

Holistic Pest Management in Mango Orchards by Manipulating Canopy Architecture: A Review

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ABSTRACT

Canopy management practises in mango may be helpful in sustaining the quality fruit production in high density mango orchards and to achieve potential yield per unit area without having any deteriorating effect on quality attributes. Ideal canopy for efficient light utilization for better photosynthesis and the leaves inside the canopy will no longer act as parasitic for leaves of top and peripheral branches. Further, more availability of light in canopy will also reduce the chance of pest and diseases, which will ultimately reduce the cost of cultivation and by this way socio-economic status of orchardist will be automatically improved.

Keywords: Pest and diseases; mango malformation; fruit drop; high plant density; light penetration

INTRODUCTION

Mango of family anacardiaceae is one of the choicest fruits in the national and international markets due to its attractive colour, aroma and taste and recognized as a good source of vitamin-A, vitamin-C, carotenoids, digestible sugars, dietary fibers and antioxidants like mangiferin, lutein and zeaxanthin. Although it is commercially grown between 23° North and 24.5° South latitudes of the world, the tree usually grows and produce successfully in frost-free regions with a marked dry season and high heat accumulation. Mango can tolerate a wide range of climates from warm temperate to tropical; however, anthracnose can become a serious problem for mango cultivation in humid or high rainfall areas. In high rainfall areas, fruits at the time of maturity are exposed to disease like anthracnose and these fruits are less attractive because of blackening of the peel[1-5].

Improvement of productivity continues to be the foremost issue for mango breeders as it is imperative to improve the productivity and quality of mangoes to meet the global need. High density planting is adopted worldwide in mango to enhance the production per unit area, however, without timely intervention in tree growth, microclimate of the orchard is affected by lower light interception by the leaves and lesser air flow inside the canopy resulting in increasing humidity

congenial for rapid multiplication of insect and disease causing pathogens. Mango hoppers (*Amritodus atkinsoni* Lethierry, *Ideoscopus niveosparus* Lethierry and *Ideoscopus clypealis* Lethierry) are monophagous insects which hamper fruit set and lead to dropping of immature fruits. Both nymphs and adults cluster suck sap from the lower side of tender leaves and inflorescence, resulting in panicle drying and enormous yield loss. The trees having dense inflorescence and orchards with closer spacing are severely affected by hoppers (Reddy and Dinesh). Mango mealybug (*Drosicha mangiferae*) is polyphagous, dimorphic and notorious pest of mango orchard, the nymphs and females of which suck sap from tender leaves, shoots, panicles and fruit peduncles thereby affecting fruit set and causing premature fruit drop. Infested plants are also prone to sooty mould (*Capnodium mangiferae*), a fungal infection, due to which, photosynthetic activity is affected. The orchards with dense canopy structure are more prone to mealy bug infestation (Karar). Fruit flies (*Bactrocera* spp.) are polyphagous pests whose females puncture the immature fruit peel with ovipositor and insert the eggs into the mesocarp in aggregates. The maggots tunnel and feed on the fruit pulp. Its damage is higher in high density orchards as fly has more chance to access greater number of fruits per unit area and per unit time as compared to traditional orchards with wider spacing. The disease incidence in

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mango orchard is also influenced by tree spacing and canopy orientation. Powdery mildew (*Oidium* sp.) fungus attacks leaves, flowers and young fruits, due to which, defoliation occurs and panicles are destroyed resulting in failure of fruit set. The disease reduction is directly affected by increased light intensity, which is altered by canopy architecture manipulation. Anthracnose (*Colletotrichum gloeosporioides*) is another fungus which is favored by wet, humid and warm weather in the orchard with dense tree canopies. On mango panicles, symptoms are small black or dark-brown spots, which enlarge, coalesce and kill the flowers before production of fruits thereby reducing yield. Fruits affected by anthracnose develop sunken, prominent, dark brown to black decay spots before or after picking which may drop from trees prematurely [6-10].

