20 Acari – Leaf-Feeding Mites

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Mites living on cotton belong to three large superfamilies of phytophagous mites, i.e. Tetranychoidea, Tarsonemoidea and Eriophyoidea. Representatives of these groups each have a particular morphology and cause characteristic damage.

The Tetranychoidea, which are subdivided into Tetranychidae or spider mites and Tenuipalpidae or false spider mites, are coloured, the females are visible with the naked eye and measure 0.3–0.5 mm. They puncture cells of the epidermis and parenchyma and absorb the contents. The damage takes the form of spots of variable intensity on leaves that can eventually cause drying and defoliation.

Tarsonemoidea have an oval translucent bright body whose largest dimension varies from 0.1–0.3 mm. The phytophagous species mainly live on young leaves that have not yet unfolded, which are particularly sensitive to substances contained in the injected saliva. They cause leaf deformation and can even stunt the whole plant. The only species incriminated causes bronzing on leaf undersurfaces and limb margin deformations. As the leaves age, they may split or crack open.

Eriophyoidea have a vermiform body and only two pairs of legs. They are small, with a body length ranging from 0.1–0.25 mm. They have a waxy white colour and generally can only be seen with a stereomicroscope. Unlike tetranychid mites, eriophyid mites do not kill the leaves they attack. On cotton, they either cause velvet-like hair to appear on leaves and petiole or induce the appearance of galls and branch deformation. They have a very narrow range of host plants and in most cases they are only collected on a single plant species. They are capable of transmitting virus infections.

In these three superfamilies, reproduction is characterized by male-producing parthenogenesis (arrhenotoky), i.e. males are born from an unfertilized haploid egg, females from a diploid egg. Some species reproduce by female-producing parthenogenesis (thelytoky) and in this case the life cycle only comprises individuals with 2 N chromosomes.

Only tetranychid and tarsonemid mites have a severe impact on cotton farming in the world. Tetranychidae outbreaks tend to occur in arid regions, whereas Tarsonemidae cause more problems in humid regions that are very cloudy during the period of cotton cropping. The importance of the damage is considerably increased because of the destruction of the natural predators of these mites which occurs as a consequence of insecticide treatment designed to control a major cotton pest.

TETRANYCHOIDEA

Tetranychidae

The species and their distribution

Thirty-six tetranychid species (Table 20.1) are reported to be pests of cotton in different parts of the world but only nine of them have real economic significance: they belong to the genera *Oligonychus* and *Tetranychus.*

Mites of the genus *Oligonychus* colonize the upper leaf surface, while those of the genus *Tetranychus* feed on the under surface (Plate VIII.2). In the latter case the injury shows on the upper surface as whitish areas where feeding has occurred.

Oligonychus gossypii (Zacher), originally described on cotton in Togo, is widespread in all tropical Africa and is also known in Central America and Brazil. This relatively large species is dark red in colour. It is very common on many host plants in West Africa and appears to be sensitive to acaricides.

Tetranychus desertorum Banks, the desert spider mite, has been recorded in the southern USA, and Central and South America. The females are carmine in colour. Cases of resistance to organophosphates have been reported (Cranham and Helle, 1985).

Tetranychus gloveri Banks is known throughout tropical America. The name *Tetranychus tumidus* Banks has been wrongly used for this species by many authors. *T. tumidus* is the water hyacinth spider mite, while *T. gloveri* infests many plants (Boudreaux, 1979). The females are carmine and the freshly laid eggs are colourless.

Tetranychus lombardinii Baker and Pritchard, first described on cotton in Mozambique, has subsequently been collected on cotton plantations in Malawi, Zimbabwe and South Africa (Meyer and Rodrigues, 1966; Meyer, 1987). The females are dark red with a dark spot on each side of the body.

Tetranychus ludeni Zacher, although widespread throughout the tropics, is known as a cotton pest in Mozambique, South Africa and Australia. The females are carmine with reddish legs. Some strains of this species may be resistant to organophosphates (Cranham and Helle, 1985).

Tetranychus neocaledonicus Andre (=*Tetranychus cucurbitae* Rahman and Sapra = *T. equatorius* McGregor). The vegetable mite has a wide host range and is

Table 20.1. Tetranychidae reported to be pests of cotton, their alternative host plants, and their world distribution.

