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Four-year experiences with exclusion netting row covers in an organic apple orchard: handling, relevant pests and diseases

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Abstract

This study provides data for of a four-year period (2018-2021), comparing two systems of exclusion netting row covers (1. Keep in Touch, 2. Keep in Touch – Antiacqua (with rain cover)) with not netted control trees. Both netting systems reduced scab infections on fruit and leaves. Simultaneously, approx. 50 % of fungicide applications could be reduced in the Antiacqua system. Handling times for both systems were comparable to widely applied hail net systems. However, woolly aphid and apple leaf miner infestation increased in both netting systems and especially in the Antiacqua system. Particularly in 2020, tremendous woolly aphid infestation in the Antiacqua system outweighed its positive effect.

Keywords: Exclusion netting, mono row cover, rain cover, keep in touch, keep in touch Antiacqua

Introduction

Exclusion netting row covers (henceforth enrc) against *Cydia pomonella* L. have been widely applied in France and Italy, and their 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). On basis of these 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 (woolly aphid (*Eriosoma lanigerum* Hausmann), and apple leaf miners (*Leucoptera malifoliella* Costa)), control of apple scab (*Venturia inaequalis* (Cooke) G. Winter), time measurements in handling of both systems, and yield data.

Material and Methods

Experimental Design

The experiment was conducted in an organically managed orchard of the Competence Centre for Fruit Production at Lake Constance (KOB) located in Ravensburg, Germany. The netting systems were installed in an orchard consisting of 'Jonagored' trees on rootstock M9 with a planting distance of 3.2 m × 0.8 m. The orchard was planted in 2009. 'Jonagored' trees were split up in 3 different treatments: 1. Control plot with a traditional hail net system and customary plant protection input, 2. Keep in touch system (henceforth kit) and 3. Keep in touch Antiacqua system (henceforth kitaa)). Both systems were installed in early summer of 2017. Thus, this study focuses on experimental results gained in the years 2018 till 2021. The experiment was arranged in blocks, with 4 replications per treatment, each replication consisting of 23 trees. Both netting systems remained without the application of Granulovirus agents during the assessed four-year period. Additionally, each year of the trial the application of fungicides was terminated in the kitaa treatment from the moment the application of Granulovirus agents started (mid of May) until fruit harvest. In the years 2019-2021 annually between 9 and 11 applications of Granulovirus agents were omitted in both

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netting systems and additionally 47% - 53% of fungicide applications were economised in the kitaa system (table 1).

Table 1: Reduction in number of Granulovirus applications in both enrc systems and reduction in number of fungicidal applications in kitaa treatment (Percentage compared to Control treatment).

year	Granulovirus savings (applications/year)	Reduction of fungicides in kitaa treatment
2019	11	47 %
2020	13	53 %
2021	9	53%

Netting systems

1. Keep in touch system (kit): Enrc with a mesh size of 2.2 × 2.3mm on the upper and lower parts, and 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 as kit, but with an additional 1.5m wide piece of a thick knitted double layer of Microtex® texture attached to it on the upper part. This texture 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.

In 2018-2020 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 from 2019 till 2021.

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. Therefor all leaves were classified regarding the number of mines per leaf: 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 were separately 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 long shoots of each replication (100 shoots per treatment) were examined to assess the scab infestation on leaves. Scab infections on fruits was documented by grading 600 fruits per treatment in the following categories: 0= no visible infestation; 1= 1-3 infested spots; 2= 3 and more infested spots.

Yield per single tree

In each replication, 5 representative trees (20 trees per treatment) were selected to determine the number of fruits per tree and fruit weight (kg/tree).

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

In course of the observed four-year period, the share of codling moth infested fruit ranged annually between 0 % and 1.3 %. Due to that low level of infestation an implication of the efficacy of the netting systems against codling moth cannot be drawn. Over the four-year period of this trial, the pest organism with most visible impact was the woolly aphid. The increase of woolly aphid population started already in the first year subsequent to the installation of the enrc systems and was limited to the kitaa treatment. In 2018, 25 % of kitaa trees have shown visible woolly aphid infestation (figure 1). However, on two-thirds of those infested trees (17 %) only few infested spots were visible. In the following year 79 % of kitaa trees showed infestation, while 16 % of kit trees and no control trees were infested. Limited to the kitaa treatment, not only the total degree of infestation but also the graveness of symptoms advanced, resulting in 25% of the trees being heavily infested. In 2020, woolly aphid infestation reached its peak with 100% infested trees in all treatments. Due to an exceptional mild winter (e.g. February 2020: + 4,6 °C compared to the long term average value) and a warm and dry growing period, regional levels of aphid infestation were generally high. In 2021, the overall infestation level declined in all three treatments, still reaching highest infestation in the netted treatments with the biggest share of heavily infested trees in the kitaa system.

