Integrated Crop Pollination for Squashes, Pumpkins and Gourds

Squashes, pumpkins and gourds need pollination

Squashes, pumpkins, and gourds belong to the genus *Cucurbita*. They are grown in gardens and on farms in every state. The plants are all self-fertile (e.g. a single plant can produce fruits), but each massive flower is of a single sex, either a pollen-bearing male or a fruiting, female flower. Therefore, pollen transfer is essential to producing fruit. Although few bee species want the large, sticky pollen, they drink from the generous pool of nectar hidden inside the bottom of every flower, and transfer pollen during that process. Those that don't want squash pollen groom it off periodically and discard it, leaving yellow flecks on the leaves.

Both of these zucchini fruit received poor pollination. *Photo: Jim Cane, USDA-ARS.*

Integrated crop pollination: ensuring good pollination

Squash and pumpkin plants produce new flowers daily. These flowers last for only one morning, then wither. It is during these few morning hours that many hundreds of pollen grains need to be received by each female flower. Most bees will only deposit a few dozen to several hundred pollen grains. Consequently, each female flower must receive multiple bee visits during the single morning that it is open in order to set fruit. If unpollinated, flowers abort, and poorly pollinated flowers yield small, misshapen fruits (e.g. pinched tips, curved fruits). Commercial growers of squash and pumpkin stock their fields with honey bees at rates between 1 and 3 hives per acre. However, where wild bees are abundant, growers can curtail hive rentals or eliminate them altogether. Integrated crop pollination is *the use of managed pollinator species in combination with farm management practices that support, augment, and protect pollinator populations to provide reliable and economical pollination of crops*. This guide highlights the major pollinators of squashes, pumpkins and gourds and practices to support those pollinators.

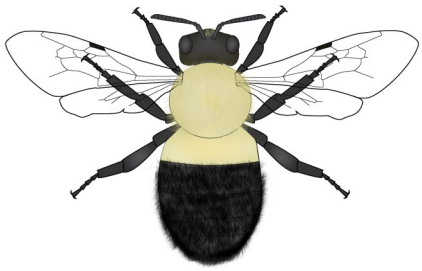
Squash bees drinking nectar from the base of a male squash flower. *Photo: Katharina Ullmann, The Xerces Society.*

Are your squashes well-pollinated? Poor pollination results in excessive fruit abortion and sparse seed set. It is most easily revealed by slicing an over-mature summer squash lengthwise to look for small undeveloped seeds at the deformity (fruit tip or inner curve). In pumpkins, fruit weight increases with seed number. Alternatively, play the bee yourself. Clip a fresh male flower, peel away the petals, and wipe its pollen thickly all over the terminal lobes of a female flower. Flag the base and watch fruit development over the next week or two. Clip the flagged green fruit and a like-sized fruit nearby, slice them open lengthwise, and compare them for their content of developing seeds.

Meet the Pollinators

All bees visiting squashes and pumpkin transport pollen on their hind legs when they are collecting pollen, either as a wet pellet (bumble and honey bees) or dry in hair brushes. If they are visiting flowers for nectar, then pollen might be located on other parts of their body. They all nest underground - except for honey bees and some bumble bees. Only the squash bees (*Peponapis* and *Xenoglossa* bees) are strict floral specialists who get all their pollen only from *Cucurbita* (e.g. squash, pumpkin and gourds). These specialists don't even use melons or cucumbers for pollen. The other visiting bees are all floral generalists. Most commercial growers supply fields with European honey bees. However, in many locations, unmanaged populations of squash bees or bumble bees are abundant enough to pollinate daily bloom; the squash bees will do their work before honey bees awaken. Across the United States, the following bees are the most common visitors to squashes and pumpkins that bear traits for being good pollinators.

European honey bees (*Apis mellifera)***:** Found across the United States. These bees are social, living in large, perennial hives of up to 50,000 individuals, including 14,000-19,000 adult worker bees. Honey bees enter squash and pumpkin flowers slowly and are a satisfactory squash pollinator. They are useful for new plantings, late-flowering pumpkins, or where wild squash bees or bumble bees are not abundant. They are also useful to ensure pollination in large fields experiencing a pulse of bloom. Hives are typically placed alongside pumpkin fields at a rate of 0.5 to 3 hives/acre. However, in some regions of Pennsylvania wild bee populations are so abundant that growers are not stocking fields with honey bees. While honey bees will forage up to 3 miles from their hive, most prefer to forage on nearby flowers. Honey bees are usually removed from fields as soon as bloom is complete.



Bumble bees (various *Bombus* species) – Bumble bees are found throughout the United States and are the most efficient pollinator of squash and pumpkin flowers; they deposit roughly 3 times more pollen on squash and pumpkin flowers than honey bees or squash bees. These bees are primitively social: they transition from a solitary queen, into a social colony, and then back to a solitary bee. Bumble bees variously nest in old rodent nests, grass hummocks, or tree hollows (including songbird nest boxes). A mated queen prepares her nest in early spring and then collects pollen and nectar for her first daughters. These daughters will be workers who take over foraging and nesting chores. Colonies grow more populous over the summer. Towards the end of the summer, the colony turns to producing future queens and male bees called drones. The colony then dies, survived only by the newly mated queens who will overwinter until the next spring. Bumble bees are big, hairy, round bees that are larger than honey bees. They are more commonly found on later-blooming pumpkins than early blooming squash.

Squash bees (*Peponapis pruinosa* and *Xenoglossa angustior*): The squash bee, *P. pruinosa*, is found across the United States except from the Dakotas west through Oregon and Washington. These bees are not social, each female excavates her own earthen nest and only produce one generation per year. Researchers do not know exactly how many eggs a female lays in her life time, but most solitary bees lay between a few eggs and dozens of eggs. Females often build nests in aggregations. So, if you discover one squash bee nest, there is likely another nearby. They are similar in size to honey bees and have pale hair stripes across their abdomen. They are direct and fast flyers.