Species	Alternative host plants	Geographic distribution	References
Petrobia latens (Muller)	Monocotyledons	Europe, North Africa, South Africa, North America, Australia	Baker and Pritchard, 1953; Pritchard and Baker, 1955
Eutetranychus africanus (Tucker)	Citrus, frangipani, castor bean, breadfruit	Egypt, Mozambique, South Africa, Madagascar, Mauritius, Burma	Attiah, 1967; Meyer and Rodrigues, 1966; Meyer, 1987
Eutetranychus citri Attiah	Citrus	Egypt	Yousef *et al.*, 1976
Eutetranychus orientalis (Klein)	Citrus, frangipani, castor bean, papaya	Southern Asia, Middle East, Tropical Africa	Attiah, 1967; Jeppson *et al.*, 1975; Meyer, 1987
Eutetranychus palmatus Attiah	Date palm	Egypt	Yousef *et al.*, 1976
Allonychus littoralis (McGregor)	Avocado	Ecuador, Central America	McGregor, 1955
Eotetranychus falcatus Meyer and Rodrigues	Peanut, Hibiscus, Sida	Tropical Africa	Meyer and Rodrigues, 1966; Meyer, 1987
Eotetranychus smithi Pritchard and Baker	Rose, Rubus	USA, Japan, Madagascar	Caldwell, 1967
Mononychellus planki (McGregor)	Beans, peanut, soyabean	Brazil, Colombia, Puerto Rico	Flechtmann and Baker, 1970
Oligonychus andrei Gutierrez	Grewia	Madagascar	Gutierrez, 1967
Oligonychus coffeae (Nietner)	Tea, mango, frangipani, cassava, rose	Pantropical	Meyer and Rodrigues, 1966
Oligonychus intermedius Meyer	Dombeya, Grewia	South Africa, Malawi	Meyer, 1987
Oligonychus mangiferus (Rahman and Sapra)	Mango, rose	Pantropical	Mohamed, 1963

Table 20.1. Continued

Species	Alternative host plants	Geographic distribution	References
Oligonychus peruvianus (McGregor)	Grapes, willow, carob, avocado	California, Texas, Mexico, Guatemala, Venezuela, Trinidad, Peru	Estebanes and Baker, 1968
Oligonychus gossypii (Zacher)	Cassava, citrus, rose	Tropical Africa, Madagascar, Central America, Brazil	Baker and Pritchard, 1960; Jeppson *et al.*, 1975
Oligonychus mcgregori Baker and Pritchard	Ficus, Lonchocarpus	Central America, Mexico	Baker and Pritchard, 1953; Estebanes and Baker, 1968
Oligonychus stenoperitrematus (Ugarov and Nikolskii)	Maize, watermelon, thistle	Former USSR	Pritchard and Baker, 1955
Tetranychus amicus Meyer and Rodrigues	Banana, cassava, peanut	South Africa, Mozambique, Reunion, Mauritius	Meyer and Rodrigues, 1966; Gutierrez, 1974
Tetranychus canadensis (McGregor)	Apple, plum, rose, horsechestnut, poplar	Canada, USA	Pritchard and Baker, 1955
Tetranychus desertorum Banks	Leguminous forage crops, beans, Graminae, horseweed, eggplant, melons	Southern USA, Central and South America, China, Japan	Nickel, 1960; Wang, 1981
Tetranychus gigas Pritchard and Baker	No other known host	Texas and Arizona	Pritchard and Baker, 1955
Tetranychus gloveri Banks	Beans, eggplant, banana	Southern USA, Central and South America, Guam	Boudreaux, 1979
Tetranychus lombardinii Baker and Pritchard	Hibiscus, banana, Solanaceae	South and East Africa, Madagascar, Australia, Indonesia	Gutierrez and Schicha, 1983; Meyer, 1987

