Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 151-158

Received: 15-09-2018
Accepted: 17-10-2018

G Sarada
Assistant Professor, Department of Entomology, College of Horticulture, Anantharajupeta, Dr. YSR. Horticultural University, Andhra Pradesh, India

T Nagalakshmi
Scientist, Department of Plant Pathology, Horticultural Research Station, Anantharajupeta, Dr. YSR. Horticultural University, Andhra Pradesh, India

K Gopal
Professor and Controller of Examinations, Venkataramannagudem, YSR Horticultural University Andhra Pradesh, India

KM Yuvaraj
Professor, Department of Horticulture, College of Horticulture, Anantharajupeta, Dr. YSR. Horticultural University, Andhra Pradesh, India.

Correspondence
G Sarada
Assistant Professor, Department of Entomology, College of Horticulture, Anantharajupeta, Dr. YSR. Horticultural University, Andhra Pradesh, India

Citrus rust mite (*Phyllocoptruta oleivora* Ashmead): A Review

G Sarada, T Nagalakshmi, K Gopal and KM Yuvaraj

Abstract
The citrus rust mite (CRM), *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), infests plants of genera *Citrus* and *Fortunella* (family Rutaceae). CRM infests leaves, branches and fruits causing fruit rind russeting resulting in loss in yield and fruit quality making them unfit for export. The damaged fruits have surface bronzing (damage), peel shrinkage, lower juice volume, higher soluble solids, higher acids and higher concentrations of acetaldehyde and ethanol than normal fruits. CRM injury to the leaves is also one of the predisposing factor for the development of greasy spot, a disease caused by the fungus, *Mycosphaerella citri* Whiteside. CRM infestation may lead to 40% fruit yield loss and nearly 25% reduction in fruit volume. These microscopic organisms have very short life cycle of 7 to 10 days with many overlapping generations per year and with maximum infestation found during late June to August months. In the present paper the nature of damage, biology and ecology of the pest were clearly reviewed. Monitoring methods and other components of integrated management methods viz., cultural, chemical, IGR's, botanicals and biological control were also been reviewed in detail. However, regular monitoring and resistance management were emphasized as the prime important aspects for programming a sound integrated pest management programme as a future perspective in this present review.

Keywords: citrus, rust mite, biology and management

Introduction

Citrus belong to Rutaceae family, the genera Citrus (Oranges, Mandarins, Pomelos, Grapefruit, Lemons, Limes and Citrons), Fortunella (kumquats) and Poncirus (trifoliate oranges) contain the principal commercial species [66] and it is originating in tropical and subtropical Southeast Asia. India ranks sixth in the production of citrus fruit in the world. In India, citrus fruits are primarily grown in Maharashtra, Andhra Pradesh, Punjab, Karnataka, Uttaranchal, Bihar, Orissa, Assam and Gujarat. At present, in India total area under citrus fruit production is 976.0 thousand hectare (15.18% of total area under fruits) with a production of 11,717.0 thousand MT (12.35% of total production under fruits) and productivity of 12.08 MT/HA and total area under Sweet orange cultivation in India is 191.0 thousand hectare (2.97% of total area under fruits) with a production of 3,305.0 thousand MT (3.48% of total production under fruits) and productivity of 17.30 MT/hectare [50].

Citrus is thought to have originated in Southeast Asia [34]. It is currently grown in over 140 countries on six continents. It distributes in a belt spreading approximately 40° latitude on each side of the Equator and is found in tropical and sub-tropical regions where favourable soil and climatic conditions occur. A total of 104 phytophagous mites were reported on citrus worldwide. They belong to the families Phytoptidae, Eriophyidae, Diptilomiopidae, Tarsonemidae, Tenuipalpidae, Tuckerellidae and Tetranychidae [72]. *Phyllocoptruta oleivora* is a serious pest of citrus in most humid regions of the world and is currently considered the most economic arthropod pest of citrus, causing fruit rind russeting resulting in loss in yield and fruit quality. It infests twigs, leaves, and fruit of all citrus species and varieties, but its order of preferences lies as lemons > grapefruit > oranges> tangerines [39]. Yothers and Mason (1930) proposed that the citrus rust mite was probably introduced on nursery trees when they were first brought into Florida for propagation, and the spread of the citrus rust mite over Florida, and probably in other citrus-growing states, was principally through infested nursery stock. Mites were readily carried on air currents between adjacent citrus groves. Nearly all of the mites captured in dispersal traps were adult females and were found in greater proportions in traps than would be expected from the sex ratio of mites on fruit [13]. Mites can disperse within and between trees by a number of means. Most can wander around over a limited area of the plant surface. They can be dislodged easily and transported by wind or rain or by visiting birds and insects or by people or machinery working between the trees. Nursery trees may be infested due to use of infested bud wood [2].

Origin and Distribution

The citrus rust mite (CRM), *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), is thought to have originated in Southeast Asia-the indigenous habitat of citrus [77, 14]. It now occurs in almost all citrus-growing areas in the world, including Europe, Africa, southern Asia, Australia and Pacific Islands, North, Central and South America and the West Indies [20]. The species probably was introduced into many citrus-growing countries on imported fruit or planting material [14] and is now considered as a serious pest of citrus in most humid regions of the world where the crop is grown [40, 21]. Several years prior to 1879, in which the citrus rust mite was first reported and described, Florida orange growers were very much concerned about the cause of russetted fruit. Some growers attributed it to a fungus, others to adverse soil conditions. Accordingly, J.K. Gates was the first to find the mites on oranges and immediately ascribed russeting to their presence. This discovery eventually led to the description of the species by Ashmead (1879).

