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A review on advancement on wilt disease of *Psidium Guajava* L. with special reference to management

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Abstract
Guava, is one of the most promising fruit crops of India and is considered to be one of the exquisite nutritionally valuable and remunerative crops. It is grown almost in all the states of India. It is a hardy crop and is cultivated successfully even in neglected soils and is attacked by a large number of pathogens, mainly fungi. Wilt is the most destructive disease for guava plant in India and losses due to this disease are substantial. Wilt of guava from India was first reported in 1935 from Allahabad. *Fusarium oxysporum f. sp. psidii and, F. solani* have been reported as causative agents of this disease. The disease is soil-borne and is difficult to control. Wilt is predominantly caused by the species of *Fusarium,* of which *F. oxysporum* is generally the main cause. The other species of *Fusarium* i.e., *Fusarium solaniai* also dominates in isolation. Since, the disease results in the complete mortality of the affected plants, the loss is total. Although, severe loss is there in the annual crops also, huge monitory losses *occai* especially in perennial fruit trees as it is a loss of labour of several years. Guava is a crop where this disease is very serious and it can be said that this is the only disease of guava which is threatening guava cultivation in India. It causes monitory as well as nutritional loss. The present communication, deals guava wilt to depict its present status.

Keywords: Guava, Wilt, Fusarium spp., Management

Introduction
Guava is considered as one of the exquisite, nutritionally valuable and remunerative crops. Guava fruit contains 2-5 times more vitamin C than orange and is also good source of calcium, phosphorus, and iron. High concentration of pectin in guava fruit may play a significant role in the reduction of cholesterol and thereby decrease the risk of cardiovascular disease [26]. Traditionally, different parts of plants, i.e. fruits, leaves, roots, and bark are used in the treatment of gastroenteritis, diarrheoa, and dysentery reported by Singh [68]. Despite these advantages, there are a number of problems that affect guava production. In India, it is grown in almost all of the states. It is a hardy crop and is cultivated successfully even in neglected soils. Wilt of guava is one of the most important disease of guava especially in India and loss due to this disease is substantial [28]. The disease was first reported by Das Gupta and Rai from the orchards of Lucknow in India [54]. Wilt is the most destructive disease of guava and causes 5-60% loss in guava production in India [55]. Assessment of loss around Lucknow revealed that losses vary from 5-60 per cent and above 5-year-old guava plants are more prone to wilt incidence [46]. Losses due to wilt disease are substantial [6]. During 2009–2011 a survey of guava plants affected with wilt symptoms were studied in severely affected areas of India *viz*. Allahabad, Agra, Farukhabad, Lucknow, Punjab, Ranchi and Rewa, and wilt incidence ranged from 75% to 90%, while severity ranged between 30% and 55% on infected plants. *F. oxysporum f. sp. psidii* and *Fusarium solani* are the predominant pathogen causing wilt of guava [25 and 72], although, *F. oxysporum f. sp. Psidii* and *F. solani* were the most commonly isolated fungal species from these regions. The average productivity can at least be doubled, if wilt disease is managed effectively. Work in last two decades at CISH, Lucknow revealed that the disease can be effectively managed, if complete package of integrated disease management practices is followed, which include use of resistant root stock, biocontrol, intercrop with cultural practices and resistant varieties. Complete wilt management schedule is available and

needs to be implemented in totality.

Losses

Loss assessments due to wilt disease in guava were estimated in different terms by different workers. Singh and Lal [67] estimated5-15% loss amounting to almost 1 million rupees due to guava wilt every year in 12 districts of U.P. In West Bengal, the disease reduced the yield by 80% *i.e.,* from 113.5 q ha^{-1} in healthy plantations to about 18.16-22.7 q ha^{-1} in affected orchards [10]. Chattopadhyay and Bhattacharjya [7] attempted in vein to regenerate the affected trees. The new seedlings, grafted or planted in the affected areas showed stunted growth, flowered rarely and succumbed to wilt within a very short time. Seven thousand acres of land in Andhra Pradesh, reduced the land value to half by the presence of the disease [29]. In general, losses due to wilt in guava around Lucknow area vary from 5-60% [52, 53].

