

## The role of eriophyoids in fungal pathogen epidemiology, mere association or true interaction?

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**Abstract** A considerable number of plant feeding mites representing different families such as Acaridae, Siteroptidae, Tydeidae, and Tarsonemidae interact with plant pathogenic fungi. While species within the Eriophyoidea appear to be the most common phytophagous mites vectoring virus diseases, little is known of their role in fungal pathogen epidemiology. In the present article, we present two studies on eriophyoid-fungal relationships.

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The first focusing on the association between *Aceria mangiferae* and the fungal pathogen *Fusarium mangiferae* in mango is presented as a case study. The second, as the research is still in a preliminary phase, reports on quantitative and descriptive associations between the cereal rust mite *Abacarus hystrix* and rusts caused by *Puccinia* spp. Mango bud tissue colonized with *F. mangiferae*, and wheat and quackgrass leaves colonized with *Puccinia* spp., supported significantly higher populations of eriophyoid mites. Both mite species were observed bearing the spores of the respective pathogens on their body integument. *Aceria mangiferae* vectored the pathogen's spores into the bud, the sole port of entry for the fungal pathogen and the frequency and severity of fungal infection increased in the presence of *A. mangiferae*. While it appears that eriophyoids are playing a role in fungal epidemiology, clearly further research is needed to enhance our understanding of direct and indirect (plant mediated) interactions between plant pathogens and eriophyoid mites in different plant-pathogen systems.

**Keywords** Eriophyoidea · Fungi · Mite-fungus-plant interactions · *Aceria mangiferae* · *Abacarus hystrix* · *Fusarium mangiferae* · *Puccinia* spp.

## Introduction

The evolution of mycophagy in the Acari has been well reviewed by Krantz and Lindquist (1979) based on the premise that the ability to feed on vascular tissues arose through feeding on fungi in some mite groups and also on the adaptive strategies and ecological relationships associated with the mycophagous habits that provide parallels to those related to phytophagy. A considerable number of mites representing many families in different suborders interact with plant pathogenic fungi. Herbivores may facilitate fungal infection by two main mechanisms: either by vectoring pathogen spores or by creating wound sites for fungal penetration (Agrios 1980; Hatcher and Paul 2001).

Abdel-Sater and Eraky (2001) reported that the acarid mites, *Tyrophagus putrescentiae* Shrank and *Rhizoglyphus robini* Claparede, when living on bulbs, transfer the fungal pathogens *Aspergillus niger*, *Nectria haematococca*, *Rhizopus stolonifer* and *Penicillium chrysogenum* attached to the outside of their bodies. Conversely the transfer of *Aspergillus flavus* and *Aspergillus ochraceus* is performed through their digestive tracts along with their foods. *Rhizoglyphus robini* are attracted to and penetrate *Fusarium* infested bulbs more rapidly than healthy ones (Okabe and Amano 1990, 1991).

*Fusarium poae* is associated with the siteroptid mite, *Siteroptes avenae* (Muller). Microscopic examination of *S. avenae* feeding on *F. poae* cultures revealed the presence of sporothecae containing microsporidia of the fungus. This close association between the mite and fungus is considered responsible for causing *Fusarium* glume spot on wheat in South Africa (Kemp et al. 1996).

The relationship of tydeid mites and mycophagy was emphasized by Krantz and Lindquist (1979). For instance, the tydeid *Parapronematus acaciae* Baker feeds and breeds on fungi that commonly occur on the leaves of citrus (McCoy et al. 1969). *Lorryia formosa* Cooreman was an effective sanitizing agent in citrus groves because it reduced levels of sooty mould fungi (Mendel and Gerson 1982). *Tydeus caudatus* (Dugés) densities positively correlated with levels of the grapevine downy mildew, *Plasmopara viticola*, in north eastern Italy (Duso et al. 2005). The tydeid, *Orthotydeus lambi* (Baker) plays a role in reducing the severity of powdery mildew on grapes caused by the fungus *Uncinula necator*, suggesting the important role of mycophagous mites as potential biological

control agents of plant pathogenic fungi (English-Loeb et al. 1999). *Vitus vitifera* (Vitaceae), with closed off domatia, harbored lowered populations of *O. lambi* and higher levels of *U. necator* (Norton et al. 2001).

