FINAL Report

Name of Partner Organization: Lincoln University

Project Title: *Improving the Profitability of Small Farms in Missouri by Reducing Inputs through the Integration of Farmscaping and Small Ruminants for Insect Pest and Weed Control.*

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Summary: This 3-year research / outreach project aimed at developing sustainable, biologically intensive pest management solutions that integrate farmscaping components (trap cropping and insectary plants) with selective small ruminant grazing for insect pest and weed control and to improve the long-term overall profitability of organic vegetable production systems by reducing input costs and providing ancillary ecosystem services. Results from University research revealed that a trap crop mixture composed of Red Russian kale, glossy collards and mighty mustard was effective at attracting specific pests such as the cross-striped cabbage worms, harlequin bugs, and aphids, pulling them away from the cash crop. However, other pest species such as the imported cabbage worm was evenly distributed in trap crop and cash crop plants, an indication that there is still a need to improve the trap cropping system developed. The integration of trap cropping and insectary plants reduced pest densities in a field-scale study, demonstrating the potential of becoming an effective component of IPM by maximizing natural enemy - pest interactions. Research at grower cooperators' land showed that for farm # 1 Red Russian Kale was the best trap crop for indicating aphid pressure. For farm # 2, the trap crop mixture also attracted aphids and Harlequin bugs, resulting in less pest densities in the broccoli cash crop. Aphid mummies (aphids that were parasitized by a wasp) were found only on trap crop plants. Additional research indicated that AZERA® and Pyganic® insecticides applied at the highest label rate is the most viable tool organic farmers have to suppress hard-to-kill insects such as harlequin bugs. The last project objective aimed at assessing the effectiveness of sheep grazing for controlling weeds while also suppressing insect pests through grazing. At the University farm, weaned lambs were used to graze the grass in the row middles of a blueberry orchard. The type of fencing used was Gallagher Smart Fence, a 4-strand portable fence, and a solar-powered energizer to electrify the fence. The sheep were confined to the grassy areas between the rows and along the edges. While this type of selective grazing proven effective, some mowing was still necessary but mowing intervals were which led to some cost savings. Several farmers in Missouri have adopted farmscaping as a simple, effective, and affordable approach to enhance the abundance and diversity of natural enemies (parasitic wasps and predatory insects) of key pests of vegetables. Overall, this project has resulted in the development of organic IPM strategies that effectively protect Brassica crops from the most important insect pests. The numerous outreach activities that were conducted reached over 2,000 farmers in a 3-year period.

Introduction

Brassicas are important commercially grown vegetable crops that are attacked by multiple insect pests. The most common lepidopteran pests are the cabbage looper, *Trichoplusia ni* (Noctuidae), the cabbage moth, *Mamestra brassicae* (Noctuidae), the diamondback moth, *Plutella xylostella* (Plutellidae), the imported cabbageworm, *Pieris rapae* (Pieridae), and the cross-striped cabbageworm, *Evergestis rimosalis* (Pyralidae). Besides lepidopteran pests, brassicas are also fed upon by several aphid species (Hemiptera: Aphididae), cabbage maggot, *Delia radicum*, (Diptera: Anthomyiidae), flea beetles (Coleoptera: Chrysomelidae), and the harlequin bug, *Murgantia histrionica* (Hemiptera: Pentatomidae). Managing this complex of insect pests represents a challenge for organic producers. While some OMRI-listed botanical and microbial insecticides are available to producers, in some cases they are expensive and, in most cases, lack residual activity. Boosting populations of naturally occurring beneficial insects has been advocated as a more sustainable alternative to the insecticide-based pest control. However, in agricultural monocultures, non-crop vegetation is usually excluded to minimize competition with crops and maximize yield. The resulting high concentrations of entirely uniform crops allow herbivores to build up large populations rapidly. Experiments have demonstrated that less diversified systems tend to have more pest outbreaks than more diversified system. As a result, many modern agroecosystems have unfavorable environments for beneficial arthropods due to high levels of disturbance and lack of enough floral resources. In a farmscaping context, insectary plants are used to enhance the survival, fecundity, longevity and behavior of natural enemies and increase their effectiveness at suppressing pests in nearby crops. Organic farmers are also looking at alternatives for weed management. This main goal of this project was to evaluate trap cropping (non-crop plants) to attract and arrest pests, and insectary plants to bring beneficial arthropods to the cropped areas. Additional research aimed at evaluating grazing by sheep to vegetable residue (on-farm research) as a way of conducting field sanitation by removing the pests and the host plants after harvest.

Research results

Objective 1: To evaluate the attractiveness of six Brassica trap crops to multiple insect pests in the absence of a cash crop (years 1 and 2).

Two field experiments were conducted in 2014 and 2015 at the Lincoln University, Alan T. Busby Organic Research Farm, Jefferson City, MO to evaluate (1) the attractiveness of eight different trap crops to the key pests of crucifers (2014) and (2) the efficacy of selected trap crops in reducing the densities of multiple pest species in cabbage (2015).

In 2004 (= potted-plant trials), 3 field trials were conducted encompassing entire growing season during early- (May-June), mid- (June-July) and late- (August-November) field trials in the year 2014. The trap crops evaluated were arugula, *Eruca sativa* (cv. Arugula OG), broccoli, *B. oleracea* var. italica (cv. Bestar), cabbage (cv. Farao), collards (cv. Champion), kale, *B. oleracea* var. acephala (cv. Red Russian), mighty mustard, *B. juncea* (cv. Pacific Gold), mustard greens (cv. Southern Giant Curl) and rapini, *B. rapa* (cv. Spring Raab) for their attractiveness to the key crucifer pests. Each field trial was conducted in a randomized complete block design (RCBD) with four replications. A replicate consisted randomly arranged rows of eight trap crops spaced 1.2 m apart. Within a row, a total of six plants of each trap crop were placed with 46 cm spacing. The potted trap crops were exposed to a natural population of insect pests from May 6 to June 16, June 19 to August 4, and September 18 to November 7 for the early-, mid- and late-field trials, respectively. Observations for crucifer pests [e. g., imported cabbageworm (ICW), diamondback moth (DBM) and harlequin bug] were recorded by assessing a whole plant (n = 6) twice a week. At each observation, the number of eggs laid by ICW and harlequin bug on trap crops were recorded and marked to avoid repetition in subsequent observations. Similarly, the numbers of immature stages (larvae and pupae) of ICW and DBM, the nymphs and adults of harlequin bug were recorded and removed after each recording. For ICW and DBM, the number of larvae and pupae were summed for each observation to obtain the combined numbers of immature (larvae + pupae). Similarly, for harlequin bug, the numbers of nymphs and adults were summed to obtain the combined numbers of (nymphs + adults). The cumulative numbers of eggs (ICW and harlequin bug), immatures (ICW and DBM), and nymphs and adults (harlequin bug) on individual plants were obtained for the entire observational period of a trial. In addition, the numbers of other pest species [e. g., flea beetles, *Lygus* spp., cabbage weevil, cabbage looper (CL) and aphids] were also recorded but without removing them.

Based on the findings of 2014 trial, for the 2015 study (= field-scale trial) 3 trap crops were selected: collards, kale and mighty mustard were selected as potential trap crops, each attractive to particular pest species. Thus, five different trap cropping treatments: (1) collard, (2) kale, (3) mighty mustard, (4) mix – a mixture of collards, kale and mighty mustard, and (5) control – cabbage were used to further assess their efficacy in reducing the densities of key crucifer pests on the main crop (cabbage, cv. Golden Acre). A border trap cropping system with 10% of plants as a trap crop was designed to evaluate their impact on the key pest in cabbage crop.

<u>Highlight of results: Potted-plant trials – 2014.</u>

Imported cabbageworm (ICW). In the early-season trial, the number of eggs per plant was significantly greater in collards compared to other trap crops ($t_{1,\,21}$ = - 4.3, P < 0.05). The number of larvae + cocoons recorded per plant was also significantly greater in collards compared to other trap crops ($t_{1,\,21}$ = - 3.9, P < 0.05), except broccoli (Fig. 1A). Unlike this result, in the mid-season trial, the number of eggs was significantly greater in broccoli compared to other trap crops ($t_{1,\,21}$ = - 4.7, P < 0.05), whereas the number of immatures was similar among the trap crops (Fig. 1B). In the late-season trial, the numbers of ICW stages were very low to produce any significant differences among the trap crops. Based on the results from all three field trials, collards and broccoli were the most attractive trap crops for ICW in early- and mid-trials, respectively.

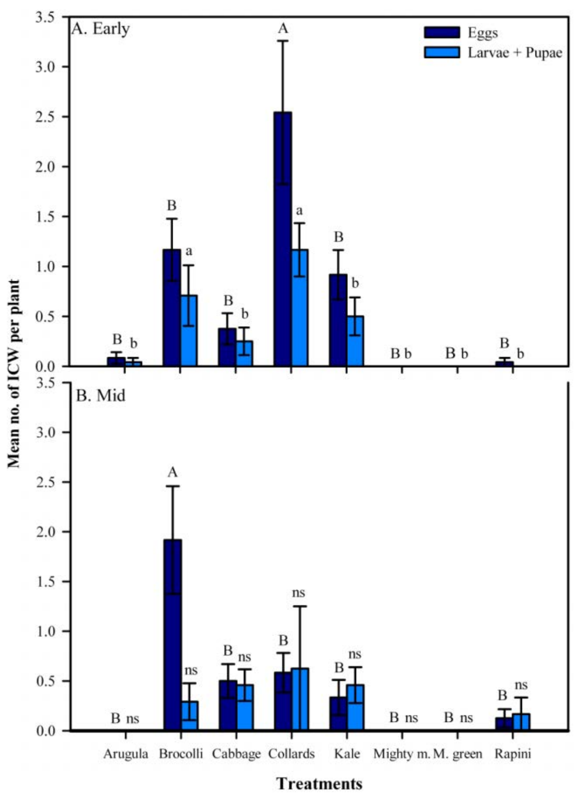


Figure 1. Mean numbers of imported cabbageworm (ICW) eggs, and larvae and pupae (± SE) per trap crop plant in (A) early- and (B) mid-season trials. For each insect immature stage, bars with different letters indicate significant differences according to ANOVA and Tukey's tests at P ≤ 0.05. **On the right: Imported cabbage worm.**

Diamondback moth (DBM). The mean number of DBM immatures per plant was highest in the mid- (0.40 ± 0.08) followed by late- (0.08 ± 0.02) and early-season (0.07 ± 0.02) field trials. In the mid-season trial, the number of immatures was significantly greater in kale compared to other trap crops ($t_{1,\,21}$ = -4.3 – 5.6, P < 0.05). In other field trials (early and late), the numbers of immatures were similar among the trap crops (Fig.2). This result showed that at higher densities of DBM (as in case of mid-trial), kale was the most attractive trap crop.

