Influence of Different Netting Structures on Codling Moth and Apple Fruit Damages in Northwest Croatia

Ivana PAJAČ ŽIVKOVIĆ [1(✉)]
Tomislav JEMRIĆ [2]
Mladen FRUK [2]
Josip BUHIN [2]
Božena BARIĆ [1]

Summary

During the vegetation season of 2015 exclusion nets were set up in IPM apple orchard in Krapina (Croatia) to test their effectiveness in preventing the attack of codling moth to apple fruits. Nets were the same in mesh size (2.4 x 4.8 mm) but different in color (white, red, yellow) in order to examine their effect on vegetative growth and quality of apples. To assess the presence of pest, weekly sampling of codling moth on pheromone traps in protected and unprotected (control) net rows was conducted. Single row netting structures resulted in a highly significant reduction of codling moth catches on pheromone traps in comparison to the unprotected control in the experimental orchard. The percentage of codling moth infested fruits during the harvest time was considerably lower, in the protected net rows in comparison with unprotected rows. The lowest percentage of damaged fruits was recorded under the red net (0.96%), followed by white net (1.04%) and yellow net (2.86%). Percentage of damaged fruits in unprotected row amounted to 11.39%. Considering the fact that the mean net efficiency amounted to almost 90%, these results confirm the effectiveness of netting structures in the protection of apple fruits from CM damages.

Key words

Cydia pomonella, pheromones, anti-hail nets, physical control

[1] University of Zagreb, Faculty of Agriculture, Department for Agricultural Zoology, Svetošimunska cesta 25, HR-10000 Zagreb, Croatia
✉ e-mail: ipajac@agr.hr
[2] University of Zagreb, Faculty of Agriculture, Department of Pomology, Svetošimunska cesta 25, HR-10000 Zagreb, Croatia

Received: June 15, 2016 | Accepted: November 2, 2016

ACKNOWLEDGEMENTS
The work presented in this paper was financed from the LIFE13 ENV/HR/000580 project.

Introduction

The codling moth (CM), *Cydia pomonella* L., is the major pest infecting the apple, both in Croatia and abroad. Besides apples, pest attacks pears, walnuts, quince and some stone fruits causing economic losses in fruit production (Ciglar, 1998). In Croatia this pest has two generations per year but due to climatic changes and frequent chemical control treatments in some areas, with intensive apple production, a third generation can be observed (Pajač et al., 2012). The pest was originally present in Eurasia, but during the last two centuries it dispersed around the world with the spread of the cultivation of apples and pears (Franck et al., 2007). It has achieved a nearly global distribution, being one of the most successful insect pests known today (Thaler et al., 2008). Over 70% of the insecticide treatments in apple orchards are currently applied to control CM populations. As a consequence of these treatments, CM developed resistances to various groups of synthetic insecticides in the USA and Europe (Franck et al., 2007). In order to reduce CM resistance development, alternatives to insecticides are required. The standard in IPM apple production is based on application of environmentally and toxicologically acceptable treatments with an emphasis on application of ecologically friendly, alternative and non-chemical control methods such as using EPNs and pheromones (attract-and-kill method and mating disruption) (Ciglar et al. 2000; Maceljski, 2002). In recent studies, special attention is given to testing insect exclusion netting systems (e. g. anti-hail nets) in apple production. The anti-hail nets are widely used to protect apple fruit against hailstorms and hail damage (Baiamonte et al., 2016). It has been shown that the use of anti-hail nets has beneficial effects against Lepidoptera species such as CM. The anti-hail nets form a physical barrier to the entry of adult moths and have a disruptive effect on the reproductive behavior of the CM, thus preventing the fruit damages in apple orchards (Tasin et al., 2008; Sauphanor et al., 2012).

This research was conducted as part of a research project aimed to increase the fruit quality due to the effects of differently colored photo selective anti-hail nets. Objective of this study was to test effectiveness of insect exclusion netting systems in preventing the attack of CM to apple fruits (cv. Braeburn).