Taxonomic History

The CRM was first mentioned and described by Ashmead (1879) as *Typhlodromus oiliioonc*s. However, Ashmead a year later (1880) emended his first spelling to *Typhlodromus oleivorans*. According to Ewing (1923), the genus *Typhlodromus* is a synonym of *Phytoptus*, which in turn is a synonym of *Eriophyes*, consequently the rust mite had long been placed in the genus *Eriophyes* [77]. Banks (1907) was the first to mention it under the name of *Phyllocoptes oleivorus* (Ashmead). In 1938, Keifer erected a new genus, *Phyllocoptruta* and since then the citrus rust mite has been called *Phyllocoptruta oleivora* (Ashmead) [15].

Host Preference

The CRM infests plants of genera *Citrus* and *Fortunella* (family Rutaceae) [20]. On many citrus species and varieties grown in Florida, observed the following order of severity of infestation: Lemon > Lime > Citron > Grapefruit > Sweet orange > Tangerine > Mandarin [75]. Brussel (1975) also observed higher overall mite populations in grapefruit groves than in orange groves in Surinam. Achor *et al.,* (1991) reported that upper surface lesions on ’sunburst’ mandarin associated with feeding by CRM were more severe than on other citrus cultivars.

Pest and its damage

Yothers and Mason (1930) demonstrated that the epidermal cells of the fruit were damaged by citrus rust mite. McCoy and Albrigo (1975) further confirmed that citrus rust mite can only feed on the epidermal cell layer of leaves and fruit, since the length of its piercing chelicerae is on the order of 7 µm which is less than the depth of one cell. Citrus rust mite feeding on twigs results in a "bronzing" of the green twigs. Such damage may contribute to a loss of vitality in the tree. Damage to citrus fruit caused by CRM normally affects only the surface layer of epidermal cells on the fruit. Fruit surface injury differs depending on time of injury and variety of fruit injured [30]. Its damage is popularly known as 'rind disorder' on Kinnow mandarin, 'mangu disorder' on Sathgudi orange, 'rusting' on grapefruit, 'Lalya' on Nagpur mandarin and 'sharkskin' on lemons and limes [65]. In the case of grapefruit and lemons or limes, injury during the early months of the fruit's growth will cause a silvering of the peel and if severe, may result in a condition known as "sharkskin". When this occurs early enough fruit size is reduced. When the fruit is mature, this injury is called "russeting". Late injury takes a high polish and is called "bronzing" [30, 57]. Typical aspect of rust mite injury on an infested tree is that only some of the fruits are heavily attacked, whereas others are damaged only slightly or not at all. Even on a single fruit, the rust mite tends to infest only a portion of the fruit, leaving the rest undamaged. This partial russeting on fruit also occurs on leaves, and the mite spatial distribution is consistent with these damage patterns. CRM on citrus fruit tend to avoid the bright sunlit area of a fruit in the direct solar beam where the temperature may reach 45°C.

Visible leaf injury is less common than fruit injury. However, leaf injury can occasionally be severe [45]. Injury to the upper leaf surface is confined to epidermal cells and appears as small brownish spots or blotches resembling the "russeting" condition common to immature fruit (Fig 4). Injury to the lower leaf surface is confined to epidermal cells which include the stomatal guard cells. Lower surfaces often show 'leaf mesophyll collapse' appearing first as yellow degreened patches and later as necrotic spots [4, 34, 57]. Damage to the guard cells can result in an increase in the transpiration rate. Damage to the lower leaf can result in some leaf drop especially in late fall or winter during dry periods [41]. The CRMs prefers the lower leaf surface to the upper surface [69]. Active feeding by dense populations of mites (50-200/$cm^{2)}$ during summer and autumn on oranges significantly increased the ethylene emission at the time of russeting and stimulated premature degreening in autumn [44]. Savitri and Ramasubba Reddy (1988) reported that low mite population on the marble sized fruits caused slight rusty blotches on the rind over a period of 25-30 days, which gradually increased to light dirty colour and completely dirty white colour resembling wood apple was appeared 30-45 days after appearance of rusty blotches. Griffiths and Thompson (1957) suspected the possible effects of CRM injury to the leaves on the development of greasy spot, a disease caused by the fungus, *Mycosphaerella citri* Whiteside. In several field experiments, Van Brussel (1975) demonstrated that rust mite injury to leaves was positively correlated with increasing severity of greasy spot infections. CRM were also found on the branches just after they had become reasonably mature, in some cases so abundantly as to cause russeting on the bark. But high mite populations on branches are seldom seen, and possible mite injury to branches is not of much concern to growers.

