Ecologically-based Pest Management Strategies for Imported Cabbageworm in Broccoli

Final Report for GNC15-214

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Grant Recipient: University of Minnesota
Region: North Central
State: Minnesota
Graduate Student:

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Project Information

Summary:

A controlled greenhouse study evaluated the effects of imported cabbageworm herbivory on induction of glucosinolates (secondary plant metabolites) and subsequent imported cabbageworm growth and performance on two broccoli (*Brassica oleracea* var. *italica*) cultivars ('Beneforte' and 'Green Magic'). A field study was performed in 2015 and 2016 at two sites to evaluate six broccoli cultivars ('Belstar,' 'Fiesta,' 'Green Magic,' 'Marathon,' 'Packman,' and 'Thompson') for natural resistance to imported cabbageworms and for performance in yield and crown quality. Our research goals were two-fold: 1) to advance the understanding of the roles that glucosinolates play in natural and induced plant resistance, especially on cultivated crops and 2) to make broccoli cultivar recommendations to organic growers, thereby contributing to Minnesota's ability to produce high-quality, organic broccoli.

Introduction:

The imported cabbageworm (*Pieris rapae* Linneaus) is an insect pest the feeds exclusively on species of the Brassicaceae. It is a serious economic pest in commercial horticulture as larvae chew large holes in leaves, can destroy developing heads of broccoli, cauliflower, and cabbage, and otherwise contaminate or stain produce, rendering it unmarketable. Imported cabbageworms are notoriously difficult to manage in organic production systems, and organic brassica growers traditionally rely upon floating row covers or biopesticides to prevent feeding damage. Natural pest resistance is important when making cultivar recommendations for production systems with limited pest management options, and glucosinolates (GSLs), secondary metabolites in brassicas, may play a role in

resistance to insect pests. GSLs are constitutive (naturally present) and inducible (activated) in the plant, and they are toxic to generalist insect pests. However, the relationship between GSLs and imported cabbageworms, a brassica specialist, is complex and not well understood, and more research must be done to better understand their roles in natural and induced resistance against insect pests, especially on cultivated crops.

Moreover, demand for local produce is on the rise in Minnesota and elsewhere in the Upper Midwest. While the demand for local produce has increased at the consumer level, there has not been a concurrent increase in research to meet those demands. In surveys done in 2009, 2011, and 2014 by the Minnesota Department of Agriculture, organic fruit and vegetable growers ranked "organic variety trials", "insect pests and management", and "variety development" as several of the top five research priorities. Though there are recent broccoli cultivar recommendations for the Upper Midwest, these recommendations assume conventional management. In organic systems, crops need to yield a consistent and high-quality product over diverse, sometimes sub-optimal, climatic conditions and endure various biotic and abiotic stressors, and therefore cultivar trials in organic systems should be performed to determine adaptability to local growing conditions and performance in systems with restricted agronomical practices.

Project Objectives:

Induced herbivory greenhouse study

i) Determine if feeding by imported cabbageworms influences broccoli defense by inducing two glucosinolates (glucobrassicin and neoglucobrassicin)

ii) Determine if previous feeding affects subsequent imported cabbageworm growth and performance

Broccoli cultivar trial

i) Determine natural imported cabbageworm egg and larval populations on six broccoli cultivars

ii) Determine concentrations of glucobrassicin and neoglucobrassicin of six broccoli cultivars and correlate to insect pressure

iii) Determine yield and crown grading of six broccoli cultivars

Cooperators

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Research

Materials and methods:

Induced herbivory greenhouse study

Three replicate experiments were performed in one year at the University of Minnesota – Twin Cities Plant Growth Facilities (St. Paul, MN) with 21ºC daytime temperatures and 15.5ºC nighttime temperatures and 12 hours of supplemental daylight. Two broccoli (*Brassica oleracea* var. *italica*) cultivars ('Beneforte' and 'Green Magic') were used in the study. 'Beneforte' was chosen for its higher than average concentrations of GSLs while 'Green Magic' was chosen for its lower than average GSL concentrations.

To inflict feeding damage, fourth instar imported cabbageworms fed on 2 month old broccoli foliage for 72 hours. Damage treatments were: 1) 0 larvae/plant as a control; 2) 2 larvae/plant as "light" damage; 3) 4 larvae/plant as "heavy" damage. After feeding damage, plant response was measured by quantifying GSL concentrations, specifically neoglucobrassicin and glucobrassicin, to determine if damage treatments induced the concentration of these GSLs to higher levels. Second instar imported cabbageworms then fed on damaged plants until pupation occurred. Days to pupation, pupal fresh weight, and leaf area consumed were measured to determine imported cabbageworm growth and performance in response to previous feeding damage.