Material and methods

The effect of the anti-hail photo selective nets (TENAX IRIDIUM) on CM was tested during the vegetation season of 2015 in IPM apple orchard (N 46° 9′ 47″, E 15° 52′ 52″) in northwest part of Croatia (Krapina). In 12-year old apple orchard, six apple cultivars (Braeburn, Idared, Golden Delicious, Granny Smith and Jonagold) are grown in planting system of 1 x 3 m, in the plantation of 3600 m^2. The apples are treated in the accordance with integrated pest management but during the investigation period in the year of 2015, only one (knock down) insecticide treatment by using thiacloprid was applied before setting up nets. Trial was conducted on the apple cultivar Braeburn on three neighboring apple tree rows situated in the center of plantation. In each row three neighboring apple trees were selected and completely covered with anti-hail photo selective nets. Nets were the same in mesh size (2.4 x 4.8 mm) but in different colors (white, red and yellow) in order to examine their effect on vegetative growth and quality of apples. Three repetitions of each color of nets and uncovered control were set up and each repetition contained one CM delta sticky pheromone trap (Csalomon®). The traps were placed in orchard during the second half of April, before the first flight of CM was theoretically possible. The catch of moths was counted on a weekly basis. Monitoring of adult CM was conducted by the end of September. During the harvest time all apple fruits from each repetition were picked up and evaluation of the damages was done according to typical signs of CM larvae damage.

Data on the total catches of CM were compared between uncovered control and different colored net types by analysis of variance (MATLAB, 2015) and the mean separation was estimated using Tukey's honestly significant test. Efficacy of net types was calculated according to Abbot.

Results and discussion

The first catch of CM was recorded on 16th May on uncovered control and that has actually been the first consistent catch (5 moths) which in our growing conditions requires insecticide treatment. The first catch of CM under different colored nets was recorded under white net one month later (15th June) (Figure 1). From the flight dynamic of CM three peaks of its population could be observed. On unprotected control the CM population exceeded economic threshold of 5 moths almost during the whole flight period and under different colored net types this threshold was exceeded only once on 25th July (white net) (Figure 1). During the flight period of CM a total of 131 specimens were caught on uncovered control and altogether 19, under different colored nets (11 on white, 6 on red and 2 on yellow).

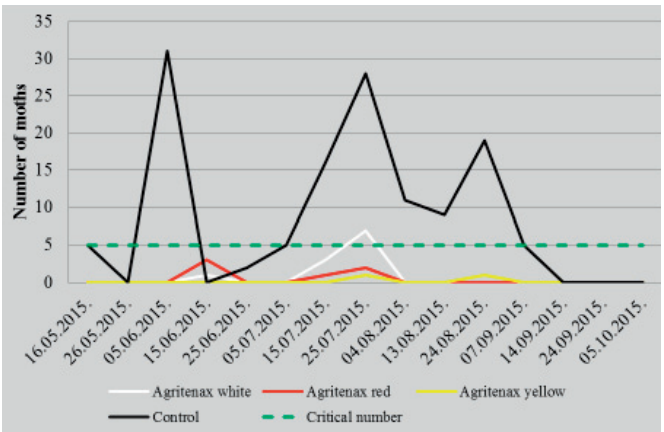

Figure 1. The flight dynamics of CM from apple orchard (Krapina) under different colored nets and uncovered control in regard to CM economic threshold

An analysis of variance (ANOVA) showed significant variation in total catches of CM between control and different colored net types. A post hoc Tukey test showed that the control alone and different colored net types differed significantly at $p < 0.001$; the total catches of CM between different colored nets were not significantly different (Table 1).

Table 1. Tukey's honestly significant difference (HSD) in CM captures between uncovered control and different colored net types

	Agritenax white	Agritenax red	Agritenax yellow
Agritenax white			
Agritenax red	0.9995 n.s.		
Agritenax yellow	0.9954 n.s.	0.9998 n.s.	
Control	0.000043318***	0.000020315***	0.000011013***

*** $P < 0.001$; ** $P < 0.01$; * $0.01 < P < 0.05$; n.s. $P > 0.05$.

Sauphanor et al. (2012) reported that the netting reduced fruit injury by up to 91% compared to the unprotected rows in the experimental orchard. In our investigation the mean net efficiency amounted to almost 90% (Table 2) therefore, this method proved to be very effective in protecting apple from CM damages. However, covering the trees with anti-hail nets can modify the orchard microclimate and reduce the interception of light, thus potentially causing negative consequences on the organoleptic quality of apple fruits (cv. Braeburn) what was observed by Baiamonte et al. (2016). Since the netting system form a physical barrier to the entry of insect pests, it potentially serves as a barrier to beneficial insects (e. g. ladybugs, true bugs, syrphid flies), so this effect on them should be closely investigated.

