Dr. Kimberly A. Stoner
Department of Entomology
The Connecticut Agricultural Experiment Station
123 Huntington Street, P. O. Box 1106
New Haven, CT 06504

Phone: (203) 974-8480
Fax: (203) 974-8502
Email: Kimberly.Stoner@ct.gov
Website: www.ct.gov/caes

Founded in 1875
Putting science to work for society

Bees on Alternative Flowering Plants on Vegetable Farms in Connecticut

Pollination is essential for the production of many fruit, nut, and vegetable crops. Because honey bees have suffered major losses in recent years, there has been an increase in research on the many species of other wild bees present on farms, revealing their importance in pollinating crops. One recent worldwide survey of 41 different crops found that in most cases, while honey bees can supplement the pollination services of wild bees in increasing fruit set, they cannot adequately substitute for them (1). Wild bees cannot be moved from one place to another to find plants in bloom like honey bees, so they need a diversity of flowers as sources of nectar and pollen onsite throughout their lifespan (2).

Many crops grown on vegetable farms benefit from bee pollination, including cucumbers, melons, pumpkins, squash, beans, tomatoes, and small fruit such as strawberries and raspberries (3). Many of these crops are visited more frequently by wild bees than by honey bees, including tomatoes, pepper, and watermelon (4). In my own research on pumpkins, in three years of studies, we have found that most of bee visits to pumpkin flowers are by wild bees rather than honey bees, and this has been confirmed by others (5,6,7). Both numbers and diversity of wild bees are important in providing pollination services to vegetable farms – for example, the complement of wild bee species pollinating tomatoes and watermelon at the same time of year in the same region of New Jersey were quite distinct (4).

With a Conservation Innovation Grant from the Natural Resources Conservation Service (NRCS) of the US Department of Agriculture, we have been studying alternative flowering plants on vegetable farms – cut flowers, herbs, cover crops, wildflowers, and weeds – and what bees they attract. With a crew of summer workers, we went to 10 vegetable farms in 2011 and 2012 and measured the bees in two ways:

1. Timed observations – using a stopwatch we counted the numbers of bees seen in either two minutes (for cultivated plantings in rows) or five minutes (for fields of cover crops, weeds, or wildflowers). Observing bees on the wing, we could count the numbers in certain classes: honey bees, bumble bees, carpenter bees, green bees, tiny bees (such as sweat bees), megachilids (leaf cutter bees), and other bees.

2. Netting bees - Collecting a sample of bees with an insect net, killing them in soapy water, bringing them back to the laboratory, and identifying them to species. Again, these samples were timed, so that we could make a fair comparison between samples on different flowering plants. Although it is unfortunate that we have to kill bees to make an accurate identification, it is important to know which bees and how many species of bees are attracted to different plants.

Our study was limited, in general, to herbaceous annuals and perennials, because we were not equipped to count and collect bees on trees and shrubs, and the study ran from late April to mid-October. Trees and flowering shrubs are important sources of pollen and nectar for bees, particularly in spring, so there are some groups of bees, including many in the genera *Andrena, Osmia, Megachile,* and *Colletes,* that are active in spring and important pollinators of fruit trees, but were only a small part of our sample.

I have a separate fact sheet on the flowering plants we found, and which attracted the most bees, including honey bees, bumble bees and "other" bees based on the timed observations (link). In this fact sheet, I focus on the diversity of bees we collected in the net samples, and present a brief summary for each group of the most common bee species, their biology, including listing a few crops they are known to visit, and what flowers we found them visiting on vegetable farms in Connecticut. We found 98 species of bees in our net samples on 10 farms, about 30% of the bee species known to exist in Connecticut (Ascher, personal communication). All of the species are listed in a table at the end.

