Seed Treatment with Clothianidin Reduces *Bagrada hilaris* (Hemiptera: Pentatomidae) Damage to Crucifers[1]

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Bagrada hilaris (Burmeister) (Hemiptera: Pentatomidae) is an invasive pest native to countries in Africa, the Middle East, and Asia (Reed et al. 2013, J. Integr. Pest Manag. 4(3), doi: http://dx.doi.org/10.1603/IPM13007). The pest was found on cruciferous plants in the central coast of California in 2012 (Joseph 2014, J. Entomol. Sci. 49: 318–321), 4 yr after its initial detection in California in Los Angeles Co. (Palumbo and Natwick 2010, Plant Health Prog., http://www.plantmanagementnetwork.org/pub/php/brief/2010/bagrada/, doi: 10.1094/PHP-2010-0621-01-BR). *Bagrada hilaris* prefers *Brassica* crops, including broccoli (*Brassica oleracea* var. *italica* Plenck), cauliflower (*B. oleracea* L. var. *botrytis*), and cabbage (*B. oleracea* L. var. *capitata*), which are the top vegetable crops grown in agricultural areas of California's central coast. In 2016, *Brassica* crops were valued at more than US$778 million in Monterey Co. alone (Monterey Co. Crop Rep. 2017, http://www.co.monterey.ca.us/Home/ShowDocument?id=65737).

Bagrada hilaris feeding injury has been observed when the seeds germinate immediately following planting (Joseph et al. 2017, J. Entomol. Sci. 52: 468–471), as well as on the young plants up to the five-leaf stage (Reed et al. 2013). This feeding affects normal plant growth and sometimes plant survival. Widespread stand loss and stunting have been observed in *B. hilaris*–infested *Brassica* fields. *Bagrada hilaris* feeding often triggers production of multiple shoots, which produces a number of smaller, unmarketable broccoli, cauliflower, or cabbage heads. In California's Salinas Valley, broccoli and cabbage are primarily direct-seeded; whereas, cauliflower is transplanted. Broccoli is usually planted at approximately 15.2-cm spacing between seeds.

Management of *B. hilaris* in field-grown *Brassica* primarily relies on multiple applications of pyrethroid, neonicotinoid, or carbamate insecticides during the

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vulnerable seedling and young plant stages. Although these insecticide applications have reduced *B. hilaris* damage in these crops, the practice increases the overall use of insecticides. Insecticide seed-coating is a precise placement of low doses of insecticide around the seed, which has shown improved pest control and uses a reduced amount of insecticide. Effectiveness of seed-coating technology for *B. hilaris* control has not been previously documented in California's central coast. The objective of this study, therefore, was to evaluate the efficacy of insecticides against *B. hilaris* when applied as a seed coating.

In 2015, two experiments were conducted in two vegetable fields, approximately 0.5 km apart, in Gonzales, CA. The plants in both the experiments were exposed to natural *B. hilaris* infestations. The first experiment was planted on 4 August, and the second experiment was planted on 23 September. Insecticide-coated 'Gazelle' cabbage seeds were planted in 101.6-cm-wide $\times$ 7.62-m-long plots in two rows. The seeds were planted at high density using seed planters (Jang TD1 Precision Seeder, Jang Automation Co., Ltd., Chungbuk-Do, Korea). In the first experiment, plants were thinned to 17.8-cm spacing 2 weeks after planting; plant stands were not thinned in the second experiment. The same seed-coated treatments were evaluated in both experiments. These were: three rates of clothianidin-coated seeds (0.750, 1.170, and 1.680 mg/seed), thiamethoxam-coated seeds (1.160 mg/seed), and nontreated seeds (control). The insecticide-coated seeds were provided by Valent U.S.A. Corp. (Livingston, MT). Various rates of clothianidin-coated seeds were included as treatments because the amount per seed can vary by spacing of planted seeds in the soil to be consistent with amount of insecticide per hectare. The insecticide-coated seed treatments were arranged in randomized complete block design with four replications in the first experiment and five replications in the second experiment.

For evaluation of the first experiment, 20 second leaves (not including cotyledons) were randomly collected on 21 September from each plot and rated for *B. hilaris* feeding injury. The damage rating scale system assigned ratings ranging from 0 to 4 based on *B. hilaris* feeding defoliation injury ($0 = 0\%$; $1 = 1–25\%$; $2 = 26–50\%$; $3 = 51–75\%$; $4 = >75\%$). Plant height of 20 randomly selected plants per plot was also measured on 17 September in the field without destructively sampling the plants.