Table 2. The number of CM infested fruits under different colored nets and uncovered control during the harvest time on the apple cultivar Braeburn with estimation of netting system efficiency

Types of nets/Control	Repetition	Number of examined fruits	Number of attacked fruits	Sum of attacked fruits	Average efficacy of nets
Agritenax white	1	142	1	4	88.92%
	2	128	1		
	3	116	2		
Agritenax red	1	120	1	3	91.67%
	2	92	1		
	3	100	1		
Agritenax yellow	1	96	0	6	83.33%
	2	96	6		
	3	114	0		
Control	1	108	13	36	
	2	97	11		
	3	111	12		

Results of our study are consistent with similar studies in which nets significantly reduced the number of CM catches (Tasin et al., 2008; Sauphanor et al., 2012). The results of Tasin et al. (2008) showed a disrupting effect of the nets on males during mate location, with a decreased number of males able to locate a calling female or a synthetic source of sex pheromone. As a consequence, a consistently lower fruit injury was observed in net-covered vs. uncovered plots (Tasin et al., 2008; Sauphanor et al., 2012). The lower fruit damages have also been confirmed by our study. Altogether 36 damaged apples were observed on unprotected control, while the number of damaged fruits under different net types was about the same (in average 4 apples) (Table 2). The percentage of infested fruits was considerably lower, in the protected net rows in comparison with unprotected control. The lowest percentage of damaged fruits was recorded under the red net (0.96%), followed by white net (1.04%) and yellow net (2.86%). Percentage of damaged fruits in unprotected control amounted to 11.39%. According to these results, we can conclude that the red net was the most effective one with an average efficiency of 91.67% (Table 2).

Considering the fact that the highest number of CM was observed under white net, we expected that the highest percentage of damaged fruits would be under this net. Thus, we assumed that this difference between CM catches and fruit damages comes from the fact that pheromones attract only males and we don't have data about existing female population under nets.

Conclusion

The use of different colored netting structures resulted in a highly significant reduction of CM catches on pheromone traps in comparison to the unprotected control in the experimental orchard. The percentage of CM infested fruits during the harvest time on the protected control was considerably lower compared to unprotected control. Considering the fact that all netting structures were not full exclusion nettings (e.g. in some cases it was impossible to hermetically seal the nets) their use has successfully protected the fruits of apples from CM attack (compared to the control).

References

Baiamonte I., Raffo A., Nardo N., Moneta E., Peparaio M., D'Aloise A., Kelderer M., Caserac C., Paolettia F. (2016). Effect of the use of anti-hail nets on codling moth (*Cydia pomonella*) and organoleptic quality of apple (cv. Braeburn) grown in Alto Adige Region (northern Italy). Journal of the Science of Food and Agriculture 96 (6): 2025–2032

Ciglar I. (1998). Integrirana zaštita voćaka i vinove loze. Zrinski, Čakovec

Ciglar I., Barić B., Tomšić T., Šubić M. (2000). Suzbijanje jabukovog savijača (*Cydia pomonella*) metodom konfuzije. Agronomski glasnik 1-2: 85-93

Franck P., Reyes M., Olivares J., Sauphanor B. (2007). Genetic architecture in codling moth populations: comparison between microsatellite and insecticide resistance markers. Molecular Ecology 16: 3554–3564

Maceljski M. (2002). Poljoprivredna entomologija. II. Izdanje, Zrinski, Čakovec

MATLAB Release (2015). The MathWorks, Inc., Natick, Massachusetts, United States. Trial version.

Pajač I., Barić B., Mikac K. M., Pejić I. (2012). New insights into the biology and ecology of *Cydia pomonella* from apple orchards in Croatia. Bulletin of Insectology 65 (2): 185-193

Sauphanor B., Severac G., Maugin S., Toubon J. F., Capowiez Y. (2012). Exclusion netting may alter reproduction of the codling moth (*Cydia pomonella*) and prevent associated fruit damage to apple orchards. Entomologia Experimentalis et Applicata 145: 134–142

Tasin M., Demaria D., Ryne C., Cesano A., Galliano A., Anfora G., Ioriatti C., Alma A. (2008). Effect of anti-hail nets on *Cydia pomonella* behavior in apple orchards. Entomologia Experimentalis et Applicata 129 (1): 32–36

Thaler R., Brandstätter A., Meraner A., Chabicovski M., Parson W., Zelger R., Dalla Via J., Dallinger R. (2008). Molecular phylogeny and population structure of the codling moth (*Cydia pomonella*) in Central Europe: II. AFLP analysis reflects human-aided local adaptation of a global pest species. Molecular Phylogenetics and Evolution 48: 838–849

acs81_17