Claudia Daniel, Andreas Haeseli, Franco Weibel **(October 2001)**

Research Institute of Organic Agriculture (FiBL); Ackerstrasse; CH-5070 Frick, Switzerland (www.fibl.ch)

The side effects of lime sulphur on predaceous arthropods, i.e. Typhlodromus pyri, and other leaf occupying arthropods[1]

1. Introduction

At the moment lime sulphur is very popular. But it has also a long history.

- In 1814 it was described for the first time in the United States (BORIANI 1994).
- In 1851 it was the first pesticide, which was directly applied to the leaves of ornamental plants in Versailles (France) to keep them free from fungal diseases, aphids and mites (BROWN 1978).
- At the end of the 19th century it was widely used in the United States to protect plants from San- Jose scale (*Quadrospidiotus perniciosus* Comst.) (BORIANI 1994).
- Thereby in 1908 it was the first pesticide where a development of a resistance (of San-Jose Scale against lime sulphur) was documented (BROWN 1978).

After lime sulphur was only used for winter treatments against scales (Coccoidea) during the last years, it is now admitted for organic agriculture without indication in the European Union (BBA 2000). In Switzerland an registration is also discussed.

Nowadays mainly organic apple growers pin their hope on lime sulphur. Actually lime sulphur has a lot of advantages. Used as fungicide against apple scab (*Venturia inaequalis* (Cooke) Winter) even a curative effect is described in literature (TRAPMAN & DRECHSLER 2000). Lime sulphur may replace copper-fungicides and because of its curative effect it makes the use of infestion prediction models in organic apple production more effective (TRAPMAN & DRECHSLER 2000). But it can also be used against storage diseases (KELDERER ET AL. 1997), sooty blotch (*Gloeodes pomigena* (Schweinitz) Colby and *Schizothyrium pomi* (Mont. Ex. Fr.) Arx) (KIENZLE ET AL. 1995, KELDERER ET AL. 1997) as well as against Rosy Apple Aphid *(Dysaphis plantaginea* Pass.) (LÖSCH ET AL. 1998), scales (KELDERER 1995), spider mites (*Panonychus ulmi* Koch) (BORIANI 1994) and for blossom thinning to regulate crop load (MÖSSLER 1998, KELDERER ET AL. 1997 & 1998, BERTSCHINGER ET AL. 2000, WEIBEL 2000).

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But until now data of toxicity on beneficial or indifferent arthropods are lacking. The available data in literature only describes the side effects of winter applications (BORIANI 1994). By the use as scab-fungicide lime sulphur is now frequently applied during the vegetation period.

Because of its broad efficacy spectrum side effects on beneficial arthropods can not be excluded, especially predaceous mites are in the focus of interest, because numerous studies have documented detrimental effects of sulphur applications on predaceous mites (ENGLERT 1981, FAW 2000a, FAW 2000b, FRIEDRICH & RODE 1996, HAAS 1987, HÄSELI & GRAF 1992, HIEBLER 1991, HOLZER ET AL.1994, KETTNER 1986, KREITER ET AL. 1996, KREITER ET AL. 1998, MOHR ET AL.1994).

The most important predator of spider mites in middle Europe is *Typhlodromus pyri* Scheuten. If it is abundant in sufficient densities from approximately 0.5 to 1 *T. pyri* per leaf, it can keep the red spider mite (*Panonychus ulmi* Koch) and the two spotted spider mite (*Tetranychus urticae* Koch) below economically damaging levels (BOURQUIN 1989, FORTMANN 1993, HARZER 1993, KARG 1992, KOHLER ET AL. 1991).

The purpose of this study was to estimate the effects of lime sulphur on predaceous mites, especially *T. pyri*, in six field trails on apple, vine and plums.

2. *Material & Methods*

The studies were conducted on six different sites in northern Switzerland, 2 organically cultivated apple orchards, 2 organic plum orchards, 1 experimental vineyard, 1 experimental apple orchard.