The *B. hilaris* population was very high during the second experiment; thus, the growth and development of most of the surviving plants were severely affected. Plant density within each treatment was evaluated on 17 October by counting only live plants in each plot. On 23 October, plant heights of 20 randomly selected plants per plot were measured. Number of plants, plant height, and *B. hilaris* feeding injury ratings were log-transformed ($\ln[x + 1]$) to establish homogeneity of variance and then subjected to analysis of variance using the general linear model procedure in the Statistical Analysis System (SAS Institute 2012, SAS Version 9.4. SAS Institute Inc., Cary, NC). Treatment means were separated using the Tukey's Honestly Significant Difference method ($P < 0.05$).

Bagrada hilaris feeding severely affected the growth and development of nontreated plants compared to clothianidin-treated plants (Fig. 1). In the first experiment, the plant height was significantly greater in clothianidin treatments

Fig. 1. Cabbage plants with clothianidin-coated (A), and nontreated seeds (B) from the first experiment. (Photo by S. V. Joseph.)

of 1.680 and 1.170 mg/seed than in the nontreated check treatment ($F = 5.3$; df = 4, 12; $P = 0.011$; Fig. 2A). There was no difference in plant height among the thiamethoxam, the lowest dose of clothianidin, and the nontreated check treatments. Leaf damage rating was significantly lower in the treatment with clothianidin 1.680 mg/seed than in the thiamethoxam treatment ($F = 4.3$; df = 4, 16; $P = 0.024$; Fig. 2B). In the second experiment, number of seedlings ($F = 13.6$; df = 4, 16; $P < 0.001$; Fig. 3A) and leaves per seedling ($F = 9.1$; df = 4, 16; $P < 0.001$; Fig. 3B) were significantly greater in all clothianidin and thiamethoxam treatments than in the nontreated check.

Based on these results, plant development and survival were significantly improved with clothianidin seed coating, especially at the two higher rates. Additional research is warranted to determine the number of foliar applications needed to ensure crop protection when *B. hilaris* populations are large. Moreover, clothianidin-coated broccoli and cabbage seeds were recently registered for use in California. Results suggest that a wider space will be better for *B. hilaris* control with high dose of clothianidin per seed. Future studies are also necessary to understand the movement of clothianidin in the soil and waterways and potential environmental impact of residues to nontargets in surface waters.