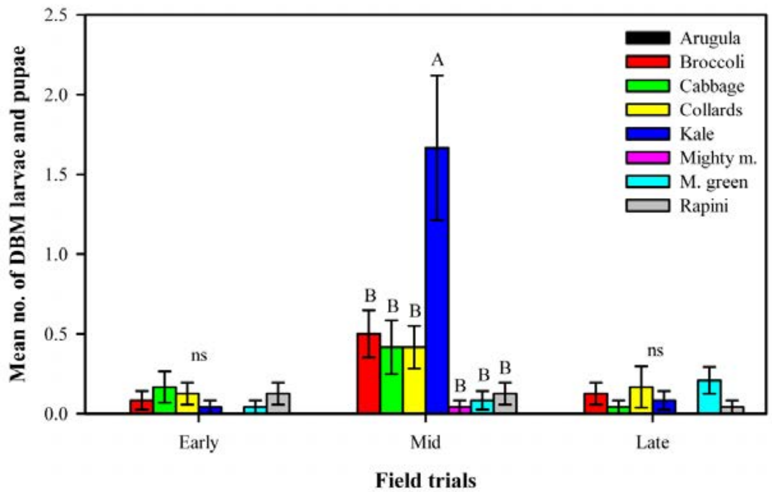


Figure 2. Mean number of diamondback moth (DBM) larvae and pupae (± SEM) per trap crop plant in early-, mid-, and late-season trials. For each trial, bars with different letters indicate significant differences according to ANOVA and Tukey's tests at P ≤ 0.05. **On the right: Diamondback moth.**

Harlequin bug. A population of harlequin bug was observed in mid- and late-field trials. In the mid-trial, a total of 8 batches of eggs were found on mustard greens (mean = 4.0 per plant) compared to none on other trap crops ($F_{7, 21}$ = 3.4, P = 0.01). In addition, the numbers of nymphs and adults were greatest in mustard greens and mighty mustard, but did not differ significantly with other trap crops. In the late trial, the harlequin bug oviposition was not observed and the number of nymphs and adults was lower (0.03 ± 0.02) than that was observed in the mid trial (0.95 ± 0.23). The results showed that mustard greens were the most preferred host for oviposition, while nymphs and adults were equally attractive to mustard greens and mighty mustard.

Other insect pest species. Populations of other pest species (flea beetles, *Lygus* spp., and cabbage weevil) were occurred in the early- and mid-trials and were significantly greater in mighty mustard, mustard greens and rapini compared to other trap crops. Infestation of cabbage looper was not observed and a very low population of aphid was recorded (data not shown).

Highlight of results: Field-scale trial – 2015.

Imported cabbageworm (ICW). The number of ICW eggs was significantly greater in collards (5.18 ± 0.54) ($t_{1, 12}$ = -2.8, P < 0.05) and was significantly fewer on mighty mustard (0.38 ± 0.70) ($t_{1, 12}$ = 4.8, P < 0.05), compared to other trap crops (Fig. 3A). The number of ICW immatures was significantly fewer on mighty mustard (0.03 ± 0.02) than other trap crop ($t_{1, 12}$ = 2.3, P < 0.05) (Fig. 3B). Despite of these differences, the numbers of both eggs and immatures were not significantly different among trap cropping treatments (Fig. 3A and 3B).

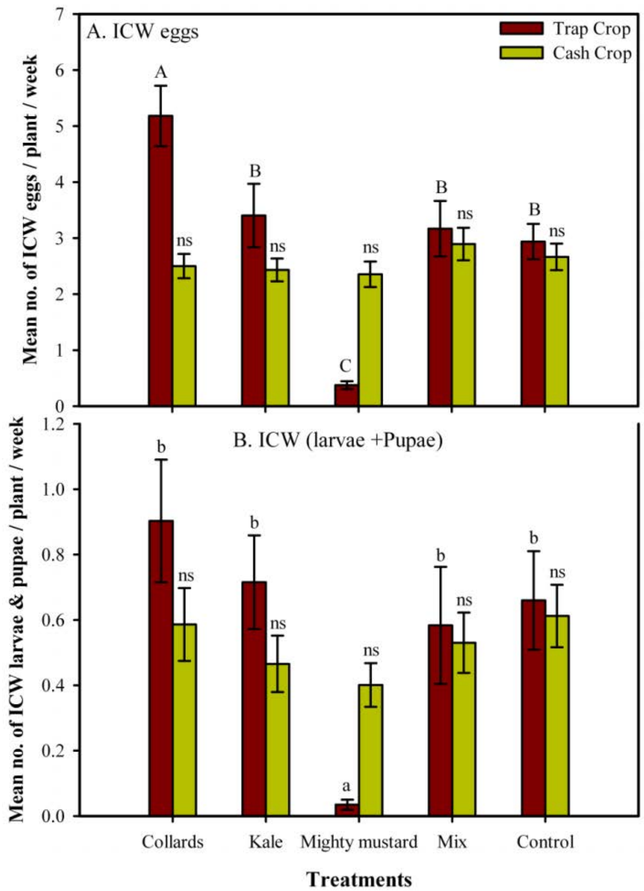


Figure 3. Mean number of imported cabbageworm (ICW) eggs (A), and larvae and pupae (B) per plant per week on perimeter-row trap crops planted either, singly or in a mixture and cash crop (cabbage) plants, compared to control plots (no trap crops). For each type of plant (trap crop or cash crop) bars with different letters indicate significant differences according to ANOVA and Tukey's tests at $P \leq 0.05$.

Correlation analyses for ICW showed the numbers in trap crops were positively related with the numbers in cabbage (Table 1). Among the trap cropping treatments, the positive relationship was greatest in the control plot (Table 1).

Table 1. Relationship between the number of caterpillar pest species (stages) that occurred in trap crops and cabbage (cash crop) based on the Pearson's correlation coefficient.

Trap crops / **Caterpillar pests (stage)**	**Collards**	**Kale**	**Mighty mustard**	**Mix**	**Control**	**Overall**
ICW (egg)	0.39*	0.23*	0.09	0.25*	0.43*	0.27*
ICW (larva + pupa)	0.46*	0.50*	0.03	0.17*	0.63*	0.39*
CL (egg)	0.05	0.20*	-0.02	0.03	0.05	0.11*
CL (larva + pupa)	0.15*	0.18*	0.06	0.36*	0.28*	0.20*
DBM (larva + pupa)	0.09	0.04	-0.02	0.07	-0.05	0.05

Asterisks represent significant relationships between pest numbers that occurred on trap crops and cabbage cash crop at 5% level of significance.

Cabbage looper (CL). The number of CL eggs was significantly greater in kale (0.34 ± 0.09) compared to mighty mustard (0.02 ± 0.02) and control (0.10 ± 0.04) ($t_{1,\,12}$ = -2.7 – 3.6, P < 0.05) (Fig. 4). The number of CL immatures was similar among the trap crops. Despite of these differences, the numbers of both eggs and immatures were not significantly different in cabbage receiving different trap cropping treatments. The correlation analyses for CL showed the number of immatures was positively related with the numbers in cabbage and this relationship was greatest in the mix treatment (Table 1).

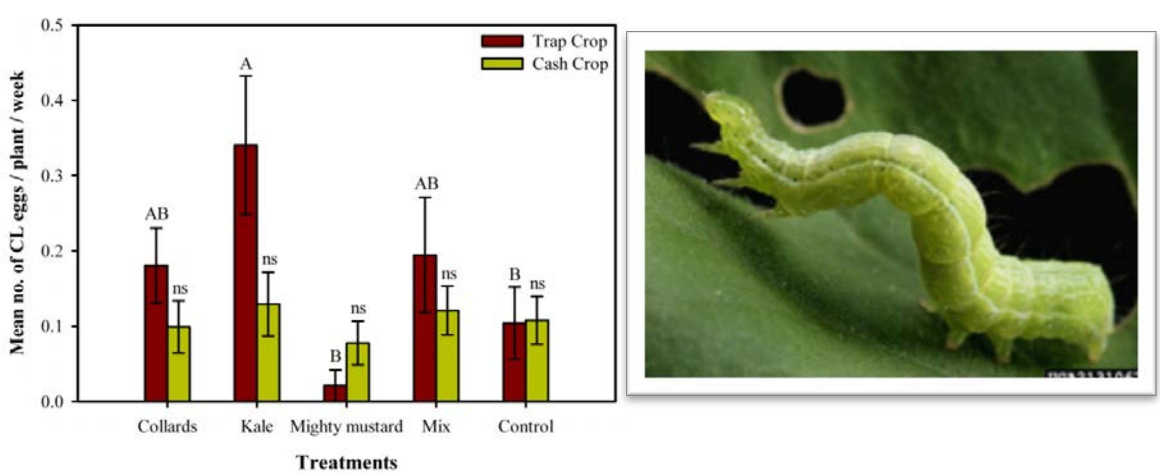


Figure 4. Mean numbers of cabbage looper (CL) eggs (± SEM) per trap crop and cabbage per week. For each type of plant (trap crop or cash crop) bars with different letters indicate significant differences according to ANOVA and Tukey's tests at P ≤ 0.05. **On the right: Cabbage looper.**

Diamondback moth (DBM). The number of DBM immatures was significantly greater in kale (0.42 ± 0.08) compared to other trap crops ($t_{1,\ 12}$ = -5.4 – 6.2, $P < 0.05$); and significantly fewer in mighty mustard (0.01 ± 0.01) compared to kale, collards and mix trap crops ($t_{1,\ 12}$ = 2.3 – 6.3, $P < 0.05$) (Fig. 5). The correlation analyses showed the number of immatures in trap crops was not related with the numbers in cabbage, irrespective of treatments being imposed (Table 1).