Symptomlogy

First external symptom of the disease is the appearance of yellow coloration with slight leaf curling at the terminal branches, becoming reddish at the later stage and subsequently shedding of leaves take place. Twigs become bare and fail to bring forth new leaves or flowers and eventually dry up. Fruits of all the affected branches remain underdeveloped, become hard, black and stony. The entire plant becomes defoliated and eventually dies. It requires almost sixteen days for complete wilting. Some trees affected linger on even up to 252 days and then die [45]. Misra and Pandey [45] also studied variations in the symptoms during different time of the year. They noticed yellowing of the leaves with inter-venial chlorosis during the month of August, which drop even with the slight shaking of the plants. During September, general drooping of the leaves takes place. During October complete wilting of plants are seen with almost dried leaves and small dried black fruits hanging on the branch. Few plants also show partial wilting, which is a very common symptom of wilt in guava. It is also recorded that some plants show wilting of variable degree (leaf yellowing, g, drooping of leaves, drying of terminal branches or partial wilting) g) durm. g different months but later escape/resist wilting. g. These plants start recovering from December onward. It was recorded that out of total wilting plants, around 17% plants, which initially show some symptoms of wilting, ultimately escape/resist wilting[25].The finer roots show black streaks, which become prominent on removing the bark[14]. The roots also show rotting at the basal region and the bark is easily detachable from the cortex. The cortical regions of the stem and root show distillct discoloration and damage. Light brown discoloration is noticed in vascular tissues [5]. Wilted plants later show bark splitting. The pathogen attacks young as well as old fruit bearing trees but older trees are more prone to the disease [52, 53]. New seedlings and grafts also show disease symptoms [67, 19, 20]. Chakraborty and Singh [3] identified mainly two types of symptoms *i.e.*, slow wilt (where plant takes several months or even a year or two to wilt after the appearance of initial symptoms) and sudden wilt (where plant takes 15 days to one month to wilt after the appearance of in initial symptoms).

