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HORTICULTURE

# Khasi mandarin: its importance, problems and prospects of cultivation in North-eastern Himalayan region

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**Abstract**

Northeast India is recognized as an important part of the Indo-Burma biodiversity hotspot. It is one of the 25 global biodiversity hotspots accepted at present. This is also considered as the richest and one of the most endangered places for plant survival in the world. This area is known as one of the centers of origin of various Citrus species. Among the Citrus crops available in northeastern region, Khasi mandarin is the most economically important one and plays a vital role in the socio-economic development of the people in this region. Khasi mandarin is well known for its quality, fruit colour, unique sugar-acid blend and shelf life which make it the most popular citrus cultivar in northeastern region of the country. It covers the largest area in the region due to its commercial value. Assam and Meghalaya have the maximum area and production of Khasi mandarin. The health benefits of oranges have been well known for centuries, but it has therapeutic values that have long been utilized in conventional herbal medicine. Experimental studies shows that its bioactive compounds have tremendous pharmaceutical activity like, antibacterial, antimicrobial, antiviral, antioxidant, cancer preventing etc. which clearly indicate the potential of the crop for the pharmaceutical industry. Although India is fourth largest producer of orange in the world but due to the problem of citrus decline the average yield of orange in India is alarmingly low as compared to other countries. This review thereby summarizes the medicinal and nutritional value of mandarin, their economic importance, problems and prospects of cultivation in northeastern region.

**Highlights**

- Bioactive compounds of mandarin orange and its pharmaceutical activity
- Nutritional profiling of mandarin orange
- Decline of Khasi mandarins, its causes and management strategies. Scientific cultivation, in vitro shoot tip grafting, disease studies etc.Keywords: Backcross progenies, submergence, sub1 gene, survival percentage, yield per plant, oryza sativa

**Keywords:** Khasi mandarin, medicinal value, mandarin decline, bioactive compounds, nutritional importance and health benefits

The loose-skinned Khasi mandarin orange (*Citrus reticulata* Blanco) belongs to the family *rutaceae* is one of the most financially important and worldwide accepted fruits. It constitutes about 43.6% of the total citrus fruits produced and occupies nearly 38.2% of the total citrus area in India (National Horticulture Board 2010-11). Commonly it is known as Sohniamptra in *Khasi*, Humoptira or Komola in *Assamese*, Komla in *Bengali* and *Manipuri* (Singh 1990). India is the fourth largest producer of orange in the world followed by Brazil, USA, and China. The total area under cultivation for mandarin is 3.11 lakh hectare with the production of 29.06 lakh tons. The total export of orange from India is 33628 metric

tons with the value of ₹ 3529 lakh. Bangladesh is the biggest importer of Indian orange and share 89.6% of total export (NHB 2012-2013).

The northeastern region of India is considered as one of the natural home or primary gene centre (Ziegler and Wolfe 1961, Ghosh 1977, Govind and Yadav 1999, Ray and Deka 2000, Ghosh 2007) and reservoir of various *Citrus* species including mandarin orange (Tanaka 1958, Singh and Chadha 1993, Chadha 1995, Hazarika 2012). In this region, many *Citrus* species originated and later dispersed to leading citrus growing countries of the world. Meghalaya is the major state in both area and production in the northeast (Singh 2001). The northeastern Himalayan region is one of the three major centers of mandarin orange in India. Approximately 1600 ha are under mandarin orange cultivation scattered over nine states namely Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura, Sikkim and the Darjeeling district of West Bengal, where this high value crop contributes significantly to the small farm economy. A few ecotypes like 'Darjeeling mandarin' or 'Khasi mandarin' are excellent in quality and have good export potential (Ghosh and Singh 1993). Recently the Meghalaya government has obtained the Geographical Indication (GI) of goods for Khasi mandarin in the year 2014 under the Geographical Indication of goods (Registration and protection) Act 1999.

Moreover, the state of Manipur, Mizoram, Meghalaya and Tripura of northeast India falls under the 'Indo-Burma Region' of biodiversity hotspot, which is highly diverse and one of the most endangered places for plant life on the earth (http://www.biodiversityhotspots.org) while the state of Arunachal Pradesh and Sikkim belong to eastern Himalayan biodiversity hotspot. Due to the problem of citrus decline, recently the average yield of orange in India is gradually going to be low (9.3 Mt/ha) as compared to other countries like USA (32.6 Mt/ha), Brazil (24.7 Mt/ha) and China (13.7 Mt/ha) (NHB 2012-2013, FAOSTAT 2013). The global problem of citrus decline warranted special attention of agricultural scientists during the past few decades. Citrus decline in India refers to a particular syndrome known as dieback. It involves the defoliation of young shoots and dying back of twigs from the tip downwards, resulting in loss of vigour, general health, and decreased fruit production. The disorder is reported to have been present as early as the eighteenth century (Cheema and Bhat 1929, Capoor 1963) but it has assumed alarming proportions during the last century causing heavy losses and increasing concern to the growers. Citrus is infected with large number of viruses and virus like pathogens worldwide and in India too (Ahlawat and Pant 2003). There are several factors responsible for the citrus decline but the major factors are insect/pest, some viral, fungal and bacterial diseases and nutritional deficiency. Three decade studies on dieback of citrus revealed that a few virus and virus like pathogens play the major role in citrus dieback or decline (Ahlawat 1997). The viruses reported from mandarin in India are *Citrus tristeza virus* (Chakraborty *et al*. 1992, Biswas 2008), *Citrus yellow mosaic virus* (Ahlawat *et al.* 1985) and *Indian citrus ring spot virus* (Byadgi and Ahlawat 1995).

Furthermore, mandarins of northeastern region have got little attention towards infecting viruses and extremely limited information as well as experimental data are available for the occurrence and spread of viruses in this part of India. However, merely one report of tristeza virus (Bhagabati *et al.* 1989) and one report of yellow mosaic virus (Ahlawat *et al*. 1985) are available based on simple survey and indexing in Khasi orange for the entire northeast region of India. Apart from this, Biswas (2008, 2010), Biswas *et al.* (2012) and Tarafdar *et al.* (2013) have characterized *Citrus tristeza virus* based on biological reaction and sequencing of viral genome. Some *Citrus tristeza virus* variants have been reported but it is only confined to Darjeeling hills which cannot be the true representation of entire northeastern Himalayan region of India. Due to this there is a lack of awareness among growers about the practice of raising orchards from disease free material. Although area under cultivation is growing but the budwoods are always taken from sources which are already diseased helping the virus in surviving and spreading further. It is, therefore, hypothesized that if appropriate planting material is used for raising orchards, there can be sharp increase in productivity which is expected by the growers of northeastern Himalayan region as evident from the persistent demand of the farmers for disease free quality planting material.