Therefore, tree productivity shows declining trend with the overlapping of adjacent tree canopies, if tree vigour management is not practiced, right from planting. And production potential of perennial fruit tree can only be harnessed by adoption of canopy architecture management which involves the removal of selected branches as well as topping to maximize light penetration throughout the canopy thereby reducing pest population within the canopy. Besides, pesticide can be precisely utilized for pest management in low dense canopy (Kerns). In this review, we shall discuss in about the holistic approach of pest control by canopy management strategies so as to achieve and sustain the potential yield of mango in high density orchards [11-20].

Relationship between canopy architecture and pest incidence

The distribution of pests within tree canopy is heterogeneous. It is obvious that under higher planting density, plant canopies overlap into the rows, reducing light incidence on leaves, thereby making the tree canopy dense and compact which encourage more pest and disease incidence. Observed maximum incidence of mango hoppers/inflorescence and powdery mildew/ inflorescence in closer plant density of 5 m × 5 m (48.10 and 0.61% more than those of 10 m × 10 m, respectively), besides reducing fruit yield and total soluble solids by 43.37 and 3.57%, respectively in mango cv. Kesar under Pune, Maharashtra condition (Fig. 1). Management and maintenance of tree vigour implies finding the correct balance between growth, vigorous enough to bear large fruit and to provide light penetration, and air circulation inside canopy for minimum pest and disease occurrence in the interior canopy [21-30]. Found that the penetration of light and spray chemicals into canopies by pruning in citrus orchard lead to a gradual reduction in amounts of dead wood in trees. They stated that dead wood holds spores of many major post-harvest pathogens, and cause mechanical injures to fruit. Protection of re-growth after pruning from pests and diseases is necessary. Pruning makes trees easier and faster to spray, thus spray units should be recalibrated to reduce spray costs. It is advisable to revise pest management plans to enable inside-canopy fruit and flush to be protected. Thus alteration of the population dynamic of pests is expected from the manipulation of tree architecture. Beside the direct effects of branch or shoot removal as a sanitation practice

against borers and foliar pests are involved in the success of direct control of pests in orchards: canopy porosity, and the orchard height and shape. Canopy architecture manipulation affect quality of chemical spray and/or diffusion of pheromone within the orchard and canopy. The penetration of sprayed compounds in the orchard canopy (i.e. particle deposition on leaf and fruit) is reported to be different according to tree total leaf area and tree size; the deposit of the active ingredient on the target organs is greater in small and porous trees. However, to promote tree architecture manipulation as a control method of insects and diseases, research is needed on the within-tree spatial dynamics of colonization of insets and pathogens in relation to tree growth pattern. Indeed, the level of insect infestation or disease incidence and the colonization dynamics within the tree are of utmost importance to understand which categories of shoots, leaves or fruits are more susceptible to insect and disease attack during the growing season and are to be manipulated through tree pruning to decrease infestation rates. There is also a need of wide and inter-disciplinary field of research to investigate the relationship between architectural and chemical aspects of the plant and insect and pathogen behaviour. Complementary experimental and modelling research on the subject has to provide some bases to improve the knowledge on the benefits and risks of various manipulations of tree architecture in orchards. Thus, knowledge about tree phenology, pest and disease cycles affecting local trees and incorporation of this knowledge into management systems is very much essential for sustainable production of quality fruits in high density mango orchards [31-40].

Relationship between canopy architecture and mango malformation

Mango malformation caused by *Fusarium mangiferae* is a serious malady in mango production, occurring worldwide and causing significant economic loss due to the general incapacity of malformed vegetative and inflorescences bearing fruits. Mango tree malformation has been attributed to a four-fold decrease in the chlorophyll levels, particularly in the chlorophyll a contents in the leaves, which is decreased with an increase in the number of malformed shoots, as reported in 'Dashehari' mango trees under subtropical climate of Delhi. On young seedling the disease appears at quite an early stage. Even 3-4 months old plants have been found to be affected. The malformed bunch may be at the apex or lower down at leaf axil. The seedlings produce small shoot lets bearing small scaly leaves with a bunch like appearance on the shoot apices. Apical dominance is lost in these seedlings and numerous vegetative buds sprout, producing hypertrophied growth, which constitutes vegetative malformation. The multi-branching of shoot apex with scaly leaves is misshapen and have dramatically shortened internodes known as "Bunchy Top", also referred to as 'Witch's Broom'. Floral malformation appears in the panicles, which impacts fruit production since affected inflorescences usually do not set fruit. Thus, it is more serious problem than vegetative malformation. The symptoms appear in the primary; secondary and tertiary rachises which become short and thickened and are much enlarged or hypertrophied and highly branched. Such panicles are greener and heavier with increased crowded

