

NORTHEAST IPM PROPOSAL

A TRAP CROP SYSTEM FOR MANAGING TARNISHED PLANT BUG DAMAGE IN NORTHEAST STRAWBERRIES

8/1/10-7/31/11

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Revised Scope of Work, NE-RIMP Project 2010-02775

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SCOPE OF WORK:

The original proposal requested funds over three years to address three primary objectives, including several sub-objectives. The award was reduced to a one-year time period, with corresponding reduction in funds. Hence, we have modified our objectives accordingly. We will address parts of the original objective one and the first year of objective 3, while dropping objective 2. Our modified objectives are listed below:

Objective 1a. Quantify TPB abundance and strawberry damage as affected by management of winter canola: Insecticide control of TPB in canola.

The objective is to be addressed by G. Loeb and M. Pritts at Geneva and Ithaca Experiment Stations during the 2010-2011 field seasons.

Objective 1b. Quantify TPB abundance and strawberry damage as affected by management of winter canola: Bare ground barrier between canola and strawberry.

The objective is to be addressed, in consultation with the PI, by K. Demchak and R. Marini at PSU research farm during the 2010-2011 field seasons.

Objective 2. Quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York.

The objective is to be addressed primarily by G. Loeb along with cooperating growers in the Finger Lakes area of New York in consultation with M. Pritts, K. Demchak and R. Marini, during the 2010-2011 field seasons.

PROJECT NARRATIVE

PROBLEM, BACKGROUND & JUSTIFICATION:

Introduction/Problem Statement

The tarnished plant bug (TPB) *Lygus lineolaris* is a key pest of strawberries and many other crops grown in the Northeast and other regions in the country (Schaefer 1981, Young 1986). Both adult and immature TPB use their piercing and sucking mouthparts to feed on young, actively growing plant tissue, including developing strawberry fruit. In strawberries TPB feeding kills achenes and causes misshaped or catfaced fruit that can only be used for processing, greatly reducing its value (Schaefer 1972, Handley and Pollard 1993). Given the high value of fresh strawberry fruit, the threshold for damage from TPB is very low and insecticide control measures are often required, sometimes multiple times during the fruiting season (Schaefer 1972, Mailloux and Bostanian 1988, Kovach et al. 1993 Bostanian 1994). In NY and PA, the only NE states for which economic data is available, in 2008 a combined 2600 acres of strawberries were harvested with a value of \$22.7 million (USDA-NASS, 2009). Approximately 1800 additional acres are harvested in other Northeast IPM region states (USDA-NASS 2007b). Insecticides are applied to about 80% of this acreage (USDA NASS Agricultural Chemical Usage, 2001 and 2007a) with much of this targeting TPB at an estimated cost of a quarter to half a million dollars per year. In addition to the expense, the insecticides used are older generation materials (e.g. organophosphates, carbamates, pyrethroids) that have broad-spectrum activity and as such, can disrupt natural control of other arthropod pests of strawberry (e.g. spider mites). Newer, more narrow-spectrum insecticides are not particularly effective against TPB. Moreover, problems with insecticide resistance have also emerged in some cropping systems (Snodgrass 1996, Snodgrass and Scott 2000). Thus, there is a need for alternative approaches to TPB management that reduce or eliminate insecticide applications.

The goal of this project is to determine the potential of using an attractive trap crop to intercept TPB before they become established in the strawberry crop thereby reducing their abundance and damage in strawberry. An effective trap crop should be more attractive than strawberry, relatively inexpensive and easy to grow, and complement other farm production needs. The spring-flowering winter canola, *Brassica napus*, is an excellent candidate. It is termed winter canola (a winter annual) since it requires a winter chilling before flowering as compared to strictly annual canola that does not require chilling. Seed is available from commercial sources and is relatively inexpensive. It is seeded in the late summer/early fall, overwinters well, and begins flowering early in the field season prior to strawberry and at a time when overwintered adult TPB are searching for feeding and oviposition sites. Winter canola is a highly preferred host for TPB as it begins to form flowering inflorescences (see background). This proposal addresses three objectives to explore the practicality of using a winter canola trap crop for managing TPB in strawberries with a particular emphasis on June-bearing varieties. However, the results will have implications for managing TPB in day-neutral strawberries and tree fruit crops such as apples and peaches.

1. Quantify TPB abundance and strawberry damage as affected by proximity to and management of winter canola. We will use replicated plots of strawberry either companioned with winter canola or not to better quantify patterns of abundance of TPB and damage in strawberry. We also will examine three approaches to minimizing spill

over of TPB from canola to adjacent strawberry: 1) extend flowering time and attractiveness of winter canola by partial mowing, 2) killing TPB in canola with an insecticide and 3) including a bare ground barrier between canola and strawberry.

- 2) Evaluate winter canola varieties to maximize attractiveness to TPB but minimize TPB performance.** We propose to evaluate multiple winter canola cultivars under controlled cage and laboratory conditions for attractiveness to adult TPB, egg laying and nymph survival. The optimal variety would maximize attractiveness and egg laying but minimize TPB population growth potential.
- 3) Quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York and Pennsylvania.** The adoption of the winter canola trap crop approach to managing TPB by strawberry growers will depend, in part, on the level of control, the savings in terms of reduced pesticide use, and costs of planting and managing the trap crop. The most realistic way to obtain this information is through on-farm trials working with cooperating growers in representative areas of the Northeast region. Growers will assist us in ensuring that all costs are considered.

Background

The North American Strawberry Grower's Association (NASGA) and the California Strawberry Commission have provided funding to conduct preliminary experiments related to this project in 2008 and 2009 indicating clear interest and support from the grower community. Moreover, research on TPB is explicitly listed as a priority on the 2009 Northeastern IPM Center Vegetable Working Group list of needs and priorities (http://northeastipm.org/work_vegpriority2009.cfm). The report also notes a general need for research on how to promote plant health and suppress insect, disease and weed problems through cultural and biological production practices, which this project directly addresses. In the 2007 New England Pest Management Strategic Plan for Strawberry, TPB is listed as one of three key insect pests (<http://www.ipmcenters.org/pmsp/pdf/NewEnglandStrawberryPMSP.pdf>). Based on the report, 87% of strawberry acreage is affected annually with yield losses of up to 100% without management. One of the research needs identified in this report is to "Discover an effective way to target management against egg-laying females before bloom period in the crop." The report also indicates a need for the development and testing of organic options for managing TPB and a trap crop approach may accomplish this. One of our field trials (Ithaca) will be conducted using organic practices. The reports mentioned above, authored by committees made up of growers, extension educators, and researchers, clearly indicate our project is addressing the needs of stakeholders. We include letters of support from individual strawberry growers and grower groups in the appendix.

