International Journal of Agriculture, Environment and Biotechnology
Citation: *IJAEB*: **16**(02): 135-147, June 2023
DOI: 10.30954/0974-1712.02.2023.11

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

REVIEW PAPER

A Deep Insight into Physiological Disorders of Mango (*Mangifera indica L.*)- A Review

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Paper No. 1084 **Received:** 28-01-2023 **Revised:** 24-05-2023 **Accepted:** 02-06-2023

ABSTRACT

In recent years, Indian mango orchards have experienced falling growth, which has decreased production and yield. Physiological disorders are one of the main challenges to the fruit industry that cause economic losses globally, along with insects, pests and diseases. Mango growers are attempting to switch their cultivation methods from mango to other crops as a result of losing hope in and interest in mango farms. Physiological disorders include abnormal exterior or interior circumstances as well as atypical fruit growth patterns brought on by abiotic causes such as high or low temperature, moisture content, nutritional and hormonal imbalance, faulty pollination or fertilisation etc. The majority of disorders include multiple contributing causes, such as nutrition and environment, however some disorders are primarily brought on by one component. Therefore, it is important to comprehend the origin of a given problem and how to solve it using a particular management strategy. This review not only explains the physiological problems that affect fruit crops and cause significant losses for fruit growers, but it also discusses the management strategies that will undoubtedly aid the farmers in quickly resolving this issue so that they are able to obtain satisfactory financial rewards from mango cultivation.

HIGHLIGHTS

- Physiological disorders are one of the major challenges to the fruit industry that cause economic losses globally.
- Physiological disorders include abnormal exterior or interior circumstances as well as atypical fruit growth patterns brought on by abiotic causes such as extremes temperature, moisture content, nutritional and hormonal imbalance etc.
- To understand the underlying causes of physiological disorders in order to implement long-term management strategies to treat the specific disorder.
- The use of various management strategies, such as the application of a balanced fertilizer dose, good agricultural practices, irrigation and weed management, chemicals, use of resistant varieties etc., can be used to overcome the physiological disorders that are a barrier for the production of quality fruit.

Keywords: Mango, physiological disorders, abiotic factors, management

Mango, a very important fruit crop of India, is the most-liked fruit among producers, dealers and consumers due its very high nutritional value and demand on both the domestic and international markets (Sharma and Krishna 2014). Its fruits are

How to cite this article: Maurya, P., Kumar, V., Jain, S., Amulya, S., Jagga, S., Kiran, B., Jayachandran, A. and Kothiyal, K. (2023). A Deep Insight into Physiological Disorders of Mango (*Mangifera indica* L.)- A Review. *Int. J. Ag. Env. Biotech.*, **16**(02): 135-147.

Source of Support: None; **Conflict of Interest:** None

a rich source of the nutrients needed for a healthy life and to lower the risk of fatalities like cancer and cardiac arrest, including antioxidants, vitamins, total phenols, and dietary fibres (Talcott *et al.* 2005). As a result of its distinctive flavour, popularity, and health advantages, it is frequently referred to as the "King of Fruit" (Singh 1960; Litz 2009). India is the largest producer of mangoes with 46.02% and 45.88% of the total world area and production, respectively. Mango is the most widely grown fruit crop in India, covering 2.35 million hectares and producing 21.011 million tonnes (Anonymous, 2021-22). India is the home to more than 1,600 different species of mango, although its contribution to the export revenue for mangoes from agricultural products has been less than 2% (Krishna *et al.* 2020). Physiological disorders related to mangos are one of the main causes of low productivity and low export potentiality and have an impact on mango production at every stage, from the nursery plants to the fruits in storage or transit. The fruit quality, nutritional level, which is a determining element for export, is also hampered by these physiological problems, which result in substantial economic losses for the growers each year and has become a bottleneck in export and expansion of mango industry.

The term "physiological disorders" describes tissue breakdown that is not brought on by either pathogen invasion (disease-causing organisms) or mechanical damage. They might appear in response to a poor pre- or post-harvest environment, particularly one with a high temperature, or to a lack of nutrition during growth and development. Physiological or abiotic disorders are distinguished from other types of disorders by the fact that they are not caused by any biological entities like viruses, bacteria, fungi, insects etc., but rather by abiotic factors (inanimate), meaning that their agents are non-living in nature and cause deviation from normal growth. They induce physical or chemical alterations in a plant that are drastically different from what is normal and is commonly caused by an external factor. In certain instances, it is simple to recognise non-infectious disorders, but in others, it might be challenging or even impossible. Once they have happened, the majority of them cannot be rectified. A lack or excess of a substance that is necessary for life or the presence of a substance that interferes with life are frequent causes of physiological disorders. It can have an impact on plants at all phases of development. Because they happen without or in the absence of infectious agents, they are not contagious. Physiological disorders in mangoes can indeed cause damage to the plants themselves and create vulnerabilities that may allow pathogens to enter and further impact the crop (Singh *et al.* 2019). By addressing these disorders, growers can help improve the overall health and productivity of mango trees. Details of different physiological disorders along with their management strategies are as follows.