Causal organism

The exact cause of the disease is still not fully understood but the pathogens, *Fusarium oxysporum f. sp. psidii, F. solani, Macro phominaphaeseoli, Rhizoctonia bataticola, Cephlosporium sp*. and Gliocladiumroseum and many other pathogens are reported by different workers may be the incitant of the disease. Prior to 1941, wilt was considered to be caused by *Cephalosporium sp.* (Vestal, 1941) [74] and also invariably isolated *Cephalosporium* from roots of wilted plants. Das Gupta and Rai [12] first time reported the association of Fusarium sp. Later, Prasad *et al.* [64] attributed wilt due to *Fusarium oxysporum* (Fr.) Schl. and proposed the name *Fusarium oxysporum* (Fr.) *Schl. f. sp. Psidii* Prasad, Mehta and Lal. It was also supported by Edward and Srivastava [18, 61, 62]. Edward [19, 20] also observed that *F. oxysporum f. sp. psidii* exist in a variety of forms, which differ in cultural and morphological characters. Besides the involvement of above pathogens, association of the other pathogens have also been suspected in inducing wilt disease of guava. In West Bengal, both M. phaseoli and *F. solani* were reported to incite wilt either individually or in combination. In either case, the fungus first colonizes the surface of roots and then enters in to its epidermal cells. Thereafter, intercellular mycelium establishes first in epidermal cells and then spreads into cortical cells which get considerably damaged and filled up with the mycelium. *Fusarium solani* enters the xylem vessels, grows inside and blocks them. *Macrophomina phaseoli* first invades the phloem and destroys it. The xylem vessels are also attacked in a few cases [7, 8, 10]. Edward [19, 20] reported *that F. oxysporum f. sp. psidii* penetrate either directly through the root piliferous layer of the guava seedlings or through openings caused by secondary roots. Hyphae are found in the xylem vessels of the roots of the inoculated plants [19, 20]. Histopathological observations made by various workers in naturally wilted and artificially inoculated plants revealed the presence of *F. solani, F. oxysporum* and *M. phaseolina* in vascular tissues [7, 8, 19, 20, 61, 62, 5, 71]. *Gliocladiumvermoesenii* Corda., a known saprophytic fungus, is also found associated with diseased plants [5]. *F. oxysporumf. sp. psidii, F. solani, F. coeruleum, F. moniliforme* and *Rhizoctonia solani* were also reported from rhizoplane as well as from the soil from Varanasi[16]. *Cylindrocarponlucidium, Gliocladiumvirens* and *Bartiliniarobillardoides* caused drooping and subsequent wilting of guava seedlings grown in Hoagland's solution on artificial testing (Misra and Pandey, 1992) [44]. In a recent study Misra and Pandey [39] and Misra and Pandey [42, 45, 46] reported that *Gliocladiumroseum* as a most potent pathogen, which reproduces symptom of wilt on artificial inoculation. They also developed an inoculation technique i.e. stem hole inoculation technique, which reproduce the wilt symptom very quickly. Although several pathogens have been reported for the cause of wilt in guava by different workers but *Fusarium oxysporum* f. sp. *Psidii* and *Fusarium solani* were found to most important pathogen associated with this disease. Therefore, in present review the wilt disease of guava has been described in detailed with special reference to *Fusarium* sp. infection in India. Assessment of genetic diversity of *Fusarium solani* from different agro-ecological regions of India was also done by Misra *et al.* [36]. A phylogenetic tree based on RAPD data was generated showing the three major clades. Additionally, specific primer set was used for detection of *F. solani* and all tested isolates showed positive result in PCR assay.

Epidemiology

There is clear picture on the period of higher disease incidence during the year. Extensive studies on the progress of natural wilting of guava plants during different months have been made. Misra and Pandey [37, 40, 41, 45] at Lucknow

found that wilting generally start after rains during August, September and maximum wilting occur during October month. Some plants, which show slight yellowing start recovering from December onwards. On analysing the weather data, it was found that higher rainfall during July-September with maximum temperature ranging from 31.3 to 33.5°C and minimum temperature ranging from 23 to 25°C and humidity around 76 per cent favour the wilt incidence. It was also found that two months are required for the complete wilting of plants (from appearance of 1st visible symptom to complete wilting). However, minimum period was found only 16 days. There are variable reports about the severity of disease at different pH levels and variable fertilizer levels. However, the disease is common in different types different fungicides *viz*. bavistin, topsin M, indofil M-45, thiram, blitox check the various wilt pathogens in laboratory effectively, but these pathogens increase their aggressiveness with profuse spore mass production in the soil, once the effect of these fungicides diminishes in soil and hence cannot be recommended. These chemicals are costly and repeated application is not economical also. Moreover, seeing the soil mass, increasing aggressiveness of the pathogen, profuse spore production and economics, chemical management does not seem practical. Besides fungicides, some soil amendment chemicals/cakes/fertilizers were also evaluated for control of wilt. Mathur *et al*. [33] found wilt control by soil treatment with 1.82 kg. lime or gypsum/tree, although the control mechanism was not well understood. Oil cakes like neem cake, mahua cake, kusum cake supplemented with urea @ 10 kg and 1 kg respectively also check the disease [13]. At ICAR CISH, Lucknow it was found that wilt could be checked by application of 6 kg neem cake + 2 kg gypsum per plant [43]. These can be integrated as one of the components in the integrated disease management practices.