Economic importance

The CRM infests every *Citrus* species plant. When climatic conditions are favourable, a rapid population increase resulting into a serious damage to foliage and fruits in a short time. Infested fruits have discoloured skin (fruit-russeting), which make them unfit for export. In all probability the CRM ranks third among the injurious pests on citrus in Florida, being exceeded in amount of damage done only by the purple scale (*Lepidosaphes beckii* Newm.) and the citrus whitefly (*Dialeurodes citri* Ashm.), and the total loss sustained by the industry is very great. Although the CRM causes injuries to fruits, leaves, branches and may even be related to greasy spot infections, it's most economic importance is due to fruit surface damage. Heavy infestation of rust mites causes not only fruit surface discoloration but also increased fruit drop and size reduction, with an associated loss in fruit quality and yield [14]. Sanchez *et al.,* (1985) reported that Single mite damages 0.048% of the fruit surface per day in sweet oranges. Allen (1978), Huan *et al*. (1992) and Yang *et al*. (1994) showed that infestations of CRM also affect fruit growth and cause premature fruit drop. McCoy (1976) further indicated that citrus rust mite injury to the lower leaf surface appeared to be associated with defoliation. Increased water loss from lower leaf surface, may possibly be enough to cause leaf abscission. But leaf abscission may not be severe enough to affect tree vigour and subsequent yield of 'Valencia' orange. Allen (1979) showed that water loss rate for on-tree 'Valencia' oranges was about 3 times higher for rust mite-damaged fruit than for undamaged fruit regardless of fruit age, sun exposure or type of damage. Fruit drop were increased by CRM damage on ''Valencia' and 'Pineapple' oranges and also in 'Duncan' grapefruit. About 40% fruit yield loss in grape fruits was reported in Surinam due to CRM damage. Since fruit drop is cumulative, the earliest damage can have the greatest total effect. A model has been developed to quantify the effect of damage on fruit drop [5, 8]. In addition to the size effects of citrus rust mite damage there is a slight increase in percentage of soluble solids and percentage of acids for damaged fruit with negligible change in the solids/acid ratio. The increase in solids is on the order of 1%, and therefore this gain does not offset the volume loss from size reduction which can be 25%. In addition, juice from damaged fruit may contain higher concentrations of acetaldehyde and ethanol than normal fruit. Off-flavors were detected only in juice extracted from fruit with extensive surface bronzing and peel shrinkage where the acetaldehyde and ethanol concentrations were highest [39]. Mc Coy *et al*. (1976) showed that at harvest, fruit with localized and extensive surface bronzing (damage) and peel shrinkage had a lower juice volume, higher soluble solids, higher acids, and higher concentrations of acetaldehyde and ethanol than normal fruit. Similarly the fruits with >25% of skin damage were smaller than the uninfested fruits, contained more soluble solid sugars, vitamin C and lower total acidity [28]. The fruit rind thickness of 2.8mm in infested fruits compared to 2.2mm in healthy fruits of Rangpur lime [60].

Biology

CRM adults have an elongated, wedge-shaped body about three times as long (1/200 of an inch or 0.13mm) as wide. Their colour varies from light yellow to straw colour (Fig1,3). The mite has two pairs of short, anterior legs and a pair of lobes on the posterior end which assist in movement and clinging to plant surfaces [39]. The females are longer than the males. Both are yellow to yellow brown, spindle shaped and rather slender. The adult females deposit spherical, pale, large eggs singly in depressions on fruit and leaf surfaces. Female CRMs have been observed laying up to 20-29 eggs each. The eggs hatch in about 3 days in summer. There is a larval stage and a nymphal stage, which resembles the adult except for the smaller size before they become adults. At an average maximum temperature of 32ºC mean incubation period was 3 days, nymphal period of 3.1 days in summer and 5.5 days and 9.7 days egg and nymphal periods in winter (Fig 2). The total life cycle was completed in 7-10 and 14 days in summer and winter respectively and at 81°F it is 7 to 10 days or as short as 6 days. Kalaisekar (1999) reported the egg and nymphal periods of CRM in sweet orange as 1.9 and 5.9 days and fecundity of 12 eggs/ female. So there are many generations during summer-autumn. During the summer, each nymphal stage lasts from 1 to 3 days. During the months of May, June and July, a life cycle from egg to egg can be completed in 7 to 10 days. This time is increased to 14 days in the winter, depending upon the temperature [37]. Development continues in winter and spring, but at a slower rate [2, 57]. Brusssel (1975) stated that CRM completed its life cycle in 8 days oranges and grape fruits and the entire reproduction is parthenogenetic with an average fecundity of 26 eggs/ female. Allen (1995) reported that highest development rate occurred at 25 ºC and Ebrahim (2000) reported that optimum temperature for development is between 30 and 32°C.

Behaviour and Ecology

CRM tend to aggregate within trees and on individual fruit as a result of environmental factors, notably sunlight and temperature. Rust mites can endure hot sun but tend to avoid direct sunlight. This avoidance of direct solar exposure results in non-injured fruit areas commonly called "sun spots". Shaded groves and the shaded side of fruit do not usually exhibit mite densities as high as semi-shade areas. Generally, the north bottom quadrant of the tree is preferred and supports the highest mite populations. The least favorable conditions for CRM buildup are found in the south top quadrant [39]. Yang *et al.,* (1997) and Kalaisekar (1999), reported that highest mean surface damage on fruits was at north quadrant followed by east, south and west quadrants. The pest invades the fruits as soon as the petals dropped and infestation reaches a high level when the fruits reached an average of 1.2 cm diameter. When the fruits began to ripen, the mites leave the fruit for other fresh fruit [28].

The seasonal abundance of the CRM has been discussed by numerous researchers. In Florida, rust mite is present on citrus trees throughout the year. The lowest population occurs in January and February. During March and April their numbers increase rapidly. During May and the first part of June the rate of increase is much more rapid than at any other time of the year. The period of maximum infestation usually occurs during late June or July or even August, well after the beginning of rainy season. During the later part of the rainy season, mite populations diminish almost to the point of extinction. The high humidity (RH) favoured the epizootic development of the fungal pathogen *Hirsutella thompsonii*, the major factor responsible for rapid mite population decline. Mite populations on leaves followed the same pattern as on fruit. The period of maximum infestation occurs first on lemon and then on grapefruit and about one month later on orange. Rust mites increase very rapidly when RH exceeds 70%. Mite populations also increase after abnormally high rainfall.

Dean (1959a) reported that rust mite populations increased particularly during periods of high relative humidity while periods of low relative humidity and very windy weather seemed unfavourable. Brussel (1975) reported that during rainy season, counts of rust mites were low, and mite population increased at the beginning of the dry seasons. Maximum counts were reached in 4-5 weeks, and then dropped to a low level in a similar period in Surinam.

