



TREE GROWTH, FLOWERING AND FRUITING

Litchi is an evergreen tree with round dome-shaped top, spreading branches and dense shining leaves. The tree reaches up to 12 m or more in height. When grown under congenial climatic conditions radial diameter of the tree's canopy is also nearly 12 m. The branches are crooked or twisted, low-hanging and spreading, forming a head broader than the height. In some varieties, the branches are fairly straight and more or less upright, forming a compact, rounded head. In some cases, however, the tree assumes fairly wider spreading (horizontal) growth than its height. During initial years of establishment, pace of tree's vegetative growth is highly influenced by growing environment and nutrition. It can change with variation in hormonal balance in the internal tissues, difference in climate, soil or cultural practices. Although the precise knowledge of growth processes is complicated and of little relevance to the litchi growers, but the basic understandings are important and will help us to make wise decisions in the field. This chapter gives some fundamental information about the structure of plants, both above and below the ground, how they grow and why they respond in certain ways. Later on, in discussing more practical aspects of fruit growing, pruning in particular, these structures and ideas will be further amplified.

Growth of Shoots

Litchi is an evergreen tree and there is no complete cessation of growth at any particular time of the year. However, the growth is drastically slowed down during winter months and there are sufficient literatures to show that the trees undergo some sort of dormancy or rest during winter months. At the end of winter in February-March, the buds start to grow at a rapid rate and trees may bear a new vegetative flush. Usually the growing buds are positioned either laterally on branches or at their tips. They can be formed in the previous growing season and remain dormant over the winter for four months or more.

The buds are mainly of two main types i.e., mixed buds, which contain leaves and flowers, and simple buds, which produce either leaves or flowers alone. From leaf or mixed buds, shoot growth begins in spring and continues for a period of time, depending on the

position of the shoot on the plant and on the type of plant. In litchi, shoots continue to grow throughout the year and there may be 3-5 vegetative flushes in a year. This is a biological adaptation to enable the tree to be photosynthetically active round the year, on which it depends for further support. A number of factors will determine the length of this growth period, often called a growth flush. Primarily, internal nutrient content, distribution and balance of hormones, and the environmental conditions determine the growth of shoots. In other words, while shoot development is dependent on temperature, water, mineral nutrients and the products of photosynthesis, overall growth and development is controlled by a fine balance of hormones arising from tissues that are part of the shoot or that come from other organs, such as roots and fruits.

The growth habit can differ considerably among cultivars. Some genotypes have vigorous vegetative flush and are more erect. Litchi is slow growing tree to reach full size. Stem is thick, uneven, and short with off white to greyish brown coloured, rough bark. Branches are rather weak and they tend to droop during initial growth stages. In later stages, the branches tend to form V-shaped crotches which are easily broken off by the wind. In grownup plants, however, the thick limbs develop wider crotches, which sustain wind pressure. The litchi tree produces a number of annual shoots, which give it a very attractive appearance in all seasons. Its ornamental qualities are further enhanced at harvest time when bunches of bright red fruits hang from the periphery of the tree. It has good longevity for more than 100 years. Usually litchi trees (asexually propagated - layers) start bearing after five to six years while seedling trees take a distinctly longer duration of nearly eight to ten years to come into bearing. The entire life span of a tree can be divided into four distinct stages for adoption of suitable cultural practices to manage the orchard for maximum return.

Juvenile or Non-bearing Stage

Litchi trees in the age group of 1 to 6 years usually remain juvenile and non-bearing. Some trees may start bearing in the fifth year or even fourth year, but by 6th year majority of the trees in a orchard come into bearing. During this stage, plant has accelerated growth to develop scaffolds and main branches and produces 3 to 5 vegetative flushes in a year. In this phase, the orchardist should start efforts to develop a good strong frame of the tree. Irrigation and fertilizer requirement of this stage vary from other stages. Even in subtropical climates, where temperature are sufficiently low to induce floral initiation, vegetatively propagated litchi takes several years before it begins to flower. This is a clear indication that litchi has longer juvenile period with respect to floral initiation. In seedling litchi, this juvenile period may last from 6 to 10 years, while in layered plants it lasts 4 to 5 years. It has nevertheless been reported that layered trees obtained from old and mature branches may flower in the year of planting itself.

Management and upkeep of young non-bearing litchi orchard is essential as this accelerates the growth of the young plant and minimizes the juvenile period. Up to 3 years of age, the

main aim for the litchi orchard management is to accelerate the plant growth to develop better tree frame which makes platform for higher production throughout the life span of the tree. Generally, young litchi plant sprouts 5 times in a year to form canopy with a certain quantity of vegetative growth. Therefore, newly planted young saplings should be properly nourished to promote better vegetative growth in this period. It has been anticipated that after attaining the age of 5-6 years, the plant develops good canopy width and height (1.5-2m) and becomes ready for bearing some fruits. Other management practices like weeding, hoeing of plant basins, plant protection; water management, etc. should be done as per requirement.

Early Bearing Stage

The litchi trees between 6 and 10 years of age are in the early bearing stage . This is a delicate stage when a major transformation from vegetative to reproductive growth takes place. During this stage, the plant keeps enlarging its canopy and produces fruits too. At this stage, it is essential to maintain a balance between vegetative growth and fruiting since the young plants tends to have more vegetative growth. Sometimes, the fruit production is suppressed or reduced due to excessive vegetative flushing particularly in spring season during this stage. This is a formative stage when lot of pruning and training is required to shape the canopy.

