying, or by rodents. Seeds are placed in alternate layers of sand

to provide and low temperature and proper aeration in the stratification pit. The top is covered with Sphagnum moss to maintain moisture level.

- The pit or tray is irrigated at regular intervals to maintain appropriate moisture status

ii. Refrigerated stratification

- An alternative to outdoor field stratification is refrigerated stratification.
- It is useful for small seed lots or valuable seeds that require special handling.
- Dry seeds should be fully imbibed with water prior to refrigerated stratification. Twelve to twenty four hours of soaking at warm temperature may be sufficient for seeds without hard seed coats.
- After soaking, seeds are usually placed in a convenient size box in alternate layers of well washed sand, peat moss or vermiculite.
- A good medium is a mixture of one part of coarse sand to one part of peat, moistened and allowed to stand for 24 hours before use. Seeds are placed in alternate layers of sand or medium.
- The usual stratification temperature is 4-7°C. At higher temperature seeds sprout prematurity and low temperature delays sprouting.
- The medium should be re-moistened. The stratified seed is separated from the medium prior to sowing in nursery beds.
- The stratification of seeds results in quick and uniform germination and therefore the seed should be subjected to stratification invariably under all conditions.

Table 3.1. Effect of seed stratification period on per cent germination of important temperate fruits

Kind of fruit	Stratification period (days)	% germination
Apple	70-75	70-75
Kainth (<i>Pyrus pashia</i>)	30-35	90-95
Peach	60-70	55-60
Apricot	45-50	75-80
Almond	45-50	85-90
Walnut	95-100	80-85
Pecan	70-75	75-80

- c. Leaching of inhibitors:** It is established fact that some inhibitors and phenolic compounds are present in seed coverings of many species, which inhibit germination. Therefore, soaking of seeds in the running water for 1224 hours or placing them in water for few hours help in leaching off the inhibitors and phenolic compounds, which help in easy seed germination.
- d. Pre-chilling:** In seeds of certain plant species, dormancy can be overcome by pre-chilling treatment. In this treatment, the imbibed or soaked seeds are kept at a temperature of 5-10⁰C for 5-7 days before sowing. After that seed can be sown in the field immediately.
- e. Pre-drying:** This is also a useful practice in some seeds to overcome seed dormancy. In this treatment, the dry seeds are subjected to a temperature of 37-40⁰C for 5-7 days prior to sowing. After this, seed can be sown in the field.

f. Seed priming: Seed priming refers to the procedures followed to overcome dormancy in freshly harvested fruits. Most widely used seed priming procedures are osmo- conditioning, infusion and fluid drilling.

- In osmo-conditioning, the seeds are placed in shallow layer in a container having 20-30 per cent solution of polyglycol (PEG). The seeds are then incubated at 15-20⁰C for 7-21 days, depending upon seed size and plant species.
- Different hormones and fungicides can also be added to protect the seeds from pathogens. After this, the seeds are washed and dried at 25⁰C and are stored until use.
- In infusion, the hormones, fungicides or insecticides and antidotes are infused into dormant seeds through organic solutions. In this process the seeds are placed in acetone or dichloromethane solution containing chemicals to be used for 1-4 hours.
- Afterwards, the solvent is allowed to evaporate and seeds are dried slowly in vacuum desiccators for 1-2 hours. The seeds absorb the infused chemical directly into the embryo when soaked in water.
- In fluid drilling, the seeds are suspended in a special type of gel before sowing. Now-a- days different types of gels are available in the market but sodium alginate, guar gum and synthetic clay are most widely used in fluid drilling.

g. Treatment with chemicals:

Some compounds other than hormones are also used to break dormancy but their role is not clear. Thiourea is one example known to stimulate germination in some kinds of dormant seeds. The seeds are soaked in 0.5 – 3 per cent solution of thiourea for 3-5 minutes. Afterwards seeds are rinsed with water

and are sown in the field. Similarly, potassium nitrate and sodium hypochlorite also stimulate seed germination in many plant species.

h. Hormonal treatment

- Among various hormones, GA3 is commercially used for breaking seed dormancy in different types of seeds. The concentration of GA3 depends upon the kind of seed but generally a concentration of 200-500 ppm is most widely used.
- Cytokinin is another group of hormones used for breaking physiological dormancy and stimulating germination in seeds of many species. Kinetin and BA(6-benzyle aminopurine) are commercial preparations of cytokinin used for breaking seed dormancy. Soaking seeds in 100 ppm solution of kinetin for 3-5 minutes is highly effective concentration for overcoming seed dormancy of many species. Ethrel also stimulates germination in seeds of some species.

Table 3.2. Recommended concentrations of growth hormones in temperate fruits for increasing seed germination

Crop		Concentration
Apple	Thiourea	5000 ppm
	Kinetin	25 ppm
	GA	50 ppm
	Ethrel	100-200 ppm
Pear	GA	150 ppm
	Thiourea	5000 ppm
Peach	Thiourea	5000 ppm
	GA	400 ppm
	BA	400 ppm

Walnut	GA	250 ppm
	Ethrel	1000 ppm

Hormonal changes during stratification:

A triphasic change in endogenous hormones in many seeds is depicted in Fig.3.1.

- A reduction of ABA
- Increased synthesis of cytokinin and gibberellins
- Reduction in hormone synthesis in preparation for germination.
- In general, gibberellins promote germination in dormant seeds, while ABA inhibits germination.
 - Pre-sowing treatments with certain seeds not only stratification reduce the requirement and improve the seed germination but also enhances seedling growth in a number of temperate fruits.

AgroMind

- Plant regulators can be used to break or prolong the dormancy. Sprouting of potato tubers and onion bulbs is a common phenomenon in storage.
- Pre-harvest spray of maleic hydrazide (MH) at 2000 ppm applied 15 days before actual date of harvest prolongs dormancy in the above storage organs by inhibiting the sprouting.
- In fruit trees of apple, plums and figs, early flowering is induced by spraying Dinitro orthocresol at 0.1 % in oil emulsion.
- Seed treatment of tomato with GA at 1 00 ppm breaks the dormancy and increases the percentage of germination.
- ABA controls embryo dormancy, and GA enhances embryo germination. Seed coat dormancy involves the mechanical restriction of the seed coat, this along with a low embryo growth potential, effectively produces seed dormancy.
- GA releases this dormancy by increasing the embryo growth potential, and/or weakening the seed coat so the radical of the seedling can break through the seed coat. Different types of seed coats can be made up of living or dead cells and both types can be influenced by hormones; those composed of living cells



[CLICK HERE to Join AgroMind Telegram Channel](#)

Topic 4 Polyembryony, apomixis, chimeras and bud- sports

Polyembryon means that more than one embryo develops within a single seed. It is also known as adventitious embryony (Nucellar embryony or Nucellar budding).

- Polyembryony can develop from several distinct causes. Specific cells in the nucellus or sometimes with integument have embryos. Genetically, these embryos have the same genotype as the parental plant and are apomictic.
- Adventitious embryony occurs in many plant species but is most common in citrus and mango. In these species, both zygotic and apomictic embryos are produced. In other species (e.g. *Opuntia*), no pollination or fertilization is needed.
- Polyembryony is common in mango and citrus. In trifoliolate orange (*Poincirus trifoliata*) several seedlings arise from one seed.
- Of these seedlings, one seedling, usually the weakest may be sexual, and the others arise apomictically from cells in the nucellus, which are diploid copies of the mother plant.

Horticultural significance of polyembryony

- Nucellar seedlings in citrus are completely free from viruses, because the embryo sac and adjoining tissues are impregnated at flowering time with some unknown powerful substances which kills all the viruses. For immediate requirement of planting material, development of nucellar lines is the quickest and easiest method. The major possible horticultural applications of polyembryony are:
 - Nucellar seedlings are true-to-type seedlings
 - Such seedlings are genetically uniform and can be used as virus free **Rootstock**
 - More vigorous seedlings – continuous vegetative propagation leads to decline in vigour in citrus
 - Development of virus free seedlings and bud wood

- Significance in breeding programmes

Apomixis

In some species of plants, an embryo develops from the diploid cells of the seed and not as a result of fertilization between ovule and pollen. This type of reproduction is known as apomixis and the seedlings produced in this manner are known as apomicts. Apomictic seedlings are identical to mother plant and similar to plants raised by other vegetative means, because such plants have the same genetic make-up as that of the mother plant. Such seedlings are completely free from viruses. Plants that produce only apomictic embryo and are known as obligate apomicts and those which produce both apomictic and sexual seedlings are called facultative apomicts.

Types of Apomixis: Maheshwari (1950) classified apomixis into four groups:

1. **Recurrent Apomixis:** In this type of apomixis, the embryo develops from the diploid egg cell or from the diploid cells of the embryo sac without fertilization. As a result, the egg has normal diploid number of chromosomes, just like the mother plant (Fig.4.1). The species, where recurrent apomixis commonly occur are, *Parthenium*, *Rubus*, *Malus*, *Allium*, *Rudbeckia*, *Poa*, *Taraxacum*, etc
2. **Non-Recurrent Apomixis:** In this case, the embryo develops either from the haploid egg cell or from some other haploid cells of the embryo sac. In this case, haploid plants are produced, which contain only one set of chromosome of the mother plant. Hence, the haploid plants are sterile in nature and cannot be normally perpetuated into the next generation. Non-recurrent apomixis occurs only in a few species such as *Solanum nigrum*, *Lilium* spp. etc.
3. **Nucellar Embryony or Adventitious Embryony:** In this type of apomixis, the embryos arise from diploid sporophytic cells outside the embryo sac i.e. cells of the nucellus, integuments etc. This type of apomixis is quite common in citrus and certain varieties of mango, where fertilization occurs normally and sexual plus a number of apomictic (nucellar) embryos develop.
4. **Vegetative apomixis or bulbils:** In some species of plants, such as *Allium*, *Agave*, *Poa* etc., the flowers in an inflorescence are replaced by bulbils or vegetative buds, which sprout, while still on the mother plant and turn into new daughter plant.

Advantages

- Assured reproduction in the absence of pollinators, such as in extreme environments
- Maternal energy not wasted in unfit offspring (cost of meiosis)

- Some apomictic plants (but not all) avoid the male energy cost of producing pollen

Disadvantages

- Can't control accumulation of deleterious genetic mutations
- Usually restricted to narrow ecological niches lack ability to adapt to changing environments

Clone

The term clone may be defined as a group of genetically uniform individuals, derived originally from a sexually produced individual or from mutations and maintained exclusively by asexual means from one ancestor.

- The common examples are Bartlett pear, Delicious apples, Sultana grapes and Dashehari mango.
- The goal of vegetative propagation is to reproduce progeny plants identical in genotype to a single plant. The biological process is known as cloning and the resulting population of plants is called a clone.
- The uniformity of individual plants, within a clonal population is a major advantage of clonal cultivars of fruit and nut crops.
- Clonal propagation helps in fixing genotypes, uniformity of population, facilitates propagation and reduces juvenile phase, combine more than one genotype into single plant (grafting) and control phases of development.
- If environmental conditions are favourable and the clone is managed properly, its trueness-to-type can be maintained for hundreds of years.

Genetic variations in a clone

Mutation

Mutation is a single-step genetic change or sudden heritable change within cells of a clone. In general, these changes take place spontaneously, in the plants regular but rare intervals.

- A mutation is a genetic change involving some part of the DNA molecule. Genetic mutations result from structural changes in the nuclear DNA of the chromosome in the nucleus. DNA also occurs in mitochondria and chloroplasts and defects here can produce genetic changes.
- Chromosomal changes may be due to chance rearrangement of the four bases in the DNA molecule (point mutation) rearrangement of different parts of the chromosomes (deletion, duplication, translocations and inversions), addition or subtraction of individual chromosome (aneuploidy), or the multiplication of entire set of chromosome (polyploidy).
- The rate of mutation can be increased by treatment with specific mutagenic agents e.g. X-ray, gamma rays and certain chemicals.

Bud- sports or bud mutations

- When mutation occur and suddenly appear as a chance in the branch of a plant, is called bud sport or bud mutations, because they appear to have originated within a single bud.
- Detection of a new mutant within a clone may require a series of vegetative propagated generations and multiple propagations from many buds of the same plant.
- Many 'sports' have become commercial cultivars. Mutations may affect fruit (colour, shape, time of maturity), tree structure (spur type), time of bloom, and as a host of other traits. Sometimes these mutants have highly useful

horticultural traits and have given rise to important new cultivars ('Ruby Red' grapefruit, red coloured sports of apple and pear.)

- On the other hand, mutations may be undesirable and give rise to misshapen fruits, low production and susceptibility to diseases.

Chimeras

- It is the most important kind of genetic variant within clones typified by various kinds of variation. The name chimera was historically given to certain unique clonal variants now known to have arisen as graft chimeras.
 - Chimeras develop because of the unique architecture of the apical meristem and the strategic location of the mutation in a dividing cell near the apex of the apical meristem.
 - The three important types of chimeras are based upon the distribution patterns of mutated and non-mutated cells.
 - Buds arising at different positions on a sectorial chimera may produce shoots consisting of mutated and non-mutated cells, entirely of mutated cells or entirely of non-mutated cells or sectorial (rarely), mericlinal or periclinal chimeras as described herewith.
- a. **Periclinal chimera:** The mutated tissues occupy layers of cells that completely surround an inner core of non mutated tissue. For examples in many red colored fruit cultivars in apple, the red pigment is located only in the epidermal layers; whereas the cells of the inner tissue have alleles for green or yellow colour. Similarly, some black berry (*Rubus* spp.) cultivars are thorn less; because the cells making up the epidermis do not have this allele. Periclinal chimeras are relatively stable if propagated stem or grafting.

- b. Mericlinal chimera:** This combination is similar to the periclinal except that the cells carrying the mutant gene occupy only a part of the outer cell layer. In case of a red mutant on a yellow delicious fruit, the surface of the fruit may have longitudinal streaks or sectors of red on an otherwise yellow surface (Plate 4.3). This type is unstable and tends to change into periclinal chimeras, revert to the non-mutated form, or continue to produce mericlinal shoots.
- c. Sectorial chimera:** The mutated cells in this combination occupy an entire sector of the stem including all layers of the shoot apex. Sectorial chimeras appear if the mutation occurs in roots and very early stages of embryos where the cells of the growing point do not occur in layers. In general, this type is unstable and tends to revert to mericlinal and periclinal chimeras.
- d. Graft chimera:** In horticulture, a graft-chimera may arise in grafting at the point of contact between rootstock and scion and will have properties intermediate to those of its parents. A graft-chimera is not a true hybrid but a mixture of cells, each with the genotype of one of its parents is a chimera. Hence, the once widely used term "graft-hybrid" is not descriptive; it is now frowned upon. In practice graft-chimeras are not noted for their stability and may easily revert back to one of the parents.



Topic 5 Vegetative Propagation methods Introduction

A large number of horticultural crops are raised through one or the other vegetative methods. Several methods of vegetative propagation have been standardized for different horticultural crops. However, one method of propagation may be suitable for a particular crop but may not be suitable for the others. Similarly, one crop may be propagated on large scale with different methods of propagation, whereas, the others may have only one method. Further, the success of different propagation methods is influenced by the environmental conditions. Hence, one method for a particular crop may be highly successful in a particular locality, but cannot be of any

value in the other. For instance, side veneer grafting is successful method of mango propagation in north India but in Konkan region of Maharashtra, epicotyl or stone grafting is more successful. The different methods of vegetative propagation include:

1. Propagation by apomictic seedlings (mango, citrus etc)
2. Propagation by cuttings and layering (propagation on its own root system)
3. Propagation by grafting and budding (propagation on the root system of other plants)
4. Propagation by specialized vegetative structures (propagation by bulbs, tubers, rhizomes, corms, suckers, runners, bulbils, slips and crown etc.
5. Micropropagation i.e. propagation through tissue culture system

Importance and advantages of propagation by cuttings

- Now-a-days, propagation system are more market driven than production driven, which means that propagators must first analyze market demands and then select and develop cultivar utilizing optimum propagation techniques to produce plants for the customers.
- Cuttings are still most important means of propagating ornamental shrubdeciduous species as well as broad and narrow leaved types of evergreen plants.
- Cuttings are also widely used in commercial green house propagation of many floricultural crops. **Advantages**
- Many new plants can be produced in a limited space.
- It is inexpensive, rapid and simple and does not require the special techniques necessary in grafting, budding or micropropagation.
- No problem of graft incompatibility with rootstock and poor graft union etc.
- No variation due to variable seedling rootstocks.

Disadvantages

- The advantages of rootstock like induction of dwarfism, drought or disease resistance etc. cannot be utilized
- Plants raised through cuttings have lesser longevity as they are susceptible to various diseases and insect-pests.

Types of Cuttings

On the basis of plant part used and relative positions on a plant, cuttings are classified in various groups as shown in:

- a) Stem cuttings:** A stem cutting is any cutting taken from the main shoot of a plant or any side shoot growing from the same plant or stem. The shoots with high carbohydrate content usually root better. Broadly, there are four types of stem cuttings, namely hardwood, softwood, semi-hardwood and herbaceous cuttings.
 - i. Hardwood cuttings:** Cutting from mature and lignified stem of shrubs and trees are called as hardwood cuttings. Hardwood cuttings are prepared during dormant season, usually from one-year-old shoots of previous season's growth (Plate 5.1). The size of cuttings varies from 10 to 45 cm in length and 0.5 to 2.5 cm in diameter, depending upon the species. Usually, the cuttings of 25-30cm length, with pencil thickness are preferred. Each cutting should have at least three or more buds. While preparing the cutting, a straight cut is given at the base of shoot- below the node while a slanting cut, 1 to 2 cm above the bud is given at the top of cutting. However, in case of hollow pith species such as kiwifruit, top cut should also be close to bud to avoid drying up of top portion. For tropical and subtropical crops, straight cut is given at top in order to minimize transpiration loss and slant cut should be given at the base to expose more area for absorption of water and nutrients. This helps in maintaining the polarity of the shoot and if rain occurs, water does not accumulate on the tip of the cutting, which saves the cutting from fungal infection. A number of deciduous fruit plants like grape, kiwifruit, hazel nut, chest nut, fig, quince, pomegranate, mulberry, plum, olive, and gooseberry etc. are commercially propagated by hardwood cuttings
 - ii. Semi-hardwood (green wood) cuttings:** Semi-hard wood cuttings are those made from woody, broad-leaved evergreen species with partially matured wood. These types of cuttings are mostly used in evergreen fruit plants like mango, guava, lemon, jackfruit some shrubs and shrubby ornamental plants. The length of the cuttings varies from 7 to 20 cm. The cuttings are prepared by trimming the cuttings with a straight cut below the node and removing a few lower leaves. However, it is better to retain two-to-four leaves on the top of the cuttings. While planting 1/4th cutting should be inserted in the soil. The best time for taking such cuttings is summer, when new shoots have emerged and their wood is partially matured. It is necessary that leafy cuttings should be rooted under conditions when water loss from the leaves is minimum.