## Morphological Characteristics

As per the National Research Centre for Citrus (NRCC), Amravati Road, Nagpur (Maharashtra) the Khasi mandarin has the following morphological characters:

1. Tree growth habit of full grown bearing tree: Erect
2. Leaf length of fully expanded leaves of spring flush: 70- 80 mm
3. Leaf width of fully expanded leaves of spring flush: 30-40 mm
4. Fruit weight at harvest maturity: 110 – 140 g
5. Fruit diameter at harvest maturity: 60-70 mm
6. Fruit length at harvest maturity: 55-65 mm
7. Shape of fruit base at harvest maturity: Truncate
8. Shape of fruit apex at harvest maturity: Truncate
9. Fruit rind (epicarp) colour at harvest maturity: Dark orange
10. Fruit rind thickness at harvest maturity: 2-3 mm
11. Fruit juiciness at harvest maturity: More than 45%
12. Total soluble solids at harvest maturity: More than 11° brix
13. Titratable acidity (% citric acid) at harvest maturity: 0.5-0.7%
14. Number of seeds per fruit at harvest maturity: More than 5
15. Seed boldness (weight of 20 seeds in g) at harvest maturity: More than 1.10 g

### *Nursery Management*

Mandarin trees are propagated either by seed or vegetative means. The most preferred method is vegetative propagation over other means as it ensures true to type plants, uniform quality, early bearing etc. 'T' budding is most favored propagation method but due importance should be given in the selection of virus free scion variety. Singh (2000) reported that in northeastern Hill region seedlings are being used for limes and mandarin orange. Mother plant selection for seed and budwood is the most important criterion for production of healthy planting material. The productivity, longevity, fruit quality and disease free quality depend on mother plants. That's why, mother plants selection should be from authentic sources with well known ancestry in respect to health, vigour, regular bearing and high yield with good fruit quality. Budwood always must be taken from healthy developed wood of present session growth or next to last growth. For rootstocks, seeds have to be collected from mature and healthy fruits of disease free mother plant. This is important because rootstock is for imparting the characters like productivity, vigour, precocity, physico-chemical characters of fruits, longevity of tree, disease resistance characteristics etc. Mostly the seeds of the *Citrus* spp. are recalcitrant and can be handled only by following the storage protocol. It is desirable to raise nursery in light, well drained fertile soil, free from soil borne pathogens and nematodes. Minimum height of seed bed should be 10 cm with 1 m width, which help in easy cultural operations. In order to raise the healthy primary nursery, plastic tray of 60×40×12 cm size is ideal. Seeds are sown in sterilized soil mixture (one part fertile soil + two part sand) with a spacing 2.5-3.5 cm in the row of 7.5 to 10 cm between the rows. For raising secondary nursery, a bed of 3x3 m size with a height of 8-10 cm from ground level is prepared. Seedlings, when 10-12 cm tall, having 8-10 leaves are usually transplanted to secondary nursery. For Khasi mandarin, nursery is raised in the month of June-July and budding is done in the month of March-April. Bud union should be at height of 20-25 cm above the ground level to avoid the burial of the union and thereby avoid infection. For the nursery management against the pests and diseases like leaf miner, leaf eating caterpillar, citrus psylla and aphids the application of quinalphos @ 1.0 ml or monocrotophos @ 0.5-1.0 ml and against mites dicofol @ 1.5 ml/l water are recommended for secondary nursery (Hore and Barua 2004).

### *Medicinal Uses of Mandarin*

The mention of various citrus fruits has been found in Ayurvedic works of Dhanwantri (10$^{th}$ B.C.), Charak and Susruta written in 600 to 500 B.C. The species described are *Citrus medica* (Beejpur or Matulung), *C. jambhiri* (Jambhiri nimbu), *C. aurantifolia* (Nimbuk, Kagzi nimbu), *C. limetta* (Mitha nimbu), *C. grandis* (Amalvetas, Chakotra), and *C. reticulata* (Narang or Santra) (Sharma *et al.* 2004). Mandarin is widely consumed around the world for its delicious qualities, but it also has therapeutic

values that have long been used in traditional herbal medicine (Zhang *et al.* 2012). Some of the medicinal uses of mandarin orange are mentioned below:

- Mandarins are eaten to allay fever and catarrh. The fresh rind is rubbed on acne. The poultice of roasted pulp is used for skin diseases. Because of its bioflavonoids and inositol, complete mandarins are very useful. It contains a considerable amount of the vitamin like glucoside, hesperidin mostly (75-80%) present in the rind, rag and pulp. The infusion of immature fruit is used for the treatment of stomach and intestinal problems. (Morton 1987, Anonymous 2014, 2009).
- The mixture of pulverize inner bark and wine is taken as a tonic and carminative. In China a vinous decoction of husked orange seeds is prescribed for urinary diseases. The fresh leaves juice or a decoction of the dried leaves can be used as a carminative or useful on sores and ulcers. In Ecuador, seed extract is used for the treatment of malaria. (Morton 1987, Anonymous 2014, 2009).
- Chinese people used the flowers medicinally who lived in Malaya. In Italy and France orange flower water is used as cologne. In Italy, decoction of the dried leaves and flowers is given as an antispasmodic, cardiac sedative, antiemetic, digestive and remedy for flatulence (Morton 1987).
- In traditional Chinese medicine, the dried peel is used for abdominal swelling, to increase digestion, and to reduce phlegm, and its various parts are used to cure cutaneous problem, hemiplegia, snake bite, fever, loss of taste, chronic rheumatism, stomach ache, menorrhagia, spleenomegaly, edema and cardiac diseases, bronchitis and asthma (Xian *et al.* 2007, Min-Sheng *et al.* 2008).
- In the conventional Chinese medicine the dried mature fruit peels have been widely used for centuries as remedies for indigestion and to improve inflammatory syndromes of the respiratory tract (Yung-Sheng *et al.* 2010).
- In Vietnam, seeds are traditionally used for the treatment of infectious diseases, frequent urination, a major symptom of urinary tract infection, as well as inflammation of the breast and scrotum (Loi 1999, 2000).
- Mandarin has been used in traditional Chinese medicine, the dried pericarp of the fruits is used mainly as an expectorant or stomachic; the pericarp of the unripe fruits is used among other things in the treatment of hernia; the dried unripe fruits of orange and its cultivated variant are used in diarrhoea, anal prolaps and frank prolaps; the seeds are used mainly in the treatment of hernia (Tang and Eisenbrand 1992).
- Decoctions from *C. reticulata* seeds protect the uroepithelium against *E. coli* infection (Vollmerhausen *et al.* 2013).

### *Nutritional Importance and Health Benefits of Mandarin*

The health benefits of oranges are well known for centuries. The oranges are not just known for its high vitamin C content; these are also a good source of beta carotene, a powerful antioxidant to check free radical damage, magnesium for blood pressure, potassium for cardio vascular health, and thiamin for converting food to energy (Anonymous 2009). It is also rich in dietary fiber and contains folates, niacin, pantothenic acid, pyridoxine, riboflavin, vitamins A, E and K, and phytonutrients (Table 1). Here are a few examples of some of the benefits of oranges.