A moist substrate seemed to interfere with moulting, and rain also interfered in oviposition since rust mites avoided egg-laying on wetted parts of the food plants. The part of fruit exposed directly to sunlight was less attractive to the rust mite than others, but these areas were also exposed to dew condensation at night. Peak CRM incidence was noticed in the months of January and February with 13-20 ºC as favorable temperatures for survival and a negative correlation with minimum temperature, positive correlation with relative humidity and rainfall was observed in sweet orange at Andhra Pradesh [53, 36]. The most favourable conditions for rapid multiplication observed during the heaviest rainfall periods, which are May/June and August/September [35]. Citrus rust mites overwinter on all parts of the tree. In the spring, the mites migrate to the spring flush where they feed and begin to reproduce on the leaves. They move to young fruit as it becomes available, usually in mid-April. Throughout April and May CRM populations remain higher on leaves, but in June, higher populations become predominant on fruit. During the summer, citrus rust mites are more abundant on fruit and foliage on the margins of the canopy [39].

Management and Monitoring Techniques

Field monitoring or scouting is the foundation for making decisions in an IPM program. CRM monitoring procedures and action thresholds are the backbone of IPM programs. Monitoring programs for this pest is often end at the beginning of winter (November), because average winter conditions do not cause CRM populations to increase. Monitor orchards for CRM once in every two weeks. It takes two weeks or more for rind damage to become visible when populations on fruit exceed 50 mites/cm^2. However, under favourable conditions, CRM population more than quadrupled on infested fruits during a 2-week period. To sample, check randomly selected trees that are dispersed enough to give a representative sampling of the entire orchard. This can be done by moving in a diagonal direction or Z-shaped pattern. The sampling size should be one tree per 2 acres, with a minimum of 20 trees per orchard. Check for pests on the underside of young foliage. The fruit should be selected randomly from a shady area that is about an arm's length. The number of citrus rust mites is not important. From these observations (one hundred per 10-acre block) calculate the percentage of CRM infested fruit; i.e., fifteen infested lens fields is equal to 15% infested fruit. This procedure is very labour efficient because it does not require any counting of mites and is utilized for both fresh and process fruit (39).

Cultural management

Populations of plant-feeding mites may be affected by a range of uncontrolled factors and by agricultural practices. Withholding irrigation is a practice that alters the phenology of the plants and may affect the dynamics of the mite populations. Knapp *et al*. (1982) observed that a higher population of CRM consistently occurred in orchards with sub-canopy irrigation than in orchards with overhead irrigation. This is an indication that irrigation management needs to be included in the analysis and management of mite populations. Horticultural practices like hedging and topping alters the environment in the grove by allowing more solar exposure resulting into a more clustered mite population within the tree leading to greater fruit damage due to aggregation of the CRM [39].

Weed management and maintenance of green cover crops or weeds may also affect the abundance of phytophagous and predatory mites in citrus. Osburn and Mathis (1944), Muma (1961) found no difference in CRM populations in trees on clean cultivated plots and in trees grown in plots with ground cover plants. However, Gravena *et al*. (1993) observed lower incidences of CRM, *Brevipalpus phoenicis* and higher population densities of phytoseiidae in trees with green ground cover than in trees without weeds. Withholding irrigation for a period followed by the resumption of water supply definitely induces the development of new vegetative and fructiferous shoots, thereby providing the mites with food of higher quality [40]. Knapp *et al*. (1982) documented the effects of complete and strip herbicide applications in a pineapple orange grove and found significantly higher populations of CRMs on plants with complete herbicide treatment, suggesting that different horticultural practices influence the population dynamics of these plant feeding mites. Since CRM also reproduces on leaves and citrus trees have evergreen vegetation, effective control will require targeting CRM when its populations are at their lowest during the dormant period. Thus, pre-bloom proactive spray initiation found Significant and providing long term reduction of CRM densities compared to the traditional post-bloom spray with gross returns being1.1 to 1.3-fold. This novel approach also preserves predatory mite populations which would provide additional control to various mites. The better CRM control achieved made its adoption an effective alternative both ecologically and economically [61].

Biological control

Predaceous mites have been recognized as highly important in regulating phytophagous mites and other pests on citrus**.** The most common predatory mites' families in citrus orchards are Stigmaeidae, Cheyletidae, Cunaxidae, Bdellidae, Ascidae and Phytoseiidae, with the phytoseiidae being the most abundant predatory mites in this crop [17, 44, 58].

Eleven predatory mites were recorded, on sweet orange plantations in Brazil comprising 10% of the mite population, belonging to Phytoseiidae and Ascidae. Phytoseiidae was the richest family, with ten species**.** *Phyllocoptruta oleivora*, *Panonychus citri* and *Brevipalpus phoenicis* infestation is about 44.7% of the total phytophagous mites on sweet oranges in Brazil [68]. The phytoseiid mites have potential for the biological control of insects and phytophagous mites like *B. phoenicis*, *P. oleivora* and *P. citri* [27]. Schwartz (1976) reported *Amblyseius citri* as predaceous mite on many citrus mites including CRM. Similarly, *A. Stipulates*, *A. Californicus*, *A. Potentiblae*, *Agistermus exsertus* and *Tydeus* sp. were also reported to be CRM predators [42, 70, 18]. Three predatory mites *Amblyseius elinae*, *A. deleoni* and *A. Lentiginosus* were reported on citrus red mite and the citrus rust mites in coastal orchards in New South Wales [2]. *Galendromus helveolus* (Chant) is one of the most prevalent predaceous mite species found on CRM and was recovered in at least 11 months of the year from citrus foliage. In the field *Iphiseius degenerans* (Berlese) and *Amblyseius swirskii* Athias-Henriot (both Acarina: Phytoseiidae) were the main predators found, the former being dominant during the critical winter and spring months, the period of low pest populations in Israel [10]. *Hirsutella thompsonii* will cause suppression of CRM populations 6 to 8 weeks after the beginning of mite population buildup. During this period, the CRM infestation may reach injurious densities and inflict economic injury. Its efficacy is well studied in USA, Surinam, Israel and China and recorded very promising. In China a single application of laboratory produced *H. thompsonii*, at a dose of 1.0-1.5 g /L to citrus caused 90% reduction in mite population in three days. *Beauveria bassiana* @ 1x10^8 conidia/ml was reported to be pathogenic against CRM providing 90% mortality in a laboratory trial [64]. Two Cecidomyiidae, *Feltiella* sp. and *Lestodiplosis* were found efficient predators on all the stages including eggs of CRM [56]. Others include the dusty-wing, Semidalis cucina (Hagen) and the strawberry mite, Agistemus floridanus Gonzalez. The ability of these predators to reduce citrus rust mite populations has not been determined. Aqueous seed extract of *Jatropha curcas* (Euphorbiaceae) exhibited the strong acaricidal activity against CRM in Indonesia [24]**.** Other natural enemies which feed on rust mites and spider mites include ladybird beetles and other small insect predators. These organisms attack mites on foliage and fruit, but generally are not effective in keeping populations below damaging levels.