Young Bearing Orchards

This is the very delicate stage of orchard management where more visionary approach should be followed in skillful manner. During young bearing stage between 10 and 20 years, plant needs more nutrients for proper growth and bearing. At this stage, the tree keeps enlarging canopy and produces economic fruit yield. Therefore, the management should be aimed to balance at both vegetative and reproductive growth. It is important that at this stage, there must be optimum balance between vegetative growth and fruit production. Excessive vegetative growth adversely affects fruit setting while excessive fruit load reduces development of tree canopy. Skillful orchard management at this stage includes maintenance of optimum number of bearing branches as per the nutritional status and health of plant. Young trees tends to have more vegetative growth, therefore, it has been observed that sometimes fruit production is suppressed by excessive vegetative flushing particularly during autumn. Therefore, effective measures like ringing, girdling, fostering of winter shoots, use of paclobutrazol, etc. can be applied for proportional crop production.

Full Bearing Orchards

After attaining the age of 20 years, litchi tree enters into the phase where vegetative growth and fruiting are relatively balanced and the trees acquire nearly full canopy. The age of litchi tree ranges between 20 and 70 years. This phase is known as full bearing stage or commercial bearing period. The main features of this stage are well-distributed primary, tertiary branches and fruiting terminals, which bear the fruits and vegetative flush in a balanced proportion for

normal fruiting. At this stage, tree reaches its full yield potential and continuously produces almost similar yield until it is 70 years old. Therefore, a well-managed orchard will be commercially highly productive for a period of 50 years. There are evidences to show that the litchi trees are equally remunerative even after attaining the age of 100 years. The main aim of orchard management at this stage is to produce maximum yield with maximum feeding. At this stage, different fertilizers should be applied at different periods of cycle. Foliar sprays of nutrients and plant growth regulators are also essential to ensure higher production. Timely plant protection, short treatment, intercultural operations, water and canopy management for higher production should be judiciously followed. To have regular yields, the vegetative flushing pattern, its time and health should be monitored and attempts should be made to check excessive vegetative growth through chemical and cultural manipulations.

Old Declining (senile) Orchards

This stage comes usually after 70 years or thereafter when symptoms of ageing are becoming apparent. When orchard is not managed properly continuously for a prolonged period the decline may start quite early i.e. after 45 or 50 years of establishment. The plant then becomes old with big canopy, restricted flushing and low fruiting. Such trees need special management plan like reiterative pruning, re-canopy building and promotion of new shoots etc. Litchi tree has strong renewal ability therefore; the old and unproductive orchards can be rejuvenated for further higher production. Heavy regenerative pruning followed by optimum fertilizer and moisture management near feeding root zone are the main management practices for such orchards.

Root

The root system of the litchi plant varies depending on the method of propagation used. Trees, grown from seed, develop strong tap root system with a well-distributed secondary and tertiary root system. However, most of the trees in commercial orchards are propagated by air layering. Layered plants are characterized by a very shallow root system where the taproot is virtually non-existent. Air layered trees have no tap root system, most of the feeder roots are within upper 45 cm and only a few roots below 90 cm level. The absorbing roots start at soil level and descend to a depth of approximately one meter. It has been observed that root growth is continuous with only three periods of no visible root extension and that mean absolute extension rates are lower than those for stems are. There is hardly any consistent relationships between the timing for root and stem extension growth.

Roots provide moisture for the plant. This is not only the water, the plant needs to build or repair its structures, but also the water needed for transpiration. Under hot, dry and windy conditions the volume of water needed is much greater. They absorb nutrients, such as nitrogen, potassium, phosphorus and number of minor elements from the soil. Roots may also have an association with mycorrhizal fungi which assist the uptake of nutrients that the

plant may not otherwise be able to retrieve. Roots contribute to plant growth regulation by producing and transporting hormones or other chemical signals, both to the roots and to the above-ground organs of the plant. Roots store organic compounds and minerals for use on subsequent occasions, as required. Storage also occurs in the above-ground portions of the plant. Re-mobilization of stored carbohydrates, amino acids and minerals is especially valuable during or after stress periods, when regrowth is demanded, or in spring to develop new shoots and flowers.

Leaf

Litchi leaves are compound with 7-12 lamella, alternate, coppery red or red to pale green or even creamy when young and bright, dark green when matured. They may be lanceolate, oblong-lanceolate or even elliptic in shape, measuring 7.5 to 20 cm in length, 2.5 to 6 cm in width (petiole and rachis) and smooth but coriaceous in texture. The base of the leaf blade is rounded. A leaf consists of ten to twelve pairs of leaflets. They may be arranged along the rachis directly or obliquely opposite to each other, each on its own small stem (petiole) and are between 3 and 25 mm in length. The leaflets are glossy with shorter internodal length, dark green on the upper side and dull and waxy on the underside. Small-leaved varieties with shorter internodal length are usually less vigorous. The leaves in the young growth flushes tend to have beautiful reddish bronze colour in some genotypes.