Lygus spp. are important pests of numerous crops grown worldwide including the US and Canada (Knight 1975, Young 1986, Schwartz and Footitt 1998, Wheeler 2001 and references therein). *L. lineolaris* or tarnished plant bug (TPB) feeds on over 300 different hosts including dozens of plants of agricultural importance (Young 1986). TPB is a significant pest of many fruit crops (e.g. strawberries, peaches, raspberries, apples), vegetable crops (beans, lettuce, broccoli, tomatoes, peppers) and field and seed crops (cotton, alfalfa, canola) (Young 1986). Specifically, it feeds on rapidly dividing tissue such as young fruit (Tingey and Pillemer 1977, Young 1986).

Of the dozens of crops damaged by TPB, strawberries are particularly vulnerable. TPB feed on and kill embryos causing seriously misshaped fruit (apical seediness, catfacing) (Handley and Pollard 1993). These fruit are not suitable for fresh market thereby greatly reducing their value. Because of the high value of strawberries, the economic threshold for TPB is quite low (Mailloux and Bostanian 1988). Hence, growers often resort to broad-spectrum insecticides. Examples include pyrethroids (e.g. Danitol [fenprothrin]), organophosphates (e.g. malathion), and carbamates (e.g. Lannate [methomyl]) (USDA NASS 2007a). The wide use of insecticides can lead to increased occurrence of insecticide resistance and destruction of the TPB natural enemy complex.

The focus of this proposal is on TPB as a pest of June-bearing strawberries (see Pritts and Handley 1998 for description of production practices). June-bearing varieties are grown as perennials, flowering for a brief period early in the growing season. They are mostly grown in central and northern states with New England, NY, PA, MI, OH, and Pacific Northwest being the major producing areas. TPB is a pest of both day-neutral and June-bearing strawberry. The restricted flowering and fruiting time of June-bearing varieties, however, may enhance the effectiveness of a trap crop approach. The use of winter canola as a trap crop for day-neutral varieties grown as annuals is beyond the scope of this project, although some of the results are applicable.

TPB overwinters as adults and is multivoltine, completing ≥ 2 generations per year depending on latitude. Survival of adults over the winter is reported to be relatively low in cold climates (Painter 1929). We assessed this using cages placed outdoors containing wild-caught adult TPB in late fall and quantifying survival through the winter. The result suggests that in colder climates adult abundance in spring is low and this may increase the effectiveness of trap crops.

Overwintered adults are first observed on early-flowering weed species including a number of different species in the Brassica family (Boivin et al. 1981, Cleveland 1982, Snodgrass et al. 1984, Fleischer and Gaylor 1987, Womack and Schuster 1987, Bostanian 1994). Through the season, TPB tracks host plants based on flowering phenology (Boivin et al. 1981, Bostanian 1994, Loeb et al. 2007). Since strawberry is one the first crop plants to begin flowering in the spring, it is also colonized by overwintered adults. Both these adults and the first generation nymphs cause injury to June-bearing strawberry (Mailloux and Bostanian 1988). Hence, the focus of a trap crop in relation to managing damage from TPB in June-bearing strawberries is on the overwintered adults.

Trap Crops and Lygus Bugs

Trap crops represent a manipulation of the agricultural landscape in which stands of plants that attract or in other ways intercept the pest are deployed near the focal crop thereby reducing pest abundance and damage (see reviews by Hokkanen (1991) and Shelton and Badenes-Perez (2006)). To be effective, trap crops should be more attractive than the focal crop during at least part of the growing season. There is precedence for the successful use of trap crops in controlling *Lygus spp.* Western tarnished plant bug (WTPB) *Lygus hesperus* has a strong preference for alfalfa over cotton and strips of alfalfa interplanted with cotton can

significantly reduce damage to cotton squares (Sevacherian and Stern 1974, Godfrey and Leigh 1994). Alfalfa has also been used as a trap crop for managing WTPB damage in a commercial planting of day-neutral strawberry. Sewzey et al. (2007) showed that WTPB concentrated in alfalfa strips near organic strawberry. Vacuuming the WTPB from the alfalfa resulted in reduced damage in strawberry that was comparable to vacuuming the entire strawberry planting (standard organic control measure) that lacked the alfalfa strip leading to significant economic savings for the grower. Without vacuuming the alfalfa, WTPB spilled over into the adjacent strawberry causing increased damage.

The success of a trap crop is dependent on the target pest and cropping system. Several factors come into play but the bottom line for TPB and June-bearing strawberry is that the trap crop needs to flower prior to June-bearing strawberry and be a preferred host for TPB. As noted above, alfalfa is a preferred host for *Lygus* species however it does not flower prior to June-bearing strawberries (Loeb et al. 2007). As an alternative to alfalfa, we propose using canola *Brassica napus* as a trap crop for TPB in the June-bearing system. Canola is grown in many parts of the world for its oil and for forage. Winter varieties of canola require chilling before flowering. They are seeded in late summer/early fall, overwinter as rosette plants, and flower early in the spring. Our initial studies, involving ten cultivars, indicate that winter canola overwinters well in the Finger Lakes region of New York and forms flowering buds and flowers a week or more before June-bearing strawberry. Overwintered TPB readily colonized winter canola in our trials, starting at the flower bud initiation period. At the same date, TPB did not colonize adjacent strawberry plots that were not yet flowering (mean in canola = 2.7 bugs per 30 s vacuum sample, SE = 0.3, mean in strawberry = 0.0, $X^2 = 39.4$, $P < 0.001$, generalized linear model (GLM) procedure). In our initial trial with winter canola and strawberry, TPB abundance during the strawberry fruiting period was lower in the middle of strawberry plots adjacent to winter canola compared to the middle of strawberry plots lacking canola (mean for strawberry with canola = 0.5 bugs, SE = 0.3, mean for strawberry without canola = 2.0, SE = 1.1, $X^2 = 3.85$, $P = 0.05$, GLM procedure). On the exterior of plots, however, we did observe a spike in TPB damage in strawberry plots with canola (mean = 9.9 damaged berries/m, SE = 2.4) compared to the strawberry edge without canola (mean = 4.0 damaged berries/m, SE = 0.7) ($X^2 = 9.9$, $P = 0.002$, GLM procedure). We address this spill over effect in this grant by either treating the canola with an insecticide as strawberry begins to flower, manipulating the winter canola by partial mowing to lengthen the flowering period thereby maintaining attractiveness, or by including a bare-ground barrier between the canola and strawberry.