Table 20.1. Continued

Species	Alternative host plants	Geographic distribution	References
Tetranychus ludeni Zacher	Compositae, Cucurbitae, Leguminosae	Pantropical, in greenhouses in more temperate areas	Meyer and Rodrigues, 1966; Davis, 1968; Meyer, 1987
Tetranychus macfarlanei Baker and Pritchard	Beans, Hibiscus, pumpkin	India, Mauritius, Madagascar	Jose and Shah, 1986 and 1988
Tetranychus marianae McGregor	Castor bean, passionflower	Australia, Pacific Islands, Tropical America	Davis, 1968; Jeppson *et al.*, 1975; De Moraes *et al.*, 1987
Tetranychus neocaledonicus André	Polyphagous	Pantropical	Meyer and Rodrigues, 1966; Gutierrez, 1976
Tetranychus pacificus McGregor	Deciduous fruits, walnut, grapes, leguminous forage crops	Interior western USA, Mexico	Jeppson *et al.*, 1975
Tetranychus piercei McGregor	Banana, papaya, Palmae	Southeast Asia	Fauvel, personal communication
Tetranychus rooyenae Meyer	Hibiscus, Solanaceae	South Africa, Malawi	Meyer, 1987
Tetranychus schoenei McGregor	Deciduous fruits, beans	Eastern and southeastern USA	Jeppson *et al.*, 1975
Tetranychus tchadi Gutierrez and Bolland	Beans, soyabean	Chad, Senegal, Mali	Gutierrez and Etienne, 1981
Tetranychus turkestani Ugarov and Nikolskii	Polyphagous	Regions of the northern hemisphere with a temperate or mediterranean climate, South Africa	Uspenskii, 1978; Meyer, 1987
Tetranychus urticae Koch	Polyphagous	Cosmopolitan but more widespread in temperate climate	Jeppson *et al.*, 1975; Meyer, 1987
Tetranychus yusti McGregor	Beans, soyabean, Compositae, Leguminosae, Graminae	Southeastern USA, Mexico, Central America, Ecuador, Nigeria	McGregor, 1955; Matthysse, 1978
Tetranychus zambezianus Meyer and Rodrigues	Soyabean	Angola, Zimbabwe, Mozambique, Madagascar	Meyer and Rodrigues, 1966; Meyer, 1987

distributed throughout tropical regions. It is an important pest mite in India, Madagascar and Africa where it is common on cotton. The females are bright red with clearer legs. Numerous acaricides are effective against this mite and no resistant strain has been reported in the literature.

Tetranychus pacificus McGregor, the Pacific spider mite, has been recorded from British Colombia to California and Mexico. It is a pest of a wide variety of crops. Feeding females are greenish with dark spots on each side of the body. It is one of the most difficult tetranychid mites to control because its populations have developed resistance to several acaricides (Jeppson *et al.*, 1975).

Tetranychus turkestani Ugarov and Nikolskii (=*Tetranychus atlanticus* McGregor). The strawberry spider mite is usually collected in regions with a temperate or Mediterranean climate. It feeds primarily on low-growing hosts, less often on fruit trees. Females are straw coloured or greenish with dark spots on each side of the body. They can hibernate, the winter forms being bright orange. In California this species predominates in fields during late spring and early summer (Leigh, 1985). Cases of resistance to organophosphates have been reported (Cranham and Helle, 1985).

Tetranychus urticae Koch, the two-spotted spider mite is considered to be a complex that includes *Tetranychus cinnabarinus* (Boisduval) (Dupont, 1979). More than fifty synonyms have been used for this species, the best known being *T. telarius* L., *T. bimaculatus* Harvey, *T. arabicus* Attiah and *T. cucurbitacearum* (Sayed). *Tetranychus urticae* originates in the temperate zones but is frequently found in intensively farmed regions of the tropics. Its strains show resistance to most of the acaricide groups (Cranham and Helle, 1985). When obliged to survive on spontaneous vegetation in tropical regions, it is often less competitive than indigenous Tetranychidae, despite its large polyphagia. On the other hand its resistance to pesticides allows it to predominate in regularly treated areas. Summer females have two colour forms: carmine with a dark spot on each side of the body (*cinnabarinus* form) and green with similar spots (*urticae sensu stricto* form). Hibernating females are uniformly orange.

Other Tetranychidae mentioned by different authors cited in Table 20.1 have been collected on cotton and manage to develop on this plant without attaining outbreak proportions. These species are actually only found in limited areas near other host plants that are more favourable to their multiplication and constitute infestation reservoirs.

Tetranychus tchadi Gutierrez and Bolland (=*Tetranychus joanni* Meyer), which was first found on soybean and beans in Chad and Senegal, has been collected on cotton in Nigeria (Meyer, 1987) and was recently found on this plant in Mali. *Eotetranychus falcatus* Meyer and Rodrigues, first reported in South Africa, Mozambique, Zimbabwe, Malawi and Angola (Meyer, 1987) has been identified in Togo and Mali. *Tetranychus piercei* McGregor, which was described in Southeast Asia on different crops, was also recently identified on cotton in the Philippines (G. Fauvel, personal communication, 1991).

