Available online at www.sciencedirect.com

ScienceDirect

Agriculture and Agricultural Science Procedia 6 (2015) 30 – 37

Agriculture and Agricultural Science Procedia

“ST26733”, International Conference "Agriculture for Life, Life for Agriculture"

Do Wildflower Strips Favor Insect Pest Populations at Field Margins?

Séverin HATT[a]*, Roel UYTTENBROECK[b], Thomas Mendes LOPES[c], Aman PAUL[d], Sabine DANTHINE[e], Bernard BODSON[f], Julien PIQUERAY[g], Arnaud MONTY[h], Frédéric FRANCIS[i]

[a]*AgricultureIsLife.be & Functional and Evolutionary Entomology Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[b]*AgricultureIsLife.be & Biodiversity and Landscape Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[c]*Functional and Evolutionary Entomology Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[d]*AgricultureIsLife.be & Food Science and Formulations Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[e]*Food Science and Formulations Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[f]*Crop Science Unit and Experimental Farm, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[g]*Natagriwal asbl, Passage des Déportés 2, 5030 Gembloux, Belgium*

[h]*Biodiversity and Landscape Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

[i]*Functional and Evolutionary Entomology Unit, University of Liege, Gembloux Agro-Bio Tech, Passage des Déportés 2, 5030 Gembloux, Belgium*

Abstract

Reducing pesticide use is one the major issues of today’s agriculture. Among other possibilities, attracting and conserving pest natural enemies in agricultural landscapes by providing them habitats is promising. Wildflower strips (WFS) sown at field margins are one of these potential habitats. They are known to attract and conserve a large diversity of insects, as they provide them food resources such as pollen and nectar, as well as shelter and overwintering sites. However, the risk of attracting insect pests at field margins may represent an obstacle to their adoption by farmers. Conversely, it would be interesting if such WFS could play the role of pest trap crops. In an experimental field sown with WFS intercropped with oilseed rape (OSR) (*Brassica napus* L.), its coleopteran pests were trapped in both WFS and OSR using yellow pan traps between April and June 2014. More than 130 000 *Meligethes* spp., *Ceutorhynchus* spp. and *Psylliodes chrysocephalla* (L.) adults were trapped. *Meligethes* spp.,

* Corresponding author. Tel.: +32 (0) 81 62 21 75; Fax: +32 (0) 81 62 21 75.
E-mail address: severin.hatt@ulg.ac.be

Peer-review under responsibility of the University of Agronomic Sciences and Veterinary Medicine Bucharest
doi:10.1016/j.aaspro.2015.08.034

Ceutorhynchus spp. were significantly more abundant in the OSR compared with WFS when adults emerged and populations reached their abundance peak. Before and between these periods, the few adults trapped were significantly more abundant in the WFS compared with the OSR. Concerning *P. chrysocephala*, too few individuals were caught for analysis. Results showed that OSR was more attractive than WFS when coleopteran pests were abundant. In this study, WFS sown for insect conservation may neither favour insect pest conservation at field margin, nor be considered as trap crops.

Peer-review under responsibility of the University of Agronomic Sciences and Veterinary Medicine Bucharest

Keywords: wildflower strips, oilseed rape, *Meligethes* spp., *Ceutorhynchus* spp., insect conservation.

1. Introduction

Oilseed rape (OSR) (*Brassica napus* L.) is an important crop in Europe. In 2013, surfaces sown with OSR represented 57 % of those dedicated to oleaginous (European Commission, 2013). In Wallonia (Belgium) especially, OSR is almost the only oleaginous cultivated crop (Service public de Wallonie, 2014) covering 13 000 ha in 2012 (European Commission, 2013). However, OSR is known to be attacked by several insect pests. Among these, 5 species belong to the *Coleoptera* order (Williams, 2010): (1) the blossom beetle (*Meligethes aeneus* Fabricius, *Coleoptera*: *Nitidulidae*), (2) the cabbage stem flea beetle (*Psylliodes chrysocephala* L., *Coleoptera*: *Chrysomelidae*), (3) the cabbage stem weevil (*Ceutorhynchus pallidactylus* Marsham, *Coleoptera*: *Curculionidae*), (4) the cabbage seed weevil (*Ceutorhynchus assimilis* Paykull, *Coleoptera*: *Curculionidae*) and (5) the rape stem weevil (*Ceutorhynchus napi* Gyllenhal, *Coleoptera*: *Curculionidae*). The biology of these pests have been described for a long time (Free & Williams, 1978) and recently reviewed in detailed by Williams (2010).