Using early flowering to concentrate a pest to allow more efficient control has been successful in other systems. Such an approach has been shown to have promise at commercial scale for winter canola as the focal crop and the cabbage seedpod weevil as the pest (Cárcamo et al. 2007). These researchers planted a perimeter trap crop of *B. rapa*, a close relative of winter canola, that flowers about 1 week earlier than winter canola. The weevils concentrated in the trap crop where they were treated with an insecticide leading to a net reduction in pesticide use and costs. A similar approach has been used against Colorado potato beetle using early-planted potato on field margins to concentrate overwintered adult beetles (Hunt and Whitfield 1996, Hoy et al. 2000).

The mobility of the target pest and method of host finding will also influence the success of a trap crop. Trap crops are less likely to be successful for pests that have a limited ability to detect and move to hosts such as some species of aphids (Potting et al. 2005). *Lygus* bugs are well known for their mobility (Butler 1972, Fleischer et al. 1988, Carriere et al. 2006) and behavioral and population studies clearly indicate an ability to actively find hosts (Boivin and Stewart 1983, Fleischer et al. 1988, Loeb et al. 2007).

Practical considerations of winter canola as a trap crop

In addition to being effective in reducing damage in the focal crop, a trap crop has to be practical and cost effective for the grower relative to the alternative management tactic (e.g. insecticides). Winter canola has several advantages as a trap crop for TPB and June-bearing strawberries. Because it is an important oil crop, winter canola seed is readily available and reasonably priced (\$10/acre at a seeding rate of 5 lb/acre). Also because it is an agricultural crop, a number of insecticides are labeled for use on it if it is necessary to treat to prevent movement of TPB into strawberry (mainly pyrethroids like gamma-cyhalothron [Proaxis], and lambda-cyhalothrin [Warrior]). There is not a concern for pathogens moving from canola to strawberry. To the contrary, mustard species, including canola, have been investigated for their potential as biofumigants to suppress nematodes and diseases (Halbrendt 1996, Kirkegaard and Sarwar 1998, Matthiessen and Shackleton 2005). More generally, canola is considered a good rotational crop as a source of soil organic matter and soil aeration. Winter canola is not a strong competitor and will not present a major weed problem. In our winter canola plots, we find limited amounts of self-seeding the following year. The area covered by the trap crop will influence costs and benefits and the key is finding the correct balance between being large enough to trap sufficient numbers of TPB but not so large that it is prohibitively expensive. The specific requirements will depend on the system but based on other successful examples, 8 to 15% trap crop area to crop area is to be expected (Shelton and Badenes-Perez 2006).

Justification

The principal beneficiaries from this research are growers in the Northeast who produce June-bearing strawberries for whole-sale, retail, direct and U-Pick markets who experience regular problems with TPB. As noted previously, this would entail the majority of growers in the Northeast (see New England Pest Management Strategic Plan for Strawberry), but also growers in the north central and northwest regions of the US (over 6,000 acres,) (USDA NASS 2007b) who primarily produce June-bearing strawberries. Although not explicitly examined in this proposal, some of the results and principals are applicable to managing TPB for day-neutral strawberries. Moreover, TPB is also a major problem early in the season for apple and peach crops in the Northeast (Agnello et al. 2006) where winter canola trap crops could be effective.

The current approach to managing TPB involves monitoring and application of broad-spectrum insecticides when the economic injury level is exceeded. Use of a canola trap crop offers several potential economic and environmental advantages over broad-spectrum insecticides. Consider a hypothetical 5-acre planting of June-bearing strawberry with a history of TPB problems where the grower has needed to apply insecticide 1.5 times per season at a cost of \$225/yr for the five acres. Compare this to planting a 0.5 acre strip of canola (10% of area of crop) at a cost of \$5 for the seed and three hours of labor/machinery use for land prep and seeding = \$75. Even adding in an additional \$15 to the costs to treat the half-acre of canola with

an insecticide to prevent damage to berries on the border would bring the cost to \$95 with the trap crop compared to \$225 for insecticide-based management. The difference could be larger if a miticide (\$200/five acres) is also required in some years due insecticide disruption of natural biological control of spider mites. Hence, the amount of insecticide could be reduced, along with accompanying negative impacts on the environment and potentially on human health, without increased costs of production. This assumes the trap crop is equally effective in controlling damage as insecticide control as well as other assumptions. The research proposed here will allow us to better estimate the costs and benefits of a canola trap crop. We will be able to provide growers with essential information for decision making, thus paving the way for adoption of a novel approach to managing this key strawberry pest.

OBJECTIVES AND ANTICIPATED IMPACTS:

This research project addresses three primary research objectives that upon completion will produce the knowledge base necessary to recommend the use of winter canola as a trap crop for managing TPB damage in strawberries grown in the Northeast while reducing the use of disruptive, broad-spectrum insecticides. The specific objectives are:

- 1. Quantify TPB abundance and strawberry damage as affected by proximity to and management of winter canola.**
- 2) Evaluate winter canola varieties to maximize attractiveness to TPB but minimize TPB performance.**
- 3) Quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York and Pennsylvania.**

Based on results of this research, a novel IPM practice could be adopted by the majority of strawberry growers growing June-bearing strawberries in the NE. We estimate the results would directly apply to over 4,000 acres of strawberries in the Northeast and an additional 6,000+ acres grown in the north central and northwest sections of the country where June-bearing strawberries are predominantly grown (USDA NASS 2009). The use of a trap crop to keep TPB out of June-bearing strawberries could reduce application of insecticides on strawberry by one or more application per acre. Almost all insecticides used for controlling TPB in strawberries would be considered high risk in that they are broad-spectrum, older generation materials that negatively affect beneficial arthropods.

The economic benefits of using a winter canola trap crop would come directly from reduced expenses for broad-spectrum insecticides to control TPB. This would be balanced against the extra costs of planting and managing winter canola. Assuming 1.5 insecticide applications are saved per acre of strawberries where the trap crop is employed with an estimated per application cost of \$30/A, this would save \$45/A. A winter canola trap crop, using 1/10 acre trap crop per acre strawberry, is estimated to cost \$16 per acre of strawberry (assume seed = \$10 per acre canola, planting costs = \$150 per acre of canola at \$25/hr for labor and machinery) for a net savings of nearly \$30/A. Additional savings could come from not needing to apply insecticides or miticides for secondary pests created by the use of broad-spectrum insecticides on TPB. Additional costs of the trap crop could come from a need to treat with insecticide to prevent TPB from moving into the edge of strawberry plantings.