The tarsonemid, *Steneotarsonemus spinki* Smiley, appears to open ports of entry for the fungi, *Helminthosporium* and *Sarocladium oryzae* (Cardenas et al. 2003), which are responsible for grain discoloration of rice, *Oryza sativa*. *Steneotarsonemus ananas* (Tryon), the pineapple leathery pocket mite or pineapple fruit mite, is host specific to pineapples throughout the world (Mourichon 1991; Petty et al. 2002). Trichome cells fed upon by *S. ananas* serve as a favorable substrate for development of the fungus *Penicillium funiculosum*, the causal agent of inter fruitlet corking, leathery pocket, and fruitlet core rot/black spot (Petty et al. 2002).

While several species within the Eriophyoidea are apparently the most common phytophagous mites vectoring viral diseases (Oldfield and Proeseler 1996), little is known of their role in fungal pathogen epidemiology. In the present article, we present two studies on eriophyoid-fungal relationships. The first focuses on the association between *Aceria mangiferae* Sayed and the fungal pathogen *Fusarium mangiferae* Britz, Wingfield & Marasas in mango and is presented as a case study where we describe some of the underlying mechanisms clarifying the role of the mite in mango malformation epidemiology. In the second study, as the research is still in a preliminary phase, we report on quantitative and descriptive associations between the cereal rust mite *Abacarus hystrix* (Nalepa) and rusts caused by *Puccinia* spp.

### **The role of the mango bud mite in mango malformation: a case study**

Mango malformation is a severe disease, widely distributed in almost all mango-growing regions worldwide (Crookes and Rijkenberg 1985; Kumar et al. 1993; Ploetz 2001; Ploetz et al. 2002; Kvas et al. 2008). Symptoms of disease are associated with hormonal imbalance in the host that results in misshapen growth of both vegetative and reproductive parts of the tree (Majumder and Sinha 1972; Prasad et al. 1972; Kumar et al. 1993; Ploetz 2001, 2003). Vegetative malformation includes hypertrophy of young shoots, shorter internodes, dwarfed malformed leaves and an overall tightly bunched appearance of the shoot. Inflorescence malformation includes short, thick and branched axes of the floral panicles, larger flowers containing increased numbers of male and hermaphroditic flowers that are either sterile or eventually abort. Malformed inflorescences do not bear any fruit, resulting in great economic losses.

The etiology of mango malformation disease was controversial for many years and many factors have been suggested as causal agents of disease such as: nutritional deficiencies, hormonal imbalance, viruses, phytoplasmas, fungi and mites (Narasimhan 1954; Nariani and Seth 1962; Zaher and Osman 1970; Denmark 1983; Ochoa et al. 1994; Ploetz 2001). *Aceria mangiferae*, the mango bud mite, was hypothesized as the causal agent of mango malformation for over 40 years mainly due to high numbers of mites observed in malformed trees, and also because other members of the Eriophyoidea are known to cause proliferation, “witches broom” and gall symptoms of inflorescences in other plants (Westphal and Manson 1996). Despite the fact that the fungal theory was well established following Koch’s postulates with several fungi, certain members of the genus *Fusarium* have been shown to cause the disease (Summanwar et al. 1966; Varma et al. 1974; Chakrabarti and Ghosal 1989; Manicom 1989; Ploetz and Gregory 1993; Freeman et al. 1999; Noriega-Cantú et al. 1999; Britz

et al. 2002; Ploetz 2003; Marasas et al. 2006; Kvas et al. 2008; Lima et al. 2009; Rodríguez-Alvarado et al. 2008), It is also clear now that *A. mangiferae* is not the causal agent of mango malformation, however, various studies suggest that the mite interacts with the fungal pathogen resulting in increased severity of disease (Prasad et al. 1972; Sternlicht and Goldenberg 1976; Gamliel-Atinsky et al. 2009a).

