EVALUATION OF INSECTICIDE CHEMISTRIES AGAINST THE LEEK MOTH (LEPIDOPTERA: ACROLEPIIDAE), A NEW PEST IN NORTH AMERICA

DANIEL L. OLMEAST® AND ANTHONY M. SHELTON
New York State Agricultural Experiment Station, Department of Entomology, Cornell University, 630 West North Street, Geneva, NY 14456, USA

*Corresponding author; E-mail: dan.olmstead@cornell.edu

Abstract

The leek moth, Acrolepiopsis assectella (Zeller), is a newly introduced micro-lepidopteran pest in North America that attacks Allium crops, including onion, leek, and garlic. Eggs are laid on leaves and emerging larvae may cause extensive damage by mining leaves, feeding on leaf surfaces and feeding directly on bulbs. Little is known about existing natural enemies for this pest in North America, but classical biological control introductions are underway in Canada. However, other management options are needed because the threat to the onion production industry in New York State and the Great Lakes Region is imminent. Laboratory studies showed that lambda cyhalothrin (Warrior® II), spinetoram (Radiant® SC), methomyl (Lannate® LV), chlorantraniliprole (Coragen®), and spinosad (Entrust®) significantly increased larval mortality, compared to the control, at 2, 4, and 8 days after treatment, while Bacillus thuringiensis and azadirachtin insecticides did not. These results are explained in part by the behavior of the insect.

Key Words: Acrolepiopsis assectella; leek moth; onion leaf miner; teigne du poireau; onion; leek; allium

Resumen

La polilla del puerro, Acrolepiopsis assectella (Zeller) es un micro-lepidóptero plaga recientemente introducido en América del Norte, que ataca los cultivos de Allium incluyendo cebolla, puerro y ajo. Los huevos son puestos en las hojas y las larvas recién salidas pueden causar daño severo por las minas que hacen en las hojas, la alimentación sobre la superficie de las hojas y la alimentación directa a los bulbos. Se sabe poco sobre los enemigos naturales existentes para esta plaga en América del Norte, pero están realizando introducciones del control biológico clásico en Canadá. Sin embargo, otras opciones de manejo son necesarias debido a su amenaza inminente a la industria de producción de cebolla en Nueva York y la región de los Grandes Lagos. Ensayos de laboratorio mostraron que el cialotrina lambda (Warrior II), spinetoram (Radiante SC), methomilo (Lannate LV), clorantraniliprol (Coragen) y spinosad (Entrust) aumentó significativamente la mortalidad de larvas, en comparación con el control, a los 2, 4 y 8 días después del tratamiento, mientras que insecticidas Bacillus thuringiensis y azadiractina no lo hizo. Estos resultados se explican en parte por el comportamiento del insecto.

Palabras Clave: Acrolepiopsis assectella, la polilla de puerro, cebolla, minador de la hoja; teigne du poireau, cebolla, puerro, Allium
large commercial onion production occurs in Os- 
wego County, NY, located 300 km to the south. A. 
assectella represents a threat to this area and oth- 
er onion production areas in New York that report 
annual harvest values of greater than $54 million 
(USDA-ERS 2011). If A. assectella becomes estab-
lished in New York, it may also spread to other 
states in the northeast where Allium vegetable 
production is important.

Acrolepiopsis assectella has few known natu-
ral enemies in North America and pest pressure 
is often more severe than in Europe (Jenner et 
al. 2010b; Jenner et al. 2010c). Biological control 
with a parasitoid has worked well in Europe, and 
introduction of Diadromus pulchella (Wesmael) is 
underway in Canada (Jenner et al. 2010a; Jen-
ner et al. 2010c). These efforts are important but 
additional options are needed because of the im-
mediate threat to onion production in New York 
State and the Great Lakes Region (Mason et al. 
2011). Cultural control options have been evalu-
ated for A. assectella. Intercropping has not prov-
en effective, but trap cropping shows promise (As-
aman 2002; Asman & Ekborn 2006).