In the Northeast there are approximately 2500 commercial growers producing June-bearing strawberries (USDA NASS 2007b). Given the financial and environmental incentives outlined above, we anticipate that a substantial number of growers would be interested in adopting a trap crop tactic. In addition to these incentives, a canola trap crop tactic could benefit PYO operations in terms of advertisement of environmentally sound IPM practices. Also, growers may find other benefits to using canola, such as suppression of nematodes or increasing soil organic matter.

Although this is not explicitly an extension proposal, there will be an outreach effort to educate strawberry growers about the benefits of using the trap crop approach. Part of that effort will involve at least one article summarizing results for the web-based *New York Berry News* [<http://www.nysaes.cornell.edu/pp/extension/tfabp/newslett.shtml>] and Penn State's *Fruit Times* [<http://fruittimes.cas.psu.edu>] and *Vegetable and Small Fruit Gazette* [<http://horticulture.psu.edu/cms/veg crops/node/112>]. Articles from these sites are re-distributed by regional and county-based extension offices and are frequently reprinted in newsletters reaching growers in other states. We will also prepare an article for the *New York Fruit Quarterly*, a publication of the New York Horticulture Society that reaches the majority of strawberry growers in New York. We do not have specific plans to conduct formal training sessions during this project although the 8 cooperating growers we work with as part of objective 3 will receive training to carry out the project and it is likely that some of these sites will serve as sites for twilight meetings or other grower meetings.

It is difficult to estimate adoption rates, but given the above outlined advantages, we can anticipate growers will be very interested. Not only is there potentially significant economic and environmental savings, an effective trap crop could remove an important impediment (insecticides for TPB) to transitioning to organic production. Organic strawberry production is currently uncommon in the Northeast.

APPROACH AND PROCEDURES BY OBJECTIVE:

Objective 1. Quantify TPB abundance and strawberry damage as affected by proximity to and management of winter canola.

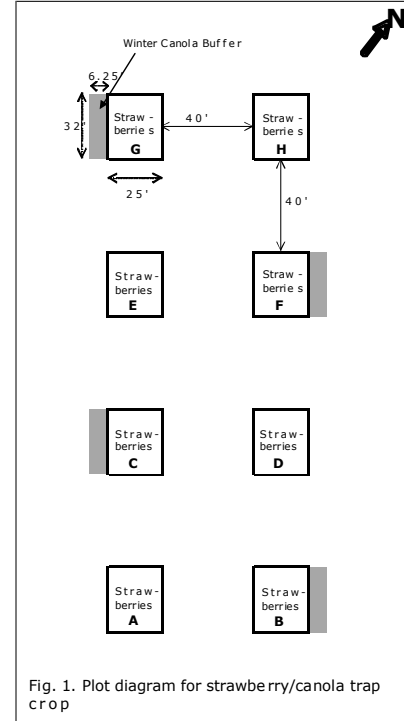
We will accomplish this objective in two phases or sub-objectives. In phase 1, we will compare TPB abundance and damage in strawberry for plots adjacent to winter canola and plots without canola. In phase 2, we will examine several options to minimize the movement of TPB from winter canola into border area of strawberries.

1a, Phase 1. The experiment is a randomized complete block design of the June-bearing strawberry cultivar 'Jewel', planted in the spring of 2008 (Geneva Experiment Station) and spring of 2009 (Cornell Experiment Station in

Ithaca), and the plot plan is shown in Figure 1. This is a matted row production system with 4-foot centers and planting density of one plant per 12 inches. There are 8 rows of strawberry per plot with each row roughly 25 ft in length (area of plot = 800 ft²). Plots are separated from each other by 40 ft in all directions. Orchard grass was seeded around the plots and this will be mowed on a regular basis to minimize presence of any flowering weed species. In late August 2009 winter canola was seeded on one edge of half the strawberry plots at a rate of 5 lb/A (6.25' by 32' = 200 ft²) using a mixture of varieties found to be attractive in preliminary experiments conducted in 2008-2009. We will evaluate patterns of TPB colonization, population size, and damage to strawberry using these plots in 2010, 2011, and 2012 with modifications described below.

Abundance of TPB will be assessed at least once per week by timed vacuum sampling (30 seconds to 1 minute per sample) in winter canola, strawberry adjacent to canola, strawberry without canola and mowed grass/weeds adjacent to strawberry without canola. After counting, TPB will be returned to the area from which they were collected from, after being immobilized with CO₂. We will take samples in the strawberry plots at two distances from the borderline with the trap crop or border grass (0-3 ft away for an edge sample, 9 to 15 ft away for an interior sample). For plots with winter canola, we will take samples from each of the four sides of the rectangular plot of canola. For plots without canola, samples will be collected from a corresponding area of mowed mixed grass and weeds. Samples will be collected from the start of flower initiation in winter canola and continue through fruit ripening. Damage assessments of strawberries will be taken from 10 randomly chosen 1.5 ft sections in the edge 3 ft zone (either adjacent to winter canola or grass edge) and from 10 randomly chosen 1.5 ft sections in the interior of strawberry rows (9-15 ft). For each assessment, all near ripe to ripe berries will be collected, counted, scored for characteristic TPB damage, other damage, or poor pollination (see Rhainds et al. 2002), and weighed.

Data analysis and expected results. Depending on data distribution and variances, appropriate transformations will be performed as needed, and data will be analyzed using either PROC GLIMEX or PROC MIXED in SAS (SAS Institute 2009) to evaluate the influence of winter canola, distance from edge, and time on abundance of TPB in strawberry and TPB damage. We anticipate that TPB will concentrate in winter canola as it starts to form flower buds. This should translate into reduced TPB abundance and damage in adjacent plots of strawberry relative to strawberry plots without canola, especially in interior areas. However, TPB abundance and fruit damage at the edge of winter canola may be increased relative to control plots due to spilling over of TPB from the canola. We address this issue under phase 2 experiments described below in the second and third year of the project.



Potential pitfall. We are experienced with the horticultural practices associated with management of strawberry plants and also with canola. One potential issue could be that plots of strawberry are not sufficiently separated such that winter canola will influence TPB colonization patterns for the isolated strawberry plot. To reduce interplot movement between strawberry without canola and strawberry with canola we will place 1 m high vertical barriers made from shade cloth between plots. This has been shown to reduce movement of TPB among plots of trefoil (Wipfli et al. 1991). The majority of TPB move below 1m height (Ridgway and Gyrisco 1960). If we experience weed problems within the canola planting we will double the seeding rate in subsequent trials.

