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Reviving Citrus Splendor: Managing Mandarin Decline in Northeast Himalayas

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SUMMARY

Mandarins, a citrus species, face numerous biotic stressors leading to significant economic losses from citrus decline. In North-East India, where mandarins are cultivated, forty-two insect species exacerbate this issue due to the region's high rainfall and humidity, ideal for pest proliferation. Various factors contribute to citrus decline, including suboptimal orchard sites, drainage issues, and inadequate nutrition. Additionally, improper practices like mixed planting and neglect worsen the situation. Common ailments include Phytophthora root rot, attacks by borers and aphids as well as viral infection. The present article explores the causes, symptoms, and management strategies for mitigating citrus decline in the northeastern Himalayan region.

INTRODUCTION

Cultivation of Mandarin oranges (*Citrus reticulata*) is greatly affected by a multitude of pathogens, presenting substantial obstacles to cultivators. The diminishing state witnessed in Mandarin orchards arises from various origins. Historical data attributes this decline to factors such as soil irregularities, nutrient scarcities, and invasions by parasitic organisms like fungi and the greening pathogen (Raychaudhuri et al., 1969; Ahlawat & Raychaudhuri, 1998). Despite documentation of this ailment dating back to the 18th century (Capoor, 1963), its severity has increased in recent epochs, causing significant losses and escalating concerns among growers (Ahlawat, 2007). Mainly, the proliferation of insect pests, fungi, bacteria, and viruses has emerged as the principal causative factor, greatly hindering Mandarin production. Typically, following a vigorous initial growth phase lasting five to six years, Mandarin orange and other citrus species display a gradual decline characterized by reduced vigor and productivity. Although afflicted trees generally avoid mortality, they display symptoms such as stunted growth, chlorotic foliage, sparse canopy, twig dieback, and an overall weakened appearance (Shivankar, 2000). In regions marked by high rainfall and humidity, such as the northeastern territory, conducive conditions prevail for prolonged pest and disease activity, exacerbating the issue (Ghosh, 1978). Several contributing factors, including suboptimal site selection, high water tables, poorly drained soils, inferior planting materials, inadequate nutrition, excessive shading, subpar management practices, and pressures from pests and diseases, have been identified as leading to orchard decline in the region (Gupta, 2000). Additionally, cultivation of inappropriate intercrops poses a significant concern, potentially causing root injuries, especially to feeder and fibrous roots (Upadhyaya, 2000; Yadav, 2000). Cultivation of incompatible intercrops, such as arecanut, jackfruit, and banana in the Khasi and Jaintia hills, and maize, ragi, buckwheat, and ginger in Sikkim, leads to compromised Mandarin growth and canopy development. Conversely, prudent intercropping with appropriate crops like radish, cauliflower, cabbage, carrot, tomato, peas, fodder crops, cowpea, rice bean, soybean, and okra can improve soil fertility while increasing growers' incomes. Furthermore, papaya and pineapple cultivation during the initial orchard establishment phases can be advantageous. Nevertheless, widespread neglect, mixed planting practices, improper spacing, vigorous weed growth, inadequate nutrition (particularly zinc and calcium deficiencies), and invasions by Phytophthora root rot, gummosis, powdery mildew, canker, scab diseases, borers, aphids, scales, mites, and leaf miners collectively contribute to the severe decline observed in Mandarin orchards (Hore & Barua, 2004; Ghosh, 1978). Consequently, due to a combination of factors including lack of awareness, challenges associated with hilly terrains, and deficient marketing infrastructure, growers often exhibit apathy towards orchard management, content with the fruits garnered from nature's bounty.

Role of Insects/Pests and Diseases for Decline

In the northeastern region, a total of 42 insect species have been identified as significant pests in mandarin and other citrus cultivation, exacerbating the issue of citrus decline (Hore and Barua, 2004). The escalation in insect infestation is likely linked to deforestation and the continuous emergence of new flushes in

the region, typically occurring from February to March, sometimes extending into April, with minor flushes in June-July and September-October. Shivankar (2000) attributes the insect pest problem to several factors: (i) the absence of effective plant protection measures, (ii) intense and prolonged rainfall, (iii) the presence of dispersed orchards, (iv) widespread neglect, and (v) the uneven terrain. The symptoms, diseases, and pest management strategies for mandarin cultivation have been periodically outlined by various researchers (Shivankar et al., 2002; Das et al., 2007; Hore and Barua, 2004; Ahlawat, 2007).