Chemical control

Chemical control in mite management is the most effective and largely followed by the farming community. The thiocarbamate fungicide mancozeb was most effective in reducing CRM population and resulted in the highest yield of healthy fruits in oranges [62, 32, 33, 36]. Similarly, Nagalingam and Savitri (1983) reported that Mancozeb or Zineb(0.2%) and quinalphos or phosolone(0.05%) are effective pesticides in CRM management. Pre-bloom spray of difolatan suppressed populations of the citrus CRM, until July in Florida [15]. The use of copper and nutritional sprays containing MnO and zinc have caused increases in citrus rust mite (CRM) populations by suppressing the fungus *H. Thompsonii*, when applied during a season of environmental factors favouring optimum fungal growth [39].

The use of spray oil as a selective fungicide, were effective in controlling greasy spot and has significantly increased the natural control of CRM populations [39]. Oliveiria *et al.,* (1985); Flores *et al.,* (1996) reported dicofol as effective acaricide against both CRM and its predator *Euseius mesembrinus*. Wettable sulphur is another acaricide which was found effective against CRM till 45 days after application [45, 46]. Monochrotophos (0.05%), Phosolone (0.05%), Triazophos (0.05%), profenophos (0.05%) and azadirachtin 0.5% are the most efficient pesticides in reducing CRM population on fruits in Sweet orange [36]. Foliar application of dicofol (1.5ml), wettable sulphur (3ml), Propargite (1ml), abamectin (0.3m)l, Ethion (2ml) /L of water are reported as effective pesticides against mites in citrus [53]. However copper fungicides either directly or in combination with other fungicides are having the stimulatory effect on CRM activity [16].

During the 1970s, chlorobenzilate and dicofol were used most widely against CRMs. But by 1980s pests have developed resistance because of their widespread use. In 1980s other products like abamectin, aldicarb, hexakis and oxamyl were reported effective. But by 1990s again these products failed to control the pest. Abamectin (Agri-Mek® 0.15EC) and diflubenzuron (Micromite® 25WS) were reported to be slightly toxic, with the residual killing effect existing less than 1 day post-spray to *Galandromus helveolus*, a predator mite with no significant adverse effects on adult survival, fecundity and egg viability when exposed to the pesticide residues [67]. The pesticides bromopropilate 65 cm³; fonnetanate 22, 5 g and formetanate 31, 5 g per 100 litres of water were most effective against rust mites even upto 68 days after spraying on orange trees in Brazil [54]. Even as new products such as pyridaben become labelled for CRMs, the products will affect beneficial agents, and pests will develop resistance to the products [35, 69]. Therefore, resistance management continues to be an important reason for a sound integrated pest management program. Research with oils has produced guidelines for the most effective pesticidal oils with the least adverse effects on trees. Mite infestations can be controlled using multiple low concentration (0.25–0.5%) oil sprays. The oils suffocate the mobile stages and the oil deposits on the plant surface can reduce feeding and egg-laying behaviour. When applied properly, oils provide a very useful tool for controlling some citrus pests without damage to beneficial organisms but the sprays require careful use to avoid plant injury [35].