Commercially, such cuttings are rooted under intermittent mist, fog or under polyethylene sheets laid over the cuttings

- iii. Softwood cuttings:** Cuttings prepared from the soft-succulent and nonlignified shoots, which are not hard or woody, are called as softwood cuttings. Such types of cuttings are very prone to desiccation. Therefore, proper arrangement for controlling humidity is required. Usually the size of cutting is 5-5.7 cm but it may vary from species-to-species. In general, some leaves should be retained with this type of cuttings. The best time for preparing softwood cuttings is late summer. Softwood cuttings generally root easier and quicker than other types, but require more attention and sophisticated equipments. Similarly, the temperature should be maintained 23 to 27°C during rooting at the base of cuttings.
- iv. Herbaceous cuttings:** Herbaceous cuttings are made from succulent nonwoody plants like geranium, chrysanthemum, coleus, carnation and many foliage crops. These are usually 7-15 cm long with few leaves retained at the upper end. These are rooted under the same conditions as that of softwood cuttings, requiring high relative humidity. Bottom heat is also useful for initiation of rooting process. Herbaceous cuttings of some plants exclude a sticky sap (as in geranium, pineapple, cactus etc.) that interferes with root initiation process. In such cases, basal ends of cuttings should be allowed to dry for few hours before planting. Generally, fruit plants are not propagated by herbaceous cuttings.
- b) Root cuttings:** Propagation by means of root cuttings is also a simple and cheap method of vegetative propagation in species, which are difficult-to-propagate by other methods. In general, the plants, which produce suckers freely, are easily propagated by root cuttings. For preparation of root-cuttings, roots which are of 1cm thickness and 10-15cm long are cut into pieces (Fig.5.3). The best time for taking root cutting is late winter or early spring, when roots are well supplied with stored food material. However, in temperate fruits, root cuttings are prepared in the month of December and are kept in warm place in moss grass or wet sand for callusing and are then transplanted in the nursery during February-March in the open beds. Blackberry and raspberry are commercially propagated by this method. However, kiwifruit, breadfruit, fig, rose, mulberry, apple, pear, peach, cherry and persimmon are also propagated by root cuttings.
- c) Leaf cuttings:** Propagation through leaf bud cuttings is partially useful in species where leaves develop root system but die because of non-development of shoot system. Leaf bud cuttings are particularly useful when planting material is scarce

because each node in leaf can be used as cutting. Leaf bud cutting should preferably be prepared during growing season because buds if enter into dormancy may be difficult to force to active stage, thereby inhibit the rooting in such cuttings.

d) Leaf bud cuttings: A leaf bud cutting consists of a leaf blade, petiole and short piece of stem with attached axillary bud of actively growing leaves (Fig.5.4). In leaf bud cutting, 10-15 cm stem portion is used when propagating material is small. It is an useful method of propagation in blackberry, raspberry, lemon, camellia etc.

Layering techniques

Layering is a form of rooting of cuttings in which adventitious roots are initiated on a stem while it is still attached to the plant. The rooted stem (layer) is then detached, transplanted, while later becomes a separate plant on its own roots. It is a natural mean of propagation in black raspberries and trailing blackberries or it may be induced artificially in many plants like clonal rootstocks of apple. In general, better rooting in the layers can be obtained by ringing or wounding, etiolation or by the use of rooting hormones like IBA, NAA and by providing favorable environmental conditions (temperature and humidity) .

Advantages

down” at a location 15 to 20 cm from the tip forming a “U” shape. Bending, twisting, cutting, or girdling at the bottom of the “U” stimulates rooting at that location. The base of the layer is covered with soil or other media, leaving the tip exposed.

b) Compound or serpentine layering

It is a modification of simple layering in which one-year-old branch is alternatively covered and exposed along its length (Fig.5.2). The stem is girdled at different points in the underground part. However, the exposed portion of the stem should have at least one bud to develop a new shoot. After rooting, the sections are cut and lined out in the field. In this way, many new plants can be made from one branch. It is also an easy plant propagation method, but is suitable only for plants producing slender, long and flexible shoots. Muscadine grape is commercially propagated by this method.

c) Continuous or trench layering

It is the most common method of propagation for woody plants, which produce long vines and are difficult-to-propagate by other methods of propagation. Vigorous rootstocks of apple like M-16, and M-25 and walnut can easily be propagated by trench layering. In this method, it is important to establish a permanent row of plants to be propagated.

The method the mother plants are planted at the base of a trench at an angle of 45° in rows spaced 90 cm apart. The long and flexible stems of these plants are pegged down on the ground to form a continuous line of layered plants (Fig.5.3 and plate 5.1). The young shoots that arise from these plants are gradually mounded up to a depth of 15-20 cm in autumn, winter or at the end of the growing season, depending on the species to be propagated.

d) Air layering (Marcottage, Gootee, Pot layerage)

Air layering is an ancient method of layering, originally introduced from China and now commercially used for propagation of a number of tropical and subtropical trees and shrubs including litchi, guava, mango, longan, persian lime (*Citrus aurantifolia*), ficus, croton etc. Air layers are made in the spring or summer on stems of the previous season's growth. The presence of active leaves on the layered shoot speeds root formation. Layers are prepared by making an upward cut about 5 cm long at or about the center of the shoot. The shoot is then girdled by removing a ring of bark about 2 cm wide. The upper part of wound is applied with IBA paste made in lanolin. The wound is covered with moist sphagnum moss in a way to provide complete cover to it. Polyethylene film is wrapped around the moss grass in such a way as to leave no opening, which could allow evaporation of moisture from the moss. The rooted layers may be severed from mother plant and may be planted in the nursery under shade. **e) Mound /Stool layering or stooling**

The term stooling was first coined by Lynch in 1942 for mound layering. It is a method of propagation in which the shoots/plants are cut back to the ground and soil or rooting medium is mounded around new sprouts/shoots to stimulate roots to develop at their bases. This method is commercially used to propagate apple, pear, quince, currants, gooseberry and other fruit crops. In stooling, the mother plant is headed back to 15 to 20 cm above ground level during dormant season.

- The new sprouts will arise within 2 months. The sprouts are then girdled near the base and rooting hormone (IBA), made in lanolin paste, is applied to the upper portion of the ring.
- The concentration of IBA depends on species to species but generally; 3,000 to 5,000 ppm is commonly used. These shoots are left as such for

Topic 6 Physiology & Biochemical basis of Rooting Introduction

Adventitious root formation is an organized developmental process involving discrete biochemical, physiological and histological events in the induction, initiation, development and elongation of root primordia. In general, regeneration of a new plant from a cutting basically depends on two fundamental properties of the plant cell.

- a) Totipotency:** which states that individual cell contains all the genetic information required for producing a new plant of same kind.
- b) Dedifferentiation:** which means the capacity of mature cell to return to a meristmatic condition and develop into a new growing point.

In some species, cuttings root very easily as in grapes, while in some species, rooting takes place only after some treatments, where as others do not root at all.

Therefore, it becomes mandatory to study the anatomical and physiological basis involved in the process of rooting of cutting.

Anatomical basis of rooting of cuttings

- Adventitious roots in stem cuttings of many woody plant species have been reported to originate from various tissues(Fig.6.1). ARF in woody plants generally originate in young secondary phloem, but also arise from vascular rays, cambium or pith (Hartmann and Kester, 1983).
- The origin of adventitious roots has been reported to be callus tissue in difficult-to-root species. Poor rooting in stem cuttings of certain woody species has been correlated with extensive sclerification.
- Thick lignified walls of sclerenchyma tissues were physiological or mechanical barriers to adventitious root formation in poor-to-root species like *Fagus*, *Prunus* and *Quercus*. Generally, four anatomical changes are observed in adventitious root formation.

These anatomical changes are:

- Dedifferentiation of specific mature cells
- Formation of root initials from the dedifferentiated specific mature cells
- Development of root initials into organized root primordia and formation of vascular connection between root primordia and conducting tissues of the cuttings emerging through the cortex and epidermis
- Emergence of roots outside the cuttings

In herbaceous plants, adventitious roots generally appear just outside and between the vascular bundles. In woody plants, one or more layers of xylem and phloem are present and adventitious roots are formed in the stem cutting from the living parenchyma cells. After emergence, the roots develop root cap and other tissues of the root. Adventitious root and shoot usually arise within the stem (endogenously) near vascular tissue, outside the cambium.

Dedifferentiation of specific mature cells: It is also referred as callus formation and rooting process. When the cuttings are placed in a suitable medium, a mass of undifferentiated parenchymatous cells, called as callus, is usually developed at the base of the cutting and only then the root initiation process takes place. There was a belief that callus formation is necessary for rooting of cutting but now it has been established that callusing and root initiation are two independent phenomena and can occur simultaneously. Though, excess of callus formation may hinder root initiation in some species.

Formation of root initials: Root initials are sometimes developed in the intact stem of certain woody plants, even before cuttings are made from them. These root initials remain dormant in the stem. These dormant root initials are called as preformed or latent root initials. When the cuttings made from such stems are placed in favorable environmental conditions, these root initials become active and roots are developed rapidly and easily from them. Occurrence of root initials is quite common in willow, hydrangea, poplar, jasmine, currant and citron. In some clonal apple and cherry rootstocks and old trees of apple and quince, the preformed root initials show a swelling (outgrowth) on the stem and are more often called as burr knots. Cuttings taken from plants having burr knots usually root better and easily as compared to those having no burr knots.

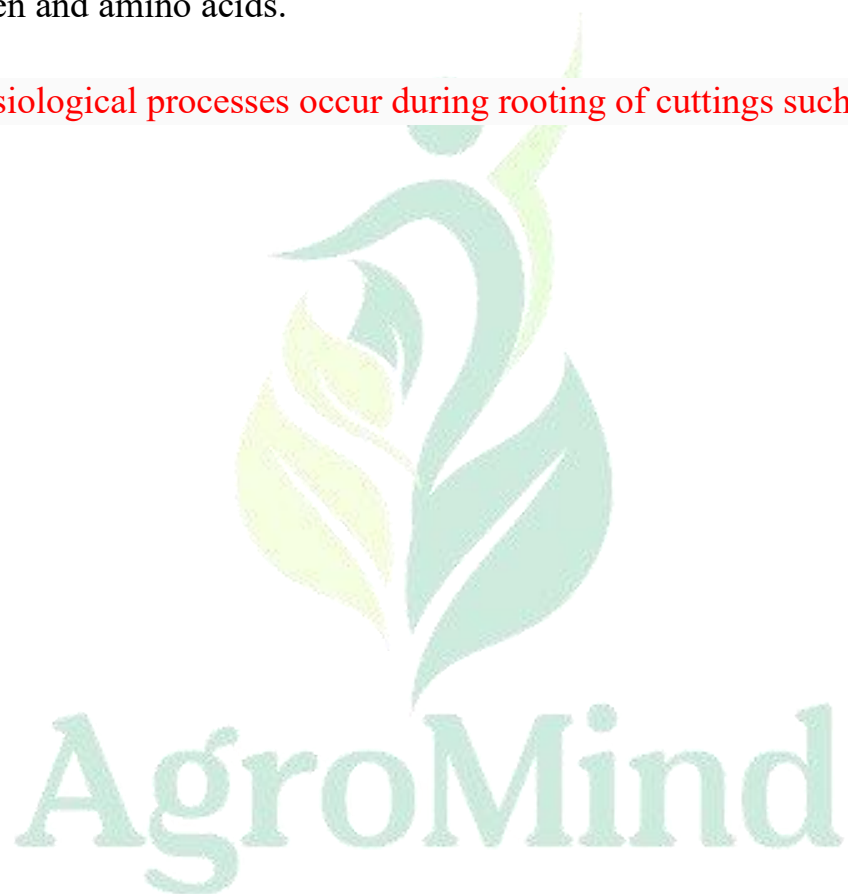
Stem structure and rooting: It has been found that certain type of stem structures or tissue relationship plays a vital role in adventitious root formation in the cuttings. The development of continuous sclerenchyma ring between the phloem and cortex of the stem is generally considered as an anatomical barrier to the rooting of cutting as in olive and in some leaf cuttings. Similarly, presence of sclerenchyma fibers in the cortex of stem may cause difficulty in the rooting of cuttings in some species as in English Ivy and *Hedera helix*.

Physiological basis of Rooting of Cuttings

Prerequisites for adventitious root formation to occur include:

- Availability and receptivity of parenchyma cells for regenerating new meristmatic regions
- Various modifications of the rhizocaline complex of phenolics (inhibitors, promoters, rooting co-factors) auxin, enzyme system
- Substrate needs such as carbohydrate accumulation and partitioning and changes in nitrogen and amino acids.

Several physiological processes occur during rooting of cuttings such as:



Growth regulators: Various growth regulators such as, auxins, cytokinins, gibberellins, abscisic acid and ethylene influence rooting of cutting. In addition, various other natural occurring promoters and inhibitors may also take part in the root initiation process.

a) Auxins: During 1934, indole-3-acetic acid (IAA) was identified as the first naturally occurring auxin having activity, which takes part in inducing rooting in the cuttings. Later on Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) were found to be more effective in inducing rooting in cuttings.

1. For initiation of rooting in the cuttings, continuous supply of auxin is basically required for the first 3-4 days.
2. Usually, the cuttings do not respond to exogenous application of auxin once the rooting process has initiated.
3. IBA treatments may control endogenous auxin levels of cuttings either through direct regulation of the IAA oxidase system or indirectly through the transport of auxin protectors.

b) Cytokinins: Cytokinins are responsible for growth and differentiation of the cells. Various natural and synthetic chemicals like kinetin, zeatin and 6-benzyl adenine have cytokinin activity. In general, cuttings having high endogenous levels of cytokinins have more difficulty to root than those having low cytokinin activity.

- Similarly, if cytokinins are applied artificially, root initiation process is inhibited. However, cytokinins at very low concentration promote root initiation process, while high concentrations inhibit it.
- Cytokinins strongly promote bud initiation in root cuttings of some species as in *Bryophyllum* and *Convolvulus*.

c) Gibberellins: Gibberellins are a group of naturally occurring compounds first isolated in Japan during 1939. They are primarily known for their elongation

effects in the intact stems. The high concentrations of gibberellins (10⁻³M) usually inhibit root initiation process in cuttings but lower concentration (10⁻¹¹ to 10⁻⁷M) promotes it. The inhibitory effect of higher doses of GA₃ is mainly due to prevention of early cell division, involvement in transformation of mature stem tissues to the meristematic conditions. Therefore, many gibberellins antagonist chemicals like Alar, Arrest or Absciscic acid which usually promote rooting in cuttings.

- d) **Absciscic acid:** The role of absciscic acid in rooting of cuttings is not very clear and reports are highly contradictory. However, its effects on rooting depend upon concentration and nutritional status of the stock plant from which the cuttings have been prepared.
- e) **Ethylene:** Ethylene, gaseous material produced by the plants, has a promoting effect on rooting of cuttings at low concentration. Ethylene application at 10ppm induces root formation in stem and root cuttings but at higher concentration (100ppm or above) decrease or inhibit it. Root promotion activity of ethylene is supposed to be due to its synergistic effects on auxin synthesis, which alternately leads to root initiation process.

Role of vitamins: Endogenous optimum level or exogenous application of vitamin promotes root initiation process in the cuttings. Thiamine (vit B₁), pyridoxine (vit B₆), niacin and biotin B-complex vitamins and vitamins K or H all are known to stimulate the rooting process in different plants. Vitamin, if applied with some auxins like IAA, NAA or IBA have synergistic effect on root initiation in cuttings of different plant-species.

Presence of buds and leaves: It has been demonstrated by many workers that presence of leaves on the cuttings exerts a strong stimulating influence on the root initiation process in cuttings. The leaves produce carbohydrates, which are translocated downward to the base of stem, where it promotes root formation.

Further, the leaves and buds are powerful auxin producers and their transport to basal parts may initiate rooting faster as in poplar, grape and currant. If the buds are removed from the cuttings, the root formation may be hindered adversely. Rooting co-factors: Many rooting co-factors have been isolated from cuttings of different plants. These co-factors are naturally occurring substances that appear to act synergistically with auxin, primarily IAA, for root formation in cuttings. Bouillenne and Went were the first to name the root-forming factors of leaf, cotyledon and buds as rhizocaline in 1933. Later, a new hypothesis was proposed, highlighting that rhizocaline is a complex of three components viz:

1. A specific rooting factor, which is translocated from buds, leaves, characterized chemically as ortho-dihydroxy phenol
2. A non-specific factors (auxin) in low concentration, which is also translocated from leaves and the buds, and
3. A specific enzyme, probably polyphenol oxidase present in pericycle, phloem or cambium.

According to this hypothesis, ortho-hydroxyphenol reacts with auxin, giving rise to rhizocaline wherever the enzyme is present. The formation of rhizocaline leads to the reactions involved in the root initiation process.

Another hypothesis proposed by Hess (1968) indicated that a number of co-factors interact with IAA, resulting in IAA co-factors complex, which subsequently initiates rooting.

1. Generally, the easily rooted plants have a large number of co-factors and in higher concentration than in difficult-to-root plants.
2. One of these co-factors (no 4) consists of highly active substances characterized as oxygenated terpenoids.

3. Another co- factor (no.3) was identified as chlorogenic acid. Later, it was postulated that phenolic compound more especially catechol, reacts synergistically with IAA in root formation.
4. This oxidation of ortho-dihydroxy phenol is one of the first steps leading to root initiation process.