Host resistance

Guava cvs. Chittidar, Hafsi, Safeda Riverside, Rolf and Stone acid were reported susceptible and Psidium cattleianum var. lucidium and Syzigiumcumini (Jamun) resistant to wilt (Edward, 1961). Varieties, white guava No. 6229, Clone.32-12, Webber and Popeno from Florida (USA), Hart and Rolf from Florida but acclimatized at Allahabad, Riverside and Rolf from California (USA), Safeda from Sri Lanka, Banarasi (Andhra strain), Dholka, Sindh and Nasik (Bombay strain) were reported tolerant to wilt disease [34]. Singh*et al*. [69] reported that among 10 red-fleshed cultivars, only one of Allahabad was found infected by *Fusarium solani*. Among the 15 white-fleshed cultivars, Lucknow 49 was free from the disease and in Allahabad Safeda incidence was only 4 per cent, whereas Karela and Behat Coconut suffer heavily (33%). None of the species, *Psidium aracae, P. cattleianum, P. cattleianum var. lucidium, P. corecium, P. cujavillus, P. guineese and P. fridichsthalanum* developed wilt infection. Edward and Gaurishanker, [17] reported that *Syzigiumcuminii, Psidium molle, P. quianense*, Chinese guava (*P. friedrichsthalianum*) and Philippine guava resistant to wilt.

Disease management

To achieve a meaningful management of the pathogen and a substantial degree of disease control, all the four components of disease pyramid are to be managed. This goal can be achieved by the integration of methods directed against the causal agent, in favour of the host and for modification of the environment. The package of practices consisting of a combination of cultural, biological, chemical methods and host resistance help in reducing the diseases.

Disease management through chemicals

Different chemical managements have been suggested by different workers. Chaubatia paste, water-soluble 8-Quinolinol sulphate, benlate or bavistin, metasystox and zinc sulphate, thiophanate methyl, captafol and thiabendazole were suggested [1, 27, 73, 2, 32]. In South Africa tebuconazole, propiconazole, prochoraz, triforine and carbendazim + flusilazole were found effective *in vitro* evaluation [30]. Misra and Pandey [40] reported that though different fungicides *viz*. bavistin, topsin M, indofil M-45, thiram, blitox check the various wilt pathogens in laboratory effectively, but these pathogens increase their aggressiveness with profuse spore mass production in the soil, once the effect of these fungicides diminishes in soil [37] and hence cannot be recommended. These chemicals are costly and repeated application is not economical also. Moreover, seeing the soil mass, increasing aggressiveness of the pathogen, profuse spore production and economics, chemical management does not seem practical. Besides fungicides, some soil amendment chemicals/cakes/fertilizers were also evaluated for control of wilt. Mathur *et al.* [33] found wilt control by soil treatment with 1.82 kg. Lime or gypsum/tree, although the control mechanism was not well understood. Oil cakes like neem cake, mahua cake, kusum cake supplemented with urea @ 10 kg and 1 kg respectively also check the disease. At ICAR CISH, Lucknow it was found that wilt could be checked by application of 6 kg neem cake + 2 kg gypsum per plant [43]. These can be integrated as one of the components in the integrated disease management practices.

Disease management through cultural practices

Mathur [35] advocated that wilt could be controlled by proper sanitation in the orchard. Wilted trees should be uprooted, burnt and trench should be dug around the tree trunk. Edward [19] suggested that while transplanting, roots of plants should not be severely damaged. Maintenance of proper tree vigour by timely and adequate manuring, inter-culture and irrigation enable them to withstand infection. The pits may be treated with formalin and kept covered for about 3 days and then transplanting should be done after two weeks. Prasad *et al*. [63], Khan and Misra [31], Misra, 2004 [48] and Misra *et al*. [49] reported intercropping with turmeric or marigold could restrict the wilting of guava. Misra [16] also observed that the orchards, which were having frequent tillage, had more incidence of wilt compared to less tilled orchards. Tillage during monsoon enhance wilt incidence (personal observation). During a conversation with a guava farmer at Lucknow, it was informed that he does not allow tillage in guava orchard during monsoon period and afterwards till December. Hence, tillage should be avoided during monsoon and afterwards till December. As the disease is soil borne in nature, flood irrigation spreads the disease. Hence, separate basin irrigation or drip irrigation should be encouraged for the management of disease. These cultural practices are useful and should be adopted for integrated management practices as important component.

