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Predation capacity of soil-dwelling predatory mites on two major maize pests

Antoine Pasquier^{a,b}, Thibault Andrieux^a, Paloma Martinez-Rodriguez^a, Elodie Vercken^b, Maxime Ferrero^a

^a Bioline agrosociences, R&D, 1306 route de Biot, 06560 Valbonne, France.

^b Université Côte d'Azur, INRAE, CNRS, ISA, France.

Original research

ABSTRACT

The western corn rootworm *Diabrotica virgifera virgifera* (WCR), and the wireworm *Agriotes sordidus* (WW), whose eggs and first instar larvae develop in the first few centimeters of soil, are major crop pests. As soil-dwelling predatory mites are known as potential biocontrol agents against many pests, we investigated the predation capacity of *Stratiolaelaps scimitus*, *Gaeolaelaps aculeifer* and *Macrocheles robustulus* on immature stages of WCR and WW in a laboratory setting. While eggs of WCR and WW were never consumed, all three predator species attacked both WCR and WW first instar larvae. While these results need to be confirmed in natural conditions, our work identifies the early larval stage instead of the egg stage as the most vulnerable stage for control against WCR and WW with soil-dwelling predatory mites.

Keywords click beetle; corn pest; *Laelapidae*; *Macrochelidae*; biological control

Introduction

Western corn rootworm (WCR) *Diabrotica virgifera virgifera* LeConte, 1868 (Coleoptera: Chrysomelidae) and Wireworm (WW) *Agriotes sordidus* Illiger, 1807 (Coleoptera: Elateridae) are two underground crop pests present in Europe and North America. WCR used to be a specific corn (*Zea mays* L.) pest but one population recently became a pest for soybean (Curzi *et al.* 2012), and its economic impact in Europe is estimated at 700 million euros per year in a worst case scenario of no control (Wesseler and Fall 2010). WW causes economic damages on many vegetable and arable crops (Burgio *et al.* 2012) and is considered as one of the most harmful *Agriotes* species from the agronomic perspective (Furlan 2004).

Some pest management tools exist to control WCR populations such as pesticides, GMOs producing the *Bacillus thuringiensis* toxin and crop rotation. However, at least one WCR population evolved and became resistant to each of these pest control methods (Gassmann *et al.* 2011; Pereira *et al.* 2017). Regarding WW, pesticide use is the main method used to control pest populations but the commission implementing regulation 2013/485/EU is restricting the use of neonicotinoids.

In this context, Prischmann *et al.* (2011) promoted a novel approach for the biological control of WCR by showing that soil-dwelling predatory mites species may feed on WCR eggs and first instar larvae. In previous studies, numerous soil-dwelling predatory mites that inhabit the first centimeters of the soil have showed potential to control pests such as nematodes, thrips or flies (Carrillo *et al.* 2015). *Gaeolaelaps aculeifer* (Canestrini), *Stratiolaelaps scimitus* (Womersley) and *Macrocheles robustulus* (Berlese) are three species that are already

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Corresponding author

Antoine Pasquier:

antoinepapass@gmail.com

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commercialized. The purpose of this study was to document the predation success of these three species of generalist soil-dwelling predators on WCR and WW immature stages in a low cost/low time experimental set up, before investing in a larger scale trial.

Material and methods

Biological material

Koppert Biological systems provided *Macrocheles robustulus*, commercialized under the name Macro-mite©. They were maintained on vermiculite for 2 months. *Gaeolaelaps aculeifer* was provided by EWH Bioproduction, Denmark. The population was maintained during 8 months on a substrate made of 1/3 third blond sphagnum peat and 2/3 of fine vermiculite. *Stratiolaelaps scimitus* individuals are commercialized by Bioline AgroSciences, under the name Hypoline©. This population has been maintained on blond sphagnum peat for 2 years.

The three species used in the experiment were kept in climatic chambers at $25\text{ °C} \pm 0.5\text{ °C}$ and $70\% \pm 10\%$ RH and in darkness. BugDorm-5002 insect rearing boxes (L21 x W21 x H6 cm) with nylon screen port (104 x 94 cm, 300µm aperture; Bugdorm©) were used as rearing units with the container floor layered with 1 cm of plaster of Paris. Three times a week moisture and food were maintained, by dripping water onto the plaster of Paris floor and provisioning mixed life stages of *Aleuroglyphus ovatus* (Troupeau).

WCR diapausing eggs were provided by the Centre of Agriculture and Bioscience International (CABI), Hungary. They were stored at $7\text{ °C} \pm 0.5\text{ °C}$, known to be below their temperature of development (Vidal *et al.* 2005). Before starting the experiment, we sieved the eggs from their substrate and selected only turgescient eggs for predation assays. We placed WCR eggs on plaster of Paris in a climatic chamber at $25\text{ °C} \pm 0.5\text{ °C}$ and $70\% \pm 10\%$ RH. We added water twice a week on the substrate to break diapause and trigger egg development. We checked daily for hatched eggs and collected first instar larvae for predation assays. Arvalis, a French applied agricultural research organization dedicated to arable crops, provided WW eggs and first instar larvae in Petri dishes filled with a sample of soil from their collection site. Once an egg or a first instar larva was isolated, we inserted it in the predation device with a predatory mite.