Leaves serve two main purposes. First, they are small manufacturing units which, using the energy of sunlight, combine water and carbon dioxide to form carbohydrates. This is the process of photosynthesis. Carbohydrates are the fuel of plants. They may be used directly as an energy source or as building materials for other plant organs. They may be stored for later use as, for example, sugar or starch; sugar beet and potatoes are obvious examples. Generally, growers should encourage maximum leaf exposure to sunlight, which will produce an optimum balance between growth and reproduction. Leaves shaded by other leaves are inefficient and represent wasted energy, while flower buds on shoots with such leaves tend to be unfruitful.

The second main purpose of leaves is to draw up water from the soil and control the water status of the plant. The steady loss of water (transpiration) through small orifices called stomata (singular – stoma) pull water through the roots, trunk, branches and twigs. These stomata close at night and open or close at other times, depending on the prevailing environmental conditions. To replace the water lost by transpiration, water is drawn up from the soil, bringing up mineral elements essential for plant growth, i.e. phosphorus, potassium, nitrogen, sulphur, calcium, etc.. Other chemicals, Such as cytokinins manufactured in the roots, may be carried in this transpiration stream to the upper parts of the plant. Loss of water by transpiration helps to keep leaves and plants cool in hot weather, but, of course, depletes the soil moisture. If this is not replaced, it will lead to water stress. Plants reduce water stress either by modifying leaf structure and distributing stomata to reduce evaporation, as do eucalyptus,

or by producing an extensive and strong root system, as do grapes. Stomata on all plants close under conditions of water stress. Stomata in litchi are present only on lower surface of the leaves and there are no stomata on the glossy upper surface.

Vegetative Flushing

Flushing refers to the emergence of new shoots on the comparatively older shoots. The flushing enlarges tree size and produces leaves for utilizing sun light for carbohydrates synthesis which supports fruit development in the following season. The intraplant variation in flushing and shoot growth pattern influences the overall floriferousness of the litchi plants. All the shoots with second flush emerging during August and the third flush, emerging during November bear panicle in the month of February. A higher shoot girth and larger number of leaves per unit shoot length in the second flush are crucial for flower bud differentiation. Cessation of growth of second flush before the emergence of third flush results in panicle emergence. The carbohydrate content of previous season flush appears to contribute towards the emergence of third flush and ultimately the panicle as the content decreases during the third flushing. The phenol content of all the flushes increases during the initiation of new flush.

Shoot growth in litchi is not continuous. Generally, there is a rapid period of shoot elongation and leaf expansion followed by a period of leaf maturation, before the next period of shoot growth. In litchi, the duration and interval of growth are strongly related to environmental conditions. Combination of low temperature and high vegetative flush maturity is necessary for floral initiation to occur. Exposure to high temperatures invariably results in the production of vegetative shoots, irrespective of flush maturity. Strong floral initiation is marked by the emergence of terminal panicles and accompanying axillary panicles. A decrease in vegetative flush maturity or increase in temperature results in a decrease in axillary shoot formation and the production of several intermediate shoot structures. These include leafy panicles, stunted panicles, partially emerged buds and non-emergent swollen buds, often produced on the same tree. Both temperature and flush maturity can influence subsequent shoot structure of litchi. Relationship between leaf flushing (*viz.* early, mid and late season) and yield of litchi indicates that out of the three flushes, *viz.* early (after harvest), mid (August to October) and late (after November) season; the early and mid-season flushing influence the yield, whereas, the late season flushing does not have any contribution towards yield. The mid-season flush (appearing in August-October) is of more significance in cultivars Bedana, Bombai and Deshi, whereas, the early season flush (appearing in July) is the desirable vegetative flush in the rest of the cultivars with respect to yield.

Dormancy or Rest period

The litchi trees undergo a period of rest or dormancy during winter. It is a period without any externally observable growth activity in mature shoots for about 3-5 months depending on the variety and prevailing climatic conditions. This is a pre condition required for the

successful flowering. This dormancy is naturally induced by low temperatures in subtropical environments and soil moisture deficits under tropical conditions or may be by both ways under some situations. Low nitrogen supply also promotes this rest in mature shoots. Though, the term dormancy or rest is used to explain this stage of growth, however the plants are not physiologically in a dormant stage. During this period plants photosynthesize very actively and produce carbohydrates for storage which is used for further physiological control of flower bud differentiation and flowering.

High temperature, high soil moisture and high nitrogen levels in the soil or in plant tissues might break this rest and force the plant to flush again and again. Induced and untimely flushing affects the physiology of trees by changing the food reserve base and leads to a further vegetative growth. Plants under such conditions produce poor crops during the ensuing fruiting season. This generally happens due to planting of a cultivar which is not suitable for a particular climate. When a variety, with a tendency to have rest under low temperature led climatic conditions is planted under high temperature environments, it does not undergo rest and continues to produce vegetative flushes which hamper its performance in the changed environment. Although much research is required before it can be precisely defined how physiological processes and environment determine floral initiation, it is generally believed that litchi needs a period of vegetative dormancy to initiate floral buds. Apparently this dormancy can be induced by several factors including low temperatures, moisture stress, nutritional factors, cincturing and auxin sprays.

Flowering Period

The flowering period varies with the genotype and environmental condition. Generally, the flower bud differentiation in litchi starts in December and completed by the end of January. Subsequently emergence of flower panicle starts in January and is continued up to the end of February. Prior to floral bud initiation, the twig first begins to give out vegetative growth and then just at the terminal end of the vegetative shoot, a reproductive bud in form of recemose panicle appears.

