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Passive dispersal of the grape rust mite *Calepitrimerus vitis* Nalepa 1905 (Acari, Eriophyoidea) in vineyards

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Abstract

Modes of passive dispersal of the grape rust mite *Calepitrimerus vitis* (Eriophyoidea) were investigated in a vineyard of South-Western Germany. More than 200 Eriophyoidea per month were trapped in a wind chamber during summer (32,1 % *C. vitis*) suggesting long-distance dispersal by air currents. Rain washed part of the adult *C. vitis* population from the foliage. SE micrographs suggest that quiescent nymphs are affixed to the leaf by a substance of unknown nature. However, the role of rain in *C. vitis* colonisation of uninfested vineyards is still unclear, as is the role of phoretic transport by arthropods. For the first time, evidence of rust mite dispersal by human activity is presented. A large number of *C. vitis* was found adhering to clothes and hands of workers carrying out customary cultural practices in the vineyard. Other arthropods, including *Typhlodromus pyri*, the main predator of *C. vitis*, were also passively transported by wind, rain and human activity.

1 Introduction

The grape rust mite *Calepitrimerus vitis* (NALEPA 1905) is a pest of grapevine and is distributed worldwide. During the last two decades, this eriophyoid mite has become an increasing problem in many wine-growing areas in Europe (i. e. CARMONA, 1978; BAILLOD and GUIGNARD, 1986; KREITER and PLANAS, 1987; REDL and HIEBLER, 1991; SCHRUFT, 1991 PEREZ-MORENO and MORAZA, 1997). In the spring, vinegrowers are often surprised by severe damage caused by hibernating females. The symptoms observed consist of reduced shoot growth, shortened internodes and leaf distortion. The potential for serious damage to occur can usually be predicted by estimating the rust mite infestation in the previous year, and populations can be controlled by a well-timed treatment in the spring. However, in some vineyards, outbreaks of grape rust mites occur unexpectedly. Frequently, the young plantings are attacked, leading to retarded shoot growth. How such early, sudden infestations develop is not fully understood.

Among all known modes of host plant colonisation by Eriophyoidea (PADY, 1955; DAVIS, 1964; TRESH, 1966; BARKE et al., 1972; SCHLIESSKE, 1977, 1979, 1989; EASTERBROOK, 1978; BERGH and MCCOY, 1997), aerial dispersal is considered the most important (JEPPSON et al., 1975; SABELIS and BRUIN, 1996; BERGH and MCCOY, 1997). Other modes of dispersal such as active within-plant migration, passive spread by rain and transport by animal vectors (phoresy) have also been observed in a few eriophyoid species (SMITH, 1960; BEHRENS, 1964; SCHLIESSKE, 1977, 1989; BERGH, 1992; SABELIS and BRUIN, 1996; GRAHL and LEUPRECHT, 1998; DUFFNER, 1999).

Although *C. vitis* has been known in viticulture since the beginning of the 20th century (NALEPA, 1905; MÜLLER-THURGAU, 1906; FULMEK, 1912), no research on its dispersal has been carried out, except for studies on its spread via infested graft (MÜLLER, 1918, 1930; SZENDREY et al., 1995; WOHLFARTH et al., 1996). MÜLLER (1918, 1930) and SZENDREY et al. (1995) reported that hot water treatment of dormant grapevines eliminated *C. vitis* infestation, while the viability of buds were not significantly affected by this treatment.

In order to better understand such outbreaks of grape rust mites in vineyards, we carried out field studies to assess possible modes of their passive dispersal.

2 Materials and methods

2.1 Locality

The research was conducted on 25 year old Müller-Thurgau and Kerner vines in the typical South-West German espalier-type training system ("Flachbogenerziehung"), with a 1.3 m vine spacing and 2.0 m row spacing, respectively. The vineyard faced west and was located on an 18° slope at the State Institute of Enology and Viticulture, Freiburg, Schlierbergsteige, South-West Germany. The prevailing wind direction was South-West. Regular fungicide applications were made, but no insecticides or herbicides were used during the study.