1b, Phase 2. Based on our preliminary data (background section), we anticipate some spill over of TPB from winter canola into the edge of adjacent strawberry plots. In phase 2 we propose to test three different approaches to minimizing this movement in the second and third year of the study. Approach 1 is to treat the canola with insecticide as the canola goes to seed and the strawberry begins to set fruit, to be carried out in year 2 of the project (2011 field season). Half of the canola plots at the Geneva planting will be treated with the pyrethroid Warrior II once at a rate of 1.5 fl. oz/A at the time of strawberry fruit set. At the Ithaca site, an organic insecticide with pyrethrum (Pyganic EC 5.0) will be applied twice, seven days apart, at a rate of 16 fl. oz/A to half of the canola plots. Plots will be evaluated for TPB and TPB damage as detailed under phase 1.

Approach 2 to be tested at both Geneva and Ithaca in 2012, involves lengthening the flowering time of winter canola to maintain attractiveness through the major fruiting period of strawberry. This will be achieved by cutting tops of 50% of winter canola plants for half of the winter canola plots after flower bud formation in the spring using a weed whip. Based on previous trials (Loeb unpublished), this will promote regrowth and delayed flowering thereby effectively lengthening the presence of flowers in the canola plot by several weeks. Preliminary behavioral trials indicate that flowering canola is significantly more attractive to TPB adults than flowering strawberry (over 90% of adult TPB chose flowering canola over flowering strawberry in a cage choice test). Plots will be evaluated for TPB and TPB damage as detailed under phase 1.

Approach 3 involves evaluating the effect of different distances of a bare ground barrier between the canola and strawberry planting on movement of TPB from canola to strawberries. This will be tested during the 2010-11 and 2011-12 field seasons using a mixed strawberry variety plot located at the PSU Horticulture Research Farm at Rock Springs, PA. The planting is comprised of 180' long rows of strawberry of 2 cultivars in a randomized design with a total of 8 rows. A 12-foot wide canola strip will be planted in the late summer of 2010 at a 45 degree angle relative to the strawberry rows running half of the length of the rows. Starting at mid-field, a second diagonal row of canola will be planted. The soil surface around the canola will be kept free of vegetation. Vertical barriers that are perpendicular to the rows of strawberries and also divide the row of canola will be set up at 12.5 ft increments or less. These barriers will channel dispersing TBP towards the strawberries, rather than within the canola row. During the 2011 field season TPB abundance will be assessed in each canola plot and in the first four rows of strawberries across from the canola block once per week from canola bloom through strawberry harvest using a vacuum sampling system as described above. TPB damage to strawberry fruit

will be evaluated in each strawberry plot across from canola. Details in carrying out the experiment may be modified slightly for the second season if potential improvements in design become apparent.

Data analysis and expected results. Depending on data distribution and variances, appropriate transformations will be performed as needed, and data will be analyzed using either PROC GLIMEX or PROC MIXED in SAS (SAS Institute 2009) to evaluate the influence of winter canola, distance from edge, and time on abundance of TPB in strawberry and TPB damage. Approach 3 will be evaluated by regressing the distance of bare ground on TPB abundance and fruit damage. We anticipate that TPB will concentrate in winter canola as it starts to form flower buds. Insecticide treatment of canola will reduce TPB damage in border strawberries relative to strawberries bordering canola not treated with insecticide. We also anticipate that extending flowering of the winter canola will decrease the spill over effect from canola to strawberry. Separating canola from strawberry with bare ground should reduce damage in strawberry up to some optimum distance.

Potential pitfalls. Cutting strips of winter canola to stimulate regrowth and extended flowering may disturb TPB, causing them to move. However, we plan to do the cutting prior to flowering of strawberry and therefore, do not anticipate the TPB will settle there. There is a concern that treating canola with a pyrethroid insecticide may have a negative impact on any pollinators present in the canola. Timing of insecticide application will be at the end of the canola bloom period, when the canola is less attractive to bees but hopefully prior to the time that tarnished plant bugs may move to the strawberries.

Objective 2) Evaluate winter canola varieties to maximize attractiveness to TPB but minimize TPB performance.

In our preliminary research we identified five cultivars of winter canola that met our basic requirements for an effective trap crop: they establish and survive the winter well, bloom prior to June-bearing strawberry, and are readily colonized by overwintered TPB. The five cultivars are Kronos, Sitro, Baldur, Virginia, and KS4022 (advanced selection from Kansas State canola breeding program) (Stamm et al. 2008). Here we propose to further evaluate these cultivars for differences in adult attraction and colonization, oviposition, and nymphal survival.

Seed from the five varieties will be obtained from Dr. Mike Stamm, Canola Breeder at Kansas State University. Prior to experiments described below seedlings will be chilled in growth chambers in order to initiate flowering and then will be maintained in the greenhouse. TPB for these trials will be obtained from our laboratory colony. These are reared on artificial diet following methods described by Cohen (2000).

2a. Adult orientation and colonization. A Y-tube olfactometer, as described by Blackmer et al. (2004), will be used to compare relative attraction of adult TPB to the five winter canola cultivars, each initially compared to strawberry leaves. Briefly, filtered, moistened air is pushed through each arm of the Y-tube and out the bottom leg. Prior to entering the arm, filtered air is pushed through chambers that will either contain intact strawberry leaves (strawberries will be vegetative when canola is blooming) or intact flower buds or flowers of winter canola. Adult

TPB, starved for 24 to 48 hours, are singly placed in the bottom leg of the Y-tube and allowed to move upwind. A choice is recorded when the adult moves into one arm or the other. Note the adult is not able to see the test plants and screening prevents escape out the ends of the arms. After making a choice, or 5 minutes, the adult is carefully removed from the Y-tube and the tubes cleaned before the next trial. A minimum of 25 males and females (approximately 7 days old, and assumed to be mated) will be tested for each cultivar. The three most preferred cultivars relative to strawberry foliage will be compared against each other using the Y-tube olfactometer (three pair-wise combinations) to determine relative attractiveness.

Screen cages approximately 1.0m in length by 0.6m in depth and 0.6m in height will be used following procedures outlined by Fleischer and Gaylor (1987) to evaluate colonization by adult TPB for the three most attractive winter canola varieties above. Plants of roughly similar total surface area are placed on either side of cage with an equal number of TPB ($n = 30$ at a 1:1 sex ratio) placed on each side. A partition in the middle of the cage (made of wood) is closed for the first 24 hours to allow bugs to settle. After 24 hours the partition is removed so that bugs can move freely between the two sides. After 48 hours the partition is replaced and the number and sex of TPB present on either side is determined. Trials for each of the three pair-wise comparisons will be repeated at least three times using multiple cages.