Bumble Bees - *Bombus* –

The most common bee species we collected was *Bombus impatiens*, the common eastern bumble bee. *Bombus impatiens* was more common than the honey bee overall and even on three of the four farms that had honey bee hives on the farm. Bumble bees are similar to honey bees in that they are generalists, feeding on and pollinating a wide diversity of flowers over a long season. As shown in the table, *Bombus impatiens* visits many vegetable crops, and although only the queens are present in small numbers early in the season when apples bloom, they visit apple flowers, too. Bumble bees visit the flowers of mid-season small fruits, including blueberries and caneberries, such as raspberries and blackberries in large numbers (8). Bumble bees can "buzz pollinate" flowers that only release pollen in response to a particular frequency of vibration, including tomatoes, blueberries, and other crops (9).

In addition to *Bombus impatiens*, we collected 4 other species of bumble bees (the genus *Bombus*), all of which are visitors to at least one vegetable crop in addition to visiting apples. Nationwide, the diversity of bumble bees has been declining – many species have been decreasing in numbers and range, even though a few species, such as *Bombus impatiens*, remain abundant (10).

Bumble bees form colonies, but unlike honey bees, the entire colony does not survive the winter – only a mated queen overwinters; she then has to establish a new colony from scratch in the spring. In order for a queen bumble bee to produce a successful colony, she must be able to find a suitable nesting site (hole in the ground or clump of grass) and be able to feed herself with nectar and feed her larvae on pollen and nectar through the spring. Once a group of workers

reach adulthood, the colony needs a steady supply of flowers through the summer to increase in numbers, followed by abundant flowers in the fall for new queens to build up reserves to be able to survive without feeding over the winter (11).

There is concern nationwide, and even worldwide, about species of *Bombus* that have recently had great decreases in numbers or geographic range. Some of these species, such as *Bombus affinis, B. terricola, and B. pensylvanicus,* were collected in Connecticut in the past, but have not been recorded here in several years (12). While bumble bees as a group are still common, it is important to maintain a diversity of species, especially those such as *B. affinis* and *B. terricola*, which were important pollinators of cranberries as recently as 1990 (13).

Flowers that are good for bumble bees include clovers; herbs such as lavender, anise hyssop, motherwort, basil, and sage; cut flowers such as zinnia, celosia, and ageratum, and wildflowers such as goldenrod and asters. Biennial vegetables such as radish, brassicas and cilantro, and their weedy and cover crop relatives can provide flowers early in the spring. Flowering trees and shrubs, such as willows, New Jersey tea, and redbud are also critical sources of nectar and pollen early in spring (11).

Honey bees – *Apis mellifera*

Whole books are available on how to manage honey bees, including lists of honey plants for different seasons of the year. Among plants attractive to honey bees we found on vegetable farms were several vegetables allowed to go to seed, including Brassica (plants in the cabbage family such as collards, kale, Chinese cabbage, mustards, and Asian greens), chives and garlic chives, and cilantro. Among the clovers, crimson, alsike, and white clovers have better flowers for honey bees than red clover, which has its nectar deep in the flowers where it is difficult for honey bees to reach. Buckwheat is another cover crop that favors honey bees. In the fall, sunflowers and goldenrod are attractive to honey bees.

Sweat bees – *Halictus, Lasioglossum, Agapostemon, Augochlorella, Augochlora, Aucochloropsis*

Many of these small bees are visitors to vegetable and fruit flowers. *Halictus* and *Lasioglossum,* two genera of small dark bees, include many different species that look similar unless you are a bee specialist. There is a lot of variation in life history among these bees, too – they vary from being eusocial (having colonies with a single queen living together over the winter) to having entirely solitary females, each of which makes her own nest (14). Like many other bees, they are attracted to Brassicas allowed to flower. They are also attracted to flowers in the aster family such as sunflowers, cosmos, calendula, black-eyed Susan (*Rudbeckia*) and daisies.

The distinctive bright green sweat bees in the genera *Agapostemon, Augochlorella, Augochlora*, and *Aucochloropsis* are also visitors to vegetable flowers, but are also generalists found only in small numbers spread over many different types of flowers in our study.

