Research Review Article

Indian Journal of Agricultural Sciences **86** (6): 703–17, June 2016/ReviewArticle

Physiological disorders in perennial woody tropical and subtropical fruit crops: A review

RAJESH KUMAR[1] and VINOD KUMAR[2]

ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar 842 002

Received: 14 December 2015; Accepted: 17 March 2016

ABSTRACT

The productivity as well as the quality of fruit crops is affected to a greater extent due to various physiological disorders. The extremes of environmental variables like temperature, moisture, light, aeration and nutritional imbalances result in disturbances in the plant metabolic activities leading to these disorders. While the symptoms may appear disease-like, they can usually be prevented by altering environmental conditions. In fruit crops, the deficiency of micronutrients causes many more disorders than that of macronutrients. These disorders have become widespread with diminishing use of organic manures, adoption of high density planting, use of rootstocks for dwarfing, disease and salt tolerance, unbalanced NPK fertilizer application and extension of horticulture to marginal lands. To get high quality fruit and yields, micronutrient deficiencies have to be detected before visual symptoms are expressed. This article presents a critical review on cause and characteristics of physiological disorders in important woody perennial fruit crops, viz. mango, litchi, guava, citrus, aonla, pomegranate, sapota, cashew, coconut, bael, ber and jackfruit, besides providing an insight into the gaps and researchable issues. The critical analysis of the nature, origin and causative factors of these non-pathogenic disorders will help in formulation of management strategies, reducing the loss to a significant level.

Key words: Abiotic factors, Nutrient deficiency, Perennial fruit, Physiological disorders

India ranks second in fruit production in the world after China. Diverse types of perennial fruits are grown in India, among which mango, litchi, guava, citrus, aonla, pomegranate, coconut, sapota, bael, ber, cashew, jackfruit are major ones having high economic values and export potential as well. They also provide livelihood security to the fruit growers and nutritional security at national level. Hence, greater attention is required towards increasing the quantum and quality of production by preventing the losses due to various factors. As per an estimate, worldwide approximately 70% of crop yield reduction is the direct result of abiotic factors (Acquaah 2007). Though, India is the second largest producer of fruits in the world, the productivity in India is dismally low. The physiological ecology of woody perennial fruit crops are very much influenced by hereditary characters and environments (Kozlowski *et al*. 2000, Acquaah 2007, Kumar 2015). Reasons for low productivity of fruit crops in India are primarily physiological or stress related disorders such as alternate bearing, unfruitfulness, fruit drop, fruit cracking, sun-burn or scorching, malformation, wilt, granulation, deformities, etc. rather than biotic and other related factors (Sharma 2006, Sandhu and Gill 2013). Abiotic factors negatively affect the crop productivity worldwide, leading to a series of morphological, physiological and biochemical changes that adversely influence plant growth and development (Chattopadhyay 1994). This is further complicated by climate change scenario involving an array of ecological stress factors like increased atmospheric temperature and decreased soil osmotic potential caused due to uneven, irregular and unpredictable rainfall pattern. If we look at production of tropical and subtropical perennial fruit crops, we find that the adverse climatic conditions singularly or in combination induce cellular damage and change in physiological processes in plant body ultimately affecting the fruit production. The plant architecture above the ground and the root system below interact with the environmental, edaphic and genetic factors causing physiological disorders.

[1]Principal Scientist (e mail: rajeshkr_5@yahoo.com), Horticulture; [2]Senior Scientist, Plant Pathology (e mail: vinod3kiari@yahoo.co.in)

Cause and characteristics of physiological disorders

Physiological or abiotic disorders are mainly caused by changing environmental conditions such as temperature, moisture, unbalanced soil nutrients, inadequate or excessive soil minerals, extremes of soil pH and poor drainage. It is important to manage physiological disorders which often require background and characteristic studies from the consequences of past event (nature origin) that results in breakdown of tissues causing significant losses (Sharma 2006). Disturbance in the plant metabolic activities results from environmental variables, an excess or deficit of soil nutrients and genetic variability (Sharma 2006, Sandhu and Gill 2013, Krishna 2012).

The difference between physiological or abiotic disorders from other disorders is that they are not caused by living organisms (viruses, bacteria, fungi, insects, etc.), but they are the result of abiotic situations (inanimate) which causes deviation from normal growth. Non-infectious disorders in some cases are easy to identify, but others are difficult or even impossible to recognize. Physiological disorders not only cause damage themselves but also serve as the 'open door' entry for pathogens. The damage caused due to physiological disorders may be reversible or irreversible depending on time and extent/intensity. Most of them are non-reversible once they have occurred (Sandhu and Gill 2013). The direct and indirect effect of abiotic factors, ability to redirect nutrients to imperative processes and the induction of adequate metabolic processes are crucial for successful quality fruit production and that too in sustainable manner. Understandings of abiotic or physiological factors are important for successfully managing them.

Factors implicated in occurrence of physiological disorders

Temperature: Temperature (both high and low) play a vital role, be it temporary or constant, can induce morpho-anatomical, physiological and biochemical changes in plant body, leading to altered crop growth and erratic bearing behaviour (Chattopadhyay 1994, Menzel and Waite 2005, Galán Saúco 2009). The temperature range that supports specific fruit crop growth and production is generally region specific (Shao *et al.* 2010). Optimum temperature for vegetative growth, transition into reproductive phase and later for fruit growth and development differ widely. Most fruits originat from the tropical or subtropical regions are chilling sensitive (Gross *et al.* 2002). These crops are injured after a period of exposure to chilling temperatures below 10 to 15°C but above their freezing points. At the chilling temperatures, the tissues weaken because they are unable to carry on normal metabolic processes and cellular dysfunctions (in chilling-sensitive species) occur in response to stress (Wang 1982). The temperature induced physiological disorders may bring alterations and dysfunctions in biological activities at cellular level, viz. stimulation of ethylene production, increase in respiratory rate, interference in energy production, increase in activation energy, slowing or aggravating of protoplasmic streaming, increase in permeability, reduction in photosynthesis, enzyme inactivation, membrane dysfunction and alteration of cellular structure leading to the development of a variety of injury symptoms such as growth retardation, deformities, surface lesions, internal discoloration, water-soaking of the tissue, off-flavour, decay and failure to ripen normally (Saltveit and Morris 1990, Menzel and Waite 2005).

Irradiance (intensity, photoperiod and spectral quality): Fruit plant respond to light of varying intensity at different stages of growth and development phases. Likewise, Carbon exchange rate (CER) is strongly dependent on irradiance, absorption and utilization of photon energy. Low irradiance causes insufficient light penetration into canopy influencing CER directly by reducing photon energy utilization, thus decreasing productivity. UV radiation acts as an abiotic physical elicitor of resistance mechanisms and thus leads to a rapid increase of stress response compounds. High influence of UV radiation causes cellular damage by generating photoproducts in DNA. In many cases, the radiation effect can induce the development of secondary stresses such as oxidative stress, water deficit and temperature stress affecting plants biological system resulting in inhibition of growth and cell division apart from the induction of oxidative stress, direct capture of radiation by metabolites, mutations in the DNA at genetic level, loss of semi-permeable nature of membrane at cellular level (Krishna 2012).

Majority of perennial trees in course of hardening or adaptation acquire specific ability to repair the radiation-induced damage. The growth cycle of perennial fruit plants under a marked diurnal or rhythmic variation with distinct season change (temperature) is due to inherent radiation tolerance property, also varies with organ to organ in the plant body. The studies indicate that there is some role for intercellular salts and other compounds, which are stored in large quantities to neutralize the radiation induced injury to cell and tissues (Menzel and Waite 2005). The biological systems are sensitive to incident light because of the presence of chromophores that absorb radiation and stimulate biological functions. There is need for exhaustive studies to know the precise physiological significance of radiation effect, which are supposed to be climatic fastidious fruit crop. The availability of light, either totally or partially, its quality and source is very important. Too much red or blue spectrum and its duration of light can affect plants and their growth, depending on the situation and plant.

Relative humidity: Relative humidity (RH) exert strong influence on vegetative growth, floral induction, flowering and its phases, fruit set, production and productivity in almost all the tropical and subtropical fruit crops of perennial nature (Sharma 2006). Low and high humidity may affect fruit yield and its quality through poor pollination, failure or poor pollen germination, unfruitfulness (mango and litchi), fruit cracking, sunburn/scorching effect, etc. (Sharma 2006, Sandhu and Gill 2013). The indirect effects of low and high humidity in combination with other climatic stresses may onset leaf senescence and may cause premature leaf shading, drastically reducing the photosynthetic surface area. Drier months in the tropics when the subsoil moisture and the atmospheric humidity are very low, lead to desiccation of leaves in guava, citrus, litchi and others (Chattopadhyay 1994). Low RH accompanied by high or excess of temperature will generally cause a problem. Higher RH over longer periods of time like in a greenhouse or wet climate areas can lead to biotic stresses by favouring establishment of certain location specific disease organisms.

Atmospheric conditions: Atmospheric conditions overall play havoc with fruit trees in some parts of the country. One of the most notable is acid rain that over time causes water and soil to become too acidic to grow any plant. Too much cloud or heavy smog can also exert negative effect on plants causing low light intensity situations (Sandhu and Gill 2013). The changing edaphic situations in the rhizosphere affect production adversely due to altered root growth activity and nutrient interactions. In many fruit trees, the time of flower opening depends on the environmental conditions. The seasonal fluctuations may cause erratic behaviour in natural expression leading to physiological disorders (Chattopadhyay 1994).

Carbon dioxide concentration: Too high or low levels of CO_2 can also affect plant growth and this situation is commonly confronted in closed atmosphere places like greenhouses and it must be controlled for proper plant growth. The photorespiration, i.e. respiration under light intensity, and post illumination evolution of CO_2 is seen to be higher provided there is higher O_2 concentration in the atmosphere. Further, light period also exhibits higher evolution of CO_2 in fruit plants of tropical and subtropical origin, where higher phototranspiration causes a depression in the net photosynthesis output in plants and reflects its effect upon their growth and reproduction (Chattopadhyay 1994, Singh 1992). Now the situation has attained the alarming situation and efforts have been started for sequestration.