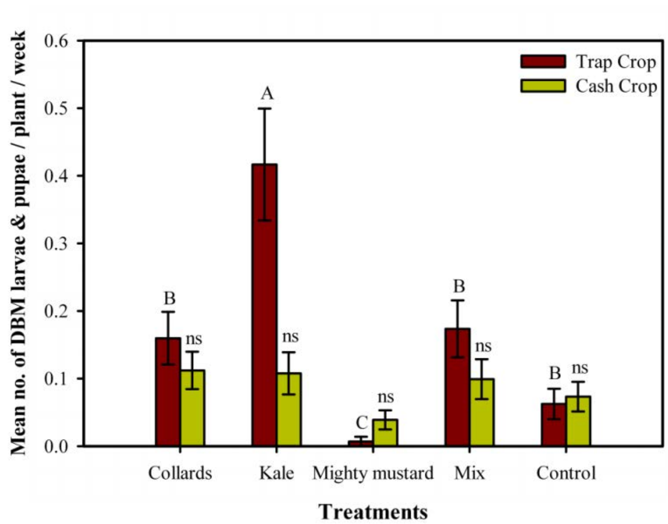


Figure 5. Mean number of diamondback moth (DBM) eggs (± SE) per trap crop and cabbage per week. For each type of plant (trap crop or cash crop) bars with different letters indicate significant differences according to ANOVA and Tukey's tests at P ≤ 0.05.

Harlequin bug and aphids. A population of harlequin bug was observed late in the field trial. A total of 22 eggs in the kale and 19 nymphs in mighty mustard were recorded on June 15th and June 20th observations, respectively. Although the numbers of live (1.69 ± 0.94) and mummified (= parasitized) (0.75 ± 0.06) aphids were greatest in the mixed trap crops, they did not differ significantly with other trap crops. Similarly, the numbers were also greatest in cabbage in the mixed treatment (alive: 0.26 ± 0.06; parasitized: 0.20 ± 0.04), but they did not significantly differ between the treatment plots.

On-farm research by organic farmer cooperators

Bear Creek Farms. Mr. and Mrs. Hail conducted a large scale evaluation of trap cropping at their organic farm. They devoted about 2 acres of their land to grow broccoli as cash crop. The perimeter rows were planted with Red Russian kale, following our recommendation. In one of the rows they decided to plant some collards, which is a plant species that was also found to be attractive to some insect pests. AZERA (OMRI-listed) insecticide was used by the Hails to kill insect pests on trap crop plants.

Figure 6 below shows natural infestation by aphids in the 3 trap crop plants that were evaluated and in the cash crop (broccoli). It shows that aphids had a significant preference for kale, followed by mustard, compared to collards.

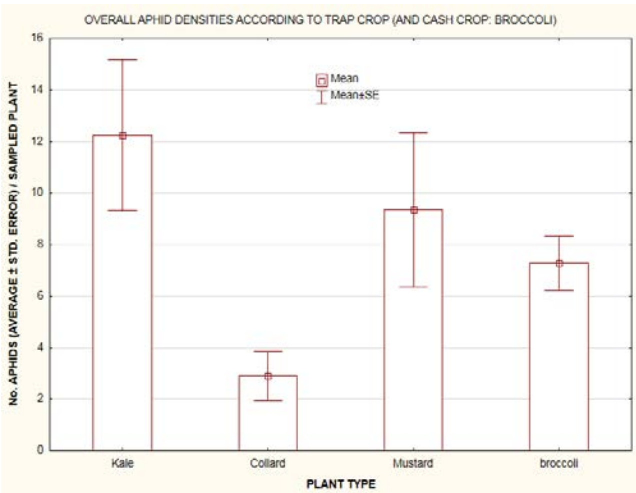


Figure 6: Mean number of aphids recorded on sampled plants at Bear Creek farm in our 2015 study. Trap crop plants are kale, collard and mustard. Cash crop is broccoli. **On the right: Mustard aphid**.

<u>Green Gate Family Farms</u>: Mr. Ken Barber and Katie Nixon conducted a trap cropping trial at their farm. As background information about the farm, 2014 is the second year growing Brassicas on it. Spring crop of brassicas was in two different beds about 100 ft away from fall crop. The spring crop was heavily infested with Harlequin bugs when it was tilled under in early summer and planted with a cover crop of mustard, radish, and oats. Fall broccoli and cabbage crop (w/kale) was planted in mid-August. The trap crop plant that was evaluated was red Russian Kale at a rate of 4-6 plants at the beginning and end of each bed giving this arrangement: Kale – 150 ft of broccoli - kale (bed 1) and kale – 100 ft of cabbage - kale (bed 2).

Observations by these farmers indicated that in general the population of Harlequin bugs was high and they found similar numbers on the trap crop and on the cash crop (broccoli). A very limited amount of Harlequin bugs (like one every ten plants) were found on the cabbage. Thus, it seems that under high Harlequin bug pressure there is some sort of spillover effect onto the broccoli that is close to red Russian kale whereas kale successfully protected cabbage against Harlequin bugs.

Mr. Barber and Ms. Nixon also recorded more Harlequin bugs in the kale than in the cabbage. This provides evidence that kale could be a good trap crop to protect cabbage, but if populations are very high, kale may not be able to protect broccoli effectively. More research is planned for 2015.

AZERA (OMRI-listed) insecticide was sprayed against harlequin bugs. There was a negative response from the bugs when AZERA was sprayed, as insect pests ran away from the plants when sprayed. According to the farmers (quote): "*When the plants were observed the day after AZERA was sprayed* *there are few numbers. Ken said he did some rough counts and an average of six bugs was present before he sprayed and about half that number after. We think that AZERA could be more effective if we had a quicker response to the presence of the bug*".

Quote by farmers: "*On Oct. 6th we sprayed a combination of AZERA/pyganic/Bt. When we observed the crop after spaying and the bug populations were greatly reduced in all beds. I also believe the colder temperatures helped to keep the populations from rebounding*."

Overall, farmers' provided the following statements (quotes):

1. *Red Russian Kale was the best trap crop for indicating aphid pressure. They would always appear on those leaves first in large numbers.*
2. *As for caterpillars, they were always present on everything. We continued to combat them with regular BT sprays.*
3. *Harlequin bugs were the hardest to control the first two years. They did show up first on the trap crops, which gave us warning to start spraying Azera. This was effective early in the season, but they were inevitable as we progressed into the summer.*
4. *In 2015 and 2016 harlequin pressure was significantly reduced. We are not sure if this is due to weather, cultural practices, or spraying; likely a combination of the three. One thing we have been diligent about is rotating where the crop has been, and removing the crop residue. If the goats grazed the area, we removed the leftover stalks to the compost (far from the growing area) and if we could not get the goats in to the crop area, we brought the residue to them.*
5. *We have also started growing Sweet alyssum with all of our cash crops and the effects have been excellent. The trick is to remove the Alyssum after it is done flowering. We have noticed they old Alyssum plants harboring the very pests we would like to avoid, Specifically Harlequin bugs and cucumber beetles.*

Objective 2: To quantify the ability of six species of insectary plants to attract natural enemies of pest insects in the absence of a cash crop.

The present study was aimed at identifying insectary plant species that are attractive to natural enemies to enhance the biological control of specific target pests. Our goal was to identify plants that provide nectar and pollen as well as habitat for natural enemies in the context of an organic cabbage production system. Our first field study (in 2015) investigated the attractiveness of seven insectary plant species to natural enemies, while a second field study (in 2016) evaluated the five most effective insectary plant species identified from the first study.

Insectary plant species were selected based on the following criteria: general hardiness, high level of flower production, seed availability to farmers and adaptation to agriculture areas. The seven species of insectary plants that were evaluated in 2015 were: (1) buckwheat, *Fagopyrum esculentum*, (Polygonoaceae), (2) sweet alyssum, *Lobularia maritima*, (Brassicaceae), (3) mighty mustard, *Brassica juncea*, (Brassicaceae), (4) dwarf sunflower, *Helianthus gracilentus*, (Asteraceae), (5) basil, *Ocimum basilicum*, (Lamiaceae), (6) dill, *Anethum graveolens*, (Apiaceae), and (7) fennel, *Foeniculum vulgare*, (Apiaceae). Within a block, each experimental plot was 3 m in length and 1.82 m in width, and consisted of 30 insectary plants of a particular species arranged in 2 rows of 15 plants each. Treatments were assigned using a randomized complete block design and replicated four times. In 2016, only the five most effective insectary plant species from 2015 were evaluated: buckwheat, sweet alyssum, mighty mustard, dwarf sunflower, and basil.

Highlights of Findings.

Natural enemy diversity. A total of 1,210 individuals in 2015 and 586 individuals in 2016 from nine insect families were recorded through visual observation during the flowering period of the insectary plants. Samples recorded were primarily composed of herbivores (51%) and natural enemies (49%) in 2015 (Table 3a), and herbivores (52 %) and natural enemies (48%) in 2016 (Table 3a). Similarly, a total of 888 individuals in 2015 (Table 2b) and 730 individuals in 2016 (Table 3b) were trapped on sticky cards (data not shown in tables). Potential natural enemies represented 387 (44%) in 2015 and 229 (31%) in 2016 of the overall arthropod composition.