Broccoli cultivar trial

In the summers of 2015 and 2016, a field study was performed at two certified organic farms in Minnesota, Cornercopia in St. Paul and Garden Farme in Ramsey. The Cornercopia plots were surrounded by diversified vegetables and buckwheat while the plot at Garden Farme was surrounded by wildflowers, raspberries, and horseradish. There were four replicates arranged in a randomized block design for each site and year. The study evaluated six broccoli cultivars ('Belstar,' 'Fiesta,' 'Green Magic,' 'Marathon,' 'Packman,' and 'Thompson') for natural resistance to imported cabbageworms and for performance in yield and crown quality. Cultivars were chosen based on their availability as organic or untreated seed and their tolerance to heat.

Seeds were started indoors in early June and transplanted in early July. Beginning three weeks after transplant, imported cabbageworm egg and larval populations were counted weekly by scouting a subset of plants in each plot. GSL concentrations were measured in foliage collected from plants at early-heading stage in mid-August. GSL concentration and egg and larval counts were then correlated. Mature crowns were harvested from late August to mid-September. Crowns were weighed and divided as marketable or unmarketable. Marketable crowns were then sorted based on quality (based on the US Standards for Grades of Italian Sprouting Broccoli).

Data analysis

All data were analyzed using R statistical software version 3.1.2 (The R Foundation for Statistical Computing, Vienna, Austria). In the greenhouse study, days to pupation data were log transformed to obtain normality; analysis was done on transformed data but untransformed means are reported. The significance of differences between treatments for GSL concentrations and *P. rapae* fitness parameters was determined using a one-way ANOVA. Significance of treatment by variety was done using a two-way ANOVA. Differences in mean values were identified using Tukey's Honest Significant Difference (HSD) and were considered

significant at the $P < 0.05$ level. In the cultivar trial, analyses of egg and larval counts and crown grading percentages were performed with the Kruskal-Wallis rank sum test at the $P<0.05$ level. If significant results were detected, additional posthoc tests were performed. The significance of difference in GSL concentrations as well as average marketable crown weights were determined using one-way ANOVA. Significance of year and location was determined using a two-way ANOVA. Differences in mean values were identified using Tukey's HSD and were considered significant at the $P<0.05$ level.

Research results and discussion:

Induced herbivory greenhouse study

Neoglucobrassicin and glucobrassicin concentration were not significantly different between damage treatments, indicating that feeding by fourth instar imported cabbageworms did not induce GSL to higher levels in this study, which is contrary to much of the published literature. However, the concentrations of these two GSL were significantly different between the two cultivars tested, with 'Beneforte' having higher levels of glucobrassicin overall and 'Green Magic' having higher levels of neoglucobrassicin.

The overall growth and performance of imported cabbageworms was influenced by cultivar but not by previous feeding damage. Overall, larvae consumed less total leaf area and weighed less as pupae when feeding on ‘Beneforte', indicating that cultivar may be important in resistance against imported cabbageworms. Though we could not make direct correlations between GSL concentrations and larval growth and performance parameters due to the need to remove leaf material, larvae showed more negative growth and performance on the cultivar that also had a significantly higher glucobrassicin concentration, suggesting a relationship.

In conclusion, it appears that cultivar is more important in larval growth and performance than the presence or absence of previous imported cabbageworm damage.

Broccoli cultivar trial

Mean egg and larval abundance did not significantly differ between the cultivars. This is similar to a study that found no difference in susceptibility of 6 kale varieties to imported cabbageworms (Santolamazza-Carbone et al. 2014). However, it contradicts studies that found that imported cabbageworm abundance was significantly different on 2 cabbage varieties (Broekgaarden et al. 2010 and Poleman et al. 2009). Moreover, in 2015, more eggs and larvae were counted on plants at Garden Farme than at Cornercopia, indicating that location had a large influence on imported cabbageworm abundance, and location may be more important than cultivar.

Neoglucobrassicin and glucobrassicin concentrations differed significantly by cultivar but differences were variable depending on year and location. Overall, 'Packman' had the lowest concentrations of neoglucobrassicin, though the results were not always significant, while 'Green Magic' had the lowest concentrations of glucobrassicin. GSL are sensitive to many biotic and abiotic factors, which may explain the variation across years and locations. Additionally, there was no strong relationship between neoglucobrassicin and glucobrassicin concentrations and egg and larval counts, indicating that these GSLs could not explain imported cabbageworm egg and larval abundance.