Predation tests

Adult mites (unsexed) were isolated and starved during 7 days in 2 mL Eppendorf tube containing 1 mL of dried plaster of Paris before the predation tests (El Adouzi. *et al.* 2017). The top of the tube was pierced and covered with a 106 µm wide nylon fabric to allow ventilation. 100 µL of water was added every 3 days during the starvation period to maintain relative humidity necessary for the survival of the mites. The tubes were stored in a climatic chamber at $25\text{ °C} \pm 0.5\text{ °C}$ with $70\% \pm 10\%$ RH.

For each test, one egg or one larva of WCR or WW was introduced in a tube containing a predatory mite and the predation success was observed during 10 minutes with a stereomicroscope. We used an indirect source of light, controlled at 100 lux (measured with the Digital Illuminance meter TES 1335), to minimize natural behavior disruption of these lucifugous species. We considered predation to occur when mites impaled the prey with their chelicerae. We chose to observe predation on a short duration because some of the preys could suffer from the abrasive texture of the plaster of Paris if left to dry. The experiment was replicated twenty times for each prey/predator combination.

Statistical analysis

The statistical analyses were done on R. 4.0.3. Predation success when encountering a larva of WCR or WW was compared among the predator species using a General Linear Model (GLM)

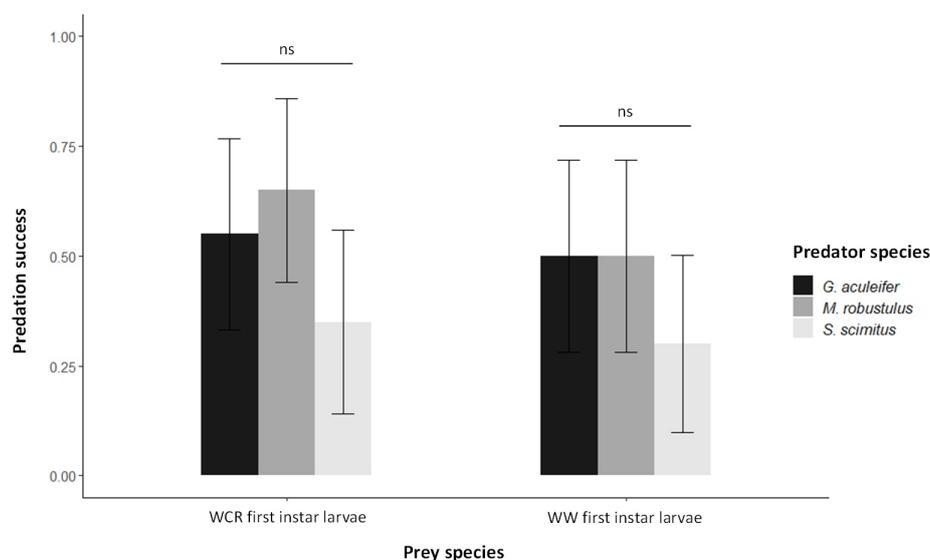


Figure 1 Predation success of *G. aculeifer*, *S. scimitus* and *M. robustulus* on WCR and WW first instar larvae during the 10-minutes predation assays. n=20. NS = no significant difference among predator species (p -value > 0.05). The error bars represent the 95% confidence interval for the predation success.

following a binomial distribution. As almost no predation on eggs was observed, except for *G. aculeifer* on WCR for which the confidence interval was not different from zero. Accordingly, predation data of all three predator species on eggs were not analyzed.

Results and discussion

The aim of this study was to investigate the predation potential of commercially available soil-dwelling predatory mites on WCR and WW. The predation success varied from 30 to 65% and was similar among the predator species either on WCR larvae ($\chi^2_2 : 3.8, P = 0.150$) or WW larvae ($\chi^2_2 : 2.2, P = 0.329$) (Figure 1). These results confirm the conclusion from Prischmann *et al.* (2011) on this development stage for *G. aculeifer*, and open larger perspectives for the biological control of both WCR and WW with other soil-dwelling predatory mites.

Regarding egg predation, WW eggs were never attacked by any of the three species, while in contrast with Prischmann *et al.* (2011) WCR eggs were attacked by *G. aculeifer* but only in 10% (+/- 13%) of the assays. The duration of experimentation (7 to 14 days for Prischmann *et al.* (2011)) might explain this difference in our results. In any case, our results emphasize the need to target a specific developmental stage to reduce most efficiently damage to plant. Indeed, eggs are not consumed by the predatory mites, while later stages of WCR and WW are able to protect themselves against predators thanks to their hemolymph properties or the presence of a sclerotized cuticle (Furlan *et al.* 2004; Lundgren *et al.* 2009). First instar larvae might thus be the most susceptible stage for efficient control of WCR and WW by predatory mites.

Despite our simple experimental design, we established a proof of concept that predatory mites might consume larval stages of major maize pests, which open perspectives for the development of a biocontrol strategy. It is worth noting however that our protocol did not reflect realistic environmental conditions. First, soil-dwelling predatory mites are very sensitive to low humidity (El Adouzi *et al.* 2017), yet as a total of 240 predatory mites were

kept alive and active for 7 days using our protocol, this suggests that these conditions were adapted to all three species survival. Second, population-scale parameters such as density are also known to affect predation (Abrams 2000), which could reduce control efficiency. This stresses the necessity to set up larger scale experiments to consider whether predatory mites will effectively be able to find and control the first instar larvae of these pests in the soil.

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