Table 2. Number of arthropods visiting insectary plant species recorded through visual observations in 2015.

a. Visual observations								
ARTHROPOD FAMILY	**PLANT SPECIES**							
Natural enemies	Ba	BW	Dill	D.Sun	Fen	M.mus	SA	**Total**
Coccinellidae	44	45	8	31	47	50	21	246
Syrphidae	26	71	28	14	15	18	21	193
Tiphiidae	2	30	1	3	3	1	5	45
Braconidae	2	3	0	6	2	5	5	23
Tachinidae	10	25	2	3	1	6	5	52
Pentatomidae	1	1	1	1	1	1	0	6
Formicidae	10	3	1	12	0	0	2	28
						Total Natural Enemies		**593**
Pests								
Chrysomelidae	11	7	2	1	1	194	179	395
Miridae	65	16	47	44	25	15	10	222

							Total pests	**617**
Total arthropods	**171**	**201**	**90**	**115**	**95**	**290**	**248**	**1210**
b. Sticky cards								
Natural enemies								
Coccinellidae	7	8	6	6	1	7	10	45
Tachinidae	22	42	22	23	12	17	12	150
Braconidae	22	14	26	24	7	13	12	118
Ichneumonidae	12	10	6	14	6	16	10	74
Total natural enemies	**63**	**74**	**60**	**67**	**26**	**53**	**44**	**387**

Key: Ba= Basil; BW= buckwheat; D.Sun= Dwarf Sunflower; Fen= Fennel; M.mus= Mighty mustard; SA= Sweet Alyssum.

Table 3. Number of arthropods visiting insectary plant species recorded during visual observations in 2016.

a. Visual observations						
ARTHROPOD FAMILY	**PLANT SPECIES**					
Natural enemies	Ba	BW	D.Sun	M.mus	SA	Total
Coccinellidae	12	13	24	11	5	65
Syrphidae	15	15	4	14	46	94
Geocoridae	1	2	2	0	7	12
Braconidae	7	0	3	5	6	21
Ichneumonidae	3	2	8	6	8	27
Tachinidae	2	10	1	3	18	34
Pentatomidae	6	3	3	16	1	29
					Total Natural Enemies	**282**
Pests						

Miridae	35	5	12	18	13	83
Chrysomelidae	0	6	2	72	141	221
					Total pests	**304**
Total arthropods	**81**	**56**	**59**	**145**	**245**	**586**
b. Sticky cards						
Natural enemies						
Coccinellidae	1	1	0	0	0	2
Tachinidae	22	18	15	5	8	68
Braconidae	37	35	18	22	24	136
Ichneumonidae	5	5	4	6	3	23
Total natural enemies	**65**	**59**	**37**	**33**	**35**	**229**

Key: Ba= Basil; BW= buckwheat; D.Sun= Dwarf Sunflower; M.mus= Mighty mustard; SA= Sweet Alyssum.

Over the course of the study, the insectary plant species attracted natural enemy communities composed of similar taxa, but with different relative abundances (Figures 7 and 8). In 2015, we observed a natural enemy community composed of six families which were Coccinellidae, Syrphidae, Tachinidae, Tiphiidae, Braconidae and Pentatomidae. Based on Shannon-Wiener diversity indices, we did not find any significant differences among the plant species in the distribution of natural enemy families ($F = 2.04$, $df = 6, 21$; $P = 0.4$) (Table 4). However, mighty mustard and fennel were dominated by single natural enemy, the pink lady beetle, *Coleomegilla maculata* (Coccinellidae) (> 60%), whereas syrphid flies (Syrphidae) (68%) were predominant on dill. Sweet alyssum, dwarf sunflower, basil and buckwheat were represented by diverse taxa with a more even distribution of natural enemy families (Figure 7).

Table 4 Shannon-Wiener diversity indices calculated for each insectary plant species for each replication, and mean ± SEM values. Data were based on visual observations of natural enemies visiting insectary plant species in 2015. Mean values not superscribed by the same letter are significantly different according to ANOVA and Fisher-protected LSD ($P < 0.05$).

	Shannon-Wiener index				
Insectary plants	*Rep 1*	*Rep2*	*Rep3*	*Rep4*	Mean ± SEM
Basil	1.39	0.82	1.07	1.32	1.15 ± 0.13 a
Buckwheat	1.09	1.18	1.30	1.59	1.29 ± 0.10 a
Dill	0.69	1.15	0.33	1.19	0.85 ± 0.20 a
Dwarf sunflower	1.21	0.68	1.39	1.42	1.17 ± 0.17 a
Fennel	0.50	0.56	0.69	0.89	0.66 ± 0.08 a
Mighty mustard	0.87	1.31	0.41	1.16	0.93 ± 0.19 a
Sweet alyssum	0.69	1.27	1.36	1.21	1.15 ± 0.15 a

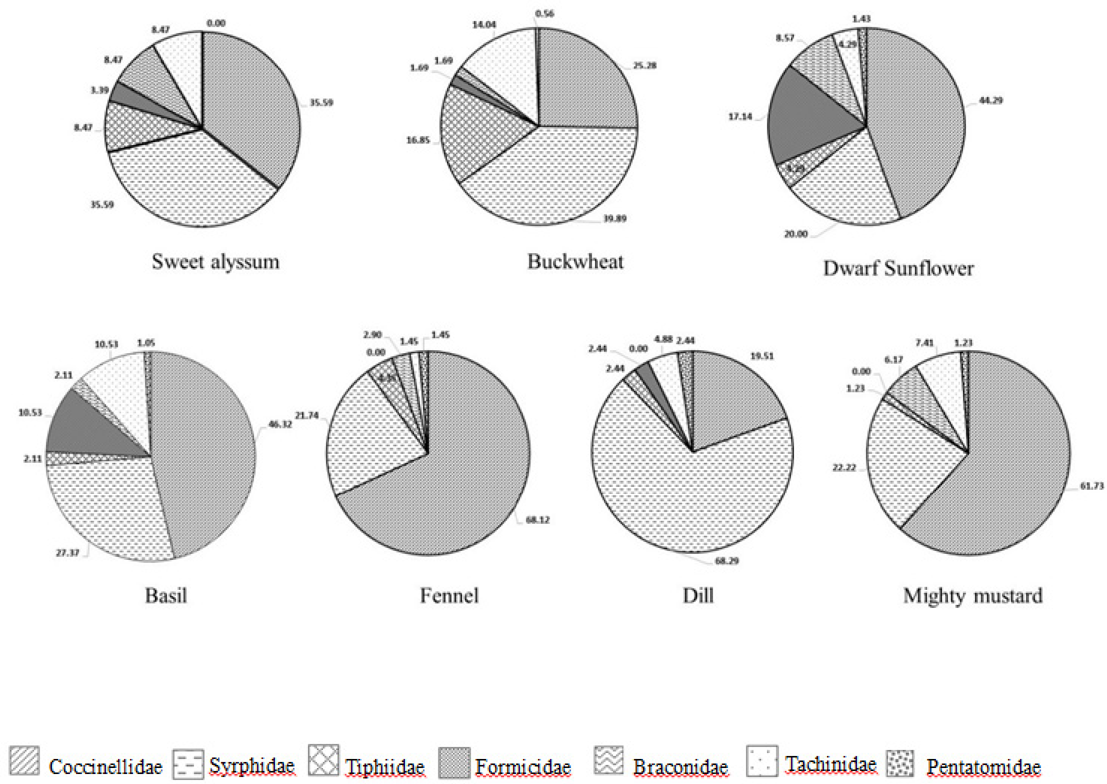


Figure 7: Diversity of natural enemies at the family level visiting seven insectary plant species during the months of July and August, 2015. For each plant species, the proportion of total natural enemy abundance is shown.

In the 2016 study, all insectary plant species attracted similar taxa of natural enemies but with different relative distributions. These taxa were Coccinellidae, Syrphidae, Tachinidae, Braconidae, Geocoridae, Ichneumonidae and Pentatomidae. From Shannon- Wiener diversity indices, we found that all the species showed a more even distribution of natural enemy families except for dwarf sunflower (F = 3.62, df = 4, 15; P = 0.02). Dwarf sunflower was dominated by *C. maculata* (Coccinellidae) (50.5%) whereas sweet alyssum was dominated by syrphid flies (Syrphidae) (53.33%) (Figure 8). In contrast to the 2015 study, mighty mustard was not dominated by single taxon.

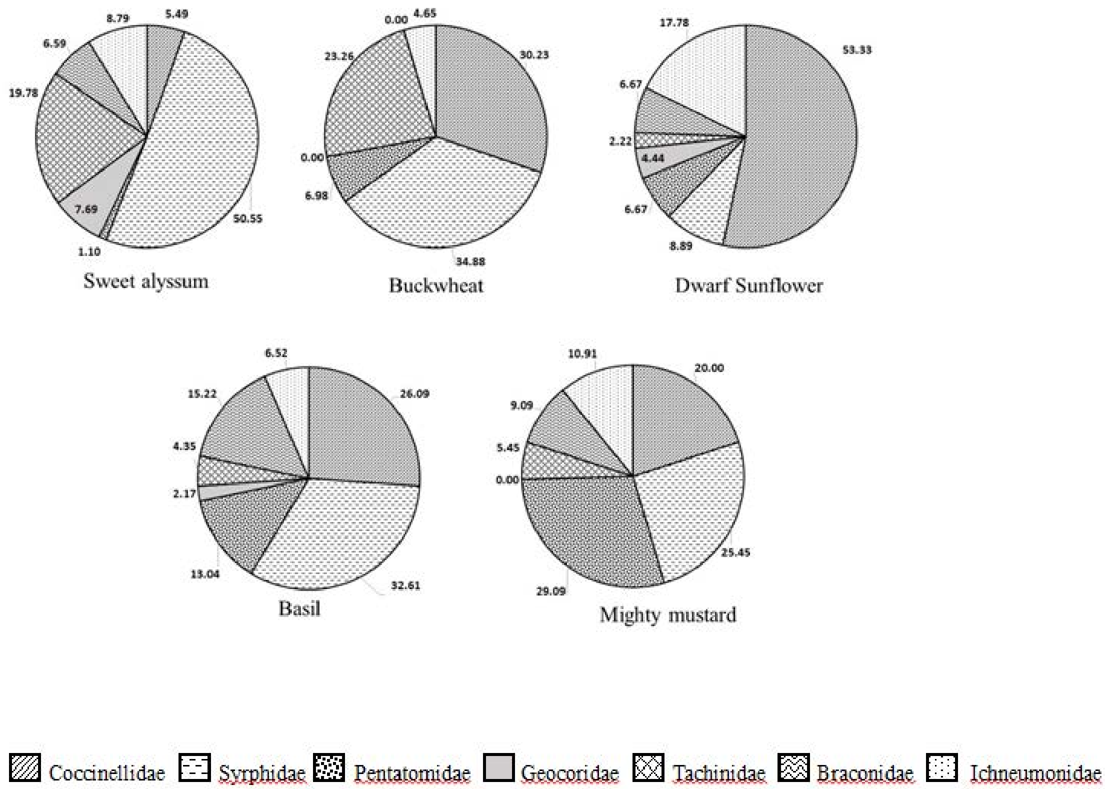


Figure 8: Diversity of natural enemies at the family level visiting five insectary plant species during the months of July and August, 2016. For each plant species, the proportion of total natural enemy abundance is shown.