Heat stress/scorch injury: This is one of the major physiological disorders especially in hot climates and it is caused by injury from direct sun exposure/intensity or just simply from too hot climate. Fruit plants are seen to exhibit varying response to high and low temperature effects, having specific temperature range for growth and production cycle, if grown beyond the optimal temperature exhibits reactions on morphogenesis, thermoperiodicity and survivability. The most adverse effect of heat stress is induction of plant or organ injuries apart from slowing down of photosynthetic rate and rapid increase in respiration rate (Chattopadhyay 1994, Sandhu and Gill 2013).

Winter/cold injury and frost: Depending on severity, frost injury may cause browning of fruit tissue, deformation, puckering and damaging of fruit parts to complete spoilage. Frost injury can lead to heavy economical loss to growers due to sudden decline/death of many fruit trees. Frost damaged parts generally show evidence very quickly. Winter injury can also occur in the form of ice and/or snow damage. Injury in the form of slight damage to severe injury or death can also occur from excessively low soil temperature (Chattopadhyay 1994, Sandhu and Gill 2013).

Wind injury: Wind injury can also aggravate cold injury or winter injury, especially if the humidity is low at the time of the cold period. This is especially hard on buds or tender fruits. Wind damage can be as simple as plant parts rubbing together causing surface scarring which also serve as entry points for pathogens. Apart from wind injury, the mechanical or physical injury also occurs, where plants are physically damaged by people, animals, equipment, etc. This is important as every site of tissue injury is a potential entry point for pathogens (Chattopadhyay 1994, Sandhu and Gill 2013).

Chemical injury: Any kind of foreign chemical applied in the wrong dosage or at the wrong time is capable of doing physical damage to fruit trees. Most chemical injuries will come from pesticides applied at too high rates, at wrong time or during very hot parts of the day. Damage from chemical injury may appear as red, yellow or brown spots on the fruit skin, leaf tips turning brown, stunted or misshapen fruits, to overall browning and death of a plant (Sandhu and Gill 2013).

Physical soil problems: The selection of a good site for growing is very important as soil can have a physiological effect on the plant, which can take many forms. Compacted soil allows water to percolate slowly into the soil causing saturated conditions resulting in soil deformation. Compaction can be due to low organic matter in many soils which makes the work difficult on such soils. There will be poor interaction of feeding roots and nutrients available for the plants in the rhizosphere resulting in stunted growth and low/poor quality fruit yield (Chattopadhyay 1994, Sandhu and Gill 2013).

Water stress: The reduction in soil water content in the rhizosphere is reflected as decline in leaf relative water content causing stomatal closure and disturbances in metabolic activities, which in turn is expressed as decrease in many physiological processes leading to various types of disorders. Water stress causes improper root development, cupping and mottling of leaves followed by necrotic patches on the leaves. Fruit bud differentiation, flowering and fruit setting disturbances also take place in case of water stress as these are dependent on the moisture status of the soil during the metamorphosis in number of fruit trees. Water stress caused by too much rain can enhance choking problem due to standing water (Sandhu and Gill 2013). Drought may have different effects on fruit yield and quality depending on the level and timing of water deficit. Mature trees can tolerate quite long periods between irrigations before production is affected. The various research studies have indicated that the drought tolerance of fruit crops also depend on the type of soil. The more pronounced drought sensitivity of larger trees could be underpinned by greater inherent vulnerability to hydraulic stress, the higher radiation and evaporative demand experienced by exposed crowns (Bennett *et al.* 2015). There is a need for long-term quantitative documentation of tree phenological patterns in India in diverse climatic zones (Singh and Kushwaha 2005).

High salts (Electrical conductivity): High concentration of salts can cause symptoms which appear as physical problems, but they are actually caused by chemical imbalance in the soil. High content of salts in soils which might be due to excessive fertilizer usage or naturally because of soil chemical conditions is known to have multifarious effects on tree growth and metabolism altering physiological and biochemical process (Bogges *et al*. 1976). These results in disorders like small, stunted, slow growing trees or leaf tip burn, unproductiveness and poor quality fruits (Sandhu and Gill 2013).

Nutrient imbalances: Nutrient imbalances affect trees growth and development, flowering, fruit set, fruit development and quality fruit yield in many fruit crops. Nutrient-wise review of various physiological disorders in fruit trees is presented here:

Nitrogen: Slower and improper root growth is associated with nitrogen deficiency in fruit crops. The stem growth is also adversely affected with respect to length and spread of branches. A narrower angle between crotches in a number of fruit crops and young leaves becoming smaller is reported (Smith and Scudder 1951, Sen *et al*. 1947). Interveinal yellowing, development of anthocyanin pigments, rolling of leaves, yellowing, chlorosis and necrosis, premature defoliation and overall reduction in growth were reported in various fruit plants as N-deficiency symptoms (Kender and Anastasia 1964, Goldweber 1959, Chattopadhyay 1994). In most of the subtropical and evergreen fruit crops, profuse and continuous vegetative growth may adversely affect the flowering pattern and quality and maturity of fruits. Inferior fruit qualities due to high nitrogen were reported in citrus, guava, litchi and mango, where the fruit trees may not produce sufficient flowers during the flowering time.

Phosphorus: Reduction in root growth due to phosphorus (P) deficiency was reported for most of the fruit plants. Smaller number of rough, deep green and thick leaves of small size was reported in citrus species, cashew, guava, litchi and mango (Chatterjee and Dube 2004). Dieback of meristematic regions was reported in some fruit crops. Young and Koo (1969) reported leaf spotting followed by defoliation and dieback in mango due to excess P application and its excess uptake, reduced contents of many nutrient elements (N, K, Mg, Fe, B, Zn and Ca) availability resulting in nutrient imbalances (Chatterjee and Dube 2004).

Potassium: The deficiency of potassium causes distinct disorder in the form of chlorosis, stunted growth, fruit size and shape deformation in many fruit crops of annual and perennial nature. Its deficiency causes margin necrosis in mango, litchi, guava, sapota, citrus etc. (Singh 2009). The distinctive characteristic of the K deficiency symptoms is the yellowing of tip of older leaves followed by inward leaf curling and death. In citrus, leaves, chlorophyll gets bleached in certain areas followed by browning, scorching and interveinal chlorosis near the margin (Ulrich and Ohki 1966). Leaves may be brittle, smaller in size and light coloured in sapota. The total foliage may also be smaller.

Calcium: Under calcium (Ca) deficiency, roots do not develop properly. Insufficient number of root hairs are produced which get burnt under acute deficiency. The characteristic symptoms like leaf chlorosis, reduced trunk growth, smaller, thickened leaf production and tip burn in citrus were observed (Shear 1975). Apart from these, soft nose in mango and fruit cracking in litchi were reported. Excess application of Ca retards the growth of plants due to induction of nutrient imbalance. Excess Ca in the growing media also increases the soil pH and induce nutrient imbalance between the basic elements like K, Mg and Na in the exchange complex. Presence of excess Ca in soil may liberate N_2 from the applied ammoniacal nutrients if soil temperature is sufficiently high (Chattopadhyay 1994).

Sulphur: In most of the subtropical fruits (citrus, guava), were the development of pale green colouration followed by yellowing of older leaves were reported. In mango, leaves develop dark green colour followed by necrotic spots on the leaf margins and heavy defoliation may occur. Excess of sulphur in the soil increases acidity. Mottling of leaves, yellowing followed by necrosis and abscission were reported due to excess of sulphur in most of the fruit plants. On the contrary, the higher synthesis of amino acid with higher doses of N and S and more root production under higher doses of P and S make the total growth of the plants increased (Chatterjee and Dube 2004).

Zinc: The symptoms of zinc deficiency in many fruit crops (more particularly in citrus, guava and mango) first appear on the apical leave where irregular developments of leaves smaller in size cause cupping and wrinkling. The deficient trees do not flower and also get unproductive with no flush. Extreme reduction in yield with poor fruit quality is also observed. It is a serious problem in waterlogged and saline areas (Sharma 2006, Sandhu and Gill 2013). Toxicity due to excess of Zn nutrition may cause burning of roots, stunted, stubby growth and premature leaf fall (Chattopadhyay 1994).

Copper: Copper requirement of plants varies with species, varieties and even due to different rootstocks. In case of citrus and other fruit plants, the copper deficiency causes tip burn leading to exanthema. The tips die back forming rosette appearance of the growing shoots. Due to dieback, the apical dominance is lost and large numbers of axiliary shoots are produced from the trunk and main branches. Development of light green leaves with grey or brown patches and tip burning have been reported in mango. Production of fruits in most of the fruit plants is adversely affected by copper deficiency, as fruit produced are deshaped, coarser, insipid and without much juice content (Chatterjee and Dube 2004). The delay in fruit maturity and ripening is also reported due to its deficiency. Under excess condition of copper in soil the production of the year may fail. In acidic soil the antagonism effect occur with iron and chlorotic symptoms may occur (Chattopadhyay 1994).

Iron: The overall growth of the tree is affected due to iron deficiency and the weight of shoots and new growth is reduced. The leaves turn yellow (*chlorosis*) during iron deficiency and the entire shoot become yellow to yellowish green under extreme conditions, showing the symptoms like drying of twigs and also dieback disease (citrus, guava, mango). Iron deficiency may occur due to the presence of excess calcium in the soil (*lime induced chlorosis*). Poor flowering, fruiting and delay in maturity affecting production have also been reported in some fruit crops. The excess of iron in the soil poses a threat to the uptake of Cu, show symptom of Mn deficiency. The morphological expressions like speckling of necrotic spots on leaves, poor root development, development of brown spots on leaves, fall of leaf and fruits were reported in citrus and other subtropical fruits (Chatterjee and Dube 2004).

Boron: The boron deficiency causing disorder and damage in a number of fruit crops. Deficiency is often expressed as development of water soaked areas on the leaves, development of corky tissues and purpling or yellowing of interveinal portion of young leaves. Its deficiency in guava results in internal necrosis and affected portion becomes hard. Fruit size is reduced and leaves start falling. Cracking of fruits are seen in extreme cases. Mature and old leaves may also show corky veins. Due to disturbed metabolism, the leaves may lose phenolic compounds and fall prematurely. Short internodes, brittle pale green leaves curving one side and stunted growth in mango were reported. The boron deficiency led disorders cause fruit cracking in litchi limiting fruit yield and quality. In case of excess application, leaves fall prematurely, young twigs die back and trunk ooze gums in many fruit trees (Chatterjee and Dube 2004).

Magnesium: Chlorotic symptoms appear on older leaves in case of deficiency. Chlorosis may also develop in the younger leaves and the leaves may have necrotic spot under severe deficient condition. But the overall growth of the plant may not be affected, unless the deficiency is beyond the tolerable limits as the requirement of the element is much lesser than other essential elements (Chatterjee and Dube 2004).