Similarly, ABA was also found to be associated as one of the co-factors in root initiation. The action of phenolic compounds in root initiation is mainly in protecting the natural occurring auxin IAA from destruction by indole acid oxidase. Rooting co-factors have been found in *Hedera helix*, Crab C, MM106 and M-26 apple rootstocks and Old Home pear.

Nutritional factors: The nutrient status of plant from which cuttings are taken, also plays vital role in root initiation process of the cuttings.

1. Low nitrogen and high carbohydrate resources usually favour root initiation process compared to high nitrogen and low carbohydrate reserves.
2. High nitrogen content usually favours luxuriant growth and hinder root initiation process but extreme N-deficiency also hinders the rooting process.
3. Thus, high C: N ratio should be maintained in the stock plants before taking cuttings from them.

Endogenous rooting inhibitors: In addition to root promoting substances, certain endogenous root-inhibiting substances are also present in some plant species, inhibiting the process of root initiation.

1. Therefore, cuttings of certain plants do not root easily mainly because of presence of endogenous inhibitors.
2. For example, the cuttings of *Vitis berlandieri* do not root easily as compared to the cuttings of *Vitis vinifera* because of presence of higher concentration of abscisic acid.

Topic 7 Grafting techniques

Before going into the details of different methods of grafting, it becomes very important to know about the basic terminology related to grafting methods. **Grafting:** Grafting is a process by which two living parts are joined together in such a manner that they would unite together and subsequently grow into a composite plant. Usually graft has two parts, the scion and rootstock.

Scion: Scion refers to that part of a graft combination that becomes the top of the plant. Scion is the short piece of detached shoot containing 3 or more dormant buds, which when united with the rootstock or inter-stock, comprises the upper portion of the graft and from which will grow the stem or branches or both. It should be of the desired cultivar and free from diseases.

Rootstock: The rootstock is the lower portion of the graft, which develops into the root systems of the grafted plant. It may be seedling, a rooted cutting, or a layered or micro-propagated plant.

Inter-stock: Inter-stock is a piece of stem inserted by means of two graft unions between the scion and rootstock. Inter-stocks are used to avoid an incompatibility between the rootstock and scion, to produce special tree forms, to control diseases or to take advantage of its growth controlling properties.

Vascular cambium: Vascular cambium is a thin tissue located between the bark and the wood. Its cells are meristmatic i.e. they are capable of dividing and forming new cells. For successful graft-union, the cambium of the scion is placed in the close contact with the cambium of the rootstock.

Callus: Callus is a term applied to the mass of parenchymatic cells that develop from and around wounded plant tissues. It occurs at the junction of a graft union, arising from the living cells of both the scion and rootstock. The production and interlocking of these parenchymatic cells (callus) constitute one of the important step in callus bridge formation between the scion and rootstock in a successful graft.

Reasons for grafting and budding

- Perpetuating clones that cannot be readily propagated by cutting, layers, division or other asexual methods

- Obtaining the benefits of certain rootstocks
- Obtaining the benefits of certain plants (double working)
- Changing cultivars of established plants (top working)
- Precocity in bearing
- Reduction in juvenility
- Obtaining special forms of plant growth
- Repairing the damaged parts of trees
- Study and elimination of viral diseases
- Studying the developmental and physiological processes

Elements for successful grafting

There are five important elements for any successful grafting operation. These are:

- The rootstock and scion must be compatible.
- The vascular cambium of the scion must be placed in intimate contact with that of the rootstock.
- The grafting operation must be done at a time when the rootstock and scion are in the proper physiological stage.
- Immediately after completion of grafting, all cut surfaces must be protected from desiccation.
- Proper care must be given to the grafts for some period of time after grafting.

Types of Grafting

1. Detached scion grafting

A. Apical grafting

Whip-and –tongue grafting

Splice grafting (whip grafting)

Inarching

Bridge grafting

Bracing **Detached Scion Grafting**

A. Apical grafting

Splice or whip grafting:

- In this method, it is essential that both the stock and scion should be of equal diameter. The various steps involved in splice grafting.
- For this, about one-year-old rootstock is headed back at a height of 20-25 cm from the soil and a splice (diagonal) cut of 2.5 to 6 cm long is made at the distal end of the rootstock with the help of a sharp knife.
- A similar slanting cut is made on the proximal end of the scion. The cuts should be smooth and the cut surface of both the rootstock and scion are bound together and tied firmly with polythene strip.
- After the union has taken place, the rootstock above the union is lopped off gradually. Sprouts arising below the grafting union must be removed at regular intervals to divert flow of metabolites for the growth of scion only.

Whip and tongue grafting:

- It is modified form of whip grafting. It differs from whip grafting that a reverse cut is made downward at a point about 1/3rd of the distance from the tip and should be about 1/2 the length of first cut.
- The various steps involved in splice grafting are shown in Plate 7.2. To obtain a smooth-fitting graft, the cut should not split.
- The rootstock and scion is then inserted into each other, with the tongues interlocking. It is important that vascular cambium layer match along at least one side, preferably along both sides.

- The lower tip of the scion should not overhang the stock as there is a likely hood of the formation of large callus knots.



[CLICK HERE to Join AgroMind Telegram Channel](#)

- The use of scions larger than root stock should be avoided. After the scion and rootstock are fitted together, they should be securely held by tying with budding/grafting tape or polythene.
- This method gives better success than splice grafting because of better cambial contact between stock and scion due to formation of tongue.
- Regular de-shooting of sprouts on stock is required to obtain better growth of scion.

Cleft grafting:

- It is one of the oldest methods of field grafting. It is used to top work trees, either in the trunk of a small tree or in the scaffold branches of a bigger tree.
- The various steps are shown in Plate 7.3. In making the cleft-graft, a heavy knife is used to make a vertical split for a distance of 5 to 8 cm down the center of the stub to be grafted. This split is made by pounding the knife in with a hammer.
- The branch is sawed off in such a way that the end of the stub is smooth and free from knots for at least 15 cm.
- In this method, two scions are inserted, one at each side of the stock where the vascular cambium layer is located. The scions should be 8 to 10 cm long and 10-15 mm in thickness and should have two or three buds.
- The side of the wedge, which is to go to the outer side of the rootstock should be slightly wider than the inside edge. When the knife is removed, a hard wooden wedge is inserted to keep it open for the subsequent insertion of the scion.
- The graft should be wrapped with a polyethylene strip properly to prevent wilting of the scion. The scion starts growing after 2 to 3 months of grafting. The right time for cleft grafting is the later part of the dormant season or just before the start of active growth.

- Pear, walnut, hazelnut, pecan nut and grapes are propagated by this method.

Wedge grafting (saw-kerf grafting):

- It is performed in late winter or early spring before the bark begins to slip. A sharp, heavy, short bladed knife is used for making a V-wedge in the side of the stub or stock about 5cm long.
- Two cuts are made, coming together at bottom and as far apart at the top as the width of the scion. These cuts extend about 2 cm deep into the side of the stub.
- The base of the scion is trimmed and a wedge shape cut exactly the same size and shape as the opening. With the two vascular cambium layers matching the scion is tapped downward firmly into place and slanting outward slightly at the top so that the vascular cambium layers cross.
- After all scions are firmly tapped into place, all cut surfaces including the tips of the scion, should be waxed thoroughly. It is called saw-kerf grafting because the cuts in the side of the rootstock can be made with a saw rather than the sharp knife.

Saddle grafting:

- The saddle grafting can be bench grafted by hand or machine. The rootstock and scion should be of the same size. The scion is prepared by cutting upward through the bark and into the wood opposite sides of the scion.
- The knife should penetrate more deeply into the wood as the cuts are lengthened. Before the scion piece, and the saddle shape is gradually formed by removing pieces of the wood.

- The rootstock is cut transversely and then two upward cuts are made on either side. The apex of the rootstock is carved to fit the saddle so that vascular cambia of both stock and scion match.
- The graft is tied and cut surfaces are sealed by polythene until the graft-union is formed.
- It is used for the propagation of grape and rhododendron cultivars.

B. Side grafting methods

Side veneer grafting:

- This method is used for grafting small potted plants such as seedling of deciduous trees, shrubs and fruit crops. A shallow downward and inward cut from 2.5-3.5 cm long is made.
- At the base of this cut, a second short inward and downward cut is made, inserting the first cut, so as to remove the piece of wood and bark.
- The scion is prepared with a long cut along one side and very short one at the base of the scion on the opposite side.
- These scion cuts should be of the same length and width as those made in the rootstock so that the vascular cambium layers can be matched as closely as possible. After inserting the scion, the graft is tightly wrapped with polythene strips.
- After the union has healed, the rootstock can be cut back above the scion in gradual steps. This method is commercially used for raising mango and walnut plants.

Side-tongue grafting:

- In this method, the cut is made at the base of the scion, like the cut made in whip-and tongue graft. Then, a thin piece of bark and wood from stock and scion is completely removed.
- Then a reverse cut is made downward in the cut on the rootstock starting 1/3rd of the distance from the top of the cut. This second cut in the rootstock should be of the same length as the reverse cut in the scion.



- The scion is then inserted into the cut of the rootstock, the two tongues interlocking, and the vascular cambium matching. The graft is wrapped tightly, to avoid desiccation.
- The top of the graft union is left intact for several weeks until the graft union is healed and may be cut afterwards above the scion gradually so that the buds on the scion are forced into active growth.

C. Detached scion grafting methods Bark Grafting (Rind grafting):

- It is very simple method of propagation and some nurserymen prefer it, because it can be done without splitting the stub, which prevents the entry of pathogens.
 - It can be done in branches, which are 25 to 30 cm long. It should be done in spring when the bark of the stock slips easily.
 - It is important to note that the scion used in bark grafting should be dormant. The rootstock is first sawed off at a point, where bark is smooth. If the stock is thick many scions can be inserted.
 - For each scion, bark is split downward, about 5 cm from the top of the stub. Scions of 10-12cm length containing 2-3 buds are prepared by giving a slanting cut (5cm) downward along one side of the base.
 - On the other side, a small cut is made. The scion is then inserted in the centre of split between the bark and wood of the rootstock. The longer cut of the scion is placed against the wood.
 - The scion is held firmly by using adhesive tape. Afterwards, all the exposed portions of the stub and scion should be tied with polyethylene strip tightly. The scions will start sprouting after 6-8 weeks in case of successful grafts.
- #### **D. Root grafting (Whole root and Piece-root grafting):**
- In this method, the seedling rootstock, rooted cuttings or layered plant is dug up and the roots are used as the rootstock for the graft.

- The entire root system may be used (whole-root graft) or the roots may be cut into small pieces and each piece is used as a rootstock (piece-root graft). As the roots used are relatively small (0.5-1.5 cm) in diameter, the whip and tongue graft is generally used. Root grafting is usually bench grafted indoor during the late winter or early spring.
- In preparation of root-grafts, the root-pieces should be 7.5 to 15.0 cm long and the scions of about the same length containing two to four buds are used.
- After the grafts are made and tied properly, they are bundled together in groups of 50 to 100 and stored for callusing in damp sand, peat moss or other packing material.

Approach Grafting

The characteristic features of approach grafting are that two independent, self-sustaining plants are grafted together. After the formation of union, the top of rootstock plant is removed above the graft union and the base of the scion plant is removed below the graft union. Generally, it is performed with one or both of the plants to be grafted, which are growing in a container. Rootstock plants in containers may also be placed adjoining to an established plant, which is to furnish the scion part of the new grafted plant. It must be performed in the season when plants are in active growth because under such conditions, rapid healing of the graft-union will take place. The important methods are:

Spliced approach grafting:

- In this method both scion and stock should be of same thickness. A splice of 45cm bark and wood is removed both from stock and scion (Fig.7.3).
- The cut on both the partners should be of the same size and should be smooth too. The cut surfaces of stock and scion are bound together with some suitable tying material and waxed properly.
- The stock above the union and scion below the union are cut after sometime, when proper union has taken place. It may be necessary to reduce the leaf area of

the scion if it is more than the root system of the rootstock **Tongue approach grafting:**

- The tongue approach grafting is the same as the spliced approach grafting, except that after the first cut is made in each stem to be joined, a second cut downward on the stock and upward on the scion is made, by providing a thin tongue on each piece.
- By interlocking these tongues tightly, a closely fitted graft union can be obtained.

Approach grafting:

- The inlay approach grafting may be used if the base of the rootstock plant is considerably thicker than that of the scion plant. The various steps involved are shown in Fig.7.5.
- A narrow slot, 7.5 to 10 cm long is made in the bark of the rootstock plant by making two parallel cuts and removing the strip of bark between. This can be done only when the rootstock plant is actively growing and their bark slipping easily.
- The slot should be exactly as wide as the scion to be inserted. The stem of the scion plant, at the point of union, should be given a long shallow cut along one side, of the same length as the slot in the rootstock plant and deep enough to go through the bark and slightly into the wood.
- This cut surface of the scion branch should be laid into the slot cut in the rootstock plant and held there by nailing with two or more small, flat headed wire nails. The entire union must then be thoroughly covered with grafting wax. □ After the union has healed, the rootstock can be cut off above the graft and the scion below the graft.

Inarching:

- Inarching is similar to approach grafting as rootstock and scion plants are on their own roots at the time of grafting.
- It differs in that the top of the new rootstock plant usually does not extend above the point of the graft-union as it does in approach grafting. Inarching is used to replace roots damaged by cultivation equipments, rodents or diseases.
- It is very advantageous in saving a valuable tree or improving its root system. In this method seedlings (or rooted cuttings) planted beside the damaged tree, or suckers arising near its base are grafted into the trunk of the tree to provide a new system to supplement the damaged roots.
- The seedlings to be inarched into the tree should be spaced about 10-15 cm apart around the circumference of the tree if the damage is extensive.

The seeding of compatible species is planted around the tree during dormant season and grafted when active growth commences in them during early spring. Inarching will enhance growth of uninjured older trees.

A thin slice of bark (6-10 cm in length) at about 20 cm above the ground level is removed from the stock with a sharp knife. A similar cut is made in the scion. Thus, the cambium layers of both stock and scion are exposed. These cut are brought together and tied firmly with the help of a polythene strip.

After the successful union, stock above and scion below the graft union are lopped off gradually. In low rainfall areas, it should be done with the onset of rains, while in regions of heavy rainfall; it should be done soon after the rainy season is over, provided temperature does not fall below 15°C

3. Repair Grafting Bridge

grafting:

- Bridge grafting is basically not a method of propagation but a form of repair grafting only in plants, which have been damaged either by frost, rodents or insects. It may, however, be kept in mind that bridge grafting is only helpful if the trunk is damaged but the root system of the plant is healthy.
- In this method, first the damaged portion of the stock is cleaned and the irregular edges of the girdled area are cut evenly.
- The scion of desired variety is inserted in such a way that it is attached at both upper and lower ends into the living bark. Similarly, it is important that scions should be inserted right side up to ensure the polarity.
- The exposed injured wood must also be covered otherwise; it may serve as an entry channel for decaying organisms.

Bracing:

- Bracing is a form of natural branch grafting that is used by fruit growers to strengthen scaffolding limbs of a tree in order to support the load of the fruit crop. In this method two strong, young lateral shoots from the limbs are to be braced.
- A rope or electrical cord is used to temporarily brace the larger limbs. The weaved smaller shoots, which will naturally graft, are tied with waxed string or poly tape to keep them together.

4. Softwood grafting

- This technique of grafting is commercially used for raising mango, sapota, tamarind and cashewnut in western India. In this technique, grafting is done with mature, procured scion on the emerging soft, coppery-red shoot of the rootstock, which is 60-70 days old.
- The basic technique involves the beheading of rootstock with a sharp knife. Then, a slit is made on the beheaded stock to insert the procured scion. The lower portion of scion is made in wedge shape so that both the faces of scion fit with the stock. Both stock and scion are tied with help of a polyethylene strip.
- The scion is then covered with a polythene bag (100 gauge) and tied with thread to keep the scion fresh till the complete union is formed. After sprouting, the bag is removed. To have better success, the leaves on the stock must be retained.
- This technique is effective in dry hot weather or in areas of low precipitation where mortality of nursery raised grafts is very high.

5. Epicotyl grafting

- It is also called as stone grafting. In this method, germinating seeds of less than two weeks old are wedge or splice grafted with mature scion. Moderate temperature and high relative humidity are major factors related to success of epicotyl grafting. For splice grafting, germinating seeds less than 2 weeks old are used as rootstock.
- A 2-3 cm long slanting cut is made in the epicotyl with a matching cut on the proximal portion of the scion and then these are tied firmly with polythene strip. In wedge grafting, the selected 2 weeks old seedlings are headed back, by retaining 6-8cm long stem with the stone.

Topic 8

Budding techniques

Introduction

Budding is a form of grafting in which one bud and a small section of bark with or without wood is used, in comparison to grafting, in which the scion consists of a short-detached piece of stem tissue with several buds. Chip budding and T-budding are the most important types of budding for fruit crops and woody ornamentals.

The type of budding method to be adopted depends upon the bark's slipping, ability of the stock and scion, which coincides with the period of active growth in season and when newly formed tissues are easily torn as the bark is lifted from the wood. Among the different methods, chip budding can only be done when bark is not slipping.

Advantages

- It is the best propagation method if the propagating material is scarce and valuable.
- Budding is useful in plants, which release excessive wound gum (e.g. stone fruits) from injury caused to wood portion of the stem at the time of grafting.
- Budding union is stronger than grafting so damage by wind or storm is less compared to grafted plants.
- Budding is comparatively simple, efficient and quicker method of propagation than grafting.

Selection of bud-wood

- While selecting bud-wood, one should be careful enough to use vegetative buds than the flowering buds for budding.

- The vegetative buds are usually small and pointed while flower buds are large and plump. In case of bud wood to be procured from distant place, the leaves must be removed by leaving petiole intact.
- The bundle of bud-wood should be packed in moist jute or sphagnum moss, or cloth and should be kept moistened in the transit.