- Folates in oranges helps prevent birth defects and is good for the heart. Wilbur *et al.* (2000) reported the importance of folate to human health where it was shown to reduce neural tube birth defects by up to 75% when taken by women prior to conception and during pregnancy. Folate has also been associated with a reduced risk of heart disease by lowering blood serum homocystine levels.
- Pectin found in oranges is a dietary fiber reported to reduced the serum cholesterol, hypercholesterolemia and promote the excretion of fats, bile acid, cholesterol (Baker 1994) and posses growth suppression of prostate cancer cell (Hsieh and Wu 1995).
- Rouseff and Nagy (1994) reported that a 227 ml serving of either grapefruit or

orange juice will provide 100% of the U.S. Recommended Daily Allowance (U.S. RDA) intake for vitamin C.

- Therapeutical value of carotenoids found in orange could be the important first line of defence against ROS and also took part in catalytic activity. It helps in the deactivation of carcinogens (Ram and Singh 2006).
- Matsuda (1991) in Japan evaluated the primary orange juice flavonoid, hesperidin and found significant ability to inhibit histamine release from pertinent mast cells of rats, suggesting that hesperidin may be an effective component with anti allergic action.
- In orange good quantity of naringenin is found. The neuro-protective action of naringenin is established (Zbarsky *et al.* 2005) and this helps the management of diabetic neuropathies.
- Aruoma *et al.* (2012) reported that citrus fruit extracts represent an excellent candidate for nutraceuticals and functional foods geared towards the management of diabetes, cardiovascular diseases and cancer.

### *Commercial Prospect of the Crop*

Mandarin has significant economic value for its essential oil due to their aromatic compounds (Minh Tu *et al*. 2002). Flavours of lime are used in beverage, confectionary, cookies and desserts (Buchel 1989, Dharmawan *et al*. 2007). For flavoring of liquor the exocarp of *C. reticulata* is used. Few studies have already reported the chemical composition of *C. reticulata* peel oil (Shaw 1979, Lawrence 1992). Chutia *et al*. (2009) suggested that mandarin oil and its components can be used as an alternative of synthetic fungicides or preservatives.

Furthermore, Three types of flavonoids occur in citrus are flavanones, flavones and flavonols, amongst them polymethoxylated flavones, such as nobiletin (hexamethoxyflavone), and tangeretin (pentamethyoxyflavones) fond in mandarin fruit pericarp (Duke 1992) are of particular interest since polymethoxylation is associated with more potent biological activity (Macheix *et al.* 1990, Benavente-Garcia *et al.* 1997). It was found that tangeretin was the most potent of all citrus flavonoids tested for ability to inhibit the invasion of tumor cells into normal tissue fragments in organ culture (Bracke *et al.* 1991). The polymethoxyflavones show chemopreventive potential in antimutagenic and antitumor properties (Li *et al.* 2009). Citrus peels contain more bioactive compounds, such as phenolic acids, flavonoids, limonoids, and fibre (Qizhen and Hui 2010). Experimental studies have demonstrated its analgesic, antibacterial, antimicrobial, antiviral, antiyeast antifungal, antidiarrheal, antiinflammatory, uricosuric activity, antimutagenic, antisplasmodic, antiatherogenic, antiperoxidative activity, anticarcinogenic activity, and radical scavenging activity (Sacchetti *et al.* 2005, Sokovic and Griensven 2006). According to Rane Zab and Bhaskar (2012) the ethanolic peel extract of mandarin contains bioactive compounds such as Maltol, 3,5-Dihydroxy-6- methyl-2,3-dihydro-4H-pyran-4-one, 5-Hydrxoymethylfurfural, Nitroisobutylglycerol, Heptamethoxyflavone, Glycerol, etc. (Table 2) which have tremendous pharmaceutical values and clearly indicate the potential of the crop for the pharmaceutical industry.

### *Production*

The rich soil conditions, wide rainfall range and existence of different altitude from almost sea levels to 1500 m above, place this part of India a unique position for the adaptation of almost all the *Citrus* species and varieties of commercial importance. In spite of being a natural home of many *Citrus* species, hardly any of the northeastern state figures standing in the mandarin production scenario in the country. Area and production of eight northeastern states are given in Table 3. In the region, low productivity of mandarin may be due to long spells of rainfall (up to 6-7 months), soil erosion due to cultivation up to $60^{O}$–$70^{O}$ slopes, plantation on seedlings, no use of modification in acidic soils, zinc deficiency, rainfed cultivation, malnutrition of major and minor elements, no management for pests and diseases and predominance of viruses like tristeza and greening (Singh and Srivastava 2006).

Rootstocks have varied effects on scion vigour and size, fruit yield and quality and tolerance to various biotic and abiotic stresses. These also differ in their adaptability to various soils and micorrhizal dependency (Ford 1959, Nemec 1978, Castle 1987). Horticultural performance of citrus scion cultivars is affected by rootstocks in several ways *viz*. (i)

precocity in bearing, (ii) uniform tree size, (iii) cropping and fruit quality control, (iv) tolerance to unfavourable soil factors such as salinity, high pH and poor drainage and (v) tolerance to *Phytophthora,* parasitic nematodes and viruses (Wutscher, 1979). The very little information has restricted the use of various germplasm in the northeastern region. Bhattacharya and Dutta (1952) reported Kata jamir *(C. jambhiri)* as a satisfactory rootstock for the Khasi mandarin. However, it shows less intensity of dieback symptom as compared to mandarin seedlings, but it is vulnerable to soil salinity and root rot disease but also susceptible to nematode infection, which might be the main reason for citrus decline (Agarwal 1982). Due to this reason only, it has been replaced by the trifoliate orange and their hybrids. Chadha and Singh (1990) summarised the information on the basis of horticultural performance of the rootstocks to the stress (Table 4).