A pictorial showing various aspects of the field study that Ms. Binita Shrestha conducted in 2015 as part of her MS project is presented in the next page.

View of one of the four replicates of the study; (B) Ms. Binita Shrestha (MS student) and cages used to exposed cabbage plants infested artificially with Diamondback moth larvae to detect wild parasitic wasps – dwarf sunflower plants are also shown; (C) Dwarf sunflower plants before bloom; (D) Pink lady bug and a syrphid fly, commonly seen in some insectary plants (see graph above); (E) Team members who provided assistance to Ms. Shrestha so that she could conduct her study successfully.

Natural enemy abundance

Visual observations. Summing all observations of natural enemies across replicates and sample dates, in 2015 buckwheat attracted the greatest number of natural enemies followed by basil and mighty mustard. In contrast, in 2016, sweet alyssum attracted the greatest number of natural enemies, followed by mighty mustard. The most abundant natural enemies were *C. maculata* and syrphid flies in both years (Tables 4 and 5). In 2015, all seven plant species except for dill attracted comparatively high numbers of *C. maculata* ($F = 2.9$, df = 6, 21; $P = 0.033$) (Figure 9A). Buckwheat was the most attractive plant for syrphid flies ($F = 3.7$, df = 6, 23; $P = 0.011$) and for tiphiid wasps ($F = 5.2$, df = 6, 23; $P = 0.002$) (Figures 9B and 9D). The number of tachinid flies ($F = 1.73$, df = 6, 21; $P = 0.16$) was not significantly different among plant species (Figure 9C). Similarly, the response of other natural enemies including braconid wasps ($F = 1.023$, df = 6, 21; $P = 0.4$) and the spined soldier bug, *Podisus maculiventris* ($F = 0.166$, df = 6, 21; $P = 0.9$) were not influenced by plant species.

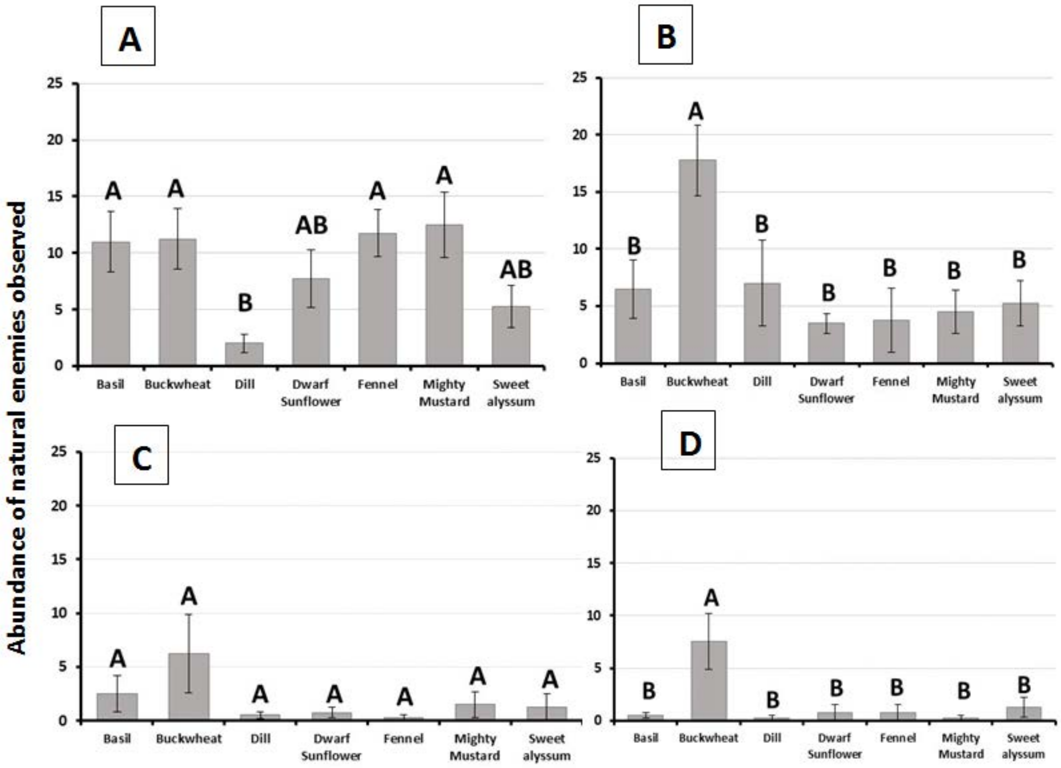


Figure 9: Number (mean ±SEM) of natural enemies in the families (A) Coccinellidae (represented by the pink lady beetle, *Coleomegilla maculata*), (B) Syrphidae, (C) Tachinidae, and (D) Tiphiidae recorded on seven insectary plant species through visual observation during the months of July and August, 2015. Data were averaged across the eight sampling dates. Columns not superscribed by the same letter are significantly different according to ANOVA and Fisher-protected LSD ($P < 0.05$).

In 2016, we did not observe significant differences in the relative abundance of *C. maculata* across plant species ($F = 1.92$, df = 4, 14; $P = 0.16$) (Figure 10A). In contrast to 2015, sweet alyssum was the most attractive plant for syrphid flies ($F = 9.06$, df = 4, 14; $P = 0.0007$) (Figure 10B). The abundance of tachinid flies and *P. maculiventris* differed significantly among plant species. Sweet alyssum attracted more tachinid flies than any other plant treatment except for buckwheat ($F = 4.01$, df = 4, 14; $P = 0.02$) (Figure 10C), whereas *P. maculiventris* was attracted in significantly greater numbers to mighty mustard compared to any other plant species ($F = 4.64$, df = 4, 14; $P = 0.01$) (Figure 10D).

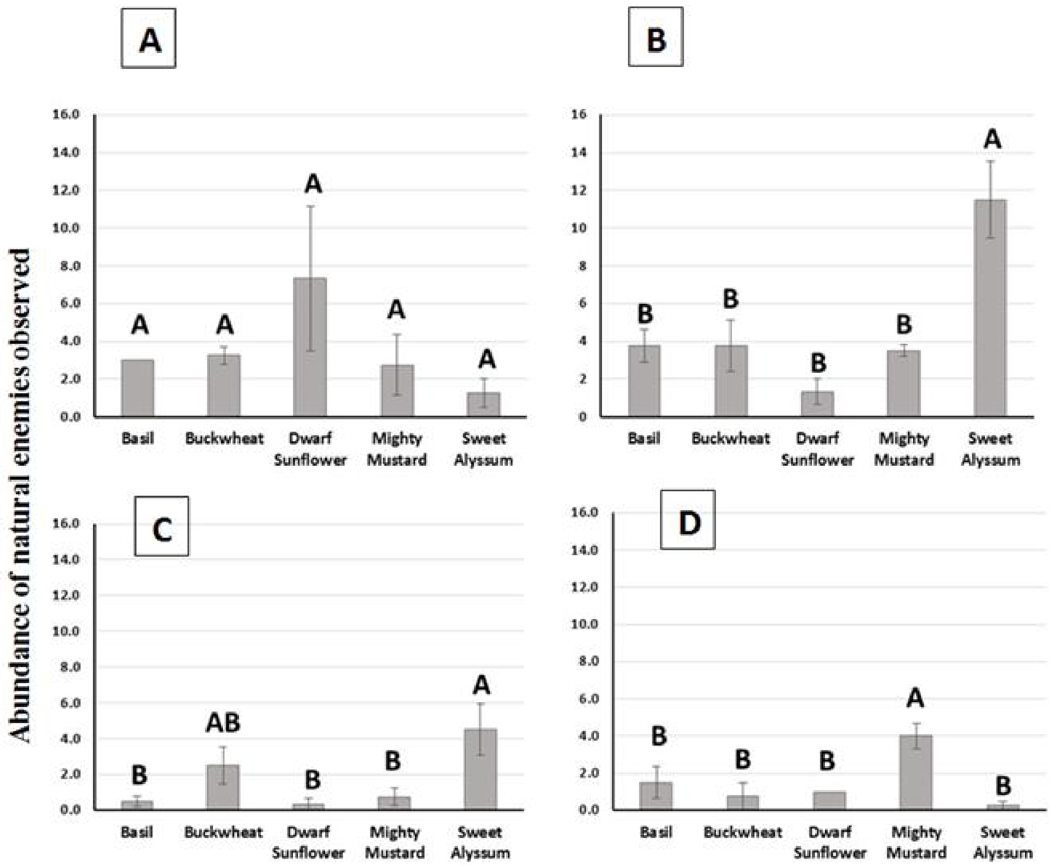


Figure 10: Number (mean ±SEM) of natural enemies in the families (A) Coccinellidae (represented by the pink lady beetle, *C. maculata*), (B) Syrphidae, (C) Tachinidae, and (D) Pentatomidae (represented by the spined soldier bug, *P. maculiventris*), recorded on five insectary plant species through visual observation during the months of July and August, 2016. Data were averaged across the ten sampling dates. Columns not superscribed by the same letter are significantly different according to ANOVA and Fisher-protected LSD tests ($P < 0.05$).

A separate large study was conducted in 2016 with the goal of evaluating the integration of insectary plants with trap crops to attract natural enemies and suppress insect pests in an organic cabbage agro-eco system. The study was carried out from 29 June to 6 October 2016 at the Lincoln University's certified organic Alan T. Busby Farm located in Jefferson City, MO. The experimental area consisted of four 30.4 x 18.3 m blocks (replications). The land was prepared on 13 May 2016 by plowing, disking, and roto-tilling. Eight rows were prepared as raised beds that were 120 cm wide x 15.2 cm tall. Drip irrigation was installed on top of the beds and they were covered with 1.2 m wide white plastic mulch. For each replicate, a perimeter row was selected for insectary plants, the second row was used for trap crop plants, and rows 3-6 were used for the cabbage cash crop. Within each replicate, trap crop / insectary plant treatment combinations (see below) were assigned randomly.

