Exclusion netting row covers in organic apple orchards: implications regarding practicability, pest organisms and disease control

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Abstract

This study compares trees under two different exclusion netting systems: I. keep in touch system II. keep in touch antiacqua system (additional coverage of the trees with water repellant netting structure) with control trees under a common hail net system over a period of two years (2018 and 2019). The utilized cultivar is Jonagored grafted on rootstock M9. The main focus was on so far less considered aspects such as the occurrence of non-target pest organisms (woolly aphids, green apple aphid, apple leaf miner), fungal diseases (apple scab) and the practicability of exclusion netting systems compared to common hail net constructions. While codling moth control without the application of pesticides in the exclusion netted systems was feasible, secondary pest organisms were generally more abundant in the keep in touch antiacqua system compared to the other two treatments. Despite a reduction of approximately 50% of fungicide application, high efficacy in scab control (leaves and fruit) was achieved in the keep in touch antiacqua system. Time expenditure for closing the netting systems in winter was increased compared to common hail net systems.

Keywords: Exclusion netting, *Cydia pomonella*, rain cover, woolly aphid, Green apple aphid

Introduction

Since the development of exclusion netting row covers (henceforth enrc) against *Cydia pomonella* L. in 2005 and their wide application in France and Italy, the good efficacy for codling moth control has been thoroughly investigated in several studies (Alaphilippe et al. 2016, Chouinard et al. 2016, Kelderer et al. 2010, Kelderer et al. 2018, Romet et al. 2010). Moreover deploying enrc before or during bloom revealed a promising thinning effect in apple production (Elsysy et al. 2019, Kelderer et al. 2014). On basis of this promising results, this study compares two different netting systems on Jonagored trees with not netted control plots. Supplementary to previous trials, this study focuses on the impact of enrc towards secondary pest organisms (green apple aphids (*Aphis pomi* de Geer), woolly aphids (*Eriosoma lanigerum* Hausmann), and apple leaf miners (*Leucoptera malifoliella* Costa)), control of apple scab (*Venturia inaequalis* (Cooke) G. Winter), and the practicability of both systems.

Material and Methods

Experimental Design

The experiment is conducted in an organically managed orchard of the Competence Centre for Fruit Production at Lake Constance (KOB) located in Ravensburg, Germany. In spring 2017, the netting systems were installed in an orchard consisting of Jonagored trees on rootstock M9 which were planted in 2009. Since the systems were installed subsequent to the beginning of codling moth flight in 2017, this study focuses on experimental results gained in 2018 and 2019. The experiment is arranged in a randomized block design, with 4 replications. Thus, 4 rows were selected and each separated in 3 parts (each replication

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comprising 25 trees): 1. Control plot with a traditional hail net system, 2. Keep in touch system (henceforth kit) and 3. Keep in touch antiacqua system (henceforth kitaa).

Netting systems

1. Keep in touch system (kit): enrc with a mesh size of 2.2 × 2.3mm on the upper and lower parts respectively 2.3 × 4mm on the central part, and a total row-width of 6m.

2. Keep in touch antiacqua system (kitaa): enrc consisting of two segments. A lateral netting system as described above, and attached to that on the upper part a 1.5m wide piece of a thick knitted double layer of Microtex® texture, which impedes the passage of water, but allows a good air circulation. Metal arches of 1.4m width were installed on the wooden poles, where the Microtex® texture is placed upon to provide sufficient rain protection.

To prevent early scab infections, the kitaa system was opened before the ascospore infection period in spring, while the kit was opened just after the blossom period. Both systems remained without the application of granulovirus agents. Aiming to further reduce the amount of applied plant protection agents, spraying of fungicides was suspended in the kitaa plots from the time on when granulovirus agents were applied in control plots in 2019.

Rating scheme of observed parameter

***Leucoptera malifoliella* (Costa)**

To assess the damage caused by the apple leaf miner, 10 shoots from lower tree parts and 10 shoots from upper tree parts (20 shoots of each replication ≙ 80 shoots per treatment) have been examined. Therefore all leaves were examined and classified regarding the amount of mines per leaves: 0= no visible mine; 1= 1 mine; 2= 2mines; 3= 3 and more mines.

***Aphis pomi* (de Geer) & *Eriosoma lanigerum* (Hausmann)**

Damage caused by the green apple aphid and the woolly aphid have separately been assessed by visually classifying all trees in 4 categories: 0= no visible infestation; 1= visible but minor infestation; 2= visible, intermediate infestation; 3= heavily infested trees, resulting in contaminated fruit.