ALTERNATE BEARING

Alternate, biennial or irregular bearing, is indeed a common issue in mango trees, particularly in the north, east, and central parts of India. This pattern refers to the tendency of mango trees to bear a heavy crop in one year (on year) and a significantly reduced or no crop in the following year (off year). The reason behind this behaviour is the nutritional exhaustion of the tree. When a mango tree produces a heavy crop in one season, it expends a significant amount of energy and nutrients to support fruit development. As a result, the tree becomes depleted and is unable to put forth new flushes or growth, which ultimately leads to poor or no yield in the subsequent season. Certain mango varieties, such as Dashehari, Langra, and Chausa, which are commonly grown in North India, are prone to biennial bearing. On the other hand, mango varieties found in South India, like Totapuri Red Small, Bangalora, and Neelum, are known to be regular bearers, meaning they produce a consistent crop every year (Ahlawat *et al.* 2014). Mango trees, when heavily laden with fruits, generally do not produce new shoots. Even after the harvest, if new shoots do emerge, they are often minimal in number and do not flower in the following year. This is because the development of new vegetative flushes in mango trees requires a certain level of maturity, typically around 8-10 months, for the differentiation of flower buds. If it blooms and bears fruit this year, it will typically develop new shoots in March and April of the following year, which will bloom the succeeding year, so that flowering and fruiting will occur alternate years. The biennial bearing phenomenon in mango trees has been attributed to various factors, including genetic, physiological, environmental, nutritional, and hormonal influences (Bhargava *et al.* 2011). These factors can interact and contribute to the irregular bearing pattern observed in mango trees. Nutritional exhaustion resulting from a heavy crop in one season is one of the key factors affecting the tree's ability to yield in the following season (Kundu *et al.* 2017).

Causative Factors

(i) **Environmental factors:** Spring frost, extreme temperatures (both low and high), low atmospheric humidity, and rainfall patterns can play a significant role in triggering the cyclic behaviour of alternate bearing in mango trees. These environmental conditions during critical stages of flower bud differentiation and fruit development can influence the tree's ability to bear a crop in the following season.

(ii) **Physiological factors:** Hormonal imbalances and shoot maturity are important factors in the flowering process of mango trees. A higher level of auxin and a lower level of gibberellin are crucial for the development of floriferous shoots that bear flowers. During the off year, the ratio of gibberellin (GA_3) to auxin increases, favouring vegetative growth over flowering.

(iii) **Genetic factors:** Varietal differences can contribute to the alternate bearing behaviour of mango trees. Some mango varieties are inherently more prone to biennial bearing than others.

(iv) **Crop overload:** The production of a heavy crop during the on year can lead to nutritional exhaustion in the tree. The tree becomes incapable of producing new flushes, which are necessary for flower bud differentiation. Additionally, fruit overload can also modify the hormonal balance of the tree, affecting its ability to flower in the following season.

(v) **C:N ratio:** A higher starch reserve, total carbohydrates, and carbon-to-nitrogen (C: N) ratio are favourable for flower bud formation. The availability and balance of nutrients, particularly nitrogen, carbon, and carbohydrates, can influence the tree's ability to initiate and develop flower buds.

(vi) **Occurrence of insect pests and diseases:** Insect pests and diseases can have a detrimental impact on mango trees, affecting their overall health and productivity. Infestations and infections can disrupt the tree's physiological processes, including flower bud development and fruiting (Singh *et al.* 2017).

Management strategies

(i) Paclobutrazol (PP333) is a plant growth regulator that can be applied as a soil drench or foliar spray in September. Its use can promote early maturation of vegetative flush and stimulate flowering in the following year.

(ii) Removing some of the flowers from "on year" trees and conducting pruning just after harvesting can help maintain a proper balance between vegetative and reproductive growth. Pruning also allows more sunlight to reach the inner areas of the orchard, resulting in better tree performance every year. Additionally, pruning can stimulate the production of new shoots that may mature in the next flowering season.

(iii) Ringing, or the removal of a strip of bark from branches or the trunk of the tree, can be practiced to induce flowering in the off year. This technique interrupts the downward movement of food reserves, stimulating the formation of fruit buds. Ringing should be done in August or early September, before the time of fruit bud differentiation (Singh *et al.* 2017).

(iv) Smudging involves the creation of slow fires to emit smoke under mango trees, which can induce flowering. Additionally, the application of Ethrel, a plant growth regulator, can also stimulate flowering in mango trees.

(v) Cultivating mango varieties that are known to be regular bearers, such as Amrapali, Mallika, Ratna, Dashehari-51, Pusa Arunima, Pusa Shrestha, Pusa Pitambar, Pusa Lalima, Pusa Pratibha, Arka Anmol, Arka Aruna, Arka Puneet, and Arka Neelkiran, can help ensure more consistent yields in commercial cultivation.