In terms of the large cotton farming regions in the world, *T. urticae* and *T. turkestani* are the most widespread in China, the former USSR and the Middle East (Uspenskii, 1978; Demillo, 1979; Cai, 1985). *Tetranychus urticae, T. ludeni* and *T. neocaledonicus* are most common in India (Gupta, 1985). In Africa, in addition to

T. urticae which is rampant in Egypt (Yousef *et al.*, 1976) and was introduced into South Africa (Meyer and Rodrigues, 1966) as well as into Benin, Ivory Coast and Senegal in intensively cultivated areas, cotton plantations are attacked by species from the surrounding spontaneous vegetation. These include *T. lombardinii, T. neocaledonicus* and *T. ludeni* in East Africa and South Africa (Meyer and Rodrigues, 1966; Duncombe, 1977) and *Oligonychus gossypii* and *T. neocaledonicus* in West Africa.

Tetranychus urticae is present in all regions of the USA, along with *T. turkestani* and *T. pacificus* in California (Leigh, 1985), *T. desertorum* in Texas (several authors cited by Nickel, 1960), and *T. gloveri* in Louisiana and all over the southeast (Jeppson *et al.*, 1975).

Life history (Fig. 20.1)

With the exception of *Petrobia latens* (Muller) which reproduces by thelytoky and is of secondary importance (Baker and Pritchard, 1953), all the species shown in Table 20.1 reproduce by arrhenotoky. In all cases, there are three active larval stages between the egg and the adult (larva, protonymph, deutonymph), alternating with three resting stages (protochrysalis, deutochrysalis and teliochrysalis). The total development time of *T. urticae* growing on cotton at a constant temperature of 25°C and a constant relative humidity of 50% is nine days for males and 9.2 days for females (Gutierrez, 1976).

Reared at 25°C, most females of the *Tetranychus* species mentioned (*T. desertorum, T. neocaledonicus, T. pacificus, T. turkestani* and *T. urticae*) live for three to four weeks and lay 50 to 100 eggs (several authors reviewed by Sabelis, 1985).

In tropical regions, a generation lives for 15 to 20 days depending on the

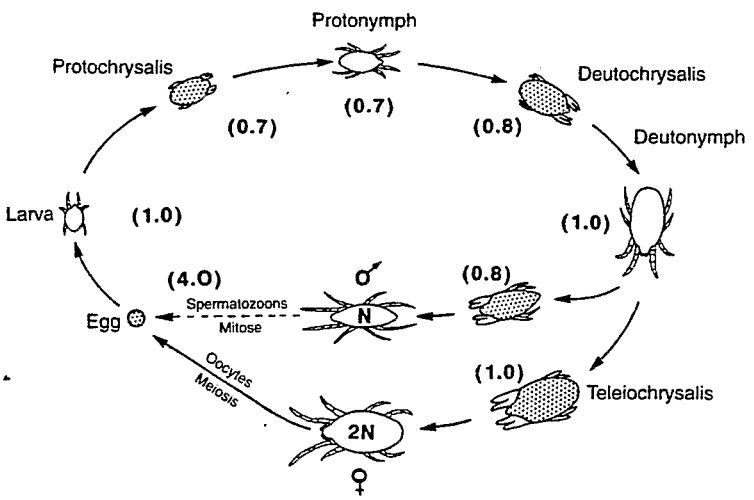

Fig. 20.1. Life history of a tetranychid mite. Figures in brackets indicate the length in days of the different development stages of *Tetranychus urticae* Koch bred at 25°C and RH 50%.

period of the year, meaning that there can be as many as ten successive generations of tetranychid mites during the period of cotton cropping (Gutierrez, 1976).

Dispersal and within-plant distribution

Tetranychid mites can crawl along plants and the ground. For long-distance dispersion they can be carried from one location to another on man, insects or birds but the main means of dispersion is probably wind: mites lower themselves from the host plant on silk threads, that serve as balloons or parachutes to carry them considerable distances.

Working on three species (*T. urticae, T. pacificus* and *T. turkestani*) in California, Carey (1982) demonstrated that on developing cotton plants, females found colonies about midway up the plant and that the majority of the mites occupied the fifth to the tenth mainstem leaves below the apical plant terminal. By late season they move into the plant terminal.

Damage and crop losses

Mechanical injury to epidermal and mesophyll cells leads to important water losses. Cell chloroplasts are damaged and the intensity of photosynthesis is reduced. Disturbance of metabolic processes results in decreased growth, flowering and cropping.