The trap crop system evaluated consisted of a mixture of collards, *Brassica oleracea* var. italica, kale, *B. oleracea* var. acephala and mighty mustard, *B. juncea* based on previous research conducted by Manandhar and Pinero (2015). The abundance of trap crop plants was ~20% that of the total number of cabbage plants grown per plot. The two species of insectary plants evaluated were buckwheat (*Fagopyrum esculentum)* and sweet alyssum (*Lobularia maritima*), either alone or in combination. These plants were selected based on results from Chapter II indicating an ability to attract abundant and diverse taxa of natural enemies. The cash crop was cabbage cv. Golden acre. Five insectary plant / trap crop treatment combinations were evaluated: (1) buckwheat with a trap crop mix, (2) sweet alyssum with a trap crop mix, (3) buckwheat and sweet alyssum with a trap crop mix, (4) trap crop mix without insectary plants and (5) no insectary plants and no trap crops i.e., cash crop alone. All of the seeds used for this study were organic and purchased from Johnny's Selected Seeds (Winslow, ME). Insectary plants, trap crops, and cabbage seeds were sown in OM1 organic germinating media and grown in the greenhouse until transplant.

Trap crop and insectary seedlings were transplanted on 1 July 2016. The seedlings of buckwheat (3-week old) and sweet alyssum (5-week old) (14 of each per treatment plot) were transplanted onto the perimeter row raised bed with 21.6 cm inter-plant spacing, whereas kale, collards and mighty mustard (6-week old) seedlings (3 of each per treatment plot) were transplanted with 46 cm inter-plant spacing. On 19 July 2016, 48 six week-old Organic Golden acre cabbage seedlings were transplanted onto raised beds (rows 3-6 of each plot) with 46 cm inter-plant spacing.

Highlights of Findings.

In brief, the presence of insectary plants increased egg-laying by predatory pink lady beetles, *Coleomegilla maculata,* and by the parasitic wasp, *Cotesia orobenae,* in the kale trap crop (Figs. 11A & 12A). In contrast, the abundance of natural enemies in the collard trap crop was not affected by the presence or absence of insectary plants (Figs. 11B & 12B). The abundance of adult predatory lady beetles foraging on the insectary plants was influenced by insectary plant treatment.

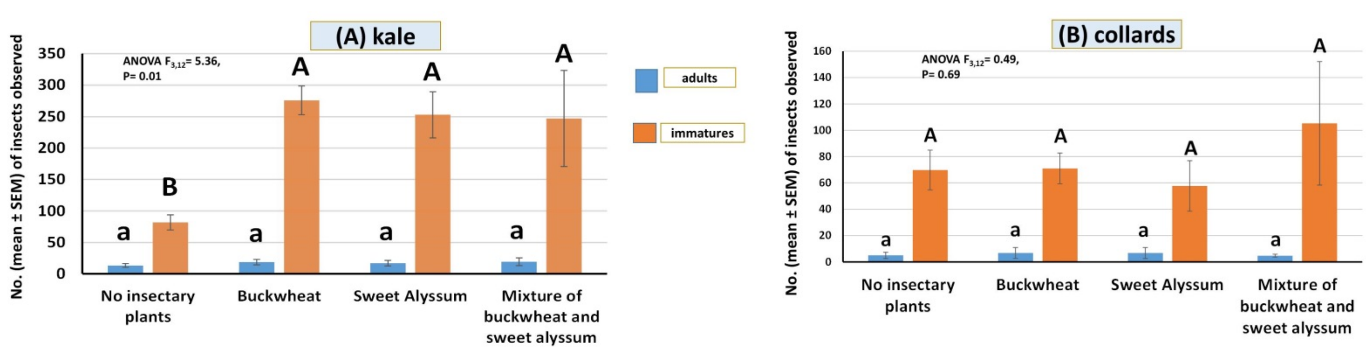


Fig. 11. Number of adult and immatures (eggs and larvae combined) of predatory pink lady beetles, *Coleomegilla maculata,* recorded on A) kale trap crop, B) collard trap crop.

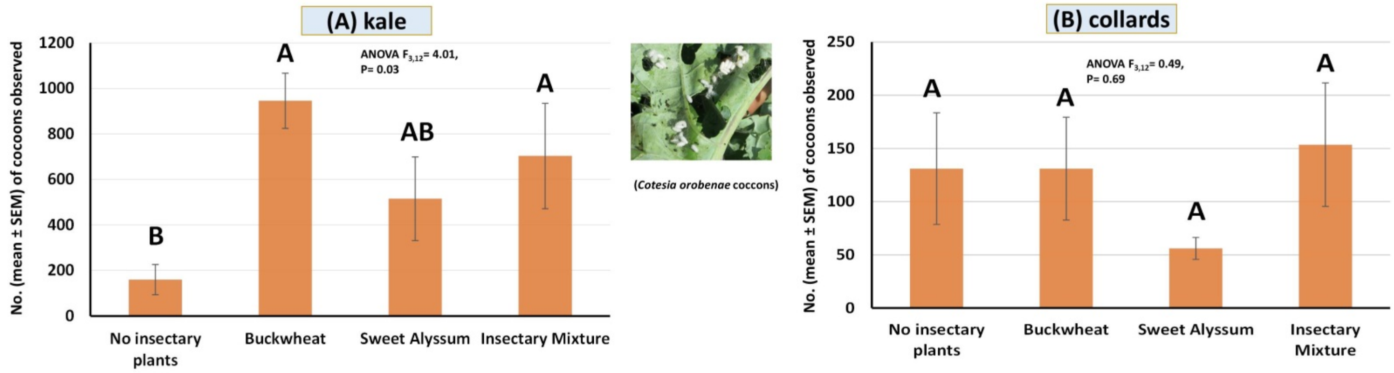


Fig 12. Number of cocoons of the parasitic wasp *Cotesia orobenae* recorded on the pest cross-striped cabbageworms, *Evergestis rimosalis.* A) kale trap crop, B) collard trap crop.

Significantly more adult *C. maculata* were found on buckwheat alone than on sweet alyssum alone, whereas the mixture of both plants attracted intermediate number of *C. maculata* adults (Fig. 13).

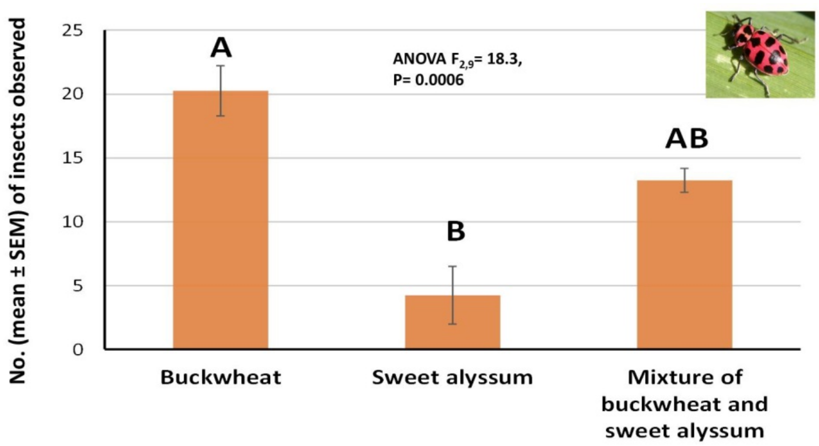


Fig. 13. Abundance of predatory pink lady beetles, *C. maculata,* foraging on insectary plants.

In the cash crop, the lowest abundance of the pest cross-striped cabbage worms, *Evergestis rimosalis,* was documented when insectary plants were present whereas the presence of trap crops had no effect on pest abundance (Fig. 14).

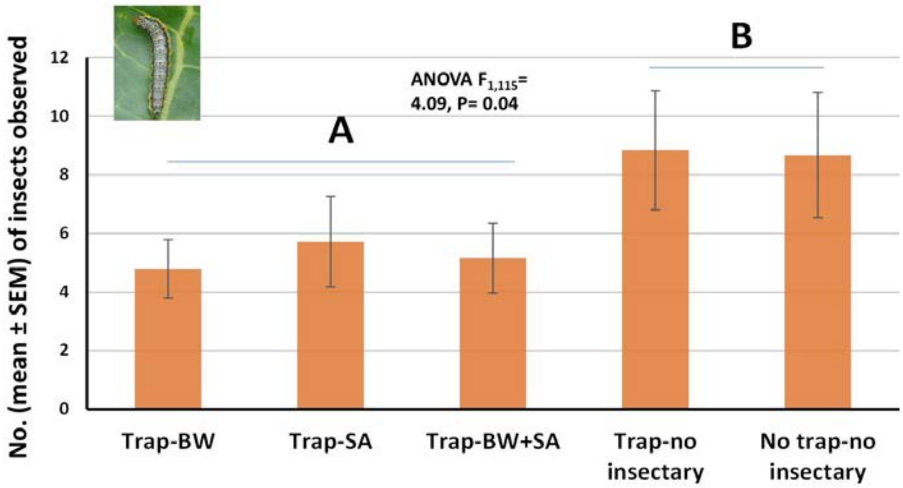


Fig 14. Abundance of cross-striped cabbageworms, *E. rimosalis,* on cabbages, according to treatment.

Objective 3: To evaluate OMRI-listed insecticides against harlequin bugs.

Insect pests that concentrate in trap crops must be removed from the population by killing them using OMRI-listed materials, by physical means (e.g., hand removal, flaming, vacuuming), or by natural enemies. Four OMRI listed insecticides were chosen for this study, based on various vegetable production guides and recommendations from growers: (1) *Pyrethrins,* brand name Pyganic™; (2) *Spinosad,* brand name Entrust™, (3) A mixture of *Pyrethrins* and *Azadirachtin,* brand name Azera™, and (4) *Azadirachtin,* brand name Aza Direct™. These insecticides represent three different modes of action and are labeled for use in many vegetable crops for management of insects in at least three different orders. Pyganic and AZERA were the most effective insecticides (Fig. 15).