Trunk and stem borer (*Monochamus versteegi* Ritsema, Cerambicidae: Coleoptera**):** The predominant pest infesting mandarin trees within the North-Eastern Himalayan (NEH) region and is identified as a significant threat. Larvae of this pest penetrate the trunk in close proximity to the tree's base, excavating tunnels adjacent to the pith. One effective method for pest management involves the manual collection and eradication of adult specimens. Additionally, implementing a soil treatment regimen by applying a 5% concentration of aldrin to the soil surrounding the trees at depths ranging from 6 to 8 centimeters serves as a preventive measure to mitigate against infestation.

Citrus leaf miner (*Phyllocnistis citrella* Stainton, Phyllocnistidae : Lepidoptera): The larvae of this species exhibit a distinctive behavior of creating zigzag-shaped mines on foliage. Subsequent infestation induces characteristic symptoms such as yellowing, twisting, and eventual desiccation of the affected leaves. Effective management strategies involve the application of monocrotophos 36 WSC solution (0.036%) between the months of March to August. Furthermore, fenvalerate solution at a rate of 1 ml/litre of water demonstrates significant efficacy for duration of up to 45 days following application. Natural control measures involving the predatory species, namely black chalcid and chrysopid, show promising potential for regulating the population of this pest.

Citrus psylla (*Diaphorina citri*, Kuwayama, Psyilidae: Homoptera) is characterized by its orange-yellow nymphs, which extract cell sap from new growth and flowers primarily during the months of March-April and July-August. Management of this pest involves the application of monocrotophos 36 WSC (0.036%) during periods of new flush emergence, while *coccinellids* serve as effective predators against the nymphs.

Citrus aphids (*Toxoptera spp.*, Aphididae: Homoptera) pose a threat as both adults and nymphs feed on the sap of tender leaves and shoots, leading to plant devitalization. Severe infestations result in curled and deformed leaves. The spread of the *Citrus tristeza virus* by various aphid species necessitates control measures such as foliar application of 0.02% methyl demeton or monocrotophos at weekly intervals. *Coccinellids* also play a significant role as predators of aphids.

Mealybug (*Planococcus citri* Risso, Pseudococcidae: Horoоptera) is economically damaging to Khasi mandarin crops in Meghalaya, with nymphs and females causing significant damage to leaves and fruit bases, leading to heavy fruit drop. Effective management strategies include pruning affected shoots in winter and spraying a mixture of dimethoate (150 ml) and kerosene oil (250 ml) in 100 liters of water to control mealybugs.

The **fruit-sucking moth** (*Othresis fullonica*) targets ripening fruits during late evening hours, puncturing them to suck juice, potentially leading to infections and fruit rot. Prevention methods involve collecting and destroying dropped fruits, followed by orchard smoking in the late evening. Poison bait consisting of malathion (20g), diazinon (50 ml), brown sugar (200g), vinegar, and water (2 liters) per wide-mouth bottle, applied at a rate of one bottle per 25-30 trees during September-October, proves effective. Additionally, hanging methyl eugenol (pheromone) traps aids in controlling fruit flies.

Citrus butterfly (*Papilio demoleus* L., Papilionidae: Lepidoptera) poses a threat to nurseries, with larvae causing severe damage by feeding on leaves from the margin inwards. Control measures include spraying with endosulfan 35 EC (0.05%) or monocrotophos (0.036%) upon detection of an attack.

Bark eating caterpillar (*Inderbela spp.*, Melarbelidae:Lepidoptera)poses a significant threat to regions including Meghalaya, Mizoram, and Arunachal Pradesh. The larvae consume bark tissue, creating perforations in stems for concealment, ultimately stunting tree growth. To mitigate this pest, it is advised to remove webbing and administer methyl parathion 50 EC (0.1%) to main limbs and trunk during February-March.

Mites (*Eutetranychusorientalis*Klien, Tetranychidae:Acarina) sustains itself by extracting cellular sap from leaves and fruits, leading to desiccation and necrosis. Effective control measures involve foliar application of dicofol at 1.5 ml/L or monocrotophos at 1 ml/L upon detection to minimize infestation.