(vi) Rejuvenating old mango trees by grafting or budding them with regular bearing varieties is another recommended approach.

This technique allows the conversion of the alternate bearing habit into a regular one.

MANGO MALFORMATION

Mango malformation is indeed a serious disease that affects mango production in North Indian mangoes. It was first reported in Dharbhanga, Bihar, in 1891 and has since become a national problem, affecting mango-growing regions across northern, central, eastern, and western parts of India. Some of the affected regions include Uttar Pradesh, Punjab, Bihar, Madhya Pradesh, Delhi, Gujarat, Haryana, West Bengal, and Orissa. However, the southern region of India is comparatively less affected by this disorder.

(a) Vegetative malformation: Vegetative Malformation (VM) is commonly observed in young seedlings. The affected seedlings exhibit small shootlets with small, scaly leaves that form a bunch-like appearance at the shoot apex. This condition is also known as "bunchy top." In some cases, the affected seedlings remain stunted and eventually die, while others may exhibit normal growth above the malformed areas. The clustered vegetative buds swell and lose their apical dominance, contributing to the bunchy top appearance.

(b) Floral malformation: Floral malformation primarily affects the panicles of mango trees and is particularly destructive during the bearing stage. The affected panicles appear compact and often exhibit a green and sturdy appearance. Due to their weight, the malformed panicles tend to bend downward. In these panicles, there is an increased ratio of sterile male to hermaphrodite flowers, resulting in no fruit set in the affected branches. This directly impacts the productivity of the tree. Embryo abortion occurs at a faster rate in the malformed flowers, further contributing to the reduction in fruit yield.

Certain mango cultivars, such as Bombay Green, Dashehari, Lucknow Safeda, and Chausa, are highly susceptible to mango malformation. However, cultivars like Elaichi, Alib, and Bhadauran are completely free from this disorder. While these resistant cultivars exist, their use is often limited due to their inferior fruit quality. Nevertheless, resistant cultivars can be utilized in breeding programs to develop new varieties with both resistance to mango malformation and desirable fruit characteristics.

Causative factors

The cause of mango malformation has been the subject of extensive research, and there are various factors that have been proposed as potential causes. These factors include cultural practices, nutritional imbalances, mites, fungi, viruses, hormonal imbalances, and more. However, the exact cause of this disorder remains controversial and complex. One study by Ansari *et al*. (2013) suggested that the fungus *Fusarium mangiferae* is responsible for mango malformation. This fungus produces ethylene, which may stimulate the production of stress ethylene in the malformed tissues of mango trees. Low temperatures can induce the production of "stress ethylene," which may also contribute to malformation (Singh *et al.* 2017; Mishra *et al.* 2016). The temperature conditions during late winter or early spring seem to play a significant role in the growth of the fungi associated with mango malformation. A temperature range of 21-27°C (maximum) and 8°C (minimum) along with a relative humidity of 85% is considered conducive for the growth of these fungi, leading to a higher incidence of malformation on newly emerged panicles (Kundu *et al.* 2013).

Management strategies

(i) Application of NAA/Planofix (200 ppm) during October, prior to fruit bud differentiation. This treatment is followed by debloosming (removal of flowers) of newly emerged panicles or buds during January-February. This approach aims to control the disorder by regulating flower development.

(ii) During the first week of October, spraying different phenolic compounds such as catechol, cinnamic acid, and tannic acid at a concentration of 2000 ppm is recommended. These compounds have been found effective in reducing floral malformation in mango trees.

(iii) Several anti-malformin substances can be sprayed on panicles just after emergence (when they are 4-6 cm long) to control malformation. Glutathione at 2250 ppm, ascorbic acid @ 2110 ppm, and $AgNO_3$ @ 600 ppm are examples of substances that have been found effective in controlling malformation.

(iv) Applying nutrients like phosphorus (P) and potassium (K), as well as micronutrients like zinc (Zn) and boron (B), just after harvesting can help reduce the incidence of malformation. Moderate amounts of nitrogen (N) are also recommended to minimize vegetative malformation. Zinc and boron aid in the biosynthesis of auxins, which can help reduce the incidence of mango malformation.

(v) Once malformed panicles or vegetative shoots emerge, it is beneficial to remove them at a distance of 15-20 cm below the point of occurrence. This helps minimize the spread of the disorder within the tree.

SPONGY TISSUE

The occurrence of "spongy tissue" in mango, first noted in cv. Alphonso in 1932, has been a significant problem in mango-growing regions of Maharashtra, Gujarat, Andhra Pradesh, and Karnataka in India. It has led to a considerable loss of fruit, estimated to be around 30% (Bhargava *et al.* 2011). This disorder not only affects the sale of mangoes in India but also impacts the international market. The major symptoms of spongy tissue include the development of non-edible, sour, yellowish, and sponge-like patches with or without air pockets in the mesocarp of the fruit during ripening. Interestingly, these external symptoms are not apparent at the time of picking or when the fruit is fully ripe. They can only be observed when the ripe fruit is cut open. The affected fruit pulp remains unripe and starchy due to unhydrolyzed starch caused by histological and biochemical disturbances resulting from heat in mature fruit at pre- and post-harvest stages.