Manganese: Interveinal chlorosis up to leaf margins followed by browning and necrosis are caused due to manganese deficiency in mango, guava, citrus and other subtropical fruits. However, the symptoms primarily develop on older leaves, while growth of younger leaves is delayed leading to stunted growth of the whole tree. In mango, leaves become thicker and blunt. The affected plants produce discoloured fruit with chlorotic spots. The maturity of fruits also delayed. The visual symptoms developed due to excess of manganese are marginal yellowing in citrus, leaf curling and die back in mango (Chatterjee and Dube 2004).

Genetic/hereditary factors: Many times genetic/hereditary factors become cause of physiological disorders. Unfruitfulness or failure to set fruits is caused by internal factors like sterility from impotence, sterility from incompatibility and sterility from embryo abortion. However, the causes of sterility also found to be associated with fundamental genetic influences and processes due to evolutionary tendencies and internal physiology (Sharma 2006). The reproductive biology of highly cross pollinated fruit crops is dependent on pollination. Generally, ovary growth and cell division are temporarily reduced during the period of anthesis until pollination and fertilization occur, since the presence of fertilized ovules normally reactivates cell division, triggering fruit development (Gillaspy *et al*. 1993). It is widely accepted that reactivation of fruit development requires synthesis and action of growth regulators such as GAs and auxins (Nitsch 1971, Goodwin 1978, Pharis and King 1985). Hence, current evidence suggests that fruit set, fruit development and maturity are also influenced by the interactions of genetic and environmental factors. As several reports suggest that exogenous GA considerably improves fruit set of self-incompatible genotypes in which the absence of cross pollination results in negligible parthenocarpic fruit set (Pharis and King 1985).

Physiological disorders of important fruit trees

Some important physiological disorders, their possible causes and suggested corrective measures for important commercial fruit crops are discussed here.

Mango

The complexity of events leading to the occurrence of physiological disorders makes it more difficult to ascertain the causative agent as a pathogen or pest. Physiological disorders of mango (*Mangifera indica* L.) are the result of imbalances in metabolism induced by some factors in the pre- or post-harvest environment that lead to cell collapse and development of brown areas on part of the fruits (Subramanyan *et al*. 1971, Galán Saúco 2009). Pre-harvest factors that predispose mango fruit to physiological disorders include growing location, orchard condition, tree nutrition and condition at the time of harvest (Galán Saúco 2009). The proper understanding of the causes of the important physiological disorders which are serious production constraints of high-quality fruits were developed (Subramanyan *et al*. 1971, Sharma 2006, Galán Saúco 2009, Sandhu and Gill 2013). The qualitative improvement of existing mango cultivars can be accomplished through genetic transformation like control of fruit quality and elimination of physiological disorders of certain selections and alteration of other undesirable aspects (Lim and Khoo 1985).

Internal fruit breakdown: 'Internal fruit breakdown' include soft nose (watery flesh near the distal end), jelly seed (over ripe flesh around the seed surrounded by firm flesh), stem end breakdown (open cavity in the pulp at the stem end), spongy tissue (areas of the flesh that appear spongy and have greyish black discolouration), soft centre and soft flesh (Winston 1984, Schaffer 1994, Galán Saúco 2009). Temporal and spatial differences in symptom development within the fruit have been found in case of soft nose, jelly seed and stem end cavity (Raymond *et al*.

1998). While the affected mesocarp matures more rapidly than the healthy flesh and acquires a characteristic deeper yellow colour, the affected tissue may be so extensive that greyish watery tissues appear over the whole mesocarp (spongy tissue), whereas absence of latex and lack of firmness in proximal end have been observed in black tip disorder (Malo and Campbell 1978, Winston 1984, Joshi and Roy 1985, Chaplin 1986, Katrodia and Bhuva 1993, Sharma 2006, Sandhu and Gill 2013). At the early stages of internal breakdown, N, P, Ca, and B concentrations were found significantly higher in affected fruits than in healthy. These results indicated that a nutritional imbalance during early fruit ontogeny may be responsible for internal breakdown. It is also possible that an unknown factor triggered the biochemical processes that resulted in those elevated N and P concentrations in the disordered fruit, resulting in the early ripening of the mesocarp (Sharma 2006, Sandhu and Gill 2013). Symptoms in the mesocarp range from pale flesh colour to the development of delineated starchy areas with air pockets, a condition termed spongy tissue. Severely affected fruits are characterized by considerably reduced flesh firmness, uneven peel and pulp ripening, and reduced total soluble solids making it inedible (Galán Saúco 2009).

Spongy tissue: The occurrence of spongy tissue in mango was first noted in 1932 in cv. Alphanso by Cheema and Dani (1934) as a serious problem in orchards in the states of Maharashtra and Gujarat. In this disorder, a non edible sour, yellowish sponge like patch develops in the mesocarp of the ripening fruit. The affected fruit tissue is visible only when the fruit is cut. Studies clearly indicated that the fruit affected with spongy tissue exhibited much lower amylase activity compared to healthy tissue of mango cv. Tommy Atkins mango (Katrodia and Rane 1989, Lima *et al*. 2001, Shivashankar *et al.* 2007). Lower activity of amylase and other enzymes related to the carbon metabolism in the pulp of spongy tissue affected fruits of Alphonso was also reported by Gupta *et al*. (1985). An appreciable reduction in non-reducing sugars in spongy tissue as compared to the healthy tissue (Amin 1967) and higher starch content in spongy tissue pulp (Burdon and Moore 1991, Ravindra and Shivashankar 2004) were noticed. Biochemical studies of spongy tissue affected fruit pulp in mango by Selvaraj *et al.* (2000) indicated that the affected pulp had higher acid to sugar ratio, higher starch, polyphenols and reduced non-reducing sugars, carotenoids, ascorbic acid and protein. The intensity of this disorder depends upon the cultivar, size of the fruit, fruit weight, fruit maturity, season, soil type, soil moisture, geographical location, tree aspect, root stock and time of harvest (Sharma 2006). Among the responsible factors are larger sized fruits, low in calcium content, delay in harvesting and pre-harvest exposure of sunlight (Sharma 2006, Ahlawat *et al*. 2013). Katrodia and Rane (1989) finally concluded that convective heat arising from soil is the major cause of this disorder. Practice of sod culture having natural vegetation of dhorth (*Desmostachya binnata*), green vegetation, leguminous crop cover and also growing of some tolerant cultivars like Ratna, Arka Punit can reduce the incidence of this disorder (Sharma 2006, Ahlawat *et al*. 2013).

Soft nose: Soft nose was first reported from Florida (USA) in one of the commercially important cultivar Kent and later on in Indian cultivar Mulgoa and further in other cultivars which were derived from these. This malady has become more complicated since, the affected fruit presents healthy external appearance. The mesocarp of the affected fruits showed cell separation and cell wall degeneration with soft nose, whereas cell cohesion is maintained in the healthy mesocarp. In advanced cases, tissues are greyish black, spongy and extend further (Sharma 2006, Ahlawat *et al*. 2013). The symptoms of this malady appear in fruits which are retained on the trees for longer time (delay in harvest) and allowed to ripen on the tree. High nitrogen and low calcium content in soil aggravates the incidence. Early harvesting at maturity or cultivars maturing early should be grown. Proper post-harvest handling also reduces the occurrence of this malady (Subramanyan *et al*. 1971, Galán Saúco 2009, Sandhu and Gill 2013).

Mango malformation: Malformation is the most serious disorder of mango in India and other mango growing countries of the world (Crane and Campbell 1994), causing heavy loss to the growers. In India, it is very common in Punjab, Delhi, Bihar, Madhya Pradesh and Uttar Pradesh, while less prevalent in southern part of the country. The origin and cause of this malady is described as disease (Summanwar 1967, Varma *et al*. 1974, Misra and Singh 2002) and a physiological disorder (Sattar 1946, Majumdar *et al.* 1976). It was first reported about 120 year back from Darbhanga district in Bihar by Maries (Watt 1891). Till date the etiology of this disorder remained confusing and no effective control measure is known (Ram and Yadav 1999, Pant 2000, Bains and Pant 2003). A hormonal imbalance between growth promoters and inhibitors is found in mango malformed trees. There is auxin depletion and formation of malformin like substances (Azzouz *et al*. 1978). The poor cultural practices such as unploughed land, improper tilth, etc also lead to this disorder (Baghel *et al*. 1994). The nutritional imbalances also reported due to use of imbalanced fertilizer mixture such as N, P, K and non-availability of the essential nutrients in soil. There are many opinions that environmental factors (humidity, temperature, rainfall, etc) are also responsible for this malady (Azzouz *et al*. 1978, Baghel *et al*. 1994). There are considerable reports authentically narrating the fungus *Fusaruim moniliformae* var. subglutinans isolated from malformed panicles and also the attack of mites as another cause of malformation. If the disease is to be controlled chemically then it may be effective only when combination of fungicide and insecticides are used to kill the fungus and the mites (Yadav 1972). Balanced fertilizer mixture and spray of plant growth regulators also reported to reduces the incidence of this disorder. Use of anti-malformins like glutathione and ascorbic acid are equally useful. The usual practice is to prune off the affected panicles and shoots soon after they appear and bury them in the soil or burn them immediately.

Black tip: This disorder is widespread in India which was first described in 1909 (Prakash and Srivastava 1987). The occurrence of this disorder was also reported from China (Zhang *et al*. 1995). The first symptom of this disorder is etiolation and yellowing of the distal end of fruit. In some cases the affected mesocarp matures more rapidly than the healthy flesh and acquires a characteristic deeper yellow colour and the absence of latex and lack of firmness in proximal end was observed (Malo and Campbell 1978, Winston 1984, Joshi and Roy 1985, Chaplin 1986, Katrodia and Bhuva 1993, Sharma 2006, Sandhu and Gill 2013). Later affected fruit show brown to black necrosis of tissue, which may harden at the distal end. The affected areas are flattened and sunken, and the inner portion is soft with dark brown liquid oozing from the tissue. In severe cases, the necrosis extends to the entire fruit. The vascular bundles in the pedicel may turn brown and decay, while affected fruit do not secrete latex at harvest (Galán Saúco 2009). In India, growing of mango near brick kiln were widely reported (Majumdar and Sharma 1985, Sharma 2006, Sandhu and Gill 2013), while in China, it was reported that fluorine is the causal agent of this disorder (Zhang *et al*. 1995). The prevailing climatic condition, more particularly dry hot climate may enhance the effect of gases in aggravating the incidence of this disorder. The practice of spraying three times with borax (0.6%) and caustic soda (0.8%) at stages (i) prior to flowering (ii) during flowering/ bloom and (iii) at fruit set control this disorder (Majumdar and Sharma 1985).