2b. Oviposition and egg survival. Following procedures developed in the Loeb lab (Rhains and English-Loeb 2003) we will assess female oviposition choice and egg survival for the five canola varieties listed above. We will use large plastic cages with holes cut in the bottom through which the inflorescences of the five cultivars will be inserted. Seventy-five adult TPB (2:1 female to male ratio), 7-10 days in age, will be released into the cage and allowed to forage and oviposit for 48 hours at which time they will be removed with an aspirator. Plants will be moved to the greenhouse and maintained for four days at which time the portion of the inflorescence inserted into the cage will be cut and the stem placed in a water pick. A dissecting scope with transmitted light will be used to count eggs after which the tissue will be placed into rearing cups. After an additional 4 days the tissue will be examined for live nymphs. The cage oviposition and egg survival trial will be repeated at least ten times.

2c. Survival and development of nymphs. We will use potted plants that have initiated flowering to assess survival and development of nymphs for the five winter canola varieties listed above. Twenty second instar TPB nymphs will be transferred into organically grown cages attached around the flowering inflorescence of each plant. They will be allowed to feed for two weeks at which time the developmental stage (nymph or adult) and weight of each surviving TPB will be recorded. At least 10 replicates of each winter canola variety will be assessed.

Data analysis and expected results. Response of adult TPB in Y-tube trials will be evaluated using logistic regression. A logistic model with a robust variance estimator to account for possible within-plant correlation will be used to assess TPB choice of canola plants in colonization trial using partitioned cages (SAS Institute 2009). Depending on data distribution and variances, appropriate transformations will be performed as needed, and data will be analyzed using either PROC GLIMMIX or PROC MIXED in SAS (SAS Institute 2009) to evaluate the influence of winter canola variety on number of eggs oviposited and number of nymphs that successfully hatch. The effect of variety on egg survival (number of

nymphs/number of eggs) will be tested using ANOVA after arcsin transformation. Logistic regression will be used to analyze the effect of variety on survival and developmental stage of nymphs caged for two weeks on inflorescences (dead, live nymph, live adult). A priori we do not know the degree to which differences among varieties will emerge in these trials. We do know in field tests that the number of TPB found in plots varies among winter canola varieties (preliminary data).

Potential pitfalls. We do not anticipate any major problems accomplishing these lab and greenhouse experiments. The Y-tube olfactometer system has been successfully tested in Loeb lab as have techniques for choice tests in cages, oviposition and egg survival quantification, and rearing of nymphs in organandy sacks. The one possible constraint is that we will need to repeat some experiments over time to obtain sufficient sample sizes and this will be accounted for in statistical analyses.

Objective 3. Quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York and Pennsylvania.

We will directly work with 8 commercial strawberry growers to quantify the practicality of using winter canola as a trap crop to manage TPB damage in June-bearing strawberry. (See appendix for letters from the growers who have so far agreed to participate.) At each farm a single established block of strawberry approximately 1 to 5 acres in size will be selected. The block will have rows at least 180 ft long and contain at least 30 rows. Canola will be seeded at 10 lb/acre rate in the fall of 2010 parallel to rows at one end covering an area roughly equal to 10% of half of the field while the opposite end of the rows will not have canola. The grower will prepare the land for seeding in early August. The strawberry planting will be managed following standard grower practices with the exception that strawberry rows used for assessments (see below) will not be treated with broad-spectrum insecticide until data have been collected.

Assessments will involve both quantification of TPB, TPB damage, and yield and costs associated with managing the trap crop. The following season after seeding of canola researchers will assess TPB abundance in canola, in the first two edge rows of strawberry immediately adjacent to canola, in interior rows 7-8 adjacent to canola, in the first two edge rows of strawberry on far side of the block away from the canola, and in interior rows 7-8 away from canola using techniques described under objective 1 from the start of flowering in canola to near harvest. Depending on the landscape surrounding the strawberry field, the location of the area planted to canola and sampling locations may be changed to minimize the effect of non-treatment influences on the results. During harvest fruit in ten randomly chosen 1.5ft subplots within the four strawberry sampling areas will be evaluated for TPB damage, weight, and yield.

In order to better assess costs associated with the trap crop, cooperating growers will be requested to record the following information:

1. Time and equipment used to prepare and seed field and mow/disk after harvest.
2. Use of section of land if it had not been used for winter canola.

The trial will be repeated during the 2011-2012 season, making modifications based on results from the previous year and other objectives.

Data analysis and expected results. Depending on data distribution and variances, appropriate transformations will be performed as needed, and data will be analyzed using either PROC GLIMEX or PROC MIXED in SAS (SAS Institute 2009) to evaluate the influence of winter canola, distance from edge, time, and site on TPB abundance or damaged fruit. Data will be analyzed as a randomized complete block design, where farms will serve as blocks. Combining damage and yield data with grower assessments and estimated costs of grower time, equipment time, seed costs and other costs we will model the costs and benefits associated with the use of the canola trap crop. Some changes may be made in the second year depending on results from this and other objectives.

Potential pitfalls. One risk with this objective is that TPB populations may not be high at some sites. Conducting trials at multiple sites will help address this, as well as finding cooperators with a history of TPB pressure.

TIME FRAME OF ACTIVITIES:

PA collaborators will focus mainly on Obj. 1b, approach 3 and Obj. 3 with PA growers. NY collaborators will work on all objectives.

Objective	Fall/wint 2009-10	Sp/sum 2010	Fall/wint 2010-11	Sp/sum 2011	Fall/wint 2011	Sp/sum 2012	Fall 2012
Obj. 1a,	X	X					
Obj.1b, app 1			X	X			
Obj.1b, app 2					X	X	
Obj.1b, app 3			X	X	X	X	
Obj. 2a		X	X				
Obj. 2b			X	X	X		
Obj. 2c					X	X	
Objective 3			X	X	X	X	
Analysis			X	X	X	X	X
Reports					X	X	X

EVALUATION PLAN:

Please refer to our Logic Model for this project. Results of this research will provide a foundation for going forward with implementation of a trap crop approach using winter canola to manage TPB in June-bearing strawberry. The anticipated impacts of this research on future strawberry production and IPM practices in the Northeast and other regions where June-bearing strawberry are produced, however, will not be measurable within the three year time frame of the project. Beyond the project we will have the on-farm experiences and data from objective 3 to share with growers through extension publications, summer and winter meetings and informal conversations. Also, the growers cooperating with this project will have opportunities to share results with other growers. All of the collaborators on this project have significant formal extension responsibilities and work closely with extension educators, strawberry growers and grower organizations. To aid in incorporating the trap crop tactic into existing crop management, we will develop a “how to” manual to be made available as a web-based resource. In addition, as authors of the *Cornell Pest Management Guidelines for Berry Crops* (M. Pritts is

editor and author of horticultural information, G. Loeb authors the sections on arthropod management) and the *Mid-Atlantic Berry Guide for Berry Growers* (K. Demchak, coordinator), we will include reference to the trap crop tactic and associated published information as an alternative to broad-spectrum insecticides. Because this is a novel approach, future surveys of grower practices will be very informative as to the extent of adoption and the associated changes in pesticide applications.