Since the 1960's, OSR coleopteran pests are mainly controlled with chemical insecticides (Thieme et al., 2010). Nowadays, those from the pyrethroid family are the most common in Western Europe (CETIOM, 2014). However, pest resistances to these insecticides appeared (Thieme et al., 2010) as well as societal concerns about health (Baldi et al., 2013) and environmental hazards (Gibbons et al., 2014). Therefore, the need to develop integrated pest management (IPM) strategies for OSR arose (Rusch et al., 2010).

Among other practices, conservation biological control (CBC) is promising (Jonsson et al., 2008). CBC is defined as "manipulating the environment (e.g. habitats) of natural enemies to favor their survival and/or increase their performance resulting in a better efficiency [in terms of predation and parasitism]" (Barbosa, 1998). Such habitats may be woodland, hedgerow, wildflowers strip (WFS). When they exist, they are found at field margins and constitute landscape elements in agricultural areas. Many studies focused on the effect of landscape complexity on insect pests (Valantin-Morison et al., 2007) and natural enemies (Marino et al., 1996; Kruess, 2003). More precisely, WFS are known to conserve a high diversity of insects (Haaland et al., 2011) such as useful natural enemies for pest control (Alhmedi et al., 2009; Balzan & Moonen, 2014).

WFS are diverse across Europe. They may be mono- or plurispecific, annual or perennial, and variously managed (Haaland et al., 2011). However, it has been recently shown that mixes with high flower functional trait diversity tend to conserve a larger diversity of insects (Balzan et al., 2014). This supports the idea that promoting functional trait diversity within the flower mixes, more than their species diversity itself, may limit functional redundancy, increase functional complementary (Díaz & Cabido, 2001) and finally improve their efficiency in terms of insect conservation (Altieri, 1999; Landis et al., 2000; Moonen & Bàrberi, 2008).

Even if interests for WFS has arose these last years (their sowing at field margins is supported by the European agri-environmental schemes in many countries and regions such as Wallonia – Service public de Wallonie, 2012), some farmers may still be reluctant to adopt them, since it has been reported that they could be a source of pests such as slugs in OSR (Frank, 1998). However, such an effect on insect pests remains unstudied to our knowledge. Conversely, interest in trap crops as a sink of insect pests is high. According to Cook et al. (2007), "trap crops can be plants of a preferred growth stage, cultivar, or species that divert pest pressure from the main crop because they are more attractive". Taking part of IPM, and more specifically "push-pull" strategies (Shelton & Badenes-perez, 2006), they are seen as a promising practice to reduce chemical treatments on OSR (Cárcamo et al., 2007). In this way, could WFS sown for insect conservation play also the role of insect trap crops?

2. Materials and Methods

2.1. Experimental design

This field study was conducted in the experimental farm of Gembloux Agro-Bio Tech (University of Liège) in Gembloux, Belgium (50°34'03.25''N; 4°42'27.45''E) (Figure 1). Three similar perennial WFS (8 x 125 m) were intercropped with three winter OSR fields (27 x 125 m) (Figure 2). OSR was sown on September 10th 2013. WFS were composed of 17 common wildflower species in Wallonia (Table 1) and 3 grass species: *Festuca rubra* (L.) (sown at a density of 1.5 kg/ha), *Agrostis capillaris* (L.) (5 kg/ha) and *Poa pratensis* (L.) (5 kg/ha). Grass was sown with a Wintersteiger seeder and flowers with a Nodet seeder, both on June 6th 2013.