Disease management through varietal resistance and root stock

Edward [21] reported cultivar Chittidar, Hafsi, Safeda Riverside, Rolf and Stone acid susceptible and guava species *Psidium cattleianum var. lucidium* and other genera

Syzigiumcuminii (Jamun) resistant to wilt. Edward and Gaurishanker [17] further reported that *Syzigiumcuminii*, *Lagerstraemiaindica*, *Psidium cattleianum* (*Psidium molle*), *P. quianense*, Chinese guava (*P. friedrichsthalianum*) and Philippine guava are resistant to wilt. The strawberry guava (*Psidium* cattleianum) has been reported relatively hardy species from Reunion [60]. At ICAR CISH, Lucknow, Misra [58] studied the relative field tolerance of 20 guava cultivars and categorized them into different groups on the basis of their natural susceptibility. The cultivars Allahabad Safeda, Florida Seedling, Guinees, Hafsi, Karela, Mirzapuri Seedling, Nasik, Pear Shaped, Sindh, Superior and White Fleshed proved highly susceptible; Behat Coconut and Pourtgal as susceptible; Apple Colour, Chittidar, Seedless, Spear Acid, Superior Sour Lucidium, Red Flesh and Smooth Green as tolerant. The cv. Chittidar is graded as reasonably good cultivar, which has reasonable level of resistance as well as good quality and taste and can directly be used as resistant material. Stock-scion compatibility was also evaluated. When cv. Safeda as scion and the resistant material reported by Edward and Gaurishanker (1964) [17] *i.e., Syzigiumcuminii, Lagerstraemiaindica, Psidium cattleianum (Psidium molle), P. quianense, Chinese guava (P. friedrichsthalianum)* and Philippine guava) as rootstock were evaluated, Lagerstraemiaindica proved incompatible, Syzigiumcumini (Jamun) as partially compatible and other guava species as compatible. They suggested use of resistant rootstock as a possible means for management of guava wilt. Later, at ICAR CISH Lucknow, Misra [49] again tried *Syzigiumcumini* (Jamun) as root stock and found late incompatibility with scion, although for few months' scion survived on this root stock, but could not pickup growth. Further working on the root stock, Misra*et al*. [51] identified F1 population of *Psidium molle X Psidium guajava* free from wilt, when grown in wilt sick plot and inoculated repeatedly with *Gliocladiumroseum, Fusarium solani* and *Fusarium oxysporum*. This is compatible root stock with any variety of guava which can be multiplied on it. This material is now used at CISH, Lucknow as resistant root stock for multiplying plants of choicest variety of guava.

