Pre- and Postharvest Management Practices for Litchi Production in India

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Abstract

Litchi (*Litchi chinensis*) is an important woody mycorrhizal fruit tree originated in China. In India, the agroclimatic conditions of foothills of the Himalayas in northern states like Bihar, West Bengal, Uttarakhand, Jharkhand, Punjab, and northeastern states such as Assam and Tripura provide immense scope for litchi cultivation. Various abiotic and biotic factors affect the litchi cultivation and production. Optimum temperature, humidity, soil nutrition, and climatic conditions are the deciding factors to support litchi cultivation, but insect and pest infestation severely affect the overall production of litchi. Insects are the major limiting factor affecting litchi production compared to the diseases. Various agricultural practices such as propagation methods and girdling also have an influence on the litchi plantation and overall productivity of this delicious fruit. The present chapter focuses on economically important pests and diseases and their control measures to reduce the infestation altogether with pre- and postharvest management practices to increase the productivity and shelf life of mature litchi fruits during storage as well as transportation process, respectively.

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3.1 Introduction

The litchi (*Litchi chinensis* Sonn.) is one of the most delicious fruits which China has given to the world. It belongs to the family *Sapindaceae*. A monograph on litchi was written by Tsai Hasing in 1059 AD, is considered to be the oldest publication on litchi fruit. No Chinese dinner was considered complete without dried litchi nuts. The spread of the litchi to other parts of the world has been limited and has taken place only comparatively in recent times. India is probably the second largest litchi producer in the world. It was introduced in Bengal at the end of the eighteenth century.

Litchi is a typical non-climacteric subtropical fruit and only commercially grown in two narrow strips from 17° to 26° altitude of southern and northern hemispheres (Menzel and Simpson 1986). Litchi cultivation has been reported since 1500 BC by the people of Malayan descent and has been growing for thousands of years in the southern Guangdong province of China. From China, it reached Myanmar by the end of seventeenth century and was introduced in India about 100 years later. It reached West Indies by 1775, followed by Madagascar and Mauritius around 1870. It was introduced in Hawaii in 1873 by a Chinese trader. From India it arrived in Florida between 1870 and 1880 and was introduced in California in 1897. Litchi was reported to be brought to Australia by Chinese migrants in 1954 and reached Israel sometime between 1930 and 1940. Presently, litchi is grown in Central and South Africa, throughout Asia (China and India), South Africa, Australia, Mauritius, Madagascar, Thailand, and Vietnam, and these are now the major litchi-producing countries in the world. Some of the major litchi-producing countries and their major cultivars are listed in Table 3.1. A survey was conducted in 2013–2014 and reported that the area under litchi production in India was 84.2 thousand Ha. and total production estimated 585.30 thousand MT. The major area under litchi cultivation falls in Bihar, West Bengal, Uttarakhand, Assam, Chhattisgarh, Jharkhand, Odisha, Tripura, and Punjab (Table 3.2). Among all litchi-growing states of India, Bihar contributes 40% of total litchi production in India. Other states like West Bengal, Jharkhand, Assam, Chhattisgarh, Uttarakhand, Punjab, Odisha, and Tripura contribute 16, 10, 8.2, 6.4, 5.2, 4.8, 3.5, and 3.4%, respectively (Saxena et al. 2014). There is a scope for the further extension of this fruit crop along the entire foothill region of Uttarakhand, submountain region of Uttar Pradesh, and Punjab states of India (Nijjar 1981).

Litchi is one of the most environmentally sensitive subtropical fruit crops. It is a non-climacteric fruit, and shelf life at room temperature (30 °C) is less than 72 h. However, maintaining cold chain with optimum temperature range of 1–2 °C and relative humidity between 90 and 95%, can enhance the shelf life of sulfur treated

Table 3.1 Litchi producing countries and major cultivars

S. No.	Country	Major cultivars
1.	China	Boh Lup, Baitong-Ying, Fay Zee Siu, Hoak Yip, Kwai May (Red), Long Lue, No-Mai Chee and Wai Chee, Sum Yee, Hong, Souey Tung, Tai So, and Brewster
2.	Australia	Fay Zee Siu, Tai So, Bengal,Wai Chee, Kwai May Pink, Salothiel
3.	India	Bedana, China, Culcuttia, Late Seedless, Late large Red, Elaichi, Shahi, Rose Scented, Purbi, Dehradun
4.	Indonesia	Local selections
5.	Israel	Mauritius
6.	Madagascar	Madaras, Mauritius, Tai So
7.	Philippines	Sinco, Tai So, ULPB Red
8.	South Africa	Mauritius, Mc Lean's red, Tai So, Madras, Bengal
9.	Thailand	Chacapat, Hoak Yip, Kom, Tai So, Wai Chee, Baidum
10.	USA	Brewster, Hoak Yip, Kwai Wai, No Mai Chee, Shanchi, Kaimana Brewster.
11.	Vietnam	Vaithieu
12.	Taiwan	Hoak Yip, Sah Keng

Source: The litchi crop in Asia and Pacific regional office for Asia and the Pacific, FAO corporate document repository. http://www.fao.org/documents/en/

Table 3.2 State-wise area production and productivity of litchi in India

State	2011–2012		2012–2013		2013–2014	
	Area (000 Ha.)	Production (000 MT)	Area (000 Ha.)	Production (000 MT)	Area (000 Ha.)	Production (000 MT)
Bihar	31.1	236.4	31.28	256.43	31.48	234.20
West Bengal	8.9	85.3	9.19	90.00	9.30	93.90
Jharkhand	4.8	57.5	5.27	58.24	5.27	58.24
Assam	5.3	41.5	5.63	49.64	5.38	48.08
Chhattisgarh	4.5	27.1	4.99	30.89	5.36	37.63
Uttrakhand	9.5	19.0	9.49	19.16	9.44	30.71
Punjab	1.7	24.5	1.75	26.52	1.85	28.00
Odisha	4.5	20.1	4.46	20.26	4.47	20.32
Tripura	3.2	16.6	3.46	17.97	3.88	20.18
Others	3.2	16.6	7.23	10.98	7.74	14.04
Total	**80.40**	**538.10**	**82.70**	**580.10**	**84.17**	**585.30**

Source: All Indian 2013–2014 (Final Estimates), Department of Agriculture & Cooperation

as well as fresh litchi by 3–5 weeks. Dehydration, brown discoloration of pericarp, and rotting greatly reduce commercial value of fresh litchi. In the production side, the major problem is low and irregular yield due to poor flowering and fruit set which may be due to different biotic and abiotic conditions.