Fig. 1. Wildflower strip sown in the experimental farm of Gembloux Agro-Bio Tech (University of Liège). (Picture: Séverin Hatt)

Table 1. Flower species sown in the wildflower strips.

Family	Species	Density (kg/ha)
Apiaceae	*Anthriscus sylvestris* (L.) Hoffm.	0.3
Apiaceae	*Heracleum sphondylium* (L.)	0.1
Asteraceae	*Achillea millefolium* (L.)	0.4
Asteraceae	*Crepis biennis* (L.)	0.1
Asteraceae	*Hypochaeris radicata* (L.)	0.1
Asteraceae	*Leontodon hispidus* (L.)	0.2
Asteraceae	*Leucanthemum vulgare* Lam.	0.2
Dipsacaceae	*Knautia arvensis* (L.) Coulter	0.2
Fabaceae	*Lotus corniculatus* (L.)	0.1
Fabaceae	*Medicago lupulina* (L.)	0.1
Fabaceae	*Trifolium pratense* (L.)	0.1
Geraniaceae	*Geranium pyrenaicum* Burm. fil.	0.1
Lamiaceae	*Origanum vulgare* (L.)	0.1
Lamiaceae	*Prunella vulgaris* (L.)	0.2
Lythraceae	*Lythrum salicaria* (L.)	0.2
Malvaceae	*Malva moschata* (L.)	0.1
Rubiaceae	*Galium verum* (L.)	0.2

2.2. Insect trapping and identification

Insects were trapped with yellow pan traps in the WFS and the OSR. Five traps were placed along each strip, separated by 25 m. Thirteen m separated the traps in the WFS from those in the OSR (Figure 2).

Traps were filled with water and a few drops of detergent to reduce the water surface tension. They were emptied and refilled once a week between April 9th and June 25th 2014 (total of 11 weeks). Insects were conserved in Ethanol 70 %. Only the major coleopteran OSR pests were considered. *Meligethes* spp. and *Ceuthorhynchus* spp. were identified until the genus level, respectively following Kirk-Spriggs (1996) and Morris (2008), while *Psylliodes chrysocephala* were determined following Doguet (1994).

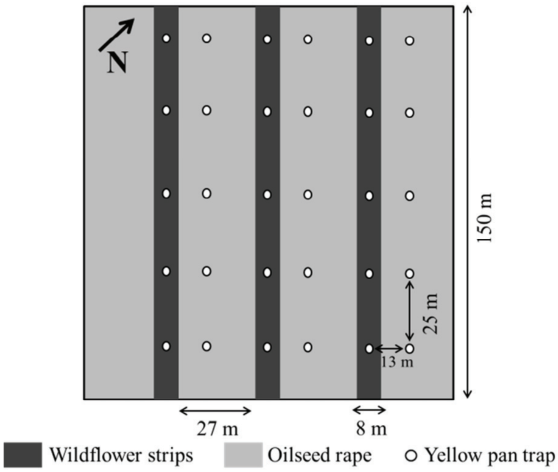


Fig. 2. Experimental field design.

2.3. Statistical analysis

As traps were emptied and refilled each week, the effect of the type of vegetation (WFS or OSR) on the abundance of *Meligethes* spp., *Ceutorhynchus* spp. and *P. chrysocephala* was tested using an Analysis of Variance (ANOVA) for each week. Preliminarily, a log10 (x+1) transformation was applied to the data to guarantee the normality of the residues and the homogeneity of the variance. These hypotheses were verified respectively by using the Shapiro-Wilk test and the Bartlett test. However, when they could not be accepted, a test of Kruskal-Wallis was realized instead.

3. Results and Discussions

3.1. The pollen beetles (Meligethes spp.)

More than 104 000 *Meligethes* spp. adults were trapped. They were mainly abundant in mid-April (around 20 individuals per trap on average on April 23rd) and June (more than 500 individuals per trap on average the whole month) (Figure 3).