Citrus nematode (*Tylenchulus semipenetrans)* adversely impacts tree growth and productivity without causing mortality. Management strategies include the application of dichlorofenthion at 45 ml/ha to diminish nematode populations.

Phytophthora root rot or gummosis manifests as rootlet decay, trunk girdling, and foliage deterioration, often accompanied by yellow gummosis at the cambium and longitudinal bark fissures. Control methods include establishing Phytophthora-free nurseries, painting Bordeaux mixture on trunks up to 50-60 cm, and utilizing tolerant rootstocks.

Twig blight, attributed to *Bacillus theobromae* and *Colletotrichum gloeosporioides*, results in reduced canopy volume and fruit yield. Pruning dead twigs and employing benzimidazole sprays are effective management approaches.

Citrus scab, caused by *Elsinoe fawcettii*, induces corky outgrowths and leaf deformities, impairing plant vigor. Disease-free plant selection, removal of infected foliage, and prophylactic sprays of captafol or benomyl aid in disease management.

Sooty mold, associated with *Capnodium spp*., proliferates on insect secretions, impeding plant growth. Regular application of Bordeaux mixture effectively controls this disease.

Powdery mildew, caused by *Acrosporium tingitaninum*, manifests as white patches on leaves and twigs, leading to foliage discoloration. Tridemorlh, triadimefon, and benzimidazole sprays are recommended for control.

Citrus greening, caused by Phloem-restricted gram-negative bacteria (*Candidus liberibacter asiaticus*, *Candidus liberibacter africanum*), results in stunted growth, twig dieback, and mottled leaves, ultimately reducing fruit quality. Control measures involve uprooting and burning infected trees, managing the vector citrus psylla, and administering tetracycline or penicillin injections.

Citrus canker, caused by *Xanthomonas citri* bacteria, manifests as water-soaked lesions that progress to brown, corky spots. Disease control entails pruning and incinerating infected twigs, spraying emerging flushes with 1% Bordeaux mixture, or applying streptomycin sulphate (500 ppm).

Moreover, citrus including mandarin orange is mostly infected with number of viruses and virus like pathogens internationally (Ahlawat and Pant 2003). After a long studies on dieback of citrus revealed that a few virus and virus like pathogens play the major role in citrus dieback or decline (Ahlawatand Srivastava 1997) and these are briefly described as follows.

Citrus Tristeza Virus(CTV):

It is a phloem limited plant virus with long flexuous particle, 2000 × 11–12 nm in size belongs to the genus Clostero virus is transmitted mainly by brown citrus aphid, *Toxoptera citricidus* in semi-persistent manner and spread over distant areas by transportation of infected planting material (Rocha-Pena et al. 1995). In India CTV is one of the important factors causing decline of mandarin in the Darjeeling hills (Ahlawat and Raychaudhuri 1998, Biswas 2008). CTV infects nearly all the citrus species, cultivars, and inter-generic hybrids and some citrus relatives, inducing symptoms like decline, stem pitting, seedling yellows, vein clearing and flecking (Biswas 2010, Biswas et al. 2012, Lee et al. 2000, Sharma et al. 2012). CTV isolates differ in their biological characteristics, types and intensity of symptoms induced in different citrus hosts and aphid transmissibility (Karasev et al. 1995). Since CTV is transmitted by aphids, *Toxoptera citricidus, Aphis gossipii, A.spiraecola, T. aurantii.* These insect vectors can be controlled by using biological and non-biological methods in order to stop spread of the diseases. Non biological methods include use of insecticidal sprays, insect traps, reflective mulches etc. Different biological agents include parasitoids, predators and microbes. Parasitoids are insect specific. The genera Aphelinus, Mesidia and Mesidiopsis of Aphelinidiae (Super family Chaloidoidae) are of parasitoids of aphids.Similarly different coconellides are useful predators of aphids. Entomopathogenic fungi like *Verticillium lecanii* and *Paecilomyces farinosus* are in practice to control T. citricidus and Aphis gossypii (Varma and Ghosh 2000). The biotechnological approaches have opened new dimensions to develop virus free planting material (Parthasarathi 1999, Ahlawat 2000b) and Foundation blocks from STG plants at different citrus growing regions need to established which will again require regular testing for virus or virus like pathogens.

