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Response of predators to habitat manipulation in potato fields

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ABSTRACT

Determining the impact of habitat manipulation and predator species diversity on prey suppression is crucial in developing predictions for the impact of biological control programs. Biological control literature contains controversial evidence for the impact of increased predator species diversity and habitat manipulation on prey suppression. We investigated the individual and combined effects of two predator species (*Coleomegilla maculata* (DeGeer) and *Lebia grandis* Hentz) on the herbivore *Leptinotarsa decemlineata* (Say) in potato fields with and without rye mulch. In surveys of the endemic populations we detected that *C. maculata* is approximately 16 times more abundant than *L. grandis* and the two predator species responded in opposite manner to the habitat manipulation treatment in potato fields: on average 35% of all *C. maculata* but 85% of all *L. grandis* collected over two field seasons were found in tilled plots vs. rye mulched plots. In field cages we investigated the effect of mulching and predator identity on *L. decemlineata* suppression. Neither predator was influenced significantly by the presence of rye mulch. *L. grandis* was effective in suppressing the target prey relative to the control but *C. maculata* in the single species as well as in the two-species assemblages was not consistently able to suppress prey relative to the control. This study found no support for positive multi-predator effects since the two predator species assemblages performed as predicted based on the results from individual predators. Practical implications of this study suggest focusing conservation biological control efforts on *L. grandis* to maximize its density in *L. decemlineata* infested potato fields.

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1. Introduction

Agricultural habitats can be manipulated to increase predator abundance and/or diversity with the ultimate goal of achieving better biological control of pests (Root, 1973; Barbosa, 1998; Landis et al., 2000). Structurally complex habitats can increase prey survival by providing refuge from predators (Finke and Denno, 2002; Grabowski, 2004; Langellotto and Denno, 2004) and by modifying predator behavior to benefit herbivore survival (Finke and Denno, 2006). On the other hand, predator foraging efficiency may vary inversely with habitat heterogeneity, thus reducing the predators' effectiveness in prey suppression in complex habitats (Karieva, 1983; Hughes and Grabowski, 2006). Some of these conclusions are confounded by the fact that generalist and specialist natural enemies are likely to respond to habitat heterogeneity differently (Sheehan, 1986). Since predators naturally occur in assemblages in different types of habitats, it is necessary to understand the effect of habitat context on multiple predator–prey interactions. Biodiversity theory predicts that a predator assemblage will impose greater prey mortality than even the most effective predator species alone, thus a reduction in predator species diversity leads to decreased consumption of the target trophic group (Cardinale et al., 2006 and references therein). Differences in predator species diversity can result in drastic changes in the impact of predator assemblage on pest survival (Snyder and Wise, 1999; Moran and Scheidler, 2002; Mathews et al., 2004). The identity of the species in an assemblage and the structure of a predator assemblage may play an important role in determining its effectiveness in suppressing pests. In general, the key to effective conservation biological control may be to design tactics that enhance the relative abundance of the most effective predator within the predator community (Straub and Snyder, 2006).

Crops with intensive pesticide inputs are at risk of resistance developing in key pests, and this issue has become a significant challenge in the management of numerous pest species, including the Colorado potato beetle (*Leptinotarsa decemlineata* (Say); Coleoptera: Chrysomelidae) (Whalon et al., 2008). *L. decemlineata* has several natural enemy species (Ferro, 1994), but biological control methods fail to reduce populations below economic threshold levels in conventionally managed potato fields (Ferro, 1994). The only published study to date (Brust, 1994) that examined the effect of straw mulch (i.e., structurally complex habitat) in potatoes on the natural enemy assemblage of the *L. decemlineata* reports on field observations of predators and concludes that natural enemies

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significantly reduced *L. decemlineata* populations in mulched compared to non-mulched plots.

The current study was set up to investigate the impact of habitat manipulation on two predator species alone and in combination. We began by surveying the abundance of two focal predator species of *L. decemlineata* in potato fields in order to examine their responses to rye mulch. Then we designed a field cage experiment to test the hypothesis that the identity and relative abundance of the two predator species has an effect on prey suppression. We tested this hypothesis in mulched and un-mulched potato plots. In addition, we asked the question if these treatments affected plant damage.

2. Materials and methods

2.1. Study site

Field experiments were conducted in 2006 and 2007 in Beltsville, MD, in two different fields for the 2 years, ca. 1 km apart, since potatoes were grown in rotation. The two habitat treatments were rye mulched (structurally complex) and conventionally tilled (structurally simple) potato fields. Areas of the field designated for both habitat treatments were seeded with winter rye (*Secale cereale* L., 100 kg/ha) in September 2005 and 2006 in ca. 1 ha experimental fields. In the following April of each year, before potato seeding, fields were divided into blocks (12 m by 30 m for each block). Three randomly assigned blocks were tilled to incorporate the rye stalks into the soil and another three randomly chosen blocks were left with the rye intact. Therefore, in tilled plots, potatoes were grown without mulch, but all other management methods were the same as in the rye mulched plots.