3.2 Abiotic Factors Affecting Litchi Cultivation

3.2.1 Climate and Temperature

The litchi cultivation and productivity depends on appropriate climatic conditions which is the most limiting factor in the extension and spread of this delicious fruit. It requires a moist subtropical or tropical climate without heavy frost or hot dry winds. Low humidity can be compensated to some extent by liberal irrigation in the dry periods. Dry atmosphere and cold snaps between 1–4 °C in winters are beneficial. Seasonal variations in temperature are necessary for bumper fruiting. In Southern India, where the seasonal fluctuations in temperature are limited, litchi grows successfully only on hill slopes up to an elevation of 35,000 f. which are cooler than plains. In litchi-growing tracts of India, temperature varies from 21 to 37 °C during the flowering and fruiting seasons. In Southern China, the home of litchi, the annual rainfall is 60 in. but this high rainfall is by no means absolutely essential. It grows successfully with drip irrigation in the state of western Uttar Pradesh, India, where the annual rainfall is not more than 35 in. Prolonged rains are not desirable, especially at the time of flowering, when it interferes with pollination. Alternate spells of rain and dry heat in summers cause fruit splitting and drops. The split fruit rots quickly and is not fit for consumption and marketing. Splitting of fruits also takes place if the fruiting season is extremely dry. The relative humidity varies between 80% and 90% during day and night in many litchi-growing areas. This is, however, not essential if good irrigation facilities are available. The limiting factors in the extension of the litchi cultivation areas in India is the hot and dry wind prevalent during the months of April to June when fruit matures. At present, the entire area under litchi cultivation is confined to the foothills of the Himalayas, where the humidity in these months is comparatively high. It can be extended away from the Himalayas if sufficient irrigation facilities in the summer months and adequate wind breaks are provided.

The young plants during the first 3 or 4 years are very susceptible to the frost and need to be protected, but mature trees can withstand mild frost easily. Horticultural studies revealed that frost resistance varies at different stages of tree development. Trees are more susceptible to frost during their dormancy in the cold weather, whereas they are not susceptible to frost when the trees are in flush. Consequently, early frost is less dangerous than the late frost.

Sunburning and skin cracking of developing fruit could be a serious problem in litchi and are promoted by high temperature, low humidity, and low soil moisture in orchards. Temperature higher than 38 °C in combination with humidity lower than 60% promotes litchi fruit cracking. Inadequate moisture during the early period of fruit growth results in the hardening of skin which results to sun burn. It may crack when subjected to increased internal pressure as a result of rapid aril growth following irrigation. The different litchi cultivars show variation in sunburning and skin cracking symptoms which subsequently damages the pulp. The cultivars which have relatively thin skin, few tubercles per unit area, and rounded or flat shape are less prone to cracking. Frequent irrigation during the critical period of aril

growth and spraying of zinc sulfate (1.5%) at weekly interval starting from pea stage of fruit growth to harvest and spray of gibberellic acetic acid (GAA) at 40 ppm and ethephon at 1.00–10.00 ppm application reduces the incidence of fruit cracking.

3.2.2 Soil

Litchi can grow in a variety of soil types provided they are well drained, but it grows best in a deep well-drained loam, rich in organic matter. The water table should be at least 1.5–2 m deep. The litchi roots can stand immersion for a considerable time, provided the water is flowing as stagnant water causes root decay. In West Bengal, it grows near the bank of Hooghly River. It has been reported that litchi grows well in slightly acidic soil compared to neutral or slightly alkaline soil. In the state of Bihar in India, litchi grows well in soil containing organic matter up to 30%. Thus, it is apparent that it grows well in acidic soil as it can also grow in calcareous soils. Addition of lime to maintain pH between 5.0 and 5.5 would be beneficial. The roots are covered with tubercles containing mycorrhizal fungi to a larger extent. These fungi grow on the roots of the litchi which mutually benefit both plant and fungi. Arbuscular mycorrhizal (AM) fungi supply mineral nutrients to the roots, influence plant development, and enable mycorrhizal plants to overcome biotic and abiotic stresses. The litchi tree provides carbohydrates to fungi which help it to complete its life cycle. Hence, it is recommended that the new saplings of litchi may be planted in the vicinity of the old litchi tree which helps in the introduction of mycorrhizal fungi to the roots of the new plants of litchi. High organic content and well-acraled soils which do not dry up are not suitable for the growth and development of the mycorrhizal fungi. Studies on the mycorrhizal fungi and litchi host interaction have shown that litchi plant could allocate up to 30% of their manufactured carbohydrate to AM fungi, whereas the fungi in return provide 80% of plant phosphate and nitrogen. A fairly high percentage of clay in the soil is beneficial, but in India and Florida (USA), litchi plants have flourished on light loamy soils as well. Deep plowing may be necessary if the soil is compact. Litchi trees tolerate poor drainage but do not grow well in standing water. Surface drainage should be installed if such conditions exist. If nematodes are expected to be a problem, fumigation should be carried out.

3.3 Nutritional Management (Fertilization)

Fertilization practices in commercial litchi orchards differ due to differences in climate, soil, and availability of different kinds of organic and inorganic matters. The practices for litchi cultivation on alluvial or red basaltic soils require application of 300–400 g urea, 100 g superphosphate, and 25–50 kg compost per tree just after harvest but not later than July. At the time of blossoming, 100 g urea, nitrogen–phosphorous–potassium (NPK) per tree needs to be applied. To prevent

Table 3.3 Manure and fertilizer schedule for litchi cultivation

Age of plant	FYM (Kg)	C.A.N.	Per plant/year (in Kg)	
			Super phosphate	Nitrate of Potash
1–3 years	10–20	0.3–1.00	0.2–0.6	0.05–0.15
4–6 years	25–40	1.00–2.00	0.75–1.25	0.20–0.30
7–10 years	40–50	2.00–3.00	1.50–2.00	0.30–0.50
10 years and above	60	3.5	2.25	0.60

Source: Nijjar (1981)
FYM Farm yard manure, *CAN* Calcium Ammonium Nitrate

fruit drop, trees are sprayed with 0.1–0.2% urea and sometimes with 0.2% magnesium sulfate. A light fertilization should be carried out with care immediately after field transplanting due to the sensitivity of litchi roots to fertilizer burns. Heavy application should be delayed after a year or after one or two growth flushes. One-year-old trees are provided with 30 g urea per plant per month. Highly analyzed mixed fertilizer such as NPK (15:4:11) is given every 3 months together with the urea. Fertilizers in subtropical areas are withheld during cold months to prevent flushing. Whereas in Australia general recommendations for 5-year-old litchi trees are 150 g urea, 300 g single superphosphate, and 150–200 g potassium sulfate application. These quantities are increased by 20–30% each year till trees attain the age of 15 years, when each application rate increases to 1200 g urea, 1200 g superphosphate, and 600–800 g potassium sulfate. No fertilizer is applied to flower-bearing trees in the spring to prevent vegetative growth in the autumn to enhance the flowering. The conditions for floral induction, besides tree condition, are temperature and water stress conditions for litchi. Manure and fertilizer schedule for litchi is listed in Table 3.3.