branching; possessing numerous flowers that remain unopened. Malformation increases the number of male flowers in an inflorescence and the ovary of malformed bisexual flowers is exceptionally enlarged and non-functional with poor pollen viability or either sterile or, if fertilized, eventually abort. The mechanism of fungal pathogen causing malformation may be via root, which completely colonize the seedling root systems and become systemic, spreading to apical plant tissues including apical buds. Mango bud mite, *Eriophyes mangiferae*, may also play an important role in the natural development of malformation, and is often observed in high numbers on malformed trees. Mango malformation is highly linked with flushing pattern mango. More number of malformed panicles emerges on triple flushes followed by double and ceased flushes. Noted that early cessation of vegetative growth favours increased fruit production and leads to reduction of malformation of inflorescence. It is again speculated that the emergence of more malformed panicles on double and triple flushes could be due to prolonged growth of these shoots, leading to depletion of their carbohydrate reserves, and thus to a reduced number of sufficiently matured terminals for normal development of panicles (Lu). Muhammad et al. proved that older flushes (ceased flushes) attained maturity and got more blooming with low intensity of malformation of inflorescence. Abiotic factors directly or indirectly affect the incidence of the malformation disease. Studies have revealed a correlation between abiotic factor like temperature and occurrence of mango malformation as seasonal variation in temperature at the time of flowering affects the intensity of malformation. In north-west India the disease is severe at 10-15°C, mild at 15-20°C, sporadic at 20-25°C and nil at temperature over 25°C depending upon the mean temperature during flowering (Kumar). Occurrence and severity of the disease can be correlated with ambient temperature at the time of flowering. As, in Egypt, the panicles appearing in the spring shoots have been found to be most severely affected. Found significant effect of pruning floral malformation in 23-25 years old high density orchards of mango cv. Amrapali, Mallika and Deashehari under subtropical climate of Delhi. The highest number of floral malformed panicles was observed in un-pruned trees, whereas, minimum in light pruned trees (tip pruning of 30 shoot cm from apex). Less malformed panicles in moderately pruned trees lead to realization of higher yield compared to un-pruned trees because later had slow growth and higher floral malformation. Severe pruning results in a higher number of young leaves which contain higher levels of chlorophyll a and total chlorophyll than in non-pruned trees which may result in a substantial reduction in floral malformation after pruning. Annual bearing cultivar such as 'Amrapali' exhibits lower polyphenol oxidase (PPO) activities and shows higher incidence of malformation compared to biennial-bearing cultivar like ' '. Thus, PPO activity is inversely related both to flowering and the incidence of malformation, and decline during fruit bud differentiation in the 'on'-year (Sharma). PPO activities are found to be highest in severely-pruned trees and lowest in lightly-pruned trees in an 'on'-year; thus justifying an increase in pruning intensity, which result in higher PPO activities. After pruning, mango plants may induce a self-defense mechanism by increasing the activities of both PPO enzyme fractions. Thus, increased severity of pruning not