2.2 Dispersal by wind

A freely rotatable PVC chamber mounted on a pole (SCHLIESSKE, 1977) was used to trap *C. vitis* dispersed by wind. The chamber consisted of a PVC pipe (200 cm long, 20 cm i. d.) enclosed at both ends by a PVC ring with an aperture of 10 cm. The pipe was always oriented into the wind direction by a weather vane. The chamber

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floor was covered with 91 glass slides (2 275 cm^2) thinly coated with vaseline. Air passed through the 10 cm wide opening, slowing down thereby allowing particles held in the air to sink and adhere to the surface of the slides. The device was positioned on the upper side of the vineyard 2 m above ground, next to a weather station which recorded temperature, rainfall and windspeed from April to November 1996. From 11. 5. to 10. 11., glass slides were replaced monthly and trapped mites were counted at 50× magnification. Besides Eriophyoidea, Phytoseiidae and other mites (Tydeidae, Tetranychidae) were also counted. All other arthropods trapped (i. e. Diptera, Aphidae, Hymenoptera) were checked for phoretic mites. Mites were cleared in lactic acid and embedded in Hoyer's medium.

Between 11. 8. 96 and 10. 9. 96 a second wind chamber was positioned in a vineyard in Niedereggen (Markgräflerland, ca. 30 km south of Freiburg).

2.3 Dispersal by rain

C. vitis dispersal by rain was studied on two neighbouring vines (cv. Müller-Thurgau) known to be heavily infested by grape rust mites. The level of infestation was determined by sampling vine leaves using the "25-leaf-method" (BOLLER, 1984). Rectangular PVC containers (1.22 m^2) were placed underneath the vine and positioned to collect all water run-off from the foliage. On 26. 8. 1997, run-off water from the two vines was collected during a 30 minute rain (7 mm) and filtered through two sieves of 90 µm and 32 µm aperture (Retsch, Haan). *C. vitis* adults and larvae were counted at 40× magnification and the occurrence of other arthropods was also noted.

2.4 Dispersal by humans

C. vitis dispersal by people working among vines, carrying out customary practices (leaf cutting, pruning etc.) was studied in eight rows of heavily infested Kerner and Müller-Thurgau vines on 6. and 8. 9. 1997. Mites adhering to the long-sleeved cotton shirts worn by workers during four 30-min. work intervals were recorded. The shirts were taken immediately to the laboratory and soaked separately for 2 hours in 4 l of water containing 4 ml wetting agent (Tween 20). The water was filtered by two fine sieves (90 µm and 32 µm) and counted for mites under a stereo microscope (Zeiss SV 8; magnification 40×). Other arthropods collected from clothes were also counted.

2.5 Low temperature scanning electron microscopy

The SEM picture was made in the SEM laboratory Basel, using a Balzers cryopreparation unit SCU 020 attached to a JEOL JSM 6300 scanning electron microscope (DUFFNER et al., 1998).

3 Results

3.1 Dispersal by wind

The total number of Eriophyoidea trapped from the air in Freiburg, Schlierbergsteige, during the 1996 season was 843 (fig. 1), the number of *C. vitis* trapped was 271 (32,1 %). All catches included females and males of *C. vitis*. Several species were not determinable. The following Eriophyoidea species or genus trapped could be determined: *Calepitrimerus vits, Colomerus vitis, Aculus schlechtendali, Phytoptus pyri, Vasates comatus, Cecidophyopsis ribis, Epitrimerus pyri, Tegonotus acutilobus, Tegonotus spec., Eriophyes spec., Anthocoptes spec.,*