These observations are consistent with their biology. According to Williams (2010), a first generation of adults emerges on early spring and flies on cruciferous for mating and oviposition. At this season, the winter OSR is at the green bud stage or already flowering. A second generation usually emerges in late spring/early summer, as we observed in June. During these two abundance peaks, significantly more *Meligethes* spp. were found in OSR compared with WFS (April 16th: $F=10.23$, $P=0.003$; April 23rd: $F=11.33$, $P=0.002$, June 04th: $F=15.89$, $P=4.36e-04$; June 11th: $F=21.81$, $P=6.83e-05$). These results suggest that over-wintered *Meligethes* spp., as well as those from the summer generation, are more attracted by the OSR than by the wildflowers. Concerning the over-wintered generation, these results are consistent with Free & Williams (1978), who showed that pollen beetles are more abundant in crops, when these start flowering, than in field margins. Indeed, at flowering, visual (the yellow colour – Döring et al., 2012) and chemical (isothiocyanate volatiles – Blight & Smart, 1999) cues of OSR have been shown to play an important role in the attraction of *Meligethes* spp.

At the end of OSR flowering, larvae drop from the flower canopy on the soil to pupate (Williams, 2010). Thus, it is coherent to find individuals from the summer generation abundantly in the OSR in the beginning of June, as they emerged from there. Later on, *Meligethes* spp. abundances were similar between OSR and WFS. Indeed, as the OSR was not flowering anymore at this period, the polyphagous beetles may have found pollen in the wildflowers. As highlighted by Free & Williams (1978), this source of food may be important before the over-wintering period.

In May, few adults were trapped (less than 20 on average each week). This is coherent with their biology, as most of them are pupating at this period. However, the few adults remaining were found significantly more abundant in the WFS than in the OSR (May 14th: F=10.29, P=0.003; May 21st: F=16.28, P=3.82e-04). Similarly, the polyphagous *Meligethes* spp. may have found pollen resources in the wildflowers when the OSR flowering period was finishing, reducing then pollen supply.