Time of Budding

Budding time usually depends upon the availability of well developed budwood of the desired cultivar. In most plants, these conditions exist at three different times during the year:

1. Spring budding

- In spring budding, the bud must be dormant and the rootstock just begins to start growth as soon as the bark slips easily on the rootstock.
- The period of spring budding is short and should be completed before the rootstock has made much new growth. Due to combination of dormant bud and active growing buds on the rootstocks, the bud sprouts and develops easily.
- The bud sticks are collected well in advance of actual budding operation and stored at -2 to 0°C temperature to hold them dormant by wrapping them in moist jute cloth or sphagnum moss.
- The rootstock top is cut after 2-3 weeks of budding, when healing has taken place, by giving a slanting cut. Spring budding is commonly done in citrus.

2. June budding

- June budding is done in early part of the growing season i.e. mid-May to mid-June. Budding is done in the early part of the growing season and the inserted bud is forced to sprout immediately.
- The bud is taken from the current season's growth. This method is preferred in areas having relatively long growing season. June budding is used mostly to

produce stone fruits (peaches, nectarine, almond, apricot, plums, cherry, *ber* and *aonla* etc.).

- A seedling of 30 cm height, 3-5 mm diameter can be used for budding. June budding should not be done after late June, so as to obtain nursery plant of satisfactory size.
- In June budding, the rootstocks are smaller and have less stored food in them. Usually, 3-4 leaves are also retained below the bud.
- The healing of bud usually takes 2-3 weeks under normal environmental conditions. If leaf stock or petiole drops off cleanly, it is a good indication of bud union and if it has adhered strongly and starts shriveling and darkens, it indicates budding failure.
- The rootstock is immediately cut after healing process, leaving at least one leaf above the bud and several below. Other sprouts should be rubbed off or discouraged to ensure fast growth of scion bud.

3. Fall budding

- Fall budding is particularly important in northern areas and cold deserts where the growing season is short. Fall budding is done in late summer, and not in autumn.
- The rootstock are large enough by late summer to accommodate the bud and the plants are actively growing with the bud bark slipping easily, should be moderately vigorous, actively growing and containing healthy bud in the leaf axils.
- As bud sticks are selected, the leaves should be cut off immediately, leaving only a short piece of leaf petiole attached to the bud to help in handling the bud while performing budding.

- The best buds on the stick to be used are usually on the middle and basal portion. Buds on the succulent terminal portion of the shoot should be discarded as they are immature.
- After the buds have been inserted and tied, nothing needs to be done until the following spring. If the budding operation is done properly, the bud piece should unite with the rootstock in two to three weeks, depending upon growing conditions.
- Even though the union has formed, buds on most deciduous species usually do not grow or push out in the fall, since they are either in a physiological rest or inhibited by apical dominance.
- By spring, the chilling winter temperatures overcome the rest influence and the buds start growing. Most of the tropical, subtropical and temperate fruits like *aonla*, mango, guava, *ber*, *bael*, jackfruit, stone fruits, walnut, chestnut and hazelnut etc. are propagated during this period.

Stages of Bud/Graft Union Formation

There are four stages viz; pre-callus, callus formation of cambial bridge and healing of the bud union.

- Pre-callus stage:** It lasts for 5 to 8 days, after budding or grafting operation. During this stage, there is no sign of callus formation and scion falls if the wrapping material is removed.
- Callus formation:** After 5th to 8th day, the callus formation may take place in the bud/graft union. The process of callus formation is fast in firmly attached stock and scion. The initiation of callus formation takes place either from stock, scion or both. Usually, living cells of recently formed xylem and phloem play active role in the callus formation.

Formation of cambial bridges: The parenchymatous cells of the callus form a cambial bridge within 12 to 15 days after budding. After the formation of cambial bridge, de-differentiation of secondary xylem and phloem takes place after 36-48 days of budding. Afterwards, the partial movement of stock to scion takes place. The bud union is completed within 6-7 weeks, if conditions are favourable.

Healing of the bud/graft union: After de-differentiation of secondary xylem and phloem of both stock and scion, there is formation of many new xylem and phloem cells after 6-8 months of budding or grafting. The callus unites completely with the scion pith and the union heals completely. In general, better contact and alignment of the cambial cells of stock and scion helps in development and proliferation of callus.

Methods of Budding

- a) **Chip Budding:** Chip budding is done in early spring, summer or autumn. In chip budding, a chip of bark and wood is removed from the smooth surface between the nodes of the stock. The various steps involved are shown in Plate 8.1. A chip of similar size and shape is also removed from the bud wood of the desired cultivar. For which, a 2-3cm long downward cut is made through the bark and slightly into the wood of the stock. Then a second cut of about 2.5cm is made so that it bisects the first cut at an angle of 30-45° and the chip is removed from the stock. Similarly, a chip of bud is removed from the budwood, ensuring that the bud is in the middle of chip. The bud chip inserted in the stock in such a way that cambium of the bud chip should have direct contact with the cambium of the stock. It is then tightly wrapped with polythene strip, leaving the bud uncovered. The bud may sprout after 3-4 weeks and afterwards the wrapping material should be removed. When the bud starts growing, the stock may be cut above the bud union.
- b) **Shield or T-budding:** As the name indicates, shield is the shape of the bud and 'T' is the shape of cut given on the rootstock. It is the most common method of budding used by nurserymen worldwide. For shield budding, one year old rootstock seedlings of 25-35 cm height and 2-2.5 cm thickness is selected. The bark of seedlings should slip easily. The selected bud of desired cultivar is inserted 15-20cm above the ground level and is tied with a polythene strip. For performing budding operation, a "T" shaped cut is made on the selected portion of the stock with the help of a sharp budding knife. The incision should be given through the bark not the wood. The two flaps of bark are loosened with the help of budding knife. The healthy bud is removed from the bud wood by cutting shallowly about 5-6 mm below and 2-3cm above the bud. This shield piece containing a bud is inserted in the "T" cut made on the rootstock. The shield should be covered by two flaps of the bark, but bud should be exposed. The buds are pressed firmly, fitted into the "T" cut and finally tied with polythene strip. When bud healing process is over, the bud may attain a height of 15-20cm, the remaining portion of the stock is cut to about 10-15cm above

the bud. Plants with thin bark, with sufficient flow of the sap like apple, pear, peach, plum, apricot, cherry, rose and citrus are propagated by this method.

- c) **Patch budding:** In case of patch budding, a rectangular patch of bark is removed completely from the rootstock and replaced with a patch of bark of the same size containing a bud of the cultivar to be propagated. It is a slower and difficult to perform method than T-budding. It is widely used in thick-barked species, such as walnuts, pecans and rubber tree, where T-budding gives poor results due to poor fit around the margins of the bud-particularly the top and bottom. It is usually done in late summer or early fall, but can be done in spring also. In patch budding, the stock and scion should preferably be of same thickness (20-25mm). The various steps involved are shown in Plate 8.3. First, a rectangular piece of bark (25mm long and 10-15cm wide) is removed from the stock and a similar patch, containing a bud is removed from the scion by making two horizontal cuts above and below the bud and then two vertical cuts connecting the horizontal cut. After removing the patch, the bud should fit tightly at the top and bottom. It is then wrapped with polythene strip, keeping the bud uncovered. The wrapping material should hold the bark tightly and cover all the cut surfaces to prevent free entry of air or water or pathogens. After the bud starts sprouting, the stock above the bud union may be cut off step-by-step. In addition to pecan nut and walnut, mango, rubber plant, *aonla*, jackfruit and *jamun* are also propagated by this method.
- d) **Ring or annular budding:** In this type of budding, a complete ring of bark is removed from the stock and it is completely girdled. A similar ring of bark containing a bud is removed from the bud stick and is inserted on to the rootstock. The various steps involved are shown in Fig.8.2. The thickness of stock and scion should be of same size. It has been utilized in ber, peach and mulberry because the newly emerged shoots from the heavily pruned plants are capable of giving such buds for budding, which can be easily separated. In this method since the stock is completely girdled and if the bud fails to heal in, the stock above the ring may eventually die.
- e) **Forkert budding:** In forkert budding, the stock is prepared by giving two vertical cuts and a transverse cut above the vertical cuts to join them. The bark is removed carefully along the cuts, so the flap of bark hangs down. The scion is prepared in a fashion similar to patch budding, having the size similar to cuts made on the stock. The scion is then slipped into the exposed portion of the stock and the flap is drawn over the inserted bud patch. It is then tied with a suitable wrapping

material. After successful growth of bud, the portion of stock above the union is removed carefully.

- f) **Flute budding:** In flute budding, the patch of bark is removed from the stock in such a way that it almost completely encircles the stock except with a narrow bark connection between the upper and lower cuts on the stock. A similar patch of bark is removed from the bud stick containing a healthy bud. The shield containing the bud is then inserted in the vacant area of the stock and the shield should fit tightly on the stock. It is then wrapped with suitable wrapping material, leaving the bud uncovered. The other procedure is same as in patch budding. Because of the presence of a narrow connecting strip of bark on the stock, it remains alive even if the bud fails to sprout.
- g) **I-budding:** In I-budding, the bud patch is cut in the form of a rectangle or square like patch budding. With the same parallel-bladed knife, two transverse cuts are made through the bark of the rootstock. These are joined at their centre by a single vertical cut to produce the shape of letter-I. The two flaps of the bark can then be raised to insert the bud patch beneath them. A better fit may occur if the side edges of the bud patch are slanted. While tying the I-bud, one should ensure that the bud patch does not buckle outward and leave a space between the rootstock. I-budding is the most appropriate method of propagation when the bark of the rootstock is much thicker than that of the bud stick. In such cases, if the patch buds are used, considerable paring down of the bark of the rootstock around the patch would be necessary.
- h) **Micro-budding:** Micro-budding is used successfully for propagating citrus particularly in Australia. It is similar to “T” budding except that the shield (bud piece) utilized is thin and tiny like “T-budding”; the micro-budding is also not done under aseptic conditions. The petiole is cut off just above the bud and then bud is removed from the bud stick by a flap cut just underneath the bud. Thus, only the buds are utilized in micro-budding. In stock an inverted “T” cut is made and the tiny shield containing the bud is inserted in it and later tied with a thin plastic tape. The tape may be removed soon (15-20 days) after the healing has taken place.

Topic 9 Factors influencing Rooting of Cutting and Layering

The ability of rooting in different plant species varies widely. The rooting of cuttings is influenced by several internal and external factors, which include

1. Physiological condition of the mother plant

- Physiological condition of the mother plant can exert great influence on the rooting of cuttings. For example, cuttings taken from the plants deficient in water often show reduced rooting.
- Cuttings root better if taken in early morning hours, when plants are in turgid condition, than the one taken from water deficient plants.
- Similarly, the nutrient status of stock plant also exerts a strong influence on the development of roots in cuttings. It has been reported in apple and raspberry that their cuttings root and sprout better when taken in fall when carbohydrate content was the highest and survival was very poor in summer, the time when carbohydrate storage was less.
- Plants supplied with excessive nitrogen have luxuriant growth but cuttings taken from such plants produce poor roots. Thus, low N and high CHO balance in stock plant is necessary for better rooting. To obtain better rooting, blocking of CHO reserves by girdling has been found very useful as it blocks the downward movement of CHO, hormones and other root-promoting factors.
- Internal factors of plant such as, auxin level, rooting co-factors and CHO etc. also affect the root initiation process of cuttings. Thus, the girdling of shoots prior to their use as cuttings is useful for stimulation of rooting.

2. Juvenility factors

- In most plant species, the cuttings taken from juvenile (young) growth phase often root better than from adult phase. It implies that the ability of cuttings to form adventitious roots decrease with the increase in the age of the plant
- In fruit plants like mango, apple, apricot, olive, citrus, pear, peach etc, the cuttings often root better if they are taken in juvenile phase. Cuttings taken from old non-bearing plants rarely root better
- It is proven fact that plants produce more rooting inhibitors with the growing age and thus inhibit root initiation process in the cuttings taken from them.
- The phenolic level also decreases with the increase in the age of plant.
- The juvenility in mature plants can be induced artificially by heading back, spraying GA₃, forcing of sphaeroblasts, by rooting, grafting adult forms on to juvenile from and /or through dis-budding.

3. Type of the wood

- A proper choice of wood is an important factor because the wrong choice may be quite harmful as it may result in complete failure of rooting of cuttings. In general, the capacity of the cuttings to root depends upon the type of wood taken by the propagator.
- Usually, the cutting taken from the lateral shoots root better than the ones taken from terminal shoots. It is particularly true with plum, spruce and pines etc. It may be due to the reason that the lateral shoots have more stored food (CHO), which facilitates better rooting in the cuttings.
- In hardwood cutting, more roots are developed in the basal portion of the shoot than the cuttings taken from mid or top of the shoot, because accumulation of CHO and root promoting substances are in higher concentration at the basal parts.
- Similarly, formation of some root initials in the basal portions probably under the influence of root promoting substances from bud and leaves may be responsible for it.
- The cuttings taken from vegetative shoot root better than flowering shoots, perhaps due to presence of high level of rooting co-factors (hormones) in vegetative shoots.

4. Presence of leaves and buds

- In most species, the rooting process is inhibited if leaves and buds are removed from the cuttings. The promoting effect of leaves and buds in root initiation is due to the fact that these are the primary source of carbohydrate and auxin synthesis and other root promoting co-factors in the plants.
- These root promoting co-factors are transported by the leaves and buds to the basal portion of the cuttings for root initiation.

- The effect of buds on rooting may vary with the time of the year. Usually, growing buds promote rooting and dormant buds inhibit it. Presence of buds in easy-to-root species stimulates rooting but in difficult-to-root species, rooting is inhibited.
- The promoting effect of buds on rooting during dormancy period may be due to the higher auxin and low inhibitor supply to the basal portion of the cutting. However, in some species, the leaves are removed to reduce the loss of water due to transpiration.

5. Presence of viruses

□

6. Position of the basal cut in the cutting:

In some plants, rooting is better when the cut is made just above or below the node, in others rooting is better if cut is made at the node and still in others, and position of the cut has no effect on root initiation process.

7. Season

- In some cases, season of the year, when cuttings are made has significant influence on rooting of the cutting.
- In deciduous plants, the hardwood cuttings could be made in dormant season and semi hard wood or softwood cuttings in the growing season.
- The evergreen plants usually have one or more flushes of growth in a year and thus cuttings should be prepared at various times in relation to growth flush but more especially in spring or later fall, depending upon the species. For examples, the leafy cuttings of olive root better under mist if produced during

late spring and summer but rooting is completely inhibited if taken in midwinter.

- For softwood cuttings of deciduous plants, the best rooting is obtained if the cuttings are prepared in spring, when leaves are fully expanded and shoots have attained some degree of maturity.
- For best results in broad-leaved evergreen plants, cuttings should be prepared after a flush of growth has been completed and wood is partially matured, particularly during spring to late fall.
- Similarly, in narrow-leaved evergreen plants, the results are better if cuttings are prepared during late fall to late winter.

8. Treatment of cuttings: Various treatments have been demonstrated to treat cuttings before planting for root initiation. These treatments include use of growth regulators, mineral nutrient, fungicides, wounding, etiolation and girdling.

i) Use of growth regulators: Among growth regulators, IBA has been found to be the most ideal compound for promoting rooting in cuttings in most of the plant species. The concentration varies from plant-to-plant and type of cuttings used. In addition NAA, 2, 4-D and 2, 4, 5-T are the other root promoting auxin. However, 2, 4-D and 2,4, 5-T are potent weed killers and may inhibit shoot-development in certain species. Their concentration and degree of success also depend upon species and type of cuttings used. IAA is highly sensitive to light and is destroyed by strong sunlight, though NAA and 2, 4-D are stable.

ii) Mineral nutrients: Treatment of cuttings with nitrogenous compounds (organic and inorganic) usually promotes rooting of cuttings in several plants. Among different organic forms of nitrogen, asparagines and adenine are most effective. Boron also plays important role in rooting process of certain plant species. It promotes root growth rather than root initiation. The combination of nutrients (N,

B) with auxin (IBA) is the most effective treatment for root initiation and development process in many plant species.

iii) Fungicides: In some instances, the rooting of cuttings initiate at better rate but their survival is low because these are attacked by pathogens. Thus, treatment of cuttings before planting with fungicides like captan and benomyl, gives better results. The fungicides may be used as powder dip, following IBA treatment or these may be mixed with IBA powder before treatment. Captan is more suitable, because it does not decompose easily and has long residual effect. **iv) Wounding:** Wounding is helpful in cuttings having old wood at the base. Wounding promotes rooting in cuttings in several ways:

- a) It tears sclerenchyma rings of tough cells in cortex, exterior to the point of origin.
- b) It helps in better absorption of moisture, growth substances from the rooting medium.
- c) Due to higher excretion of hormones in the wounded area, respiration rate is increased
- d) Division of cells in the wounded area and adjacent cells is faster
- e) Wounded cells release ethylene, which act as root promoting hormone All these conditions induced by wounding help in better root-initiation process.

v) Etiolation treatment: Etiolating is the oldest horticultural practice in which light is excluded from the plant or its part for sometime during the growing season. It is believed that exclusion of light reduces the photodecomposition of naturally occurring auxins and resulting in accumulation of auxins which ultimately synergies the root-initiation process. In etiolation, the basal portion of the newly emerged shoots is kept under complete darkness by covering them with a black polythene

cover and the terminal portion is allowed to grow in normal condition. After sufficient time, depending upon the species, the shoot is cut down, its basal portion is treated with auxin (IBA) and cuttings so prepared are planted in the nursery. The trench, mound and stool methods of propagation in which basal portion of the shoots are kept in darkness by soil cover are based on the principle of etiolation. Etiolation is useful in difficult-to-root plant species like mango, jackfruit and avocado.

vi) Girdling: In case of girdling a ring of bark 2.5 to 3.0 cm is removed from the base of the shoot, which is to be used for the preparation of cuttings. It can also be done by making a notch or tying a wire around the shoot. This process helps to initiate the rooting process much early in some plant species. Girdling basically blocks the downward movement of carbohydrates, hormones and other root promoting factors. When to girdle and from where to girdle, differs widely with different plant species. However, cuttings of mango, litchi, guava, citrus root-better if the shoots are girdled 10-15 days before preparing of cuttings from them.