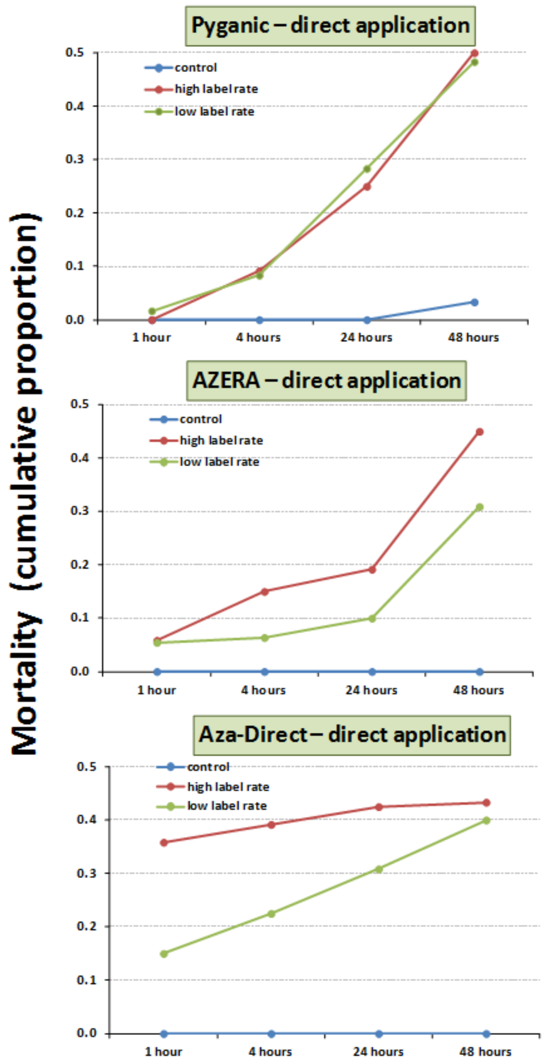


Figure 15. Mortality induced by two OMRI-listed insecticides to Harlequin bug adults when insecticides were sprayed 24 hours BEFORE placing insects on experimental treated plants or when insects were sprayed DIRECTLY.

AZERA insecticide was also evaluated by Ms. Robbins Hail (farmer cooperator – Bear Creek farms) and she reported low efficacy in the field, even at the highest label rate. Our laboratory observations indicate that the waxy coating of the insect's body minimize exposure to the organic insecticides. In other words, when insecticides are sprayed, they drip off the insect. In addition, we have discovered that the behavior of the insect also plays a role. When disturbed, insects hide in the underside of leaves, therefore they are less likely to get in contact with the materials. The combination of both situations seems to result in lack of insecticide efficacy.

Objective 4: To evaluate the use of small ruminants for weed control and insect pest suppression

In 2014, at two different times of the year, sheep were used to graze the row middles of a 3,000 blueberry planting at the Lincoln University Organic farm. The first period was on May 1-13, 2014 and included 38 ewes and new lambs. They were removed to facilitate installation of weed mat on the blueberry beds. Otherwise, would have continued grazing until forage was gone or it was too hot/sunny. On October 17-23, 33 weaned lambs were used to graze the grass. The size of the area fenced went from 0.25 to 0.5 acres depending on livestock numbers and forage availability. The type of fencing used was Gallagher Smart Fence, a 4-strand portable fence, and a solar-powered energizer to electrify the fence. The sheep were confined to the grassy areas between the rows and along the edges. By using electric fencing, the sheep could not access the blueberries as they will eat the leaves and tender branch tips.

Grazing results: In the spring, the ewes preferred forbs and weeds, grazing the fescue last. In the fall, the lambs preferred forbs, weeds and fescue, grazing the mature crab grass only when pressured to do so. Some ramifications of selective grazing include: Mowing is still necessary, but mowing intervals are longer and less weed-eating is required which led to some cost savings.

Observations aimed at assessing the level to which small ruminants, in particular goats, can graze various species of cover crops were also conducted. Sorghum sudan grass found acceptable by goats. We expect to show that in vegetable systems sheep can be used to graze crop residue and summer fallow thereby addressing some challenges faced by farmers including some level of insect pest management, and management of remaining crop and cover crop residue.

In 2015, the team conducted a demonstration study aimed at assessing the level of weed control exerted by five different organic weed management methods: (1) flaming (white), (2) cultivation, (3) vinegar with surfactant (blue), (4) Avenger Weed Killer Concentrate [with and without surfactant] (red), and (5) control. Sheep and goats were placed in two weedy areas for 24 hours for demonstration purposes because plots that were prepared by us to be grazed did not have enough weed biomass at the moment at which aforementioned treatments were applied. Some pictures of the treatments that were evaluated are shown below:

As part of one In-Service Education training that was held at the Lincoln University Busby Organic research farm on May 27th, 2015, these demonstration plots were visited by around 30 Extension staff and faculty from University of Missouri Extension, Lincoln University Cooperative Extension, NRCS, and Missouri Department of Agriculture. Attendees increased their level of knowledge on tweed management using non-traditional methods.

On-farm research by organic farmer cooperators as part of objectives # 1 and # 4

During 2015, Ms. Katie Nixon and Mr. Ken Barber, organic farmer cooperators, wanted to focus on an evaluation of grazing of Brassica cash crop residue by sheep. The following text, which has not been edited, and pictures were directly provided by these two farmers:

"We have grown Brassicas organically on our farm for five years. We typically grow them in both the spring and fall. By the time we harvest our spring crop in early summer, we typically have a large population of harlequin bugs and stink bugs (and caterpillars if we have not done a good job spraying BT). Our last harvest for our spring crop this year was mid-July. Six goats came from Lincoln University in late July and were put on the field with the brassicas. The total area was a little over 3000sq. ft. There was still plenty of brassica crop residue/live growth (and pests among it) in the field when they were turned out. We also had a strong weed population in the pathways and some in beds we had harvested over a month before. The goats went after the weeds first. In a few days, when the weeds were gone, they started eating the cabbage and broccoli. The broccoli was consumed first followed by the cabbage. It was eaten down to the stalk within a week at which point the goats were shifted over to the weedy area to the east of the production field. Unfortunately our transplants for fall production failed and we were not able to plant a fall brassica cash crop. However, about two weeks after the goats were moved off we observed that some of the cabbage and broccoli started to re-grow. We scouted the brassicas two times in the course of the next month after we saw the re-growth and we did not detect the presence of Harlequin bugs. We did observe that the caterpillar population was quite elevated by the end of September, but we had not sprayed BT since July.

On August 12th the goats were weighed. They had lost a little weight. However, before coming to our farm they had been grazing in the woods with plenty of brush available".

Dr. Charlotte Clifford-Rathert, Lincoln University State Small Ruminant Specialist and project collaborator, provided the sheep to Ms. Nixon and Mr. Barber. Her team weighed the sheep before and after introducing them into the cropped area. It was found that for the first 2-3 days, sheep selectively grazed on the weeds and somewhat ignored the Brassicas. However, once the weeds were down, sheep opted to graze on the Brassicas, and shortly thereafter consumed the crop residue, as described above by the farmers. Overall comments by our farmer cooperators are presented below:

1. *Goats do not prefer the brassica crops that we let them in to graze on once the cash crop was done, but they will eat it of there is nothing else.*
2. *Sometimes it was challenging to get the goats into the area where the cash crop was, because of time needed to set up the temporary electric fencing. They are very good at getting out of poorly secured areas. Sheep behaved "better".*
3. *One thing we have been diligent about is rotating where the crop has been, and removing the crop residue. If the goats grazed the area, we removed the leftover stalks to the compost (far from the growing area) and if we could not get the goats in to the crop area, we brought the residue to them.*

Outreach

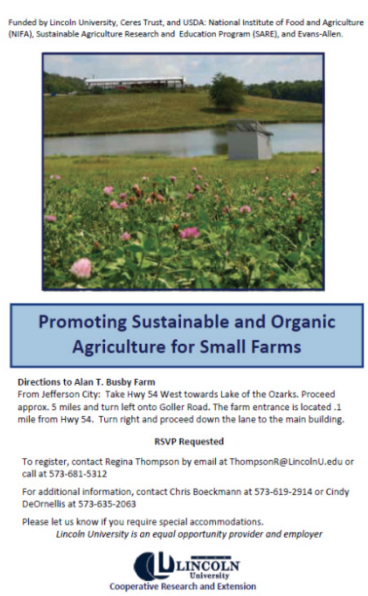
Numerous outreach activities were conducted from 1/23/2014 to 7/31/2017. Overall, over 2,000 farmers were reached out in a 3-year period. The most important activities are listed below, by year:

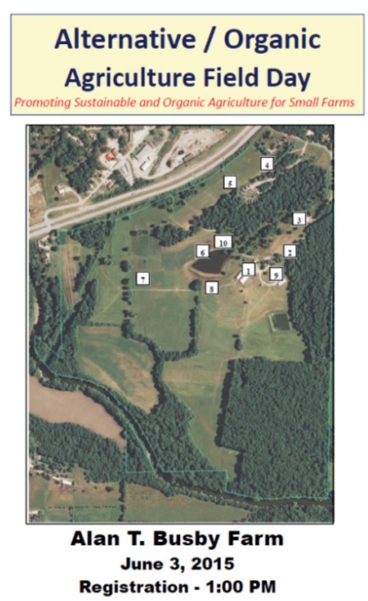
2014

1. **Second Alternative Agriculture Field Day held at Lincoln University's Organic Research Farm held on June 4, 2014.** With 280 acres of organic-certified land, Busby farm is the largest organic research farm in Missouri. This field day showcased our main research activities; about 110 small- and mid-scale farmers had the opportunity to receive research-based information on how to improve their farming operations and network.
2. **Second Vegetable and IPM Festival** held at Lincoln University Carver Farm on August 14, 2014. While this farm is not certified organic, most research and outreach being conducted by the LU IPM program in this farm follows organic practices. Audience: 90+ farmers.
3. **Presentation (1.5 hours) by Mr. Jacob Wilson (Lincoln University IPM program) and Mr. Phillip Boydston (Lincoln University Small Farm program)** at the National Small Farm and Trade Show Conference held on October 23-25, 2014, in Mexico, MO. Presentation title: "Integrating Cover Crops into Farming Systems". Audience: 19 farmers.