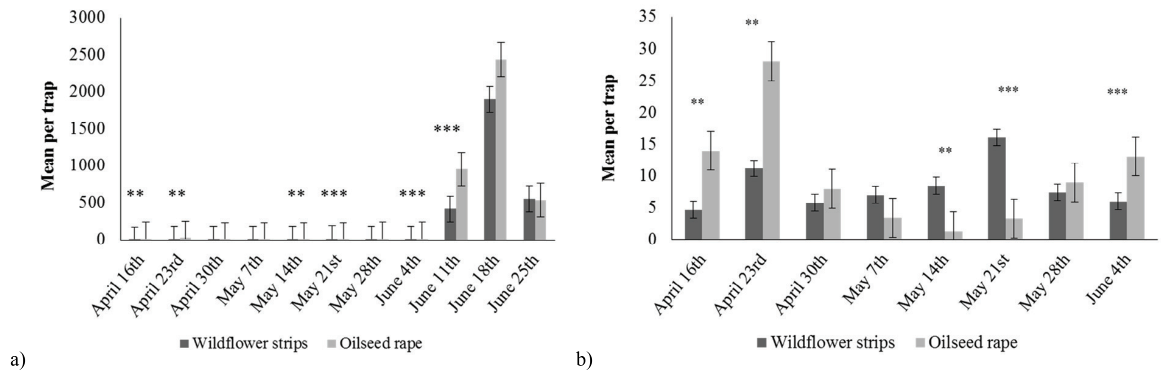


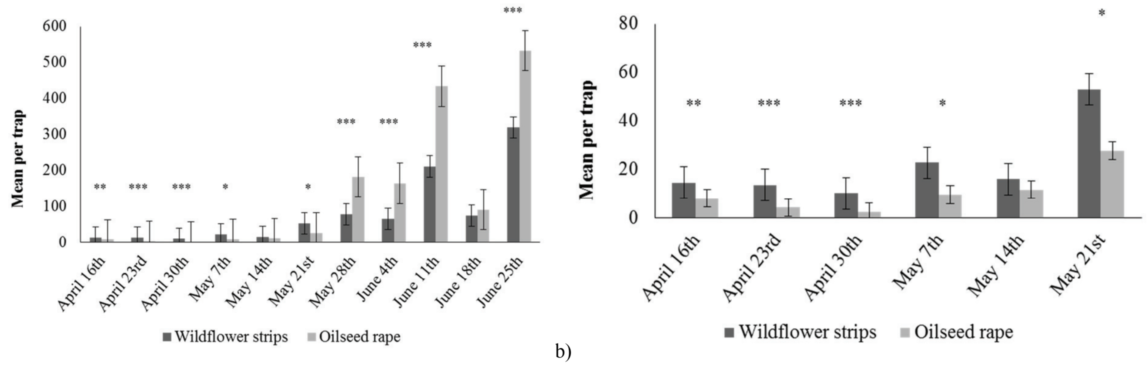
Fig. 3. Mean number (with Mean Standard Error bars) of *Meligethes* spp. per trap in the wildflower strips and oilseed rape during the whole trapping period (a) and with a focus on the first weeks (b). **P<0.001; ***P<0.0001.

3.2. The true weevils (Ceutorhynchus spp.)

More than 35 000 *Ceutorhynchus* spp. adults were trapped. They were significantly less abundant in the first half of the trapping period than in the second (Figure 4). From April 16^{th} to May 21^{st}, not more than 50 weevils were caught on average per trap, whereas they were found by hundreds from May 28^{th}. Until May 21^{st}, the weevils were found significantly more abundant in the WFS than in the OSR (April 16^{th}: F=7.79, P=0.009; April 23^{rd}: F=42.24; P=4.83e-07; April 30^{th}: F=33.6, P=31.16e-06; May 05^{th}: Kruskal-Wallis X^2=6.24, P=0.01; May 21^{st}: F=9.50, P=0.004). Conversely, they were significantly more abundant in the OSR than in WFS from May 28^{th} excepted for June 18^{th} (May 28^{th}: F=23.21, P=4.56e-05; June 4^{th}: Kruskal-Wallis X^2=14.73; P=1.24e-04; June 11^{th}: F=39.49, P=8.56e-07; June 25^{th}: Kruskal-Wallis X^2=8.55, P=0.003).

According to Dmoch (1965), *Ceutorhynchus* spp. usually overwinter in field margins. Thus it would have been consistent to abundantly trap weevil adults at their emergence in the WFS. However, from their emergence on June 4^{th}, significantly more adults were trapped in the OSR. Before June, they were trapped in little amount. Nevertheless, their little but still presence in WFS is not coherent with Free & Williams (1978) and Williams (2010), who assumed that *Ceutorhynchus* spp. are oligophagous on *Brassica* species.

Finally, the presence of abundant adult weevils in OSR from June is more consistent. According to Williams (2010), some *Ceutorhynchus* spp. may emerge in the late spring. This is the case of *C. assimilis* for instance, which fly after emergence on *Brassica* plants, feed on buds, flowers and stem tips, and females lay their eggs in pods. However, in our study, almost no OSR plant was flowering in the end of May, suggesting that such weevils flew later than usual on OSR. Nevertheless, trapping adult weevils in a higher abundance in the OSR than in the WFS at this season is coherent with the biology of such species for which females may search for pods to lay their eggs (Free & Williams, 1978).



a) b)

Fig. 4. Mean number (with Mean Standard Error bars) of *Ceutorhynchus* spp. per trap in the wildflower strips and in the oilseed rape during the whole period of trapping (a) and with a focus on the first weeks (b). *P<0.01; **P<0.001; ***P<0.0001.

3.3. The cabbage stem flea beetles (Psylliodes chrysocephala)

Only 128 cabbage stem flea beetle adults were trapped during our experiment (less than 3 adults on average per trap). On this basis, no further analysis appeared relevant to us. This quasi absence of *Psylliodes chrysocephala* at this season is coherent with their biology, as adults emerge in early autumn to feed on cotyledons and young leaves of winter OSR (Williams, 2010).