The Panicle/ Inflorescence

Litchi bears flowers on terminal or axillary panicles. The panicle is determinate and composed of several branches produced on current season's wood (Fig. 8.1). They are normally produced terminally in clusters of 10 or more, but in some trees high percentage axillary panicles are also produced. The terminal panicles are usually more robust and more productive as compared to lateral panicles. Panicles are generally in mixed form with the lowest buds producing leaves only, the middle buds producing floral buds in the axils of the leaves and the topmost buds producing only floral branches and sometimes very small leaves which do not persist. The number and percentage of the different types of flowers in litchi vary greatly with cultivar, environmental conditions, tree and panicle within a tree. The proportion of functional female



Fig. 8.1: Flowering Panicles in Shahi litchi trees

flowers varies between 10 and 60 per cent. Each panicle produces hundreds of small, white, greenish or yellowish flowers, when the tree is in full flower. The inflorescence is a branched panicle bearing unisexual flowers on cymes.

Flower

Flower is terminal or auxiliary arising from the axil of first or second upper most leaf of the new shoot. It bears tiny, greenish white or yellowish flowers and is branched racemosely. The inflorescence varies from 10 to 35 cm in length and 5 to 30 cm in spread. Litchi flowers measure 3 to 6 mm in width when fully open and rest on pedicels measuring approximately 1.5 mm. They possess a cup-shaped calyx with 4-5 short, serrated sepals from which petals are totally absent. Flowers are usually produced in later winter or early spring and there are three types of flowers which open in succession on the same panicle. The flowers vary in terms of degree of sexual development, that is, length and functionality of the stamens and development and functionality of the pistil. In litchi, three types of flowers are found.

Male or Staminate Flowers (Type-I or M1)

These flowers are lacking pistil. The position is occupied by a structure which contains a pink, pubescent protuberance which is very rudimentary or aborted form of pistil lacking both, stigma and style. The pistil is surrounded by 4-12 stamens (usually 8) with hairy filaments. The filament varies 5-6 mm in length. In some flowers, the filaments are 2-3 times longer than the anther. While in some, they are equal to length of the anthers. Type I is defined as non-functional male, which opens for 10 days. Stamens are long, thin creamy white filaments which are deflexed and inserted into an angular glabrous nectary disc. Anthers are small, 2

celled, elliptical, emarginated at apex, fixed, and longitudinally dehiscent, initially pale white and become brownish at maturity. During the time that an individual flower remains open, the pollen sacs mature and the anther dehisce longitudinally one after the other, not simultaneously and discharge the pollen. Pollen grains are small, triangular having nipple like angles with three germinating pores. Ovary is very small, reddish white and abortive. The flowers possess nectar discs at their base, but these are not very well developed.

Hermaphrodite Female Flower (Type-II or F)

These flowers resemble the hermaphrodite male flower with short filament except that the lobes of the stigma open down the vertical cleft. They are called Type II or F flowers which appear and remain functional only for 2 days. These flowers have small but completely developed pistil attached to a short peduncle. The ovary has 2 to 4 carpels, each containing an ovule. The surface of the ovary is pubescent with protuberances which persist and give the fruit its rough surface. The ovary is long with a short style whose apex is split into two lobes. When these are open, the white, sticky surfaces of the stigmas are exposed. The nectar disc is found at the base of the ovary and produces an abundant secretion which attracts insects. Usually, only one of the lobes of the ovary develops into a fruit, the others are aborting. Occasionally, however, two lobes may develop, producing 2 fruits each containing a seed, which remain embedded in their bases. The pistil is usually surrounded by 5-8 stamens with very short filaments (less than 1.5 mm in length). The anthers do not normally dehisce and contain little viable pollen which creates the situation of cross pollination.

Hermaphrodite Male Flower (Type-III or M2)

Type III is a functional male flower but with more hermaphrodite features than Type I flower. Stamens and pistil are present but the lobes of stigma don't open to permit the entrance of pollen. The filaments vary in length. Stamens are in two sets of length out of which, those with long filaments are fertile. Pistil consists of short undivided style and stigmatic branches which is nonfunctional. Type III flowers have an ovary which has certain resemblances to both the above-mentioned types. Type-III flowers open for 7-10 days. It is surrounded by 6 to 10 stamens which are similar to those of Type I flowers, has a rudimentary style and stigma and also a nectar disc. Pollination does not appear to occur in these flowers since the stigmatic lobes do not open.

The three types of flowers occur in succession on the same tree, usually on different panicle or branches. However, the first flowers to appear on any given tree are may not necessarily be Type-I. There seems to be a tendency in young trees for Type II flowers to open first.

The duration of flowering (anthesis to pollination) in litchi is between 20 and 45 days, depending on the cultivar, season and the location. Floral anthesis occurs both during day and night, with peak opening in the early hours of the morning (6.00 hrs). Temperatures

below 8°C suppress flower opening, but this occurs in the rainy and dry seasons. Under very dry conditions, the young flowers may dehydrate and fail to develop. High night temperatures (approx. 21°C) reduce the duration of female flower anthesis.