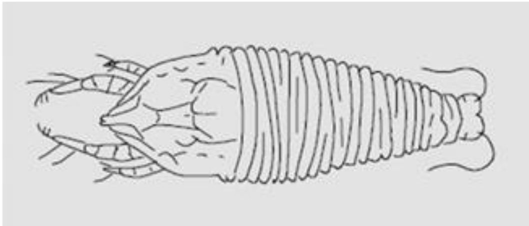

Fig 1: Adult citrus rust mite

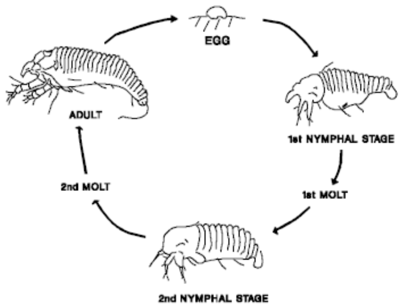

Fig 2: Citrus rust mite life cycle

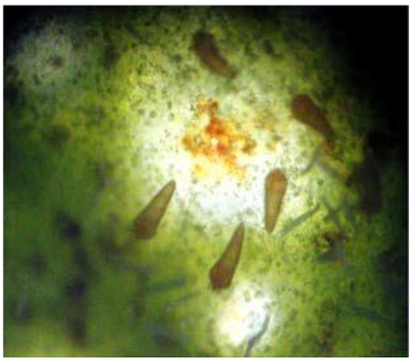

Fig 3: Adult rust mites on fruit pericarp

Fig 4: Russeting on sweet orange fruit

Conclusion and Future Thrust

The citrus rust mite is regarded as the most serious pest on fruits, mature leaves and branches of *Citrus* Species, in all the citrus-growing areas around the world, causing fruit rind russetting resulting loss in yield and fruit quality. The rusting symptoms on fruits appear 2-3 weeks after the populations on fruit exceed 50 CRMs/cm^2. Under favorable conditions, CRM populations are more than quadrupled on infested fruit during a 2-week period. Hence monitoring plays very important role in its management. Correlation of weather parameters and mite populations is an important pre-requisite while preparing 'forecasting models' based on which mite populations can be predicted in advance, so that an effective mite management strategy can be planned in advance to prevent the mites reaching economic threshold level. Since these are microscopic organisms prophylactic control measures are to be taken rather than curative measures. Many chemical management methods are available for CRM management. However these pests have developed resistance to many traditional pesticides used in their management. Hence resistance management continues to be an important area of thrust of future research studies. Two possible solutions to the problem of mite resistance might be the discovery of effective acaricides, to which mites are unable to develop resistance or the development of negatively correlated acaricides. Research on spray oils, has produced some guidelines towards the discovery of effective pesticidal oils with the least adverse effects on the sprayed trees providing environmental safety. Pesticides selection should be such that they have little or no effect on natural enemies and thus maintaining the ecological balance. The misuse of insecticides can sometimes allow an explosion of mites. Further, long-term research encompassing chemical applications and evaluations of the mite populations are necessary as a step towards development of control programs taking into consideration the seasonal phenology of key pests for a better management of the orchards.

References

1. Achor DS, Albrigo LG, Mc Coy CW. Developmental anatomy of lesions on 'sunburst' manadarin leaves initiated by citrus rust mite feeding. Journal of the American Society for Horticultural Science. 1991; 116(4):663-668.
2. Agfact H, Beattie GAC, Gellatley JG. Mite pests of citrus. Reviewed January, 2003 (first edition 1983), NSW Agriculture (www.agric.nsw.gov.av).
3. Albrigo LG, Mc Coy CW. Characteristic injury by citrus rust mite, *Phyllocoptruta oleivora* (Ash) to orange leaves and fruits. Proceedings of the Florida state Horticultural Society. 1975; 87:48-55.
4. Albrigo LG, McCoy CW. Characteristic injury by citrus rust mite to orange leaves and fruit. Proc. Fla. State Hort. Soc. 1974; 87:48-55.
5. Allen JC. The effect of citrus rust mite damage on citrus fruit drop. Econ. Entomol. 1978a; 71:746-750.
6. Allen JC. The effect of citrus rust mite damage on citrus tree growth. J con.Entomol. 1979a; pp. 195-201.
7. Allen JC, Yang Y, Knapp JL, Stansly, Rosen D. The citrus rust mite story: a modelling approach to a fruit-mite-pathogen system. Pest management in sub tropics: biological control a Florida perspective, 1994; pp. 36-39.
8. Allen JC, Yang Y, Knapp JL, Stansly PA. The citrus rust mite story: A modelling approach to a fruit-mite-pathogen system. In: Pest management in the subtropics: Biological control - a Florida perspective, eds. D. Rosen, F. Bennett and J. Capinera. Intercept Ltd. Andover, UK (in press), 1994a.
9. Allen JC, Yang Y, Knapp JL. Temperature effects on development and fecundity of the citrus rust mite (Acari: Eriophyidae), Environmental Entomology. 1995; 5(6):1083-1088.
10. Argov Y, Domeratzky S, Gerson U, Steinberg S, Palevsky E. Augmentation and conservation of indigenous generalist acarine predators for the control of citrus rust mite, *Phyllocoptruta oleivora*, in Israel. IOBC/wprs Bulletin. 2007; 30(5):9-15.
11. Ashmead WH. Injurious and beneficial insects found on the orange trees of Florida. Canada. Ent. 1879; 11:159-160.
12. Banks N. Catalogue of the Acariña, or Mites, of the United States. U. S. Nati. Mus.Proc. 1907; 32:595-625.
13. Bergh JC. Ecology and aerobiology of dispersing citrus rust mites (Acari: Eriophyidae) in Central Florida. Environmental Entomology. 2001; 30:318-326.
14. Brussel EW Van. Inter-relations between citrus rust mite, fungi, *Hirsutella thompsonii* and greasy spot on citrus in Surinam. Centre for Agricultural Publishing and Documentation Wageningen, 1975.
15. Bullock RC. Aerial Difolatan for citrus rust mite control in Florida. Proc. Fla. State Hort. Soc. 1981; 94:3-5.
16. Carl C. Childers. Effect of different copper formulations tank mixed with fenbutatin-oxide for control of citrus rust mites (acari: eriophyidae) on Florida citrus. Florida Entomologist. 1994; 77(3):349-365.
17. Chiavegato LG. Mites from citrus culture, p. 601-641. In: O. Rodrigues, F. Viegas, J. Pompeu Jr., Amaro A.A. (Eds.), Citricultura Brasileira, 2.ed., Campinas, Cargill. 1991, 941 pp. (in Portuguese).
18. Chen CY, Xu YX, Fei DB, Deng GQ. A preliminary study on the predaceous mite, Chinese Journal of Biological Control. 1988; 4(4):181.
19. Tydeus sp. of *Phyllocoptruta oleivora*. Chinese J. of Biol. Control. 1988; 4(4):176-178.
20. Commonwealth Institute of Entomology. Distribution maps of pests. Series A (Agricultural), Map no. 78 (revised). 1970, London, Commonwealth Institute of Entomology.
21. Davidson RH, Lyon WF. Insect pests of farm, garden and orchard. 1987, John Wiley & Sons, New York.
22. Dean H.A. Seasonal distribution of mites on Texas grapefruit. J. Econ.Entomol. 1959a; 52(2):228-232.
23. Ebrahim HM. Influence of temperature and relative humidity on the biology and life table parameters of *Phyllocoptruta oleivora* and Aculops pelekassi (Acari: Eriophysiae) on 'Hamlin' orangein central Florida. Egyptian J Agric. Bes. 2000; 78:143-161.
24. Edy Syahputraa, Otto Endart. Acaricidal activity of tropical plant extracts against citrus mites and their effect on predators and citrus plants. International Research Journal of Agricultural Science and Soil Science. 2013; 3(4):99-106.
25. Ewing HE. The generic and specific name of the orange rust mite. Fla. Entomol. 1923; 7: 21-22.
26. Flores AE, Flores S, Badii MH, Aranda E, Hernandez. Susceptibility of citrus rust mite, *Phyllocoptruta oleivora* and the predatory mite, *Euseius mesembrinu* to the acaricides Dicofol. Southwestern Entommologist. 1996; 21(1):83-84.