From May to August 2000 samples of 100 leaves per treatment were taken from the base part of the new shoots. Densities of mites and other leaf occupying arthropods were counted by examining the leaves with a microscope.

Average numbers of mites per leaf from the lime sulphur treated trees were compared with an untreated control or an control treated with the organic standard fungicides, copper and sulphur. Different concentrations of lime sulphur, 1 and 2%, and the effects of two and three applications during the bloom were tested.

The statistical comparison was done with JMP program (version 3.2.2) using Kruskal-Wallis-(Chi-Square)-Test with an α-level of 0.05. If the over all effect test was significant the different treatments were compared pairwise, also with Kruskal-Wallis-(Chi-Square)-Test.

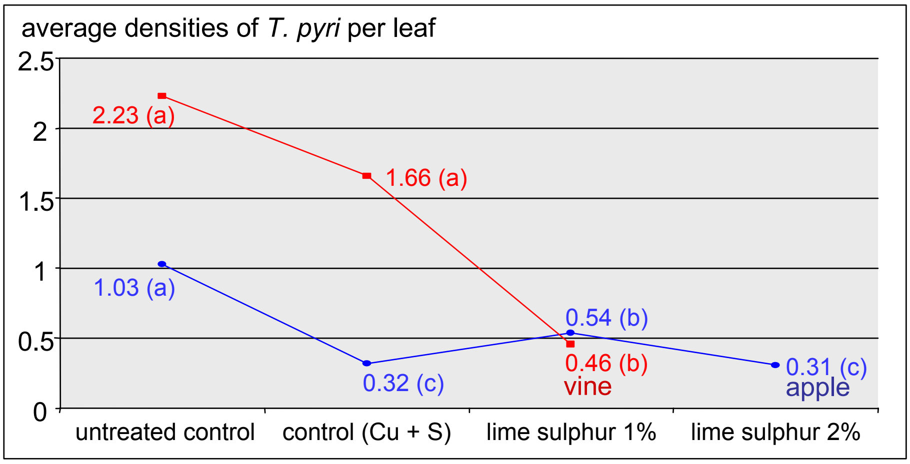
3. *Results and discussion*

Apart from *T. pyri* only the red spider mite, *P. ulmi*, could be observed on apple leaves in densities worth mentioning. The two spotted spider mite (*T. urticae*) and thrips (Thysanoptera) were barely detectable on apple leaves.

Grape blister, *Colomerus vitis* Pagenstecher, was found relatively abundant on vine leaves. On the leaves from a very extensively managed plum orchard about 5 not further identified species of indifferent or beneficial mites as well as larvae of predaceous gall midges (Cecidomyiidae) were detected.

3.1. Typhlodromus pyri

Graphic 1 shows the results of the experimental orchard and vineyard in Frick.



Graphic 1: average densities of *T. pyri* per leaf
(Experimental orchard and vineyard, Frick, completely randomised block design with 9 repetitions, treatment between beginning of May and beginning of July;
samples: 100 leaves per treatment and specie were taken Mid-July
statistical comparisons: Kruskal Wallis (Chi-Square) Test, $p < 0.05$, done separately for each specie)

In this site (Graphic 1) and in one plum orchard, where lime sulphur was compared with an untreated control, a significant decrease in densities of adult *T. pyri* between 50 and 80% were detected. The reduction of *T. pyri* by lime sulphur is not surprising, because the damaging effects of sulphur on predaceous mites are known (ENGLERT 1981, FAW 2000a, FAW 2000b, FRIEDRICH & RODE 1996, HAAS 1987, HÄSELI & GRAF 1992, HIEBLER 1991, HOLZER ET AL.1994, KETTNER 1986, KREITER ET AL. 1996, KREITER ET AL. 1998, MOHR ET AL.1994). The observed decrease in densities corresponds to the results of the annual scab experiments at Research centre of Laimburg (KELDERER 1995, 1996, 1997, 1998).