Clustering: This disorder was first observed in UP in 1984, also called *Jhumka*, is characterized by good initial fruit set in bunches at the tip of panicles. Such very small fruits cease to grow beyond pea or marble stage and drop down without attaining full size. These tiny fruits are dark green in colour with a deeper curve in the sinus beak region as compared to normal developing fruits and resemble unfertilized fruits which drop down very quickly after turning yellow. Dashehari variety is more prone to this disorder (Sharma 2006, Ahlawat *et al*. 2013). The main cause of *Jhumka* is the absence of a sufficient population of pollinators in the orchards, indiscriminate spraying against pests and diseases, use of synthetic pyrethroids, monoculture of Dashehari and bad weather during flowering. Spraying 300 ppm NAA during October-November is recommended. Monoculturing should be avoided, particularly in case of Dashehari, 5-6% of other varieties should be planted in the orchard (Sharma 2006).

Fruit drop: The natural fruit drop of mango may go up to 99% at various stages of growth and varies with cultivars. The cultivar Langra is more susceptible to drop, while 'Dashehari' is the least. Embryo abortion, climatic factors, disturbed water relation, lack of nutrition, attack of disease and pest and hormonal imbalances are the major factors that lead to fruit drop. It was managed by regular irrigation during the fruit setting and development period, application of growth regulators like NAA (40 ppm) or 2,4-D (20 ppm) - about 6 weeks after fruit set as well as spray of micronutrients (0.8% zinc sulphate or 4.0% potassium nitrate) at bloom-stage in mango cv. Dashehari (Sharma 2006, Sandhu and Gill 2013).

Biennial bearing: Also known as alternate bearing is one of the most serious problems which render mango cultivation less remunerative to the growers. It refers to yield variations in alternate years i.e. a year of optimum or heavy fruiting followed by a year of little or no fruiting. The problem of biennial bearing is a varietal character governed by genetic makeup. This complex problem can be solved to some extent by adopting integrated nutrient management and pruning-training techniques (Agarwala *et al*. 1962, Sharma 2006, Galán Saúco 2009).

Mango decline: Mango decline is becoming a serious problem in major parts of northern and central India. There is mortality of upper twigs which progress to further larger branches. Affected trees have thin canopies of lustreless green leaves and sickly look. Decline is associated with several biotic and abiotic stresses. The poor orchard floor management, poor nutrition, and salt injury are the main causes of the decline (Galán Saúco 2009). Growing of *dhaincha* as green manure in the inter-space of the orchard, application of gypsum (50 kg/ tree at >50 years aged) around the basin beneath the canopy are preventive measures to save decline. FYM and compost should be applied every year in the orchard. Spraying of micronutrients to avoid the deficiency especially boron and zinc is recommended (Sharma 2006).

Litchi

Litchi (*Litchi chinensis* Sonn.) is affected by many physiological disorders like fruit cracking and splitting, flower and fruit drop, sunburn, retarded fruit development, irregular bearing and black tip, etc. The incidence and severity of these physiological disorders vary with locality, season, cultivar and orchard management practices (Kumar and Kumar 2008).

Fruit cracking: This is the most important disorder occurring in almost all the important litchi growing countries of the world causing losses as high as 5-70% (Menzel and Waite 2005, Singh *et al*. 2012). Losses up to 14% (mean 3.8-5.9%) during 2012 and 2013 due to 'fruit cracking' at harvest of fruits in Bihar state of India was reported by Kumar *et al*. (2016). This disorder is associated with hot dry weather, drought and low calcium concentrations. It has been observed that early ripening cultivars under poor management practices are more susceptible to this disorder. The other nutrient element found to be associated with fruit cracking is boron (deficient soils). A high concentration of abscisic acid and low gibberellins was found in the fruit pericarp, seed and aril of cracked fruits. Insects, hail, and the sun can damage the skin during cell expansion and induce cracking towards harvest. In general, it has been observed that fruit skin cracking often occurs, when there is sudden change in soil moisture or there is drought soon after fruit set. Cell division is reduced and the fruit skin becomes inelastic, and often splits when the aril grows rapidly before harvest. This can occur after irrigation or heavy rain, or just after an increase in relative humidity. It was reported that application of calcium @ 2 ml/l liquid formulations and gibberellins @ 20 ppm reduced the activity of cellulose and thereby reduced cracking (Sinha *et al.* 1999, Peng *et al*. 2001, Kumar and Kumar 2008). Chandel and Sharma (1992) reported that application of 2, 4-D and NAA @ 20 ppm reduced fruit cracking. Boron sprays in the form of borax or boric acid @ 2g/l at the initial stage of aril development in conjunction with sufficient soil moisture in the root zone prevented from fruit cracking significantly (Kumar and Kumar 2008). Constant moisture and appropriate humidity is needed at the time of fruit maturity. Irrigation at 30-40% depletion of available soil moisture is quite helpful in reducing cracking of fruits. Mitra *et al.* (2014) reported that irrigating the orchard at 20% pan-coefficient and placement of dessert cooler or by irrigating the orchard through overhead sprinkler completely control fruit cracking. The soil moisture conservation in the root zone for prolonged period can be achieved by providing mulching beneath the canopy (Sharma 2006, Kumar and Kumar 2008, Sandhu and Gill 2013). Early cultivars or particularly those cultivars which have relatively thin skin, few tubercles per unit area and rounded to flat in shape are less prone to cracking. Planting wind breaks (a row of tall growing trees, such as seedling mango and *jamun*) around the orchard provides protection from desiccating hot winds reduces the malady.

Sunburn: Occurrence of sunburn on fruits is a serious problem in litchi producing countries like India, South Africa, Australia and Thailand (Kanwar and Nijjar 1972, Joubert 1986, Sanyal *et al.* 1990, Menzel *et al*. 2002). The damage caused due to sunburn occurs up to 0.9-19.13% in different varieties. Sunburn affected fruits up to 44.5% (mean 14.9%) during 2012 and up to 27% (mean 10.4%) during 2013 at harvest of fruits in Bihar state of India was reported by Kumar *et al*. (2016). Besides environmental factors, cultivars, hormonal, nutritional and soil moisture factors have also been found associated with this disorder (Chadha and Rajpoot 1969, Joubert 1986, Sharma and Ray 1987, Sanyal *et al*. 1990, Menzel *et al*. 2002, Menzel and Waite 2005). The fruits in orchards having scanty irrigation during fruit development stage favour sunburn (Menzel and Waite 2005). In light and sandy soils, only light irrigation with increased frequency (4-5 days interval) is found to reduce the chances of sunburn in farmers field (Kumar and Kumar 2008).The trees provided with sufficient quantities of organic manures such as compost, FYM, cakes, green manure, vermicompost and irrigation applied at regular interval during fruit development and ripening stage prevents fruits from sunburn. Raising wind break around the orchard have also been found to reduce sunburn problems.

Flower and fruit drop: Litchi trees suffer a heavy flower and fruit drop between flowering and fruit maturity. Only a small proportion of flower (2-18%) is carried up to maturity in different cultivars. The quantum of flower and fruit drop varies with variety, season and tree age. The fruit drop may occur due to failure of fertilization, embryo abortion, nutrition and hormonal imbalance and external factors like high temperature, low humidity and strong westerly winds (Chadha and Rajput 1969, Menzel 1984, Sharma and Ray 1987, Singh *et al*. 2012). The research evidence suggests that auxin inhibit the action of the hydrolytic enzymes polygalacturonase and cellulose, which are responsible for the degradation of the cell wall and the middle lamella in the abscission zone (Goren 1993, Menzel and Waite 2005). Timely treatment of plants for strong and healthy shoot production delays flowering phase and increases the female flower ratio and finally the fruit-set (Kumar 2015). Visits of honey-bees in orchards ensure better pollination and fertilization which increases the fruit set and retention (Kumar and Kumar 2014).

Irregular bearing: Irregular bearing is a serious problem in almost all litchi growing areas of the country and abroad (Mustard *et al.* 1956). It was observed that capacity of litchi shoots to bear is cultivar dependent while some bearing terminals of current year are more productive (70-95%) in the next year (Kumar 2015). The floriferous condition of shoots is determined largely by presence or absence of crop in previous year, rather than by how many times a shoot grow vegetatively before its differentiation into a floriferous condition. It has also been observed that adoption of faulty management practices lead to irregular bearing, even in regular bearing cultivars. Faulty management practices include late application of manures and fertilizers (particularly nitrogenous fertilizers), high frequency and heavy irrigation just before the panicle emergence and flowering period. Late harvesting and severe pruning and training operations may lead to non bearing in that particular year of operation. Applying proper nutrition, irrigation and controlling insect-pest infestation can significantly reduce the intensity of this malady. The proper pruning and training operations (semicircular canopy) give rise to strong and healthy flush that bear fruits in ensuing season. Late pruning and training should be avoided (Kumar and Kumar 2008, Kumar 2015).

Retarded/ underdeveloped fruits: This disorder is not well documented but cause considerable loss due to poor quality fruits (Kumar and Kumar 2008). Ensuring presence of pollinators in the bearing orchards during flowering to fruit set stage and spraying plain water in early morning hours of the day during the advanced stage of fruit growth and development have been found highly effective. An arrangement of sprinkler system of irrigation may be done to reducing this disorder (Kumar and Kumar 2008).

Black tip: The occurrence of black tip is not widespread in litchi as in case of mango. This symptom has been observed in plantation mainly in vicinity of urban areas and appears to be due to deleterious effect of smoke fumes which contain SO_2, C_2H_2 and CO_2. A small etiolated area at the distal end of the fruit develop against the normal green colour of the fruit pericarp, which gradually spreads, turns nearly black and covers the distal end completely. In the affected fruits, there is poor development of aril, seed, size and colour (Kumar and Kumar 2008). Foliar spray of zinc ($ZnSO_4$ @ 0.2%) one month before panicle initiation and boron (borax @ 0.2%) during fruit growth phase have been found to prevent this disorder.