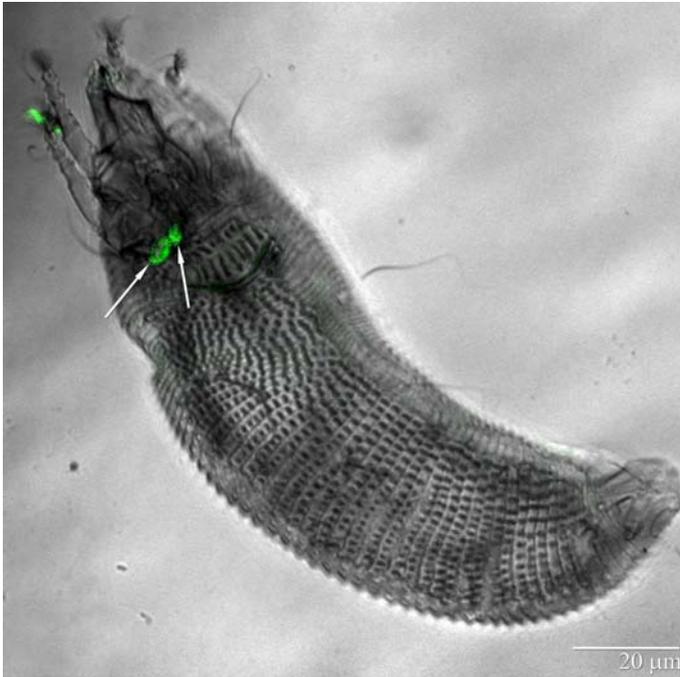
Our study was aimed at revealing the possible associations between *A. mangiferae* and the fungal pathogen *Fusarium mangiferae*. The specific objectives of the study were to: (1) assess whether *A. mangiferae* can carry conidia of *F. mangiferae* on or within its body; (2) determine the role of the mite in vectoring fungal conidia into the infection site; (3) determine the role of the bud mite in promoting the fungal infection process, and (4) evaluate the possible role of the bud mite in long-distance aerial dissemination of the fungal conidia. A green fluorescent protein (gfp)-marked strain of *F. mangiferae* was used throughout this study which distinguished it from that used in previous studies (Nariani and Seth 1962; Summanwar and Raychaudhuri 1968; Manicom 1989; Labuschagne et al. 1993) and helped distinguish the pathogen from other contaminants and opportunistic fungi. Below we will briefly describe the major results and implications from this study; a detailed account of this research can be found in Gamliel-Atinsky et al. (2009a).

### Bearing conidia on or within the body of *Aceria mangiferae*

In order to test whether *A. mangiferae* can bear *F. mangiferae* conidia, two methods were used: the first one was aimed at determining whether the conidia attach to the outer integument of the mite and if this attachment is specific to a certain part of the body. Mites were exposed to the GFP-marked isolate of *F. mangiferae* and then inspected under a confocal microscope. In the second method, the possibility that the mite carries conidia within its body was assessed using a low-temperature scanning electron microscope (LT-SEM), taking measurements of both conidia and mite stylets (measured directly and indirectly according to the diameter of the feeding holes in the plant). We hypothesized that the diameter of the smallest conidia is larger than the diameter of the mite's stylets. Results from these observations demonstrated that external rather than internal bearing of conidia is feasible since mites were observed with conidia clinging to their body (Fig. 1) and LT-SEM measurements indicated that the width of the mite mouthparts was substantially smaller than the diameter of the smallest conidium (Fig. 2). Moreover, since there is a lack of continuity between the midgut and the hindgut of eriophyoid mites (Nuzzaci and Alberti 1996), fungal spores cannot be transferred and secreted in feces. Internal bearing of pathogens by eriophyoid mites is a known phenomenon with viral pathogens due to their minute size (Oldfield and Proeseler 1996). Associations with fungi is apparently only possible via external-body attachment, such as in the case of acaropathogenic fungi (McCoy 1996).

### Vectoring conidia to penetration site

One possible benefit for *F. mangiferae* from this bipartite association is reaching the infection site. Results from our recent study demonstrated that the apical bud is the exclusive penetration site for the fungal pathogen (Gamliel-Atinsky et al. 2009b) which also serves as the exclusive living habitat of *A. mangiferae*. Most conidia of *F. mangiferae* disseminate in the air and randomly fall on the tree canopy which takes up most of the surface area of the orchard. One possible route of reaching the hidden, small apical bud is



**Fig. 1** Mango bud mite, *Aceria mangiferae*, bearing gfp-marked conidia (arrows) of *Fusarium mangiferae*, the causal agent of mango malformation disease