3.4. Wildflower strips for insect conservation: a source or a trap for insect pests?

Our results suggest that WFS sown for insect conservation may neither be a source of insect pests for the adjacent crop, nor be considered as trap crops.

Both pollen beetles and weevils were scarce in the WFS before or between the adult's abundance peaks. Even if at these periods, more adults were trapped in the WFS than in the OSR, their abundance remained very low, suggesting that WFS do not shelter large flying adult pest populations.

Nevertheless, such a suggestion should be confirmed with observations of the insects at their different development stages. Indeed, pan traps only catch flying adults while insect overwintering implies larval and pupal stages. Trapping adults with soil emergence traps, as described by Casanova (2001), would also provide key information about OSR pest overwintering sites.

When adults emerged, resulting in an increase of their populations, they were significantly more abundant in the OSR than in the wildflowers. This suggests that OSR remained more attractive for them than WFS. This higher attractiveness of OSR compared to WFS also implies that these last could not be considered as trap crops. Actually, most of the research studying trap crops to control OSR pests worked on *Brassicaceae* plants: *Brassica napus* (L.) itself (Buntin, 1998), *Brassica rapa* (L.) (Cárcamo et al., 2007), *Brassica nigra* (L.) Koch, *Raphanus sativus* (L.) Domin, *Eruca sativa* Miller, *Brassica juncea* (L.) Czern & Coss, *Sinapis alba* (L.) (Veromann et al., 2014). None of these plant species was sown in our WFS. Even if *Meligethes* spp. are known to be polyphagous feeders (Free & Williams, 1978), they oviposite mainly on *Brassica* species (Borg & Ekbom, 1996; Kaasik et al., 2014), while *Ceutorhynchus* spp. are known to be oligophagous on *Brassicaceae* (Free & Williams, 1978).

Moreover, WFS sown for insect conservation are known to attract pest natural enemies (Haaland et al., 2011). Among others, parasitoids, known to be efficient biocontrol agents, feed on flower nectar (Wäckers, 2004; Vattala et al., 2006) and thus may be abundant in such WFS. Especially, some belonging to the *Pteromalidae* family are important parasitic wasps of *Ceutorhynchus* spp., while the *Meligethes* spp. are hosts of some *Ichneumonidae* spp.

(Ulber et al., 2010). The few pollen beetles and weevils observed in the WFS may become hosts for these parasitoids, and thus support their presence at field margins. In a second step, their efficiency as biocontrol agents will depend on their ability to migrate in the adjacent crops and parasitize pests.

4. Conclusions

In this study, OSR was more attractive than WFS for both *Meligethes* spp. and *Ceutorhynchus* spp. during their population peaks. Before and between peaks, the number of adults remained very low in both kinds of vegetation. These results suggest that WFS sown for insect conservation do neither favour insect pest conservation at field margin, nor can be considered as trap crops. However, these results should be confirmed by for instance observing larvae and pupae in WFS and OSR, trapping adults with soil emergence traps, and compare it with observations and trappings in fields without WFS. Moreover, further research is needed to determine if these WFS favour the presence of natural enemies, especially parasitoids, who are known to be efficient biocontrol agents against OSR coleopteran pests.

5. Acknowledgements

This research was funded by the CARE AgricultureIsLife, University of Liège.

References

Alhmedi, A., Haubruge, E., Francis, F., 2009. Effect of stinging nettle habitats on aphidophagous predators and parasitoids in wheat and green pea fields with special attention to the invader *Harmonia axyridis* Pallas (*Coleoptera*: *Coccinellidae*). Entomological Science, 12(4):349-358.

Altieri, M.A., 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment, 74(1-3):19-31.

Baldi, I., 2013. Pesticides: effets sur la santé. INSERM, Institut national de la santé et de la recherche médicale, Paris.

Balzan, M.V., Bocci, G., Moonen, A.-C., 2014. Augmenting flower trait diversity in wildflower strips to optimise the conservation of arthropod functional groups for multiple agroecosystem services. Journal of Insect Conservation, 18(4):713-728.