3.4 Biotic Factors Affecting Litchi Cultivation

3.4.1 Insect

The major loss faced by litchi cultivation is due to insects which are of greater concern in litchi production than diseases. These are described as below:

3.4.1.1 Erinose Mite/Eriophyid Mite, *Aceria* (*Eriophyes*) *litchii* Keifer

It is also known as hairy mite, hairy spider, or dog ear mite. It is a small whitish insect hardly visible to the naked eye. It lives at the base of the hairs on the undersurface of the leaves and causes a brown velvety growth. Pits are formed which may develop into galls and finally the leaves curl up. The adult sucks the sap from the leaves during winters. The breeding starts in March, and maximum activities are found in July. The life cycle is completed in about a fortnight. The mites are very small measuring 0.13 mm long and pinkish-white in color. All stages have only four legs (Waite and Gerson 1994; Waite and McAlpine 1992). The fruit

setting is disrupted if the mites move from leaves to the fruits. The mites can be controlled by destroying the affected leaves on the trees manually as well as those which have fallen down should be burnt or put in the pits and buried in soil. Banding of the trees in the month of December with one and a half feet wide plastic band, the upper and lower end of band wrapped with cotton thread (sutli) and coated with coal tar, can prevent the adult and nymphs of mite and mealybug from climbing up the litchi tree. Spraying the trees with any contact miticide, namely, Kelthane (0.1%) and Phosphamidon (0.3%), is also effective. The leaves can be destroyed either by burning or by burying in deep soil. For banding, coal tar or cloth band soaked in weak crude oil emulsion can be used. If the crude oil is too strong, then it may also kill the litchi tree.

3.4.1.2 Bark-Eating Caterpillar (*Indarbela quadrinotata* Walker, *I. tetraonis* Moore)

The attack of bark-eating caterpillar has been observed on the older trees, but it is not a very serious pest of litchi. The branches, especially the old ones, have elongated zigzag ribbonlike messy web with the presence of brownish ribbonlike loose masses of excreta which remain attached with the main scaffold branches at the point of injury. The caterpillar is very harmful to the litchi trees as it feeds on the bark, and in this process it seriously injures the plant vessels through which nutritional plant sap is transported between the plant system, which adversely affect the growth and fruit-bearing capacity of the tree. At times, the infested branches can dry up, and during serious infestation, the whole tree may die. It is a peculiarity of this pest that it prefers older trees than the young ones.

The adult is a large-sized moth with a wing span of about 4 cm in female and 3 cm in male, light gray to light brick red in color with dark brown patches or dots on it. The female adult moth lays eggs in groups of 15–25 during May–June which hatch after 8–11 days. The larvae take shelter in a web of wood bark powder and excreta, and continue feeding on the surface of the bark up till September. Afterward, they bore into bark and underlying tissues in the branches. These become fully grown up by December and pupate in late April. Caterpillars bore inside the bark or main stems and branches about 150–250 mm deep during night. They come out during the night to feed on the bark which is protected by large silken webs that cover the entire affected portion. Later they bore through the bark into the wood. In case of severe infestation, sap movement is disturbed and flush is adversely affected. The larval habit is quite important. It remains in hiding practically the whole day and comes out for feeding on fresh areas during the night only. The pupation starts from April onward and takes place within the larval gallery. Pupal period is only 3–4 weeks.

The rational approach is to clean the web and fumigate with any ordinary fumigants such as carbon disulfide, petroleum, or formalin and check the caterpillars. This operation may be carried with any one of the above fumigants by putting the whole swap of cotton wool dipped in liquid fumigant and inserting the same into the hole which should thereafter be plucked with mud. Another somewhat simpler approach is to inject a strong persistent insecticidal liquid

formulation into the web of the larvae and also smear the same up to some distance outside the hole so that when the larvae come out in the night, it may get poisoned. Spraying of either of the insecticide that is dichlorvos (0.03%), trichloroform or endosulfan (0.05%), parathion (0.05%), and methidathion or azinophosmethyl (0.05%) is recommended for its control.

3.4.1.3 Anar Butterfly (Fruit-Eating Caterpillar) *Virachola isocrates* Fab

This pest causes moderate damage to several fruits including litchi, which is distributed throughout India. The larval stage is the most important stage of this pest. The larvae bore into the fruit and feed on its content. It actually creates a lot of mess, and offensive smelling matter oozes out from the entrance hole. Obviously, the wound caused by this pest gets infected with a number of bacteria and fungi which results in the rotting of the fruits.

The female butterfly lays eggs singly on various parts of the shoot, but the young caterpillar which hatches out within a week or 10 days starts feeding on fruit and bores into the litchi fruit. They do not feed on leaves. The larval period may last from 2 weeks to one and a half month. The preparation takes place and pupal period varies from a week or so to more than a month. The breeding of the pest continues throughout the year since it is a polyphagous pest in nature which is influenced by the climatic or weather conditions. As the larvae bore directly into the fruit, there is no satisfactory control measure for this pest. There are few control measures such as vapor heat treatment (VHT) or hot water treatment (HWT) which may be applied for its control. Sometimes infestation is so serious that it may cause 90% damage to the fruit by this pest alone. The effective options may be searched to attract the adults for trapping. The infested orchards may be sprayed with phosphamidon (0.05%) or metasystox (0.3%) at monthly interval. The first spray should be carried out in the month of April in northern parts of India.