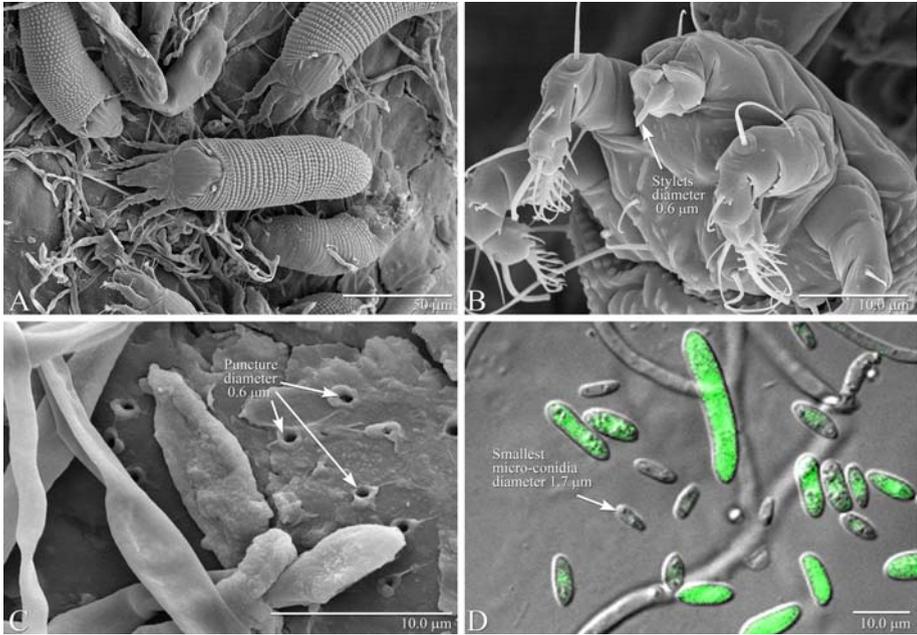
via the bud mite which possesses the ability of actively seeking out and reaching the apical bud from any location in the tree. In order to test the role of the mite in vectoring conidia into apical buds, an experiment on potted plants was performed. The experiment consisted of four treatments of different combinations of mites and/or conidia that were placed on leaves 5 cm away from apical buds. Our results showed that conidia reached the apical bud only in the treatment where both mites and conidia were co-inoculated on the leaves, demonstrating the potential of eriophyoid mites as vectors of fungal pathogens (Table 1).

#### Assisting conidial penetration

Two quantitative evaluations of the possible role of *A. mangiferae* in fungal penetration, a process taking place inside apical buds, were assessed. When apical buds of potted mango plants were inoculated with *F. mangiferae* in the presence and absence of bud mites, the frequency and severity of fungal colonization were significantly higher in buds inoculated with both fungus and mites (Table 2). This result clearly demonstrated that the presence of mites within the buds enhanced fungal colonization.

#### Association between fungal infestation and mite population levels

Another quantitative evaluation was designed in order to determine whether the presence of the fungus affected mite populations within the bud. Numbers of bud mites were compared within colonized and non-colonized buds by the fungal pathogen during 2006 and 2007. Higher numbers of mites were detected in buds colonized by the fungus rather



**Fig. 2** **a** SEM image of mango bud mites, *Aceria mangiferae*, feeding on bud bracts; **b** SEM image of mango bud mite anterior ventral view of stylet. **c** SEM image of respective feeding puncture holes; **d** confocal image of gfp-marked conidia and micro-conidia of *Fusarium mangiferae*

**Table 1** Total number of *Aceria mangiferae* and green fluorescent protein (gfp)-marked conidia of *Fusarium mangiferae* detected within 20 apical mango buds

Inoculation with	Bud mites	Conidia
Mites with gfp conidia	28 <sup>a</sup>	9
Mites alone	35	0
Gfp alone	0	0
Untreated control	0	0

<sup>a</sup> All numbers different from zero were found significant ( $P < 0.05$ ), according to a  $t$ -test analysis of the average number of mites and conidia per apical bud, (modified from Gamliel-Atinsky et al. 2009a)

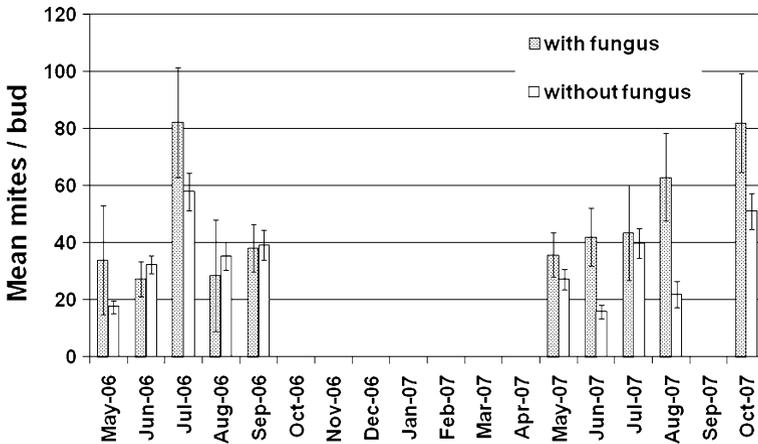
**Table 2** Frequency (%) and severity (%) of green fluorescent protein (gfp)-marked *Fusarium mangiferae* colonization in buds in the presence or absence of *Aceria mangiferae* over a 2 year period

