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Plant–eriophyoid mite interactions: specific and unspecific morphological alterations. Part II

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Abstract The paper presents recent advances related to both specific and unspecific morphological alterations of plant organs caused by eriophyoid mites. Based on old and new case studies, the diversity of plant malformations, such as galls, non-distortive feeding effects and complex symptoms induced by eriophyoids and/or pathogens vectored by them, is analysed and summarised.

Keywords Vagrants · Gall formers · Plant growth abnormalities · Non-distortive feeding effects · Complex symptoms

Introduction

Eriophyoid mites (Acari: Eriophyoidea) form galls or live freely on various host-plants (reviewed by Oldfield 1996a, b, 2005; Royalty and Perring 1996; Westphal and Manson 1996). In both cases, their stylet mouthparts cause only a small mechanical wounding. The wounding and injecting of specific salivary secretions into host-cells, by both cheliceral stylets of eriophyoid mites, result in a specific response of the affected leaf, stem, or bud tissues such as gall differentiation, hypersensitive reaction, or non-distortive feeding effects and in some cases complex symptoms, considered as syndromes.

Despite the improvement of our knowledge and the accumulation of new data during the last two decades, a detailed study of the great diversity of eriophyoid mite–host plant interactions with respect to morphological, histological, biochemical and physiological effect is still necessary.

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This update presents a new synthesis and advances related to plant–eriophyoid mite interactions. The results related to the formation of specific or universal compounds and physiological changes in mite-injured plant tissue/organs, which in many cases affect the performance of eriophyoid mites, are synthesized in the first part of the review (Petanović and Kielkiewicz 2009). Types of morphological alterations of host plant organs with respect to eriophyoid life styles, as well as the plant symptoms characteristic of eriophyoid damage are analysed in this part of the review. Besides the great variety of specific morphological alterations, we also present many cases of so-called unspecific alterations, which could be caused by the presence of at least two agents.

Macro-morphological host-plant symptoms with respect to eriophyoid mite life styles

Evolutionary ecology, i.e. life history patterns, food plant choice and dispersal of eriophyoid mites were elaborated by Sabelis and Bruin (1996). It was discussed that the minuteness of eriophyoid mites have consequences for their impact on the host plant, their interactions with predators, and the ability to disperse. Being so small, eriophyoid mites are limited in their capacity for ambulatory movement (Oldfield 2005). They either hide in existing shelters—such as needles and leaf sheets, within buds and between bulb scales, or they induce the plant to create growth abnormalities that can then be used as shelters (leaf edge curls, erinea, galls). Nevertheless, other species of eriophyoid mites do not have such a typical refuge-seeking or refuge-creating life style. They can be found over the whole leaf surface, despite their vulnerability to predator attack and despite the opportunity to hide in narrow refuge places. They are considered as vagrants or free living eriophyoids. According to Amrine (unpublished data) in Huang (2008), it was calculated that the percentage of vagrants make up 43.6% of all species (1,618 vagrants compared to total of 3,708) of eriophyoid mites, which is higher than those of gall mites (15.8%), erineum mites (11.4%) and bud mites (8.9%). As gall, erineum and bud mites can be assumed as refuge creating mites, the percentage of this category is almost near to vagrants (36.1%), and the rest are probably the refuge seeking. Recently, Skoracka et al. (2009) calculated that Eriophyoidea are comprised mostly of vagrants (2,263 vagrants, 462 refuge-seeking and 941 refuge-inducing). However, they emphasised that we should be cautious about the conclusion as it is based on a simple records data. Generally, it could be concluded that at least a half of all eriophyoid mite species follow the vagrant life strategy and another half follow the refuge creating or seeking strategy and that both strategies might be advantageous to these mites.

Diversity of macro morphological alterations (symptoms) on plants, as the consequence of eriophyoid infestation, depends on eriophyoid mite–plant interactions, mite species, its life style, host plant species and its genotype. Vagrant species usually cause less diverse and superficially less specific symptoms than gall inducing species. On the other hand, refuge-seeking eriophyoids may sequester themselves in leaf axils, in leaf glands, or even squeeze through leaf stomata to feed and reproduce in the mesophyll layer, as in recently described species, *Schizoempodium mesophyllincola* Oldfield, Hunt and Gispert (Oldfield 2005). An interesting case is refuge-seeking mite, *Novophytoptus rostratae* Roivainen, investigated by Tchetverikov (2004). Colonies of mites were found within air cavities of the leaves, leaf sheaves, and under the epidermis of the stalks of plants of the family Cyperaceae and Juncaceae. The mites were found to feed on cells of chlorenchyma and cause “brownish striae”.