3.4.1.4 Mango Mealybug [*Drosicha mangiferae* (Monophlebus stebbingi)]

The orchard of litchi or any alternative hosts in surrounding areas such as mango, citrus, kinnow, papaya, guava, pomegranate, *Ficus* spp., etc. are prone to infestation with these large fleshy flat-bodied bugs that are about one and half centimeter long and little less than a centimeter in width, covered with waxy white mealy powder. These insects crawl downwards from the tree after fertilization to lay eggs and take shelter near the tree trunk, soil craveces, fallen leaves, and pack-houses etc. These are insects belonging to the bug group; most of these bugs suck the tender parts of the plant sap. More than 65 host plants are recorded for this pest. The sucking activities of these bugs results in the production of honey dew which encourages the growth of the sooty mould, giving a very unhealthy appearance to the plant. At times, they are found clustering in masses on young shoots like fungus outgrowth. The female is wingless, and males are winged form with one pair of wings. They have a very delicate reddish body which flies actively and fertilizes the females. The male adults have much shorter longevity than the female adults which live for a month. The adult gravid females after fertilization crawl down from the

trees along the trunk to the ground where they lay eggs at depth of about 2–6 in. and in a cluster of 300–400 eggs each. After egg laying, the female dies and remains inside the soil plant debris till the emergence of the next season. The oviposition is generally confined to an area of a few feet in diameter around the base of the tree. The female adult migrates from the trees toward the ground and oviposition in the soil where the males die soon after mating and the female soon after oviposition.

The eggs laid in the soil take quite a few months before they hatch, and their hatching has been reported to be quite appreciably influenced by the temperature and moist conditions of the soil. In northern India, hatching starts from last week of December to the third week of January. Therefore, it is advisable to start plant protection measures by the third week of December. Late monsoon and winter rains have been reported to delay the hatching. The young hatched nymphs after hatching crawl to search some suitable host plant on which they spend some time. Afterward they start migrating on other host plant, and this upward migration lasts several weeks. On reaching the freshly grown shoots, the nymphs congregate there and begin to suck the plant sap. They molt thrice during their nymphal period which lasts about 3 months or more, depending upon the environmental conditions, especially temperature. Therefore, male nymphs undergo short pupation period and transform themselves into winged adult males, whereas female-producing nymphs do not undergo any pupation changes except increase in size. Thus, there is only one generation occurring in a year.

Raking of the soil surrounding the base of the tree trunk which has been infested helps the air masses get exposed to the sun heat and get killed or eaten up by the different predators. The newly hatched nymphs can be killed by the application of soil insecticide in the affected area. The application of sticky band around the tree trunk helps in checking the upward movement of the nymphs on the litchi tree. Incorporation of the slippery material like polythene seeds in the sticky band is likely to increase the effectiveness of this band. Strong organophosphorus insecticides are sprayed which can penetrate the waxy covering of the nymphal body and can also control the pest, but such applications are likely to be more effective if carried out when the nymphs are young. The strength of the spray has to be considerably increased if they have to be applied when the pest is in the advanced developmental stage. The farmers have to be careful while selecting the insecticides so that they should not be harmful to the pollinating insects which are the main source of pollination in litchi.

3.4.1.5 Soft Brown Scale (*Coccus hesperidum* Linnaeus)

It is a pest of minor economical importance in India. The scale causes no significant damage to the fruit, but their severe presence on the fruit reduces its commercial value. The females are sometimes mistaken with mango mealybug because the egg masses are covered with white waxy filaments at the end of the scale. The scales also produce honeydew which helps in the development of the sooty mould on the fruits and panicle. This also causes discoloration of the fruits which downgrades the fruit quality and reduces its market value.

3.4.1.6 The Cocoa Moth or Fruit Borer (*Conopomorpha cramerella* Snellen)

Earlier it was known as *Acrocercops cramerella* Snellen (Bradley 1986). The moth was found to start its breeding activities on the litchi tree from August to February, and during the offseason (March to July), its restricted breeding was observed on *Eugenia jambolana* (Jamun) and *Cassia tora* (Chota Amaltas). The highest peak population of the moth was observed during September and seems to be associated with high temperature followed by high relative humidity. Low temperature and high humidity seems to be associated with its retarded growth and development. The larvae of the moth were noticed to mine the leaves and also bore the shoots and fruits of litchi. The branches of the infested trees appear withered and drop the poor flowers and fruits. The duration of the life cycle of the moth range between 13 and 20 days during August to September. The "shahi" variety was found more susceptible, while "longia" variety of litchi is highly resistant. The larvae of *Acrocercops cramerella* after hatching from the eggs bore into fruits by tunneling the fruit pulp and start feeding on it. When the larvae are full grown, they come out and pupate on the leaf surface. The larvae of *A. cramerella* were found to mine the young leaves and buds of *Cinnamomum* sp. (Cachar plant) and cause a large blotch by mining the upper epidermis of the leaf. The larvae of *A. cramerella* were found to mine the young leaves, shoots, and also bore in the fruit. The larvae on hatching from eggs were found first to penetrate the basal part of the leaves and young shoots before damaging the epidermal cell. As a result of infestation, leaf mining causes leaves to dry and fall on the ground. The infested twigs present a dropping appearance. The leaf infestation varied between 7.1 and 72.5%, while pre-infestation ranged between 47.7% and 88.9% during August to February. The highest tree infestation (88%) was observed in the month of August and lowest (47.7%) in the month of January.

Egg incubation period ranges from 6–7 days, larval period 15–18 days, and pupal period 5–8 days. Eggs are laid by a female varied between 30 and 46 numbers. Larvae undergo 5-month hibernation before pupation. Pupation usually took place inside the oval cocoon on the leaf surface. The duration of the life cycle varied between 13 and 22 days during August to February.

To control the said pest, foliar spray with the methyl demeton (0.25%) or dimethoate (0.3%) in the month of September gave good control of the pest. The larvae of *A. cramerella* could be controlled effectively by spraying of carbaryl/Sevin (0.4%).

The application of 4 kg of Castor cake and 1 kg Neem cake per litchi tree in the soil of the basin of the trees after the first shower of monsoon showed higher population reduction (56.55%).

3.4.1.7 Leaf Rollers (*Platypeplus aprobola* Meyrick and *Isotenes miserana* Walker)

The insects roll or web leaves together to form a shelter in which they feed and subsequently pupate. Heavy infestation causes extensive leaf damage, especially to developing leaves/flushes. Due of their sheltered habit, it is difficult to kill the insect

with a contact insecticide. Spraying of endosulfan or carbaryl at 2 g/L water during new leaf growth and before flowering time (at least once just before flowering) was found effective in controlling the pest.