In the entire northeastern region mandarin orange orchards are seedling originated. In the past some rootstock trials were conducted at the Fruit Research Station, Burnihat, Meghalaya. For Khasi mandarin scions Nandi *et al.* (1943) tried rootstock species and the varieties like *C. grandis, C. jambhiri, C. aurantium, C. macroptera* and *C. limon* and found that *C. limon* performed well with better vegetative growth and gave maximum fruit yield. Afterward Sheo Govind *et al.* (1994) found that the Khasi mandarin scion budded on Rangpur lime rootstock gave highest growth and yield followed by *C. volkameriana.* The features of some of the important species of the region, which may serve as suitable rootstock, are mentioned bellow

1. Rough lemon *(Citrus jambhiri)*: Trees of rough lemon turns out to be high yielder, but having poor fruit quality. It is tolerant to tristeza and fairly tolerant to saline and calcareous soils, but susceptible to foot rot and blight.
2. Trifoliate orange *(Poncirus trifoliata)*: It is a deciduous in nature and a relative of the genus *Citrus*. It is susceptible to exocortis and blight, but tolerant to root rot, nematode. Scion budded on trifoliate orange gave high yield with excellent fruit quality, which is also resistant to frost (William 2010).
3. Citranges *(Citrus sinensis* × *Poncirus trifoliate)*: Some of the citrange varieties like Troyer and Carrizo have become important rootstocks these days. They have wide range of soil adaptability, markedly resistant to soil borne diseases and nematodes and tolerant to tristeza virus. This is a cold hardy, semi dwarfing rootstock and heightens fruit quality slightly. It is highly susceptible to exocortis viroid (William 2010).
4. Rangpur lime *(Citrus limonia)*: A better rootstock with excellent adaptability to wide range of soil, predominantly for heavy soil. It is tolerant to tristeza virus and soil salinity. However, trees are susceptible to foot rot, exocortis and xyloporosis. Rootstock is used for orange and grapefruit.
5. Mandarin *(Citrus reticulata)*: The most common mandarin rootstock is *Cleoptara.* It is salt tolerant, tolerant to tristeza, exocortis and xyloporosis and fairly tolerant to *Phytophthora* root rot.
6. *Citrus taiwanica*: It is a new rootstock introduced from Taiwan. It has been found to be tolerant to gummosis and moderately salt tolerant.

Khasi mandarin, a much popular variety, is cultivated on commercial scale in valleys, sub mountain areas and in low hills of northeastern region. The entire mandarin orange orchards, in the region are primarily of seedling origin. Growers are still lacking with the knowledge of using suitable rootstocks. Soils of the plains are alluvial types, while in the hilly areas it is mostly lateritic. Citrus trees grow better in sandy loam soils having pH range 5.5 to 6.5. The orchards are situated on the unterraced hill slopes and practically no soil conservation measures have been adopted in such orchards, leading to washing of the rich surface soils by heavy erosive rains. Depending upon the slope, rainfall intensity and soil properties, measures like bunding, terracing, plugging and strengthening of slides of gullies etc. should be adopted (Hore and Barua 2004).

### *Mandarin Decline and its Management*

Mandarins are highly vulnerable to many types of pathogens. The growers in general are facing a serious problem of decline that is due to various causes. Previously it was thought that it happens due to various factors, including soil disorders, nutritional deficiencies, and parasitic agents such

as fungi and greening pathogen (Raychaudhuri *et al.* 1969, Ahlawat and Raychaudhuri 1998). The disorder is reported to have been present as early as the eighteenth century (Cheema and Bhat 1929, Capoor 1963) but it has assumed alarming proportions during the last decade causing heavy losses and increasing concern to the growers (Ahlawat, 2007). The major cause, however, is the prevalence of insect/ pest, some fungal, bacterial and viral diseases which have a significant impact and often become a major constraint in mandarin production. After 5 to 6 years of remarkable growth, mandarin orange and other citrus species generally start declining with slow reduction in vigour and production. The declined plants normally do not die but remain impecunious and unproductive. The symptoms comprised of retarded growth of trees, appearance of chloratic leaves, sparse foliage, dieback of twigs and in general, a sickly appearance of the tree (Shivankar 2000). In northeastern region, high rainfall and humidity provides a suitable condition for the growth and multiplication of most of the pests and diseases to attack the plant for a longer period. Ghosh (1978) pointed out the citrus decline as the major threat to the citrus cultivation in northeastern states. According to Gupta (2000) once flourishing mandarin orange and other citrus species of the region started declining and received a severe shock through this problem. Scientists from Assam Agricultural University, Jorhat summarized the following factors, which are responsible for decline in citrus orchards in the region - (i) faulty site selection for orchards, (ii) high underground water level, (iii) drained soils, (iv) improper planting materials, (v) inadequate nutrition, (vi) excessive shade in orchards, (vii) poor management practices and (viii) damage caused by pests and diseases.

Growing of undesirable intercrops is also a matter of concern (Upadhyaya 2000, Yadav 2000). Unsuitable intercrops may cause serious root injury, particularity to feeder and fibrous roots. In Khasi and Jaintia hills intercrops like arecanut, jackfruit, banana etc. are grown as intercrops, resulting into lanky growth of mandarin trees with very poor canopy development. Undesirable intercrops like maize, ragi, buckwheat, ginger etc. are being grown in the orange orchards of Sikkim, while certain growers of Jaintia hills grow turmeric very closely in the bearing orchards; orchards can be intercropped with radish, cauliflower, cabbage, carrot, tomato, peas, fodder crops, cowpea, rice bean, soybean, ladies finger etc. suitably, which would not exhaust the soil nutrients but provide the additional income to grower. Fruits like papaya, pineapple can be intercropped during the initial years of orchard establishment. The growers generally do not follow proper spacing requirements; moreover, manure and fertilizer application is also limited to those orchards. Plant protection measures against major pests and diseases are inadequate (Hore and Barua 2004). As a matter of fact, due to ignorance, difficulties in the cultivation in hilly terrain coupled with poor marketing facilities, the cultivators are reluctant to take care of their orange orchards and satisfied with the harvested fruits as nature's gift.

Ghosh (1978) reported that general neglect, mixed planting and undesirable intercropping, improper spacing, vigorous weed growth, inadequate nutrition (particularly Zn and Ca), infection of *Phytophthora* root rot, gummosis, powdery mildew, canker, scab diseases and attack of insects and pests like borers, aphids, scales, mites, leaf miners are common in mandarin oranges, which leads to severe decline in the region.

### *Role of Insects/Pests and Diseases for Decline*

In northeastern region 42 insect species are found to have major pest status in the mandarin and other citrus species cultivation aggravating the citrus decline problem (Hore and Barua 2004). The increase in the insect incidence may be attributed to the deforestation and continued new flushes in the region, which occurs from February to March extending up to April during some years followed by June – July and September – October (minor flushes). According to Shivankar (2000) the insect pest problem is due to the following reasons – (i) absence of plant protection measures, (ii) heavy incessant rainfall, (iii) scattered orchards, (iv) general negligence and (v) uneven topography. The diseases and pests, in mandarin, their symptoms and management practices are briefly described in Table 5.

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 (Ahlawat 1997) and these are briefly described as follows.

### *Citrus Tristeza Virus (CTV)*

CTV, one of the most detrimental pathogens infecting citrus and causes massive crop losses by killing over 100 million citrus trees worldwide including about one million trees in India (Ahlawat 1997, Bar-Joseph *et al.* 2008, Rocha-Pena *et al.* 1995). It is a phloem limited plant virus with long flexuous particle, 2000 × 11–12 nm in size belongs to the genus *Closterovirus* 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). Natural transmission of the virus also takes place by aphids, *Aphis gossypii*, *Aphis craccivora*, *Myzus persicae* and *Dactynotus jaceae* (Varma *et al.* 1960, 1965). CTV is also transmitted by dodder, *Cuscuta reflexa* (Ahlawat and Raychaudhuri 1982).