Plant galls are abnormal structures caused by many gall-forming (*syn.* ceceidogenic) organisms belonging to different systematic groups. Gall induction is common only among the eriophyoid acarines; however a few tropical species of the family Tenuiplapidae induce poorly defined galls on their hosts (Oldfield 2005). Galls induced by eriophyoids are extremely diversified in shape, size, colours, etc. Eriophyoids that induce galls are usually highly site-specific, typically inducing galls of a specific form on a specific part of the green portion of the plant. They develop on all soft parts of their host plant: stems, leaves, petioles, buds, flowers, and even fruits and seeds, except for the roots, which are apparently not suitable for mite attack (Westphal 1992).

One of the oldest classifications (Küster 1911) is based on gall morphology. According to this system, galls are divided into two major classes: organoid galls characterized as abnormal modifications of plant organs, and histoid galls, characterized by complex and sometimes novel types and arrangements of internal tissues. Histoid galls are further subdivided according to their structure into kataplasmas, usually with less differentiated tissues, and prosoplasmas, structurally more complex. Detailed descriptions of these types is presented by Larew (1982). According to this classification, eriophyoid galls may be assumed as simple or complex kataplasmas.

A comparative study of the anatomy of *Salix piperi* Bebb. leaf gall, *Alnus rubra* Bang. bead gall, *Tilia europea* L. leaf gall, erineum on *Quercus garryana* Dougl., *Fraxinus latifolia* Benth. leaflet gall, *Rhus diversiloba* T. and G. leaflet gall, leaf gall on *Populus tremuloides* Michx., leaf gall of *Prunus virginiana* L., and big bud of *Corylus avellana* L., caused by 9 gall making species, allowed Larew (1982) to distinguish two different categories of galls. The galls which possess no distinctive nutritive layer (oak erineum, trembling aspen gall) and those that remain in the structure of the healthy leaf (oak erineum, poison oak gall and trembling aspen gall) belong to the category -'simple kataplasmas'. In these cases eriophyoid mite causes relatively little tissue disruption. The remaining galls possess a distinctive nutritive layer at least during the early stage of gall development. Additionally, the disruption (homogenization) of the mesophyll layers was seen in all of them. These two characteristics indicated that the mites influenced the host plant tissue to a significant extent, and thus their galls were categorized as 'complex kataplasmas'. Within this group, it is possible to subcategorize the galls based on the thickness of the nutritive layer at gall maturity or alignment of nutritive cells and general type of nutritive cells. For example, the mature willow leaf gall has a nutritive layer which is 2–5 cells thick, while all other galls generally possess a one-cell-thick nutritive layer. A palisade arrangement of nutritive cells is seen in the willow gall and the filbert bud gall. A more random arrangement of globular nutritive cells is observed in the alder bead gall and choke cherry gall. The ash leaflet gall has a few nutritive cells arranged as a palisade, but most are small and randomly arranged. The mature gall of linden is an interesting case—both cytoplasmatically rich palisade-like nutritive cells and vacuolated randomly arranged cells lining the gall cavity.

Additionally, the position of the mite was used as one of the criteria for the classification of galls, and according to this, two major types of acarocecidia can be recognized. The first type includes galls with eriophyoid mites exposed externally on the epidermis, whereas the second one includes galls with eriophyoid mites inside the plant tissue (Mani 1964). Westphal (1992) and Westphal and Manson (1996) classified galls according to the nature of the plant organ attacked and the damage complexity degree into five major classes: (1) leaf galls, (2) stem galls, (3) bud galls, (4) fruit galls and (5) other distortions (other distortive, toxemias and non-distortive alterations are included here as well).

Examples of different plant galls caused by eriophyoid mites listed and described briefly or in detail in different monographs/reviews mentioned above (Mani 1964; Jeppson et al.

1975; Larew 1982; Westphal 1992; Boczek and Griffiths 1994; Westphal and Manson 1996) will not be repeated here.