Chilling injury: Chilling injury to litchi fruits is mainly a post-harvest disorder which occurs when there is disturbance in maintaining cool chain during fruit storage and marketing. Both temperature and duration of exposure of fruit at low temperature are important. Cultivar and growing conditions are also responsible factors for this injury (Menzel and Waite 2005, Kumar and Kumar 2008). As remedial measures the harvesting of fruits in early morning and operations like sorting, grading and packaging should be done properly in pack-houses. Transportation in refrigerated vans without breaking the cool chain can avoid the occurrence of this injury on fruits.

Guava

Bronzing: Bronzing in guava (*Psidium guajava* L.) is a complex nutritional disorder (Sandhu and Gill 2013). This disorder is very common in marginal soils of Karnataka. It manifests as development of bronze or copper colour in the interveinal tissue of older leaves while terminal ones remain green. It is due to the deficiency of P, K and Zn elements. It is also attributed to poor management and low fertility of soils coupled with soil acidity. Total defoliation, brown coloured patterns on the fruits skin and reduced yield is noticed in severe cases (Sandhu and Gill 2013). Bronzing in guava was more severe on Entisols, followed by Vertisol and Inceptisols (Dahifale *et al.* 2009). Avoiding guava plantation in acidic soils or soils with high water table along with good cultural practices including balanced irrigation, soil pH and nutrition prevents from this disorder. Foliar application of 0.5% diammonium phosphate and Zinc sulphate in combination at weekly intervals for two months reduced bronzing in guava. Pre-flowering sprays with 0.4% boric acid and 0.3% zinc sulphate increased fruit yield and fruit size (Sandhu and Gill 2013).

Fruit drop: Fruit drop is a serious concern in guava as it results in about 45-65% fruit loss which is attributed to environmental factors. This occurs due to poor fertility status of soil, poor moisture content in the rhizosphere during fruit growth, hormonal imbalance and attack of insect pest and diseases (Sharma 2006, Sandhu and Gill 2013). Proper plant protection measures and spraying of GA_3 has been found to be effective in reducing fruit drop in guava (Sandhu and Gill 2013).

Citrus

Granulation: Granulation is a serious problem of citrus (*Citrus* spp.), especially under North Indian conditions. This abnormality starts at the stem end of the fruit which gradually extends towards the stylar end. The affected juice sacs become hard and dry; fruits become grey in colour, enlarged in size, have flat and insipid taste and assume a granular texture. Granulated fruits contain less extractable juice as most of it turns into gelatinous mass (Srivastava and Singh 2005). Many factors have been associated with the development of granulation such as advanced fruit maturity, large fruit size, excessive tree vigour, severe mite infestation/damage, composition of the juice, cool dry and windy weather conditions. Tree water status and irrigation were also reported as responsible causes. Changing cultural practices (i.e. fertilization and irrigation) and use of rootstocks that encourage vigorous tree growth may favour this disorder. Species and cultivars variability in this case has also been reported as sweet oranges are more prone than tangelos, grape fruit and mandarins (Sharma 2006, Ahlawat *et al*. 2013). The incidence of granulation could be reduced by applying two to three sprays of NAA (300 ppm) in the months of August, September and October. Spraying of GA @15 ppm followed by NAA @300 ppm in October and November also reduce granulation.

Citrus decline: Citrus decline is not a specific disease but is an integrated expression of many disorders in a plant. The term decline actually signifies continuous dying of the twigs. Tree grows well for the first 5 to 6 years, but thereafter, they show retarded growth and become unproductive. In severe cases, they may wilt and die. The improper and inadequate nutrition as well as low organic matter, excess of Fe, higher uptake of Mn and non-availability of micronutrients like Zn, Cu, Mg and boron aggravate tree decline (Srivastava and Singh 2005, 2008). Apart from these the excessive irrigation, water stagnation and use of saline water also lead to citrus decline. Pests such as citrus leaf miner, fruit sucking moth, lemon butterfly, aphid, psylla and mites damage the crop either by direct feeding or acting as vectors for transmission of viruses. The incidence of citrus nematode (*Tylenchulus semipenetrans*) and burrowing nematode (*Radopholus similis*) also contribute towards citrus decline. Incidence of fungal diseases such as *Colletotrichum gloeosporiodes*, and *Phytophthora* spp. (foot rot) are predominantly associated with dieback in most of the citrus orchards in India. In India, virus and virus like pathogens which have been associated with die back are crinkly leaf, infectious variegation, exocortis, leathery leaf, mosaic, tristeza, rubbery wood and greening (Sharma 2006, Sandhu and Gill 2013). Due to the prevalence of soil salinity, viruses and nematode problems in different regions, it is highly desirable that rootstocks be thoroughly evaluated before use. Proper drainage, avoiding excessive irrigation and following clean cultivation is important to reduce the incidence of this disorder. Proper manuring and use of resistant rootstocks and disease free certified bud-wood maintains the growth and vigour of the plants. The recommended spray schedule for the control of insect pest, nematode and diseases is also important.

Fruit cracking or splitting: Cracking or splitting is common physiological disorder of citrus fruits which is especially related with limes and lemons. Lemons are more prone to fruit cracking than limes. Splitting may be radial (Longitudinal) or transverse, radial being more common. The split may be short and shallow or it may be deep and wide, exposing the segments of the juice vesicles. The cracked fruits become entry points for microorganisms making them unfit for human consumption (Sandhu and Gill 2013).

Puffing: Puffing disorder of citrus fruits occurs before it reached to maturity. The causes of this disorder have been related to the water exchange regulation through peel (Singh 1992). Accordingly, high RH together with high temperatures at fruit colour break stage increases the appearance and intensity of puffing, particularly in the period of drought (Sandhu and Gill 2013).

Aonla

Internal necrosis: Internal necrosis has been observed in aonla (*Emblica officinalis* Gaertn.) fruits. Cultivar Francis is highly susceptible followed by Banarsi. The symptoms starts with browning of inner most part of mesocarpic tissue at the time of endocarp hardening in the 2nd or 3rd week of September which later extends towards the epicarp resulted into brownish black appearance of flesh. Internal fruit necrosis is associated with boron deficiency during the fruit development. Infection was not noticed on other aonla cultivars like Chakiya, NA 6 and NA 7, which need to be encouraged for commercial cultivation (Pathak *et al*. 2003). Combined spray of zinc sulphate (0.4%) + copper sulphate (0.4%) and borax (0.4%) during September-October has been found effective (Sandhu and Gill 2013).

Fruit drop: It is a serious problem in aonla which influences the final yield of crop. There are phases (three waves) of flower and fruit drop, observed in aonla (Bajpai and Shukla 1990, Sandhu and Gill 2013). In case of the first wave, more than 70% flowers drop within three weeks of flowering, which is normally due to lack of pollination, while during the second wave the drop is that of young fruitlets at the time of dormancy break and in last, i.e. third wave the droping of fruits is due to embryological and physiological factors and it is spread over the entire period of the fruit development. It starts from later half of August and continues up to harvest (Bajpai and Shukla 1990, Sandhu and Gill 2013). Fruit drop results due to many factors such as dry spell, imbalance of hormones, improper nutrition, fluctuation in temperature, cultivars and age of tree, and number of developing fruits. Also delay in harvesting results in heavy fruit drop particularly in Banarasi and Francis cultivars (Shukla *et al*. 2000).

Pomegranate

Fruit cracking: Fruit cracking is a serious problem of pomegranate (*Punica granatum* L.) particularly in arid climate. Cracked fruits are sweet but unfit for long distance transportation. Incidence of cracked fruits varies from 10 to 70% depending upon the prevailing environmental conditions (Abubakar *et al*. 2013). Longitudinal or radial splitting of rind surface occurs. The longitudinal cracking is more prevalent where the crack originates at the naval or styler end, while radial cracking originates between the ends. The cracked fruits are breeding grounds for insects, harmful bacteria and fungi making fruits unfit for marketing and consumption. The *Mrig bahar* crop is more susceptible to cracking than the crop of other *bahars*. Various factors are responsible for fruit cracking which include fluctuation in soil moisture regimes, climate, tree nutrition, cultivars (Abubaker *et al.* 2013). Young fruits cracks due to boron deficiency while fully developed fruits cracks due to variation in soil moisture content, atmospheric humidity and temperature. Prolonged drought causes hardening of peel and if this is followed by heavy irrigation or downpour than the pulp grows and the peel cracks (Abd El-Rhman 2010, Abubaker *et al*. 2013). The intensity of fruit cracking varies with cultivars and season. Cultivars such as Bedana Bosec, Khogand, Jalore Seedless are comparatively crack tolerant whereas Guleshan, Khog, Kazaki, Sur-Anar, Francis, Shrivan, and Krasnyl are reportedly resistant to fruit cracking. Varietal features like rind thickness and texture determine the susceptibility to cracking. The

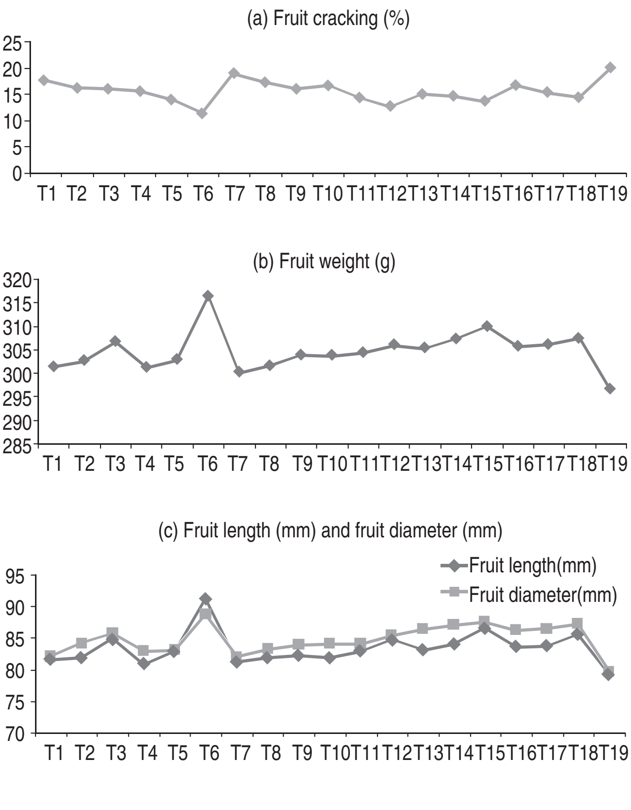

Fig 1 (a, b and c) Effect of bio-stimulants on fruit cracking and fruit quality attributes. [Treatments: T_1- Vipul (5 ml/L), T_2-Vipul (10 ml/L), T_3-Vipul (15 ml/L), T_4-Cytozyme (1 ml/L), T_5-Cytozyme (2 ml/L), T_6-Cytozyme (4 ml/L), T_7-HBRs (0.5 ml/L), T_8- HBRs (1 ml/L), T_9- HBRs (1.5 ml/L), T_{10}-Biozyme (1ml/L), T_{11}-Biozyme (2 ml/L), T_{12}-Biozyme (3 ml/L), T_{13}-Vipul + HBRs (0.5 + 5 ml/L), T_{14}-Vipul + HBRs (1 + 5 ml/L), T_{15}-Vipul + HBRs (1.5 + 5ml/L), T_{16}-Vipul + HBRs (5+0.5 ml/L), T_{17}-Vipul + HBRs (5+1 ml/L), T_{18}-Vipul+ HBRs (5+1.5 ml/L), T_{19}-Control (Water spray)]. Source: Abubakar *et al*. (2013)