Treatments	Frequency of colonization <sup>a</sup>		Severity of colonization <sup>b</sup>	
	2006	2007	2006	2007
Mites with gfp conidia	81.6	78.4	60.8	44.7
Gfp conidia alone	50.0	57.4	29.5	28.9
$P^c$	0.004	0.043	<0.0001	0.009

<sup>a</sup> Statistical analysis was calculated using a chi-square test

<sup>b</sup> Statistical analysis was calculated using a  $t$  test

<sup>c</sup> Significance refers to each pair of means per year separately



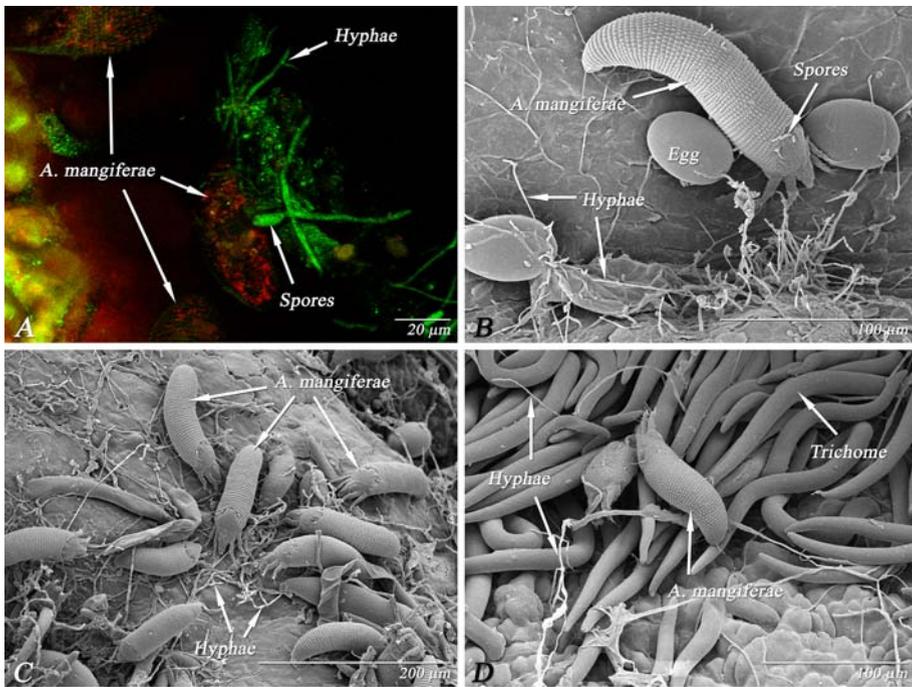
**Fig. 3** Mean density of *Aceria mangiferae* within colonized and non-colonized buds by *Fusarium mangiferae* over a 2-year survey in the Volcani experimental orchard, Bet Dagan, Israel. Bars represent standard errors of the mean ( $\pm$ SE). Biannual means were calculated and subjected to  $t$ -test analysis (results presented in text)

than in non-colonized buds (Fig. 3). When a bi-annual average was calculated for the ten sampling periods and analyzed by  $t$ -test, a significant difference was detected between 50 mites per bud found in colonized buds vs. 33.6 mites per bud found in non-colonized buds ( $P = 0.0002$ ;  $t_{586} = 3.731$ ).

Qualitative associations were assessed with both confocal and LT-SEM observations of apical buds that were inoculated with both the pathogen and the mites. Microscopic observations supported our finding by demonstrating the physical proximity and the actual contact between the two organisms within infected mango buds. Bud mites were observed in close proximity with gfp-marked hyphae and conidia, using a confocal microscope (Fig. 4a). LT-SEM observations also illustrated bud mites bearing hyphae and conidia on their body (Fig. 4b, c, d).

#### Assisting aerial conidial dissemination

Since previous attempts to trap conidia in the air failed (Varma et al. 1971) and the role of *A. mangiferae* in aerial dissemination of conidia was proposed (Ploetz 2001) we attempted to monitor both fungal conidia and mango bud mites using several trapping methods in order to shed light on the mode of conidial dissemination in the field. Conidia of *F. mangiferae* were trapped successfully using two trapping methods and an annual peak of dissemination was found in the spring/early summer months (Gamliel-Atinsky et al. 2009a). *Aceria mangiferae* was trapped throughout the season, but no fungal growth was detected after placing these mites on selective media for the fungus *F. mangiferae*. Our findings imply that conidia can reach the mango tree independently of the bud mite and thus the latter does not seem to play a role in the windborne dissemination of the pathogen.

