Effective control of *Melolontha* spp. in organic strawberry plantations by means of holistic approach

T. Małgorzata[1], E. Malusa[1,2], B. H. Łabanowska[1], T. Cezary[3], C. Loredana[4] and P. Flavia[4,5]

Abstract
The difficulties in controlling *Melolontha* spp. in organic strawberry plantations was tackled by developing a holistic strategy which included various control methods and agronomical practices. Reduction of adult populations was attempted by means of luring, trapping and by covering the row with fabric-like mulching during the period of the beetles' flight, to decrease the number of eggs deposited in the soil. Pre-planting soil tillage and sowing of crops with phytosanitary properties, in particular buckwheat (*Fagopyrum esculentum*), were found effective in reducing the population of grubs. Biocontrol treatments based on entomopathogenic fungi (*Beauveria bassiana*, *Beauveria brongniartii*, *Metarhizium anisopliae*) and entomopathogenic nematodes (*Heterorhabditis bacteriophora* and *Steinernema kraussei*) were evaluated. Data from several trials carried out in various locations and plantations in the last four years are presented. The results indicated an effective action of the different practices in reducing the number of active grubs when used independently. However, an overall satisfactory control was obtained only when the different practices were applied in combinations and, particularly for the BCAs, with an appropriate method and timing.

Keywords: Biocontrol, European cockchafer, mechanical and agronomic practices

Introduction

Poland is one of the leading producers of strawberries in the world (FAOSTAT, 2014). An increasing threat to organic crops has been registered in Poland from the white grub of European cockchafer (*Melolontha melolontha* L.) and forest cockchafer (*Melolontha hippocastani* Fabricius). Even though the control against the beetles in other areas, particularly in woods, helped to limit their number in the environment (Wagenhoff et al. 2014), they have been causing great damage to the strawberry plantations, particularly those managed by organic farming methods. Losses of plants and, indirectly, of yield have been recorded in several areas due to the feeding grubs, with strawberry and highbush blueberry plantations being among the most vulnerable. The difficulties in controlling these soil-borne pests, due to their biological cycle, was tackled by developing a holistic strategy which included the use of various control methods and agronomical practices.

Materials and Methods

Trials were established in fields of organic strawberry production in 2014-2017 in two locations, Nowa Wola and Brzostówka (Voievodship Lubelskie). Different methods of control of *Melolontha* spp. were tested:

i. a mechanical method based on soil tilling with different machines before the establishment of the plantation and collection of larvae during hand weeding;
ii. a control method based on the use of row mulching with fabric-like material;

[1] Research Institute of Horticulture, Skierniewice, Poland, email:malgorzata.tartanus@inhort.pl
[2] CREA- Research Centre for Engineering and Agro-Food Processing, Turin, Italy
[3] Siedlce University of Natural Sciences and Humanities, Siedlce, Poland
[4] CREA- Research Centre for Agriculture and Environment, Rome, Italy
[5] Natural History Museum, London, UK

iii. disposition of light traps for adult luring;
iv. sowing of pre-planting crops with phytosanitary properties;
v. biocontrol treatments using entomopathogen fungi and nematodes.

Details about the methods are provided in Results.

Results and Discussion

The strategy dealt with reduction of adult populations by means of luring and trapping, which would also effectively contribute to decrease the number of eggs deposited in the soil. Two kinds of light traps were utilized: a light-headed trap with a battery-powered Led lamp with 10 W, and a trap with 400 W halogen lamp beyond a white screen of a size 1.8x2.6 m. The latter kind resulted in higher efficacy for trapping adults, particularly males, in comparison to those formed only by the light bulb. A possible interpretation of such result derives from the evening behaviour of males, in search of females (Wagenhoff et al. 2014). The smaller traps could be less effective due to an insufficient light power for attracting the adults.

Furthermore, covering the plantation with fabric-like mulching on the row during the period of mass flights of adults was introduced to also physically reduce the possibility of laying eggs by females. In the mulched fields nearly 2-3-fold less larvae were detected, particularly those of stage L_1, in comparison to not-mulched rows. Mulching has been found to reduce above ground insect infestation (Csizinszky et al. 1995). Other physical barriers have been considered to reduce the damage from soil-borne insects (Bomford and Vernon 2005). However, we have not found any report considering using fabric mulching as a physical barrier to reduce eggs laying by insects as we tested.

Pre-planting practices such as soil tillage using sharp-edged machinery, such as a tiller and saucers, was carried out and the grubs emerging on the ground during the ploughing were collected by hand. The effect of this practice on the mortality of grubs differed considering the larval development stage. About 30 to 55% of collected larvae died after a week of breeding in laboratory, with higher mortality observed in L_1-L_3 larvae as compared to L_4. The obtained results provide further evidence that a substantial number of grubs may be mechanically damaged during tillage operations with sharp machinery and die directly during soil tillage or in subsequent days (Malinowski et al. 2001; Strasser and Schinner 1996).