Several researchers have suggested that the gall morphology is largely determined by the phytophagous mite rather than the host plant (Kane et al. 1997). For example, different species living on the same host plant can produce strikingly different effects (Boczek and Griffiths 1994). However, different congeneric species (*Cecidophyopsis* spp.), inhabiting different congeneric plant species (*Ribes* spp.), can provoke the same type of galls, i.e. bud galls (Amrine et al. 1994). Similarly, Rančić and Petanović (2008) concluded that anatomy of galls on different maple leaves, caused by three *Aceria* spp., was similar in spite of the fact that different species were the causative agents. In the same study, two different *Aceria* spp. were simultaneously observed to induce galls or erinea on the same individual sycamore maple. On the other hand, the same eriophyoid mite species can induce different symptoms to different plant species or to different developmental stages of the same host plant (Westphal 1980; Oldfield 1984; Soika and Kielkiewicz 2004). Weis et al. (1988) proposed in their review the hypothesis regarding the genes important in determining plant reactivity that have other functions in normal development and metabolism. They also recommended the methods which could be available to explore gene expression in the gall in relation to that in the rest of the plant. The host plant genotype, environment, and parasite genotype interact to determine the gall phenotype. They stated that evolution of plant–gall maker interaction is complicated by the fact that galls are phenotypic entities that develop under the influence of both plant and plant—gall maker genotypes. Development of molecular markers for eriophyoid mites provided insight into systematic position and even phylogenetic relationships of economically important species of currants, gooseberries, and grapevine (Fenton et al. 1996; Fenton 2002; Carew et al. 2004). Molecular and microarray techniques are still not used enough in eriophyoidology. We are expecting that accumulation of such results in the future will also help resolve many problems regarding the origin and the nature of specific host plant–eriophyoid mite relationships.

Apart from the category of gall makers (*sensu lato*), almost a half of eriophyoid species belong to leaf vagrants which predominantly cause so-called non-distortive changes to the host plants. Oldfield (1996b) summarized toxemias and other non-distortive feeding effects of eriophyoids considering them as specific separate type of alterations. They are related to changes in the appearance of the epidermis of green leaves, immature fruit, young stems or even bud bracts, which are variously referred to as rust, russeting, browning, bronzing, silvering, chlorotic spots, reddening etc. Symptoms could be primarily described as discolouration of plant organs, but are frequently associated with brown scarification and necrosis of infested buds, mortality of buds, witches broom or multiple branching owing to the death of primary growing points, distortion of veins, chlorotic spots, concentric ring blotch, mottle effects, hairless spots on the lower surfaces of attacked leaves, hardening and late ripening, irregular streaks, defoliation (if the collapse of lower leaf mesophyll follows extensive epidermal damage), lignifications, yellowish white areas, stunting, twisting, curling, desiccation of terminal buds or whole terminal shoots, distorted fruits, and premature drop.

Of the three families of Eriophyoidea, the Phytoptidae and Eriophyidae, among their assemblages, include many species that alter the development of plant cells upon which they feed. In many such instances, this results in the development of galls, the form of which is specific to the particular inducing species. The third family, Diptilomiopidae, consists of vagrant species. Among the largest of the three families, the Eriophyidae, the subfamily Eriophyinae consists of 66% of genera with gall-mite species, although the

Phyllocoptinae subfamily predominantly (80%) includes genera with vagrants (Oldfield 2005). It should be emphasized that non-distortive changes to plants have not been recorded in all cases of vagrant species. It is probably due to the lack of knowledge. Most of the data on the eriophyoid species life style originates from single records from literature, most often from descriptions of new species. If the population density had been low, the damage to the plant should usually be neglected. However, in the case of pest species that reproduce fast, symptoms, i.e. damages to plant organs are usually observed.

For instance, Phyllocoptinae mites *Rhombacus* sp. and *Acalox ptychocarpi* Keifer have been investigated in a case study as the recently-emerged pests of commercial eucalypt plantations in subtropical Australia (Nahrung and Waugh 2009). They cause blistering, necrosis and leaf loss to *Corymbia citriodora* subsp. *variegate* (F. Muell.) K.D. Hill & L.A.S. Johnson. Damage symptoms associated with eriophyoid mite feeding manifest as "spot type" and "patch type" of chlorotic or anthocyanic tissue discoloration.