In India, it is experimentally established by Vasudeva and Capoor (1958), Capoor and Rao (1967). CTV and its vector *Toxoptera citricidus* probably originated in the northeastern parts of India including the countries bordering this region. In most citrus growing countries CTV and its vector both moved along with the planting material in the past (Ahlawat 2005). The distribution of CTV in India has been reported by Ahlawat (1997).

In India CTV is one of the important factors causing decline of mandarin in the Darjeeling hills (Ahlawat and Raychaudhuri 1998, Chakraborty *et al.* 1992, 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).

Virus and virus like diseases can be managed by an integrated approach such as use of virus free planting material (Ahlawat and Srivastava 1997), use of host resistance, sanitation, cultural practices, control of insect vectors, and regulatory measures (Ahlawat, 2005). 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. In areas where it is difficult to find a virus free field, pre inoculation with a mild CTV strain protects trees against infection with a severe strain of CTV. This concept of cross protection has been successfully used in management of CTV with great success in Brazil where more than 8 million Para orange trees were cross protected in 1980 (Muller, 1980) and more than 50 million trees in 1987 (Urban, *et al.* 1990). It is ideal for management of tristeza since it is often endemic vector borne virus and difficult to eradicate as there are no alternative control method (Ahlawat 2005). However, in India attempts were made long back (Balaraman and Ramakrishnan 1977). The cross protection, however, could not be adopted as technology for identification of protective strains was not available at that time (Chakraborty and Ahlawat 2001).

### *Indian Citrus Ringspot Virus (ICRSV)*

ICRSV is commonly distributed all over the country and restrict the yield of quality fruits (Byadgi *et al.*1993, Byadgi and Ahlawat 1995, Thind *et al*. 1995, Thind and Arora 1997, Sharma *et al.* 2007). It was first reported by Ahlawat (1989) in Mosambi sweet orange showing Psorosis like leaf symptoms from the State of Delhi, Maharashtra and Andhra Pradesh. Several affected trees show dieback and decline type of symptoms and the quality and

quantity of fruits is seriously affected (Ahlawat and Pant 2003). A reduction in fruit weight, number, size and juice content of infected trees has also been observed (Byadgi and Ahlawat 1995, Thind and Arora 1997, Thind *et al*. 2005). Presently surveys revealed that this disease was extensively distributed in most commercial citrus cultivars (Ahlawat and Chakraborty 1990, Byadgi *et al.* 1993). Indian strain of *Citrus ringspot virus* (CRSV) is slightly different serologically and in RNA sequence from the CRSV reported from other part of the world. 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 Kagzi kalan (*C. aurantifolia* (Christen) Swingle) in different orchards of Delhi, Haryana, Punjab, Karnataka and Andhra Pradesh with incidence ranging from 5 to 83.8% and the yield loss was estimated to be 20.5 to 98.38% (Byadgi and Ahlawat 1995). Most of ICRSV affected trees showed decline or die-back symptoms and quality and quantity of fruits was greatly affected (Byadgi *et al.* 1993, 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. However, pollen transmission and a vector were suspected for natural spread of ICRSV (Ahlawat 2005). ICRSV infects most of the commercial citrus cultivars (Byadgi and Ahlawat 1995, Pant and Ahlawat 1998). Kinnow mandarin and Mosambi sweet orange are good indicator hosts for detection of ICRSV. The disease is easily transmitted by grafting. Therefore, the recommended principle is the use of CRSV free bud wood and saplings to check the spread of the disease in the virgin area. The Budwood Certification Programme together with surveillance, indexing and identification of the CRSV free mother trees should be more stringent for raising disease free planting materials. Only certified CRSV free trees should be multiplied and distributed to nurserymen for production of CRSV free saplings. Rigorous Plant Quarantine measures should be taken to stop the supply of infected bud wood and planting materials in the new planting sites (Ahlawat 2007, 2005). 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). Citrus yellow mosaic disease is a common, widely distributed and severe disease in India and reported to occur especially in sweet orange (*C. sinensis* Osbeck) in southern states and Khasi mandarins *(C. reticulata* Blanco) in northeastern states (Dakshinamurthy and Reddy 1975, Ahlawat *et al.* 1985).

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).

Citrus mosaic disease is currently only known to occur in India where it is considered a serious disease of citrus, with losses ranging from 10 to 70% in citrus orchards and nurseries. Yield reduction is up to 77% in 10 year old trees, and fruit quality is also affected (Ahlawat, 2000a). The losses caused by the disease in some sweet orange orchards, four to six year-old, are significant and the orchards were abandoned since they were no longer productive (Ahlawat *et al.* 1996). Yield of affected trees can be substantially reduced in sensitive cultivars, but an accurate evaluation of losses has not yet been performed.

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. Only strict quarantine measures and restricted movements of bud wood can limit the spread of viral pathogens. For management of virus diseases, it is essential to have mandatory budwood certification programmes (Ahlawat 2005, 2007).

### *Harvesting, Post Harvest Management and Marketing*

The oranges produced in the adjoining areas of Mawsymgram, Cherrapunji and Sheila area of Meghalaya matures in 9-12 months and have excellent quality with high commercial value and fetches good price in the market. More than 90% produce of Khasi mandarin are export to neighboring country Bagladesh and due to the unavailability for rest part of India it is not so famous. However, the oranges of Jampui hills range of Tripura are reported to have great demand in Kolkata market. Oranges have many horticultural importance and have been used by the local tribal peoples for different culinary preparations. The Govt. of Nagaland and Arunachal Pradesh in the region have started a modest extraction plant for processing of juice from *Citrus reticulate.* Even though, potential employment generating opportunities is absent. Production of value added products are meager in the region due to lack of standard indices, nonavailability of degreening, precooling and mechanized handling units. There are no adequate storage structures for the seasonal glut; as a result the farmers are bound to sale off their produce at throwaway price. Furthermore the road network to the orchards and main markets are very poor, thus transportation of the harvested material is a serious problem (Hore and Barua 2004).

### *Production of Virus Free Plant through Micro Shoot Tip Grafting*

Virus and virus like diseases can be managed by an integrated approach such as use of virus-free planting material (Ahlawat 1997), use of host resistance, sanitation, cultural practices, control of insect vectors, and regulatory measures (Ahlawat 2005). The biotechnological approaches have opened new dimentions to develop virus free planting material (Parthasarathi 1999, Ahlawat 2000b, Shelly *et al.* 2003, Hoa and Ahlawat 2004). Citrus is a perennial crop and hence just starting with healthy planting material will not serve the purpose. This material in the field would require regular monitoring and testing. Infected plants need to be quickly replaced by healthy plants. Virus free plants can now be obtained easily by shoot tip grafting (STG) (Vijayakumari and Singh 1999, Hoa *et al.* 2004). With the help of STG, the compatibility between rootstock and scion can be known in a short period of time. The quality to produce rooted plantlets within a period of two months makes STG appropriate for quarantine and germplasm exchange also. The absence of vascular vessels and higher rate of cell division as compared to the most of pathogens make the apical meristem to be free of pathogen. Micrografting technique is important mainly for woody plants because in such plants meristem culture is often difficult (Faccioli and Marani 1998). This method was used for eradication of various viruses from citrus species (Murashige *et al.* 1972, Navarro *et al.* 1975). The aspects of STG and its utilization on citrus virus research were systematically reviewed by Navarro (1981).