A comparison between physiological injuries caused by *T. turkestani, T. pacificus* and *T. urticae* shows that *T. turkestani* is the most injurious species and *T. pacificus* is somewhat more harmful than *T. urticae. Tetranychus turkestani* causes toxin-induced injury to cotton unlike the other two species (Brito *et al.*, 1986).

Authors who have carried out measurements of yield decreases due to tetranychid mites all agree that losses are severe, and that the economic significance of the damage increased with the earliness of the attack.

In the region of Sao Paulo in Brazil, outbreaks of *T. urticae* reduce the harvest by 17–25% and affect fibre quality (Oliveira and Calcagnolo, 1975). In Alabama, an early attack of the same species decreased the quality of the cotton and reduced the seed yield by 14–44% depending on the infestation level (Canerday and Arant, 1964a).

A late attack of *T. turkestani* in Alabama caused a seed loss of 13–22% (Canerday and Arant, 1964b). In Kazakhstan, an infestation by this species starting in the flowering stage, caused yield reductions of the order of 44% and losses even reached 62% when the mites attacked at the beginning of the season (Wehner, 1989).

In Zimbabwe, infestation by one of the three common species (*T. urticae, T. lombardinii, T. ludeni*) 14 weeks after germination causes damage of the order of 14%, but when it occurs six weeks after germination, losses reach 67% (Duncombe, 1977). This is partly due to the fact that the tolerance of cotton for Tetranychidae increases as the period of boll maturity approaches (Wilson *et al.*, 1987).

Natural enemies

Tetranychids are attacked by many predators, including insects and other mites.

Insects

These consist of Coleoptera, Thysanoptera, Diptera, Hemiptera, Neuroptera and Dermaptera. Only the first three orders comprise predators that are truly specific for mites. In the Coleoptera, these includes Staphylinidae of the genus *Oligota* (ten species mentioned by Chazeau, 1985) and Coccinellidae of the genus *Stethorus* (thirty-odd species mentioned by Chazeau, 1985). Out of the three families of Thysanoptera predators of mites, members of the family Thripidae are the most active in tropical countries. Diptera are mostly represented by Cecidomyiidae, whose larvae feed on tetranychid adults and all the developmental stages. Predation by Hemiptera is less frequent on cotton, since the Anthocoridae or Miridae attacking phytophagous mites are more rare in tropical countries than in the summer in temperate countries.

Insect predators are relatively indifferent to the host plant and their flying capacity allows them to focus on high concentrations of tetranychid mites. Their high sensitivity to pesticides causes their disappearance in cotton fields as soon as the first insecticides are applied, and for this reason they have not yet been considered for use in integrated biological control.

Acari

The mites which prey on tetranychid mites belong to the Bdellidae, Anystidae, Stigmaeidae and Cheyletidae families, but it is above all the Phytoseiidae which are the most widespread and effective. Sixty-three species of Phytoseiidae divided into 15 different genera have been recorded on cotton throughout the world (De Moraes *et al.*, 1986).

Numerous Phytoseiidae also show a resistance to insecticides, particularly to organophosphates. This feature is commonly made use of in integrated pest management programmes in temperate zone orchards and vineyards, and it could be employed with cotton plants in the warm regions. Although Phytoseiidae strains resistant to specific insecticide (e.g. organophosphates) have still not been introduced into cotton plantations, the impact of pesticide treatments on their survival is already taken into account when insecticides and acaricides are chosen.

Control

At present chemical application is the method most commonly employed to control outbreaks of Tetranychidae. Treatment ought only to be undertaken if infestation exceeds a threshold determined by sampling (Leigh, 1985).

Careful regular inspection of fields is necessary to detect the first appearance of an infestation, which may be confined to a few plants or localized patches within a field. Slight mottling at the base of leaves may be seen more easily than the mites. When detected early, it may be possible to 'spot' treat these areas and reduce the amount of acaricide needed. Unfortunately, prolonged use of an acaricide can lead to rapid selection of resistant populations, so acaricide rotation

Table 20.2. Tenuipalpidae reported to be pests of cotton, their alternative host plants, and world distribution.