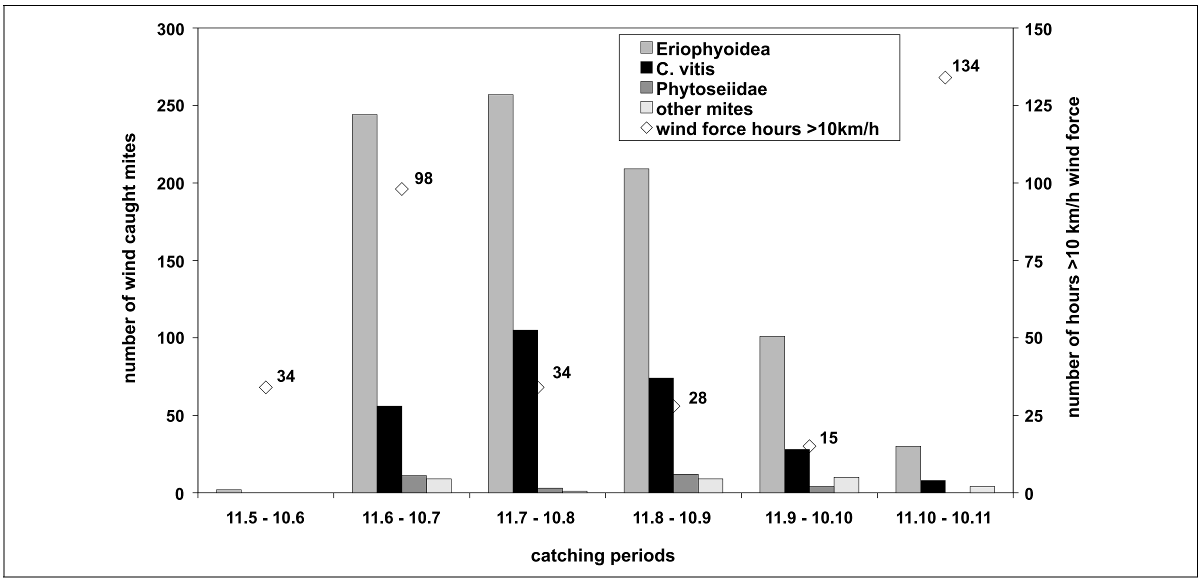
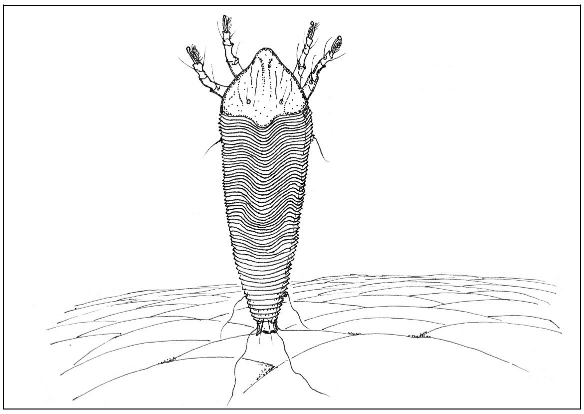


Fig. 1. Aerial dispersal of Eriophyoidea, Phytoseiidae and other mites (Tydeidae, Tetranychidae, Tarsonemidae a. o.) in 1996, Freiburg, Schlierbergsteige. The *Calepitrimerus vitis* share of Eriophyoidea is illustrated by a separate black bar. Trapping periods: 11. 5. 96–10. 6. 96, 11. 6. 96–10. 7. 96, 11. 7. 96–10. 8. 96, 11. 8. 96–10. 9. 96, 11. 9. 96–10. 10. 96, 11. 10. 96–10. 11. 96 and number of hours with wind speed > 10 km/h per trapping period.



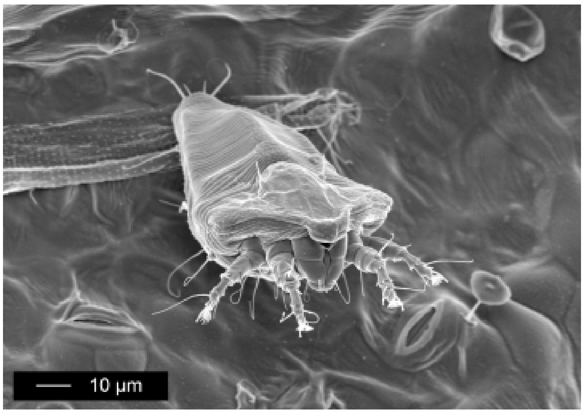


Fig. 2a, Fig. 2b. *Calepitrimerus vitis* upright standing on the leaf surface. This behavior is discussed in context with phoresy and wind dispersal.