***Venturia inaequalis* (Cooke) G. Winter**

25 shoots of each repetition (100 shoots per variable) were examined to assess the scab infestation on leaves. The leaves were classified in 4 categories: 0= no visible infestation; 1= 1 infested spot; 2= 2 infested spots; 3= 3 infested spots. Scab on fruits was documented by examining 600 fruits per treatment in the following categories: 0= no visible infestation; 1= 1-3 infested spots; 2= 3 and more infested spots.

Time measurement to assess the practicability

Time measurements for opening the systems in spring and closing the systems in winter were conducted by manual time recording.

Results

While the level of trees infested with green apple aphids in control and kit plots was homogeneous in 2018 and 2019 between 55-65%, the number of infested kitaa trees more than doubled in 2019 (97%) compared to 2018 (47%) (Figure 1a). Figure 1b displays the results of trees damaged by woolly aphids in the years 2018 and 2019. In both years, control trees were not infested. A yearly effect could be observed for exclusion netting row covers (enrc) plots which showed generally higher infestation levels in 2019. Trees covered with kit were infested on a medium level (2018: 1%; 2019: 16%) and trees covered with kitaa sustained highest infestation rates (2018: 25% and 2019: 79%). Particularly, relevant shares of heavily infested trees by both green apple aphid (23%) and woolly aphid (25%), resulting in contaminated fruit were only found in kitaa plots.

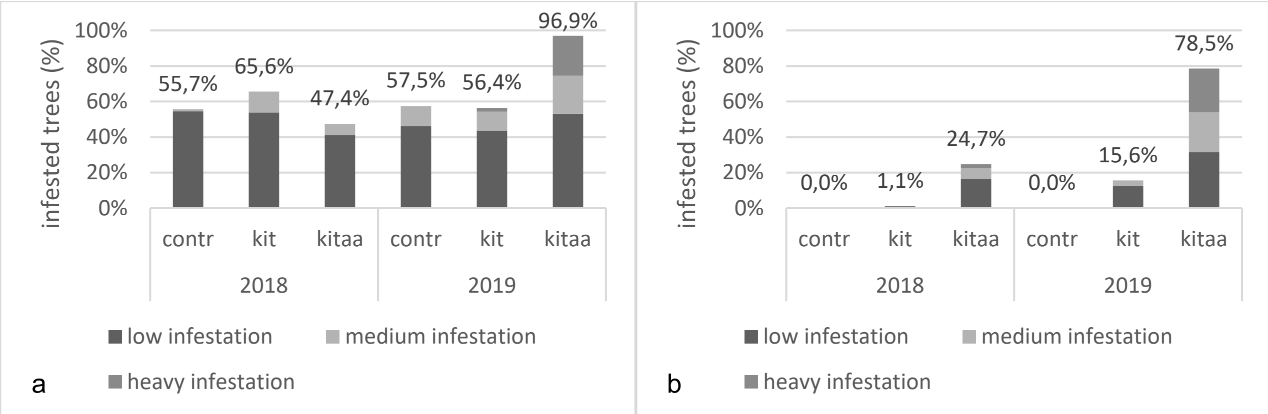

Figure 1: infested trees (%) divided in degree of damage in 2018 and 2019. a: green apple aphid; b: woolly aphid

In the years 2018 and 2019 both enrc systems sustained increased infestation with the apple leaf miner (*Leucoptera malifoliella*). With 44.9% (2018) respectively 33.2% (2019) infested leaves in total, kitaa covered trees revealed highest infestation, followed by kit covered trees (2018: 34.2%; 2019: 21.6%) (Figure 2a). Least infested leaves were found in control trees (2018: 24.5% and 2019: 16.4%). Figure 2b shows infection rates of apple scab for both leaves and fruit in 2019. Due to disease favouring weather conditions in 2019, the level of scab infestation was generally high. Compared to control and kit plots, only 47% of fungicidal applications were sprayed in the kitaa system in 2019. Despite that, trees covered with the kitaa system expressed least scab infections both on fruit (1%) and leaves (3%). Even though the same fungicidal program was applied in control and kit plots, less infected leaves (12%) and fruit (10%) were observed for trees in kit plots whereas control plots (customary fungicide application in combination with common hail net) suffered highest scab infection on leaves (22%) and fruit (18%).