9. Environmental conditions: Environmental conditions like availability of water, light, temperature and rooting media may also affect the root initiation process in cuttings. Effect of different environmental factors is summarized as under:

i) Water condition: Loss of water through leaves need to be regulated by keeping optimum number of leaves in leafy cuttings. Similarly, loss of water from the leaves should be reduced by placing the cuttings in covered propagation frames having automatic humidifiers and ventilation system, laying thin layer of polyethylene cover over the beds of leafy cuttings by using mist propagation.

ii) Temperature: Temperature is considered as one of the most important environmental factors which govern the physiological processes occurring in plant system. A day temperature of 21-24⁰C and night temperature of 13-15⁰C are

considered quite satisfactory for rooting of cuttings in most plant species. Very high or low temperature may inhibit root initiation process in the cuttings.

iii) Light: Light effects in rooting of cuttings may be due to its intensity, day length or light quality. Usually, the rooting is better in cuttings taken from stock plants grown at a low light intensity than the ones obtained from plants grown at a higher

light intensity. The photoperiod under which the stock plants are grown, may also exert an influence on the rooting of cuttings taken from them. Some plants manufacture better carbohydrates under short-day conditions and others at longday or day-neutral conditions. The orange red light of spectrum seems to favour rooting of cutting than the blue region. Further, red light (680 nm) has more inhibitory influence on rooting than the blue or far red light spectrum. **iv) Rooting medium:** An ideal medium must provide sufficient porosity to allow air and, should have better water holding capacity. It should be well drained and free from pathogens. Medium must perform three important functions □ It should hold the cutting properly.

- It should provide adequate moisture to the cuttings.
- It should permit free air passage to the base of the cuttings.

Some cuttings when rooted in sand produce long, un-branched and brittle roots but produce well branched, slender and flexible roots in perlite or peat mixtures. Generally pH near 7.0 is considered ideal for rooting process in the cuttings. The level of exchangeable calcium in the rooting medium, especially peat moss should not be high as it may also affect rooting process adversely.

Topic 10 Graft Incompatibility

The inability of two different plant parts grafted or budded together, to produce a successful union and to develop into a composite plant is termed as 'graft incompatibility'. Graft failure can be caused by anatomical mismatching, poor craftsmanship, adverse environmental conditions, diseases and graft incompatibility. Graft incompatibility occurs because of following reasons:

- Adverse physiological responses between the grafting partners
- Virus or phytoplasma transmission
- Anatomical abnormalities of vascular tissue in the callus bridge.

External symptoms of graft incompatibility

Graft union malformation resulting from incompatibility can usually be correlated with certain external symptoms. The following symptoms have been associated with incompatible graft combination:

- I. Failure to form a successful graft or bud union in a high percentage of cases.
- II. Yellowing of foliage in the latter part of the growing season, followed by an early defoliation, decline in vegetative growth, appearance of shoot die-back, and general ill health of the tree
- III. Premature death of the trees, which may live for only a year or two in the nursery.
- IV. Marked difference in growth rate of the scion and rootstock
- V. Over growth at, above or below the graft union
- VI. Suckering of rootstock
- VII. Breakdown of graft union cleanly

Types of Incompatibility

Graft incompatibility is of two types 1) Localized (non-translocated) incompatibility and 2). Translocated incompatibility.

Localized (non-translocated) incompatibility

- Graft combination in which a mutually compatible interstock overcomes the incompatibility of the scion and rootstock.
- The interstock prevents physical contact of the rootstock and scion and affects the physiology of the normally incompatible scion and rootstock.
- A good example is Bartlett pear on quince rootstock. When mutually compatible Old Home or (Beurre Hardy) is used as inter-stock the three graft combination is completely compatible and satisfactorily tree growth takes place.

Translocated incompatibility

- It includes certain graft/rootstock combination in which the insertion of a mutually compatible interstock does not overcome incompatibility.
- This can be recognized by the development of a brown line or necrotic area in the bark at the rootstock interface.
- Consequently carbohydrate movement from the scion to the rootstock is restricted at the graft union.
- Hale's Early Peach grafted onto Myrobalan-B plum rootstock is an example of translocated incompatibility.
- The tissues are distorted and a weak union forms. Abnormal quantities of starch accumulate at the base of the peach scion. If the mutually compatible 'Brompton' plum is used as interstock between Hale's Early peach and Myrobalan- B rootstock the incompatibility systems persists, with an accumulation of starch in the Brompton inter-stock.
- Nonpareil almond on Mariana '2624' plum rootstock shows complete phloem breakdown, although the xylem tissue connections are quite satisfactory. In

contrast Texas almond on Mariana- 2624 plum rootstock produces a compatible combination. Inserting 15 cm piece of 'Texas' almond as an inter-stock between the Nonpareil almond and the incompatibility between these two component.

Delayed incompatibility

- Some apricot cultivars grafted onto Myrobalan plum rootstock will not break at the graft union until the trees are full grown and bearing crops.
- Graft incompatibility can take as long as 20 years to occur. Other examples are conifers, oaks and cherry on *pazza* (*Prunus cerasoides*) rootstocks. **Pathogen**

induced incompatibility

- These graft union failures resemble incompatibility symptoms, but are due to pathogens like virus or phytoplasma. *Tristeza* is an important example of virus induced incompatibility in citrus. Failure of sweet orange (*Citrus sinensis*) budded onto sour orange (*Citrus aurantium*) rootstock is due to toxic substance from sweet orange, but lethal to the sour orange rootstock.
- Other examples are black line in English walnut (*Juglans regia*), which infects susceptible walnut rootstocks, apple union necrosis and decline and brown line of prune, which is caused by tomato mosaic virus that is transmitted by soilborne nematodes to the rootstocks and then to the graft union.
- Pear decline is due to a phytoplasma, rather than a virus.

Causes and mechanism of incompatibility

The large number of different genotypes that can be combined by grafting produces a wide range of different physiological, biochemical and anatomical interaction when grafted. Several hypotheses have been advanced in attempts to explain incompatibility.

A. Physiological and biochemical mechanism

- In case of incompatible combination of certain pear cultivars on quince rootstock, the incompatibility is caused by a cyanogenic glucoside, prunasin, normally found in quince, but not in pear tissues.
- Prunasin is translocated from the quince into the phloem of the pear. The pear tissues, breakdown the prunasin in the region of the graft union, with hydrocyanic acid as one of the decomposition products.
- The presence of the hydrocyanic acids leads to a lack of cambial activity at the graft union, with pronounced anatomical disturbances in the phloem and xylem at the resulting union. The phloem tissues are gradually destroyed at and above the graft union.
- Conduction of water and material is seriously reduced in both xylem and phloem. The presence of cyanogenic glucosides in woody plants is restricted to a relatively few genera. Hence, this relation cannot be considered a universal cause of graft-incompatibility.

B. **Modification of cells and tissue:**

The lignification process of cell in walls is important in the formation of strong union in pear-quince grafts. Adjoining cell walls in the graft union of incompatible combination contain no lignin and are interlocked only by cellulose fibres. With incompatible apricot/plum (*Prunus*) grafts some callus differentiation into cambium and vascular tissue does occur, however, a large portion of the callus never differentiates. The union that occurs is mechanically weak.

C. **Cellular recognition:** “Cellular recognition is defined as the union of specific cellular groups on the surface of the interacting cells that results in specific defined response e.g. pollen-stigma compatibility recognition responses with glycoprotein surface receptors in flowering plants.”

It has been postulated that the critical event deciding compatible and incompatible grafts may occur when the callus cell first touch. There may be cellular recognition that must occur in successful graft union formation.

Predicting incompatible combination: To be able to predict in advance of grafting whether or not the components of the proposed scion-stock combinations are compatible would be of tremendous value. The different methods used are: 1)

Electrophoresis test: This test is being used for testing cambial peroxidase banding pattern of the scion and rootstock of chestnut, oak and maple. Peroxidases mediate lignin production. Increased peroxidase activity occurs in incompatible grafts as compared to compatible auto grafts and adjacent rootstock and scion cells must produce similar lignin and have identical peroxidase enzyme pattern to ensure the development of a functional vascular system across the graft union. With electrophoresis if the peroxidase bands match the combination may be compatible, if they do not match incompatible may be predicted.

2) **Magnetic resonance imaging (MRI):** Magnetic resonance imaging can be used to detect vascular discontinuity in bud union of apple. High magnetic resonance imaging signal intensity is associated with bound water in live tissue and the establishment of vascular continuity between the rootstock and scion. Magnetic resonance imaging may be useful for detecting graft incompatibility caused by poor vascular connection.

Correcting incompatible combination: This is not a practical, cost-effective way to correct large scale planting of incompatible grafting partners. Plants would normally be rogued and discarded. With perhaps some isolated specimen trees of value, if the incompatibility is discovered before the tree die or break off at the union, a bridge graft could be done with a mutually compatible rootstock. Another costly alternative is to inarch with seedling of a compatible rootstock. The marched seedlings would eventually become the main root system.

Stock -Scion Relationships

A grafted or budded plant can produce unusual growth patterns which may be different from what would have occurred if each component part of a graftage viz., rootstock and scion was grown separately or when it is grafted or budded in other types of rootstocks. Some of these have major horticultural value. This varying aspect of rootstocks will influence the performance of a scion cultivar or vice versa is known as stock-scion relationship.

A. Effect of stocks on scion cultivars

1. Size and growth habit:

- In apple, rootstocks can be classified as dwarf, semi-dwarf, vigorous and very vigorous rootstocks based on their effect on a scion cultivar.
- If a scion is grafted on dwarf rootstocks (e.g. M.9), the scion grows less vigorously and remain dwarf only. On the other hand if the same scion is grafted on a very' vigorous rootstock (e.g. M2) the scion grows very vigorously.
- In citrus, trifoliate orange is considered to be the most dwarfing rootstock for grape and sweet oranges. On the other hand, in mango, all plants of a given variety are known to have the same characteristic canopy shape of variety despite the rootstocks being of seedling origin.
- But mango rootstocks like Kalapade, Olour have been found to impart dwarfness in the scion cultivars. Guava cultivars grafted on *Psidium pumilum* are found to be dwarf in stature. 'Pusa Srijan' guava rootstock also imparts dwarfness in Allahabad Safeda, a commercial cultivar of guava.

2. Precocity in flowering and fruiting:

- The time taken from planting to fruiting i.e., precocity is influenced by rootstocks. Generally fruit precocity is associated with dwarfing rootstocks and slowness to fruiting with vigorous rootstocks.

- Mandarin, when grafted on *Citrus jambhiri* rootstock is precocious than those grafted on sweet orange or orange or acid lime rootstocks.

3. Fruit set and yield

- The rootstocks directly influence on the production of flower and setting fruits in oriental Persimmon (*Diospyros kaki* cv. Hachiya). When it is grafted on *D. lotus*, it produces more flowers but only few mature into fruits. However, when *D. kaki* is used as the rootstock, the fruit set is very high.
- The influence of rootstock on the yield performance of cultivar has been well documented in many fruit crops. Acid limes budded on rough lemon register nearly 70 per cent increased yield than those budded on troyer citrange, Rangpur lime or its own rootstock. Sweet orange var. Sathugudi budded on Kichili rootstock gave higher yield than on Jambhiri or on its own seedling.

4. Fruit size and quality

- Sathugudi sweet oranges grafted on Gajanimma rootstocks produced large but poor quality fruits while on its own roots they produced fruits with high juice content and quality.
- The physiological disorder 'granulation' in sweet orange is very low if on Cleopatra mandarin seedlings, on the other hand, rough lemon seedling stocks induced maximum granulation.
- The physiological disorder black end in Bartlett Pear did not appear if *Pyrus communis* was used as the rootstock. When *Pyrus pyrifolia* was used as the rootstock this disorder appeared, affecting fruit quality.

5. Nutrient status of scion

Rootstocks do influence the nutrient status of scion also. Sathugudi orange trees have a better nutrient status of all nutrients in the leaves when it is budded on *C. volkarimariana* root stock than on its own rootstock or Cleopatra mandarin stocks.

6. Winter hardiness

Young grapefruit trees on Rangpur lime withstand winter injury better than on rough lemon or sour orange. Sweet oranges and mandarins on trifoliolate stocks were more cold hardy. 7. Disease resistance

In citrus, considerable variability exists among the rootstocks in their response to diseases and nematodes. For instance, rough lemon rootstock is tolerant to *tristeza*, xyloporosis and exocortis but is susceptible to gummosis and nematode. On the other hand, troyer citrange is tolerant to gummosis but susceptible to exocortis virus disease. Similarly, guava varieties grafted on Chinese guava.

(*Psidium frie-drichsthalianum*) resist wilt diseases and nematodes.

8. Ability to resist soil adverse conditions

Among the citrus rootstocks, foliate orange exhibits poor ability, while sweet oranges, sour orange, rangpur lime rootstocks exhibit moderate ability to resist excess salts in the soil. Similarly, in pome fruits, variation exists among rootstocks to resist excess soil moisture or excess boron in the soil. Myrobalan plum rootstocks generally tolerate excess boron and moisture than Marianna plum root or other rootstocks' viz., peach, apricot or almond.

B. Effect of scion on rootstock

1. Vigour of the rootstocks:

In apple, it has been found that if apple seedlings were budded with the 'Red Astrachan' apple, the rootstock produced a very fibrous root system with few tap

roots. On the other hand if scion 'Goldenburg' was budded on the seedlings, they produced two or three pronged deep roots without fibrous root system. In citrus, if the scion cultivar is less vigorous than the rootstock, the rate of growth and the ultimate size of the tree is more determined by the scion rather than the rootstocks.

2. Cold hardiness of the rootstock

Cold hardiness of citrus roots is affected by the scion cultivar. Sour orange seedlings budded to 'Eureka' suffered much more from winter injury than the unbudded seedlings.

3. Precocity in flowering

Young mango rootstock seedlings (6 months to one year old) were found to put forth inflorescence when the branches from old trees are inarched which can be attributed to the influence of scion on the rootstock.

Factors Influencing the healing of graft union

1. **Incompatibility:** Certain rootstocks and scions are incompatible, therefore the graft union between these two will not normally take place.
2. **Kind of plant:** Some species like oaks are difficult to graft, but apple and pears are very easy in producing a successful graft union.
3. **Environmental factors during and following grafting:** There are certain environmental requirements which must be met for callus tissues to develop and heal the graft union.

- a) Temperature has a pronounced effect on the production of callus tissues. An optimum temperature is essential for production of callus, In most of the temperate fruit crops callus production is retarded after 42.5° C.
- b) Relative humidity must be high is maintaining a film of water against the callusing surface is essential to prevent these delicate thin walled parenchymatous cells from drying.



Topic 11 Plant Propagation Structures

Introduction

The structures which facilitate propagation of plants are called propagation structures. Propagation structures are required for propagating plants by seed, cuttings and grafting. Propagation structures are of two types; i) The first type a structure with temperature control and ample light, such as a green house, modified quonset house, or hot bed-where seeds can be germinated or cuttings are rooted or tissues culture micro-plants are rooted and acclimatized and the ii) The unit is structure into which the younger, tender plants can be moved for hardening, preparatory to transplanting out-of-doors. Cold frames, low polyethylene tunnels or sun tunnels covered by saran cloth and lath-houses are useful for this purpose.

Greenhouses

Greenhouse has been used long back by horticulturists as a mean of forcing rapid growth of plants and extending the growing season particularly in colder areas. These are being used for whole sale production and propagation of floricultural plants, nursery stock of fruit crops and vegetable crops. A greenhouse greatly extends the variety and scope of propagation. Many kinds of green houses are used for propagation but the most suitable type is the one that admits the maximum amount of light. The schematic diagram of poly house installation with related component. This is important, particularly where most of the propagation is done in late winter and early spring. Good light conditions are essential for the steady growth of the seedlings. Experiments have shown that a greenhouse that runs from east-to-west is best for better light penetration in winter and early spring, and consequently preferable for raising seedlings at this time of the year. Moreover, it is important that

the green houses should be well away from any kind of shade such as a tree or building, including other greenhouse. Some shelter, however, from north to northeast winds is desirable. These glasshouses may be plastic polyethylene covered or made from fiberglass. Modern greenhouses are well equipped with elaborate structures and have precise control on temperature, light intensity and humidity. The size and type of greenhouses, primarily depends upon the need of the plant propagator. Glass covered greenhouses are expensive but they have long life. However, for short-term benefits, plastic covered green houses can also be made. Two types of plastics are available for the construction, polyethylene and fiberglass. Both are lightweight and inexpensive as compared to glass. Plastic covered greenhouses are lighter than glass covered ones but there is very high increase in humidity in such houses, especially in winters, which results in undesirable water drops on the plants. It can however be overcome by making adequate ventilation. Polyvinyl chloride (PVC) has also been used in construction of greenhouses but it tends to darken prematurely in sunlight. In India, construction of temporarily low-cost poly-houses is in fashion for raising nursery of fruit plant in off season. Such low cost greenhouses are constructed either on wood or metal framework and are covered with polyethylene sheet of 0.10 to 0.15mm thickness, which is resistant to ultra-violet rays. These houses are equipped with thermostat, cooler or an air conditioner or humidifier etc for rigid control on temperature and humidity. Greenhouses made from fiberglass sheet are more durable than the polythene houses, but are quite expensive. In greenhouses, two types of beds are used for raising /growing of seedlings. In greenhouses, the beds may either be prepared on ground itself or raised beds or bench type beds are used. Greenhouse structures vary from elementary home constructed to elaborate commercial installations. Commercial greenhouses are usually independent



structures of even span, gable-roof construction, well proportioned so that the space is well utilized for convenient walk ways and propagating benches. On commercial scale several greenhouses units are often attached side-by-side for eliminating the cost of conversing the adjoining walls with glass or polyethylene. The heating and cooling equipment is more economical to install and operate, as large area can be shared by the same equipment. Greenhouse construction begins with a metal framework, to which metal rash bars are fastened to support panels of glass or some type of plastic materials. Now a day's metal pre-fabricated green house with pre-bolted trusses are available from several manufacturers. The two most common structural materials for green houses are steel and aluminum. Most greenhouses are made from galvanized steel, which is cheaper, stronger and lighter.

Heating and cooling system in greenhouses: Ventilation, to provide air movement and air exchange with the outside, is necessary in all green houses to aid in controlling temperature and humidity. The attempt of sloppy green houses near the mud houses in Ladak is an attempt in these directions. The heat can be conserved by proving sealed polyethylene sheeting outside green houses, glass or fibre glasses.