Balzan, M.V., Moonen, A.-C., 2014. Field margin vegetation enhances biological control and crop damage suppression from multiple pests in organic tomato fields. Entomologia Experimentalis et Applicata, 150(1):45-65.

Barbosa, P.A., 1998. Conservation Biological Control. Academic Press, San Diego.

Blight, M.M., Smart, L.E., 1999. Influence of visual cues and isothiocyanate lures on capture of the pollen beetle, *Meligethes aeneus* in field traps. Journal of Chemical Ecology, 25(7):1501-1516.

Borg, A., Ekbom, B., 1996. Characteristics of oviposition behaviour of the pollen beetle, *Meligethes aeneus* on four different host plants. Entomologia Experimentalis et Applicata, 81(3):277-284.

Buntin, G.D., 1998. Cabbage seedpod weevil (*Ceutorhynchus assimilis*, Paykull) management by trap cropping and its effect on parasitism by *Trichomalus perfectus* (Walker) in oilseed rape. Crop Protection, 17(4):299-305.

Cárcamo, H.A., Dunn, R., Dosdall, L.M., Olfert, O., 2007. Managing cabbage seedpod weevil in canola using a trap crop-A commercial field scale study in western Canada. Crop Protection, 26(8):1325-1334.

Casanova, C., 2001. A soil emergence trap for collections of phlebotomine sand flies. Memórias do Instituto Oswaldo Cruz, 96(2):273-275.

CETIOM, 2014. Insecticides utilisables en pulvérisation foliaire. Accessed February 20, 2015, available at http://www.cetiom.fr/fileadmin/cetiom/Cultures/Colza/insectes_limaces/tableau_insecticides_colza_2014.pdf.

Cook, S.M., Khan, Z.R., Pickett, J.A., 2007. The use of push-pull strategies in Integrated Pest Management. Annual Review of Entomology, 52(1):375-400.

Díaz, S., Cabido, M., 2001. Vive la différence: plant functional diversity matters to ecosystem processes. Trends in Ecology & Evolution, 16(11):646-655.

Dmoch, J., 1965. The dynamics of a population of the cabbage seedpod weevil (*Ceuthorrhynchus assimilis* Payk.) and the development of winter rape. Ekologia Polska Seria A, 8:249-287.

Doguet, S., 1994. Coléoptères chrysomelidae: alticinae / Volume 2. Fédération Française des Sociétés de Sciences naturelles, Paris.

Döring, T.F., Skellern, M., Watts, N., Cook, S.M., 2012. Colour choice behaviour in the pollen beetle *Meligethes aeneus* (*Coleoptera*: *Nitidulidae*). Physiological Entomology, 37:360-368.

European Commission, 2013. Agriculture in the European Union. Statistical and economic information. Accessed February 27, 2015, available at http://ec.europa.eu/agriculture/statistics/agricultural/2013/pdf/full-report_en.pdf .

Frank, T., 1998. The role of different slug species in damage to oilseed rape bordering on sown wildflower strips. Annals of Applied Biology, 133(3):483-493.

Free, J.B., Williams, I.H., 1978. The responses of the pollen beetle, *Meligethes aeneus*, and the seed weevil, *Ceuthorhynchus assimilis*, to oil-seed rape, *Brassica napus*, and other plants. Journal of Applied Ecology, 15(3):761-774.

Gibbons, D., Morrissey, C., Mineau, P., 2014. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environmental Science and Pollution Research, 22(1):103-118.

Haaland, C., Naisbit, R.E., Bersier, L.-F., 2011. Sown wildflower strips for insect conservation: a review. Insect Conservation and Diversity, 4(1):60-80.

Jonsson, M., Wratten, S.D., Landis, D.A., Gurr, G.M., 2008. Recent advances in conservation biological control of arthropods by arthropods. Biological Control, 45(2):172-175.

Kaasik, R., Kovács, G., Metspalu, L., Williams, I.H., Veromann, E., Kaart, T., 2014. *Meligethes aeneus* oviposition preferences, larval parasitism rate and species composition of parasitoids on *Brassica nigra*, *Raphanus sativus* and *Eruca sativa* compared with on *Brassica napus*. Biological Control, 69:65-71.