Dehiscence of the anthers begins about one day after anthesis and continues for up to three days, with not all the anthers in a flower dehiscing simultaneously. This takes place continuously, occurring more frequently between 08.00 and 10.00hrs, with no apparent environmental, cultural or genetic effect. The pollen of Type-III flowers are more viable than that of Type-I flowers which are in turn, more viable than that of Type-II flowers. The stigma becomes receptive as soon as it begins to divide into lobes and remain receptive up to 3 days after anthesis. Maximum receptivity (75%) occurs one day after anthesis. When the stigmas cease its receptiveness, they become dry and lose their glossy appearance. Anthers dehiscence longitudinally. Pollen produced by the M2 flowers is most abundant and viable. Estimated pollen viability ranges from 4-40 per cent at the time of pollen release and decreases rapidly thereafter.

Flowering

In Indian condition, irregular bearing is seen in China group of cultivars whereas Shahi group of cultivars are regular bearer and are most preferred and thus occupy the maximum area. The problem of low and irregular bearing in some of the cultivars like China and Purbi is a major obstacle for its commercial cultivation. This is generally due to failure of plant to initiate flowers, although sometimes the flowers and fruit may be dropped due to adverse conditions. It is therefore, essential to understand the phenomenon and the conditions influencing the flowering behaviour to make litchi a profitable fruit crop.

The litchi flowers are produced on the present season's wood. The wood arises from buds of shoots which failed to produce flowers in the previous season and from those branches which flowered, but failed to set fruit. Under conditions prevailing in India, all shoots emerging in any month are capable of producing panicles in spring of the following year. Cool temperature conditions are known to induce flowering, but other factors such as the age of the stems since the previous flush also influence the response. The highest flowering occurs only in those shoots which are 15 to 16 weeks old. Both the timing of cold weather and intensity of cool night temperatures affect the flowering response.

Emergence of the panicle is the first obvious sign of flowering in litchi. After initiation, the primary axis of the inflorescence elongates and primordial of the secondary branches appear. The secondary branches develop similarly, with the development of the different floral parts taking place in axils of bracts of the main axis and branches. Each central primordium enlarges and differentiates into 2-4 hairy calyx lobes, with primordial protuberances develop from the central primordium into the carpel. The vegetative bud, which is typically dome-shaped, flattens and broadens with rapid elevations on both sides of the apex. The development of the different floral parts takes place in acropetal succession, without a dormant period between

floral initiation and anthesis.

The future panicle structure, number and type of flowers and their spatial distribution in litchi is set during panicle and floral bud differentiation. Panicles generally appear in two or three flushes, with the terminal branches developing first. Panicles are generally in mixed form and the number of flowers per panicle seems to increase in subtropical climates where low temperatures encourage dormancy. Growth of the panicle is sigmoidal and is usually complete in about 5-8 weeks, with considerable variation in the growth of individual panicles within a tree. Differences exist between cultivars with respect to the length and spread of the panicle and number of floral branches. Some general factors affecting flowering in litchi are:

1. Total duration of relatively low temperature is more important than frequency during the critical period preceding flowering.
2. Moisture stress conditions which influence floral initiation should be present during the preceding autumn and winter and fertilizer (nitrogen) should be withheld during the same period.
3. The response to cincturing depends on several factors including plant vigour, time of cincturing, cultivar and environmental conditions.
4. Exogenous auxins restrict vegetative flushing and induce floral initiation, but results have not always been consistent. The most widely used auxin is sodium naphthylene acetic acid (Na-NAA) at 100-200 mg/l is applied once or more. There is, nevertheless, a limit to the ability of exogenous auxins to inhibit vegetative flushing under constant warm and wet conditions. Growth retardants to restrict vegetative growth tested at different concentrations (1.0-4.0 g/l) of SADH (α -succinic acid, 2,2-dimethyl hydrazide), P₃₃₃ (Paclobutrazole) have significant effect on vegetative flushing or flowering but needs confirmation under Indian conditions.
5. An effect of crop competition has been reported where flowering is reduced in trees which have flowered abundantly in the previous year. However, this effect has not always been observed.
6. Genotypic effect on floral initiation has been observed in India, where early variety like Shahi is showing regular trend and late variety China, shows the alternate or heavy crop followed by low crop trend.
7. The above-mentioned factors do not act in isolation. They interact to control the pattern of vegetative development and floral initiation. Many studies have shown that floral initiation is always preceded by a period of induced dormancy in the terminal branches, but whether dormancy is the primary factor, is not known. Both carbohydrates and plant hormones have been proposed as factors controlling floral differentiation in tree crops, but a causal relationship between flowering and starch content has not been established.
8. It has been suggested that floral initiation in litchi may depend on a balance between a growth promoter (flowering inhibitor) produced by young, expanding leaves and a

flowering substance (growth inhibitor) produced by mature leaves. This assumption is supported by the fact that vegetative dormancy in the litchi appears to reduce the number of young leaves on terminal branches.

Pollination

Litchi is a highly cross pollinated crop. As a matter of fact, self-pollination in litchi can occur since functional male and female flowers are present at the same time, on the same or different inflorescences on a single tree but it is generally recognized that litchi flowers are self-sterile and therefore, require insects for pollination. An individual flower is self sterile, but possesses nectar which attracts insects like honey bees, flies, ants and wasp leading to entomophilic cross pollination. A nectary occurs on every flower as a large fleshy crenulate gland within the calyx to which the stamens and pistils are inserted. Nectar, secreted only in the morning, is highly attractive to honey bees and flies. At the time of flowering, installation of honey bee boxes in litchi orchard increases the yield up to 30-40 per cent. Beside that, growers can also obtain honey and can get extra income. Pollinators forage primarily between 06.00 and 12.00 hrs although foraging continues later in the day at much lower levels (Fig. 8.2).