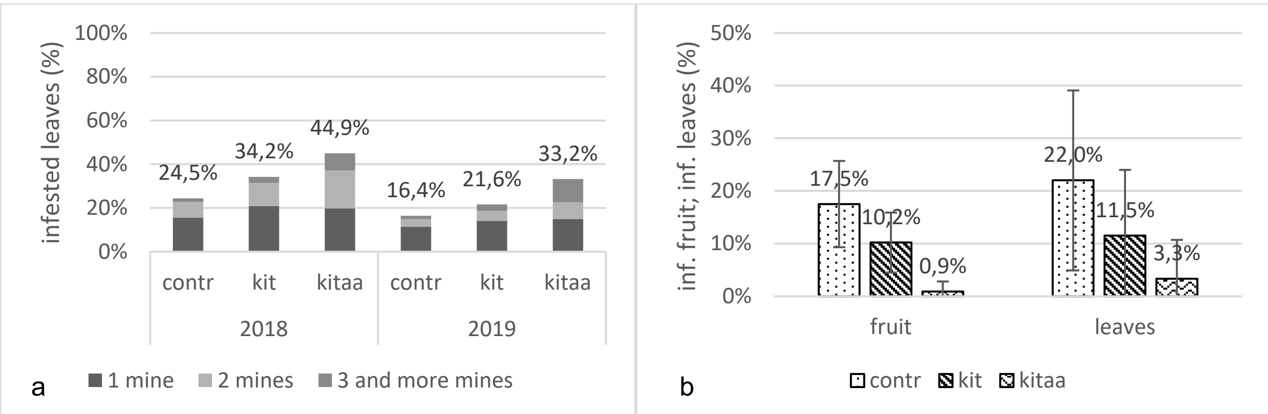

Figure 2: a: infested leaves by apple leaf miner in 2018 and 2019 divided in degree of infestation; b: scab infected fruit, respectively leaves in 2019, (error bars: ± standard deviation).

Table 1 displays measured opening and closing times for kit and kitaa as compared to time data of common hail net constructions retrieved from Burmann & Kunde (2005). While the difference among the systems in opening time is negligibly small, the closing time for kit was twice as long (+ 22.9 man hours/ha) and the kitaa system even three times as long (+ 48.8 man hours/ha) compared to a common hail net construction. In addition to that, maintenance operations within the season such as prunig or hand-thinning were done under the nets. In this case only the plugs at each pole were detached and fixed. This resulted in a time requirement of 4.7 man hours/ha in enrc systems.

Table 1: Results of the time measurement for opening and closing the kit and kitaa system. Values for control (traditional hailnet) originate from Burmann & Kunde (2005). Results are given in man hours/ha.

	opening (spring)	*closing (winter)*
contr (hail net)	20-25	20-25
kit	20	45
kitaa	30	70

Discussion

In organically managed orchards, several elements such as mating disruption, application of granulovirus agents, application of entomopathogenic nematodes (e.g. *Steinernema feltiae*), and proper sanitary orchard management need to be considered in developing a sufficient control strategy for codling moth. As additional element, exclusion netting systems have proved good efficacy in minimizing the damage caused by codling moth in all years of our experiment (data not shown) and in previous studies (Alaphilippe et al. 2016, Kelderer et al. 2010, Romet et al. 2010). However, compared to other regulation options, the installation of enrc systems means a far-reaching intervention, influencing non-target species (beneficial and pest organisms), disease development, and agronomic parameters (Chouinard et al. 2019). Some of these side effects have been highlighted in this study. An increasing level of damage from aphids, particularly woolly aphids, are in line with experiences made with single row exclusion netting systems in France (Alaphilippe et al. 2016). Sufficiently controlling high infestation rates of woolly aphids in organic production is difficult to achieve. Thus, a close monitoring and if necessary trials to control this pest organism in enrc systems need to be conducted. In 2019 the application of fungicides was reduced to approximately 50% in kitaa plots. Although the disease pressure was very high in 2019, the reduced fungicide application in kitaa plots led to very good results. Hence, a further reduction of fungicides in kitaa seems possible to control apple scab. The time measurements show an increased amount of time spent with closing the systems in winter. Possible reasons for that are a lack of experience in handling the systems, an increased amount of net material which needs to be wrapped and gathered, and the increased weight of net material (particularly the Microtex® material). Thus, further experiences in handling both enrc systems need to be gained to develop time-saving mechanisms.

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