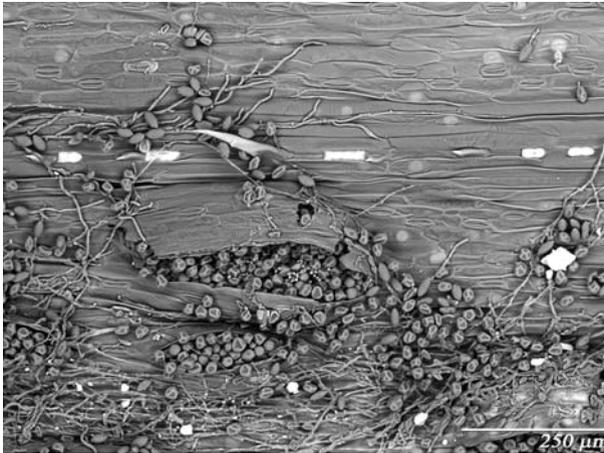


**Fig. 4** Microscopic images of the mango bud mite *Aceria mangiferae* and *Fusarium mangiferae* within inoculated apical buds. **a** Confocal microscope image of three *A. mangiferae* mites and gfp-marked *F. mangiferae* hyphae with germinating conidia surrounding them; **b** SEM image of *A. mangiferae* with fungal conidia on their bodies and eggs in close proximity of fungal hyphae; **c** SEM image of a colony of *A. mangiferae* mites and fungal hyphae around and surrounding them; **d** SEM image of *A. mangiferae* near plant trichomes with fungal hyphae proximate to them

#### Associations between the cereal rust mite *Abacarus hystrix* and rusts caused by *Puccinia* spp.

The cereal rust mite *A. hystrix* is notable among eriophyoid mites in causing losses to cultivated grasslands. It has been found to infest wheat, oats, barley, rye, rice, quackgrass, timothy, orchardgrass and many other (ca. 60–70) cultivated and wild grass species throughout the world (Amrine and De Lillo 2003). *Abacarus hystrix* feeding causes leaf discoloration and inhibition of seed production, and at high densities the mite causes withering of plants and retards their growth (Frost and Ridland 1996). The cereal rust mite is also known to transmit ryegrass mosaic virus (RMV), a serious disease of temperate grasslands, and agropyron mosaic virus (AMV), a minor disease of wheat and quackgrass (Oldfield and Proeseler 1996). The mite lives freely on the upper leaf surfaces and disperses passively on air currents (Nault and Styer 1969).

Rusts caused by *Puccinia* spp. are significant diseases affecting cereal and other grasses worldwide. Infections may occur on stems, leaf sheaths, or leaf blades and glumes. A few days post infection elongated pustules develop, subsequently rupturing the plant epidermis and exposing a mass of reddish brown urediniospores (Fig. 5). Urediniospores are released from the uredinia and may be transported over long distances by wind and infect other plants. In areas with mild climates, infected grass foliage can serve as the overwintering



**Fig. 5** SEM of a rust pustule caused by *Puccinia* spp. releasing urediniospores on the underside of a quackgrass leaf

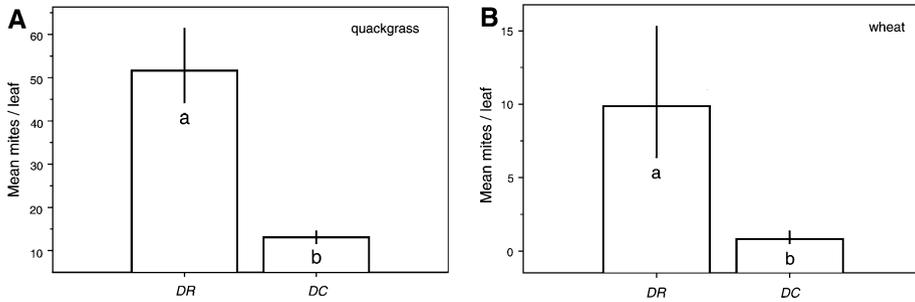
site for the mycelium and urediniospores. Another type of rust spore that may overwinter is the teliospore, from which basidiospores are produced. The latter infect non-grass hosts, e.g., barberries *Berberis* spp., and after germination two more spore types (i.e., pycniospores and aeciospores) are formed. Aeciospores can infect only grasses, giving rise to urediniospores and thus completing the life cycle (Cummings 1971; Leonard and Szabo 2005).