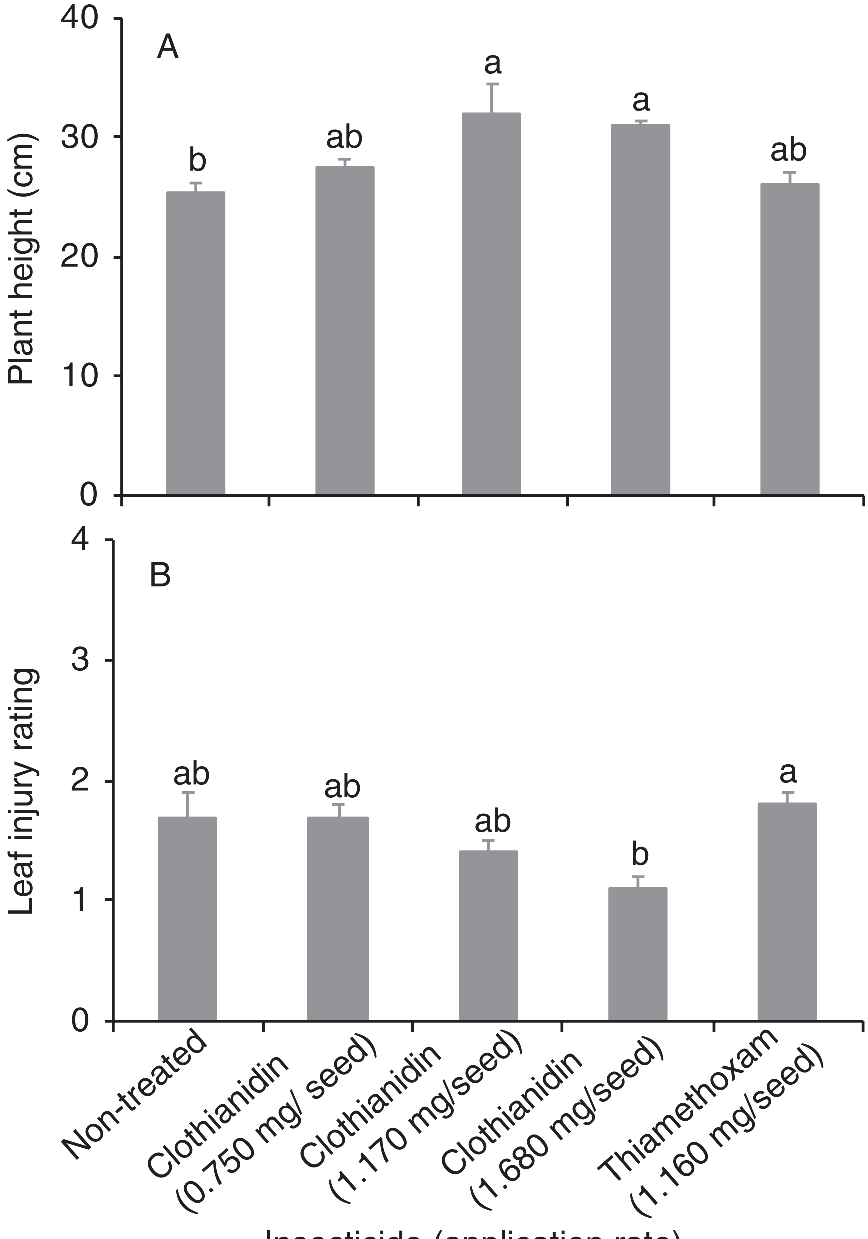

Fig. 2. Mean (± SE) plant height (A), and leaf feeding injury rating (B) when various insecticide-coated cabbage seeds are exposed to natural *B. hilaris* population in the first experiment. Bars with the same letters are not significantly different ($P > 0.05$).

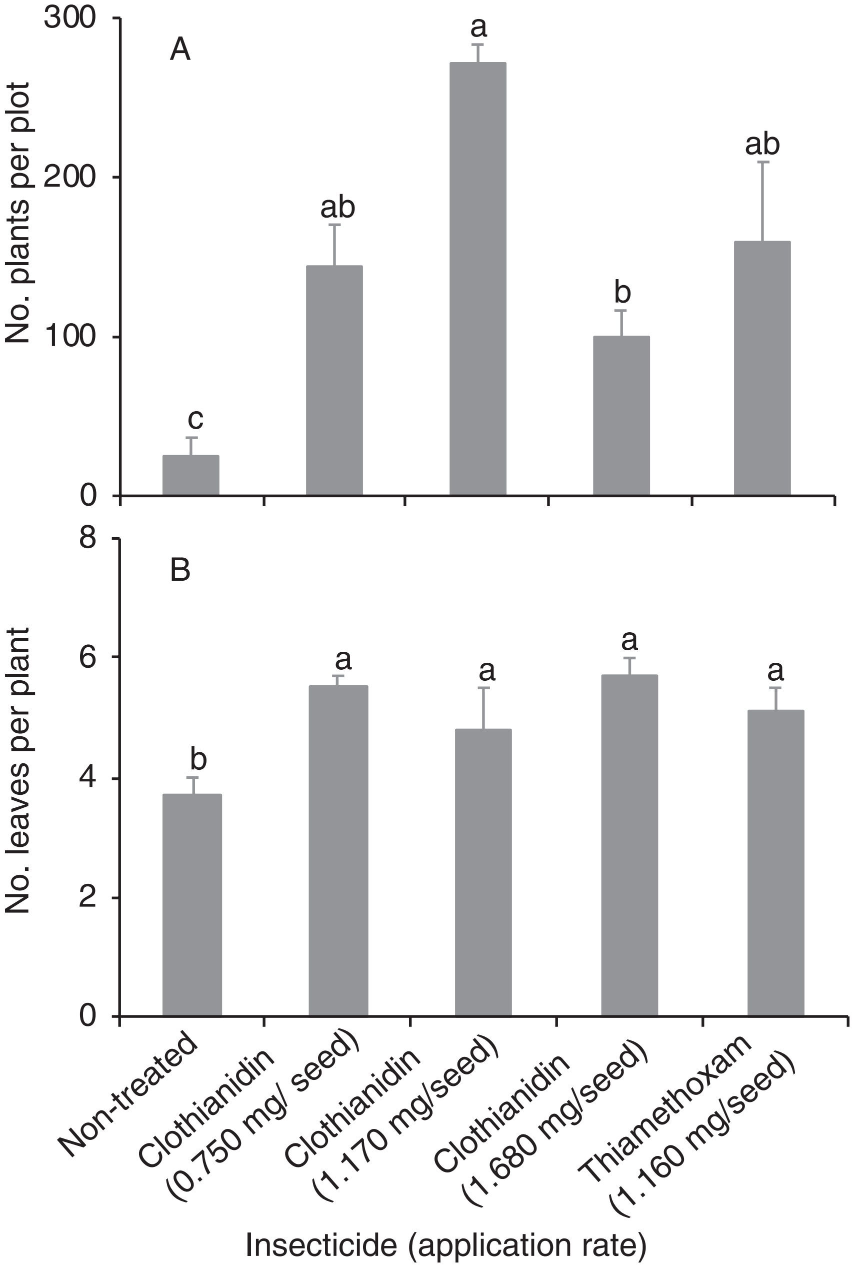

Fig. 3. Mean (± SE) number of young plants per plot (A), and number of leaves per plant (B) when various insecticide-coated cabbage seeds are exposed to natural *B. hilaris* populations in the second experiment. Bars with the same letters are not significantly different ($P > 0.05$).

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