only minimise the incidence of malformation, but also increase PPO activities. The proline contents of malformed, non-pruned seedlings are higher than in healthy seedlings due to a higher rate of biosynthesis in malformed tissues and improved translocation of amino acids from healthy to malformed tissues. The emergence of new shoots and young leaves with a low incidence of malformation after pruning, delay senescence, but reduce proline contents. Thus, moderate pruning (60 cm from the shoot tip) in high-density mango orchards can be adopted to restore optimum vegetative growth and fruiting and lower the incidence of malformation in subtropics (Singh). Early removal of malformed panicles along with pruning helps to promote healthy vegetative growth followed by emergence of normal inflorescence. During 'on' year, the malformation incidence increases due to time lag between pruning and onset of flowering and also due to increase in canopy volume. Moderate pruning of 20 cm shoot bearing malformed panicles in the month of January at panicle emergence stage can be effective in suppressing the incidence of malformation in cv, which is usually very high in early emerging flower buds and panicles,. Pruning of shoot probably removes malformation inducing principle which accumulates at the shoot tip. Conventionally, affected terminals and the subtending three nodes are cut from trees and can be removed from the field. If these measures are practiced for 2 or 3 consecutive years, the disease can be reduced to insignificant levels. Thereafter, the disease can be kept in check by removing symptomatic tissues every other year. In south Africa, , United States and Egypt, the only control method recommended commercially is the pruning of infected branches while in Mexico, pruning after harvest at 80 and 30 cm from the affected zone maintain the lowest bud deformation [40-45].

drop

The worldwide production of mango is frequently reduced by severe losses of fruit numbers throughout the growing season, a phenomenon that is referred to as premature fruit drop (Singh). Mango produces an abundance of male and polygamous flowers, but only a small proportion of the latter group is successfully pollinated and has the potential for setting fruit. The number of fruits per panicle at harvest stage is very speculative for yield estimation but it varies with the bearing behaviour of cultivar and fruit set per panicle. Numerous biotic and abiotic factors reduce pollen viability, the fertilization process of the flower, and embryo survival, which are all commonly associated with extensive fruit drop in early season. Fruit that remains in the tree attracts a greater share of the available tree resources for continued growth and development. Subsequent fruit drop is induced by any factor reducing carbohydrate availability and thus the demand of the growing fruit is not sufficiently matched by its supply. This carbohydrate imbalance can occur, for example, by air temperatures below 13°C or exceeding 36°C as a result of heavily reduced leaf photosynthesis rates in dense crowded canopy of high density mango orchards. Tree spacing has become an increasingly important consideration in fruit crop production. Closer tree spacing has significant effect on increase in tree height than that of wider spacing. This is mainly due to the competition for light

in plants at close spacing. So naturally for active photosynthetic reaction plant produce terminal branches. Similarly, increase in plant spacing result in incremental trend in stem girth while closer planting density causes lesser production of leaves and flowers per plant and fruit drop can also be more in closer plant spacing. This is mainly due to reduced light penetration in closer plant spacing which affects plant growth, flowering and fruit retention. Thus manipulation of tree canopy architecture by pruning improves light availability at the interior of tree canopy which thereby improve tree growth and fruit yield due to improvement in tree photosynthetic efficiency. Insufficient pest management in overcrowded dense canopy of high density orchard can also lead to increase in fruit drop in mango [45-55].

However, fruit drop can be minimized by severe pruning (tip pruning of 90 cm shoot from the apex) rather than light pruning (tip pruning of 30 cm shoot from the apex) or moderate pruning (tip pruning of 60 cm shoot from the apex) in mango because supply of available reserves to remaining blossoms is increased after pruning and subsequently fruit drop decreases with the pruning intensity. Pruning creates vigor, which had favorable effect on fruit set to counteract fruit drop. Un-pruned trees can have lower fruit set due to misbalanced ratio of growth promoters and inhibitors, low sugar reserve in older shoots (dead, decayed and infected) and more malformed shoots. conducted a study on 15 years old senile orchard of Indian gooseberry cv Francis to convert into productive through canopy and nutrient management. They found that 50 per cent pruning of previous season growth resulted in maximum duration of flowering, fruit set and retention, yield, physical and chemical qualities of fruit and leaf as well as soil nutrient status. Intensity of pruning significantly affects the number of fruits per panicle. Fruit set is more in moderately pruned mango trees (tip pruning of 60 cm shoot from the apex), in 'on' year but in 'off' year the maximum fruits can be observed in light pruned (tip pruning of 30 cm shoot from the apex) trees while the number of fruits per panicle is comparatively lesser in un-pruned trees in both 'on' and 'off' year (Singh). This is primarily due to unavailability of adequate light and high sex-ratio in un-pruned trees. Thus tree pruning can be used as canopy management strategy to reduce the fruit drop and improve canopy yield efficiency.