Although the members of the subfamily Phyllocoptinae of the Eriophyidae include an especially large number of leaf vagrant mite species that cause various "rust" symptoms on deciduous and evergreen broad-leafed perennials, annual broad-leafed plants, grasses, and monocots, many species of the family Phytoptidae cause abortion of buds and stunting of needles (Boczek and Shevchenko 1996). Even whole conifer seedlings may turn yellow, desiccate and die as a result of feeding of some phytoptid mites (Löyttyniemi 1969). *Nalepella* spp. and some *Trisetacus* spp. are needle vagrants causing discolouring, i.e. chlorosis and browning of needles and their drop off (Castagnoli 1996). Diptilomiopids are assumed as less harmful to plants (Jeppson et al. 1975) although some species are causative agents of serious leaf deformation and premature leaf dropping, like *Rhyncaphytoptus platani* Keifer of *Platanus* in Europe (Schliesske 1989; Castagnoli 1996). It is most probable that diptilomiopids rarely reach high population levels on plants, which could be the reason for their harmlessness. The "paradox" of this family still remains to be explained.

Complex and mixed symptoms induced by eriophyoid mite feeding and/or pathogen transmission

Apart from galls and rust (*sensu lato*), eriophyoid mites have been considered to be the causative agents of the so called non-distortive feeding effects and complex symptoms which are difficult to separate from the symptoms of pathogens transmitted by them or by mixed infestation and/or infection. Symptoms like chlorosis, phyllody, flower virescence, internode shortening, enations, fasciation, axillary bud growth, necrotic spots, wart-like structures, blastomania, "witches broom", stunting, multiple inflorescences, and vegetative and floral malformations may be confused with other causative agents like thrips, fungi, viruses and phytoplasmas, or microelement deficiency. Most toxaemias and non-distortive feeding effects are only known from descriptions of the syndrome of macroscopic visual changes in the host which accompany the presence of the mite. In many cases, eriophyoid mites are either vectors important in disease epidemiology or they prefer infested/infected plants. However, many such symptoms have been proved to be caused exclusively by eriophyoid mites (Oldfield 1996b; Duso et al. 2008). A few cases of so called mixed and/or dubious symptoms, as well as syndromes, are presented below.

Aceria parapopuli (K.) and *A. populi* (Nal.) initiate a woody bud gall on species of *Populus* in North America and in Europe respectively, consisting of a solid mass of swelling, which can continue to grow for several years. Many buds along the same twig can be attacked, with consequent retarded growth and deformation of the twig. *A. neoessigi* (K.) is the probable cause of catkin deformation of some species of poplar in North America. The inflorescences form clusters and hang like bunches of woody grapes about 10 cm in diameter and 20 cm long, which remain on the plant all summer (Castagnoli 1996).

Stenacis triradiatus (Nal.) and other eriophyoid taxa are probably the cause of a similar deformation known as "Wirrzopfe", found on species of *Salix* in Europe. Male and female catkins appear greatly modified, buds grow abnormally and internodes become shortened. However, viruses are probably also involved (Rack 1958; Westphal 1977). *Aceria fraxinivora* (Nal.), a widespread species, attacks the inflorescence of *Fraxinus* spp. Pedicels of individual flowers appear swollen, fused and distorted. These inflorescences remain on the tree for some time where they become brown and gradually form a shapeless mass (Castagnoli 1996). *Trisetacus juniperinus* (Nal.) induces a range of different, enormously severe types of symptoms in *Cupressus sempervirens* L.—enlarged deformed buds, irregular proliferations of axillary buds, blastomania, witches brooms, and deformed cones producing few seeds (Duso et al. 2008). A similar symptom of irregular proliferations of axillary buds of forsythia plants has been connected with *Aceria forsythiae* Domes (Petanović 2004). Recently, Australian vineyards have been affected by a syndrome called "Restricted Spring Growth" (RSG) which has not been associated with a clear cause yet. Bernard et al. (2005) showed that most of these symptoms were due to early *Calepitrimerus vitis* (Nal.) infestations. Severe leaf distortion and shoot length reduction depended on the mite density. Another syndrome, the so-called "Short Shoot Syndrome" (SSS), similar to the previous one, was reported in the Pacific Northwest of the USA. Symptoms were represented by bunch necrosis during early season, malformed leaves, short and angled shoots in spring, scar tissue, and bronzed leaves in summer. Walton et al. (2007) showed that SSS was associated with high *C. vitis* (Nal.) population densities (see also Duso et al. 2008). Detailed descriptions of the symptoms caused by the grape rust mite, recently investigated and called RSG or SSS have been made in the second part of the last century (Duso and de Lillo 1996 and references therein).