3.4.1.8 Macadamia Nut Borer (*Cryptophlebia ombrodelta)*

The litchi berry shows light brown sawdust like frass symptoms at the fruit holes near the stalk. When peeled, an aril colored grub 1–1.5 cm in size may be seen at the pedicle end or in the hole or even in the seed (Butani 1977; Bradley 1953).

It can be controlled by the application of one spray of azinphos-methyl (350 g/kg or 140 g/L water) or Guthion to the whole tree for 2 weeks after fruit setting. One spray gives protection for about 2 weeks. Examine young fruits with hand lens for signs of damage, and if noticed, apply second and third spray as per need during fruit development.

3.4.1.9 Litchi Stink Bug (*Tessaratoma papillosa*)

This bug leaves brown stains of about 1/8–½ in. on the infested fruit. No hole(s) is seen and neither flesh found discolored on peeling. Damage is caused by the stink bug excreting on the fruit while feeding from the fruit petiole. These bugs appear on the trees during spring (February–April). They suck the sap and blemish young fruits with their excretions. The young at the nymphal stage are often seen on the trees during late spring.

Control measures include spraying of trees with endosulfan at 150 ml/100 L of water once or twice at the beginning of fruit setting (at the late fruit developmental stage).

3.4.1.10 Fruit Spotting Bug (*Amblypelta* sp.)

After infestation, young green fruits of 1–2 cm drop heavily (Waite and Huwer 1998). There is no apparent external fruit damage noticed. As soon as the skin is removed, numerous brown pinprick holes in flesh and/or deep lesions on the developing seeds can be noticed. Treatment is necessary at the first sign of heavy fruit shedding. Spraying of endosulfan at 150 ml/100 L of water provides good control.

3.4.1.11 *Rhynchaenus mangiferae*

It feeds on newly emerged leaves and flowers and ultimately destroys them. Pre-bloomed spraying of 2.5 ml metasystox in 10 L of water or any systemic insecticide shows good control measure of the pest.

3.4.1.12 Mango Hopper (*Idiocerus clypealis, I. niveosparsus,* and *I. atkinsoni*)

These are greenish wedge-shaped small-sized insects (also known as Jassids), which varies greatly according to the species. Both adults and nymphs suck the sap from the tender plant parts such as young shoots and panicles. The insect thus causes withering away of panicles, minimizes the fruit setting, and results in the premature fruit drop. Physical injury is caused to the flower buds by ovipositions.

Nymphs are more harmful. Hoppers are mostly active in the flowering and fruiting periods.

Spray the litchi trees with malathion at 0.15% during February–March before the emergence of flowering panicles. Two to three applications are needed to control the pest effectively.

3.4.1.13 Litchi Leaf Miner (*Conopomorpha litchiella* Bradley)

It produces the symptoms like fruit borer. The female lays light yellow eggs on the leaf surface (probably on the lower surface), and larvae bore inside the midrib of leaves. The eggs hatch within 3–4 days, and the creamy white newly hatched larvae start boring into the shoots as well as the leaf blades. The larvae tunnels through the midrib and may enter leaf veins subsequently. Since the vascular system is destroyed, the leaf lamina, in parts or in full, dries up and turns brown. It also bores into newly formed panicles and the entire panicle may dry up. Maximum damage has been observed in the month of September–October resulting in the destruction of entire autumn flush.

Control measures include spraying of the trees with monocrotophos/monocil or nuvacron at 100 ml/100 L of water. Contact insecticide to be sprayed only on the new flush.

3.4.1.14 Shoot Borer (*Chlumetia transversa* Walker)

The caterpillars make a hole/bore inside the newly developed shoots/twigs and start feeding on them which causes drying of the new flesh and twigs. In case of severe infestation, the cell sap of the plant parts gets interrupted, which adversely affects the growth of the plants/saplings.

For the effective management of the pest, it is suggested that pruning should be carried out when initial infestation/damage is noticed. The dried twigs/branches should be burnt or buried by putting them in deep soil pits. For the effective control, the chemical control measures may be applied. Carbosulfan or quinalphos (0.05%) provide good control measure for the pest.

3.4.1.15 Fruit Borer (*Platypeplus aprobola* Meyer, *Dichocrosis* sp.)

It is a serious pest of litchi and causes maximum damage when plants are at fruit developing stage. The newly hatched larvae bore through the fruit stalk at the end of the fruit and damage the nuts/skin of the fruits. The higher humidity and intermediate rains provided favorable conditions for the pest development and infestation. It results in the fruit drop which adversely minimizes the fruit yield per tree as well as the fruit quality.

For the pest control, the cultural practices are most effective in minimizing the pest population such as plowing, burning of wrapping materials, sanitation (weed control and their destruction), and burying of the damaged fruits in the soil. For insecticidal control measures, twice spraying of Neem-based materials or Kamdhenu Keet Niyantrak (4–5 ml/L) provides best results. The spraying of imidacloprid (0.05%) provides best results. The first application should be applied

when fruits are pea size and second application should be followed after 15–20 days interval which helps in effective pest control.

3.4.1.16 Gall Flies (*Dasineura* sp.)

It is a major pest of litchi recorded in Muzaffarpur district of Bihar, India. It causes damage to litchi leaves especially during winters. The larvae produce galls on the leaves. The severe infestation is recorded in dense litchi plantation. The larvae pupate in the soil. After the adult emergence, they start infesting the leaves and about eight overlapping generations are recorded per annum. The adults lay eggs on the young leaves and flushes. The larvae start mining the leaves and cause watery dots and afterward they appear as a gall. These galls turn brown and ultimately drop. After the emergence of these galls, a shoot hole appears on the leaves. These galls can be controlled by dusting beneath the tree trunk with methyl parathion (2.5%) or spray of isofenphos (0.001%).

3.5 Disease Management

A number of disease-causing organisms infecting the litchi trees are listed in the literature, but none are considered serious. All are of the postharvest nature. Few are causing considerable losses in preharvest stage which are as discussed below:

3.5.1 Powdery Mildew (*Oidium* sp.)

It is a fungal disease caused by *Oidium* sp. specially observed in those litchi orchards where mango trees also exist. These diseases occur during the flowering period when the humidity is very high, accompanied by cool nights. The infected shoots/flowers/fruits show grayish whitish powdery appearance on the panicle, flower buds, fruitlets, and rachis of the panicles which later shows dark brown lesions on the litchi fruit. In severe cases, the whole panicle looks as if scorched. Within few days of its first visible symptoms, all the panicles get affected. Sometimes, growing tips of the shoots also get affected, while other parts of the plant remain quite free.