Sowing of crops with phytosanitary properties before planting were examined for the impact on the population of grubs. Among about ten different species, buckwheat (*Fagopyrum esculentum*) resulted the most efficient in reducing the number of grubs in comparison to other pre-crops (up to 100% less).

Finally, a typical biocontrol treatment, based on entomopathogenic fungi (*Beauveria bassiana*, *Beauveria brongniartii*, *Metarhizium anisopliae*) and entomopathogenic nematodes (*Heterorhabditis bacteriophora* and *Steinernema kraussei*) was evaluated with application at planting and during the season. Depending on the location and environmental conditions during the season (mainly rainfall) as well as the formulation used, the different species were able to reduce the damage from grubs' activity from 60 to 90%. The persistence of the applied entomopathogenic fungi in soil was assessed by developing a new molecular biology method that helped tuning the application method, the doses and overall performance of these fungi (Canfora et al. 2016). These were also evaluated in relation to their metabolic behavior at the presence of 96 substrates in order to understand the capacity of *B. bassiana* and *B. brongniartii* when applied alone or co-inoculated in growing in the soil and be active against the pest (Canfora et al. 2017).

Trials were also carried out testing the repellent effect against the grubs of extracts from known allelopathic plants (*Tagetes* spp., *Tanacetum vulgare*, *Mentha* sp., *Matricaria chamomilla, Allium sativum, Fagopyrum esculentum* and *Urtica dioica*), trying also to develop a method for extract delivery in soil. Among them, interesting effect was detected

for alcoholic extracts of *F. esculentum and Tagetes spp.* which would confirm the capacity of scent detection by grubs in soil (Weissteiner et al. 2012).

Conclusions

The results indicated an effective action of the different practices and methods in reducing the number of active grubs when used independently. However, an overall satisfactory control was obtained only when the different practices were applied in combinations and, particularly for the BCAs, with an appropriate method and timing.

Acknowledgements

The research was carried out within the framework of the project “Identification of innovative solutions and good practices for the protection of pests and diseases, with particular emphasis on berry crops, including strawberries, raspberries and chokeberry”, funded by the Polish Ministry of Agriculture and Rural Development in 2014–2017.

References

Bomford M.K., Vernon R.S. 2005. Root weevil (Coleoptera: Curculionidae) and ground beetle (Coleoptera: Carabidae) immigration into strawberry plots protected by fence or portable trench barriers. *Environ Entomol* 34 (4): 844-849. doi: 10.1603/0046-225X-34.4.844

Canfora L., Abu-Samra N., Tartanus M., Łabanowska B. H., Benedetti A., Pinzari F. & E. Malusà (2017) Co-inoculum of *Beauveria brongniartii* and *B. bassiana* shows in vitro different metabolic behaviour in comparison to single inoculums. Scientific Reports 7: 13102 DOI:10.1038/s41598-017-12700-0

Canfora L., Malusà E., Tkaczuk C., Tartanus M., Łabanowska B.H. and Pinzari F. 2016. Development of a method for detection and quantification of *B. brongniartii* and *B. bassiana* in soil. Scientific Reports 6: 22933, doi: 10.1038/srep22933.

Csizinszky A.A., Schuster D.J., Kring J.B. 1995. Color mulches influence yield and insect pest populations in tomatoes. *J Am Soc Hort Sci* 120(5): 778-784

FAOSTAT 2014. Accessed at http://www.fao.org/faostat/en/#home on Dec 10 2017

Malinowski H., Augustyniuk A., Łabanowska B.H. 2001. Nowe możliwości ograniczania populacji owadów żerujących na korzeniach roślin. *Progress in Plant Protection* 41 (1): 175–181.

Strasser H., Schinner F. 1996. Current status of *Melolontha melolontha* control by the fungus *Beauveria brongniartii* in Austria. IOBC/WPRS Bulletin 19 (2): 69–73.

Wagenhoff E., Blum R., Delb H. (2014). Spring phenology of cockchafers, *Melolontha* spp. (Coleoptera: Scarabaeidae), in forests of south-western Germany: results of a 3-year survey on adult emergence, swarming flights, and oogenesis from 2009 to 2011. Journal Forest Science, 60 (4): 154–165

Weissteiner S, Huetteroth W, Kollmann M, Weißbecker B, Romani R, Schachtner J, Schutz S. (2012) Cockchafer larvae smell host root scents in soil. *PLoS ONE* 7(10): e45827. doi:10.1371/journal.pone.0045827