Potatoes (*Solanum tuberosum* L. 'Kennebec', 2027 kg/ha) were seeded on 27 April in 2006 and 25 April in 2007 in a 76×30 cm plant spacing. For the rye mulch treatment, potatoes were planted into the rye cover crop and pre-emergent herbicides (*S*-metolachlor at 1.78 kg AL/ha, linuron at 981 g AI/ha and paraquat dichloride at 1.71 kg AI/ha) were applied within 1 week after planting. The field was not treated with herbicides during the experiment, but low rates of insecticides (spinosad at 16 g AI/ha on 16 June 2006, and permethrin at 27 g AI/ha on 15 July 2006, and at 54 g AI/ha on 15 and 30 June 2007) for leafhopper control, and fungicide (azoxystrobin at 161 g AI/ha on 15 July 2006 and at 96 g AI/ha on 30 June 2007) were applied as needed to protect plants from severe damage.

2.2. Predators

The predator species studied were *Lebia grandis* Hentz, (Coleoptera: Carabidae) and *Coleomegilla maculata* (DeGeer), (Coleoptera: Coccinellidae). These two predator species were chosen because they are relatively constant members of the predator assemblage that attacks *L. decemlineata* in the eastern United States (Ferro, 1994). In addition, these two species do not feed on each other in the adult stage, therefore intraguild predation was not a source of variation. Predators were collected by hand from the same field as the *L. decemlineata* eggs, 1 day before the start of the experiment and were held in the laboratory overnight (22 ± 2 °C) with access to water.

2.3. Field survey

Field surveys of naturally occurring populations of the two predators were conducted in the growing seasons of 2006 and 2007. Predators were collected between 7:30 and 11:00 h from potato foliage by hand or with an aspirator. Collections lasted for 30 min in 6 by 6 m subplots once every week through the field season. We chose this method of collection because the predators were too visually alert and highly active for conventional sampling methods (beating or quadrat sampling). Three subplots within each block were rotated weekly for these collections in order to minimize the depletion of predators from a specific part of the field.

2.4. Field cages

Field cages ($2 \times 2 \times 2$ m, 32 by 32 mesh Lumite screening, Bioquip, Gardena, California, USA) were set up at least 5 m from all edges of the plots, and were randomly assigned to predator treatment. The bottom edge of the cages was buried ~10 cm below the soil surface. Each cage covered eight potato plants arranged in two rows for a total of eight plants per cage. The experiment was set up on 18 June and again on 18 July 2007. After insect release, cages were assessed every 2–3 days for 2 weeks. Cages were moved and assembled over new plants located in the same field for the second time-replication. In total, 30 cages were set up twice in the summer (June and July), each time-set containing three replications of all combinations of the two factors (habitat type and predator treatments) and a control with no predators.

Prior to the set-up of cages, foliar arthropods were removed by hand searching, and by placing a yellow sticky trap (Bioquip, Gardena, California, USA) in each cage at the level of the foliage for 24 h. In addition, one pitfall trap per cage (15 cm diameter with ethylene glycol antifreeze) was kept open for 24 h to remove epigeal predators. *L. decemlineata* egg masses were collected with the leaflet they were laid on, from a nearby insecticide-free potato field, and were placed into the cages. Each egg mass was photographed prior to deployment in the cages in order to record the number of eggs per mass. Egg masses were attached to the surface of a leaf on a potato plant with a stapler. Ten egg masses were distributed by placing five masses in each of the two rows of plants within the cage. Predators were released into the cages immediately after egg masses were placed on the plants. Plant damage was visually estimated from each of the plants in the cages on June 22 and July 21, 2007.

In order to investigate the effect of predator identity on prey suppression, we used five treatments including control in a substitutive experimental design to isolate the effects of increasing species richness from increasing total predator abundance. All four predator treatments contained ten individuals per cage. Two treatments tested the predator species effects in single species assemblages, and two other treatments contained the following species combinations: 5 *L. grandis* + 5 *C. maculata* ('5 + 5') and 2 *L. grandis* + 8 *C. maculata* ('2 + 8'). We chose these combinations because they were representative of the relative abundances of the two species under field conditions. Each treatment was replicated in three blocks, each of which also had a control treatment cage containing ten egg masses without predators.

2.5. Statistical analyses

The numbers of predators from the field surveys were compared between the two habitat treatments with a log-linear model (Proc Genmod, link = log, distribution = Poisson, type 3 analysis). The main effects in the model were sampling date, block, mulch treatment, and predator species. We were particularly interested if the two predator species respond differently to the two types of habitats, therefore we assessed the statistical significance of mulch treatment by predator species interactions using the least-square means option ("lsmeans/pdiff" in Proc Genmod, SAS Institute Inc., Cary, North Carolina) for the 2 years separately.

We used the first two sampling dates of prey data from the cages (corresponding to the first week after predators were released in the cage) in the statistical analyses. We did this be-