During a survey of the eriophyoid fauna on grasses in Poland carried out from 1998 (Skoracka 2004), the concurrent presence of *A. hystrix* and rusts caused by *Puccinia* spp. have been reported on quackgrass and wheat. Moreover, mite specimens bearing rust spores on their bodies have been observed. Up to now, no reports have suggested the existence of relationships between eriophyoid mites and rust fungi. Here we present results of observations regarding the associations between rust fungi and the cereal rust mite.

#### Association between fungal infestation and mite population levels

Quackgrass *Elymus repens* (L.) Gould and wheat *Triticum aestivum* L. plants were collected in 1998–2001 in west Poland from 23 locations. The material included 143 samples, among them 99 samples contained quackgrass and 44 samples contained wheat. Each sample consisted of 5–10 individual shoots of a given grass species, collected randomly from the sampling location. Shoots were cut just above ground level and put into a plastic bag. The grasses were examined in the laboratory with a stereomicroscope. The presence of rust fungi per leaf was recorded. Mites were counted and mounted on slides, and subsequently identified with a phase-contrast microscope. Mean density of mites on leaves infected with rust [DR], and mean density of mites on leaves with no symptoms of rust (clear) [DC] were calculated. To test the differences between means two sample *t*-tests was applied. For computations, the S-PLUS software was used (S-PLUS 2005).

The density of the cereal rust mite was significantly higher on leaves infected by rust fungi (DR) compared to leaves with no symptoms of rust (DC). This result is true for both host species, quackgrass ( $P < 0.0001$ ;  $t_{3477} = -14.87$ ; Fig. 6A), and wheat ( $P < 0.0001$ ;  $t_{1212} = -8.86$ ; Fig. 6B).



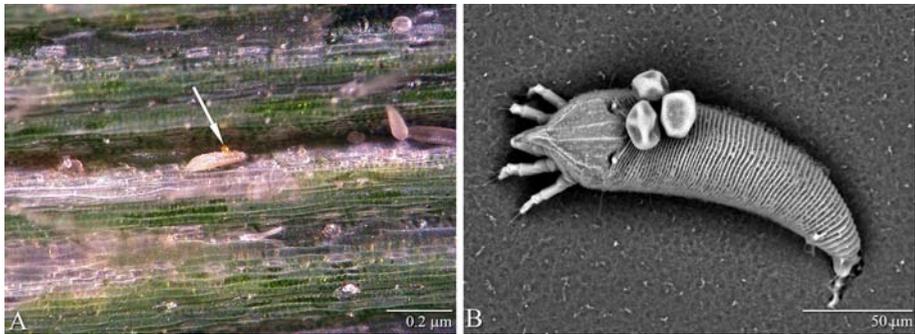
**Fig. 6** Mean density of the cereal rust mite *Abacarus hystrix* on leaves infected with *Puccinia* spp. rust (DR) and non-infected (DC) on **A** quackgrass and **B** wheat. Bars represent 95% confidence intervals around means. Different letters represent significant differences ( $P < 0.0001$ ) between combinations based on two sample *t*-test

On the leaves infected by rust, mites aggregated near rust pustules. Some mite specimens bore urediniospores attached to their dorsal opisthosoma. From one to few (about 5–6) urediniospores were observed attaching to the singular mite specimen (Fig. 7a, b).

## Discussion

Based on our LT-SEM study of infested mango bud bracts with bud mites and the pathogen (R. Ochoa et al., unpublished), we have no proof that the perforations created by *A. mangiferae* serve as ports of entry for *F. mangiferae*. However, it is clear that the presence of the mite, at least in the case of *A. mangiferae*, increases the frequency and severity of fungal infection. Similarly, *Aceria tulipae* (Keifer) was implicated in the spread of fungus-causing rot of garlic bulbs in the field (Jeppson et al. 1975). Saini and Singh (1989) reported that galls induced by eriophyoid mites harbor overwintering inoculum of the fungus *Microspphaera alphitoides* f. sp. *ziziphi*, the causal agent of powdery mildew of Indian Jujube *Ziziphus mauritania* Lam., thus improving the perpetuation of the disease from one season to the next.