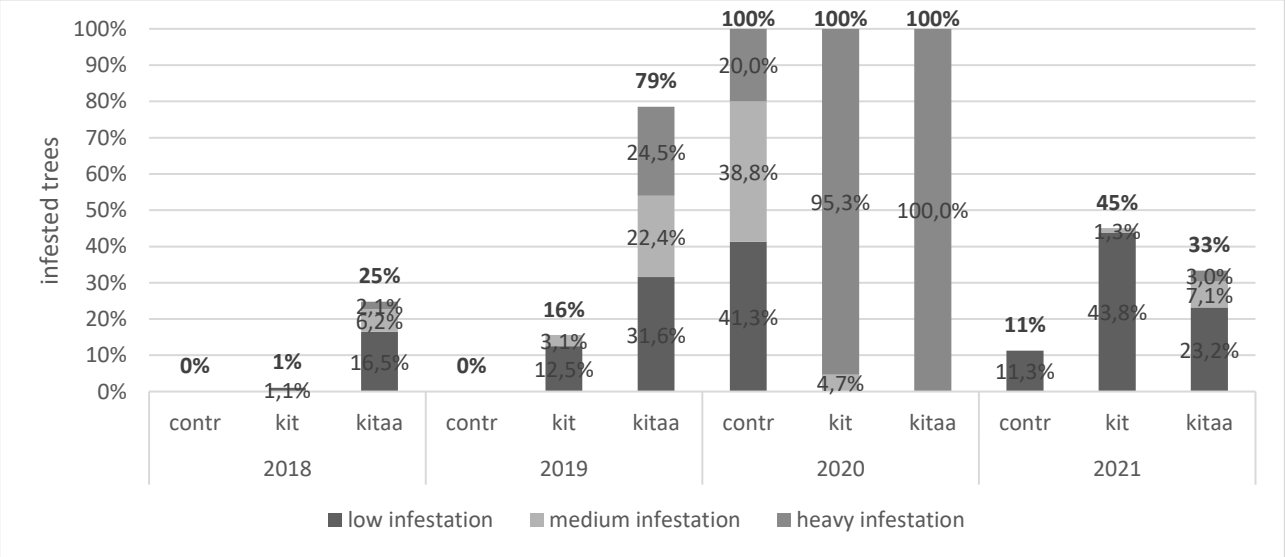

Figure 1: infested ‘Jonagored’ trees (%) by woolly aphid divided in degree of damage from 2018 till 2021.

Another collateral pest organism that stood out was the apple leaf miner. In each year of the examined four-year period, the order of infested leaves from highest to lowest was similar: kitaa>kit>contr (figure 2). Again, due to favouring environmental conditions, infestation reached highest levels in 2020.