27. Gerson U. Acarine pests of citrus: overview and non-chemical control. Syst Appl Acarol. 2003; 8:3-12.
28. GGonzalez N, Kalinin YV, Diaz E. Population dynamics of the citrus rust mite during four years, related to the phenology of 'valentia' orange. Proteccion de plantas. 1985; 6(3):35-62.
29. Gravena S, Coletti A, Yamamoto PT. Influence of green cover with *Ageratum conyzoides* and *Eupatorium pauciflorum* on predatory and phytophagous mites in citrus. Bull. Experimental & Applied Acarology. 1993; 37(1-2):117-122.
30. Griffiths JT, Thompson WL. Insects and mites found on Florida citrus. Univ. Fla. Agr. Expt. Sta. Bui. 1957; 591-39-42.
31. Hanna MA, Abdelhafez, Wahba ML. Influence of thiocarbamate fungicides on population of citrus rust mite, *Phyllocoptruta oleivora* (Ash.). Agricultural Research Review. 1975; 53(1):181-186.
32. Ibrahim GA. Effects of different fungicides on the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.) and *Brevipalpus californicus*(Banks) with their associated predatory mites. Egyptian J of Agri. Res. 1992; 70(1):207-213.
33. Iskander NG. Chemical control of the rust mite, *Phyllocoptruta oleivora* (Ashm.) and *Brevipalpus californicus*(Banks) and its side effects on the *Amblyseius californicus* on citrus trees. Egyptian J of Agri. Res. 1993; 70(2):436-472.
34. Jeppson LR, Keifer HH, Baker EW. Mites injurious to economic plants. University of California, Berkeley and Los Angeles, California. 1975; pp. 614.
35. Juan Anciso, Victor French J, Mani Skaria, Julian W, Sauls Rodney, Holloway. IPM in Texas Citrus. Texas Cooperative Extension. 2002, p-56.
36. Kalaisekar A. Bio-ecology and control of mangu mite, *Phyllocoptruta oleivora* (Ashmead) on citrus. 1999, M.Sc. Thesis, Acharya N G Ranga Agricultural Universityy, Hyderabad.
37. Keifer HH. Eriophid studies. Calif. Dept. Agric. Bull. 1938; 27(2):181-206.
38. Knapp JL, Fasulo TR, Tucker DP. The effects of different irrigation and weed latifolia, under induced drought conditions. Experimental and Applied Acarology. 1982; 24:897-904.
39. Knapp JL. Citrus rust mites Fact Sheet ENY-619, Florida Cooperative Extension Service, 1994, Institute of Food and Agricultural Sciences, University of Florida.
40. Magally Quiros-Gonzalez. Phytophagous mite populations on Tahiti lime, Citrus management practices on mite populations in a citrus grove. Proc. Fla. State Horticult. Soc. 2000; 95:47-50.
41. Mc Coy CW, Albrigo LG. Feeding injury to the orange caused by citrus rust mite, *Phyllocoptruta oleivora* (Prostigmata: Eriophyidae). Annals of the Entomological Soc. of America. 1975, 68(2):289-297.
42. Mc Murthy JS. Some predaceous mites (phytosiidae) on citrus in the Mediterranean region, Entomophaga. 1977; 22:19-30.
43. McCoy CW. Leaf injury and defoliation caused by citrus rust mite, *Phyllocoptruta oleivora*. Fla. Entomol. 1976; 59(4):403-410.
44. McCoy CW, Albrigo LG. Feeding injury to the orange caused by the citrus rust mite *Phyllocoptruta oleivora* (Prostigmata: Eriophyoidea). Arm. Entomol. Soc. Amer. 1975; 68:289-297.
45. Moraes LAH, De Menezes Porto, Braun J. Effect of three doses of sulphur on citrus rust mite, *Phyllocoptruta oleivora* (Ashmead, 1879) Acari: Eriophyidae) on citrus. Pesquisa Agropecuria Gaucha. 1995; 1(10):17-20.
46. Moraes LAH, De Porto OM, Chouene EC, Braun J, Hoss de Moraes LA, Menezes Porto Ode. Chemical control of the rust mite, (*Phyllocoptruta oleivora*). Agronomia Sulriograndense. 1988; 23(2):193-202.
47. Moraes GJ. Perspectives for the use of predators in the control of phytophagous mites in Brazil. Pesquisa Agropecuária Brasileira, Brasília. (in Portuguese, with abstract in English). 1992; 27:236-270.
48. Muma MH. The influence of cover crop cultivation on populations of injurious insects and mites in Florida citrus groves. Fla. Entomol. 1961; 44:61-68.
49. Nagalingam B, Savitri P. Chemical control of the rust mite, *Phyllocoptruta oleivora* (Ashmead) on sweet orange, South Indian Horticulture. 1983; 31(2&3):140-143.
50. National Horticulture Board Data base. 2017-18. www.nhb.gov.in
51. Oliveira CAL, De Riggotto EL Silva JRT da. Effects of the application of chemical products for the control of the rust mite, *Phyllocoptruta oleivora* (Ashm.). annals da sociedade Entomologica do Brasil. 1985; 13(2):237-247.
52. Osburn MR, Mathis W. Effect of cultural practices on the citrus rust mite. J. Econ. Entomol. 1944; 37:767-770.
53. Ramasubba Reddy K. Studies on the pest complex of citrus and chemical control of leafminer (phyllocnistis citrella). M.Sc. Thesis Andhra Pradesh agricultural University, Hyderabad, 1984.
54. Rangel RC, Hamamura R, Regitano EB, Clari AI, Mesquita LF, Cardoso MAC, Mariconi FAM. Control of citrus rust mite (*Phyllocoptruta oleivora* Ashm.1879) by a juvenoid and other pesticides. Scientia Agricola. 1993; 50(1).
55. Rao CN, Shivankar VJ. Insect pest management in citrus: An overview. National Citrus Meet(August,12-13th), NRCC, Nagpur, India Soveinir& Abstracts. 2013; pp. 192-206.
56. Raul T Villanueva. Two Species of Cecidomyiidae Predacious on Citrus Rust Mite, *Phyllocoptruta oleivora*, on Florida Citrus. Florida Entomologist. 2006; 89(2):161-169.
57. Rogers ME, Stansly PA, Childers CC, McCoy CW, Nigg HN. Rust Mites, Spider Mites and Other Phytophagous Mites. Florida Citrus Pest Management Guide, 2014, University of Florida, IFAS Extenstion.
58. Reis PR, Chiavegato LG, Alves EB, Sousa EO. Mites of the Phytoseiidae Family Associated with Citrus in Lavras County, Southern Minas Gerais State, Brazil. Anais da Sociedade Entomológica do Brasil. (in Portuguese, with abstract in English). 2000; 29:95-104.
59. Sanchez JA, Salas Padron JE, Chavez, Salas JA Sanchez. Populations of the the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.) and their relation to the damage caused to the orange, Citrus sinensis Osb; in General Teran, Nuevo Leon. Agricultura tecnica en mexico. 1985; 9(1):3-11.
60. Savitri P, Ramasubba Reddy K. A note on rust mite, *Phyllocoptruta oleivora* (Ash.) damage on Rangpur lime.