Two sprays of either 0.2% wet sulfur powder or kerathan 25% WP 0.06–0.09% during pre- and post-bloom stages at 15–20-day interval gave good control of the pathogen.

3.5.2 Anthracnose (*Botryodiplodia theobromae* Pat., *Colletotrichum gloeosporioides* Penz.)

The two types of leaf spot caused by fungi starts from the tip or the margin of laminae where deep chocolate colored spots appear. The limiting margin of the

spots with irregular outline is Vandyke brown. Black pycnidia appear on both surface of the leaves but more often on the upper surface of the leaves.

3.5.3 *Colletotrichum gloeosporioides* Penz.

It has irregular spot (brick brown in color with a prominent marsh brown margin encircling them) usually start from the tip of the laminae and extend toward the base. Mummy brown, waxy, subepidermal acervuli appear on the surface, especially the upper surface, of the infected leaves. In severe cases, flowering panicles, flowers, and fruits are also affected.

For the control of anthracnose caused by *B. theobromae*, avoid overcrowding of the trees and branches in the orchard. Burning of affected plant parts along with other sanitary measures is the control measure of this pathogen for the control of *C. gloeosporioides*. Three sprays of 3:3:50 Bordeaux mixture in February–April and September–October or application of 1.8 kg Capton (30% WP) in 45 L of water along with spreader is more effective.

3.5.4 Red Rust (*Cephaleuros mycoides*)

It is caused by an algal parasite *C. mycoides*, on the infected young leaves; small lesions of velvety white growth appear on the lower surface of the leaves. On the upper surface of the leaves just opposite to the lesions, chlorotic patches occur. As the leaves unfold and increase in size, the velvety growth becomes more prominent and dense. Larger areas of the leaves are covered with such growth. Old and thick leaves show various types of malformation (depressions and curling). The velvety growth turns light brown and finally dark brown to brick red. The affected leaves become lathery and brittle. Disease results in considerable decline in tree vigor and fruit yield. Three sprays of lime sulfur in autumn (September–October) and three sprays during February–March at 15-day interval depending upon the severity of infection gave good control of the pathogen.

3.5.5 Nematodes

Nematodes have not been reported as a serious threat to litchi cultivation. Tree decline is associated with more than a dozen species of nematodes which are reported from different parts of India (Choudhary et al. 2004; Nath et al. 1996). Roots become stubby and brown in color, and secondary feeder root development is inhibited. Although these nematodes have no significant effect on the production and quality of the litchi fruit, however, they have an adverse role to play when litchi plants are less than 4–5 years old. Under favorable climatic conditions, they may adversely affect the plant growth which may result in the death of the plant at early

stage. Some important nematode species associated with roots of litchi plant are listed below:

(a) *Rotylenchulus reniformis*
(b) *Helicotylenchus indicus*
(c) *Tylenchorhynchus leviterminalis*
(d) *Xiphinema* sp.
(e) *Hemicriconemoides litchi*
(f) *Meloidogyne incognita*
(g) *Helicotylenchus dihystera*
(h) *Hoplolaimus indicus*
(i) *Xiphinema brevicolle*

Under field conditions, these parasitic nematodes can be controlled by using Neem cake manure or mixture of carbofuran granules with organic manures. The flooding of the plantation also helps in reducing the nematode population under field condition.

3.5.6 Weed Control

Weed control is most important from the time of litchi plantation in field up till 3–4-year-old orchards. As a tree grows and expands horizontally, there is a decreasing trend of weed growth due to intercropping, shading, and underneath canopy. Use of polyethylene mulch around the plant at 1 m^2 area during the plantation time reduces the weed growth. Organic mulches are highly recommended around the base of litchi trees which are reported to be adversely affected, around the tree trunk base.

3.6 Other Factors Affecting Litchi Cultivation

3.6.1 Propagation

Litchi plant (saplings) grown from seed stage takes about 7–12 years to bear the fruits, in some areas even up to 20 years to attain fruit-bearing stage. Moreover, litchi seeds lose their viability within 4–5 days after removal from the fruits. Hence, the litchi is preferably propagated vegetatively. The most common method of propagation in India is air layering "gootee" and grafting. With the advancement of the plant tissue culture, micropropagation techniques can be opted to overcome the propagation problems.

The best time for air layering is June or beginning monsoon season. The air layers are thus removed late in August. They took the advantage of the most part of the moist monsoon season, and at the time of detachment of the young plants (branches with roots), the atmosphere is humid. These plants are shifted to nursery and may be transplanted in the field in late September. However, it would

be preferable to do the planting in the beginning of next monsoon. The layering can also be started in August, and the plants (2–3 cm diameter and 30–60 cm long) can be removed from the trees in October and planted during the next monsoon.

The process can be simplified and watering can be eliminated, if the air layer is wrapped with moist sphagnum moss and covered with polythene wraps. Treatment of ringed portion with a hormone such as 50% aqueous solution of "rootone" or 200 ppm of a naphthalene acetic acid (NAA) in lanolin helps root formation. The roots are formed in about a 2-month duration. This method is much cheaper than former. Recently, plastic material for wrapping the air layer has become easily available and is very useful. The new plants are thus raised and planted in the field.

Inarching is another method of propagation followed in case of few varieties. If the litchi seeds are kept in distilled water, they will remain viable for 2–3 weeks. Another effective technique of storing the seeds is to place a single layer of seeds between two layers of moist sphagnum moss and finally rolling it up between moisture proof papers. These can be stored up to 8 weeks in summer. The seeds are likely to germinate in storage and must be planted very carefully without damaging the young sprouts. The seeds are sown half an inch deep in a partially shady place and the soil is kept moist. The foot hills of Nilgiri, in south India, up to 30% success has been obtained in the inarching of litchi.

Recent experiments have shown that litchi can be propagated successfully from cuttings. Two-year-old cuttings treated for 24 h in 0.02%, aqueous solution of Indole acetic acid (IAA), or 0.005–0.01% solution of indole butyric acid (IBA) before planting, give very good results. Higher concentration of these hormones is harmful. The cuttings should be taken from young plants. Cuttings from older plant do not give good results.