Disease management through Biological practices

Being the soil borne nature of wilt pathogen, it is unpractical to control it with any chemical. The effects of chemicals are also hazardous for the soil and environment, moreover when the effect of chemicals diminishes, the pathogen become more virulent and aggressive. Hence, considering the above facts, it was considered more desirable to use the bio-agents for the control the wilt disease. Biocontrol is the reduction of the amount of inoculum or disease producing activity of a pathogen accomplished by or through one or more organisms other than inoculum. It is the use of natural or modified organisms, genes or gene products to reduce the effects of pests and diseases. *Aspergillus Niger* was also found very fast growing, easy to propagate and most effective in controlling the wilt disease in field. Besides this quality, it is also growth enhancer and the plants treated with *Aspergillus Niger* developed faster with more height, more thickness and more numbers of leaves, Misra*et et al*. [46]. Out of three bio-agents *Trichoderma harzianum, T. viride* and *Gliocladiumvirens, T. viride* is best for the control of wilt reported by Dwivedi and Shukla [15] Bioagents like Aspergillus niger, *Trichoderma sp. Penicillium citrinum* and some bio-dynamic antagonists have shown their effectiveness towards the control of wilt pathogens of guava. *Aspergillus niger* is found to be most effective in controlling the wilt disease followed by *Trichoderma viride* studied by Dwivedi and Shukla[15]. When relative growth of the three bioagents was studied, it was found that *Aspergillus niger* was fastest growing and most effective suggested by Singh*et al*. [69]. These can be grown easily on any substrate like maize/bajra seeds etc. and can also be multiplied on cheap substrates like Sacchrum sp. (grass) and dry and green leaves of *Psidium guajava* reported by Misra, and Prasad [47]. The efficacy of *Streptosporangium pseudo vulgare* in controlling rot of guava caused by *Lasiodiplodiatheo bromae* was also reported Shukla *et al*. [66]. Co-inoculation of the pathogen with the biological control agent completely inhibited the growth of the pathogen as indicated by the disappearance of the fungal mycelium. The growth of the pathogen immediately stopped following inoculation with the biological control agent. When these fungi were tested for the control of wilt pathogen in laboratory conditions, these were found quite effective Neelima *et al*. [59]. It was also found that at village level these bioagent can be multiplied in earthen potsbyMisra *et al*. [50].

Integrated eco-friendly approach

Considering the complexity of the problem, integrated eco-friendly approach for the management of guava wilt was suggested by Misra*et al*. [47, 48] and Misra [54]. (a) Use resistant root stock (*P. molle x P. guajava*). (b) Apply bioagent (*Aspergillus niger, Trichoderma spp. or Penicillium citrinum*) at the time of planting and regularly once every year in form of enriched FYM before monsoon. (c) Intercropping with marigold or turmeric (d) Application of neem cake and gypsum (e) Minimum tillage. Avoid tillage at least during monsoon (f) Separate basin irrigation or drip irrigation. (g) Maintain plant population (h) Maintain sanitation in orchard. It is very necessary to implement complete management practice so that effective management is achieved. Following only one or two components do not give desired result. If disease is managed the production of guava can easily be doubled.

Discussion

Wilt symptoms start from 28-30 days after inoculation and during September-October fast wilting occurs, while maximum wilting occurs in the month of October. Quantification clearly indicates that October is the most favorable month for wilt incidence which indicates that the increased disease incidence on guava in the subtropics is primarily a function of the guava plant being more vulnerable to infection under rainy/winter temperatures, rather than the pathogen becoming more competitive. In general, maximum plants takes three-month period for typical wilting after appearance of first visible symptoms though maximum time taken for complete wilting was 240 days. The aqueous extracts/leaf from *Curcuma longa* L., *Achyranthes roses, Calotropis gigantea* L. R. Br. *Cannabis sativa* L. may be more useful against Fusarium wilt pathogens of guava. The extracts/leaf of these plants can be mixed to the soil near root zone of wilted guava plant to control the wilt problem. Meanwhile consortiums of Trichoderma sp. as biocontrol agent guava wilt pathogen *viz. F. oxysporum f. sp. psidii and F. solani* may be further tested and used for effective management of the disease.

Conclusion

Guava is considered as one of the exquisite, nutritionally valuable and remunerative crops Disease is complex. (a)

Several pathogens may cause wilt of guava, However, *Fusarium oxysporum, F. solani, F. clamydosporum, Gliocladiumroseum* are important pathogens (b) Role of nematode is in aggravating the disease (c) Frequency of *F. solani* was found more common. (d) *G. roseum* was found aggressive pathogen (e) Degree of severity depends on the pathogen and strain (f) Minimum tillage should be done in guava field especially during monsoon/after rain (g) Flood irrigation to be avoided. It should be either basin irrigation or drip irrigation (h) Complete Integrated Disease Management practice need to be adopted for the effective management of disease (i) Maintenance of plant population is a practical solution and the gap made by wilted plant immediately be filled (j) In West Bengal crop rotation has proved effective, where plant growth is fast and 5-6 years old plants gives good yield.

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