Spongy tissue-affected fruits have specific characteristics, such as low pH, reduced beta carotene, vitamin C, and sugar content, and increased starch and citric acid levels. As a result, the fruit becomes unfit for human consumption. In severe cases, the entire fleshy portion of the fruit becomes soft, resembling bacterial rot (Kundu *et al.* 2013). The affected fruits emit a bad odor, making them unsuitable for consumption. Non-destructive X-ray imaging technology can be used to detect spongy tissue-affected fruits (Thomas *et al.* 1993). The intensity of the disorder depends on various factors, including the mango variety, fruit size and weight, season, soil type, fruit maturity, soil moisture, geographical location, and time of harvest. Generally, spongy tissue incidence is higher in larger fruits and when harvesting is delayed (Singh *et al.* 2017). Managing these factors and implementing appropriate strategies can help minimize the occurrence of spongy tissue in mangoes.

Causative factors

Convective heat originating from the soil is identified as a major cause of spongy tissue formation in mangoes (Katrodia and Rane, 1989). The heat generated from the soil can lead to disturbances in the fruit's histology and biochemical processes. High temperatures can cause the inactivation of ripening enzymes in mango fruits. Preharvest exposure of the fruit to sunlight is also considered a possible cause of spongy tissue formation. A study by Ravindra and Shivashankar (2004) found a close association between spongy tissue formation and the shift of the seed into germination mode. This suggests that changes in seed physiology may contribute to the development of spongy tissue. Janave (2007) observed that spongy fruits had approximately twice the respiration rate compared to non-spongy fruits during the storage period. Increased respiratory activity is believed to be responsible for the cavities observed in spongy fruits.

Management strategies

(i) Fruits should be harvested at around 3/4th maturity stage and have a specific gravity of 1.01-1.02. This ensures that the fruits are at an optimal stage for ripening and reduces the risk of spongy tissue formation.

(ii) Implementing sod culture with natural vegetation like darbha (*Desmo stachyabinnata*), *Eragrostis cynosuroides*, or using green vegetation leguminous crop cover, as well as mulching with materials like paddy straw, dry mango leaves, or black polyethylene, can help reduce the incidence of spongy tissue.

(iii) After harvest, it is important to keep the fruits in shade and expose them to low temperatures between 10-15°C for 10-18 hours. This cooling treatment has been found beneficial in reducing the occurrence of spongy tissue.

(iv) Opt for mango cultivars that are known to be resistant to or free from spongy tissue, such as Sindhu, Ratna, Arka Puneet, and Arka Anmol. Growing these cultivars can help minimize the risk of spongy tissue development.

(v) Dip the harvested fruits in cool water containing calcium chloride (2%) to remove field heat.

(vi) Install wind-breaks to protect the orchard from warm air during May. Take proper precautions during the post-harvest stage to avoid direct exposure of fruits to sunlight, which can contribute to spongy tissue formation.

(vii) The Indian Institute of Horticultural Research in Bengaluru has developed an environmentally-safe formulation called "Arka Saka Nivarak" specifically for the prevention of spongy tissue. This liquid formulation should be applied twice at the pre-harvest stage (between 40-60% maturity) by either dipping the fruits (while on the tree) in the solution or by spraying the fruits. The recommended dosage is 100 to 125 ml/liter.

CLUSTERING/JHUMKA

Clustering or Jhumka is a disorder characterized by the development of fruitlets in clusters at the tip of panicles. It was first observed in Uttar Pradesh in 1984 and is more prone to occur in the Dashehari variety. The symptoms include the formation of dark green fruitlets with a deeper curve in the sinus beak region. These fruitlets do not grow beyond the pea or marble stage and eventually drop from the tree after about a month of fruit set. In some cases, the fruit may also split longitudinally.

Causative factors

Insufficient pollination due to a lack of pollinators in the orchards is a major cause of this disorder. Adequate pollination is crucial for proper fruit development. Factors such as inefficient pollination and fertilization processes can result in the formation of clustered fruitlets. Orchards with aging and overcrowded trees may experience reduced pollination efficiency, leading to the clustering disorder. Excessive use of pesticides, particularly synthetic pyrethroids, can negatively impact pollinator populations, affecting pollination and fruit development. Monoculture, where a single variety (in this case, Dashehari) dominates the orchard, can limit genetic diversity and reduce the effectiveness of cross-pollination, potentially contributing to the disorder. Unfavourable weather conditions, such as heavy rains or high temperatures, during the flowering period can also disrupt pollination and fertilization, leading to the clustering/Jhumka disorder.