Carpenter Bees – *Xylocopa virginica*

These bees, the largest species in our region, are unfortunately familiar to most of us for their tunnels in sound wood, but they are also important pollinators. Like bumble bees, they can “buzz

pollinate" crops (9), and they have been recorded as visitors on a wide variety of vegetable and fruit crops.

Digger bees – *Andrena*

As mentioned above, many species of *Andrena* are important pollinators of spring-blooming trees and shrubs, which were not generally sampled as part of our project. However, we did collect 22 species of these ground-nesting solitary bees. One site where we caught many individuals of one species, *Andrena vicina*, was on a hedge of boxwood lining a road at one of our farms. Clovers, including both white and red clovers, were visited by *Andrena wilkella.* We also caught a diversity of species of *Andrena* in a hayfield that had been planted with a spring-blooming *Brassica* cover crop.

Long-horned bees – *Melissodes* and *Peponapis*

These ground-nesting bees with long antennae include some species that are specialists, preferring to feed their larvae pollen from only one group of closely related plants. Only females collect pollen to feed the larvae, while both males and females feed themselves on nectar, which can come from a wider range of plant species. *Peponapis* is a classic example – the females feed their larvae pollen only from squash and pumpkins (*Cucurbita*) (15). In our studies of squash and pumpkin pollination, we have seen many *Peponapis* females, but in this study of other floral resources, we caught only 3 males collecting nectar from other flowers. *Melissodes denticulata* is another example, using ironweed (*Vernonia*) as its preferred source of pollen (16), and we caught all 11 of our specimens on that plant. *Melissodes agilis* and *M. trinodis*, two species difficult to distinguish, both use sunflowers (*Helianthus*) as their primary source of pollen (16), and we caught both males and females of these species on sunflowers, but caught only males on thyme.

Small carpenter bees – *Ceratina*

These tiny bees make their nests in pithy stems, rather than in solid wood, so they are not a problem in wooden structures like the larger *Xylocopa* carpenter bees. *C. calcarata* is a generalist, visiting many different crop plants. We caught small numbers on many plant species, but caught the most, 15 females, on *Brassica* plants allowed to flower.

Megachilids –*Megachile, Osmia, Anthidium*

Some bee guides call these the "hairy belly bees" because the females have specialized hairy structures for carrying pollen on the underside of their abdomens, rather than carrying pollen on their legs, as many of the more familiar bees do. This family of bees is also called "leaf-cutter bees" because the females of some species of *Megachile* line the cells in their nests with pieces of leaves they cut and carry home. *Anthidium* bees, rather than using cut leaves, collect plant hairs to line their nests, and *Osmia* bees collect mud to line their cells. Because they will nest in carefully prepared hollow stems or straws, some species of *Osmia* and *Megachile* can be managed for use in pollination, by setting up bee houses of suitable hollow tunnels during the active season, then harvesting the dormant pupae and setting them up with nesting habitat in a new location where pollination is needed (17).

Parasitic bees – *Nomada, Sphecodes, Triepeolus*

Although all bee larvae feed on pollen as their protein source, not all species of bees collect their own pollen from flowers. Some bees are "cleptoparasites," which means that they steal food collected by other bees. Bees do this by laying their eggs in the nest of another bee species, so

that their larvae feed on the pollen and nectar stored in the nest, killing or starving the larvae of the host bee. This strategy has evolved many times among bees, so there are cleptoparasitic bees in many genera, but the three genera above are all cleptoparasites. We still catch them on flowers in the field, probably because the adults are collecting nectar to feed themselves, even though they do not need to collect pollen.

Conclusion

This study shows that diversified vegetable farms in Connecticut support a diversity of bees – 98 species collected in only 2 growing seasons on 10 farms. Although we are only beginning to document the role of diverse wild bees in pollinating vegetable crops, many of the bees we collected on non-vegetable host plants – herbs, cut flowers, cover crops, weeds and wildflowers – on these vegetable farms have been shown to be visitors of vegetable crops that benefit from insect pollination.