Between 11.5 and 10.6 only two Eriophyoidea (no *C. vitis*) were trapped. In early summer, 11.6–10. 7. 96, the number of Eriophyoidea trapped was 244, thereof 56 *C. vitis* (22,8 %). Most Eriophyoidea (257) and also the highest rate of grape rust mites (105 = 41,0 %) were found in July/August (11.7–10. 8. 96). In late summer (11.8–10. 9. 96), the number of Eriophyoidea trapped was 209 (*C. vitis*: 74 = 35,3 %) and decreased to 101 (*C. vitis*: 28 = 27,7 %) in autumn (11.9–10. 10. 96). Around leaf fall, 30 eriophyoid individuals had been trapped (11.10–10. 11. 96), thereof 8 *C. vitis* (26,6 %). In comparison to Freiburg the pipe at the location Niedereggen showed in the late summer period (11.8–10. 9. 96) less Eriophyoidea (88).

BARKE et al. (1972) stated that the minimum wind speed of 10–13 km/h is required for aerial dispersal of *Aculus cornutus*. In this study, no relationship between the number of hours with wind speed > 10 km/h and Eriophyoidea trapped was observed (Spearmans r_s = –0,0428). In early summer, 11.6–10. 7. 96, 98 hours with wind speed above 10 km/h were recorded, while the next two periods, 11.7–10. 8. 96, and, 11.8–10. 9. 96, recorded only 34 and 28 hours respectively with wind speed above 10 km/h. However, all three periods showed a similar number of eriophyoid mites captured: 244, 257 and 209, respectively.

Phytoseiidae, predators of Eriophyoidea, were also dispersed by air currents. In the first period, no Phytoseiidae were trapped, whereas in the following periods 11, 3, 12, and 4 Phytoseiidae were caught, thereof several *Typhlodromus pyri*. This corresponds to the 6 Phytoseiidae of the localisation Niedereggen in late summer. The largest number of other mites (Tydeidae, Tetranychidae, Tarsonemidae) in Freiburg was captured in the late summer (10).

None of the many insects caught in the wind-tube, including Thysanoptera, Aphidae, Cecidomyiidae or Hymenoptera (wasps, bees), were found to transport *C. vitis.* However, a remarkable behaviour was observed in mites reared both in the field and under laboratory conditions (fig. 2a, 2b), Some adult *C. vitis* on leaves were "standing" on their caudal sucker while they were either motionless or stretching their legs and moving them rapidly.

Table 1. Wash-off of *C. vitis* and other arthropods by rain (7 mm, 30 min) from *Vitis vinifera* (cv. Müller-Thurgau, Freiburg, Schlierbergsteige, 28. 8. 97).

	Washed off by rain	Leave sample (25 leaves)
Calepitrimerus vitis	5 440 adults/363 juv.	32 000 adults/ 32 000 juv.
Phytoseiidae	9	7
Tydeidae	3	2
Oribatidae	5	0
Tetranychidae	21	2
Thysanoptera	26	11
Cecidomyiidae	7	10
Cicadida	1	1
Anthocoridae	0	21

3.2 Dispersal by rain

During a rainfall of 7 mm in 30 minutes on 30. 8. 1997, 5 884 *C. vitis* were washed from a 1,22 m^2 area of foliage (tab. 1). Interestingly, while the ratio of adults to juveniles on leaves was approximately 1 : 1, 15 times more adults were washed off by rain. A sample of 25 leaves taken from the two vines after the rain contained approximately 64 000 grape rust mites.

Other arthropods often associated with *Vitis vinifera* and also washed to the ground by the rain were Phytoseiidae (11 *Typhlodromus pyri*, the main predator of *C. vitis* in South-West German vineyards), Tydeidae (*Orthotydeus götzi*), Tetranychidae (*Panonychus ulmi*), Oribatidae, Cicadida (*Empoasca vitis*), Thysanoptera and Cecidomyiidae-larvae.

Table 2. *Calepitrimerus vitis* and other arthropods adhering on clothes of workers after working half an hour in the vineyard (6. 9. 97 and 8. 9. 97, Freiburg, Schlierbergsteige).