Management strategies

(i) Introduce bee hives in the orchards during the flowering season to enhance the number of pollinators. This helps improve pollination and fruit set. It is important to restrict the use of insecticidal sprays during full bloom to avoid harming the pollinators. This ensures a healthy population of pollinators and promotes effective pollination.

(ii) Avoid monoculturing, especially in the case of the Dashehari variety. Instead, plant 5-6% of other mango varieties in the orchard. This diversification increases the genetic diversity of the orchard and promotes better cross-pollination, reducing the incidence of clustering/Jhumka. Additionally, consider top working old orchards with improved varieties as pollinizers. This practice can improve pollination efficiency and reduce the occurrence of the disorder.

FRUIT DROP

Fruit drop is a significant issue in mango cultivation, characterized by the heavy dropping of hermaphrodite flowers and young fruits, often exceeding 99% or more. In general, in mango 0.1% or less hermaphrodite flowers develop fruits to maturity. The severity of fruit drop varies among mango varieties, with some varieties, such as Langra, being more prone to fruit drop compared to others like Dashehari. The process of fruit drop can be classified into three phases: pinhead drop, post-setting drop, and May-month drop. Among these, the May-month drop is the most destructive, leading to substantial economic losses as the fruits drop before reaching maturity.

Causative factors

Self-incompatibility, inadequate pollination, unsuccessful fertilization, embryo degeneration, and the presence of defective perfect flowers can result in fruit drop. Issues with stigmatic receptivity and poor pollen transfer can also contribute to the problem. High or low temperatures, strong winds, and moisture stress can trigger fruit drop. Extreme weather conditions during flowering and fruit development stages can negatively affect fruit retention. Imbalances in nutrients and hormones within the mango tree can also lead to fruit drop. Insufficient or excessive nutrient supply, particularly nitrogen, phosphorus, and potassium, can affect fruit development and retention. Insect pests like mango hoppers and mealybugs, as well as diseases such as powdery mildew and anthracnose, competition among developing fruits for resources such as water, nutrients, and carbohydrates can result in fruit drop.

Management strategies

(i) Regular and frequent irrigation throughout the entire fruit developmental period is crucial to minimize fruit drop. Proper water management ensures sufficient moisture for the developing fruits and helps prevent water stress-induced drop.

(ii) Planting windbreaks or using other methods to protect orchards from desiccating winds can help reduce fruit drop. Windbreaks act as barriers, reducing the drying effect of strong winds on the developing fruits.

(iii) Implement timely and effective control measures against major pests and diseases in mango orchards. Pests like mango hoppers and mealybugs, as well as diseases such as powdery mildew and anthracnose, can contribute to fruit drop. Integrated pest management practices should be adopted to keep pest and disease populations under control.

(iv) Certain plant growth regulators can be applied through foliar sprays to control fruit drop in mango. NAA (naphthaleneacetic acid) at a concentration of 20 ppm applied at the pea stage of fruit development has been found to be effective. Additionally, foliar applications of GA_3 at 10 ppm, 2,4,5-TP (2,4,5-trichlorophenoxyacetic acid) at 20 ppm during full bloom and panicle initiation stages, respectively, and Ethrel at 50 ppm and Alar at 1000 ppm at flower bud differentiation stage have shown positive results in reducing fruit drop (Sharma, 2005a).

INTERNAL FRUIT NECROSIS

Internal fruit necrosis in mango is a disorder characterized by the development of dark green colour in the lower half of the fruit, followed by browning of the seed and mesocarp, ultimately resulting in a brown-black necrotic lesion. As the disorder progresses, the entire lower half of the fruit becomes necrotic, leading to longitudinal cracking of the fruit through the necrotic region and exposing the seed.

Causative factors

It is mainly due to boron deficiency.

Management Strategies

The application of boron, either through soil or foliar application, can indeed help in correcting or minimizing the disorder. Incorporate Borax at a rate of 500 grams per tree during the October fertilization. This allows the boron to be available in the soil and taken up by the tree's roots. Use a 1% borax solution and spray it on the mango trees at the time of fruit set, specifically at the pea size stage. Follow up with two additional sprays at 10-15 days interval. This foliar application ensures that the tree receives a direct supply of boron, which can be readily absorbed through the leaves and translocated to the developing fruits.

BLACK TIP

Black tip is a disorder that affects mango fruits, particularly the cv. 'Dashehari'. It was first reported by Woodhouse in 1908 in Bihar, India (Zhang *et al.* 1995). This disorder is widespread in various regions of India, including Punjab, Madhya Pradesh, Haryana, Delhi, Uttar Pradesh, Bihar, and West Bengal. The infection of fruits begins at the marble stage, which is characterized by yellowing of tissues at the distal end of the fruit. Over time, the colour intensifies, turning brown and eventually black. As the disorder progresses, the black ring at the tip extends towards the upper part of the fruit. Fruits affected by black tip ripen prematurely and become unmarketable, leading to low returns for the growers. In severe cases, the affected tissues of the fruit may have a thin layer of collapsed tissues remaining. The necrotic (dead) area is always limited to the tip of the fruit due to factors such as high stomatal density, catalase activity, and peroxidase activity. These factors contribute to the localized nature of the disorder. Among different mango varieties, 'Dashehari' is reported to be highly susceptible to black tip, while 'Lucknow Safeda' is the least susceptible. This indicates that the severity of the disorder can vary depending on the cultivar.