However, there is no report on disease free Khasi mandarin plant production following micro shoot tip grafting except two initiative work on production of micrografted Khasi mandarin by Madhav *et al.* (2001) and Sanabam *et al.* (2015).

## Conclusion

Undoubtedly, the Khasi mandarin has enormous potential for its commercialization. Even though commercialization of this particular crop has been started, it is still at a budding stage. The significance of this crop is magnified not only because of its nutritional value but also owing to its medicinal use. Significant progress has been made in Khasi mandarin research such as scientific cultivation of the crop, development of various *in vitro* shoot tip grafting protocols for the production of quality planting material, identification of important diseases and pests of the crop and its mitigation etc. Still there is a long way to go. Lots of budwoods have been imported by public and private organizations

in this northeastern hill region during recent years. For such an introduction of planting material quarantine authorities should be highly vigilant. Budwood certification programmes in each citrus growing region as an emergent need of the day so that appropriate planting material is used for raising orchards and the grower of northeastern region can be able to increase productivity. Use of biotechnological methods to produce biotic or abiotic stress tolerant Khasi mandarin is another area of research which needs to be explored to enhance the productivity of the crop. At last the extension machinery should be more active so that the available technology reaches to the farmers.

**Table 1:** Nutritional information for raw mandarin oranges (Amounts per 1 cup, sections, 195 g)

**Calorie information**

| Amounts per selected serving | | %DV |
|---|---|---|
| Calories | 103 kcal (431 kJ) | 5% |
| From Carbohydrate | 93.0 kcal (389 kJ) | |
| From Fat | 5.1 kcal (21.4 kJ) | |
| From Protein | 5.3 kcal (22.2 kJ) | |
| From Alcohol | 0.0 kcal (0.0 kJ) | |

**Carbohydrates**

| Amounts per selected serving | | %DV |
|---|---|---|
| Total Carbohydrate | 26.0 g | 9% |
| Dietary Fiber [1,4,5,6] | 3.5 g | 14% |
| Starch [1] | 0.0 g | |
| Sugars [1,3] | 20.6 g | |
| Sucrose[1,3] | 11796 mg | |
| Glucose [1,3] | 4153 mg | |
| Fructose[1,3] | 4680 mg | |
| Lactose[1] | 0.0 mg | |
| Maltose[1] | 0.0 mg | |
| Galactose[1] | 0.0 mg | |

**Fats and fatty acids**

| Amounts Per Selected Serving | | %DV |
|---|---|---|
| Total Fat [1,2] | 0.6 g | 1% |
| Saturated Fat | 0.1 g | 0% |
| Monounsaturated Fat | 0.1 g | |
| Polyunsaturated Fat | 0.1 g | |
| Total trans fatty acids | ~ | |
| Total trans-monoenoic fatty acids | ~ | |
| Total trans-polyenoic fatty acids | ~ | |
| Total Omega-3 fatty acids | 35.1 mg | |
| Total Omega-6 fatty acids | 93.6 mg | |

**Minerals**

| Amounts Per Selected Serving | | %DV |
|---|---|---|
| Calcium [1,2] | 72.2 mg | 7% |
| Iron[1,2] | 0.3 mg | 2% |
| Magnesium[1,2] | 23.4 mg | 6% |
| Phosphorus [1,2] | 39.0 mg | 4% |
| Potassium [1,2] | 324 mg | 9% |
| Sodium [1] | 3.9 mg | 0% |
| Zinc [1,2] | 0.1 mg | 1% |
| Copper [1,2] | 0.1 mg | 4% |
| Manganese[1,2] | 0.1 mg | 4% |
| Selenium[1] | 0.2 µg | 0% |
| Fluoride | ~ | |

**Source:** Nutrient data for this listing was provided by U.S. Department of Agriculture, Agricultural Research Service. 2008. USDA National Nutrient Database for Standard Reference, Release 21. http://www.ars.usda.gov/ba/bhnrc/ndl

Percent Daily Values (%DV) are for adults or children aged 4 or older, and are based on a 2,000 calorie reference diet.

"~" indicates a missing or incomplete value.

**Sources of Data**:

[1]*Nutrient Data Laboratory, ARS, USDA* **National Food and Nutrient Analysis Program Wave 6d,** 2002 Beltsville MD.

[2]*Produce Marketing Association (PMA)* **Nutrient Content of Tangerines,** 1992.

[3]*Nutrient Data Laboratory, ARS, USDA* **Variability of the sugar content of foods,** 1989 Beltsville MD.

**Protein and amino acids**

| Amounts per selected serving | | %DV |
|---|---|---|
| Protein[1,2] | 1.6 g | 3% |
| Tryptophan[1] | 3.9 mg | |
| Threonine[1] | 31.2 mg | |
| Isoleucine[1] | 33.2 mg | |
| Leucine[1] | 54.6 mg | |
| Lysine[1] | 62.4 mg | |
| Methionine[1] | 3.9 mg | |
| Cystine[1] | 3.9 mg | |
| Phenylalanine[1] | 35.1 mg | |
| Tyrosine[1] | 29.2 mg | |
| Valine[1] | 41.0 mg | |
| Arginine[1] | 133 mg | |

| | |
|---|---|
| Histidine[1] | 21.5 mg |
| Alanine[1] | 54.6 mg |
| Aspartic acid[1] | 252 mg |
| Glutamic acid[1] | 119 mg |
| Glycine[1] | 37.0 mg |
| Proline[1] | 144 mg |
| Serine[1] | 64.4 mg |
| Hydroxyproline | ~ |

**Vitamins**

| Amounts Per Selected Serving | | %DV |
|---|---|---|
| Vitamin A[2, 7] | 1328 IU | 27% |
| Vitamin C[1,2] | 52.1 mg | 87% |
| Vitamin E (Alpha Tocopherol)[1] | 0.4 mg | 2% |
| Thiamin[1,2] | 0.1 mg | 8% |
| Riboflavin[1,2] | 0.1 mg | 4% |
| Niacin[1,2] | 0.7 mg | 4% |
| Vitamin B6[1,2] | 0.2 mg | 8% |
| Folate[1,2] | 31.2 µg | 8% |
| Pantothenic Acid[1,2] | 0.4 mg | 4% |
| Choline[1] | 19.9 mg | |
| Betaine[1] | 0.2 mg | |

**Flavonoids**

| Amounts Per Selected Serving | | %DV |
|---|---|---|
| Flavanones | | |
| Hesperetin[8,9] | 15.5 mg | |
| Naringenin[8,9] | 19.5 mg | |

[4]*J Marlett* **Content and composition of dietary fiber in 117 frequently consumed foods,** 1992 Journal of the American Dietetic Association 92 2.