Species	Alternative host plants	Geographic distribution	References
Brevipalpus californicus (Banks)	Polyphagous	Pantropical, particularly reported from Mozambique and Nigeria	Meyer, 1979
Brevipalpus obovatus Donnadieu	Polyphagous	Pantropical, particularly reported from Egypt, Mozambique and South Africa	Yousef *et al.*, 1976; Meyer, 1979
Brevipalpus phoenicis (Geijskes)	Polyphagous	Pantropical, particularly reported from Egypt, Mozambique and South Africa	Yousef *et al.*, 1976; Meyer, 1979
Raoiella indica Hirst	Coconut, Arecanut	India, Mauritius	Gupta, 1985

schemes have been devised (Duncombe, 1972, 1973) in which the use of a particular chemical group within a specified area is limited to a maximum of two seasons. Farmers then change to a different type of acaricide.

Field officers often have a tendency to favour the use of compounds which also have a considerable effect on other crop pests, whereas one ought to choose them according to the species present in the field. The establishment of an acaricide rotation scheme avoids selection of resistant populations (see Chapter 27).

When there are several species present, as in California (*T. urticae, T. pacificus* and *T. turkestani*), an individual treatment affects their relative abundance (Trichilo *et al.*, 1990).

In Brazil, Andrade *et al.* (1989) reported that dimethoate ($400\,g\,l^{-1}$ and $600\,ml\,ha^{-1}$ and ethyl-chlopyrifos ($480\,g\,l^{-1}$ and $200\,ml^{-1}$) were very effective against *T. urticae* in the state of Parana. In São Paulo state, Gavioli *et al.* (1988) showed the effectiveness of abamectin ($10\,g\,ha^{-1}$ a.i.) against the same species.

In South Africa, Botha *et al.* (1988) successfully controlled *T. urticae* with pyrethroid insecticides such as fenvalerate ($200\,cm^3$ a.i. ha^{-1}) and biphenthrin ($300\,cm^3$ a.i. ha^{-1}), which were more effective than triazophos or hexythyazox.

Several studies of some cultivars show an important resistance to Tetranychidae (Leigh, 1985; Trichilo and Leigh, 1985; Sengonca *et al.*, 1986; Botha *et al.*, 1989), but these promising results have not yet been implemented.

Tenuipalpidae

False spider mites are smaller than Tetranychidae and move more slowly. Only four species (Table 20.2) have been reported on cotton, three belonging to the same genus, i.e. *Brevipalpus californicus* (Banks), *B. obovatus* Donnadieu and *B. phoenicis* (Geijskes), and a fourth, *Raoiella indica* Hirst.

Tenuipalpidae have a life cycle comparable to that of Tetranychidae and their reproduction is generally based on arrhenotoky. The species found on cotton comprise males and females, but males are extremely rare in the three *Brevipalpus* species, and reproduction of most strains living in the tropics occurs by thelytoky.

Brevipalpus californicus, B. obovatus and *B. phoenicis* are all polyphagous and cosmopolitan. They are very flat and a brick-red colour. The literature only reports their presence on cotton in Africa, but it is probable that they infest this plant in other parts of the world. They are sometimes collected in mixtures, and the species can only be distinguished after preparation and microscopic examination. They live on both surfaces of leaves near the midrib. The damage they cause is basically comparable to that of the Tetranychidae but much less widespread. Since they are sensitive to many insecticides and acaricides, their populations in cotton plantations are small and their economic impact is practically negligible.

Raoiella indica has only been reported by Gupta (1985) on cotton in India and its normal plant hosts are Palmaceae. Its presence on cotton is probably accidental in plantations located near palm trees.

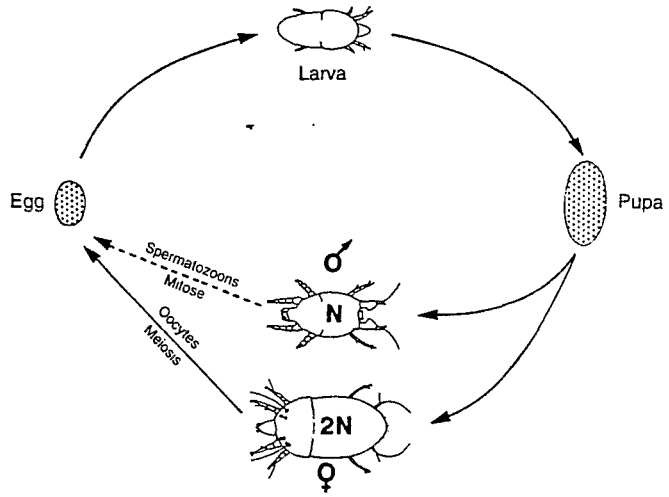

Fig. 20.2. Life history of a tarsonemid mite.