Environmental control: Greenhouses can be cooled mechanically in the summer by use of large evaporative cooling units. The “pad and fan” system is installed at one side of a green house with large exhaust fans at the other end. Fog or sprinklers can be used to cool green houses and maintain humidity but it is costlier than pad fan cooling. A maximum night temperature of 13 to 15.5⁰ C and a day temperature of 24⁰ C are generally set to start the heaters and fans; respectively. Spraying of green house with whitewash in summer and opening and cooling side and ridge vents with

a crank to control temperature and by turning on steam valves at night, whereas humidity is increased by spraying the walls and benches by hand at least once a day.

- i) **Analog control:** In this system proportioning thermostats or electric sensors are used to gather temperature information. Analog controls are costlier than thermostats, but offer better performance.
- ii) **Computerized environment control:** The amplifiers and logic circuit analogs have now been replaced by computerized environmental system, which involves microprocessor, which gathers information on a variety of sensors like temperature, humidity, light intensity, wind directions etc. to provide more precision. Although more costly than thermostats or analogs but computer controls offer significant energy and labour saving and increases production efficiency in propagation. The deviations from the present levels of temperature and humidity can trigger alarms by the computer.

Green house covering materials: The covering materials used for construction of green houses include glass, polyethylene, UV-stabilized polythene, acrylic, polycarbonate and fibreglass. The glass covered greenhouses are expensive but for a permanent long term installation under low light winter conditions because glass has superior light transmitting properties and less expensive relative humidity problems. Polyethylene materials are light weight and relatively less expensive compared to glass. Being light in weight, permits a less expensive supportive frame work than is required for glass. Polyethylene has relatively short life than glass. The UV-stabilized sheets can last for 3-4 years. Polyethylene having a thickness of 100-200 micron is generally used. The acrylic is highly weather resistant and does not

yellow with age, has excellent light transmission properties and retains twice the heat of glass, but it is more costly and brittle.

Polycarbonate: It is probably, the most widely used structures sheet material today. This material is similar to acrylic in heat retention properties, with 90% light transmission of glass. It is light in weight 1/6th of glass and easy to install. It is resistant to impact. Polycarbonate textured surface diffuses light and reduces condensation drip. For providing rigid panels fiber glass is used widely for construction of greenhouse. It transmits 80-90% of light. New materials are continuously coming onto the market, for constructing better glass houses.

Hot frames (Hot beds)

A hotbed is a bed of soil enclosed in a glass or plastic frame. It is heated by manure, electricity, steam, or hot-water pipes. Hotbeds are used for forcing plants or for raising early seedlings. Instead of relying on outside sources of supply for seedlings, you can grow vegetables and flowers best suited to your own garden. Seeds may be started in a heated bed weeks or months before they can be sown out of doors. At the proper time the hotbeds can be converted into a cold frame for hardening. Hot beds are small low structures, used for propagation of nursery plants under controlled conditions. Hot beds can be used throughout the years, except in areas with severe winters, where their use can be restricted to spring, summer and fall. Another form of a hot bed is a heated, low polythene tunnels or sun tunnels that is made from hooped metal tubing or bent PVC pipe, which is covered with polyethylene. The standard size of hot frame is 0.9 by 1.8 m. If polyethylene is used as the covering, any convenient dimensions can be used. Plastic and PVC tubing with recirculation of hot water are quite satisfactory for providing bottom heat in hot beds. Seedlings can

be started and leafy cutting rooted in hot beds early in the season. For small propagation operations, hot beds structures are suitable for producing many thousands of nursery plants, without the higher construction expenditure for larger, propagation houses.



[CLICK HERE to Join AgroMind Telegram Channel](#)

Cold frames

A cold frame is a bottomless box with a removable top. It is used to protect small plants from wind and low temperatures. No artificial heat or manure is used inside a true cold frame but many gardeners experiment with a variety of soil conditions. They utilize the sun's heat. The soil inside the box is heated during the day and gives off its heat at night to keep the plants warm. The frame may be banked with straw or manure to insulate it from the outside air and to retain heat. Cold frames include not only low polyethylene-covered wood frames or unheated sun tunnels that people cannot walk within, but also low-cost, poly-covered hoop houses. The covered frames should fit tightly in order to retain heat and obtain high humidity. Cold frames should be placed in locations protected from wind. The primary use of cold frames is in conditioning or hardening of rooted cuttings or young seedlings prior to field, nursery row or container planting. Cold frames can be used for starting new plants in late spring. Low-cost cold frame construction is the same as for hot beds, except that no provision is made for supplying bottom heat. In these structures, only the heat of the sun is retained by the transparent or opaque, white polyethylene covering. When young, tender plants are first placed in a cold frame, the coverings are generally kept tightly closed to maintain a high humidity but as the plants become adjusted, the sash frames are gradually raised or ends of the hoop house to permit more ventilation and drier conditions. The installation of mist line or irrigation provision in cold frame is essential to maintain humid conditions. During sunny days, high temperature condition can be controlled by providing ventilation and shading.

Lath houses

Lath (lath - thin strip of wood) or shade houses provide outdoor shade and protect container-grown plants from high summer temperature and high light irradiation. They reduce moisture stress and reduce the moisture requirement of plants. Lath houses have many uses in propagation, particularly in conjunction with the hardening off and acclimatization of liner plants prior to transplanting and for maintenance of shade requiring plants. In mild climates, they are used for propagation, along with a mist facility and can be used as overwintering structures for liner plants. However, snow load can cause problems in higher latitude regions. Lath house may be constructed with many kind of materials, although aluminum prefabricated lath house are available, but may be more costly than wooden structure. Most lath houses are covered with high density, woven plastic material such as saran, poly propylene fabric and UV-treated polyethylene shade cloth, which come in varying shade percentage and colours. These materials are available in different densities, thus allowing lower irradiance of light, such as 50 percent sunlight, to the plants. They are light weight and can be fastened to supporting posts.

Propagation frames

Sometimes in a greenhouse, the humidity is not enough to allow satisfactory rooting in the leaf cuttings. In such cases, enclosed frames covered with glass or plastic material may be used for rooting of cutting. These frames are useful only on grafted plants as these retain high humidity during the process of healing. Large inverted glass can also be kept over a container having cuttings. Though, high humidity is required in such frames but ventilation and shading is necessary after the rooting process has started in the cutting. Warm and humid conditions inside these structures provide excellent environment for growth of pathogenic organisms, which may

infect the propagation material. It is therefore, necessary to maintain cleanliness and proper sanitation in such structures.

Net house

Net houses are widely used as propagation structures in tropical areas, where artificial heating is not required and artificial cooling is expensive. In these areas, net houses may be constructed with roofs covered with glass or plastic film and its sides are covered with wire net. It provides necessary ventilation and maintains an ideal temperature for germination of seeds and subsequent growth of the seedlings. The roof of net house may be covered with gunny cloth or even with live plant creeper to cut off the solar radiant energy and to keep the house cool. Net house can be constructed as per the need of the propagator and therefore its size varies with the requirements of the nurserymen.

Bottom heat box

It is a simple box for promoting rooting of cutting in difficult-to-root fruit plants like mango and guava. It consists of two chambers made from galvanized iron sheets. The outer chamber has a height of 70cm with 46cm width and the inner chamber has a height of 68cm and width of 44cm. The space between the two chambers is filled with glass wool for heat insulation. Another chamber is fitted inside the inner chamber with the height of 35cm fitted with two electric bulbs at the bottom for providing heat to the cutting. The innermost chamber is filled with soil mixture or any other propagation medium and the cuttings are inserted in it. Two electric bulbs of 100 watt capacity are fitted at the bottom of the chamber to provide heat and light to the cuttings. Similarly, the temperature in the box is maintained and controlled automatically by a thermostat fitted at the bottom of the chamber. The most ideal

temperature to be maintained in the box is $30 \pm 2^{\circ}\text{C}$ because at this temperature, cuttings of mango, walnut, olive and guava root easily and profusely. The initiation of rooting in cutting varies from species-to-species but in general, it takes 1-2 months for proper development of the roots

Mist propagation unit

The rooting of softwood leafy cutting under spray or mist is a technique now widely used by nurserymen and other plant propagators throughout the world. The aim of misting is to maintain humidity by a continuous film of water on the leaves, thus reducing transpiration and keeping the cutting turgid until rooting take place. In this way, leafy cuttings can be fully exposed to light and air because humidity remains high and prevents damage even from bright sunshine. Mist also prevents disease infection in the cuttings by way of washing off fungus spores before they attack the tissues. While the leaves in this process must be kept continuously moist, it is important that only minimum water should be used. This is because excessive water leaches out nutrients from the compost, which may cause starvation. Moreover, a directly injurious effect on the cutting may occur from over watering. Hence, it is necessary to utilize nozzles capable of producing a very fine mist. A small mist propagating units are mostly used by small farmers, whereas, highly advanced impermanent units are used by the commercial nurserymen in advanced countries. Mist propagation units are used for propagation of “difficult to root, cutting in most advanced countries. Mist beds are constructed within a greenhouse. A fine mist is sprayed intermittently over the cutting at regular intervals during day and night. The mist unit is controlled by a time clock, operating a magnetic solenoid valve and is set in a way to turn on the mist for 3-5 seconds to wet the leaves and turn off for some time and when the leaves are dry. The mist is again turned on. In general, the

mist has 5 control mechanisms. Timer, electronic leaf, thermostat and timer, screen balance and photoelectric cell. The two types of timers are used in a mist unit, one turn on in the morning and off at night and the second operate during day hours to produce an intermittent mist, usually 6 seconds “on” and 90 seconds “off”. In electronic leaf, a plastic with two terminals is placed under the mist along with cuttings, the alternate drying and wetting of the terminal breaks of the current, which in turn control the solenoid valve. A thermostat controls the temperature of the mist. In screen balance control mechanisms, stainless steel screen is attached to a lever with mercury switch. When mist is on, water is collected on the screen and when weight of water is more, it trips the mercury switch. The photoelectric controls are based on the relationship between light intensity and transpiration rate. The mist unit can be set up in a glasshouse or in a polyethylene tunnel. Usually, it is set up on the propagation beds with 1.2m width. The layout of the jets is very important. While installing mist propagation until, all the jets should be at equal height. For proper functioning of mist, there must be proper supply of water. The water should have good pressure and it must be free from salts. The optimum pH of water to be used in mist unit is 5.5 to 6.5. Hard water or alkaline water may be avoided as it may block the nozzles of the mist chamber and it may accumulate on the young leaves of the cutting and thus inhibit the growth and development of roots. Further, it is essential that a well drained rooting media should be used and there should be provision for removal of excess water. Similarly, development of blue and green algal growth is very common in mist propagation structure which is considered very harmful to the propagating material and thus every care should be taken to keep mist propagating unit free from any type of algae. After rooting in the mist, hardening of the rooted cutting is important for better success in the field. When cuttings are rooted, misting should not cease abruptly as this may help in drying out of the young plants followed

by scorching, instead, a weaving off process should be adopted in which misting is continued but the number of sprays/days gradually reduce. The way is to shift the rooted cutting to a greenhouse, fog chamber, and frames,



[CLICK HERE to Join AgroMind Telegram Channel](#)

maintained at higher temperature and low relative humidity. After phase-wise hardening only, the rooted cuttings are planted at permanent location or in the nursery.

Growing rooms

A growing room is an insulated building from which natural light is usually excluded. In it, illumination is provided by artificial means. Growing rooms are now widely used commercially for the production of seedlings of bedding plants, tomatoes and cucumbers in most advanced countries. The seedlings are usually grown in trays or pots kept on benches. To save space, the benches are usually installed in tiers being vertically about 2 feet long and 6 inch wide. Each bench is illuminated with 8 feet long 125-watt fluorescent tubes mounted 1 foot 6 inches above the bench. Seven tubes over each bench provide a light intensity of 500 lumens per square feet, which is adequate for bedding plants. However, if plants grown in such houses have higher requirements for light, more fluorescent tubes can be installed over the benches containing the plants. The heat of the tubes usually maintains a temperature of at least 70°F and excessive temperatures are prevented by use of fans installed in building.

The automatic greenhouse

Today, the modern green houses can be almost completely automated thus assisting propagation. For instance, by the use of thermostats, air and bed temperature can be maintained as per the requirement. Similarly, automatic ventilation allows the ventilators to open and close in relation to temperature. Even, automatic systems of irrigation are installed in the modern greenhouses and

Topic 12 Plant Growth Regulators Introduction

Plant growth regulators (PGR) usually are defined as organic compounds, other than nutrients, that affect the physiological processes of growth and development in plants when applied in low concentration. Practically, plant growth regulators can be defined as either natural or synthetic compounds that are applied directly to a target plant to alter its life processes or its structure to improve quality, increase yields or to facilitate harvesting. The term plant hormone, when correctly used is restricted to naturally occurring plant substances. This fall into five classes: auxins, gibberellins, cytokinins, inhibitors and ethylene (gas). The term plant growth regulators include synthetic as well as naturally occurring hormones.

Main functions

Auxins: Cause enlargement of plant cell.

Giberellins: Stimulate cell division, cell elongation or both.

Cytokinins: Stimulate cell division in plants

Inhibitors: Plant hormones that inhibit or retard a physiological or biochemical process in plants.

Rooting and plant propagation

- One of the oldest uses of plant growth regulators has been to initiate or accelerate the rooting of cuttings .
- The best and most commonly used chemical for this purpose is indole butyric acid (IBA), which is decomposed relatively slowly by the auxin-destroying enzyme system in plants. Because this compound also moves very slowly in the plant, much of it is retained near the site of application.
- Another highly active auxin frequently used for root promotion is naphthalene acetic acid (NAA). As NAA is more toxic than IBA, there is a greater danger of injury to treated plants. The amides of both compounds are also effective rooting agents.
- Many phenoxy compounds, including 2,4-D, 2,4,5-T (trichlorophenoxy acetic acid) promote root formation if used at low concentrations. The type of root

systems produced varies with the growth regulators used. These phenoxy acids tend to produce bushy, stunted and thickened roots systems.

- IBA is commercially used as rooting hormone in many horticultural and forest plants including apple, peach ,plum, poplar ,ficus, grapes, kiwifruit, pomegranate, rose, tea, winged bean, rhododendron, egg plant etc.

Methods of Application

There are three major methods of applying growth regulators to stem cuttings for the induction of roots:

1. Quick dip method
2. Prolonged soaking method (Dilute solution soaking method)
3. Powder method
4. Lanolin paste method

1. Quick dip method (Concentrated solution dip)

- In the quick dip method, a concentrated solution varying from 500 to 10,000 ppm (0.05 to 1.0 percent) of auxin in aqueous solution or 50 percent alcohol is prepared, and the basal end (0.5 to 1cm) of the cutting is dipped in it for a short time (usually 3 to 5 seconds sometimes longer).
- The cuttings are then inserted into the rooting medium. Cuttings are most efficiently dipped as a bundle, not one-by-one.
- Many propagators prefer the quick dip compared to a talc application because of consistency of results and application ease.
- Greater rooting and more consistent rooting response have been reported with quick dip method than with talc. Change the solution after use at the end of the day, rather than pouring it back into stock solution.
- On extreme hot days in open areas where evaporation is high, it is best to discard the old solution and add fresh solution several times during the day.
- Stock solution that contains a high percentage of alcohol will retain their activity almost indefinitely if kept clean. One should use rubber or plastic gloves when working with these rooting compounds.

2. Prolonged soaking method

- In this method, the basal end of cuttings are soaked in dilute solution (10 to 500 ppm) for up to 24 hrs just before they are inserted into the rooting medium. The concentration varies from about 20 ppm for easily rooted cuttings to about 200 ppm for the difficult-to-root species.
- During the soaking period, the cuttings should be held at about 20°C, but not placed in the sun.
- This is generally a slow, cumbersome technique and is not commercially popular.
- Due to long duration, there are chances of variability of results, with environmental changes occurring during the soaking period.


3. Powder method

- In this method, the basal ends of cutting are treated with the growth regulators in a carrier-usually a clay or a talc. The concentration of active ingredients in the inert carrier is between 500 to 1000 ppm.
- Talc preparations have the advantage of being easy-to-use. However, uniform rooting may be difficult to obtain, due to variability in the amount of the talc adhering to the base of cutting, the amount of moisture at the base of the cutting, the texture of the stem (i.e. coarse or smooth) and loss of the talc during insertion of the cutting into the propagation medium.
- Talc formulations are generally less effective than IBA in solution at comparable concentration. Seradax-A, B and Rootone are such formulations, which are still popular among the nurserymen.

4. Lanolin paste method

- For preparing hormonal pastes, the required quantity of hormone is weighed accurately and dissolved in a few drops of alcohol.
- The required quantity of lanolin is weighed and heated slightly in a beaker under gentle flame. When the lanolin is slightly liquidified, the dissolved hormone is poured in it.
- The contents are dissolved and mixed thoroughly and allowed to cool down. The paste is ready to use.
- The growth regulators are applied to the girdled portion of a layer or stool in lanolin paste for inducing rooting.

Germination and Dormancy



Giberellic acid is the most potent germination promoter, by breaking seed dormancy in a wide range of species like peach, wild mustard, citrus, rough lemon, trifoliolate orange, sweet orange, beans, peach, chinese cabbage etc. Giberellin occurs at a relatively high concentration in developing seeds but usually drop to a lower level in mature dormant seeds. Giberellins play an important role in the initial enzyme induction, activation of reserve food and certain types of dormancy, including physiological dormancy, photo dormancy and thermo dormancy.

Cytokinin is believed to offset the effect of inhibitors like ABA in germination. It allows giberellic acid to function. Applied cytokinin can also be effective in overcoming thermo dormancy.

Ethylene has been effective in overcoming seed dormancy in snowberry (*Symphoricarops*), honey suckle (*Lonicera*), corn and other cereals, germinating

bean and pea seeds produce ethylene. Ethylene is a natural germination promoting agent for certain kinds of seeds, but has limited role in germination of seeds.

Topic 13

Micropropagation techniques

Introduction

Micropropagation refers to the production of plants from very small plant parts, tissues or cells, grown aseptically in a test tube or containers under controlled nutritional, environmental and aseptic conditions. All the biological principles of micropropagation techniques are based on the phenomenon or totipotency of cell, which implies that a plant cell has the capacity to generate into a full-fledged plant having different organs.