management strategies include growing of resistant or tolerant cultivars, proper selection of *bahar*, use of Pinolene (5%) as vapour guard, spraying GA_3 (120 ppm), liquid paraffin (1%) at 15 days interval, twice during June, application of borax (0.1%) or calcium hydroxide on leaves and fruits after fruit set. Adequate calcium and potassium levels as per soil test values need to be maintained (Singh *et al*. 2006, Sharma 2006). An experimental study conducted by Abubaker *et al*. (2013) clearly indicated that all the bio-stimulants significantly reduced the incidence of fruit cracking and improved the fruit quality significantly (Fig 1a, b and c).

Apply adequate and regular irrigation during fruiting season. The water retention capacity of the plants should be increased by the use of organic manures and then regular irrigation to maintain soil moisture is some of the measures which can reduce fruit cracking. In hot dry period fruits should be covered with butter paper bags.

Sun scald: Surface skin of fruits facing afternoon sun turns brownish black due to scorching while underneath skin is normal. To avoid this disorder proper canopy architecture should be developed which prevent the direct exposure of fruits to sunlight. Spraying kaolin during the hot summer months is useful in reducing sunscald. First spray of 5% and subsequently 1 or 2 additional spray with kaolin @2.5% at 15 days interval reduce sunscald. Bagging the fruits with butter paper covers is useful in minimizing fruit spoilage due to sunscald. White colour bags are more effective in reflecting sunlight and protecting the growing fruits (Sandhu and Gill 2013).

Aril browning: Aril browning or internal breakdown of arils in pomegranate critically affect fruit quality in some commonly grown cultivars such as, Ganesh and Bhagwa. In many cases, the intensity of the disorder in mature ripe fruits could be more than 50% causing severe loss of quality. As the fruits affected by this disorder remain free from external symptoms, they cannot be separated out before being packed, thus posing serious problems in export (Shivashankar *et al*. 2012). Aril breakdown or browning is characterized by soft, light creamy, brown, dark blackish or brown and slightly flattened arils which are deformed and possess an unpleasant odour when the fruit is cut open. This disorder is accompanied by desiccation, wrinkling and development of internal spaces in the arils. Experimental studies indicated that the juice and seed content of affected fruits have reduced level of TSS, acidity, ascorbic acid, reducing sugars, calcium, phosphorus, and enzyme catalase and increased level of non-reducing sugars, starch, tannins, nitrogen, potassium, magnesium, boron and enzyme polyphenol oxidase compared to healthy fruits (Shivashankar *et al*. 2012, Sandhu and Gill 2013). Studies have shown that the malady is influenced by diverse factors such as genetic background, pruning, growing season, fruit size, harvested date and variety (Sharma 2006, Jalikop *et al*. 2010, Sandhu and Gill 2013). It can be managed by harvesting at proper maturity period (Sandhu and Gill 2013).

Sapota

Fruit drop: Sapota (*Manilkara zapota* L.) has the problem of low fruit setting and shedding. Only about 10-12% of the total set fruits develops and retained till maturity. Most of the fruit-drop occurs immediately after fruit setting. Increase in fruit set and retention are possible by spraying NAA and GA_3 at 25 to 100 ppm during flowering and at 15-day interval (Chavan *et al.* 2009).

Corky tissue: Corky tissue (CT) of sapota is characterized by hard lump in the pulp, slightly desiccated in nature and acidic to taste. This disorder shows no distinct external symptoms and becomes visible only when the fruit is cut open. Under severe conditions, corky skin eruptions are seen (Sulladmath 2005). CT is prevalent in the cultivar 'Cricket Ball' (up to 35%). Past studies have shown that the CT affected fruits have a lower concentration of sugars associated with the accumulation of starch as compared to healthy fruits (Shivashankar *et al*. 2013). Being a climacteric fruit, sapota ripens rapidly under optimal environmental conditions after harvest. However, the CT fruits exhibit a lack of uniform ripening and the probable cause of such impaired ripening has been correlated by the changes in the rates of conversion of starch involving the activities of α-amylase, starch phosphorylase and acid phosphatase enzymes. An experimental observation by Ugalat *et al*. (2013) clearly indicated the per cent of corky tissue incidence had a positive correlation with the number of fruits per panicle and size of the fruits (big and small) (Table 1).

Cashew

Little leaf: Little leaf of cashew (*Anacardium occidentale* L.) is caused due to the deficiency of zinc. The leaves remain small in size giving rosette appearance. Application of zinc sulphate (0.5%) to the soil or by foliar spray is helpful in preventing this disorder (Berry and Sargent 2011, Sandhu and Gill 2013).

Yellow leaf spot: The occurrence of yellow leaf spot, an enigmatic disorder in cashew, is found to be associated with low soil pH (4.5-5.0). The appearance of yellow leaf spot might be due to molybdenum deficiency. The affected leaves are deficient in molybdenum (Subbaiah *et al.*1986) and had excessive amounts of manganese (Chattopadhyay 1994). The trees sprayed with 0.03% solution of ammonium

Table 1 Relationship between number of fruits/panicle and incidence of corky tissue in sapota

Number of fruits/panicle	Corky tissue incidence (%)
1	10
2	32
3	45
4	50
SEm±	0.71
LSD (P=0.01)	3.06

Source: Ugalat *et al*. (2013).

molybdate once during pre-monsoon (June) and another after end of monsoon (September) was found effective in controlling this disorder. It can also be controlled by correcting soil pH with lime (Berry and Sargent 2011, Sandhu and Gill 2013).

Coconut

Barren nuts: The occurrence of nuts without or with imperfectly developed kernel is known as barren nuts or seedless or imperfect nuts and it is a common phenomenon in coconut (*Cocos nucifera* L.) (Sharma 2006). The affected nuts are oblong in shape as compared to round shape of the normal nuts and the quantity of husk produced is less as compared to normal. The most common feature of the barren nut is frequent splitting of the shell during the period of development. The major causes attributed to this disorder are: the defective fertilization or poor pollination, nutritional deficiency such as K and B in the palm and increased production of palm in the tree. The production of barren nuts can be reduced to a greater extent by proper thinning of nuts with adequate application of P and B along with normal recommended dose of fertilizers (1 kg muriate of potash + 200 g of borax + RDF) (Sharma 2006, Sandhu and Gill 2013). The general practice of applying common salt was also found beneficial in reducing this malady.

Button shedding: Button shedding and premature nut fall are commonly observed disorder which results in considerable loss in nut yield. This phenomenon of shedding of buttons varies from 55-95% depending on conditions prevailing and on the cultivar of coconut. A large number of female flowers in the inflorescence fail to fertilize which do not develop into nuts and eventually shed. The female flowers or buttons shed after fertilization and some of the nuts fall prematurely after setting. The fall of immature nuts at a later stage of development often causes considerable loss of crop. The shedding of buttons is comparatively heavier in the dwarf palms than in the tall ones (Gangolly *et al*. 1956, Menon and Padalai 1958, Bailey *et al.* 1977, Tongdee 1991, Janik and Paull 2006). The occurrence of this malady can be managed by application of proper irrigation by avoiding drought. Maintaining good tilth by proper ploughing and better soil aeration. Thinning of bunch after two months by cutting away the nuts that are observed to lag behind in general development and those found crowded in the bunch reduces the incidence and provides sufficient space for development of remaining nuts. It has also been reported that application of potassic fertilizers help in reducing this disorder. Root feeding of coconut with 40 ppm of NAA reduces the button shedding and increases nut yield. The effort of application of 2, 4- D @ 30 ppm one month after the opening of the spathe can be made for correcting the ill effect caused of lack of pollination (Janik and Paull 2006, Sandhu and Gill 2013).

Bael

Fruit cracking: Fruit cracking is an important physiological disorder found in some commercial cultivars of bael (*Aegle marmelos*), which occurs just before the ripening stage. It is associated with sudden change in weather conditions such as temperature and humidity. Heavy irrigation or rainfall after prolonged drought is also one of the causes of this malady (Pandey *et al*. 2005). These can be managed by providing good irrigation facility, making wind breaks around the orchard and by spraying borax @ 0.1% twice at full bloom and after fruit set. The deficiency of nitrogen and zinc is common in bael orchards and can be corrected by soil application or foliar spray.

Fruit drop: The large number of flowers and fruits borne by trees are not carried to maturity and a portion of this drop during the course of development. Fruit drop is a serious problem in bael which occurs due to many factors such as strong winds, imbalance of soil moisture, improper nutrition and hormonal imbalance (Pandey *et al*. 2005, Sandhu and Gill 2013). This malady can be managed by maintaining the appropriate soil moisture level during fruit development, spraying of growth regulators (2, 4 -D, GA_3 and 2, 4, 5-T at recommended concentrations) (Sharma 2006, Sandhu and Gill 2013).