Bees collected from 10 diversified vegetable farms in Connecticut in 2011 and 2012. In our study, bees were collected in timed samples from alternative floral resources, such as herbs, cut flowers, cover crops, wildflowers and weeds. For more information on the flowers we studied, see the accompanying fact sheet (link).

Genus	***Species***	**Number of bees caught**	**Vegetable flowers visited[1]**	**Fruit flowers visited[2]**	**Alternative Flowers visited[4]**
Agapostemon		**21**			
	sericeus	5	W,Cu	A,Cr	
	splendens	1			
	virescens	15	W,Cu		
Andrena		**158**			
	alleghaniensis	8			Brassicas allowed to flower
	asteris	2			
	carlini	3		A, B,Cr	
	commoda	3		A	
	crataegi	6	Cu	A	
	cressonii	2		A,Cr	
	distans	1			
	forbesii	1		A,B	
	fragilis	3			
	hippotes	2		A	
	hirticincta	2			
	miserabilis	3		A	
	nasonii	67		A	Brassicas allowed to flower
	nuda	2		A	
	placata	2			
	pruni	3		A,B	
	sp.	4			
	vicina	21		A,B,Cr	Boxwood
	wilkella	23	T,M		Clovers
Anthidium		**24**			
	manicatum	15			
	oblongatum	9			Bird's foot trefoil
Apis		**1854**			
	mellifera	1854	W,T,M,P,Cu, Pu	A,B,Cr	Brassicas allowed to flower, chives, buckwheat, white

					clover, cilantro, sunflower, goldenrod
Augochlora		**6**			
	pura	6	W,T,M,Pe,Cu	A,B	
Augochlorella		**13**			
	aurata	13	W,T,M,Pe,Cu	A	
Augochloropsis		**1**			
	metallica	1	W,T	A,B,Cr	
Bombus		**3158**			
	bimaculatus	546	W,M	A,B,Cr	Clovers, lavender, motherwort, vetch, penstemon, thyme
	griseocollis	137	T,Cu	A,Cr	Wild radish, clovers, vetch, sunflower
	impatiens	2445	W,T,M,Pe,Cu, Pu	A,B,Cr	Sunflower, clovers, lavender, zinnia, celosia, sage, basil, ageratum, anise hyssop
	perplexus	22	W,M	A,B,Cr	clovers
	vagans	7	W	A,B,Cr	
Ceratina		**62**			
	calcarata	40	W,M,Cu	A,B,Cr	Brassicas allowed to flower
	dupla	9		A,B,Cr	
	mikmaqi	5			
	strenua	1	W	B	
Colletes		**2**			
	inaequalis	1		A,B	
	simulans	1			
Halictus		**209**			
	confusus	15	W,T,M,Cu	A,B,Cr	
	ligatus	183	W,T,M,Pe,Cu	A	Cosmos, calendula, sunflower, daisies, black-eyed Susan
	parallelus	8	W,M		
	rubicundus	3		A,B,Cr	
Hoplitis		**1**			
	pilosifrons	1			
Hylaeus		**21**			
	illinoisensis	1			
	mesillae	1	W,T		
	modestus	1	W		
	affinis or	18			Cilantro/Coriander