Indian Citrus Ringspot Virus (ICRSV)

The disease can be easily recognized in field trees by its characteristic symptoms chlorotic rings of various sizes on leaves of affected trees. The rings may be one to several per leaf and are mostly found on mature leaves. The affected cultivars were Malta, Mosambi, and Satgudi sweet orange (*C. sinensis* (L) Pers.), Nagpur orange (*C. reticulata* Blanco), Kinnow mandarin (the hybrid of Willow x king mandarin) and Kagzi lime and Kagzikalan (*C. aurantifolia* (Christen) Swingle) in different orchards of Delhi, Haryana, Punjab, Karnataka and Andhra Pradesh. Most of ICRSV affected trees showed decline or die-back symptoms and quality and quantity of fruits was greatly affected (Ahlawat and Pant 2003). The ringspot disease is graft transmissible from citrus to citrus and mechanically transmissible by inoculation from citrus to herbaceous hosts like *Chenopodium quinoa* and *Phaseolus vulgaris* var. saxa, singtamey, gheusami and alapatri (Pant et al. 1997, Pant and Ahlawat 1997, Hoa and Ahlawat 2004). So far no method other than vegetative propagation is known for its natural spread. The disease can also be eliminated from the bud sticks by dipping them in neemax, carbendazim, resorcinol, thuja and neem cake for 30, 60 and 120 minutes (Lore 1999).

Citrus Yellow Mosaic Virus (CMBV)

CMBV belongs to the family Caulimoviridae and genus Badnavirus (Baranwal et al. 2005, Huang and Hartung 2001, Pringle 1999) that causes a graft transmissible mosaic disease in citrus species and cultivars which has been named citrus yellow mosaic disease or sometimes citrus mosaic disease and results in reductions in yield and fruit quality (Ahlawat 2000a). However, the etiology of these diseases was not established. CMBV symptoms in leaves of infected field trees are bright yellow mottling and yellow flecking and vein banding. The infected trees are slightly stunted and leaf size is smaller than in healthy trees. Trees affected by the disease not only produce a significant yield reduction, but also fruits with reduced quality (yellow depressed and green elevated areas symptoms), juice and ascorbic acid content (Ahlawat et al. 1996, Ahlawat 2000a). The vector of the virus is a mealybug, *Planococcus citri* but its role in natural spread appears to be minimum (Pant and Ahlawat 1997). Contaminated field implements can transmit these diseases during orchard operations. Therefore, all the operational tools including pruning and grafting tool should be sterilized with 1-2% sodium hypochloride before use.

CONCLUSION:

Decline of mandarin orange cultivations in the North-East India is a multifaceted issue influenced by various factors including environmental conditions, pest and disease pressures, and management practices. The intricate interplay of these factors has led to significant challenges for growers, resulting in diminished orchard vigor and productivity. The role of insects and pests, such as trunk and stem borers, citrus leaf miners, citrus psylla, citrus aphids, mealybugs, fruit-sucking moths, citrus butterflies, bark-eating caterpillars, mites, and citrus nematodes, cannot be overstated in exacerbating the decline of mandarin orchards. Effective management strategies targeting these pests, including chemical applications and biological control methods, are crucial for mitigating their impact on orchard health. Moreover, the presence of various pathogens, including viruses like Citrus Tristeza Virus (CTV), Indian Citrus Ringspot Virus (ICRSV), and Citrus Yellow Mosaic Virus (CMBV), further complicates the scenario. These viruses, along with other diseases like citrus greening, citrus canker, twig blight, citrus scab, sooty mold, and powdery mildew, contribute to the overall decline observed in mandarin orchards. Addressing these challenges requires a multifaceted approach encompassing integrated pest management strategies, disease surveillance and control measures, improved orchard management practices, and the development of virus-free planting materials. Furthermore, raising awareness among growers about the importance of proper orchard management and the adoption of sustainable agricultural practices is paramount in safeguarding the future of mandarin cultivation in the region. By implementing comprehensive solutions and fostering collaboration among researchers, growers, and policymakers, it is possible to mitigate the decline of mandarin orchards and ensure the long-term sustainability of citrus cultivation in the northeastern region.

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