Micropropagation versus other propagation methods: Micropropagation propagation differs from other vegetative propagation methods as:

- A very small plant part (explants) is used as a starting material.
- The explants are maintained in small containers having well defined culture medium.
- Highly aseptic conditions are required.
- A large propagating material is produced in a very short-time.

Applications of Micro Propagation

The various applications of micro propagation are:

1. Rapid rate of multiplication of a plant clonally
2. Production of disease-free and disease resistant plants

3. Induction of mutants and selection of mutants
4. Production of haploids through anther culture
5. Wide hybridization through excised embryo and ovule culture

Principles and Practices

A. Totipotency and plant regeneration:

The term totipotency was coined by German plant physiologist Haberlandt in 1902. This is achieved by excising the explants and placing it on culture medium, which involves the following consecutive events:

- 1) Differentiation of source tissue or organ, as a result of which, all physiological mechanism activate in the cell, which leads to cell division.
- 2) Active cell division in the entire cut surface of the explants, resulting in proliferation of the callus tissue.
- 3) Organization of defined meristems, resulting in formation of shoot or root meristems or both.
- 4) Regeneration and differentiation of new organs through organogenesis or somatic embryogenesis.

B. Axillary bud proliferation

- It is considered a convenient route for micropropagation, because it does not include a callus stage and is considered safe for the preservation of clonal characteristics.
- It has been observed by many workers that a large number of axillary shoot buds grow extensively when shoot-tips or even smaller apical meristems are cultured in an appropriate culture medium, containing higher concentration of cytokinin.
- Both the excision of the explants and the cytokinin rich medium activate the bud, leading to proliferation of many side shoots, which can later be separated for further culture.

C. Organogenesis (Development of organs)

- Organogenesis from explants results in the formation of both shoots and roots.
- Generally shoots are formed first than roots.

- The regeneration of other organs occur later on, either in the same media or after sub-culturing in another medium, supplemented with different concentration of salt under different environmental conditions.

D. Somatic embryogenesis

- Somatic embryogenesis is different from organogenesis in that the regeneration and organization are bipolar i.e. the shoots and root meristems in the explants are formed simultaneously from pre-embryonic masses.
- Differentiation and organization of somatic embryogenesis usually, a two stage culture is involved.
 - First induction of pre-embryonic masses, which is usually favoured by 2,4-D or other auxins and second, by the transfer of the pre-embryonic masses to a differentiation medium in which the somatic embryos fully differentiate into organs.

Stages of Micropropagation

Micro propagation is an integrated process in which cells, tissues or organs of the selected plants are isolated, surface sterilized and incubated in growth promoting, sterile medium and environment to produce a large number of plants. The different stages are:

Stage 0: Selection of mother plant for explants isolation: The mother plant from which explants has to be excised should be

- a.) A certified and true to type representative of the desired species and or cultivar.
- b.) Healthy and free from insect pest and disease
- c.) Should be quite vigorous.

Stage1: Explant establishment in culture medium: During this stage the explant is cultured in a suitable culture medium, preferably agar based media for tissue activation and multiplication.

Stage2: Proliferation and multiplication: In this stage, repeated sub-culturing is done to encourage more proliferation, which largely depends upon the combination of growth regulators. The duration of this stage is unlimited and largely depends on the choice of propagator.

Stage 3: Plant establishment and rooting: In this stage the selected plants are forced for root formation, which can be achieved by media modification and modifying the concentration of growth regulators. The concentration of cytokinins and sugars are reduced and concentration of auxins and light intensity in the laboratory is increased to start with photosynthesis and other physiological activities.

Stage 4. Acclimatization or hardening: The plantlets developed in the culture tubes are acclimatized to specific environment having a high humidity, a low light level and a constant temperature. Besides, the roots developed in vitro are hairless and hence delicate, requiring care during transfer from culture medium. To have better survival rate, the plantlets may be transferred to container kept in mist chambers where relative humidity is maintained at higher order. Once new growth is seen, the plants may be slowly transferred to outside by exposing to increased light intensity in stages. Once plantlets are well rooted, they must be acclimatized to the green house environment. In vitro rooted plants are removed from the culture vessel and the agar is washed away completely to remove a potential source of contamination. Plantlets are transplanted into a standard pasteurized rooting or soil mixture in small pots or cells in a more or less conventional manner as shown in Plate 13.3. Initially, micro-plants should be protected from desiccation in a shaded, high humidity tent or under mist or fog. Several days may be required for new functional roots to form. Plantlets

should be gradually exposed to a lower relative humidity and a higher light intensity. Any dormancy or resting condition that develops may need to be overcome as part of the establishment process. These conditions help the plantlets in getting acclimatized to the natural conditions, which would help them in getting established in the field easily.

Culture Techniques and Medium

Culture Techniques:-

Various culture techniques such as (i) meristem culture (ii) callus culture (iii) shoot bud regeneration (iv) somatic embryogenesis (v) ovule culture (vi) embryo culture (vii) anther culture and (viii) protoplast culture are employed in micropropagation.

1. **Meristem culture:** Meristem culture involves culture of both shoot-tip and axillary-bud. The use of small shoot-tips comprising of the apical dome with one or two leaf primordia (0.1-0.5 mm) is the basis for the technique known as meristem-tip-culture, pioneered by Morel in the 1950s. Meristem tip culture is now being routinely used, mainly in horticultural crops, for the elimination of virus from infected material. Virus apparently either does not easily invade or rapidly multiply in the young meristematic tissue. A simple nutrient medium consisting only of salts, sucrose and vitamins is used in order to minimize the formation of callus. Gibberellic acid is often needed to promote adequate growth and NAA may be required to stimulate root formation.

2. **Callus culture:** A piece of sterile plant tissue with living cells is transferred to a culture medium to induce callus proliferation. Sub-culturing is then done onto a medium with or without altered growth regulator concentrations, ultimately resulting in the induction of adventitious organs or embryos. In the last stage, regenerated plants are removed from in vitro culture and slowly exposed to outer environment so that the plants can be fully autotrophic.

3. **Cell culture:** The cells are maintained in suspension cultures so as to produce free cells and are then sub-cultured to regenerate complete plant from single cells. This technique is now useful to induce variability in plant cells and to select desirable cell variants and regenerate complete plants from these variants.

4. **Embryo culture:** It involves aseptic excision of the embryo and its transfer to a suitable medium for development under optimum culture conditions. After the embryo has grown into a plantlet in vitro, it is transferred to sterile soil or vermiculite and grown to maturity in a green house. This technique is useful in the production

of interspecific and intergeneric hybrids which could not be otherwise accomplished and also in overcoming embryo abortion.

5. **Protoplast culture:** From different sources, protoplasts (the plant without any rigid cellulose wall but with plasma membrane only allowed to fuse to form a somatic hybrid) are cultured in suitable media to regenerate the cell wall and are again cultured in suitable medium for differentiation and morphogenesis.

6. **Anther culture:** The culture of anthers is of considerable value to breeders as it is possible to produce haploid plants which reveal recessive alleles. These haploid plants can be used for the production of homozygous diploids, thus avoiding generations of inbreeding. Added benefits, such as small flowers and prolonged flowering time, might be ensured from the use of haploid plants as they are usually smaller than their diploid counterparts and being sterile there will be no pollination-induced senescence. Anther culture has been used in *Pelargonium* spp. to eliminate virus, in *Lilium* spp. to produce haploid plants and in *Gerbera* to obtain different flower colour.

7. **Somatic embryogenesis:** The greatest potential for clonal multiplication is through somatic embryogenesis, where technically a single isolated cell can produce first an embryo, then a complete plant. Somatic embryogenesis and plantlet regeneration has been reported in various species of horticultural plants by using mid-rib, leaf and stem callus on modified MS basal medium supplemented with 1.0 – 2.0 mg/l 2,4-D and 0.25-0.50 mg/l BA or kinetin.

Culture medium

- Success in the technology and application of tissue culture methods depends on the selection of proper culture medium, which meets the nutritional requirements of cultured cells and tissues. The basic components of all nutrient media are inorganic salts, carbohydrates, vitamins, growth regulators, agar (for solid medium) and water. Other components including organic nitrogenous compounds, organic acids and complex substances can be important but are optional.

- The inorganic nutrients required in macro-amounts are N,P, K, Ca, S and Mg. The optimum concentration of each nutrient for achieving maximum growth rates varies considerably. The essential nutrients required in micro-molar concentration include Fe, Mn, Zn, B, Cu and Mo. The concentration of inorganic nitrogen in the culture medium varies from 25 to 50 mM. Nitrate is commonly used in the range from 25-40 mM and the amount of ammonium varies between 2 and 20 mM. Potassium is supplied in the range of 20 mM or



higher and the optimum concentrations of P, Mg, Ca and S for most tissues are 1-3 mM.

- The standard carbon source is sucrose or glucose at a concentration of 2-3%. Other carbohydrates which have been tested include fructose, lactose, maltose, galactose and starch but these compounds are generally much inferior to sucrose or glucose as a carbon source. Most media contain myo-inositol. There is no absolute requirement of myo-inositol, but its inclusion (100 mg/l) generally improves tissue growth. MS medium is the most popularly used nutrient medium in tissue culture.
- The nutrient media are supplied with certain vitamins. There is an absolute requirement (0.1-0.4 mg/l) for thiamine. Growth is also improved by the addition of nicotinic acid and pyridoxine; sometimes biotin, vitamin B12, folic acid, choline chloride, riboflavin and ascorbic acid are also added to the culture medium, depending on the type of tissue to be cultured.
- The pH of the culture medium is an important factor for maintenance of growth of cultured plant tissues. In general, plant tissues require an acidic pH, and an initial pH of 5.5 - 5.8 is optimum. The physical form of the culture medium is also an important factor determining the success or failure of tissue culture. Both liquid and solid form of culture medium are useful for initiation and proliferation of callus tissue and initial organogenesis, but for further growth of organs solid medium is essential. When culturing in a liquid medium, gentle agitation of the liquid is necessary for aeration of culture medium, rotating apparatus is used for this purpose.

Topic 14

[CLICK HERE to Join AgroMind Telegram Channel](#)

Specialized Vegetative Structures

Introduction:

The specialized vegetative structures include runners, suckers, crown, offsets, bulbs, corms, tubers, tuberous roots and stems, rhizomes and pseudo bulbs that function primarily in the storage of food, nutrients and water during adverse environmental conditions. Plants possessing these modified plant parts are generally herbaceous perennials, in which the shoot die down at the end of a growing season but the fleshy vegetative structure usually do not die and remains in the soil, which put forth new vegetative growth in the next season. Plants that survive as underground storage organs are called geotypes, which can withstand period of adverse growing conditions in their regular growth cycle. A brief description on propagation techniques used for species with specialized organs is as under:

Bulb: A bulb is a complicated structure, which consists of a short thickened stem bearing roots on the underside and thick fleshy leaves on the upper side. Bulbs are usually produced by monocotyledonous plants in which these are modified for storage of food and water and reproduction. Oxalis, is the one dicot genus that produces bulbs. Bulbs generally consist of bulb scales Fig.14.1 and Fig.14.2. The outer bulb scales are fleshy, which contain reserve food materials, where as inner scales do not function as storage organs and are leaf like. In the centre of the bulb, there is either a vegetative meristem or an unexpanded flowering shoot. Meristem develops in the axil of these scales to produce miniature bulbs, known as bulblets, which when grown to full size are known as offsets. In some species (e.g. Lilies),

the bulblets are produced in the underground organs. Bulbs are of two type's tunicate i.e. (lamine) and non-tunicate (scaly).

Tunicate (lamine) bulbs: The examples of tunicate bulbs are onion, garlic, daffodil and tulip. These bulbs have outer bulb scales that are dry and membranous. This covering or tunic, provides protection from drying and mechanical injury to the bulb. The fleshy scales are in continuous, concentric layers or lamina to provide solid structure to the bulb.

Non-tunicate (scaly) bulbs: Non-tunicate bulbs are represented by the lily, have dry coverings, loosely arranged like the petals of a flower overlapping each other. In general, non- tunicate bulbs are easily damaged and must be handled more carefully. They must be kept moist because they are injured by drying. The bulbs are propagated through offsets, bulb cuttings, scaling, scoring, stem cuttings, leaf cuttings, leaf buds and bulbils. In case of scaling, individual bulb scales are separated from the mother bulb and placed 5-6 cm deep vertically in a suitable growing media. These scales usually develop 3-5 bulblets after 4-5 weeks of planting. In many advanced countries, there is a programme to produce forcible commercial bulbs after one growing season only from scaling with preformed bulblets in lilies. Basically four types of plant development take place in this method of scaling as under:

- Epigeous-type plant (ETP) in which direct bolting bulblet is produced with foliage leaves but no scales. It is considered as the most desirable development form.
- Hypoepigeous type plant (HETP) in which rosette structure is produced first with foliage scale, which bolts after attaining some growth.

- Hypogeous type plant (HTP) forms only a rosette structure with foliage scales. It is not a commercial method.
- Non-green leaf bulblet (NLB) does not produce any foliage because the bulblet remains dormant. It is also not desirable.

Scooping and scoring are commercially used for the propagation of Hyacinth and Scilla. Scooping and scoring methods are basically used to remove apical dominance and to encourage bulb let formation. In scooping, the entire basal plate of the mature bulb is scooped out with a special sharp and curved scalpel to destroy the main shoot. Adventitious bulblets will develop from the base of the exposed bulb scales. In scoring, three straight cut are given across the basal plate and growing point of the bulb but the complete plate is not removed as in scooping. Growing point in the axils of bulb scales grow into bulb lets. After scoring and scooping, the bulbs are placed about 2.5 cm deep in dry sand or open trays at about 21°C for callusing. After callusing, the bulbs are incubated in trays at 21°C, which may be increased 29-32°C in dark or diffused light for 2 weeks and held at 80-90 percent relative humidity for 2-3 months. The mother bulb along with bulblets are planted 10cm deep in the nursery in the fall.

Tubers: A tuber is a swollen, modified underground stem, which primarily function as the storage organ of the plant. The potato, Caladium, Yam, *Jerusalem artichoke* are examples of tubers. The tuber has nodes (eyes), internodes, lateral and terminal buds. The eyes (nodes) of a tuber are spirally arranged, consisting of one or more small buds. Usually one bud in the eye sprouts and suppresses the growth of others, which shows the phenomenon of apical dominance. Usually, the removal of first sprout from the stem permits other buds to sprout. Propagation by tubers is usually

done either by planting whole tuber or by cutting the whole tuber into pieces, called as division. The each division or seed tuber should have one 'eye' or bud. The weight of a seed tuber should be between 28-56 g to provide sufficient food for the establishment of new plants. The seed tubers should be kept at 20⁰C with 90 percent relative humidity for 2-3 days prior to planting for rapid healing. These seed tubers may be treated with fungicides to prevent Rhizoctonia rot and scab. When whole tuber is used for propagation, its dormancy should be overcome by dipping the tubers in thiourea, ethrel or KNO₃. Sprouting takes place only after the dormancy is over. Tubers of *Begonia* and *Dioseorea* vines produce aerial tubers called as tubercles. These tubercles can also be used for raising new plants.

Runners: It is a specified long slender stem that develops from the axil of leaf at the crown of a plant, which prostrate horizontally along the ground. The roots appear at one of the nodes having contact with soil. After root formation in the new plant, the contact with the mother plant is automatically detached and the new plant can be separated and planted. Strawberry is a typical runner(Fig.14.4). *Oxalis corniculata*, Bosten fern, bugle (*Ajuga*) and spider plant (*Chlorophytum comosum*) are other examples of plants propagated through runners.

Suckers: A sucker is a shoot, which arises on a plant below the ground, arising from an adventitious bud on a root. The capacity of a plant to form suckers varies from species-to-species and even from variety-to-variety. Pineapple is usually propagated through suckers. In banana two types of suckers are produced water suckers and sword suckers (Fig.14.5). Water suckers are broad leaved, whereas, sword suckers are pointed and have sword shape. For propagation purpose, sword suckers are preferred over the water suckers. Suckers are separated from the mother plant and

are either planted in the nursery or directly in the field for rooting. Multiplication of apple clonal rootstocks is also done by suckers.

Off-sets (off-shoots): An offshoot is a young plant produced laterally by the parent plant or branch that develops from the base of main stem in some plants, which can easily be detached from it. The term offset is generally applied to a shortened, thickened stem of rosette like appearance (Fig.14.6). It is also applied to lateral shoots arising on the stems of monocotyledonous fruit plants, like date palm, pineapple or banana. Similarly, some cacti and succulents also produce a cluster of small plants around the base and these offsets merely need separation. For propagation, well rooted offsets are cut close to the main stem with a sharp knife and planted in a suitable medium or soil. The development of offsets in the plants can be stimulated by way of heading back the crown of the plant.

Rhizome: A rhizome is a modified and specialized stem structure in which the main axis of the plant grows horizontally at or just below the soil surface (Fig.14.7). The stem is segmented having nodes and internodes. A leaf like sheath is attached to each node, which on expansion becomes the foliage. Usually, roots develop in the vicinity of the nodes. The flowering stems, called as culms, are either produced from the rhizome tip or from the lateral branches. The banana is a typical example of rhizome. Other rhizomatous plants are ginger, bamboo, iris, sugarcane and many grasses. For propagation, the whole rhizome or piece of a clump or cutting may be used in rhizomatous plants but the division of rhizome is most commonly used propagating material. The mother rhizome is cut into sections, each having atleast one lateral bud or eye. These sections are planted in a suitable medium. Adventitious roots and new shoots will develop from the nodes and ultimately into plants, such as bamboos, the

aerial shoot or culm is used as cutting. The cuttings or sections containing 3-4 nodes are planted vertically in the soil. The new branches arise from the nodes, producing an individual plant.