3.6.2 Cultural Practices

The young litchi plants are very delicate and if proper care is not taken, the mortality after planting is very high. Planting during the monsoon season and frequent shallow irrigation or water application through drip irrigation afterward help in reducing mortality. Since the litchi prefers to grow in association of the mycorrhizal fungi, the land should not be allowed to become completely dry; otherwise, the beneficial fungi working in the root nodules of the plants are damaged, and the young plant itself suffers. However, in the humid places, if liberal irrigation facilities are available, planting can be done in spring.

The plant should be planted at least 30–40 in. distance apart under very favorable conditions for growth. A distance up to 50 in. apart is recommended in South Africa. If the trees are planted too close (high-density plantation), lack of adequate sunlight and air decreases flowering and fruiting. Nevertheless, partial shading of trees to guard against the effect of desiccating winds is desirable. Under such conditions, the trees may be planted at 25 in. spacing.

Prior to planting, the pits must be adequately supplemented with manure as the litchi plants require heavy doses of manure. Inclusion of canal silt in the pit, if

available, is also desirable. The manure dose, recommended for the pit, is 25 kg of farmyard manure and 1.75 kg of bone meal for each pit.

The young plants should be protected against frost from severe winters; this can be done by providing thatch shelter on three sides (south, west, and north) and the top. The eastern side is left open to avail sunshine. Frequent irrigation in the evening when frost is accepted is helpful in reducing cold injury. During the dry periods, the young plants should be watered frequently, i.e., twice a week, and the soil should be kept moist to prevent drying of the soil. Lack of irrigation in dry areas during fruit setting period causes fruit drop and splitting of fruits.

The irrigation of the young trees should be done by the basin system. As the trees grow, the basin size should be gradually enlarged. The older plantations are irrigated by flooding or by furrow irrigation. In Uttarakhand state of India, irrigation of old trees is done by drench method. The drenches are dug at the distance of 5–7 in. from the trunk of the litchi trees and 3–4 in. deep which is filled with water during litchi cropping season.

The cultural requirement of litchi is similar to that of the mango cultivation in India except that it is a shallow-rooted crop; hence, deep tillage or deep plowing is not recommended, which is harmful for litchi cultivation. The litchi orchards should be given tillage three or four times a year and must be kept free from weeds. Raising of cover crops or intercropping is very beneficial to the litchi crop and economical for the growers. Summer cover crops are especially useful for maintaining humidity. Intercropping of young orchards provides the much-needed income during the period when litchi plants are not in bearing stage. Leguminous crops like cowpea, beans, groundnut, and grams are to be prepared for this purpose. These young orchards can also be planted with filler trees of papaya and phalsa.

It is certain that manural requirement of litchi are high. In particular, it requires high doses of organic matter. In China about 227 kg of night soil per tree are applied every year. In Bihar state of India, little or no manure is applied to litchi since it is normally grown in naturally rich soils. Even so, the addition of manure is bound to improve the performance of trees and resulted good yield; 23–227 kg of farmyard manure or leaf mold per tree is given depending upon its age and is recommended for the Indian conditions.

It should be spread under the drip of the trees and forked into ground. The fallen leaves of the trees should not be removed. They form good mulch. The application of 2.5 kg Castor cake or 1.75 kg of Neem cake, 1.75 kg bone meal, and 3.75 kg of wood ash per tree has been recommended by authorities. If the soil is deficient in zinc, a foliar spray of zinc containing 3.62 kg of zinc sulfate and 1.81 kg of hydrated lime in 378.54 L of water is beneficial for litchi production and quantity produce.

After the initial training and building up a good framework of the trees, very little pruning is required. The litchi flowers are borne mostly on new shoots. The old branches rarely produce flowers. Snipping of the old branches to promote fresh growth is, therefore, desirable. The fruits are harvested in bunches along the shoots, and this also serves the purpose of pruning. If the trees are making too much vegetative growth both roots and shoots pruning is sometime applied. If the crown is too dense, branches should be thinned out. It should be remembered that

heavy pruning causes profuse vegetative growth, which takes place at the expense of flowering and fruiting. When the trees become too old and produce fruits of small size, heavy pruning may be carried out. This has limited commercial utility, since the fruit yield is reduced and it is also not effective for more than few years.

3.6.3 Girdling

Trunk girdling increases carbohydrate content above the girdling site which promote flowering in cultivated litchi by inhibiting new shoot growth (Huang et al. 2003; Yuan and Huang 1993). Girdling reduces AM colonization due to low glucose, fructose, starch, sucrose and quebrachitol content (Shu et al. 2016; Kiers et al. 2011). Experiments conducted in the Uttarakhand state of India have shown that in some varieties girdling done by running a pruning saw around the branches or trunk greatly increases flowering and fruiting. Girdling is, however, ineffective if the trees are in poor health and lack of major soil nutrients may decrease new flush/tree growth, 6 months prior to bud initiation. It should not be done in windy areas as the tree trunks may break which eventually results in the death of the plant. In dry areas it should be done in alternate years or only half of the trunk should be girdled in 1 year. Before girdling, the trees should be given a complete fertilizer in July after harvesting, and for next 3 or 4 weeks, they should be given sufficient irrigation in order to induce vegetative flush.

3.6.4 Maturity of Fruits

The maturity of fruits for harvesting is judged by the flattening of the tubercles. When fruit matures, the pericarp become smooth and red in color. The fruits are harvested in bunches along with a portion of branch and a few leaves. If individual fruits are harvested, skin of the fruit and stems get damaged which results in the rotting of the fruit quickly. The color of the fruits undergoes rapid changes on ripening. In the colored varieties, the bark or skin is of bright reddish color. For local consumption, the fruit is harvested when it has attained this color. However, for distant markets, the fruit should be harvested when it has just started to turn reddish (Zauberman et al. 1991).