In respect to the effect of the pathogen on mite populations, both mango bud tissue infected with *F. mangiferae* and wheat and quackgrass leaves infected with *Puccinia* spp. supported significantly higher populations of eriophyoid mites. In a bi-seasonal experiment set up to evaluate induced plant responses to herbivores and pathogens in papaya, Fournier et al. (2004) observed higher populations of the papaya rust mite, *Calacarus flagelliset* Fletchmann, DeMoraes, and Barbosa on plants previously exposed to the powdery mildew, *Oidium caricae*. The authors suggested that exposure to powdery mildew induced plant susceptibility to the papaya rust mite, possibly due to improved plant nutritional value and/or to lower expression of plant defenses. Peña et al. (2005) found higher densities of *A. mangiferae* mites on the external and middle bracts of mango buds than on the internal bracts next to the dome. The authors proposed that excess relative humidity (RH) between the bracts of the internal region of the bud precludes the bud mites from utilizing this food source. Fungal colonization of the bracts adjacent to the dome by *F. mangiferae* could cause a slight decrease in RH which might allow the mites to enter and occupy the internal region of the bud. In a study designed to evaluate the effects of the tomato spotted wilt virus on its thrips vector, *Frankliniella occidentalis* (Pergande), juvenile survival and



**Fig. 7** **a** Stereomicroscope image showing the cereal rust mite, *Abacarus hystrix*, bearing conidia of *Puccinia* spp. on its body on the underside of a quackgrass leaf (spore marked with black arrow); **b** SEM image showing the cereal rust mite bearing conidia on its body

developmental rate were consistently higher on virus-infected plants (Belliere et al. 2005). The authors hypothesized that the virus counters the negative effects of the herbivore-induced defense mechanisms thereby improving the performance of its insect vector. One remote possibility that has not been addressed is that eriophyoid mites could be directly feeding on the fungus; however, we did not observe this behavior even though the bud mites were crawling all around the mycelium. While we are aware that eriophyoids are considered obligatory plant feeders; we still think this option should be examined using molecular tools.

As eriophyoid mites and plant pathogens share the same microniche, it can be argued that the clinging of the fungal spores to the mite's body has little impact on the ecology of the system. At least in the case of the mango bud mite, we are convinced that this is not the case because it was demonstrated that the mite can vector the spores to the buds, the fungus's sole port of entry to the plant and enhance disease severity (Gamliel-Atinsky et al. 2009b). Furthermore, the spores could benefit from the ability of the mites to travel long distances by wind (Zhao and Amrine 1997). The significance of this association for the cereal rust mite has yet to be clarified. The large spore size in relation to the mite's body size and the fact that the spores appear to adhere to the mite's body even after the SEM preparation procedure may indicate that this phenomena is not by mere chance. Rust spores are disseminated in the wind and are very resilient to desiccation and ultra violet radiation, thus it is very unlikely that eriophyoid mites are part of the long range dispersal of this fungus. However, mites bearing the rust spores on their body may be playing an important role in short range dispersal by moving the spores about the plant thereby increasing the points of infection. Further investigation is necessary to evaluate the role of the cereal mite as a vector of rust spores and to assess its effect on pathogen penetration of the leaf tissue.

Our mango malformation research suggests that fungal as well as other plant pathogens may play an important role in additional cases where plant disorders have been attributed, till now, solely to eriophyoid mites. For example, on *Lantana camara* L., the lantana gall mite *Aceria lantanae* (Cook), causes vegetative deformations appearing as masses of very small leaves (Smith-Meyer 1996). Similarly vegetative malformations occur on caraway *Carum carvi* L., in association with *Aceria carvi* Nalepa (Zemek et al. 2005). On Proteaceae, witches broom has been related to *Aceria proteae* Meyer (Smith-Meyer 1996) but recently a spiroplasma has been isolated from the mite and the diseased plant tissue, possibly indicating a positive interaction between these two organisms (Wieczorek et al.

2003). Even though these examples of plant disorders do not possess the same symptoms as those of mango malformation, there do seem to be marked similarities. We propose that future research on eriophyoid related plant disorders, especially those without typical eriophyoid galls and erineae (Westphal and Manson 1996), should consider and evaluate additional pathogens as causal agents.

In summary, while it appears that eriophyoids are playing a role in fungal epidemiology, clearly further research is needed to broaden our understanding of direct and indirect (plant mediated) interactions between plant pathogens and eriophyoid mites in different plant-pathogen systems.

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