Insecticides will play an important role in a 
control strategy for this pest of high value veg-
table crops, and this has been demonstrated in 
the case of swede midge, Contarinia nasturtii 
Kieffer (Diptera: Cecidomyiidae) (Chen 2011), 
another newly introduced pest of vegetables 
from Canada. Cornell University petitioned the 
New York State Department of Environmental 
Conservation (NYSED), and was granted 2(ee) 
emergency exemptions, for 5 insecticides for con-
rol of A. assectella in 2010 based on the immedi-
ate threat of A. assectella. Requests for Entrust® 
(spinosad) and DiPel® DF (Bacillus thuringiensis 
var. kurstaki) were approved for homeowners and 
organic growers in affected regions. Approvals 
for Warrior® II (lambda-cyhalothrin), Lannate® 
LV (methomyl), and Radiant® SC (spinetoram) 
were granted for large-scale conventional grow-
ers. Continued registration of these products is 
important to prevent crop damage, and proven 
efficacy against A. assectella is key to this process.

Other insecticides might also be effective but 
a literature review indicated a lack of research 
on efficacy against A. assectella for many chem-
istries, including those with the 2(ee) exempted 
products mentioned above. This laboratory study 
was conducted to provide preliminary efficacy da-
ta for a variety of insecticides in different chemi-
cal classes that could be suitable against A. as-
sectella.

**MATERIALS AND METHODS**

Mature leek plants, Allium ampeloprasum var 
‘Lincoln’ (Bejo Seeds Inc., Geneva, New York), 
were grown in a greenhouse at a constant 15 °C 
and 16:8 h L:D. Plants were grown in 15 cm diam, 
15 cm deep plastic pots from seeds. Slow release 
fertilizer (Scotts Osmocote, 15-9-12) was applied 
twice at 3-mo intervals initiated at planting.

Acrolepiopsis assectella were reared in a labora-
tory colony that originated from field-collected pu-
pae and late instar larvae found in a home garden 
in Essex County, New York in August 2011. Pupae 
of this population were placed in clear acrylic cylin-
ders (11 cm diam × 15 cm high) fitted with screened 
caps (i.e. oviposition chambers) and a flask of 10% 
sucrose solution for adult nutrition. When adults 
emerged, a 10 cm × 3 cm piece of fresh leek leaf, 
rubbed with masticated leek pulp (Garland 2002), 
was hung from the oviposition chamber lid for a 
24-h period during which adults were given the op-
portunity to lay eggs on the leaf. Egg-laden leaves 
were collected daily. To facilitate handling and col-
lection of larvae, freshly collected leaves were cut 
into 0.6 cm squares and allowed to dry to prevent 
leaf mining by emerging neonates.

Dried egg-laden leaves were checked daily for 
neonate larvae. Acrolepiopsis assectella larvae 
were collected using a size 0 round tip paint-
brush dipped in water to prevent static charge. 
Individual larvae were transferred to single flat-
bottom 6mm diam wells of a 96-well plate (Falcon 
3912 MicroTest III Flexible Assay Plate, Becton 
Dickinson Labware, Oxnard, California) contain-
ing a small amount of leek pulp. Leek pulp was 
prepared by adding 100 mL of distilled water to 
25 g of fresh, washed leek leaves in an Osterizer 
Model 471 blender set to high for 2 min, and then 
drained of liquid with a small strainer. A sheet of 
Parafilm M was firmly pressed over the entire 
plate to form a seal over all individual wells con-
taining insects to retain moisture and humidity, 
but allow gas exchange. Plates were held at 20 °C 
and 16:8 h L:D. Larvae were transferred to clean 
trays with fresh leek pulp every 2 to 3 d. Insect 
stage was calculated using head capsule size. 
When larvae were 2nd or 3rd instars, they were 
individually placed in designated 96-well plates 
at 10 °C and 16:8 h L:D.