Sample	*C. vitis*	Phytoseiidae (*T. pyri*)	Tydeidae (*O. götzi*)	Thysanoptera	Anthocoridae	Diptera
I	7 090	2	7	2	0	0
II	11 742	2	7	12	1	2
III	9 230	3	8	6	1	0
IV	8 146	1	3	4	0	1

3.3 Dispersal by humans

C. vitis dispersal by people working among vines, carrying out customary in heavily infested vines, was considerable. An average of 9 056 ± 1 992 mites were recovered from the cotton shirts of workers (n = 4) after 30 minutes of labour (tab. 2). The maximum number of grape rust mites per shirt was 11 742. 108 *C. vitis* were recovered from both hands of one worker. Other arthropods adhering to clothes were Phytoseiidae (*Typhlodromus pyri*), Tydeidae (*Orthotydeus götzi*), Thysanoptera, Anthocoridae (*Orius* spec.) and Diptera. The ratio of grape rust mites to *Typhlodromus pyri* adhering to clothing was approximately 4 500 : 1.

4 Discussion

Calepitrimerus vitis migrates exceedingly active within vines throughout the vegetative period (DUFFNER and SCHRUFT, 1998; DUFFNER, 1999). However, the passive dispersal by air currents is considered as the most important mode of long distance movement for Eriophyoidea (SCHLIESSKE, 1989; SABELIS and BRUIN, 1996). NALEPA (1924) reported that rust mites are transported by wind on leaves and leaf sections. The same assertion was made by SCHRUFT (1991) regarding *C. vitis*. SCHLIESSKE (1977) trapped 43 Eriophyoidea in a *Prunus* orchard in Northern Germany using a PVC tube trap during one summer month. This is one fifth of the Eriophyoidea-catch obtained per corresponding period in Freiburg in 1996 and half of the catch obtained in Niedereggen. In our research, we used a similar device throughout the vegetative period. Although the vineyard in Freiburg was heavily infested with grape rust mites and the wind chamber was positioned beside the vines in wind direction, only about one third of the catch was *C. vitis.* The other gall mites trapped consisted of different species of various host plants, for example pear (*E. pyri*, *P. pyri*), apple (*A. schlechtendali*), black currant (*C. ribis*) or hazel-nut (*V. comatus*). Most of the Eriophyoidea (> 200/month), were trapped in summer, from the middle of June to the middle of September. In this time, most gall mite populations reach the highest density, as do *C. vitis* normally at the end of August in Central Europe (RÜHL and KOPF, 1994; HERRMANN and HOFMANN, 1995; DUFFNER, 1999).

DAVIS (1964) trapped Eriophyoidea at wind speed from 11 km/h to 19 km/h, BARKE et al. (1972) caught *Aculus cornutus* at a minimum wind speed of 10–13 km/h. Although a wind speed greater than 13 km/h was not recorded during 11.8–10. 9. 1996, more than 200 Eriophyoidea were trapped. This suggests that strong winds are not required for aerial dispersal of Eriophyoidea. Considering the small diameter aperture of the PVC tube (10 cm i. d.), an infinitesimal section of the air space, the amount of Eriophyoidea moving on the air in summer is unexpectedly high. Not only the pest was dispersed but also the main predator of *C. vitis* in South-West German vineyards, the phytoseiid *Typhlodromus pyri*. This confirms the observation that the establishment of *T. pyri* occurs mainly downwind (HILL, 1988).

Rain is considered to be another source of Eriophyoidea dispersal (SCHLIESSKE, 1977, 1979). As demonstrated in the case of *Cecidophyopsis ribis* on black currant (SMITH, 1960), gall mite can be washed down onto the lower parts of host plants by precipitation. For *C. vitis*, thousands of individuals per vine were washed off during a heavy rain.

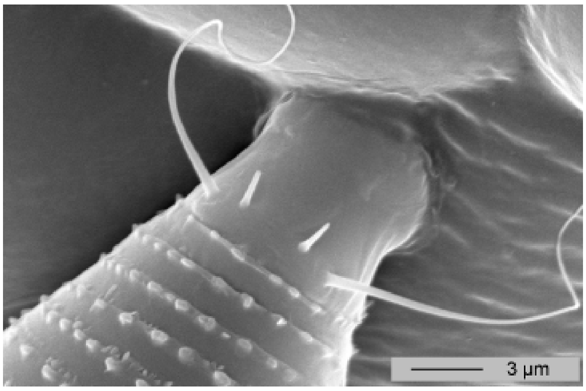


Fig. 3. Caudal sucker of a quiescent larvae of *Calepitrimerus vitis* adhered on the lower leaf surface.