	modestus[3]				
Lasioglossum		**195**			
	admirandum	4	W,T,Pe	A,Cr	
	albipenne	1	W,T	B	
	anomalum	3			
	bruneri	1	W,Cu		
	cressonii	2	W,Pe	A,B	
	ephialtum	5			
	foxii	4		A,B	
	gotham	10			Brassicas allowed to flower
	imitatum	14	W,T,Cu	A,B	
	leucocomum	18			
	leucozonium	1		A	
	nymphaearum	10	W,T,Pe		
	obscurum	1	P	A	
	paradmirandum	1		A	
	pectorale	33	T		Brassicas allowed to flower
	pilosum	37	W,T,Pe,Cu	A,B	Calendula
	quebecense	1		A,B	
	smilacinae	3		B	
	sp.	2			
	tegulare	3	W,T,Pe		
	versans	1		A,B	
	versatum	35	W,T	A,B	Brassicas allowed to flower
	viridatum	1		A	
	weemsi	3			
	zephyrum	1	W,T,Pe	A,B	
Megachile		**20**			
	brevis	1	W		
	inimica	2			
	mendica	10	W		
	rotundata	4	M		
	sculpturalis	3			
Melissodes		**66**			
	agilis	2			
	bimaculata	4	W,M,Cu		
	denticulata	11			New York ironweed
	trinodis	7			
	agilis or	42			Sunflower, thyme

	trinodis[3]				
Nomada		**4**			
	articulata	2			
	australis	1			
	tiftonensis	1			
Osmia		**11**			
	bucephala	2		A,B	
	cornifrons	1		A	
	pumila	8		A	
Peponapis		**3**			
	pruinosa	3	W,M,Cu, Pu		
Perdita		**7**			
	octomaculata	7			
Sphecodes		**5**			
	coronus	1			
	dichrous	1		A	
	johnsonii	1			
	mandibularis	1			
	pimpinellae	1			
Triepeolus		**11**			
	lunatus	1			
	remigatus	10	W,M,Cu		
Xylocopa		**120**			
	virginica	120	W,M,Cu	A,B,Cr	Celosia, sage, basil, mint
Grand Total		**5972**			

[1] W = watermelon, T = tomato, M = muskmelon, Pe = pepper, Cu = cucumber, Pu = Pumpkin. Watermelon, tomato, muskmelon and pepper from Winfree et al. 2008, cucumber from Smith et al 2013. Pumpkin from our unpublished data , and from Julier & Roulston (2009), Shuler et al (2005), and Petersen et al. (2013).

[2] A= apple, B = blueberry, Cr = cranberry. References for each of these crops: Apple: Gardner KE, Ascher JS (2006) Notes on native bee pollinators in New York apple orchards. Journal of the New York Entomological Society 114 (1-2): 86-92. Park MG, Orr MC, Danforth BN (2010) Role of native bees in apple pollination. New York Fruit Quarterly 18(1): 21-25. Blueberry: Stubbs CS, Jacobson HA, Osgood EA, Drummond FA (1992) Alternative forage plants for native (wild) bees associated with lowbush blueberry, *Vaccinium* spp. in Maine. Maine Agricultural Experiment Station Technical Bulletin 148. McKenzie KE, Eickwort GC (1996) Diversity and abundance of bees (Hymenoptera: Apoidea) foraging in highbush blueberry (*Vaccinium corybosum*) in central New York. Journal of the Kansas Entomological Society 69 (4) suppl.: 185-194. Cranberry: McKenzie KE, Averill AL (1995) Bee (Hymenoptera: Apoidea) diversity and abundance on cranberry in southeastern Massachusetts. Annals Entomological Society of America 88: 334-341.

[3] Although males of *Hylaeus modestus* and *H. affinis* can be distinguished, we are not able to between these two species for females. For *Melissodes,* more taxonomic work is needed in order to be able to reliably distinguish *M.agilis* and *M. trinodis.*

[4]Flowers visited are listed when we netted more than 8 bees in one species on one genus – although for very common bees (*Bombus impatiens, Apis mellifera*) only those flowers where the greatest numbers were caught are listed.