Kirk-Spriggs, A.H., 1996. Pollen beetles: *Coleoptera*: *Kateretidae* and *Nitidulidae*: *Meligethinae*. Handbooks for the Identification of British Insects, 5(6a). Royal Entomological Society, London.

Kruess, A., 2003. Effects of landscape structure and habitat type on a plant-herbivore-parasitoid community. Ecography, 26(3):283-290.

Landis, D.A., Wratten, S.D., Gurr, G.M., 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology, 45(1):175-201.

Marino, P.C., Landis, D.A., 1996. Effect of landscape structure on parasitoid diversity and parasitism in agroecosystems. Ecological Applications, 6(1):276-284.

Moonen, A.-C., Bàrberi, P., 2008. Functional biodiversity: An agroecosystem approach. Agriculture, Ecosystems & Environment, 127(1-2):7-21.

Morris, M.G., 2008. True Weevils (Part II): *Coleoptera*: *Curculionidae*, *Ceutorhynchinae*, 5(17C). Royal Entomological Society, London.

Rusch, A., Valantin-Morison, M., Sarthou, J.P., Roger-Estrade, J., 2010. Integrating crop and landscape management into new crop protection strategies to enhance biological control of oilseed rape insect pests. In: Williams I. H. (Ed.), Biocontrol-Based Integrated Management of Oilseed Rape Pests. Springer Netherlands, 415-448.

Service public de Wallonie, 2012. Les subventions agro-environnementales Vade-Mecum. Service public de Wallonie, Direction générale opérationnelle de l'Agriculture, des Ressources naturelles et de l'Environnement, Département des Aides Direction des Surfaces agricoles.

Service public de Wallonie, 2014. L'agriculture wallonne en chiffres. Accessed February 20, 2015, available at http://agriculture.wallonie.be/apps/spip_wolwin/IMG/pdf/L_agriculture_wallonne_en_chiffres_2011.pdf.

Shelton, A.M., Badenes-Perez, F.R., 2006. Concepts and applications of trap cropping in pest management. Annual review of entomology, 51:285-308.

Thieme, T., Heimbach, U., Müller, A., 2010. Chemical control of insect pests and insecticide resistance in oilseed rape. In: Williams I. H. (Ed.), Biocontrol-Based Integrated Management of Oilseed Rape Pests. Springer Netherlands, 313-335.

Ulber, B., Williams, I.H., Luik, A., Klukowski, Z., Nilsson, C., 2010. Parasitoids of oilseed rape pests in Europe: key species for conservation biocontrol. In: Williams I. H. (Ed.), Biocontrol-Based Integrated Management of Oilseed Rape Pests. Springer Netherlands, 45-76.

Valantin-Morison, M., Meynard, J.-M., Doré, T., 2007. Effects of crop management and surrounding field environment on insect incidence in organic winter oilseed rape (*Brassica napus* L.). Crop Protection, 26(8):1108-1120.

Vattala, H.D., Wratten, S.D., Vattala, C.B., Phillips, F.L., Wäckers, F.L., 2006. The influence of flower morphology and nectar quality on the longevity of a parasitoid biological control agent. Biological Control, 39(2):179-185.

Veromann, E., Kaasik, R., Kovács, G., Metspalu, L., Williams, I.H., Mänd, M., 2014. Fatal attraction: search for a dead-end trap crop for the pollen beetle (*Meligethes aeneus*). Arthropod-Plant Interactions, 8(5):373-381.

Wäckers, F., 2004. Assessing the suitability of flowering herbs as parasitoid food sources: flower attractiveness and nectar accessibility. Biological Control, 29(3):307-314.

Williams, I.H., 2010. The major insect pests of oilseed rape in Europe and their management: An Overview. In: Williams I. H. (Ed.), Biocontrol-Based Integrated Management of *Oilseed Rape* Pests. Springer Netherlands, 1-43.