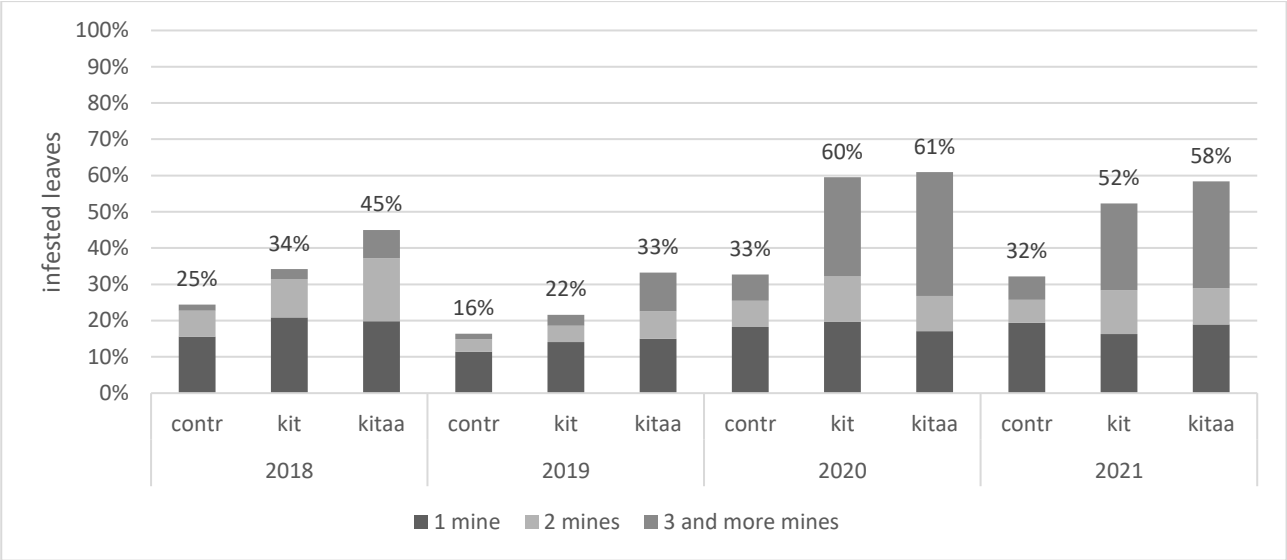

Figure 2: infested leaves by apple leaf miner 2018 - 2021 divided in degree of infestation.

The scab infestation of 'Jonagored' fruit and leaves is depicted in figure 3 a and b. In all years, scab infestation in both enrc systems was lower compared to the control treatment, whereas, except for 2021, the order of scab infestation (leaf and fruit) from highest to lowest was control>kit>kitaa in each year. In 2019 and 2021, scab infestation was particularly high on leaves, whereas 2019 and 2020 showed highest fruit infestation. In 2021, both enrc systems have shown similar leaf infestation (12%), and fruit infestation was lower in kit (2%) compared to kitaa (4%). In addition to that, yearly effects of scab infestation levels were visible. For the interpretation of these results, it must be considered, that fungicide plant protection input was reduced around 47%-53% in system kitaa due to the rain preventing effect of this system. In spite of a reduced fungicide input lowest infestation levels with apple scab were recorded in the kitaa- system in each year.

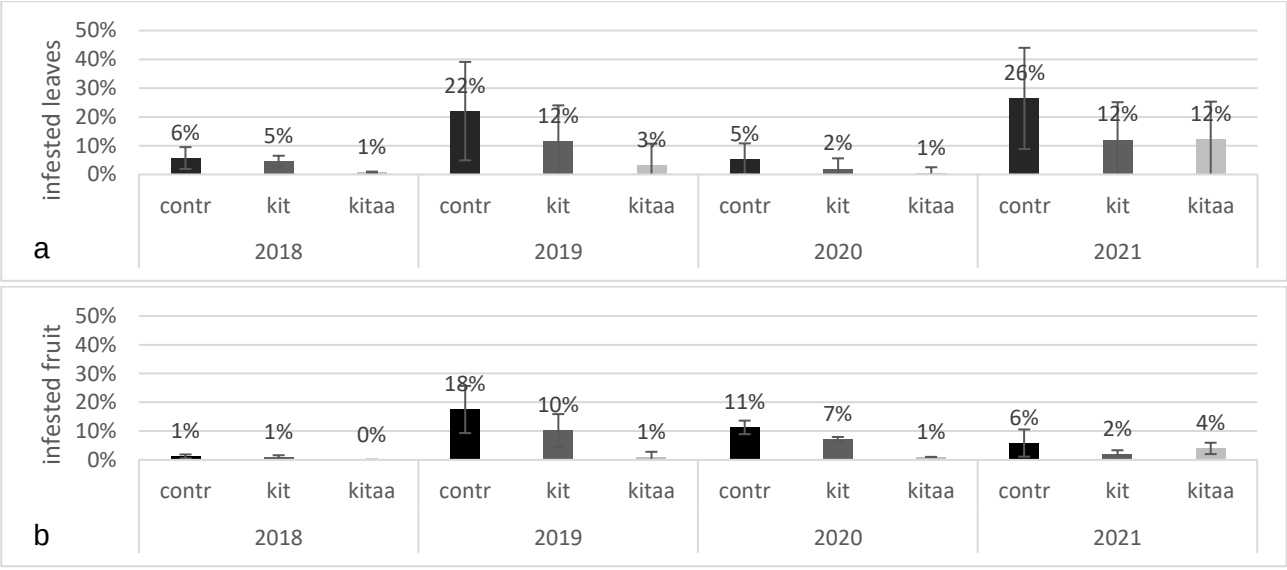

Figure 3: scab infestation at 'Jonagored' trees 2018-2021 (error bars: ± standard deviation). a: leaves b: fruit

Over the four-year period, there was no crucial difference in yield among treatments observable (figure 5). Cumulative yield of all treatments was in a range of approximately 2.9 kg/tree. In addition, the share of cider apples and first class apples was balanced among treatments.