Causative factors

The occurrence of black tip in mango fruits is believed to be influenced by several causative factors. One significant factor is the proximity of mango orchards to brick kilns. Orchards located within a distance of 600 meters from brick kilns are more prone to black tip. The fumes emitted by brick kilns, including carbon dioxide, sulphur dioxide, and acetylene, are suspected to contribute to the development of black tip. In addition to the brick kiln fumes, other factors such as irrigation, tree condition, and management practices also influence the severity of the disorder.

Management strategies

(i) Planting orchards in a North-South direction and at a distance of 1.8-2.0 kilometers away from brick kilns: By orienting the orchards in this manner and maintaining a sufficient distance from brick kilns, the incidence of black tip can be significantly reduced. The height of the brick kiln's chimney should also be at least 18-20 meters to facilitate better dispersion of fumes.

(ii) Borax (0.6%) can be sprayed at flowering initiation, during full bloom, and after fruit set. Alternatively, solutions such as caustic soda (0.8%) or washing soda (0.5%) can be sprayed during the second week of March and the third week of April.

LEAF SCORCH

Leaf scorch is a disorder that occurs when the soil or irrigation water contains a high amount of salt, particularly chloride ions. It manifests as scorching or burning of the leaves, starting from the leaf margin towards the midrib and from the tip towards the petiole, affecting the entire leaf simultaneously. In severe cases, the affected leaves may appear burned and eventually fall from the tree, leading to the gradual decline of shoots.

Causative factors

The main causative factor behind leaf scorch is the excess of chloride in the soil or irrigation water. This chloride excess interferes with the availability of potassium, leading to a deficiency of potash in the leaves. Leaf scorch is more common in saline soils, areas where brackish water is used for irrigation, or when muriate of potash is applied as a fertilizer to fulfill the potassium requirement of the plants (Kundu *et al.* 2013).

Management strategies

(i) Spray potassium sulphate (5%) on young leaves of each new flush: Applying potassium sulphate through foliar spray on the young leaves helps address the deficiency of potash and mitigates the symptoms of leaf scorch.

(ii) Collect and burn affected leaves: It is important to remove and destroy the affected leaves to prevent the spread of the disorder and reduce potential sources of reinfection.

(iii) Use potassium sulphate instead of muriate of potash: Under conditions that are conducive to leaf scorch, it is advisable to use potassium sulphate as a potassium fertilizer instead of muriate of potash. Potassium sulphate does not contain chloride, thereby avoiding further exacerbation of the disorder.

FRUIT PITTING

Fruit pitting is a recent problem observed in some Indian mango orchards, characterized by the development of small sunken pits on the peel of developing fruits(Sharma and Shukla, 2006). These pits appear on all sides of the fruit and increase in size as the fruit grows. The presence of these pits gives an unattractive and unhealthy look to the fruit, affecting its consumer acceptability. The incidence and severity of fruit pitting vary among different mango cultivars, and genetic differences are believed to play a role in this variability (Sharma *et al.* 2006).

Exotic mango cultivars tend to suffer less from fruit pitting compared to Indian cultivars. This can be attributed to the fact that exotic cultivars have less dense canopies and thicker fruit peel. In contrast, Indian cultivars often have denser canopies, which limits the penetration of light required for protein synthesis in the leaves and the translocation of nutrients to the fruit(Sharma and Singh, 2006). The poor light penetration may be associated with a higher incidence of fruit pitting in Indian cultivars.

Causative factors

In addition to light penetration issues, nutritional deficiencies have been linked to fruit pitting. Calcium (Ca) and boron (B) deficiencies are specifically associated with this disorder. It has been observed that pitted fruit tends to have significantly lower levels of Ca and B compared to normal fruit.

Management strategies

Borax can be applied around the tree trunk at a rate of up to 500 grams per tree, followed by irrigation. Borax is a source of boron, which helps address the boron deficiency associated with fruit pitting.

UNDER-SKIN BROWNING (USB)

Under-skin browning (USB) is an injury that affects mango fruit, characterized by discoloration beneath the epidermis, resulting in a grey-brown bruise-like symptom. USB can affect large areas of the fruit surface, but it does not damage the flesh. The affected areas appear darker and are clearly located under the epidermal cells, covering larger and less scattered areas of the fruit. The 'Honey Gold' mango cultivar in Australia is particularly susceptible to this disorder (Marques *et al*. 2012).