Ber

Fruit drop: Fruit drop in ber (*Ziziphus mauritiana* Lamk.) tree may be due to any one or combination of many reasons as disintegration of ovules, shrivelling of fruits and high incidence of powdery mildew. Fruit drop depends on cultivar, maturity period of cultivar (early, mid or late) and extent of fruit set, and bearing of tree (Pareek 1983, Sandhu and Gill 2013). Fruit drop has been found to be reduced by application of either 2,4-D (10-20 ppm) or 2,4-5-T (5-10 ppm) or GA3 (25 ppm) in cultivars like Kaithali, Umran, by timely irrigation of trees after fruit set, by application of adequate quantity of organic manures fertilizers during fruit development (50 kg FYM, 250 g N + 50 g P_2O_5 + 50 g K_2O per tree after pruning and fruit set), by application of NAA @ 10 ppm at fruit bloom (Singh and Singh 1976) and by foliar application of borax and zinc sulphate. Maximum fruit retention and minimum fruit drop was recorded in the trees sprayed with 1.5% potassium sulphate and 20 ppm NAA at fruit set stage by Singh and Bal (2006).

Jackfruit

Irregular shape: The irregularly shaped jackfruit (*Artocarpus heterophyllus* L.) occurs due to boron deficiency in the fruit (Janik and Paull 2006). Nutrition plays a vital role and boron is the key to improved flowering, fruiting, and internal and external fruit quality in jackfruit (Amma and Kumaran 2011).

Premature fruit drop: Premature fruit drop in jackfruit is often related to unfavourable environmental conditions, irregular watering, improper nutrition and hormonal imbalance (Ghosh 2000, Janik and Paull 2006, Amma and Kumaran 2011, Sandhu and Gill 2013). This causes huge economic loss to the growers every year. For mature tree watering must be done during dry period from blooming to throughout the growth and development period of fruit. Spray of growth regulators also help to reduce the ill effect of hormonal imbalances (Sandhu and Gill 2013).

From the review, it is clear that physiological disorders have become menace in many fruit crops resulting in huge losses to growers. There is a need for long-term quantitative documentation of tree phenological patterns in diverse climatic zones of India. Recent advances in physiology and genetics may help solve problems of perennial fruit tree production. Though molecular biology have greatly improved our understanding of plant responses to stresses in many important commercial horticultural crops, a lack of transcriptomic and genomic information hinders our understanding of the molecular mechanisms underlying fruit-set and fruit development. There is need for exhaustive studies to know the precise physiological significance of radiation effect in climatic fastidious fruit crops. Intelligent anticipatory management strategies and adaptation will be the critical components for successful and sustainable quality fruit production. Management aspects may include biophysical treatments including reclamation of deficiency and excess of nutrient elements by proper fertility status maintenance, timely agronomical operations and input application. Location specific management strategies for important perennial fruit crops will require focused attention through multidisciplinary approach including adaptation and management.

REFERENCES

Abd El-Rhman I E. 2010. Physiological studies on cracking phenomenon of pomegranate. *Journal of Applied Sciences Research* **6**(6): 696–703.

Abubakar A R, Asraf N and Asraf M. 2013. Effect of plant biostimulents on fruit cracking and quality attributes of pomegranate cv. Kandhari kabuli. *Scientific Research and Essays* **8**(44): 2 171–5.

Acquaah G. 2007. *Principles of Plant Genetics and Breeding*. Blackwell, Oxford, UK.

Agarwala S C, Sharma C P and Kumar A. 1962. The mineral nutrient element composition of the mango fruit, with particular reference to the 'black tip' disease. *Journal of Indian Botanical Society* **41**: 16–23.

Ahlawat T R, Patel C R, Rymbai H and Patel N L. 2013. Physiological disorders in tropical and subtropical fruits. *(In) Proceedings of the National Seminar on Tropical and Subtropical Fruits,* held during 9-11 January 2013 at Navsari, Gujarat, pp 229–52.

Amin H D. 1967. Development of white corky tissue in a mango fruit (*Mangifera indica)*. *Navsari Agricultural College Magazine* **6**: 14–7.

Amma S P and Kumaran K. 2011. Jackfruit in South India (Chapter-28). *(In) The Jackfruit,* pp 393–408. Valavi S G, Peter K V and George Thottappilly G (Eds). Studium Press LLC, Houston, USA.

Azzouz S, Hamdy Z M and Dahshan I M. 1978. Studies on malformed inflorescence of mango, the degree of susceptibility among different varieties. *Agricultural Research Review* **57**: 17–27.

Baghel B S, Jaiswal U S, Nema B K and Nema M K.1994. Morphological and bio-chemical studies of healthy and malformed panicles in different cultivars of mango (*Mangifera indica* L.). *Recent Horticulture* **1**: 4–10.

Bailey P, O'Sullivan D and Perry C. 1977. Effect of artificial defoliation on coconut yields in Papua New Guinea. *Papua New Guinea Agriculture Journal* **28**: 39–45.

Bains G and Pant R C. 2003. Mango malformation: Etiology and preventive measures. *Physiology and Molecular Biology of Plants* **9**: 41–61.

Bennett A C, McDowell N G, Allen C D and Anderson-Teixeira K J. 2015. Larger trees suffer most during drought in forests worldwide. *Nature Plants,* Vol 1, Article No. 15139. doi:10.1038/nplants.2015.139.

Berry A D and Sargent S A. 2011. Cashew apple and nut (*Anacardium occidentale* L.). *(In) Postharvest Biology and Technology of Tropical and Subtropical Fruits,* Vol 2, pp 414–22. Yahia E M. (Ed). Woodhead Publishing Ltd, UK.

Bogges S F, Aspinall D and Paleg L G. 1976. Stress metabolism IX. The significance of end product inhibition of proline synthesis and of compartmentation in relation to stress induced proline accumulation. *Australian Journal of Plant Physiology* **3**: 513–25.

Burdon J N and Moore K G. 1991. Soft nose disorder on mango fruit. *Planter* **67**: 477–81.

Chadha K L and Rajpoot M S. 1969. Studies on floral biology, fruit set and its retention and quality of some litchi varieties. *Indian Journal of Horticulture* **26**: 124–9.

Chandel S K and Sharma N K. 1992. Extent of fruit cracking in litchi and its control measure. *South Indian Horticulture* **40** (2): 74–6.

Chaplin G R. 1986. Post harvest physiology of mango fruit. *(In) Proceedings of the First Australian Mango Research Workshop,* Commonwealth Scientific and Industrial Research Organization (CSIRO), Melbourne, Australia, pp 261–70.

Chatterjee C and Dube B K. 2004. Nutrient deficiency disorders in fruit trees and their management. *(In) Fruit and Vegetable Diseases,* pp 3–39. Mukerji K G (Ed). Springer Netherlands. doi:10.1007/0-306-48575-3_1.

Chattopadhyay T K. 1994. *A Textbook on Pomology, Vol I: Fundamentals of Fruit Growing,* pp 144–85. Kalyani Publishers, New Delhi.

Chavan S R, Patil M B, Phad GN and Suryawanshi A B. 2009. Effect of growth regulators on yield attributes and quality of sapota [*Manilkara achras* (Mill.) Forsberg] cv. Kalipati. *Asian Journal of Horticulture* **4**(1): 176–7.

Cheema G S and Dani P C. 1934. Report on the export of mangoes to Europe in 1932 and 1934. *Bulletin of the Department of Agriculture, Bombay* **170**: 1–31.

Crane J H and Campbell C W. 1994. *The Mango*. Fact Sheet HS-2, Horticultural Science, Department of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

Dahifale H N, Durgude A G, Deshpande A N. 2009. Nutrient diagnosis for bronzing of leaves in guava orchards. *Journal of Maharashtra Agricultural Universities* **34**(1): 6–10.

Galán Saúco V. 2009. Physiological disorders (Chapter 9). *(In) The Mango: Botany, Production and Uses* pp. 303–16. Litz R E (Ed). CABI Publication, USA.

Gillaspy G, Ben-David H and Gruissem W. 1993. Fruits: A developmental perspective. *Plant Cell* **5**(10): 1 439–51.

Goldweber S.1959. Observations on lychee grown in pot culture. *Proceedings of Florida State Horticultural Society* **72**: 353–6.

Goodwin P B. 1978. Phytohormones and fruit growth. *(In)*

Phytohormones and Related Compounds: A Comprehensive Treatise, Vol II, pp 175-249. Letham D S, Goodwin P B, Higgins T J (Eds). Elsevier-North Holland Biomedical Press, Amsterdam, The Netherlands.

Goren R. 1993. Anatomical, physiological and hormonal aspects of abscission in citrus. *Horticultural Reviews* **15**: 33–46.

Gross K C, Wang C Y and Saltveit M. 2002. *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops*. Agriculture Handbook 66 U S Department of Agriculture. http://www.ba.ars.usda.gov/hb66/index.html.

Gupta D N, Lad B L, Chavan A S and Salvi M J. 1985. Enzyme studies on spongy tissue: A physiological ripening disorder in Alphonso mango. *Journal of Maharashtra Agricultural University* **10**: 280–2.

Jalikop S H, Venugopalan R and Kumar R. 2010. Association of fruit traits and aril browning in pomegranate (*Punica granatum* L.). *Euphytica* **174**: 137–41.

Janik J and Paull R E. 2006. *The Encyclopaedia of Fruits and Nuts*, pp 107–18. CABI Publications.

Joshi G D and Roy S K. 1985. Spongy tissue in mango, a physiological disorder. *Indian Journal of Horticulture* **29**: 21–2.

Joubert A J. 1986. The litchi. *(In) Handbook of Fruit Set and Development,* pp 233–46. Shaul P Monselise (Ed). CRC Press Inc., Florida.

Kanwar J S and Nijjar G S. 1972. Fruit growth studies in litchi (*Litchi chinensis* Sonn.) at Gurudaspur (Punjab). *Punjab Horticulture Journal* **12**: 146–51.

Katrodia J S and Bhuva H P. 1993. Spongy tissue in mango. *(In) Advances in Horticulture, Vol IV Fruit Crops,* pp 2 069–80. Chadha K L and Pareek O P (Eds). Malhotra Publishing House, New Delhi.

Katrodia J S and Rane D A. 1989. The pattern of distribution of spongy tissue in affected Alphonso fruits at different locations. *Acta Horticulturae* **231**: 873–7.

Kender W J and Anastasia F. 1964. Nutrition deficiency symptoms of low bush blue berry. *Proceedings of the American Society for Horticultural Science* **83**: 275–80.

Kozlowski T T, Kramer P J, Pallardy S G and Roy J. 2000. *The Physiological Ecology of Woody Plants*. Academic Press Inc., Harcourt Brace Jovanovich, San Diego, New York.

Krishna H. 2012. *Physiology of Fruit Production*, p 314. Stadium Press India Pvt Ltd.