3.7 Deficiency Symptoms of Different Fertilizers in Litchi Orchards

Application of nutrients to the soil is essential for desired growth and production. Nitrogen is the major nutrient and occupies an important place in litchi cultivation. The other major fertilizers needed are phosphorous, potassium, calcium and magnesium (Ghosh and Mitra 1990). Micronutrient consists of iron, boron, copper, zinc, and manganese which are required in very small amount to maintain the tree health

Table 3.4 Litchi leaf nutrient standards

S.No.	Nutrients (% or ppm)	Optimum level
1.	Nitrogen (%)	1.3–1.4
2.	Phosphorous (%)	0.08–0.20
3.	Potassium (%)	0.8–1.2
4.	Calcium (%)	0.5–2.5
5.	Magnesium (%)	0.4–0.7
6.	Iron (ppm)	50–200
7.	Magnesium (ppm)	30–500
8.	Zinc (ppm)	15–150
9.	Copper (ppm)	5–15
10.	Boron (ppm)	25–100
11.	Sodium (ppm)	200
12.	Chloride (%)	2.5

Source: Menzel and Simpson (1986)

Table 3.5 Litchi leaf nutrient composition at different stages of growth

S.No.	Nutrients	Two months before flowering	Ten days before flowering	After harvest
1.	Nitrogen (%)	1.32–1.34	1.46–1.48	1.08–1.22
2.	Phosphorous (%)	0.15–0.16	0.16–0.18	0.14–0.15
3.	Potassium (%)	0.96–0.98	1.02–1.04	0.88–0.92
4.	K.N. ratio	1:1.4	1:1.4	1:1.3

Source: Ghosh and Mitra (1990)

and yield. Some of the litchi leaf nutrient standards and leaf nutrient composition at different stages of growth of litchi trees are mentioned in Tables 3.4 and 3.5, respectively. The deficiency of different mineral elements showed the following symptoms in litchi.

Nitrogen: Yellowing of old leaves, stunted growth, poor flowering and small fruit size.
Phosphorous: Tip and marginal necrosis of old leaves, leaf curl, desiccation and early falling of leaves.
Potassium: Yellowing of leaves, necrotic leaf, leaf tips and margins, poor fruit set and stunted growth.
Calcium: Death of growing points.
Magnesium: Small leaves, leaf necrosis, leaf drop, poor flowering.
Zinc: Bronzing of leaflets and reduced fruit size.
Iron: Yellowing of leaf and producing die-back symptoms.
Copper: Die-back, small fruits, reduced pulp recovery.
Boron: Small fruits.

3.8 Postharvest Treatment of Litchi with Sulfur Dioxide

There are two areas in the postharvest handling chain of litchi which deserve special attention. Firstly, pre-cooling should be applied to remove field heat and provide effective temperature management during transportation. This enables maintenance of fresh quality and flavors, reduces desiccation, and prevents browning of the rind (Huang and Scott 1985). The pericarp browning is mainly attributed to desiccation of pericarp and degradation of anthocyanin pigments along with oxidation of phenolic compounds by polyphenol oxidase (PPO) and/or peroxidase (POD) enzymes which is the most important postharvest problem associated with litchi (Jiang et al. 2004). Several approaches such as heat treatment, wax coating, sulfur fumigation, application of fungicide, acid dipping, irradiation, and modified atmosphere packaging have been tried to overcome the problem of pericarp browning and shelf-life extension of litchi (Kumar et al. 2012; Yueming et al. 2008). Secondly, effective postharvest fungicidal treatment is needed to prevent fruit decay.

Litchi is a non-climacteric fruit which at 25 °C exhibits a moderate rate of respiration (30-40 ml CO_2/kg/h) and a low rate of ethylene production (less than 0.1 μl/kg/h). However, it deteriorates rapidly after harvest (Tian et al. 2005). Shelf life at room temperature (30 °C) is less than 72 h. One of the major problems associated with high temperature and humidity is the growth of saprophytic fungi, mainly *Botryodiplodia* sp., on the fruit surface. At a lower pH, deterioration by decay is reduced, but the fruit loses its freshness. The rind turns brown, dry, and brittle, and the aril wilts and shrivels. The rot problem is reduced but not entirely eliminated by cold storage. Fruits stored at 5°–7 °C also suffer from chilling injury as indicated by browning of the rind, and upon removal to ambient temperatures, the injured fruits are more susceptible to fungal infection.

The process of "sulfitation" of litchi which was initially developed in South Africa has a fungicidal effect and also ensures fixing of red color of the rind and prevents brittleness during storage and transportation. The accepted level of SO_2 in litchi pulp (aril) was fixed at 10 ppm in imported litchi by French authorities in 1989.

In the fumigation system, SO_2 is added to an endorser in order to control or eliminate undesirable microorganisms. The most appropriate system where the transportation period is less than 2 weeks to importing countries is the high concentration, short duration fumigation system. For consistency and reproducibility, a standardized fumigation procedure is used where the ratio of fruit weight and free space volume of the fumigation chamber is maintained at 1:5 particularly where gaseous SO_2 is used (Underhill et al. 1992; Underhill and Simons 1993). A French expert, Dr. J. Marchal, reported that in Madagascar it was an established practice to use 550 g sulfur for fumigation of 1 MT of litchi for 45 min by burning pure sulfur in closed chamber, and it was good enough for storing litchi at 0°–2 °C ± 1 °C for a period of up to 6 weeks (Kudachikar et al. 2007; Kumar et al. 2011). Accordingly, for the storage of litchi for a period of 7 days (under transportation) at the temperature of 10°–15 °C, 140 g pure sulfur powder was burnt for

25 min. in a closed chamber where 400 kg fresh and graded (extra class) fruits were kept in 16 plastic crates of 25 kg each capacity. Uniform air circulation inside the chamber was duly ensured.

As a matter of fact, the effect of SO_2 on the surface growth of fruit, SO_2 injury to rind, and SO_2 residue level in the treated fruits depends on the fruit concentration of SO_2 applied and varies with cultivar, particular crop (locality wise), and the duration of fumigation. That is why it is necessary to work out the specific dose of sulfur for fumigation of litchi. After the sulfur fumigation worked out at Uttarakhand state of India, the maximum residue level (MRL) of 250 ppm SO_2 in the fruit rind and 10 ppm in aril was found at the time of fruit consumption which is within nonhazardous and in permissible limits.

3.9 Quality Parameters of Litchi Fruit

(a) Litchi is true to type, preferably with lower waste index.
(b) Litchi fruit should be well developed (wt. 15–30 g) depending upon cultivar, may be 59–65 days after fruit set, and clean and fully colored with tubercle tip not fully flat.
(c) It must be mature, sweet (TSS 16–21%) depending upon cultivar, healthy, sound, and firm with good aroma.
(d) It must be completely free from insect, fungal, as well as bacterial infection and foreign materials.
(e) Stem portion (fruit stalk) should be intact and not broken.
(f) It must be completely free from cracks and splits.
(g) It must be completely free from any physiological disorder such as dull or brown color, off-flavor, oozing of liquid and chilling injury symptoms.
(h) The fruit should have firm flesh (white to creamy color) depending on the cultivar without any discoloration.

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