KEY PERSONNEL:

Greg Loeb (PI): Responsible for coordinating all aspects of the proposed research, including preparation of reports and publications. His program will manage the day to day research at Geneva (objective 1 and objective 2) as well as assist with assessments of plots at the Ithaca site for objective 1. His program will also manage on-farm trials in New York (Objective 3) and assist with on-farm trials in PA.

Marvin Pritts (Co-PI): Responsible for supervising research conducted in Ithaca with particular emphasis on objective 1 and will assist with on-farm trials associated with objective 3. Responsible for providing guidance on all aspects of this research and leadership on horticultural practices related to strawberry production.

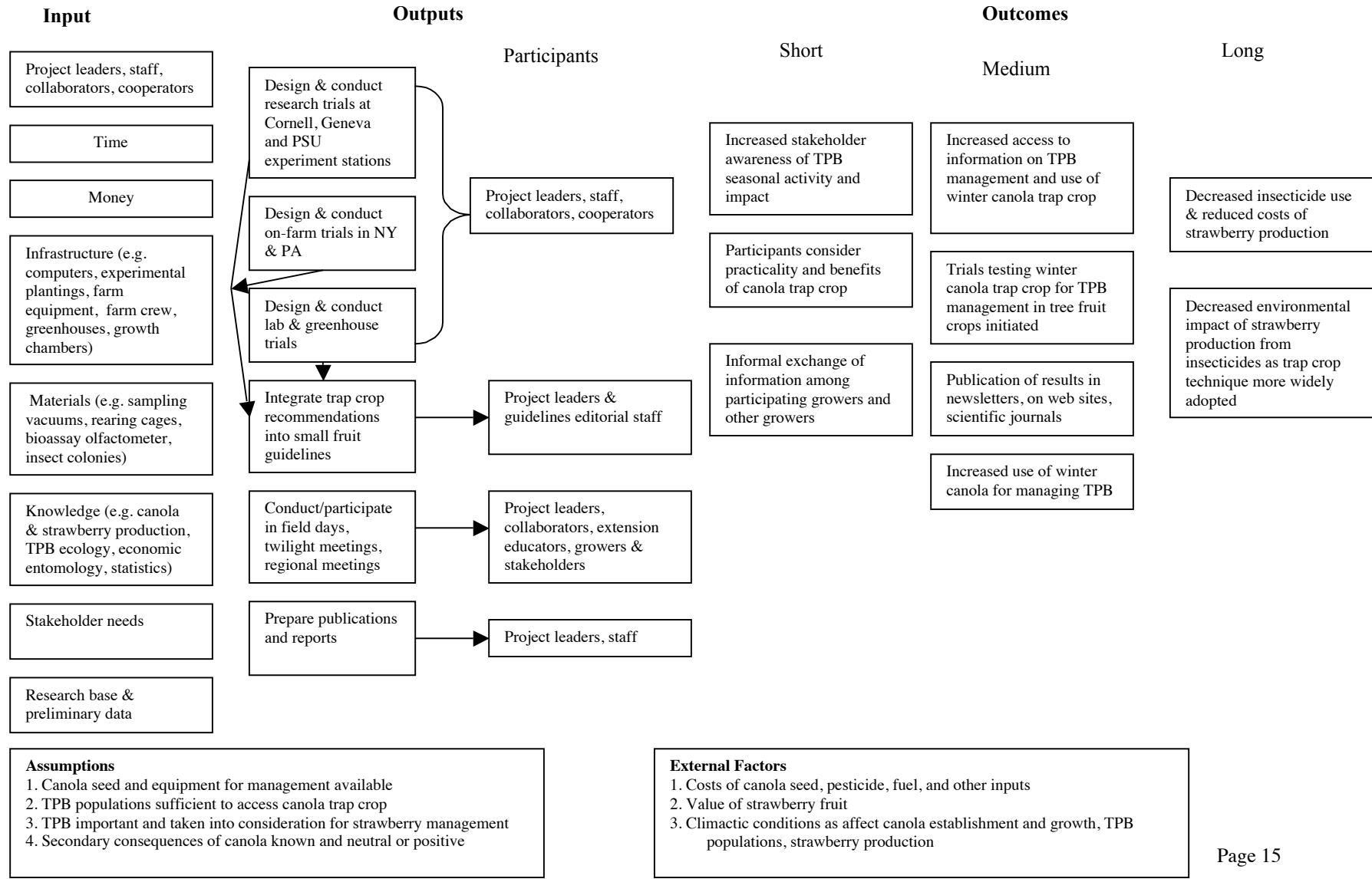
Kathy Demchak (Co-PI): Responsible for managing the day-to-day research outlined in Objective 1b, approach 3 assessing role of bare ground in minimizing movement of TPB from canola to strawberry and on-farm trials conducted in PA (objective 3). Responsible for providing guidance on all aspects of this research and leadership on horticultural practices.

Richard Marini (Co-PI): Responsible for providing guidance on experimental design and statistical analyses for all research objectives as well as horticultural practices.

SITUATION:

Tarnished plant bug (TPB) is a key pest of strawberry fruit in the Northeast with a low economic threshold resulting in the regular use of broad-spectrum insecticides that are costly and harm beneficials. An alternative approach to insecticides is to use an attractive trap crop (winter canola) to intercept overwintered TPB thereby reducing damage in strawberry and insecticide use.

PROGRAM ACTION-LOGIC MODEL



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RELEVANCE STATEMENT

Project Leaders & Cooperators

1. Dr. Greg Loeb (PI), Dept. Entomology, Cornell University
2. Dr. Marvin Pritts (Co-PI), Dept. Horticultural Sciences, Cornell University
3. Kathy Demchak (Co-PI), Dept Horticulture, Penn State University
4. Dr. Richard Marini (Co-PI), Dept. Horticulture, Penn State University

Project Title: A Trap Crop System for Managing Tarnished Plant Bug Damage in Northeast Strawberries

Project Type: Research

Project Summary:

This is a multi-state research project to develop an alternative to broad-spectrum insecticides to manage tarnished plant bug (TPB) in strawberries. TPB is a key insect pest of strawberries in the northeastern USA and many other regions of the country. The economic threshold for TPB is low in strawberry, and the application of broad-spectrum insecticides are frequently required leading to increased costs, and dangers to pesticide applicators and the agroecosystem, including negative effects on beneficial predators of strawberry pests. Our goal is to develop methods for using of winter canola, a highly preferred early-flowering crucifer, as a trap crop to attract and concentrate overwintered TPB adults from the surrounding areas thereby reducing colonization and damage in strawberry. Our specific objectives are to 1) quantify TPB abundance and strawberry damage as affected by proximity to and management of winter canola, 2) evaluate winter canola varieties to maximize attractiveness to TPB but minimize TPB population growth, and 3) quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York and Pennsylvania. Grower adoption of the results of this project could lead to substantial reduction in insecticide use and costs for strawberries grown in northeastern and north central states. The project addresses numerous objectives of the NE-RIPM program (e.g. reduce environmental and human risks, reduce dependence on pesticides, advance IPM principals in a relatively short timeframe, interdisciplinary) as well as the broad goal of advancing IPM knowledge and practices for multiple states in the northeast and surrounding regions.