Thereby the wash-off ratio of adults to juveniles was higher than that of adults and juveniles remaining on leaves. Both stages possess caudal musculated lobes termed "the anal sucker" (fig. 3), by which the mites attach themselves to the leaf surface. How this adhesion functions is not fully understood (LINDQUIST, 1996). However, our SE micrographs show a glutinous substance at the contact zone between sucker and the leaf surface exclusively in case of quiescent juveniles. This can be interpreted as an enforced attachment of quiescent larvae and nymphs to the leaf surface, thereby compensating for the unability to anchor their bodies by legs to resist removal by wind or rainfall. In addition to material found to be deposited underneath the caudal lobes of quiescent juveniles, a substance probably acting as an adhesive was frequently observed at the contact zone of *C. vitis* spermatophores and the leave surface (DUFFNER et al., 1998).

Another possible reason for the higher percentage of adults in the water run-off is their exposition in the rain because of moving from leaves to shoots. In extensive investigations to migration behaviour within the vines, more than 95 % of migrating *C. vitis* were found to be adults (DUFFNER, 1999). In this way they are more exposed to the rain than juveniles who accomplish their ontogenesis mainly on the lower side of their "nursery leaf". The huge amount of individuals caught in the rain run-off suggests a possible role of such rain events in passive dispersal of *C. vitis*. Survival of 50 % of *Aculus fockeui* after being submerged for 4 days in 15 °C water suggested that rain dispersal is possible at least in spring and autumn, when water temperatures are low (SCHLIESSKE, 1977). As to whether *C. vitis* which are transported by water streams are capable of leaving the water and colonising other vineyards is unclear.

Transport of Eriophyoidea by Arthropoda with better displacement capability (phoresy) has been observed in some species. GRAHL and LEUPRECHT (1998) found *Aculus lycopersici* attaching itself to Aphidae and being dispersed by them. BEHRENS (1964) described *Cecidophyopsis ribis* "standing upright" to become adhered to insects. A similar observation was made in case of *Aculus* *fockeui* by Schliesske (1977, 1989). In the latter study, mites erected their bodies and moved their legs in response to shaking of the leaves they were on, and to being touched with a thin needle. *Calepitrimerus vitis* showed an identical behavior (fig. 2a, 2b). However, the active leaping described by Massee (1928) and Smith (1960) in *Cecidophyopsis ribis* was not observed in *C. vitis*. The upright stance and the leg movements may have at least two functions: (i) take-off in aerial dispersal and (ii) contacting vectors in phoretic transport (Sabelis and Bruin, 1996). No Eriophyoidea were observed adhering to small winged arthropoda (Thysanoptera, Cecidomyiidae, Diptera, Hymenoptera) caught in the windtube. However the larger insects such as *Byctiscus betulae* (Coleoptera) *Empoasca vitis* (Cicada), *Vespula germanica* (Hymenoptera), *Lobesia botrana, Eupoecilia ambiguella* (Lepidoptera), which are abundant in South West German vineyards, could not be trapped with this device. Therefore, the role of larger winged insects as vectors of *C. vitis* should be investigated in the future.

Vineyards close to forests or thickets are often inhabited by vertebrates such as roes, foxes, hares and birds (Stellwaag, 1928; Vogt, 1987). It is conceivable that these animals, especially birds foraging in the vineyard, could disperse *C. vitis* adhering to pelts or feathers. The hypothesis that large organisms may play an important role in transporting Eriophyoidea is supported by our data on phoresy by humans. Other such investigations have so far been rare. Stellwaag (1928), Herrmann and Hofmann (1993) suggested that *C. vitis* could be transported by vine growers. Thousands of living grape rust mites were found on shirts and hundreds on hands of people working in the vineyard for even a short time (30 minutes) (tab. 2). The number of mites adhering might depend on the intensity and duration of contact with the vine leaves; it is likely that *C. vitis* also adhered to trousers and heads of workers in similar amounts. Therefore, the dispersal of *C. vitis* by vineyard workers themselves when moving from infested to clean areas is a potential source for new infestation.

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