Kumar K K and Kumar R. 2008. *Managing physiological disorder in litchi*. Technical Bulletin -5, ICAR-NRC on Litchi. Muzaffapur, Bihar.

Kumar R and Kumar V. 2014. Impact of pollination by European honeybee, *Apis mellifera* L. on the yield and quality of litchi (*Litchi chinensis* Sonn.) fruits in India. *Pest Management in Horticultural Ecosystem* **20**(2): 127–32.

Kumar R. 2015. Rejuvenating old, senile orchards of tropical and subtropical fruits for enhanced production and improved quality: A review. *Indian Journal of Agricultural Sciences* **85**(3): 295–313.

Kumar V, Purbey S K and Anal A K D. 2016. Losses in litchi at various stages of supply chain and changes in fruit quality parameters. *Crop Protection* **79**: 97–104. doi:10.1016/j.cropro.2015.10.014.

Lim T K and Khoo K C. 1985. *Diseases and Disorders of Mango in Malaysia*. Tropical Press, Sdn., Kuala Lumpur, Malaysia.

Lima L C O, Chittara A B and Chittara M I F. 2001. Changes in amylase activity, starch and sugar contents in mango fruits pulp cv. Tommy Atkins with spongy tissue. *Brazilian Archives of Biology and Technology* **44**: 59–62.

Majumdar P K, Singh M P and Singh R N.1976. Improved productivity of malformed mango trees. *Indian Journal Horticulture* **20**: 7–8.

Malo S E and Campbell C W. 1978. Studies on mango fruit breakdown in Florida. *Proceedings of the American Society for Horticultural Science, Tropical Region* **22**: 1–15.

Menon K P V and Pandalai K M. 1958. *The Coconut Palm-A Monograph*. Indian Central Coconut Committee, Ernakulam, South India.

Menzel C M and Waite G K. 2005. *Litchi and Longan: Botany, Production and Uses*. CABI Publishing, Wallingford, Oxfordshire, UK.

Menzel C M, Bagshaw J, Campbell T, Greer N, Noiler J, Olesan T and Waite G K. 2002. *Lychee Information Kit*. Queensland Department of Primary Industries, Nambour, Australia.

Menzel C M. 1984. The pattern and control of reproductive development in litchi: A review. *Scientia Horticulturae* **22**: 333–45.

Misra A K and Singh V K. 2002. *Fusarium subglutinans* (*Fusarium moniliforme* var. *subglutinans*) in relation to mango malformation. *Indian Journal of Plant Pathology* **20**: 81–3.

Mitra S K, Dutta Ray S K and Mandal D. 2014. Control of fruit cracking and sun-burning in litchi by irrigation and moisture conservation. *Acta Horticulturae* **1024**: 177–81. doi:10.17660/ActaHortic.2014.1024.20.

Nitsch J P. 1971. Perennation through seeds and other structures: fruit development. *(In) Plant Physiology,* a treatise, Vol 6A, pp 413–501. Steward F C (Ed). Academic Press, London.

Pandey D, Shukla S K and Nath V. 2005. Diversity of bael (*Aegle marmelos* Correa) in Bihar and Uttar Pradesh. *Progressive Horticulture* **31**: 359–62.

Pant R C. 2000. Is stress ethylene the cause of mango (*Mangifera indica* L.) malformation? *Physiology and Molecular Biology of Plants* **6**: 8–14.

Pareek O P. 1983. *The Ber*. ICAR Publication, New Delhi.

Pathak R K, Pandey D, Haseeb M and Tandon D K. 2003. *The Aonla*. Bulletin, CISH, Lucknow.

Peng J, Xi J B, Tang X D, Wang Y G, Si X M and Chen J S. 2001. Effect of $Ca(NO_3)$ and GA spray on leaves on the fruit cracking of 'Nuomici' litchi. *Acta Horticulturae Sinica* **28**: 348–50.

Pharis R P and King R W. 1985. Gibberellins and reproductive development in seed plants. *Annual Review of Plant Physiology* **36**: 517–68.

Prakash O and Srivastava K C. 1987. *Mango Diseases and Their Management-A World Review*. Today and Tomorrow's Publishers, New Delhi.

Ram S and Yadav Y K. 1999. Mango malformation: A review. *Journal of Applied Horticulture* **1**: 70–8.

Ravindra V and Shivashankar S. 2004. Spongy tissue in Alphonso mango-significance of *in situ* seed germination events. *Current Science* **87:** 1 045–9.

Raymond L, Schaffer B, Brecht J K and Crane J H. 1998. Internal breakdown in mango fruit: symptomology and histology of jelly seed, soft nose, and stem-end cavity. *Postharvest Biology and Technology* **13**: 59–70.

Saltveit M E and Morris L L. 1990. Overview on chilling injury of horticultural crops. *(In) Chilling Injury of Horticultural Crops,* pp 3–15. Wang C Y (Ed). CRC Press, Boca Raton, FL.

Sandhu S and Gill B S. 2013. *Physiological Disorders of Fruit*

Crops, p 189. New India Publishing Agency, New Delhi.

Sanyal D, Ahsan A, Ghosh B and Mitra S K. 1990. Studies on sunburning and skin cracking in some varieties of litchi. *Indian Agriculturist* **34**(1): 19–23.

Sattar A. 1946. Disease of mango in Punjab. *Punjab Fruit Journal* **10**: 56–8.

Schaffer B. 1994. Mango disorders caused by abiotic factors. *(In) Compendium of Tropical Fruit Diseases,* pp 43–4. Ploetz R C, Zentmyer G A, Nishijiona W T, Rohrbach K G and Ohr H D (Eds). APS Press, The American Phytopathological Society, Minnesota, USA.

Selvaraj Y, Edward Raja M and Rawal R D. 2000. Biochemical studies on internal breakdown-A ripening disorder in mango fruits. *Indian Journal of Horticulture* **57:** 183–8.

Sen P K, Roy P K and De B N. 1947. Hunger signs in mango. *Indian Journal of Horticulture* **5**: 35–44.

Shao W, Lai Z X, Huang Q and Guo Y Q. 2010. Changes of APX Isozymes under high temperature stress and cloning of an APX functional fragment in embyrogenic callus of litchi. *Acta Horticulturae* **863**: 183–7.

Sharma R R. 2006. Physiological disorders in tropical and subtropical fruits: causes and control. *(In) Fruit Production-Problems and Solutions,* pp 301–25. International Book Distributing Co., Lucknow, UP.

Sharma S B and Ray P K. 1987. Fruit cracking in litchi- A review. *Haryana Journal of Horticultural Science* **16**: 11–5.

Shear C B. 1975. Calcium nutrition and quality in fruit crops. *Communications in Soil Science and Plant Analysis* **6**: 233–44.

Shivashankar S, Ravindra V and Louis L. 2007. Biochemical changes in seed and mesocarp of mango (*Mangifera indica* L.) cv. 'Alphonso' and their significance during the development of spongy tissue. *Journal of Horticultural Science and Biotechnology* **82**: 35–40.

Singh A P. 2009. *Field Problems of Fruit Crops*. Foil Printers, Ludhiana.

Singh A. 1992. *Fruit Physiology and Production*. Kalyani Publishers, Ludhiana.

Singh H S, Nath V, Singh A and Pandey S D. 2012. *Litchi: Preventive Practices and Curative Measures*. SPSS Publications, Delhi.

Singh K P and Kushwaha C P. 2005. Emerging paradigms of tree phenology in dry tropics. *Current Science* **89**(6): 964–75.

Singh U R and Singh N. 1976. Effect of plant growth regulators on fruit drop, size and quality of ber (*Zizyphus Mauritiana* Lamk.) var. Banarasi. *Haryana Journal of Horticultural Science* **5**: 1–8.

Sinha A K, Singh C and Jain B P. 1999. Effect of plant growth substances and micronutrients on fruit set, fruit drop, fruit retention and cracking of litchi cv. Purbi. *Indian Journal of Horticulture* **56**: 309–11.

Smith P F and Scudder G K. 1951. Some studies of mineral deficiency symptoms in mango. *Proceedings of the Florida State Horticultural Society* **64**: 243–8.

Subramanyan H, Krishnamurthi S, Subhadra N V, Dalal V B, Randhawa G S and Chacko E K. 1971. Studies on internal breakdown, a physiological ripening disorder in "Alphanso" mangoes (*Mangifera indica* L.). *Tropical Science* **13**: 203–10.

Sulladmath V V. 2005. 'Studies on the pattern of mineral nutrient accumulation in developing sapota (*Manilkara achras* (Mill.) Fosberg) fruit with special reference to internal breakdown'. Ph D thesis, Dr. Bhimrao Ambedkar University, Agra, Uttar Pradesh.

Summanwar A S. 1967. Mango malformation: Serious economic consequences. *Indian Horticulture* **11**: 12–16.

Tongdee S C. 1991. Postharvest handling of tender coconut. *ASEAN Food Journal* **6**: 74–5.

Ugalat J, Haradari C and Singh H. 2013. Biochemical and physiological characterization of corky tissue affected fruit of sapota (*Manilkara achras* (Mill) Fosberg) cv. Cricket Ball. *Journal of Crop and Weed* **9**(1): 193–7.

Ulrich A and Ohki K. 1966. Potassium. *(In) Diagnostic Criteria for Plants and Soils,* H D Chapman (Ed). University of California, Division of Agricultural Sciences.

Varma A, Lele V C, Raychaudhuri S P, Ram A and Sang A. 1974. Mango malformation: A fungal disease. *Journal of Phytopathology* **79**: 254–7.

Wang C Y. 1982. Physiological and biochemical responses of plants to chilling stress. *HortScience* **17**: 173–86.

Watt G. 1891. *A Dictionary of Economic Products of India*, p 149. Government Printing Press, Calcutta.

Winston E C. 1984. Observations of internal mango flesh breakdown: need for standardization of terminology. *(In) Proceedings of the First Australian Mango Research Workshop*, held from 26-30 November at Cairns, Australia, CSIRO Press, Melbourne, Australia, pp 77–81.

Yadav T D. 1972. Role of mango bud mite, *Aceria mangiferae* Sayed in mango malformation. *Acta Horticulturae* **24**: 238.

Young T W and Koo R C J. 1969. Mineral compositions of Florida mango leaves. *Proceedings of Florida State Horticultural Society* **82**: 324–8.

Zhang C, Huang H and Kuang Y. 1995. A study of the cause of the mango black tip disorder. *Scientia Horticulturae* **64**: 49–54.