TARSONEMOIDEA

Tarsonemidae

Only one species has been recorded on cotton *Polyphagotarsonemus latus* (Banks), the yellow tea mite or the broad mite, previously named *Hemitarsonemus latus* (Banks). This mite is distributed throughout the tropics and is a greenhouse pest in temperate regions. It feeds on a wide variety of agricultural crops, ornamental and wild plants.

Life history (Fig. 20.2)

The developmental cycle of *P. latus* includes only egg, larva, pupa and adult stages. The oval and elongate eggs are attached to the leaf surface, and their upper surface is studded with longitudinal rows of small tubercles. The larvae are hexapodal and move and feed like adults. They pass without moulting into an inactive stage called a pupa before hatching into adults. At 26–30°C and high relative humidity, only four to five days are required to complete a generation (Schmitz, 1962), i.e. the species multiplies rapidly. The average egg deposition under such conditions is 3.5 eggs per day for six days.

Dispersion is improved by the male's habit of carrying away a female pupa, but longer-range dispersion is accomplished by wind and phoretic association with different insects (Flechtmann *et al.*, 1990).

Damage and crop losses

Lesions caused by *P. latus* appear as limb margin deformations and even perforations leading to limb lacerations. The disturbance of plant physiology takes the form of shortened internodes and reduced mean boll weight.

Polyphagotarsonemus latus is a pest of cotton in humid tropical regions, such as Central Africa (Schmitz, 1962), Uganda (Ingram, 1960), Ivory Coast (Vaissayre, 1982) and the state of São Paulo, Brazil (Oliveira and Calcagnolo, 1974).

Schmitz (1962) reported large population variations in successive years and indicated that damage was more severe when mites appeared early in the cotton-growing season. As soon as the blades of the first three fully-developed leaves at the top show marginal curling, and darker green colour, the plants lose a third of their productivity. In Brazil, Oliveira and Calcagnolo (1974) found that the yellow tea mite reduced cotton seed production by 11% over a whole plot. In Ivory Coast, Vaissayre (1982) reported that in years favourable to outbreaks of Tarsonemidae, cotton seed yields were reduced by 54%.

Control

The predators of Tarsonemidae are mainly Phytoseiidae mites and Hemiptera insects (Anthocoridae). The irregularity of tarsonemid attacks and their fast breeding rate precludes biological control, and consequently no particular research has been carried out in this field.

Organochlorine insecticides (endrin and endosulfan), which were used to control insect pests of cotton, also acted against *P. latus*, but repeated use of synthetic pyrethroids, commonly used now against bollworms has made it necessary to apply specific acaricide treatments against Tarsonemidae in regions where climatic conditions favour their multiplication.

After field trials of about 50 compounds, Vaissayre (1986) selected several insecticides that were quite effective against *P. latus*. These comprise several organophosphorus compounds (profenofos, chlorthiophos, triazophos, ethyl-chlorpyrifos, ethyl-azinphos), used at doses ranging from 250 to 450 g a.i. ha^{-1}, and abamectin at 10 g a.i. ha^{-1}. The capacity of the latter acaricide has also been reported in Brazil, in the state of São Paulo (Donatoni *et al.*, 1988; Gaviolo *et al.*, 1988).

The method of application has proved to be important, i.e complete coverage of the foliage is essential, especially for organophosphorus compounds. Treatments are generally applied between the second and third months after emergence, when the plants are particularly sensitive to infestation (Vaissayre, 1986).

No resistance to the recommended acaricides has yet been reported in this species. On the scale of the whole field, possible resistant strains may be diluted in large untreated populations living on plants in the immediate vicinity of the plantations.

ERIOPHYOIDEA

Four species from the family Eriophyidae are recorded on cotton, belonging to two subfamilies: the Eriophyinae and the Phyllocoptinae. These four mite species are restricted to the genus *Gossypium* and each has a peculiar association with cotton plants.

Eriophyinae

The body is wormlike and whitish. The shield has a narrow, basally flexible anterior projection over the rostrum.