Compared with biological standard fungicides, copper and wettable sulphur, in only two of six sites a significant reduction of *T. pyri* was detectable. The graphic 1 shows a reduction of

about 72% of *T. pyri* in lime sulphur treatment on vine. In three other cases no significant differences were found and in one case on apple (Graphic 1), there were even 40% more *T. pyri* on the lime sulphur treated trees.
The observed decrease of *T. pyri* in the standard fungicide treatment compared with the untreated control (Graphic 1) is most likely due to the sulphur, because copper is classified as non detrimental for *T. pyri* in literature (MOHR ET AL.1994). In the experiment on a commercial apple orchard, where sulphur is frequently used, only very low densities of *T. pyri* occurred. This phenomenon often appears in organic orchards and the spider mite predator *T. pyri* is replaced by predatory bugs (Miridae and Anthocoridae) and the coccinelid beetle *Stethorus punctillum* (HÄSELI & BOSSHARD 1994).

By comparing a 2% application of lime sulphur with a 1% concentration, a 40% lower density of *T. pyri* were observed in the 2% concentrated treatment (Graphic 1). Such an observation was expected, because more concentrated wettable sulphur also shows greater effects (FAW 2000a, KETTNER 1986).

In comparison with wettable sulphur no significant differences were found, but by tendency lower densities of *T. pyri* occurred in the lime sulphur treatment. This phenomenon should be examined more in detail, because wettable sulphur is active mainly in gaseous form, while lime sulphur additionally influences the arthropods by its extreme high pH-level (BORIANI & NICOLI 1995). Thus a more intensive effect of lime sulphur on arthropods is possible.

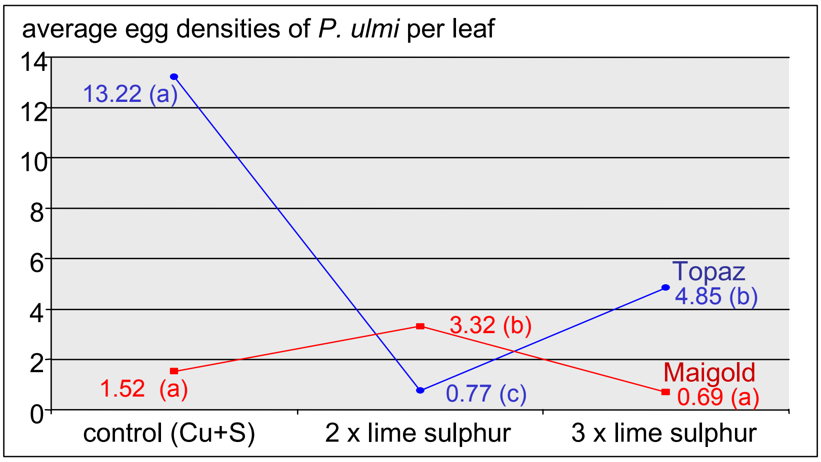
Eggs of *T. pyri* were observed in low densities and often showed no significant differences between treatments, but generally showed the same pattern like the adults.

3.2. *Panonychus ulmi*

The red spider mite, *P. ulmi*, occurred only on apples and only in commercial orchards with intensive sulphur-containing spraying programs. The effects of lime sulphur on *P. ulmi* were not clearly explainable. The graphic 2 shows the egg densities of the red spider mite from a thinning experiment.
On Topaz a decrease in egg densities in the twice lime sulphur treated plots was found, but greater densities occurred in the three times treated plots, while on Maigold reverse effects were observed: greatest egg densities per leaf were found in the twice treated plots (Graphic

2). These data indicate, that both an enhancement as well as a controlling of the red spider mite by lime sulphur is possible.

Therefore further studies should be conducted, because the use as acaricide against *P. ulmi*, as well as an enhancement of the Red Spider Mite due to its harm on predatory mites is described in literature (BORIANI 1994).