Causative factors

Major cause of this disorder is rapid post-harvest temperature reduction and physical damage during road freight. When mangoes are exposed to a sudden drop in temperature, from high ambient temperatures to 12°C-14°C, and are also subjected to physical damage during transportation, it can trigger the development of USB symptoms.

Management strategies

(i) Instead of subjecting the mangoes to immediate cold storage, it is recommended to keep them at a temperature of at least 18°C for a few days after harvest. This allows for a gradual temperature reduction and helps reduce the occurrence of USB.

(ii) It is important to minimize physical damage to the mangoes during transportation. This can be achieved by using appropriate packaging materials and handling practices that minimize bruising or impacts on the fruit.

STEM-END CAVITY (SEC)

Stem-end cavity (SEC) is a disorder observed in mangoes characterized by the formation of a cavity in the proximal area of the fruit, resulting from the deterioration of vascular tissues. The affected tissues are primarily located between the proximal end of the stone and the fruit peduncle, as well as the tissues between the stone and the mesocarp. Early-stage symptoms include the browning of affected tissues, followed by the development of a small cavity that enlarges as the disorder progresses. The interior of the mesocarp may turn yellow or orange, while the exterior remains whitish or pale yellow. SEC can affect the interior mesocarp partially or entirely.

Causative factors

The main cause of SEC are calcium deficiency and the accumulation of tannins at the proximal end of the fruit. Calcium plays a crucial role in fruit development and maintaining the integrity of tissues. Insufficient calcium supply can lead to the development of SEC. Additionally, the accumulation of tannins, which are phenolic compounds, can contribute to the formation of cavities in the fruit.

Management strategies

(i) Applying calcium to the soil in the form of gypsum: Prior to flowering, applying gypsum at a rate of 2-4 kg per tree can help reduce the severity of SEC and other internal fruit disorders. Gypsum is a calcium sulfate compound that provides a readily available source of calcium to the tree.

(ii) By ensuring an adequate supply of calcium through gypsum application, the severity of SEC can be minimized in mango cultivars such as 'Kensington Pride' (Ahlawat *et al.* 2014). This management strategy helps address calcium deficiencies and promotes healthy fruit development, reducing the incidence of stem-end cavity.

JELLY SEED

Jelly seed is a disorder that has been causing problems in certain mango-growing areas, impacting both the export and consumption of mangoes (Sharma and Krishna 2014). It was first reported by Van Lelyveld and Smith (1979) who characterized this disorder by the breakdown of the mesocarp (flesh) surrounding the seed, resulting in a less desirable appearance and potential discoloration in later stages. In severe cases, the tissue around the seed may be affected, impacting the entire fruit. The flesh at the stem end of the fruit can become fibrous, downgrading the fruit's quality. Early symptoms of jelly seed can resemble stem-end cavity, and these symptoms can be observed in both immature and mature fruits. Several mango varieties, including commercially grown Indian varieties such as 'Dáshehari' or 'Langra' (Srivastav *et al.* 2015) and exotic varieties like 'Tommy Atkins,' 'Sensation,' 'Zill,' and 'Kent,' (Oosthuyse, 1993) are susceptible to jelly seed disorder.

Causative factors

The exact cause of jelly seed disorder is not yet fully understood, but it is believed to be cultivar-dependent and can vary widely in naturally and/ or artificially ripened mango fruits (Srivastav *et al.*, 2015). Some researchers have suggested that calcium deficiency or an excess of nitrogen may contribute to the occurrence of this disorder.

Management strategies

(i) Applying dolomitic lime at a rate of 8 tons per hectare per year with the onset of the monsoon can help address calcium-related issues that may contribute to jelly seed disorder. Dolomitic lime is a source of calcium and magnesium, which are both essential nutrients for mango trees.

(ii) By providing an adequate supply of calcium through dolomitic lime application, the occurrence and severity of jelly seed disorder can potentially be reduced. This management strategy aims to address any calcium deficiencies that may be associated with the disorder.

SOFT NOSE

Soft nose is a disorder observed in mangoes that is similar to other fruit disorders such as tip pulp, flesh breakdown, stem end rot cavity, or a combination of jelly seed and SEC. In Indonesia, soft nose and tip pulp are considered to be identical to yeasty fruit rot or insidious fruit rot. However, there are macroscopic differences among these disorders, and each affects different areas of the fruit. Soft nose is characterized by partial ripening of the mesocarp (flesh) at the distal end of the fruit. In its early stages, it presents as a defined yellow area between the apex of the stone and the exocarp. The mesocarp of affected fruits shows cell separation and cell wall degeneration, resulting in a soft texture, while the healthy mesocarp maintains cell cohesion.

Causative factors

The most probable cause of soft nose is considered to be calcium deficiency. The incidence of soft nose has been correlated with low calcium concentrations in leaves and fruit. Additionally, varietal differences have been observed in susceptibility to this disorder. Soft nose typically occurs in fully developed fruit, around 14 weeks after fruit set.