Acalitus gossypii (Banks), the cotton blister mite, belongs to a genus that lacks the forefemoral seta and the foretibial seta. Females reach 225–250 μm in length. This species is known from tropical America. According to Mohanasundaram (1982), some Indian records in the literature may concern *Eriophyes puttarudriahi* (Channabasavanna). *Acalitus gossypii* produces hairy deformations on leaves and flowers. Leaves may be crumpled and shoots distorted. *Gossypium barbadense* L. (Sea Island cotton) is very sensitive to this mite, whereas *G. hirsutum* L. (Upland cotton) suffers little damage. Keifer (in Jeppson *et al.*, 1975) recommends combining field clear-up with cotton-free periods and also selecting mite-resistant cotton varieties for planting.

Eriophyes puttarudriahi (Channabasavanna), the Indian cotton blister mite, is distinguishable from the previous species by its foretibial seta typical of the genus *Eriophyes*, and also by the absence of longitudinal shield lines in the centre. Females reach 140–150 μm in length. *Eriophyes puttarudriahi* has only been recorded in India where it is collected on *Gossypium herbaceum* L. (Levant or Asiatic cotton). It causes hairy and feltlike outgrowths on tender shoots. The plants may be stunted and boll formation suppressed.

Phyllocoptinae

The body is rather fusiform, and the shield has a broad-based and rigid anterior lobe over the rostrum.

Heterotergum gossypii Keifer. Females of the cotton rust mite are light yellow and from 150–215 μm long. The abdomen has five narrow rings dorsally just behind the shield followed by 14 broad tergites bearing elongate microtubercles. The sternites(63 to 68) are completely microtuberculate. *Heterotergum gossypii* is only known from Brazil. It was described by Keifer (1955) from specimens collected on *Gossypium hirsutum* in the state of Rio Grande do Norte. This eriophyid mite bronzes the mature leaves and produces tip blighting of young leaves.

Abacarus gossypii Mohanasundaram. Females of the Indian cotton rust mite are whitish and 200–210 μm long. On the dorsum a longitudinal thanosomal trough is formed by a subdorsal ridge on each side with a central longitudinal ridge that ends before the trough ends. Known only from India this species was described by Mohanasundaram (1982) from specimens collected on *Gossypium arboreum* in Tamil Nadu. It produces white erineum patches on both sides of leaves.

Life history (Fig. 20.3)

In eriophyid mites, there are two active larval stages between the egg and the adult (first and second nymphal stages), alternating with two resting periods

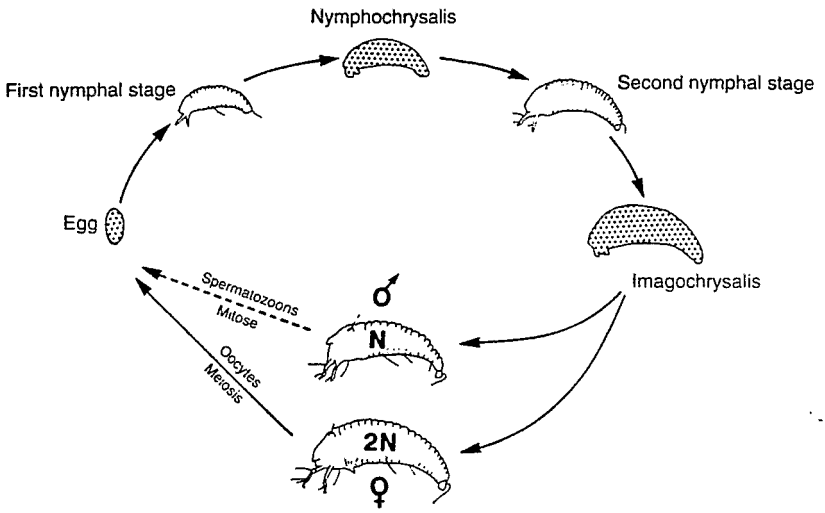

Fig. 20.3. Life history of an eriophyid mite.

(nymphochrysalis and imagochrysalis). The life histories of species living on cotton have never been studied, but the total development time is generally shorter than that of tetranychid mites reared under the same conditions. In tropical regions, reared female eriophyid mites were found to lay ten to 80 eggs during their two to four weeks of life (Jeppson *et al.*, 1975).

Natural enemies and control

Eriophyid mites are particularly attacked by other mites, i.e. Phytoseiidae, Tydeidae, Stigmaeidae and Tarsonemidae predators. Since species living on cotton cause damage that apparently has no economic impact, no particular measures have been taken against them. The differences in sensitivity observed between representatives of the genus *Gossypium* indicate that it may be possible to select resistant varieties.

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INSECT PESTS OF COTTON

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