A complex of symptoms, which should also be concerned as a syndrome, was observed on invasive cut-leaf teasel, *Dipsacus laciniatus* L. in Serbia (Petanović and Rector 2007), and was later analyzed in more detail (Pećinar et al. 2009). The most discernible effects, observed on bolted plants under field conditions were the stunted growth, shortened internodes, smaller leaves, and abnormal proliferation of deformed flower heads. Statistical analysis revealed that nine morphometric traits out of 13 were significantly different between 'healthy' and infested plants. Results of the experiments conducted under laboratory conditions demonstrated the impact of mite feeding as a slowdown in plant development and a reduction in average length and width of the leaves.

Some of the symptoms previously attributed to eriophyoid mites were proved or suspected to be induced by phytoplasmas. Multiple inflorescences on *Cirsium arvense* (L.) Scop. has always been attributed to the presence of *Aceria anthocoptes* (Nal.), since their first report in 1892 (Petanovic et al. 1997). Affected plants lately recorded in Serbia showed irregular growth, atypical branching with small leaves, shortened internodes, hardening of the green inflorescence, and reduced vigour, as well as chlorosis or reddish brown discoloration of the leaves and stems, and multiple inflorescence. In this plant 16SrIII-B subgroup phytoplasma was reported for the first time (Rancic et al. 2005). Similarly, an interesting relationship between the feeding of *Paraphytoptus chrysanthemi* K. and phyllody, changes of floral organs into vegetative ones and stunted internodes of chrysanthemum plants, was registered decades ago (Breakey and Batchelor 1950). Damage includes the stunting and curling of apical leaves, as well as bronzing, while leaves become brittle and bud clustering results in brooming. Recently, chrysanthemum plants showing flower proliferation, virescence, and stunting have been observed in Serbia. Phytoplasmas belonging to 16SrXII-A ribosomal subgroup (stolbur) were identified in symptomatic plants (Duduk et al. 2006). *Aceria spartii* (Can.), recorded in Italy and South Africa (Castagnoli 1978; Craemer et al. 1996), attack young apical shoots of *Spartium junceum* L. and cause excessive hairiness, thickening of the axis, shortening of internodes, and finally "witches broom" or cladode. Marcone et al. (1996) and Torres et al. (2002) reported that Spartium witches broom disease is associated with phytoplasma 16SrX group strain in Italy and Catalonia, Spain, respectively. X-disease-related phytoplasmas have been identified in ornamental trees and shrubs (forsythia, spirea, cypress and willow), with "witches broom", stunting, and fasciation symptoms (Paltrinieri et al.1998). Interaction of *Aceria bezzii* (Corti) and phytoplasmas of hackberry trees was reported together with the effect of drought in Italy (Mittempergher et al. (1999). As it was summarized by Oldfield and Proeseler (1996), the diameter of the oral opening and foregut of eriophyoid mites (the latter about 500 nm in an adult) may preclude ingestion of larger plant pathogens, many of which require circulation through the body of their vectors before they can be transmitted. The same authors stressed that "pleomorphic phytoplasmas may be an exception in that their limiting membrane allows them to assume a shape that might allow them to be ingested by an eriophyoid".

The transmission of phytoplasmas by eriophyoid mites has not been proven yet, so the incidence of common appearance of both causative agents of plant malformations should be studied comprehensively in the future in order to resolve their relationship, especially in many dubious cases in which symptoms are attributed to one of the causative agents.

