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CRITICAL STUDIES FOR IDENTIFICATION OF PHYSIOLOGICAL DISORDERS IN MANGO

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ABSTRACT

Mango (*Mangifera indica L.*) is undoubtedly the most important fruit crop of India with great cultural, economic and religious significance. Mango is also one of the most favoured fruit among all sections of the society in India. Due to its high palatability, excellent taste, flavour and exemplary medicinal and nutritive values, it is regarded as the king of tropical fruits. 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 the 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 root stocks for dwarfing, disease and salt tolerance, unbalanced NPK fertiliser 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 mango.

Key words : *Abiotic factors, nutrient deficiency, physiological disorders, perennial fruit.*

Mango the most important fruit of India is grown in an area of 1.23 million hectare with an annual production of 10.99 million tonnes, which accounts 57.18 percent of the total world production. This perennial tree provides livelihood security to the fruit growers and nutritional security at national level. Hence greater attention is required towards increasing the quantum and quality 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 a biotic 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 and Acquaah, 2007). Reasons for low productivity ofthis fruit crop in India are primarily physiological or stress related disorders such as alternate bearing, unfruitfulness, fruit drop, fruit cracking, sun-burn or scorching, malformation deformities etc. rather than biotic and other related factors (Sharma 2006). A biotic 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. The plant architecture above the ground and the root system below interact with the environmental, edaphic and genetic factors causing physiological disorders

Cause and characteristics of physiological disorders : Physiological or a biotic 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).

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. 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 .

Factors implicated in occurrence of physiological disorders :

(i) 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). The temperature range that supports specific fruit crop growth and production generally is region specific. Optimum temperature for vegetative growth, transition into reproductive phase and later for fruit growth and development differ widely. 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).

(2) 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.

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.

(3) 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). 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.

(4) Carbon dioxide concentration : To high or low levels of CO_2 can also affect plant growth 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.

(5) 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, thermo-periodicity 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).

(6) 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.

(7) 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.

(8) 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 .

(9) 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.

(10) 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. 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.

(11) 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).

(12) 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

Due to 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 have been reported in various fruit plants as N-deficiency symptoms (Kender and Anastasia 1964, Goldweber 1959, Chattopadhyay 1994). Inferior fruit to high nitrogen have been reported in citrus, guava, litchi and mango where the fruit trees may not produce sufficient flowers during the flowering time.

(i) Phosphorus : Reduction in root growth due to phosphorus (P) deficiency has been reported for most of the fruit plants. Smaller number of rough, deep green and thick leaves of small size has been reported in citrus species, cashew, guava, litchi and mango (Chatterjee and Dube 2004). Dieback of meristematic regions has been reported in some fruit crops. Young and Koo (1969) reported leaf spotting followed by defoliation and die back 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).

(ii) 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 in nature. Its deficiency causes margin necrosis in mango, litchi, guava, sapota, citrus etc. The distinctive characteristic of the K deficiency symptoms is the yellowing of tip of older leaves followed by inward leaf curling and death.

(iii) Calcium : Under calcium (Ca), deficiency roots do not develop properly. Insufficient number of root hairs are produced which get burnt under acute deficiency. 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.

(iv) Sulphur : 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 have been reported due to excess of sulphur in most of the fruit plants.

(v) Zinc : The symptoms of zinc deficiency in many fruit crops (more particularly in citrus, guava and mango) first appear on the apical leaves where irregular developments of leaves smaller in size causing 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 .

(vi) Copper : Copper requirement of plants varies with species, variety and even due to different root stocks. 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.**

(vii) 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.

(viii) 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. Cracking of fruits are seen in extreme cases.Short internodes, brittle pale green leaves curving one side and stunted growth in mango have been reported. In case of excess application, leaves fall prematurely, young twigs die back and trunk ooze gums in many fruit trees (Chatterjee and Dube 2004).

(ix) 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).

(x) 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 a time 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.

Physiological disorders of 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 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).

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), 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.

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.Practice of sod culture having natural vegetation of dhorth (*Desmo stachyabinnata*), 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).

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). 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).

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, this 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). 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). 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.

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 has been observed (Malo and Campbell 1978, Winston 1984, Joshi and Roy 1985, Chaplin 1986, Katrodia and Bhuva 1993, Sharma 2006). 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. 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 U.P. 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). 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) - 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).

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).

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 . 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).

CONCLUSIONS

From the review it is clear that physiological disorders have become menace in mango fruit crops resulting in huge losses to growers..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.

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