Graphic 2: average densities of *P. ulmi* per leaf
(2xlime sulphur = two applications of lime sulphur during the bloom,
3xlime sulphur = three applications of lime sulphur during the bloom,
Control = treated with copper and sulphur,
Samples: 100 leaves per treatment and variety were taken End of May
Statistical comparisons: Kruskal Wallis (Chi-Square) Test, $p< 0.05$, done separately for each variety)

3.3. Other Arthropods

Grape blister (*Colomerus vitis*) densities did not show significant differences, but in lime sulphur treatment occurred by tendency the twice amount of blisters per leaf (Table 1). An enhancement of Grape Blister due to the reduction of predators is possible.

Other not further identified mites (about 5 species, e.g. Tydeidae, further Pytoseiids and other non-detrimental species) were found on plums in a very extensively managed site, where no insecticides or fungicides were used in the last two years. In the untreated control about 0.64 not further identified mites per leaf were observed, but in lime sulphur treatment not a single of this mites was present anymore (Table 1). This observation shows, that the great diversity of mites, which appears in untreated orchards, never occurs in intensively treated sites, because a lot of mite species are very vulnerable to pesticides (HIEBLER 1991, HLUCHY 1991).

Apart from mites, larvae of predaceous gall midges were observed on the plum leaves from the extensively managed site. The treatment with lime sulphur caused a significant decrease in density of about 86% (Table 1). This result underlines the broad effectiveness of lime sulphur on arthropods.

Table 1: Densities per leaf
(Grape Blister = density of Blisters per leaf, experimental vineyard Frick; Gall Midges = density of larvae per leaf, extensive plum orchard; Not further identified mites = density of adult mites per leaf, extensive plum orchard; Statistical comparison: Kruskal Wallis (Chi-Square) Test, $p<0.05$, n.s. = not significant)

	Grape Blister		Not identified Mites		Gall Midges	
Untreated control	0.38	n.s.	0.64	a	1.88	a
Lime sulphur	0.67	n.s.	0.00	b	0.26	b

4. *Conclusions and further studies*

The significant reduction of *T. pyri* and of larvae of predaceous gall midges, the complete loss of mite-diversity and the possible enhancement of *P. ulmi* and other harmful mites (i.e. *C. vitis*) are clear disadvantages of lime sulphur. Densities of *T. pyri* between 0.5 and 1 mite per leaf as mentioned to be necessary for controlling harmful mites (BOURQUIN 1989, FORTMANN 1993, HARZER 1993, KARG 1992, KOHLER ET AL. 1991), were never reached in lime sulphur treatment, while the untreated control always showed densities above this value.

On the other hand low densities of predaceous mites are quite normal in intensively sulphur treated, biological orchards and are often replaced by other mite predators, like predatory bugs (Miriadae, Anthocoridae) or the coccinellid beetle *Stethorus punctillum* (HÄSELI & BOSSHARD 1994). Therefore further studies should include these arthropods, because lime sulphur may also have adverse effects on them (BORIANI 1994, BROWN 1978).

Furthermore the lowest application strategy in terms of frequency and concentrations for scab control should be examined to minimise the quantity of applied lime sulphur (ZIMMER 2000). In addition the effects of different application methods, for example by sprayer or overhead irrigation on beneficial arthropod as well as on scab should be studied (KELDERER ET AL. 2000).

The side effects of lime sulphur should not be considered separated from other used fungicides, moreover the whole spraying program should be included, because wettable sulphur (MILAIRE ET AL. 1974) and clay powder (HÄSELI & BOSSHARD 1994) also harm arthropods.

For agronomic interests but also from the points of view of the registration of lime sulphur and the public image of organic apple growing, the question is: whether lots of preventive applications with copper, sulphur and clay powder have more adverse effects on beneficial arthropods than fewer curative applications of lime sulphur by using an infestion prediction model.

Only by further studies under realistic farming conditions it is estimable, whether the use of lime sulphur in organic orchards can be accepted. In the common enthusiasm about this new curative fungicide, we should not forget the important role of beneficial arthropods. In this context the registration without any indication in the EU should be critically discussed.

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