[5]*Nutrient Data Laboratory, ARS, USDA* **Analysis of low-fat and new food items,** 1993 Beltsville MD.

[6]*National Cancer Institute (NCI), DHHS* **Total dietary fiber content of selected foods,** 1992.

[7]*National Institutes of Health (NIH)* **Carotenoid analyses of U.S. foods, Food Composition Laboratory,** 1997.

[8]*del Caro, A., Piga, A., Vacca, V., and Agabbio, M.* **Changes of flavonoids, vitamin C, and antioxidant capacity in minimally processed citrus segments and juices during storage.,** 2004 Food Chemistry 84 *p*.99-105.

[9]*Franke, A.A., Custer, L.J., Arakaki, C., and Murphy, S.P.* **Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii.,** 2004 J. Food Comp. Anal. 17 *p*.1-35.

**Table 2**: Bioactive components from the ethanolic peel extract of mandarin detected by gas chromatography – mass spectrometry

| Name of the compound | Molecular formula | Pharmaceutical activity |
|---|---|---|
| Maltol | $C_6H_6O_3$ | Anticonvulsant, Antifatigue, Antioxidant, Antitumour activity, Cancer preventive |
| 3,5-Dihydroxy-6-methyl-2,3-dihydro-4h-pyran-4-one | $C_6H_8O_4$ | Antimicrobial, Antiinflammatory Antiproliferative |
| Glycerol | $C_5H_{10}O_4$ | Anticataract, Antineuralgic, Arrhythmigeni, Hyperglycemic |
| 5-Hydrxoymethylfurfural | $C_6H_6O_3$ | Antimicrobial, Antibacterial |
| 2-Methoxy-4vinylphenol | $C_9H_{10}O_2$ | Antimicrobial, Antibacterial. Antiviral |
| 3-[N'-(3h-Indol-3-ylmethylene) hydrazino]-5-methyl-[1,2,4]triazol-4-ylamine | $C_{12}H_{13}N_7$ | Antimicrobial, Antibacterial. Antiviral |
| Nitroisobutylglycerol | $C_4H_9NO_5$ | Oxytocin induced activity, Antioxidant, Antistaphylococcal Activity |
| 1,6-Anhydro-beta-d-glucopyranose | $C_6H_{10}O_5$ | Antiinflammatory, Thrombolytic activity |
| 3,3',4',5,5',7,8-Heptamethoxyflavone | $C_{22}H_{24}O_9$ | Cancer chemopreventive activity, Antiinflammatory |
| Butylphosphonic acid, pentyl 4-(2-phenylprop-2-yl) phenyl ester | $C_{24}H_{35}O_3P$ | Antioxidant, Antitumour |
| 4H-1-Benzopyran-4-one, 2-(3,4-dimethoxyphenyl)-5,6,7-trimethoxy | $C_{20}H_{20}O_7$ | Antimalarial, Antitumour, Antioxidant, Antihyperglycemic |

**Table 3:** State-wise area and production of mandarin in northeast

| Sl. No. | States | 2012-13 | | 2013-14 | | 2014-15 | |
|---|---|---|---|---|---|---|---|
| | | A | P | A | P | A | P |
| | Assam | 15.85 | 195.82 | 15.67 | 188.78 | 16.78 | 215.86 |
| | Nagaland | 5.50 | 50.00 | 6.10 | 54.80 | 6.10 | 54.80 |
| | Mizoram | 8.96 | 24.10 | 13.51 | 40.43 | 17.99 | 50.00 |
| | Manipur | 5.02 | 32.64 | 5.15 | 41.20 | 5.35 | 43.00 |
| | Meghalaya | 8.42 | 39.62 | 8.60 | 40.89 | 8.78 | 42.23 |
| | Tripura | 5.28 | 28.41 | 6.30 | 33.90 | 6.30 | 22.00 |
| | Sikkim | 9.46 | 16.85 | 10.28 | 16.86 | 11.58 | 18.99 |

**Note**: "A" represents area in 000 ha while "P" represents production in '000 Tonne

**Source**: Horticulture Statistics Division, DAC&FW. Anonymous (2015).

**Table 4:** Characteristics of some selected rootstocks (Chadha and Singh 1990)

| Rootstocks Common name | Species and varieties | Horticultural performance | | | | Reaction to the stress | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Biotic | | | | Abiotic | |
| | | Yield | Quality | Plant vigour | Root system | Root rot | Exocortis | Tristeza | Nematode | Salt | Drought |
| Rough lemon | *C. jambhiri* Soh-myndong Kata-jamir, Sindhuri-nemutenga, Soh-jhalia, Nemu tenga, kachai lemon | M | M | M | M | S | R | R | S | T | T |
| Rangapur lime | *C. limonia* | G | M | G | D | MT | S | R | S | R | R |
| Sweet orange | *C. sinensis* Osbeck, Soh-niangriang, Soh-bitara, Tasi | M | M | G | M | HS | R | MT | HS | S | S |
| Troyer citrange | - | M | G | M | SH | MT | S | MT | T | HS | HS |
| Cleopatra mandarin | *C. reticulata* | M | M | M | M | T | R | R | S | HT | D |
| Trifoliate orange | *Poncirus trifoliata* | L | M | L | D | R | H | R | R | HS | HS |
| Sweet lime | *C. limmetta,* Mitha kagzi | M | M | G | M | S | S | S | MT | S | S |
| Nasnaran | | M | G | M | M | S | R | T | MT | HT | S |
| Marmalade orange | | G | M | G | D | MT | S | R | MT | R | R |
| Kharna khatta | *C. karna* Rafin., Soh-sorkar | G | M | M | D | S | T | - | MT | T | S |
| Sour orange | *C. aurantium* L., Karan jamir, Gandha-Hantara | G | G | M | D | R | T | HS | T | T | MT |

G= Good, M = Moderate, L = Low, R = Resistant, T = Tolerant, MT = Moderately tolerant, S = Susceptible, HS= Highly susceptible,