Insecticide treatments were applied at a stan-
dard volume of 285.2 L per ha and 2.8 kg per cm² 
of pressure through a single Teejet flat fan 8002 
nozzle tip with an Allen Track Sprayer (Allen Ma-
chine Works, Midland Michigan). A single potted 
leek plant, as described above, was placed into 
the spray chamber and treated. Maximum label 
rates, indicated on New York State registration 
labels, were applied with a surfactant at 1% v/v 
(Dyne-Amic®, Helena Chemical Co.) (Table 1). A 
single leaf of sufficient size was marked on each 
leek with a small pin and positioned during ap-
lication to receive an even dose of insecticide. 
Treatments were replicated 3 times for use in bio-
assays completed at 2, 4, and 8 d after treatment 
(DAT).

Bioassays were completed using 7, 8, or 9 discs 
(3.2 cm diam), cut from a treated leaf, and placed
in individual Comet™ 1 oz. portion/shot glasses (WNA, Covington, Kentucky, www.wna.biz, SKU P10). Three 2nd or 3rd instars were then placed on the surface of a leaf disc, and a clear plastic lid was placed on the cup. To determine the activity of each insecticide over time, mortality rates at 2, 4, and 8 DAT were evaluated at 48 h after exposure using different leaf discs and insects for each DAT treatment.

Mortality was analyzed using one-way ANOVA and means were separated using Fisher LSD tests. Data were arcsine square root transformed before analysis but untransformed means are presented. Analyses were carried out in JMP 9.0 for Macintosh (SAS Institute, Cary, South Carolina).

**Results**

There were significant differences in mortality between insecticides at each DAT and within an insecticide treatment over time (Table 1). Warrior® II, Radiant® SC, Lannate® LV, Coragen®, and Entrust® caused significant larval mortality, compared to the untreated check, at 2, 4, and 8 DAT. At 2 DAT, Warrior® II caused the highest level of mortality at 96.3 ± 3.7%. Radiant® SC (92.6 ± 4.9%), Lannate® LV (81.5 ± 8.1%), and Coragen® (77.8 ± 7.8%) performed well and were not statistically different from Warrior® II. While Entrust® (66.7 ± 7.8%) performed significantly better than the untreated check, it was significantly worse than the other four treatments. The biologically-based insecticides Agree® WG (14.8 ± 8.1%), Neemix® 4.5 (11.1 ± 5.6%), and DiPel® DF (11.1 ± 5.6%) were not significantly different from the untreated check (16.7 ± 12.6%).

At 4 DAT, Radiant® SC (95.2 ± 4.8%) caused the highest mortality levels, followed by Coragen® (90.5 ± 6.1%), Lannate® LV (85.7 ± 6.7%), Warrior® II (81.0 ± 9.9%), and Entrust® (71.4 ± 15.3%). No significant differences among these treatments were detected, but all showed significantly higher levels of mortality compared to the untreated check at 4 DAT. Compared to the untreated check (19.1 ± 9.9%) at 4 DAT, there were no significant differences for the biologically-based insecticides Agree® WG (9.5 ± 6.2%), Neemix® 4.5 (14.3 ± 6.7%), and DiPel® DF (14.3 ± 9.9%).

At 8 DAT, Radiant® SC (91.7 ± 5.4%) and Coragen® (91.7 ± 5.4%) had the highest levels of mortality among all treatments, followed by Lannate® LV (83.4 ± 8.9%) and Entrust® (70.9 ± 9.8%), but there were no significant differences among these treatments. Warrior® II (66.7 ± 5.4%) showed significantly higher mortality compared with the untreated check at 8 DAT, but the level of control was significantly lower than the other four insecticides. The biologically-based insecticides Agree® WG (16.7 ± 6.3%), Neemix® 4.5 (12.5 ± 8.8%), and DiPel® DF (12.5 ± 6.1%) were not significantly different from the untreated check (16.7 ± 12.6%).