CONCLUSION

The most important measures of efficiency of canopy management are yield of high quality fruits per unit of inputs. As population dynamics of mango pests are influenced by planting density, tree canopy management has become a critical component of overall tree productivity which is mandatory for adequate light penetration and air flow inside the tree canopy. Thus, it is obvious that once farmers adopt high density orcharding, formative pruning to develop proper tree architecture and annual canopy management are to be followed regularly. If these practices are followed, the management of pests and diseases would be very effective. As some studies on the effect of canopy management on population dynamics of mango pests have been conducted by some investigators, therefore, a systematic and comprehensive compilation have

been tried to explain the effects of tree canopy architecture on holistic pest management, which will be helpful for achieving good yield of quality fruits without relying on application of any chemicals or other extra inputs for pest control thereby reducing cost of cultivation and minimizing the damage of ecosystem.

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REFERENCES

1. Athani SI, and Dharmatti PR.. Effect of plant density on growth and yield in banana. Karnataka J. Agric. Sci.2009; 22, 143-146.
2. Bagchi TB, Sukul P, and Ghosh B. Biochemical changes during off-season flowering in guava (*Psidium guajava* L.) induced by bending and pruning. J. Trop. Agric.2008; 46, 64-66.
3. Bassal MA. Growth, yield and fruit quality of 'Marisol' clementine grown on four rootstocks in Egypt. Sci. Hort.2009; 119(2), 132-137.
4. Campbell CW, and Marlatt RB. Current status of mango malformation disease in Florida. Proc. Inter. Am. Soc. Trop. Hortic. 1986; 30, 223-26.
5. Darvas JM. Control of mango blossom malformation with trunk injection. South Afr. Mango Grow. Assoc. Year book.1987; 7, 21-24.
6. Davie SJ, and Stassen PJC. Mango model: growth and development of Sensation mango trees. Acta Hort.1977; 455, 135-142.
7. Dogar WA, Khan AA, Ahmed S, Tariq S, Ahmad M, Muhammad I., Muhammad N., and Khan N. Study to determine the effects of high density plantation on growth and yield of citrus. Sarhad J. Agric.2017; 33(2), 315-319.
8. Ferree DC, and Schupp JR. Pruning and training physiology. In Apple: Botany, Production and Uses, D.C. Ferree, and I.J. Warrington, eds. (United Kingdom: CABI).2003; pp. 319-344.
9. Freeman S, Gamliel-Atinsky E, Maymon M, Shtienberg D, Youssef S, and Levin AG. Mango malformation disease: Etiology, epidemiology and management. Acta Hort.2015; 1075, 207-214.
10. Gaikwad SP, Chalak SU, and Kamble AB. Effect of spacing on growth, yield and quality of mango. J. Krishi Vigyan.2017; 5(2), 50-53.
11. Hagemann MH, Roemer MG, Kofler J, Hegele M, and Wünsche JN. A new approach for analyzing and interpreting data on fruit drop in mango. HortScience.2014; 49(12), 1498-1505.
12. Haggag WM. Mango diseases in Egypt. Agric. Biol. J. N. Am.2010; 1(3), 285-289.
13. Hiffny HAA, El-Barkouki M, and El-Banna GS. Morphological and physiological aspects of the floral malformation in mangoes. Egyptian J. Hort.1978; 5, 43-53.
14. Huong PT. Some measures for rehabilitation of neglected mango orchards in Yen Chau, Son La. J. Sci. Dev.2010; 8, 69-75.
15. Karar H, Arif MJ, Ali A, Hameed A, Abbas G and Abbas Q. Assessment of yield losses and impact of morphological markers of various mango (*Mangifera indica*) genotypes on mango mealybug (*Drosicha mangiferae* Green) (Homoptera: Margarodidae). Pakistan J. Zool.2012; 44(6), 1643-1651.
16. Kaur A, and Kaur N. Mango malformation: A fungal disease, physiological disorder or malady of stress. J. Appl. Nat. Sci.2018; 10(1), 403-409.
17. Krajewskia AJ, and Krajewski SA. Canopy management of sweet orange, grapefruit, lemon, lime and mandarin trees in the tropics:

- principles, practices and commercial experiences. *Acta Hort.*2011; 894, 65-76.
18. Kumar J and Beniwal SPS. Mango malformation. In *Plant Diseases of International Importance: Diseases of Fruit Crops*, Vol. 3, J Kumar, HS Chaube, US Singh and AN Mukhopadhyay, eds. (New Jersey, USA: Prentice Hall).1992; pp. 357-393.
 19. Kumar J, Singh US, and Beniwal SPS. Mango malformation: one hundred years of research. *Annu. Rev. Phytopathol.*1993; 31, 217-232.
 20. Kumar, P., Misra, A.K., and Modi, D.R. (2011). Current status of mango malformation in India. *Asian J. Plant Sci* 10(1), 1-23.
 21. Lopez-Estrada, M.E., Noriega-Cantú, D.H., Otero-Colina, G., and Gutiérrez-Reyes, G. (2005). Orchard management and sanitary pruning on the incidence of mango malformation. *Revista Chapingo. Serie. horti* 11, 113-120.
 22. Lu, P. (2005). Use of ethrel to eliminate late flushing and promote flowering in mango. Paper presented at International Conference on Mango and Date palm: Culture and Export, June 20-23 (Institute of Horticultural Sciences, Faisalabad, Pakistan).
 23. Mahrous, H.A.H. (2004). Effect of spraying some chemical substances and a fungicide on floral malformation disease in mango. *Acta Hort* 645, 481-486.
 24. Maiti, S.C., and Sen, P.K. (1978). Studies on biennial bearing in mango III. Cessation of shoot growth and flowering. *Orissa J. Hort* 6, 43-51.
 25. Majumder, B.C., and Chatterjee, S.K. (1972). Biochemical studies on leaves with their ageing process in mango (*Mangifera indica* L.) cultivars. II: Changes of chlorophyll contents. *Punjab Hort J.* 12, 111-115.
 26. Muhammad, F., Muhammad, I., and Muhammad, A.P. (1999). Some physiological aspects of mango malformation. *Int. J. Agric. Biol* 1(3), 94-96.
 27. Nasir, M.A., Aziz, A., Mohar, T.A., Ahmad, S., and Rehman, M.A. (2006). Effect of plant spacing on the growth and quality of kinnow under Sargodha climatic conditions. *Sarhad J. Agric* 22, 37-40.
 28. Nelson, S.C. (2008). Mango anthracnose (*Colletotrichum gloeosporioides*). *Plant Disease*, 48: 1-9.
 29. Pinero, J.C., and Prokopy, R.J. (2005). Spatial and temporal within-canopy distribution of egg laying by plum curculios (Coleoptera: Curculionidae) on apples in relation to tree size. *J. Entomol. Sci* 40, 1-9.
 30. Ploetz, R.C. (2001). Malformation: a unique and important disease of mango, *Mangifera indica* L. In *Fusarium: Paul E. Nelson Memorial Symposium*, B.A. Summerell, J.F. Leslie, D. Backhouse, W.L. Bryden, and L.W. Burgess, eds. (St Paul, Minn.: APS Press), pp. 233-247.
 31. Ploetz, R.C. (2004). The major diseases of mango: strategies and potential for sustainable management. *Acta Hort* 645, 137-150.
 32. Ploetz, R.C., and Prakash, O. (1997). Foliar, floral and soil-borne diseases. In *The Mango: Botany, Production and Uses*, R.E. Litz, ed. (United Kingdom: CABI), pp. 281-326.
 33. Ploetz, R.C., *Diseases of Tropical Fruit Crops* (United Kingdom: CABI), 2003.
 34. Poornima, M.H., Gopali, J.B., Athani, S.I., Venkateshalu, and Patil, S. (2018). Impact of ultra high density, high density and conventional planting systems on major insect pests of mango. *Journal of Entomology and Zoology Studies* 6(6), 292-297.
 35. Rao, V.N.M., and Shanmugavelu, K.G. (1976). Studies on the effect of pruning on mango. *Prog. Hort* 8(1), 21-28.