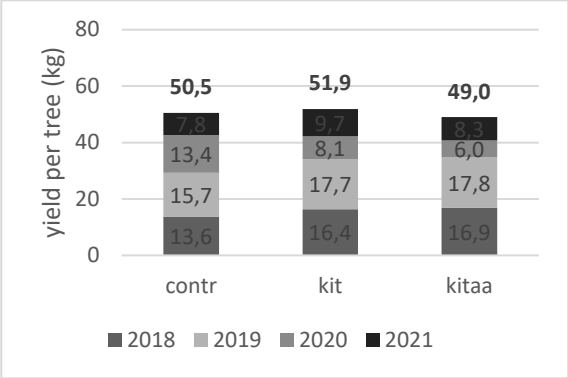

Figure 4: yield per tree in 2018-2021

Table 2: Results of the time measurement for opening and closing the systems in 2018 and 2020. Results are given in man hours/ha.

year	treatment	opening	closing	**total**
2018	kit	20	45	**65**
	kitaa	30	70	**101**
2020	kit	15	24	**39**
	kitaa	15	44	**59**
Burmann & Kunde (2005)	hail net	20-25	20-25	**40-50**

Table 2 displays measured opening and closing expenditure of time for kit and kitaa compared to data of common hail net constructions retrieved from Burmann & Kunde (2005). After installing the enrc systems in 2017, these were handled according to the manufacturer's instructions. That included closing and opening devices with carabiner in a distance of 3.5 m, which were the main reason for the fairly time-consuming opening and closing duration in 2018. After exchanging ideas with practitioners to enhance the handling, carabiner system was suspended in 2019. Instead, plugs at the poles were installed to close the nets, at a distance of approximately 10m. Additionally and in contrast to 2018, a two-sided moving platform was applied in 2020. Both changes contributed to time saving of 26 man hours/ha for kit (total of 39 man hours/ha) and 42 man hours/ha for kitaa (total of 59 man hours/ha). Except for closing the kitaa system, the time effort for opening and closing both systems is comparable to the widely applied hail net systems. However, maintenance operations within the season such as pruning or hand-thinning were done under the nets. In this case only the plugs at each pole were detached and fixed. This resulted in an additional time requirement of 4.7 man hours/ha.

Discussion

In organically managed orchards a sufficient control strategy for codling moth consists of several elements such as mating disruption, application of Granulovirus agents, application of entomopathogenic nematodes (e.g. *Steinernema feltiae*), and proper sanitary orchard management. Moreover, exclusion netting systems have proved good efficacy in minimizing codling moth infection 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). At our location, with traditionally little pressure of codling moth, both netting systems tolerated the renunciation of Granulovirus applications without an increased infestation compared to control trees. As expected, the kitaa treatment with its additional rain protection led to a decrease in scab infections on both leaves and fruit. This is in line with findings of Holtz et al. (2020) and Boutry et al. (2020). In this treatment a decrease in scab infections was possible even with a reduction of fungicide application to 50 % compared to customary plant protection. Moreover, also the kit system without rain coverage showed reduced numbers in scab infections compared to control, though provided with the same fungicide

applications. The reduced scab susceptibility of trees under kit was also perennially observed on a farm in Lake Constance area cultivating ‘Braeburn’ trees (Data not shown).

Constructional adaptations in 2019 led to handling times of both systems comparable to those of hail net systems, except for closing of the kitaa system which remains more time-consuming and laborious than the kit system. That is attributable to the combination of big amount of net material which needs to be wrapped and gathered and an increased weight of net material due to the Microtex® material. Lately, the manufacturer informed that there is a revised kitaa system up for sale that is less time-consuming in handling (personal contact).

The emerging abundance of woolly aphid especially in the kitaa treatment, is the main limiting factor in applying rain coverage systems such as kitaa under climatic conditions of the Lake Constance region. Other regions reported upcoming woolly apple aphid problems under rain protected cultivation as well (Kelderer et al. (2018), Alaphilippe et al. (2016)). In a year like 2020, infestation of woolly aphid became intolerable, causing contaminated, not marketable fruit and permanent tree damage. Up to this point there is no effective direct measure for organic producers for a regulation of woolly aphid infections. Thus, the possible negative impact of woolly aphid outweighs positive effects of reduced scab infections and simultaneously less fungicide application in the kitaa treatment at our location. Although the kit system showed a tendency for an increased susceptibility to woolly aphid and apple leaf miner as well, the severity of infestation was much higher in the kitaa treatment. Another adverse point that needs consideration in applying enrc systems is the big amount of netting material needed. To equip an orchard of 1 ha, appr. 10,500 m^2 net material for a hail net system, 17,400 m^2 for kit (+ 167 %), and 23,200 m^2 for kitaa (+ 222 %) is needed.

Acknowledgements

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