Problem, Background and Justification:

The tarnished plant bug (TPB) *Lygus lineolaris* is a key pest of strawberries and many other crops grown in the Northeast and other regions in the country. In strawberries TPB feeding causes misshaped or catfaced fruit that can only be used for processing, greatly reducing its value. Given the high value of fresh strawberry fruit, the threshold for damage from TPB is very low and insecticide control measures are often required. In NY and PA in 2008 a combined 2600 acres of strawberries were harvested with a value of \$22.7 million. Approximately 1800 additional acres were harvested in other Northeast IPM region states. Insecticides are applied to about 80% of this acreage with much of this targeting TPB at an estimated cost of a quarter to half a million dollars per year. In addition to the expense, the insecticides used are older generation materials (e.g. organophosphates, carbamates, pyrethroids) that have broad-spectrum activity and as

such, can disrupt natural control of other arthropod pests of strawberry (e.g. spider mites). Newer, more narrow-spectrum insecticides are not particularly effective against TPB. Thus, there is a need for alternative approaches to TPB management that reduce or eliminate insecticide applications.

The goal of this project is to assess the potential of using an attractive trap crop to intercept overwintered adult TPB before they become established in strawberry thereby reducing their abundance and damage. An effective trap crop should be more attractive than strawberry, relatively inexpensive and easy to grow, and complement other farm production needs. Based on ongoing research with strawberries at Cornell University, the spring-flowering winter canola, *Brassica napus*, is an excellent candidate. Seed is commercially available and is relatively inexpensive. It is seeded in the late summer/early fall, overwinters well, and begins flowering early in the field season prior to strawberry and at a time when overwintered adult TPB are searching for feeding and oviposition sites. Winter canola is a highly preferred host for TPB. In addition to serving as a TPB management tool, canola also could provide secondary benefits to growers as a soil biofumigant and source of organic matter. Winter canola is not a significant weed threat.

This project addresses the 14 outlined priorities in the following ways:

1. Reduce risks to the environment.	Only broad-spectrum insecticides are available and effective for management of TBP. The approach proposed will minimize insecticide application for this pest.
2. Reduce risks to human health.	TPB populations build in the strawberry crop prior to and during harvest, when the general public, often including children, is present in U-pick operations. The proposed approach should reduce the need for insecticides in this crop before and during harvest.
3. Stakeholder support, priority is cited.	Research on TPB is listed as a priority by the 2009 Northeastern IPM Center Vegetable Working Group and in the 2007 New England Pest Management Strategic Plan for Strawberry.
4. Pest found in at least 5 NE states.	Pest is problematic on strawberries and other fruit and vegetable crops in all states in the NE region.
5. Project fills a niche.	No effective non-chemical or reduced chemical control measures for this pest are available.
6. Multiple states, active partnership.	Project cooperators have a history of conducting coordinated trials and are located in NY and PA, the 2 NE states with the greatest number of strawberry growers and production.
7. Will advance IPM in 3 years.	Useable results will be produced within this time frame.
8. Interdisciplinary approach.	This project combines horticultural and entomological expertise to improve the strawberry growing system as a whole.
9. Reduce dependence on chemical pesticides.	This is one of the main goals of this project.
10. Has significant economic	Though per acre savings from reduced pesticide costs and lower crop loss may not be high, the large acreage grown of this crop

implications.	and high value translates into significant potential total savings.
11. Addresses underserved audiences.	While underserved audiences are not specifically targeted, the test crop is grown by a diverse set of clientele ranging from large growers to small producers just starting in agricultural production.
12. Emerging pest or problem.	TPB is not an emerging pest, but is a serious pest nonetheless.
13. Adoption by the target audience.	Traditional growers may adopt practices made possible by this research. Higher adoption rate may occur among those who wish to begin organic or sustainable fruit production, but can't because there are few TPB management tools beyond broad-spectrum insecticides. Multiple benefits of canola as a trap crop and rotational soil-building characteristics may encourage adoption.
14. Advances cost-effective IPM practice.	Costs resulting from adopting this research will be no higher, and are expected to be lower than control measures currently used.

Project Objectives and Anticipated Outcomes

This proposal addresses three objectives to explore the practicality of using a canola trap crop for managing TPB in June-bearing strawberries. The results will have implications for managing TPB in day-neutral strawberries and tree fruit crops.

- 1) Quantify TPB abundance and strawberry damage as affected by proximity to and management of winter canola.**
- 2) Evaluate winter canola varieties to maximize attractiveness to TPB but minimize TPB population growth.**
- 3) Quantify the benefits and costs associated with winter canola as a trap crop for commercial strawberry plantings in New York and Pennsylvania.**

Based on results of this research, a novel IPM practice (trap cropping with canola) could be adopted by many strawberry growers growing June-bearing strawberries in the northeast, north central and northwest regions affecting approximately 7,000 acres. The environmental and human health benefit of using a winter canola trap crop would come directly from reduced use of broad-spectrum insecticides to control TPB. There is also a potential economic savings through less insecticide use, although this needs to be balanced against the extra costs of planting and managing winter canola. Additional savings could come from not needing to apply insecticides or miticides for secondary pest problems created by the use of broad-spectrum insecticides on TPB. Having additional options for management of TPB may result in decreased crop loss for sustainable producers, though this may be difficult to measure.

Results of our research will be made available to growers through extension publications, winter and twilight meetings, and grower to grower communications. We will also include information on trap cropping in the *Cornell Pest Management Guidelines for Berry Crops* (M. Pritts, editor) and the *Mid-Atlantic Berry Guide for Berry Growers* (K. Demchak, coordinator). In this way, we anticipate having an impact on IPM practices in strawberries within three to five years. Please see our Logic Model on the following page.