Eriophyoid mites have been proven as vectors of plant viruses. Some symptoms were attributed to viruses, and some were attributed only to mites. For instance, feeding of the most intensively studied wheat curl mite (WCM), *Aceria tosichella* K., causes characteristic symptoms on wheat, a syndrome of curled, looped and trapped leaves. The same species causes kernel red streak of corn. Symptoms of wheat streak mosaic virus (WSMV), transmitted by *A. tosichella*, are light green to yellow streaks and dashes, followed by general chlorosis, stunting and, depending upon the degree of severity, poorly filled seed heads and shrivelled kernels. Symptoms of wheat spot mosaic virus (WSpMV) transmitted by this mite consist of an initial chlorotic spotting or ring spot, general chlorosis, stunting, and sometimes plant death (Styer and Nault 1996). Onion mite, *Aceria tulipae* (K.) physically damages the host by feeding upon the epidermal cells of the bulb, causing the cells to collapse and resulting in scarification. The foliage produced from infested bulb can be stunted, twisted and discoloured, symptoms reported to be similar to those caused by viral infections. In addition, *A. tulipae* is a vector of onion mite-borne latent virus (OMbLV), the causal agent of onion mosaic disease, and shallot mite-borne latent virus (ShMbLV). Infection by both viruses can be asymptomatic (Ostoja-Strazewski and Mattews 2009, and references therein). Black currant reversion disease and the vector of its causal agent, the black currant gall mite *Cecidophyopsis ribis* (Westwood), have been recognised for at least 100 years. At first, damage of this pest, done by causing galling buds and distortion of leaves, was confused with the symptoms of reversion disease. Later the symptoms of reversion were distinguished and it was shown that these mites transmit the causal agent of the disease. The symptom of the mite injury is enlargement and change of form, from conical to a spherical shape, of the gall mite infested bud. Most prominent reversion disease symptoms are expressed in leaves usually fewer in number and decreased in size, with a decrease in marginal serrations and number of main veins, and with a less clearly defined sinus at the petiole. Besides this, a marked decrease in the density of hairs on the flower buds and an increased intensity of colour in the buds are observed early in the spring. Despite much research over several decades, the causal agent has been characterised as the black currant reversion associated virus (BRAV) only recently (Jones 2000).

Only a few studies described interaction of eriophyoid species and fungi as well as the possible role of eriophyoids as vectors of these pathogens. Lakshmanan and Jagadeesan (2004) reported the presence of eriophyid mite *Aceria guerreronis* Keifer and fungus *Botryodiplodia theobromae* Pat. in malformed nuts of coconut palms in India. The fungus produced typical symptoms, such as malformation and cracking in the presence of eriophyoid mite infestation. Normal-sized nuts with cracking symptoms were recorded in eriophyid mite-infested nuts.

The combined impact of *Aceria mangiferae* Sayed and *Fusarium subglutinans* (Wollenow and Reinking) on in vitro mango seedlings was investigated by Otero-Colina et al. (2007). Two types of malformations were recognized. Growth abnormalities attributed to *A. mangiferae* were named “atrophy of apical leaves”. The apex of such seedlings showed a series of short internodes, the associated leaves were atrophic and dry, and the epidermis of leaves, stems and petioles were brown and coarse. Growth abnormalities attributed to *F. subglutinans* were named “bunchy top”. Axillary buds of such plants develop as short and thick shoots with small epinastic leaves. It was proved that the mite can act as a vector of the etiological agent of the bunchy top. Another case study of the role of mango bud mite *Aceria mangiferae* Sayed in mango malformation epidemiology, caused by the fungus *Fusarium mangiferae* Britz, Wingfield and Marasas, showed that *A. mangiferae* can vector the pathogen, assist in fungal penetration, but does not appear to have a role in aerial dissemination of conidia. The authors proposed that future research should take into consideration potential eriophyoid mites–fungi interactions (Gamliel-Atinsky et al. 2008).

If the transmission of an etiological agent by eriophyoid mites is proven, symptoms should be attributed to eriophyoid mites and pathogen, both of them being important in aetiology and epidemiology.

Conclusions and future research

Recent studies showed that different life styles (vagrant vs. refuge-creating and -seeking) are represented almost equally between eriophyoids and are hypothesized as advantageous for these mites. However, the necessity of a detailed recognition of specific symptoms and an extensive study of the great diversity of host plant interactions, with respect to morphological, histological, biochemical, and physiological effects, still exists. The great diversity of specific eriophyoid mites–host plant relationships should be recognized at different levels of complexity of plant organs, tissues, and cells. Eriophyoid mites interactions with other organisms related to their host plants, as well as food resources and habitats, enlarge this complexity. Collection, recognition, adequate description, and classification of the great many malformations of plant tissues and organs must be continued. At the same time, elucidation of eriophyoid mites–host plant specific interactions at the gene level (through microarrays) is needed and should be the future task and challenge.

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