ANOVA and Fishers LSD analysis of mortality at 2 DAT, 4 DAT, and 8 DAT within treatments did not reveal significant effects of treatment timing, with the exception of Warrior® II, where at 2 DAT, mortality was significantly higher than at 4 DAT and 8 DAT. Warrior® II mortality at 4 DAT was significantly higher than at 8 DAT and significantly lower than 2 DAT.

**Discussion**

Acrolepiopsis assectella's behavior was an important factor in this experiment and likely influenced whether an insecticide was effective, as Mason et al. (2010) suggested. Acrolepiopsis...
assectella mortality in the pyrethroid-sprayed plants was initially high but decreased as time progressed. Pyrethroids degrade quickly and the active ingredient in Warrior®, lambda cyhalothrin, has a half-life of 5 d on plant surfaces, breaking down readily in sunlight (National Pesticide Information Center 2001). Our results showed that insects exposed to the plant surface shortly after treatment were controlled before entering the plant. As time between application and insect exposure increased, the treatment became significantly less effective and declined by 29.6% (Table 1).

Spinetoram (Radiant® SC) and spinosad (Entrust®) both belong to the spinosyn class of insecticides and had longer residual activities. Spinosad has a unique mode of action, acting quickly on the insect nervous system through contact and ingestion (Thompson et al. 2000). This is suitable for A. assectella because of the short time period larvae are exposed to the plant surface. These positive results suggest more work should to be done to evaluate spinosyn products.

Methomyl (Lannate® LV) and chlorantraniliprole (Coragen®) were also effective at controlling A. assectella. Unlike lambda-cyhalothrin (Warrior®), they were effective through 8 DAT. The exact exposure pathways of these chemicals are not known. Both insecticides have contact and ingestion activity against arthropods (DuPont 2007). Methomyl does not persist long on plant surfaces, having a half-life of 3 to 7 d (Extension Toxicology Network 1993).

The bacteria Bacillus thuringiensis (Bt) must be ingested to reach target sites in the digestive tract and have an effect on the target organism. Neither of the Bt treatments (Agree® WG and DiPel® DF) effectively controlled A. assectella. This contradicts the literature in which Bt was used to treat leek plants provided very good coverage. Our results show that insecticides can be effective but will be influenced by chemical composition, mode of action and/or behavior of A. assectella. Lambda-cyhalothrin may be an effective option in situations where A. assectella have not hatched or penetrated the leaf tissue. It should be applied no more than 2 d intervals to compensate for degradation of the active ingredient, and should not be used as a one-time treatment if adults oviposit for a prolonged period. Spinetoram, chlorantraniliprole, and spinosad also provided effective consistent control for up to 8 d, so time between reaplication could be lengthened. Products containing Bt (Agree® WG and DiPel® DF) and azadirachtin (Neemix® 4.5) did not provide high levels of mortality of A. assectella and are not likely to be suitable control agents.

More work is needed because some of our findings contradict current recommendations about the effectiveness of Bt products (e.g., Allen et al. 2008). Neonate larvae burrowed into the host within min to h of hatching and 2nd instars placed on fresh leaf material also burrowed into mesophyll quickly (personal observation). It is unlikely they ingested sufficient amounts of Bt proteins to be harmed, despite the use of good foliar spray technology. Of the other options we tested for organic producers, only spinosad (Entrust®) provided decent control. Conventional growers have more effective options. Based on these tests and our knowledge of spinetoram (Radiant® SC) and chlorantraniliprole (Coragen®) for other Lepidoptera, field tests should be conducted with these newer insecticide chemistries, as well as pyrethroid and carbamate insecticides.

ACKNOWLEDGMENTS

Thanks to Amy Ivy, Executive Director and Horticulture Educator at Cornell Cooperative Extension of Clinton County for collecting populations of A. assectella for our lab. Special thanks to Sue Coonrad, Clinton County, New York, USA homeowner and gardener who sacrificed her 2011 onion crop for A. assectella collections. Finally, thanks to Dr. Jozsef Fail and Jun-ce Tian who reviewed an earlier draft of this manuscript and provided useful comments and suggestions.

REFERENCES CITED