Corms: A corm is a short, solid, much swollen underground stem, enclosed by dry scale like leaves, with one or several buds near the top, a tuft of leaves at the upper side and a ring of thick fibrous roots around the base (Fig.14.8). At the apex of corm is terminal shoot, which usually develops into a flowering shoot or leaves. Gladiolus, crocus and water chestnut are examples of some typical cormous plants. Cormous plants can be propagated through new corms, cormels or corm segments. Usually, a mother corm produces 2-3 new corms and 15-20 cormlets, the miniature corms. In general, a corm flower within a year of planting, whereas it takes 2-3 growing seasons for a cormel to flower. Division of corm is also sometimes used as a method of propagation of cormous plants. While making segments, it must be ensured that at least one eye should be present in one piece. These segments are planted vertically 5 cm deep in soil, which later develop into a full plant. Micro propagation protocols are now standardized and commercially used in gladiolus even in our country.

Pseudo bulbs: Pseudobulb (false bulb) is an enlarged fleshy stem with several nodes. It is produced by some horticultural plants (mostly orchids), mainly for the storage of food. The plants producing pseudobulbs are usually propagated through offshoots, division or from black and green bulbs produced by them. The rooted shoots are cut from the mother bulb and planted in the nursery. Some orchids, like Cattleya, Laelia, Miltonia etc. are multiplied commercially through the division of pseudobulbs. The bulb is cut into different sections by a sharp knife during dormant season. Each section is sown and new growth begins at the nodes

Topic 15 Orchard management Introduction

The ultimate success of an orcharding enterprise largely depends upon the quality and genuinity of planting materials as nursery plants are the foundation of the orchard. The variation of scionwood and rootstock has great bearing on the productivity of an orchard. Thus, it is of immense importance having all plants carefully labeled or otherwise marked. The whole process involves various steps as mentioned under:

Selection of mother trees

Creation of budwood bank

Maintenance of budwood bank/ repository of improved high yielding and commercial cultivars of different fruits at a central place, preferably at the major production areas of respective fruits under the supervision of university/ department for raising of mother blocks/ trees for further multiplication. **Selection of varieties:**

The identification and listing of cultivars to be propagated is very important. After listing the cultivars, their meritorious plants are to be selected, which give regular yields of high quality fruits and are marked for further study/use as budwood source.

Indexing of viral diseases: The progeny plants are the major source for the spread of viral diseases. There are reports available where in apple mosaic alone has been responsible for reduction of 40 per cent yield and 50 per cent productive life. The bud take success in temperate fruits is also low in affected trees. Thus, the selected meritorious trees should be indexed for virus and then categorized accordingly. The parent trees showing abnormality in characters with passage of time should be discarded from the progeny orchard.

Maintenance of mother trees: Identified mother trees are used to develop progeny hedges in large number near to the nursery site at 2x2m distance. The hedges are properly labeled and used for scion wood. Progeny trees are heavily pruned to produce scion wood in bulk. Adequate plant protection measures are also adopted to keep these progeny hedges free from the insect/pests and diseases. Such practices of maintaining scion/mother tree hedges are common in various advanced nurseries in overseas countries. Old trees of selected varieties can also be pruned severely to

develop forced shoots to be used as scion source, in the orchard site only till progeny hedges are developed.

Collection and Handling of Scion Wood For dormant grafting

- The scion wood in winter is to be stored for considerable long time. The labels and identification marks of scion wood should be considerably durable.
- Storage under moist conditions or underground needs rot proof labels and the attachments.
- Non-corrosive zinc metals have proved excellent for this purposes, provided the wire or other connection is rot-proof.
- Painted wood labels or zinc labels with pliable wire are satisfactory for most purposes.
- Bundles of budwood are tied firmly and labels are attached in such a way that they may not slip along and off the ends of scion material. Even the best method of labeling should be supplemented by notes in the gardener nursery book.
- The best method of storage of scionwood is to burry deep in soil with more packing in shady location. It also helps in completion of chilling requirement of the scion wood.
- Storage can also be done in cool chamber at 0-2⁰C but in this case budsticks are kept in well packed condition in moist sphagnum moss.

Disinfection of scion wood: To check the infection accumulated during storage, the scion wood prior to use after storage should be treated with insecticides like chlorophyriphos, tree spray oil and fungicides based on captan, dodine, etc. at convenient concentrations.

Scion for bud-grafting (Budding):

- For summer or autumn budding, shoots are collected, at the time suitable for the operation, from healthy selected progeny plants or hedges of chosen variety.
- It is usual to remove the leaves immediately to reduce water loss. This is done by severing the petiole about 12 mm from its base.
- The soft tip of the shoot may be removed. These defoliated shoots or bud sticks, may be kept in good condition for some days in a cool place. The stipules in many cases abscise after a few days but this is more a sign of viability than detriment and sometimes budder prefers to handle this type of material.

Transport of budwood: To long distances, the budwood should be air transported. The weight of consignment may be kept down by reducing the length of bud sticks to contain only the best buds. Bud sticks are first wrapped closely or heat sealed in thin 50-gauge polythene, no internal packing is used. The wrapped scionwood is then covered with an outer wrapping or waxed for protection against bruising and to receive the address label and any necessary permits.

Petiole retention or removal: The petiole base adhering to the scion wood serves as a convenient handle for grafts in the budding process but it appears to serve no other useful purpose. In subjects having large petiole base, it may prove to be disadvantageous and should be removed. It may be noted that there is no difference in success of petiolated or unpetioloated buds.

Handling of rootstock: There is a wide variation in the rate of growth of various seedlings sown after stratification or pre-sowing treatments. In general, only the most rapid growth will enable transplanting to take place after one season and two years in the seed bed is more usual.

Grading and rouging: Out of the nursery is necessary to lessen seedlings variability problem. This practice is common in various advanced countries. Unfortunately, no care is given to this aspect in our country, and probably the variable planting material is also one of the causes of low productivity in horticultural crops.

Nursery Registration ACT

For producing certified nursery stock, the fruit nurseries shall have to maintain a scion block, a seed block, and stock bed and shall have to use the propagation material only from these sources. The scion block means a planting of registered trees which serves as a source of scion wood for the propagation of certified nursery stock. The seed block means a planting of registered seed trees which serves as a source of seed for producing seedling rootstock for use in propagation of certified nursery stock. The stool bed is a mean of planting of self rooted registered mother trees/ mother stools which serves the specific purpose of producing vegetatively propagated (clonal) rootstock used in the propagation of certified nursery stock. Supply of poor quality nursery plants is one of the major causes for low productivity of horticultural, plantation and other crops in our country. Government of India had constituted model nursery regulation act long back in 1954. On this analogy different state governments have also enacted their own state nursery registration acts depending upon the available crops and local requirements to ensure availability of genuine planting material for farmers. For instance; the Himachal Pradesh fruit nurseries registration rules have been framed vide Act No. 15 of 1973. As per contents of act an application for a license to establish a fruit nursery shall be addressed to the competent authority in Form 'I' along with a treasury Challan in original of Rs. 100/- in favour of concerned state Director of Horticulture, in any Government Treasury /State Bank of India. After completing all codal formalities laid down in the act, the license is initially issued for a period of 3 years and can be extended further after submitting renewal application to the competent authority 90 days before expiry of earlier issued license. Unfortunately, despite nursery registration act, local unauthorized nurseries are mushrooming in every area, which merely follow the rules and regulations. Poor or inadequate inspections by the agencies also favour them. A nursery should be registered for the purpose of providing quality seed, rootstock and scion sources. A nursery stock should be inspected, tested for genuinity to type, freedom from viruses, insect-pests and diseases.

Licensing requirements of nursery:

1. Any person/ person(s) engaged directly with the distribution of plants, plant products, plant material, nursery stock is required to inform the department, the existence of progeny plants and their operations. He/she should obtain a nursery industry license prior to initiating such business.

2. The aforesaid firm or individual(s) are required to renew their nursery industry licenses, each year or every third year as per local nursery act in order to continue the business.

Inspection of nurseries and nursery stock certification After receiving the nursery industry license application, the department or its representative shall examine or inspect all plants, plant material, or nursery stock located or grown on the business location or any other applicable location. The department shall conduct inspection yearly or at any time as it deems the best, with or without notice. After successful completion of an inspection, the department shall issue a nursery stock certificate to the licensed nursery.

Responsibility of the applicant:

The applicant nurseryman shall be responsible, subjected to approval by the department, for the selection of the locations and the proper maintenance of registered plantings being grown. The nurseryman should maintain register regarding time of different operations/applications, nursery stock of different varieties of a crop, in a manner approved by the department.

Location of planting

The planting location shall be subject to approval by the department and shall be in an area having minimum risks for spread of infection, pests by drainage, flooding, irrigation or other means. The fruit tree nursery stock being grown shall be on rootstocks approved by the department and shall originate from the registered seed trees or from registered stool beds. Certified nursery stock should be produced on soils that have received a pre-plant nematicide or that were sampled before planting and found to be free from virus, vector and nematodes. Nursery stock meeting the requirements, when sold, shall have the variety, interstock and rootstock designated, where applicable.

Refusal, suspension or cancellation:

Registration or certification may be refused, suspended or cancelled for any plant in part or all of a planting stock under any of the following conditions:

- If nursery is not working as per the standards prescribed by the rules and regulations of state government or Government of India.
- If the plants are found to be virus infected or there are off-type plants in the nursery.
- If a registered mother tree is found virus-infected after periodic indexing.
- If the pest control requirements are not followed properly upon inspection.
- If the plants have not been properly maintained.
- If the registration number is misused.

Civil penalties:

The civil penalty for violation of any section of act not already stated will be the assessment of a civil penalty, the confiscation or destruction of any and all plants, plant materials or nursery stock found on the premises or contained in the shipment in question and /or suspension or revocation of the current nursery industry license or any future operation privileges granted under the act.

AgroMind

Topic 16 Nursery tool and Implements

For carrying out day-to-day routine cultural operations in the nursery, various tools, implements and accessories are required. Some tools are simple and are used for simple operations, whereas for carrying out specific operations, special types of equipments are required. These are listed and briefly described hereunder:

Tools for land preparation and other basic works

Kudali: It is a simple but important tool used for digging of soil, pits or any basic digging work prior to preparation of nursery beds. It has a metal (iron) blade attached to a wooden handle. It is operated manually.

Garden fork: Garden fork is used for breaking of soil clods and separation of medium size soil during preparation of nursery bed or fields.

Weeding fork: It loosens the soil and helps in weeding also. It consists of a long handle with a blade of handle teeth. It is drawn manually with the help of handle to collect the weeds and cops of plants etc.

Crow bar: It is an iron rod with one end pointed and other as a wedge shaped. It is used for digging out large or hand boulders from the soil and digging of pits. It is also used for breaking hard soil pan.

Shovel: It has iron blade of spoon shape and wooden handle and is used for within field transport of dug out soil required for leveling of field for preparation of nursery beds

Pick-Axe: It is made of carbon steel. Pick axe has two edges with provision of axial hole for attachment with handle. One edge of pick –axe is pointed and another is broadened. Pick axe is used for digging hard, compact and stony soils

Spade: It is used for lifting and turning the soil. Also used for digging the pit, preparing channel for irrigation and drainage lines

Hoe-cum-Rake: It is of rectangular shape metal blade with fork like fore edge. It is used for digging, hoeing, earthing, leveling and collecting weeds

Furrow opener: It is used for opening narrow and shallow furrow after sowing seeds in nursery.

Trowel (Khurpi): It is of shovel shape but small in size with iron blade and wooden handle. It can be made in many shapes as per local designs and requirements. It is used for hoeing, weeding and nursery plants and also for transplanting seedlings.

Axe: Iron blade, fastened to wooden handle. It is used for felling trees and cutting branches.

Bill Hook (Darat): It is made of iron curved at the far end or used for cutting hardy branches of plant and other woody shrubs in the field.

Hand leveler: It consists of narrow rectangular metal blade attached to long wooden handle

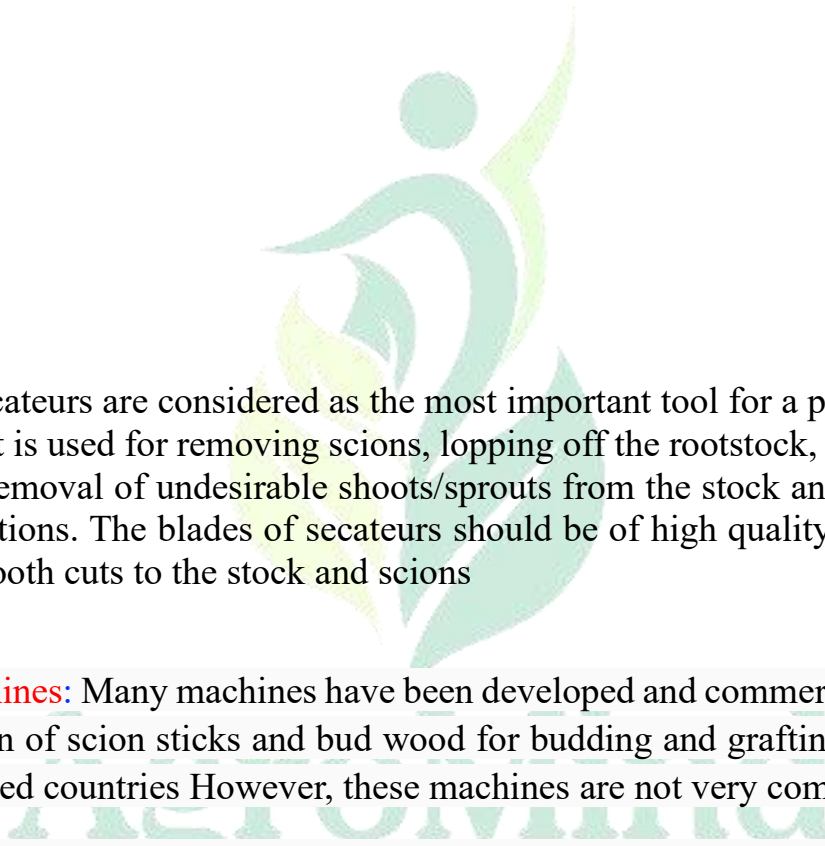
Sickle: It is used for cutting grass and leafy vegetables.

Wheel-Barrow: It is manually operated small trolley, used for carrying nursery plants, compost, fertilizers, leaf litter, horticultural produce, stones etc. from one place to another place. It can be designed into different shapes according to requirement.

Cultivator: It is a tractor drawn implement used for tilling the soil efficiently. It has types of quality carbon comprising of different sizes depending upon the plough depth. These days, hand driven small cultivator is more popular. It can plough upto ½ to 1 feet depth

Disc harrow: It is used for pulverizing the soil. It is also used for turning crop residues, weeds and other debris in the soil. It is used for deep ploughing and turning of soil. Grafting and budding tools

Knife: Knives having combined blade for grafting and budding purposes. A grafting/budding knife has a straight 7.5cm long blade and strong long handle. It has a spatula at the end of a handle, which is used for lifting the bark during budding operation. Sometimes knife has two parallel double blades, used specially for lifting or removing the patch of a bud from the budwood. Generally these knives have either a folding or fixed blade. The blade of knife should be made from high carbon steel and should always be very sharp.



Secateurs: Secateurs are considered as the most important tool for a propagator or a nurseryman. It is used for removing scions, lopping off the rootstock, preparation of scion sticks, removal of undesirable shoots/sprouts from the stock and training and pruning operations. The blades of secateurs should be of high quality carbon blade for giving smooth cuts to the stock and scions

Grafting machines: Many machines have been developed and commercially used for the preparation of scion sticks and bud wood for budding and grafting operation in many developed countries. However, these machines are not very common in India.

Pruning saw: Several types of saws are required for performing different operations involved in propagation of horticultural plants. The commonly used are crescent saws, tapered saws and straight saws. All of them have long and widely set teeth to facilitate pruning or cutting of green wood. Its blades should be narrow so that it can pass through the narrow or closely spaced branches (Fig.16.4)

Ladders: In propagation work, ladder is required for operations like cutting of bud wood, training of vigorous plants, performing layering operations and top working of declining plants. In general, step ladder or straight ladder or hook ladders are used for such operations in the field of propagation

Tying and wrapping materials: It is essential to hold scion and stock firmly together to have successful graft/bud union. For this purpose a suitable tying or wrapping material is required. Generally polyethylene tapes/strips, waxed string and cloth, raffia fibre and rubber strips are used for this purpose. In addition, adhesive tapes similar to surgical adhesive tapes but lighter in weight are also used by commercial nursery men.

Grafting wax: Wax is used by propagator to seal the graft union for preventing moisture loss and desiccation of cells at cut surface and to prevent the decay of wood by way of checking the entry of pathogens (Fig.16.5). Waxes are of two types i) Hot wax ii) Cold wax.

Labels: Labels are used for proper labeling of plants, before sale. Labels may be made of paper, card board, wooden, celluloid, aluminum and plastic etc (Fig.16.6).

Pots: Pots of different shapes and sizes are used in nursery. They may be of clay, metal or plastic usually 10cm, 15cm or 20cm for single specimen. Pots are of different types, tube pots, ¼ size, 1/2 size, 3/4 size and full size, thali and urn These are used for potting ornamental plants, fruit plants, saplings etc. Iron pots/ plastic pots are used for irrigation purpose also.

Spray-pumps: To spray protective material i.e. insecticides/pesticides/fungicides to eliminate the infection of pathogens or insects, spray pumps are very important tools. Pumps are of different shapes, size and types. Commonly used sprays are knap-sack sprayer, rocker sprayer, foot sprayer, hand sprayers or power sprayers. Depending upon the volume of nursery and specific purpose different types of sprayers are put in operation.

Chain saw: It operates using fuel (petrol/kerosene). It aid to cut wood logs of bigger size and lopping of branches and shoots.

Chain weeder: It is operated by petrol/diesel/kerosene. It is used to slash the weeds on large scale.

Rose can: A tubular pipe with rose i.e. fitted into the can through which water is sprinkled over the nursery beds until the germination of seeds and to avoid splashing of seeds from the nursery beds due to loose pipe irrigation and flood irrigation

Iron pan: It is made of iron and used for transporting pot mixtures, potted plants through head load from one place to another for short distance

Hose pipe: This is available in convenient length. Irrigation to nursery plants is made possible to any extent.

Pruning shear: It is made of iron fitted with wooden handle. It is used to prune unwanted branches, collection of scion, trimming of the edges and hedges and topiary work.

Scythe: It is long knifed, fitted with wooden handle. It is used for slashing of weeds.