 36. Reddy, P.V.R., and Dinesh, M.R. (2005). Evaluation of mango exotic collections for resistance to hopper, *Idioscopus niveosparus* Lethierry. *Indian Journal of Plant Genetic Resources* 18(1), 69-70.
 37. Schlosser, E. (1971). Mango malformation: Symptoms, occurrence and varietal susceptibility. *FAO Plant Prot. Bull* 19, 12-14.
 38. Sharma, R.R., Goswami, A.M., Singh, C.N., Chhonkar, O.P., and Singh, G. (2001). Catecholase and cresolase activities and phenolic content in mango (*Mangifera indica* L.) at panicle initiation. *Sci. Hortic* 87, 147-151.
 39. Sharma, R.R., Singh, R., and Singh, D.B. (2006). Influence of pruning intensity on light penetration and leaf physiology in high-density orchards of mango trees. *Fruits* 61, 117-123.
 40. Shawky, I., Zidan, Z., Tomi, A.E., and Dahshan, D.I. (1980). Flowering malformation in relation to vegetative growth of Taimour mangoes. *Egyptian J. Hort* 5, 123-132.
 41. Simon, S., Sauphanor, B., and Lauri, P.F. (2007). Control of fruit tree pests through manipulation of tree architecture. *Pest Technol* 1(1), 33-37.
 42. Singh, L.S., Singh, S.M., and Nirvan, R.S. (1961). Studies on mango malformation review, symptoms, extent, intensity and cause. *Hort. Adv* 5,197-207.
 43. Singh, P.N., and Rathore, V.S. (1983). Changes in moisture content, dry matter accumulation, chlorophyll and nutrient contents in mango malformation. *Indian J. Hortic* 40, 21-25.
 44. Singh, R.N., Majumder, P.K., Sharma, D.K., Sinha, G.C., and Bose, P.C. (1974). Effect of deblossoming on the productivity of mango. *Sci. Hortic* 2, 399-403.
 45. Singh, S.K. (2007). Effect of pruning on growth, yield and fruit quality of some mango cultivars planted under high density. (PhD Thesis) (New Delhi, India: Post-Graduate School, Indian Agricultural Research Institute).
 46. Singh, S.K., Singh, S.K., Sharma, R.R., and Patel, V.B. (2010). Influence of pruning intensity on flowering, fruit yields and floral malformation in three mango cultivars planted under high density. *Indian J. Hortic* 67, 84-89.
 47. Singh, Z., and Dhillon, B.S. (1994). Metabolic changes associated with vegetative malformation of mango (*Mangifera indica* L.). *Trop. Agric* 71, 320-322.
 48. Singh Z, Malik A, and Davenport TL. Fruit drop in mango. *Hort. Rev.*2005; 31, 111-153.
 49. Sirohi SC, Prakash S, Rana P, and Singh R. Effect of different levels of shoot pruning on floral malformation in mango. *Indian J. Hortic.*2006; 63, 330-331.
 50. Sirohi SC, Prakash S, Rana P, and Singh R. Response of mango malformation to severity of malformed panicle bearing shoot pruning. *Indian J. Hortic.*2009; 66, 393-395.
 51. Stassen PJC, Grove HG, and Davie SJ. Tree shaping strategies for high density mango orchards. *J. Appl. Hortic.*1999; 1, 1-4.
 52. Swaroop M, Ram S, Singh CP, and Shukla P. Effect of pruning on growth, flowering and fruiting in mango. *Indian J. Hortic.*2001; 58, 303-308.
 53. Tiwari D, Singh HK, and Shukla AK. Effect of canopy and nutrient management on senile orchards of Indian gooseberry (*Emblica officinalis*) cv Francis. *Indian J. Agr. Sci.*2015; 85(3), 365-373.
 54. Wunsche JN, and Ferguson IB. Crop load interactions in apple. *Hort.*2005; Rev 31, 231-290.
 55. Zahavi T, Reuveni M, Scheglov D, and Lavee S. Effect of grapevine training systems on development of powdery mildew. *Eur. J. Plant Pathol.*2001; 107, 495-501.