Other pollinators are screwworm, ants, wasps, Coleopterans, Hemipterans, Homopterans and Lepidopterans but it is considered that bees are the most outstanding beneficial insects for pollination in litchi. The value of the honey bee is thus obvious in the setting of litchi fruits. When litchi trees are in bloom, honey bees gather immense stores of high quality honey.



Fig. 8.2: Honey bee—the principal agent for pollination

Pollinators' activity is reduced during extremes of temperature, cloud cover, heavy rain, and strong winds and in the presence of insecticides. Presence of 10-12 standard bee colonies is sufficient to ensure good pollination and fruit setting in one hectare area. Bees are present continuously throughout blooming period. If more colonies are kept, the foraging avenues for the bees are reduced without having any adverse impact on pollination or fruit setting of the trees.

Fruit Setting

Fruit set in litchi is climate dependent and profoundly affected by temperature and humidity. Reproductive failure is common and not always explained. In some years, certain cultivars produce few or only male flowers and as a result, there is little or no fruit set. This problem can be minimized through the use of better adapted varieties and management practices to retard growth and induce flowering. Winter/spring temperature extremes affecting bloom phenology and unsettled weather limiting bee movement during bloom have been identified as other causes of reproductive failure. Fruit set occurs when pollen, primarily from M2 flowers, is transferred to female flowers. The respective stages of bloom overlap between panicles and trees, but rarely overlap within individual panicles. There is considerable variability in the number of female flowers per panicle. Cultivars with the greatest number of F flowers per panicle produce the highest yields. Female flowers comprise 10-60 per cent of all flowers produced which depend upon the age of tree, panicle and environmental conditions.

Most of the flowers are either male or pseudo hermaphrodite. Thus, a small proportion of female flowers are produced and a limited numbers of flowers have successful pollination and fertilization. As a result of successful pollination and fertilization, fruit development starts and fruit set is observed on a panicle. With the successful pollination of the flower, a burst of growth of the erstwhile ovary occurs and development of a fruit begins. However, it has been observed that the fruit-set in litchi ranges from 1 to 48 per cent depending upon the cultivar, tree vigour and environment condition. It is also believed that 20 fruits per panicle finally produce a good crop. Except under extreme environmental conditions, pollen production does not seem to be a serious limitation to fruit set, provided there is an adequate pollinating insect activity. Litchi flower has bi-lobed ovary, out of which only one lobe develops into a fruit and very rarely both the lobes develop (Fig. 8.3).



Fig. 8.3: Litchi fruit has bi-lobed ovary, only one lobe develops into a fruit; very rarely both the lobes develop as seen here in the photograph

The Fruit

The litchi fruit is botanically a drupe, which is pendant in a loose cluster (up to 0.6m long) of several dozen fruits. It may be round, ovoid, heart-shaped or even kidney-shaped. It varies in size depending on the cultivar, but can measure 5cm in length and up to 4cm in diameter. The fruit has shoulder, suture, apex and skin segments which are seen from outside. Different parts of the fruits are briefly described in following paragraphs.

Epicarp : The rind of the fruit (pericarp) is thin, tough, hard, brittle and frangible. In the immature fruit, it is green in colour but in many commercial varieties it becomes bright red when ripe. Less bright shades of red may also occur and in some cases, the fruit may even be yellow or green. The skin has sharp protuberances which are much less marked than in related species such as rambutan and pulusan. When the fruit begins to dry, the skin changes to a dirty brown colour and becomes much more brittle. This occurs rapidly, even when the fruit is still perfectly edible. Four distinct types of tissues have been noted.

- The epidermis is composed of rectangular cells with slightly thickened out cells.
- Hypodermal sclerotic cells have characteristic transverse striations. These cells occur in one to three layers and show the presence of tannin inside.
- Ordinary parenchymatous cells with slightly lignified walls and dense cell contents similar to those mentioned above.
- Thin walled parenchymatous cells occurring at the base of the tubercle. Special cells containing resinous or latex-secretion occur mostly at the sides.

Mesocarp: The mesocarp tissue is somewhat loose in consistency. Any line of demarcation between the epicarp and the mesocarp does not appear as such. In the initial stages, this tissue is composed of ordinary parenchymatous cells which, later become separated on account of the development of large intercellular spaces. In botanical terminology, the edible part of the fruit is called aril. When the fruit is developing, the aril grows continuously around the seed from which, it separates as early as it does from the pericarp. The aril contains little material from the cell membranes. The pulp or aril is an outgrowth of the outer cells of the seed coat (outer integument) and in good cultivars; it may comprise 80 per cent of fruit weight. The aril is generally translucent usually white, in some cases verging on pink, translucent, slightly acid, juicy and sweet, with a faint and pleasant aroma. Many cultivars of litchi can be distinguished by their flavour and aroma.