D = Deep, M= Medium, SH = Shallow, - = No information

**Table 5:** The diseases and pests of mandarin in the northeastern region, their symptoms and management

| Common name | Scientific name | Symptoms and nature of damage | Management |
|---|---|---|---|
| Pests | | | |
| Trunk and stem borer | *Monohammus versteegi* Ritsema, Cerambicidae: Coleoptera | Most important pest of mandarins in NEH region. The grub bores into the trunk near the tree base and makes tunnels near the pith | Collecting and killing of adults is one of the control measures. Treat the soil 6-8 cm deep around the trees with 5% aldrin to check the attack |
| Citrus leaf miner | *Phyllocnistis citrella* Stainton, Phyllocnistidae : Lepidoptera | Larvae make zigzag-mines on leaves. The infested leaves turn yellow, twist and finally dry | Spray monocrotophos 36 WSC (0.036%) during March-August. In addition fenvalerate @ 1 ml/l water is also quite effective for next 45 days. The larval predator black chalcid and the chrysopid hold good promise for its control |
| Citrus psylla | *Diaphorina citri,* Kuwayama, Psyilidae: Homoptera | Orange yellow nymphs suck cell sap from new growth and flower in the month of March-April and July-August | Spray monocrotophos 36 WSC (0.036%) during the period when new flush appears. *Coccinellid predate* Orsare also found to be effective against nymphs |
| Citrus aphids | *Toxoptera spp.,* Aphididae: Homoptera | Adults and nymphs suck the sap from tender leaves and shoots resulting in devitalisation of the plants. Affected leaves in severe cases curl up and get deformed. *Citrus tristeza virus* is transmitted by various aphids species | Foliar applicatlon of 0.02% methyl demeton, monocrotophos at week interval controls pests effectively. Coccinellids are one of the major predator of aphids |
| Mealy bug | *Planococc-us citri* Risso, Pseudococcidae: Horooptera | It is economically important pests of Khasi mandarin in Meghalaya. Nymphs and females usually feed underside of the leaves causing heavy damage to nursery and grown up plants and also attack the base of fruits near the stock end resulting heavy fruit drop | Pruning of affected shoots in winter is effective. Spraying if dimethoate 150 ml + kerosene oil 250 ml in 100 liter water checks mealy bug |
| Fruit sucking moth | *Othresis fullonica* | The moth attacks the ripening fruits during late hours in the evening. The moth punctures it making a hole in the ripening fruit to suck the juice through which infection may take place. Soon rottening starts leading to fruit drop. | Collection of dropped fruits and their destruction followed by smoking of orchard during late evening hours is suggested. A poison bait containing 20g malathion + 50m1 diazinon+200g brown sugar + vinegar + 2 litre water in a wide mouth bottle, one for a group of 25-30 trees during Sep-Oct. gives desired result. For fruit fly control hanging of methl eugenol (feromone) traps is an effective method to check the pest. |
| Citrus butterfly | *Papilio demoleus* L., Papilionidae: Lepidoptera | Larvae feed on leaves from margin inwards and the damage is severe in nurseries | Spray with endosuifan 35 EC (0.05%) or monocrotophos (0.036%) when the attack appears |

| | | | |
|---|---|---|---|
| Bark eating· caterpillar | *Inderbela spp.*, Melarbelidae: Lepidoptera | Serious pest of Meghalaya, Mizoram, Arunachal Pradesh. Grub feed on bark portion and makes holes in stems for hiding. Growth of tree is arrested | Remove webbing .and treat the main .limbs and trunk with methyl parathion 50 EC (0.1%) in Feb-March |
| Scales | *Aonidiella aurantii. Coccus hesperidus. Icerya purchasi,* | Nymphs and adults suck sap from foliage/twig, branches and stems and devitalize the plants, resulting in yellowing and early shedding of their leaves, bear low quality fruits with lesser number | Spray of methyl parathion (Q.05%) or nuvan (0.01%) also gives satisfactory results |
| Mites | *Eutetranychus orienta/is* Klien, Tetranychidae: Acarina | Extracts cell sap from leaves and fruits and causes dry necrotic areas | Foliar spray of dicofol @ 1.5 ml/L, monocrotophos 1 ml/L when incidence noticed reduces the infestation |
| Citrus nematode | *Tylenchulus semipenetrans* | Infected trees are not killed but growth and bearing is adversely affected | Dichlorofenthion @ 45 ml/ha effective to reduce nematode population |
| Diseases | | | |
| Phytophthora root rot, gummosis | *Phytophthora spp.* | Causes symptoms of decline through rotting of the rootlets, girdling of trunks and dropping of blighted leaves. A yellow gummosis zone at the cambium appears. Bark cracks, shreds in lengthwise strips | Raising of nursery in *Phytophthora* free condition Painting of Bordeaux mixture on the trunk upto 50- 60 cm. Use of tolerant rootstocks are some of the control measures |
| Twig blight | *Bacillus theobromae, Colletotrichum gloeosporioides* | Reduction of canopy volume due to this malady reduces the yield. Blighted trees on bearing suffer heavy fruit drop | Regular pruning of dead twigs, spray of benzimidazole. |
| Citrus scab | *Elsinoe fawcettii* | Newly emerged leaves are very susceptible for infection. It is characterized by irregular protuberant, corky outgrowths upto 3mm across and deeply cracked on the invaded side of leaf and a corresponding depression forms on opposite side | Disease free plant should be selected. Old infected twigs and leaves should be removed. Prophylactic sprays of captafol, benomyl controls the disease |
| Sooty mould | *Capnodium sp.* | It grows over the insect secretions and the excessive growth of sooty mould gives plant sick growth and hampers the growth of plant | Regular spray of Bordeaux mixture checks the disease |
| Powdery mildew | *Acrosporium tingitaninum* | White powdery patches of mildew appear in upper part of young leaves and on twigs. The leaf tissue upon infection turn dark watery green and later | Spray tridemorlh, triadimefon, benzimidazole |

| | | | |
|---|---|---|---|
| Citrus greening | Phloem restricted gram negative pleomorphic bacteria *Cendidus liberibacter asiaticus, Candidus liberibacter africanum* | Most of the commercial citrus cultivars in India are susceptible to greening but mandarins, tangelo and sweet oranges are highly susceptible. The affected trees remain stunted, have yellow and sparse foliage, and show twig dieback. These symptoms occur throughout the tree or confined to some branches. The most characteristic symptom is mottling of leaves. Zinc deficiency type symptoms are commonly associated with greening, resulting in confusion of nutritional problems. The fruits on affected trees are small, lopsided, poorly coloured, remain dull green, hence the disease was named as greening. | Uprooting and burning of the infected trees and controlling the vector 'citrus psylla' are the control measures. However, the disease symptoms can be suppressed by injecting the affected trees with 500 or 1000-ppm tetracycline or penicillin under pressure (10Kg/cm$^2$) (Kapur *et al.* 1992). Regular treatment with these drugs can reduce the incidence and intensity of the greening disease. |
| Citrus canker | Gram negative bacteria *Xanthomonas citri* (Hasse) Dowson | The canker lesions appear as minute water soaked roundish spots, which enlarge slightly and turn brownish and corky | Pruning and burning of diseased twigs, spraying of 1% bordeaux mixture to emerging flushes or application of streptomycin sulphate (500 ppm) are recommended for control of the disease. |

Reference: Shivankar *et al.* 2002, Das *et al.* 2007, Hore and Barua 2004 and Ahlawat 2007.

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