All yield and crown grading data were pooled to determine consistency in cultivar performance across diverse climates. 'Green Magic' produced the largest average marketable crowns (282 g) and the highest percentage (80%) of total marketable

crowns. 'Marathon' was the poorest performer, with an average marketable crown weight of 159 g and least consistency in yield. 'Belstar', 'Fiesta', 'Packman' were overall average performers with mid-range average marketable crown weights (220, 211, and 220 g, respectively), and between 72 and 77% of total marketable crowns. 'Thompson' produced the highest percentage of unmarketable crowns (53%) and had an average crown weight of 180 g.

Overall, we conclude that cultivar selection should not be based on natural resistance to pests in this case but rather based on performance. 'Belstar', 'Fiesta', 'Green Magic', and 'Packman' were top performers and produced a consistent and high-quality product. Therefore, we would recommend these cultivars as acceptable selections for organic systems in Minnesota.

Participation Summary

Educational & Outreach Activities

PARTICIPATION SUMMARY:

Education/outreach description:

Publications

Talbot, A. 2017. Evaluating natural and induced resistance of broccoli (*Brassica oleracea* var. *italica*) against *Pieris rapae.* Masters Thesis. University of Minnesota.

Academic Presentations

Talbot, A., M.A. Rogers, J. Cohen, C. Philips, and V. Fritz. 2016. Effects of glucosinolates in broccoli on imported cabbageworm larvae and implications for organic pest management. Poster presentation. American Society for Horticultural Science Annual Conference, Atlanta, GA. 8-11 August.

Public Presentations

Talbot, A. 2016. Evaluating organic broccoli cultivars for performance and natural pest resistance. Cornercopia Open House and Field Days. St. Paul, MN. 27 July and 20 Sept.

Talbot, A. 2016. Evaluating organic broccoli for natural pest resistance and performance in low-input systems. Horticulture Working Group Meeting, St. Paul, MN. 18 May.

Talbot, A. and J. Weis. 2016. Organic management of brassica insect pests. Minnesota Dept. of Agriculture Organic Conference, St. Cloud, MN. 9 January.

Talbot, A. 2015. Evaluation of six broccoli cultivars grown in organic systems. Minnesota Fruit and Vegetable Growers Association Research Tour, St. Paul, MN. 11 August.

Project Outcomes

Project outcomes:

We found that in a controlled environment imported cabbageworm growth and performance may be influenced by cultivar and that cultivars with higher

glucobrassicin content may affect imported cabbageworms more negatively. A reduction in growth and performance of one generation of imported cabbageworms may negatively affect the subsequent generation. However, it is unclear how these results translate to the field. Though cultivars varied significantly in GSL concentrations, we found no significant difference in susceptibility to imported cabbageworm abundance on the six cultivars grown in the field. GSL data are much more varied in the field, and more research must be done to elucidate their roles in an agricultural setting. It is clear, however, that location and year play an important role in insect pest populations.

Given the results from our cultivar trial, we would recommend 'Belstar', 'Fiesta', 'Green Magic', and 'Packman' broccoli cultivars for use in organic production systems in Minnesota, as they yielded well and produced high-quality crowns across years and locations. 'Marathon' and 'Thompson' did not produce a consistent crop, and therefore we would not recommended these varieties.

Economic Analysis

We do not currently have an economic analysis of the results of this study. Future work could evaluate the potential income generation of these particular cultivars based on yield and quality.

Farmer Adoption

As outcomes of this grant, we participated in two open house days through the University of Minnesota's student organic farm, Cornercopia, as well as at a research tour with the Minnesota Fruit and Vegetable Growers Association where we taught the participants about the importance of cultivar selection and natural pest resistance. Participants were engaged and enthusiastic about the cultivars in the study, but most were home gardeners. Moreover, we gave a talk at the Minnesota Organic Conference in St. Cloud, MN about managing brassica pests in organic systems, and roughly 30 farmers participated.

Recommendations:

Areas needing additional study

Additional studies should evaluate a wider range cultivars for natural resistance in both the field and greenhouse. We found significant results in the greenhouse, and additional work should elucidate these results. GSL types and classes as well as adult oviposition preference studies could elucidate these results and should be investigated

Minnesota is an ideal state to grow cool season crops such as broccoli, and a more robust study should evaluate a wider selection of cultivars for their performance in yield and crown quality across diverse conditions. An economic analysis of the potential income generation of cultivars based on performance would also be useful.

US Department of Agriculture

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