Endocarp: Two distinct tissues have been noted in endocarp. (i) the outmost one, i.e. next to the aril, is composed of two layers of rectangular cells which are considerably thickened and lignified, (ii) the tissue above it is composed of thick celled elongated parenchymatous cells with tapering walls.

The Seed: The fruit contains a single dark brown seed measuring 6 to 12 mm wide and 10 to 23 mm long. Some cultivars have a high proportion of aborted seeds (chicken tongued seeds) and thus, a high flesh recovery. The seed is surrounded by creamy and pulpy edible aril (Fig. 8.4). It is cylindrical, compressed piano-convex or concavo convex, ex-albuminous and chocolate in colour. In the seedless cultivars, seed is small, shriveled and non-viable.



Fig. 8.4: Comparative size of seed in litchi fruit; fruits with tiny aborted seeds are preferred due to their higher aril percentage

Fruit Growth

Only one of the two ovaries of the female flower normally develops into a fruit. Very rarely, two lobes develop, with the mature fruit superficially resembling two fruit adhering to each other at their bases, each containing a seed. Fruit growth is normally faster when it occurs late in the season during warmer weather. All parts of the fruit do not develop at the same time. During the first seven to eight weeks after fertilization, the fruit skin, the embryo and the seed coat are formed (Fig. 8.5). At the end of this stage, the aril or flesh is only a negligible portion of the fruit.

During the next two to three weeks, the cotyledons (or seed leaves) that comprise most of the seed are formed and the development of the aril begins. At the end of this stage, the aril is about third of fruit fresh weight. The final period of fruit growth is dominated by rapid growth of the aril (seed development also continues). At fruit maturity, the aril is about 65 to 75 per cent of fruit weight. Depending on the season and cultivar, fruit take about 12 to 16 weeks to mature.

Maximum fruit weight occurs about two to three weeks before the fruit mature. In most cultivars, the colour changes from green to yellow-red to red with advancing maturity. This

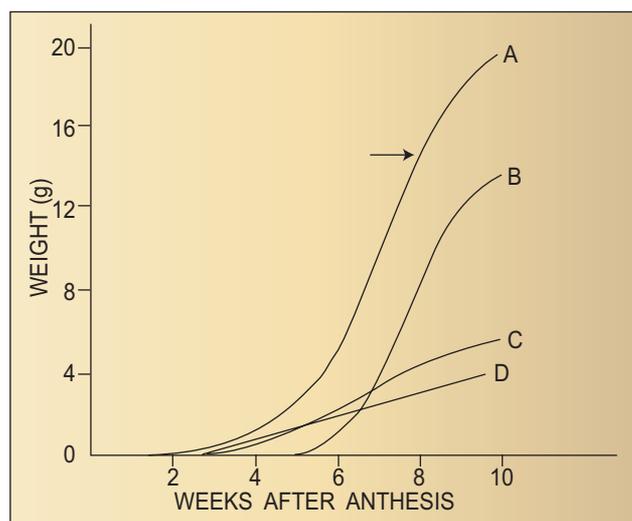


Fig. 8.5: Fruit growth in litchi shows a sigmoid growth curve

change is associated with a flattening of the skin segments and protuberances, and an increase in sugar/acid ratio and eating quality. Fruit weight is related to weather and tree culture, and ranges from 15 to 35 g for different cultivars. Cultivars that have a high proportion of chicken tongue seed normally produce smaller fruit. Some of these cultivars may also produce nearly seedless fruit. These normally weigh only 8 or 10 g. High leaf nitrogen and potassium concentrations and regular irrigation are essential for good fruit yields. High temperatures often accelerate fruit development at the expense of fruit weight. However, at very low temperatures, photosynthesis is reduced. Growth curves are typically sigmoidal for the pericarp, seed and aril as well as for the fruit itself, with final size depending on the cultivar and the environmental factor. Growth regulators (exogenous auxins and gibberellins) have shown positive influence on fruit growth.

Fruit Drop

In litchi, more female flowers are produced than fruit set and far more fruits are set than develop to maturity. Large numbers of fruits are set initially but only few remain up to maturity. Typically, in premature fruit, abscission commences soon after anthesis and continues till fruit maturity, with most fruit abscising in the first two to six weeks. This varies greatly with location, cultivar, weather and culture. In some cases, all of the fruits are dropped before maturity. The initial abscission is mainly due to failure of fertilization. Fruit can also fall due to embryo abortion. The later abscission of fruit is mainly due to competition for assimilates (Fig. 8.6). Girdling at this stage often reduces fruit drop, while drought, shade and leaf removal increase it. Fruit thinning at this time also increases the retention of the remaining crop. The major fruit