Acknowledgements

This project was supported by a Conservation Innovation Grant from the Connecticut office of the Natural Resources Conservation Service, an agency of the U.S. Department of Agriculture, under NRCS Agreement No. 69-1106-10-03. Tracy Zarrillo did a tremendous job identifying bees as well as organizing the processing, and Morgan Lowry assisted with processing and data entry. Krystian Madrid, Benjamin Gluck, Christine Bell, Meaghan Stucke, Ghada Hafez, and Ellen Bulger carried out the field work and assisted with processing. Great thanks to Sam Droege of the US Geological Survey, John Ascher of the American Museum of Natural History (now at the University of Singapore), Jason Gibbs of Cornell University (now at Michigan State University) and Sandra Rehan of the University of Pennsylvania for confirmations and identifications of the bees.

References

1. Garibaldi LA, et al (2013) Wild pollinators enhance fruit set regardless of honey bee abundance. Science 339: 1608 -1611.
2. Smith AA, Bentley M, Reynold HL (2013) Wild bees visiting cucumbers on Midwestern organic farms benefit from near-farm semi-natural areas. Journal of Economic Entomology 106: 97-106.
3. Woodcock TS (2012) Pollination in the agricultural landscape: Best management practices for crop pollination. Canadian Pollination Initiative.
4. Winfree R, Williams N, Gaines H, Ascher JS, Kremen C. (2008) Wild bee pollinators provide majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. Journal of Applied Ecology 45: 793-802
5. Julier H.E, Roulston TH (2009) Wild bee abundance and pollination service in cultivated pumpkins: Farm management, nesting behavior and landscape effects. J. Economic Entomology 102:563-573.
6. Shuler R, Roulston TH, Farris GE (2005) Farming practices influence wild pollinator populations on squash and pumpkin. J. Econ. Entomol. 98: 790-795.
7. Petersen JD, Reiners S, Nault BA (2013) Pollination services provided by bees in pumpkin fields supplemented with either *Apis mellifera* or *Bombus impatiens* or not supplemented. Public Library of Science ONE 8(7): e69819.
8. Adamson NL, Roulston TH, Fell RD, Mullins DE (2012) From April to August – Wild bees pollinating crops through the growing season in Virginia, USA. Environmental Entomology 41:813-821.
9. King MJ, **Buchmann SL** (2003) Floral sonication by bees: Mesosomal vibration by *Bombus* and *Xylocopa*, but not *Apis* (Hymenoptera : Apidae), ejects pollen from poricidal anthers. *Journal of the Kansas Entomological Society* 76(2): 295-305.
10. Colla SR et al (2012) Assessing declines in North American bumble bees using museum specimens. Biodivers Conserv DOI 10.1007/s10531-012-0383-2.

11. Hatfield et al. (2013) Conserving Bumble Bees: Guidelines for Creating and Maintaining Habitat for America's Declining Pollinators. Xerces Society for Invertebrate Conservation. 32 pp.
12. From Tracy Zarrillo's review of the Planetary Biodiversity Inventory bee database, maintained by the American Museum of Natural History.
13. McKenzie KE, Averill AL (1995) Bee (Hymenoptera: Apoidea) diversity and abundance on cranberry in southeastern Massachusetts. Annals Entomological Society of America 88: 334-341.
14. Danforth BN (2002) Evolution of sociality in a primitively eusocial lineage of bees. Proceedings of the National Academy of Sciences 99(1):286-290.
15. Hurd PD, Linsley EG, Whitaker TW (1971) Squash and gourd bees (Peponapis, Xenoglossa) and the origin of the cultivated *Cucurbita*. *Evolution, 25*: 218-234.
16. LaBerge, W E (1961). A Revision of the Bees of the Genus *Melissodes* in North and Central America: Part III (Hymenoptera, Apidae). University of Kansas Publications. Cited in Mitchell, TB (1962) Bees of the Eastern United States. North Carolina Agricultural Experiment Station Technical Bulletin No. 152.
17. Bosch J, Kemp W (2001) How to Manage the Blue Orchard Bee As an Orchard Pollinator. Sustainable Agriculture Network Handbook Series 5. Beltsville, MD.