Management strategies

(i) Providing an adequate supply of calcium to the mango trees can help prevent or minimize soft nose. Calcium can be applied as foliar sprays or as soil amendments to address calcium deficiency. The specific calcium application rate and timing should be based on local recommendations and the needs of the specific mango variety.

(ii) Implementing appropriate post-harvest practices, such as careful handling, proper storage conditions, and avoiding physical damage to the fruit, can help reduce the occurrence of soft nose. Maintaining optimal temperature and humidity during storage is also important to prevent the development and progression of fruit disorders.

RESIN CANAL DISCOLOURATION

Resin Canal Discolouration (RCD) is a disorder that affects mangoes, particularly the "Kensington Pride" cultivar. It was first reported in Australia. Naturally, it was present in 30-43% of mangoes during harvest to storage, resulting in a serious economic loss of up to 30% for export around all over the world. It is characterized by the formation of resin-like canals or ducts in the fruit, which appear as brown or dark reddish discoloration in the fleshy mesocarp portion. The discolouration is caused by the presence of resinous phenolic substances and the accumulation of starch compounds in the fruit's flesh. These resinous substances serve as a defense mechanism against herbivores and pathogens. The upper portions of the infected fruit's exocarp may have numerous black dots, and resin canals can also occur in the endocarp (seed) region (Shreedevasena and Sankar, 2020). When we cut the fleshy part of the mango to eat, it annoys the consumer and lowers the market value for the sellers (Macnish, 2016).

Causative factors

Harvesting mangoes before they have reached the appropriate maturity stage, prolonged transit times and improper handling during transportation, factors such as low oxygen, optimal carbon dioxide levels, exposure to light, abnormal humidity, and poor hygiene in storage facilities, accumulation of pressure between the fruit's exocarp and the atmosphere during transportation can trigger the formation of resin canals.Certain bacteria, such as *Enterobacter* spp., *Pantoea stewartii,* and *Pantoea agglomerans* can also increase the likelihood of RCD.

Management strategies

(i) Mangoes should be harvested at the appropriate maturity stage to minimize the risk of RCD.

(ii) Minimize the distance between the harvest location and the storage unit to decrease the duration of transit.

(iii) Employ skilled individuals for picking and transporting mangoes to minimize physical damage and pressure on the fruit.

(iv) Treatments such as spraying with mancozeb at 0.2% before the harvest can help reduce the occurrence of RCD.

(v) Dip the fruits in hot water at 52˚C for 5 minutes and apply a plant wax product (such as Waxol) at 8% to reduce RCD incidence.

STEM-END BLACKENING

Stem-end blackening is a disorder observed in the Zarda cultivar of mango in the Eastern part of India, particularly in Bihar. It causes significant losses, accounting for about 40-45% of the fruit's yield in this cultivar (Patel *et al.* 2013). The disorder is characterized by the appearance of a brownish-black spot surrounding the stem-end of the fruit. Tissue breakdown and discoloration occur near the stem-end and can extend up to the endocarp. This leads to the formation of unhealthy fruits with reduced consumer acceptability. Compared to healthy fruits, the affected fruits may have lower Total Soluble Solids (TSS) and higher titratable acidity.

It's worth noting that the affected portion of the fruit does not exhibit any off-odour or sour smell, except for the typical aroma of a ripe mango. The disorder is localized and confined only to the stem-end of the fruit. However, it can be easily confused with stem end rot, another disorder affecting mangoes.

Causative factors

The exact cause behind this disorder is still unknown.

FRUIT CRACKING

Mango fruit cracking results in substantial loss. Cracked fruits lose their marketability fast and frequently experience additional infestations by disease and pests, resulting in severe economic losses to the farmers (Singh and Rajan, 2021).

Causative factors

Cracking in fruits like mangoes can occur due to various factors, including water deficits, calcium or boron deficiencies, and environmental conditions such as extremes of temperature, humidity and rainfall. Different mango varieties have varying degrees of susceptibility to cracking. For instance, the "*Dashehari*" cultivar is known to be more sensitive to cracking compared to other varieties. This sensitivity can be influenced by genetic factors and the thickness and elasticity of the fruit's skin.

Management strategies

It has been found that maintaining appropriate soil moisture during the dry season and applying pre-harvest sprays of NAA, potassium, and boron were helpful in lowering fruit crop cracking.

CONCLUSION

Physiological disorders in mango can lead to significant financial losses for growers. Understanding the causes and implementing appropriate management strategies is crucial for ensuring quality fruit production. This knowledge can also serve as a foundation for researchers to develop innovative solutions using biotechnology, breeding techniques, and a deeper understanding of the physiological mechanisms involved. Effective approaches to managing physiological disorders in mango include balanced nutrient application, the use of plant growth regulators, timely and regular irrigation, and careful handling during harvesting and post-harvest stages. By implementing these strategies, the incidence and severity of physiological disorders can be minimized, leading to improved fruit quality and increased profitability for mango growers.

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