2015

1. **Third Sustainable/Organic Agriculture Field Day, held at Lincoln University's Organic Research Farm held on June 3, 2015.** This field day showcased our main research activities. Small- and mid-scale organic farmers had the opportunity to receive research-based information on how to improve their farming operations and to network. Research highlighted was organic weed management that included sheep grazing, supported by this project. Audience: 120 farmers.





AGENDA

Site 1: Registration and Restrooms

Site 2A: Silvopasture (combining forestry and grazing)
Dr. Charlotte Clifford-Rathert, State Extension Specialist- Small Ruminants
Dr. Ajay Sharma, Asst. Professor, Natural Resources Management
Goats can be used to control and/or eradicate invasive vegetation while creating a silvopasture in a Missouri woodland. Review the data collected, the positive impact seen so far, and different fencing options.

Site 3-A: Composting
Dr. Hwei-Yiing Johnson, State Extension Specialist- Plant Science
Composting sessions at 2:00 PM and 4:00 PM—Several composting methods will be demonstrated: aerobic, worm composting, and Effective Microbes (EM) Bokashi composting.
Green Roof, Green Walls and Vertical Gardening at 3:30 PM— Introduction to green roof, green wall and vertical gardening. Learn to use compost and compost tea to organically maintain these green structures.

Site 3-B: Biochar
Dr. Raimund Bayan, Assistant Professor, Soil & Environmental Sciences
George Kuepper, Kerr Center for Sustainable Agriculture, Horticulture Manager
Biochar can improve the quality and fertility of soil and increase yield. Properly produced biochar is safe to use in organic food production. It is normally produced by heating air-dried biomass to 400-600 degrees Celsius (752-1112 degrees Fahrenheit), destroying most contaminants. Dr. Bayan started the biochar research program at Lincoln University in 2011. Lincoln University (LU) is recognized as a center of biochar research and production in Missouri. Dr. Bayan produces biochar using slow pyrolysis, resulting in more biochar and adequate combustible gases that are sustainably used in the production process.

Site 4-A: No-till Pumpkins and Cover Crop Equipment
Dr. Jaime Piñero, State Extension Specialist, Integrated Pest Management
A no-till pumpkin production system that integrates insect pest, weed and disease prevention, while enhancing pollinators will be discussed.

Site 4-B: Organic Disease Management
Dr. Zelalem Mersha, State Extension Specialist, Plant Pathology
Martha O'Connor, Research Technician
Soil-borne diseases are a serious concern and priority challenges in organic farms. The focus for this year's field day will be damping off diseases on organic sweetcorn and Sclerotinia disease on lettuce. Open field and pot-contained demonstrations will include selecting the right time of planting, and the use of preventive and curative biofungicides such as ***RootShield***®, ***Actinovate***® and ***Contans***®.

Site 5-A: Organic Blueberry Production
Patrick Byers, MU Extension Horticulture Specialist
Nahshon Bishop, LU Small Farm Specialist
Blueberries offer potential for organic production in Missouri. This tour stop will explore blueberry cultivar selection, selecting an adapted site for blueberry production, blueberry farm establishment and blueberry culture, and blueberry disease and insect management.

Site 5-B: Monitoring and Management of Invasive Insects
Ms. Kaitlyn Kliethermes, Research IPM Technician
An overview of research involving mass trapping of Japanese beetles, as well as identification, monitoring and organic management of Spotted Wing Drosophila and Brown Marmorated Stink Bug

Site 6: Solar-Powered Irrigation and Livestock Watering System
To be determined
The 2-acre reservoir provides water for the orchard and pastures using a solar-powered pump and extensive piping system. The system is a vital component of the Busby Farm's integrated / sustainable farming operation.

Site 7: Organic Weed Management
Jacob Wilson, Extension IPM Program Associate
Demonstration and assessment of effectiveness of organic weed management alternatives: flaming, grazing by small ruminants, OMRI-listed herbicides, vinegar and cultivation.

Site 8: Multi-Species Grazing
Dr. Bruce Shanks, Assistant Professor, Animal Science
Grazing with multiple species of animals may improve performance of one or both species. Research projects focus on forage utilization, parasite control and animal performance using different combinations of cattle, sheep and goats.

Site 9: FINCA Project (Native Edibles and Native Plants for Pollinators)
Dr. Nadia Navarrete-Tindall, State Extension Specialist- Native Plants
30-minute tours of the FINCA at 2:00, 3:00 and 4:00 , starting at the FINCA tent. LUCE-Native Plants Program, FINCA Project, Farmers Market, Commercial Kitchen and Community Garden displays for walk-ins. Native plants for sale. Free food and drinks samples available by the displays.

Site 10: Farmscaping: Trap Cropping / Insectary Plants
Dr. Roshan Manandhar, Post-Doctoral Fellow, Sustainable IPM Systems
Showcasing a sustainable, biologically intensive pest management system that evaluates the effectiveness of farmscaping components (trap cropping and insectary plants). Insectary plants are most commonly described as plants that readily provide nectar and pollen food sources in a form that is attractive to natural enemies of crop pests, resulting in improved biological control.

Drs. Piñero and Manandhar presenting some of the results to the attendees of an In-Service Education workshop that took place on May 27th, 2015.

2. **Entomological Society of America Annual Meeting** (November 15-18) held in Minneapolis, MN. Poster presentation "*Evaluation of Trap Crops for Their Attractiveness to the Key Insect Pest Complex of Cole Crops in Missouri*" by R. Manandhar and J.C. Piñero. Conference was attended by over 1,000 scientists.
3. **Presentation (50 min) by our farmer cooperator Mr. Ken Barber (Green Gate Family farm) at the Advanced Organic track, at the 2015 Great Plains Growers Conference (January 8-10, 2015) held in St. Joseph, MO.** Title: "Creating the Organic Ecosystem: Challenges & Successes". Audience: 76 farmers. Below (in blue) is an excerpt of the summary of the presentation, followed by a couple of snapshots of his slides acknowledging the collaborative nature of this organic on-farm research and the support of the CERES Trust.

"Since starting Green Gate Family Farm in 2010, we have been employing strategies on our certified organic farm to improve and enhance the farm ecosystem. To us this means a focus on soil health and diversity. Promoting ecosystem health is year round strategy to improve crop health requiring vigilant observation and taking corrective measures. Some of the strategies we have employed to date are cover cropping, crop rotation, low-till/no-till practices, integrating poultry, trap cropping, farmscaping, and permaculture".

2016

1. **Fourth Sustainable/Organic Agriculture Field Day, held at Lincoln University's Organic Research Farm held on June 9, 2016.** This year, an innovative program involving seven workshops in the morning hours and hands-on field day in the afternoon was implemented. The afternoon field day brought together over 145 producers who learned about multispecies razing, organic blueberry production, organic vertical gardens, FINCA garden with native plants, silvopasture, plant disease management with OMRI products, small ruminant parasite management, composting, cucurbit pollination, trap cropping, insectary plants, invasive Insects NRCS Pollinator Habitat for the Environmental Quality Incentive Program (EQIP), and biochar. While the workshops and field day demonstrations emphasized organic production, the concepts and techniques discussed offer sustainable alternative practices for conventional producers. Audience: 145 farmers.
2. **Educational activity involving Elementary School students from Jefferson City, MO.** On June 26, 2016, students visited the Heart of Missouri Gardens, located at 1009 Big Horn Drive, Jefferson City, for hands-on activities invilving a demosntration of organic vegetable production and comsumption. Students also learned about the NEEED garden and about research and extension being conducted by Lincoln University in the areas of sustainable / organic agriculture. Audience: 130 students.

From: Jack Ryan
To: Pinero, Jaime
Cc: Essel, Albert; Paul, Kamalendu; Bob Boldt; Brittnie Brauner; Helene Richardson; Kelley Barnard; Mike Oney; Shubha Miller; Steve Herndon
Subject: Fieldtrip follow-up
Date: Tuesday, July 12, 2016 4:20:17 PM

Hello Dr. Pinero,

Just received a thumb drive from our student-photographer with photos of the fieldtrip. Those photos tell the story of a bunch of kids really tuned-in and very attentive to the material being presented by you folks from Lincoln University.

Frankly – I'm quite surprised. I was worried that we were aiming over the heads of kids that young but I was obviously wrong. That assessment is confirmed by the response from school officials who unanimously expressed their approval and suggested a repeat. Too bad it was cut short by the storm and threat of lightning. Thanks again for the excellent job you all did and the tremendous amount of work you put into it.

3. **International Congress of Entomology** held in Orlando, FL (Sep. 25-30). Poster presentation "*Attractiveness of seven insectary plants to natural enemies of insect pests in a vegetable cropping system*" by B. Shrestha, D. Finke, and J.C. Piñero (poster was awarded second place in the graduate student competition). Conference was attended by ca. 3,000 scientists.

2017

1. **Great Plains Growers Conference**, held in St. Joseph, MO (Jan. 12-14). Poster title: "*Attractiveness of seven insectary plants to natural enemies of insect pests in a vegetable cropping system*" by B. Shrestha, D. Finke, and J.C. Piñero. Conference is attended by ca. 500 farmers.
2. **Midwest Organic and Sustainable Education Service (MOSES) conference** held on Feb. 23 - 25, 2017 in LaCrosse, WI. Two posters were presented. Poster titles: (1) "*Integration of Insectary Plants with Trap Crops to Suppress Populations of Multiple Pest Species by Attracting Natural Enemies in the Cabbage Cropping System"* by Binita Shrestha, Deborah Finke, and Jaime C. Piñero, and (2) "*Optimizing a Mass Trapping System Design for Organic Control of Japanese Beetles"* by Jaime C. Piñero and Austen Dudenhoeffer. Audience: cannot be quantified, but conference is attended by 3,500+ organic farmers.

Peer-reviewed publications:

Piñero, J.C., Manandhar, R. 2015. Effects of increased crop diversity using trap crops, flowering plants, and living mulches on vegetable insect pests. TRENDS in Entomology 11: 91 – 109.