The Andhra Agricultural Journal. 1988; 35(1&2):116-117.

61. Setamou M, Sekula D. Effectiveness and economics of a novel proactive approach for managing the Citrus Rust Mite in Texas. XII International citrus congress, Spain. 2012, pp-293.
62. Schwartz A. Aftermath of rust mite infestation. Citrus and subtropical fruit journal. 1975; 44:22.
63. Schwartz A. The role of pradators in the control of citrus red mite Lowveld. Citrus and subtropical fruit journal. 1976; 509:17-19.
64. Sérgio Batista Alves, Marco Antonio Tamai, Luciana Savoi Rossi, Enrique Castiglioni. *Beauveria Bassiana* Pathogenicity to the Citrus Rust Mite *Phyllocoptruta oleivora* Spec. Rpt. 2005, 1885, 227 p., illus.
65. Shivankar VJ, Rao CN, Shyam Singh. Citrus Mites: Management - A Review. Agric. Rev. 2001; 22(2):109-114. Swingle, W. T. & Reece, P. C. The botany of Citrus and orange relatives in the orange subfamily.
    1967, Pp. 190–340 n: Reuther, W., Webber, H. J. & Batchelor, D. L. (eds.) The Citrus Industry, vol. 1, 2nd ed. California Univ. Press, Berkeley.
66. Swirski E. Contribution to the knowledge of the fluctuations in population of the citrus rust mite (*Phyllocoptruta oleivora* Ashm.) in the coastal plain of Israel. Israel J. Agric. Res. 1962; 12:175-187.
67. Teiamar Da Encarnação Bobot, Elizabeth Franklin1, Denise Navia, Thierry Ray Jehlen Gasnier, Antonio Carlos Lofego and Byatryz Mortágua De Oliveira. Mites (Arachnida, Acari) on Citrus sinensis L. Osbeck orange trees in the State of Amazonas, Northern Brazil. Acta Amazonica. 2011; 41(4):557-566.
68. Tian-Ye Chen, J Victor French, Tong-Xian Liu, John V. da Graça. Residual Toxicities of Pesticides to the Predaceous Mite *Galendromus helveolus* (Acari: phytoseiidae) on Texas Citrus Subtropical Plant Science. 2003; 55:40-45.
69. Tna DJ. Field experiments on the integrated control of citrus mites. Chinese J. of Biol. Control. 1988; 2(4):181.
70. Van Brussel EW. Interrelations between citrus rust mite, *Hirsutella thompsonii* and greasy spot on citrus in Surinam. Landbouwproefstation Suriname/Agricultural Experiment Station Bulletin. 1975, No. 98, Paramaribo.
71. Vincenzo Vacante. Review of the phytophagous mites collected on citrus in the world Acarologia. 2010; 50(2):221-241
72. Yael Argov, Eric Palevsky and Uri Gerson. Biological control of citrus rust mite using indigenous and introduced generalist Acarine predators in Israel. Second International Symposium on Biological Control of Arthropods. 2005; 9:41.
73. Yang Y, Allen JC and Stansly PA. Frequency distribution of citrus rust mite (Acari: Eriophyidae) damage on fruit in ‘Hamlin’ orange trees. Environmental Entomology. 1997; 24(5):1018-1023.
74. Yang Y, Allen JC, Knapp JL, Stansly PA. Citrus rust mite (Acari: Eriophydae) damage effect on ‘Hamlin” orange fruit growth and drop. Environ. Entomol. 1994; 23:244-247.
75. Yothers WW. Some reasons for spraying to control insect and mite enemies of citrus trees in Florida. USDA Bui. 1918; 645.
76. Yothers WW, Mason AC. Citrus rust mite and its control. USDA Agricultural Technical Bulletin. 1930; pp.176-56.
77. Yubin Yang. Population dynamics and damage effects of the Citrus Rust Mite, *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), Ph.D. thesis submitted to University of Florida, 1994.