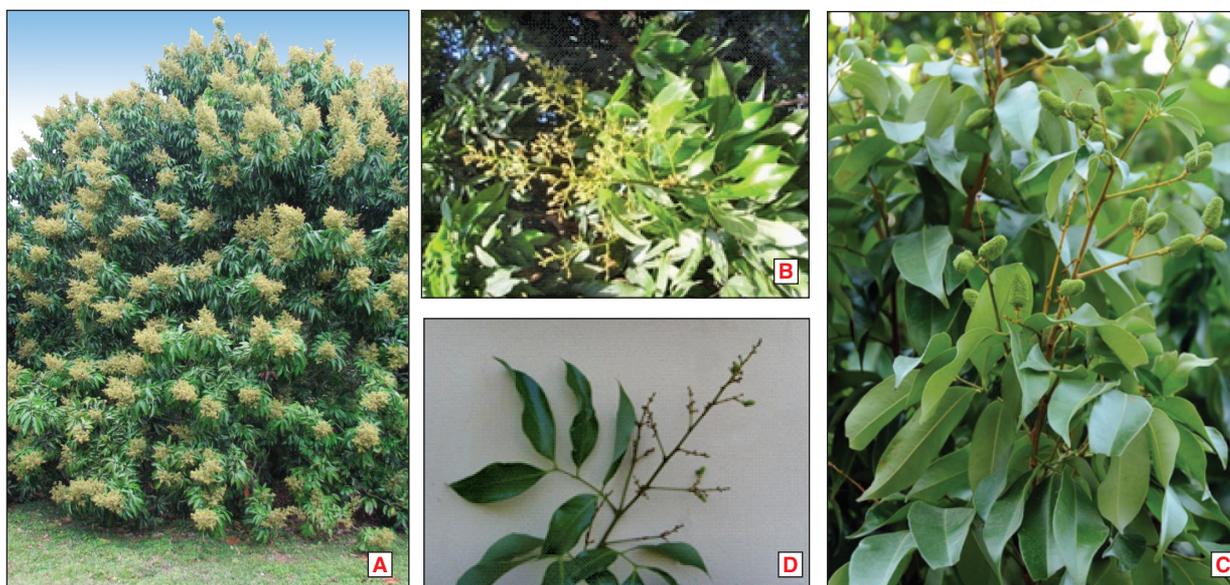


Fig. 8.6: Flowering and fruit set in Litchi (A) the plant in full bloom, (B) initial fruit set, (C) fruits at clove stage, and (D) panicle showing poor fruit set

drop period occurs before the peak demand in carbohydrates by the developing fruit. The young green fruit can photosynthesize, however, most of the carbohydrates for the fruit come from current assimilation in the leaves behind the fruit clusters. Reserves in the branches can also be used. Young leaves do not induce fruit abscission unless they develop directly behind the fruit cluster. This generally occurs when fruit set is poor. Fruit-sucking bugs and fruit borers induce fruit abscission in many orchards. In some areas, they can account for more than 90 per cent of green fruit drop.

Nutritional and hormonal imbalances have been implicated in premature fruit abscission. Experiments have shown that fruit retention can be improved by applying auxins when the fruit weigh about 1 to 2 g. Earlier or later applications are ineffective. Some of these growth regulators can also increase fruit size. Treatment with 2,4, 5-TP in order to prevent abscission and obtain larger fruit succeeded in producing fruits of an excellent colour, with chicken-tongued seeds, but the skins are prone to cracking and the fruits weigh not more than 10g. As with other fruit crops, the causes of fruit drop are numerous which includes, poor fertilization or its failure, non survival of embryo, internal nutritional factors, hormonal imbalance, moisture stress at critical stage, high wind velocity, sudden increase in temperature, in appropriate cultural factors and genetic factors of plant.

Application of micronutrients such as boron and zinc alone or in combination with growth regulators has been found effective for fruit retention up to some extent. There have been no experiments to define the role of environmental factors in premature fruit drop, although it is thought that high temperature, strong winds, extremes of soil moisture and humidity accelerates the process of fruit drop. Little work has been done on the relationship between fruit growth rate and abscission or between abscission and fruit load. The relative contribution of tree reserves and assimilate production to fruiting has not been studied either, although it seems logical to suppose that abscission of the reproductive structures is accelerated by the aforementioned environmental conditions which reduce assimilate production or favour rapid vegetative growth (over-irrigation or fertilization, especially in combination with warm temperatures).

Fruit Yield

The crop load which a tree can bear is primarily determined by the genetic make up of cultivar (Fig. 8.7) and the tree reserve level. Excess fruit drop may happen at various stages of fruit development. Even if trees have sufficient reserves, lack of nutrients or soil moisture deficit during fruit development phase or pest and disease attacks on flowers and developing fruits may act as limiting factors that control the quantum of the final crop. Therefore, at this stage trees have to be managed very well providing all necessary inputs correctly. Litchi yields are commonly unreliable and erratic and rarely approach the capacity of the tree. Abscission of fruitlets resulting from self-pollination may occur at high rates in some cultivars, resulting in high levels of hybrid fruit (76-95%) at maturity. Moreover, hybrid fruit are heavier and



Fig. 8.7: Bearing potential of a variety is genetically controlled; (A) Cv. Shahi, (B) Early Bedana, (C) Cv. Rose Scented, and (D) Cv. China. A, C, D are heavy bearing varieties while B has tendency of sparse bearing

have larger seeds, although the latter is not necessarily desirable. Well managed mature litchi orchards with usually about 100 trees/ha, can produce as much as 10-15 tonnes of fruit/ha in a good year. Orchards are usually planted at a much higher density and later thinned to have high yield in litchi. Average yields per tree ranges from 10-80 kg. A six year old tree may produce 0.9-1.4 kg of fruit, while a 12 year old tree may yield 140 kg. In general, 60-70 kg fruit/adult tree/ year is considered an acceptable yield and 120-130 kg / tree on excellent one. These acceptable and excellent yields correspond to a level of 12-13 tonnes productivity per hectare with normal spacing.