Male squash bees dart among flowers collecting nectar and seeking females beginning at or before sunrise. They have a yellow dot on their face and, in the afternoon, sleep in spent flowers; Females will begin visiting flowers in the early morning. They are broader-bodied than males and have a reddish tip to their abdomen. They tote big loads of yellow squash pollen dry on hind leg hair brushes. After the day's flowers wither, females remain in their nests, while males may stay overnight in the drying flower. Both sexes are excellent pollinators. Densities up to 1 bee/3 flowers are sustainable over years in a given squash patch. Zucchini flowers receiving seven floral visits are fully pollinated. The range of the squash bee, *Xenoglossa angustior*, is limited to southern states. They are stouter than *P. pruinosa* and more common in later blooming pumpkin fields. Both types of bees have close relatives in the U.S. Southwest and Mexico that persist on both cultivated squashes and wild gourds.

Female (left) and male (right) squash bee nectaring on a female flower. Females are slightly larger than males and have a redder coloring than males. Color may vary slightly between eastern and western populations. *Photo: Jim Cane, USDA-ARS.*

Long-horned bees (*Melissodes bimaculata*) – This particular species of long-horned bee is found from the Rocky Mountains east to the mid-Atlantic and southeastern states. These are also solitary bees that nest underground and likely has one generation per year. They are similar to honey bees in size, but are black with a pair of white hair dots on the back of their body. They may be effective squash pollinators, but are not as commonly found on squash as honey bees, squash bees, and bumble bees.

Other wild bees A number of other ground-nesting wild bees of the family Halictidae, commonly known as sweat bees, visit squash flowers around the US. They are all floral generalists. Inconsequential visitors include tiny sweat bees (*Lasioglossum and Dialictus* species), and striped sweat bees (*Halictus* species). Sweat bees that likely contribute to squash pollination are the jewel bees (genera *Agapostemon* and *Augochlora*). These bees are slightly smaller than honey bees and are a brilliant metallic green color.

Case study: bumble bees in Pennsylvania pumpkins

Researchers found that bumble bees are able to move huge amounts of pollen between pumpkin flowers. One of the most active bumble bees in Pennsylvania pumpkin fields is the Common Eastern Bumble Bee, *Bombus impatiens*.

The Common Eastern Bumble Bee is one of the most abundant wild bees in Pennsylvania pumpkin fields. *Photo: Jason Gibbs, Michigan State University.*

Unlike solitary bees, bumble bees are social bees that live in a colony. If you see two bumble bees on a pumpkin flower they may be from different colonies or they may be sisters from the same colony.

Presumably, the more colonies you have visiting your crop, the more stable your pollination will be across your fields and across seasons. For example, if you had 100 bumble bees visit your pumpkin flowers, but they were all from the same colony and that colony failed, they would all disappear from your field. Alternatively, if those 100 bumble bees came from 3 different colonies and one colony failed, bumble bees would continue to pollinate your crop.

Researchers from Pennsylvania State University recently quantified the number of colonies represented in PA pumpkin fields. To their surprise, they found that in any given field, an average of 544 Common Eastern Bumble Bee colonies were visiting PA pumpkin during bloom. That's a lot of bees given that each colony may send multiple foragers to a pumpkin field.

Why are there so many colonies in PA pumpkin? Lead researcher, Carley McGrady (Penn State), thinks it has something to do with the surrounding landscape, "Pennsylvania is a mosaic of diversified agricultural fields, scrubby meadows and patches of forest. Each piece of land offers different resources where the bees might find good nesting substrate or a range of pollen and nectar options. A variety of landscape patches in a single region provides easier access to everything a thriving bumble bee colony needs!"

On average, PA pumpkin fields had bumble bees from 544 different colonies visiting pumpkin flowers! *Photo: Nick Kraus, Pennsylvania State University.*

Practices to Support Squash Pollinators

Managed and wild bees need three things: access to flowers for pollen and nectar, safe places to nest, and protection from insecticides and some fungicides. In dry environments, managed honey bees also need access to clean, pesticide free water. Here are steps you can take to support squash pollinators:

1. Communicate with your beekeeper: If you are renting managed honey bees to pollinate your crop, draw up a contract to define the expectations of both parties. Agree on a drop off and pick up date in relation to crop bloom. Place hives in pesticide-free places on the farm and notify your beekeeper days in advance what you'll be spraying near hives.

Honey bees drinking nectar from a female squash flower. *Photo: Katharina Ullmann, The Xerces Society*

2. Protect pollinator-friendly areas on the farm: Areas that provide flowering plants and places for wild bees to nest support both wild and managed bees. For example, forested edges and old fields provide bees with pollen, nectar, and nesting sites. Field edges, if not mown too frequently, can also provide resources.

3. Plant suitable flowering shrubs or wildflowers on field edges: Adding plants that bees will use for pollen and nectar before and after squash or pumpkin bloom will support generalist social bees when the crop is not in flower. Bumble bees, honey bees, jewel bees and long-horned bees may use such bloom when adults are active. On rare occasions, specialist squash bees will visit these resources to drink nectar before squash bloom ensues. Early-season flowers that support overwintered bumble bee queens and late-season flowers that support newly emerging queens are especially valuable. Bees prefer some plants over others; select plants that bees will actively visit.

4. Plant a flowering cover crop: Cover crops that are allowed to bloom also provide pollen and nectar to bees. In addition, cover crops can benefit soil health and suppress weeds and disease. As with wildflowers, choose cover crop mixes that bloom early and late, or utilize multiple planting dates, to support bumble bees and other generalist bees. For bumble bees, ensuring bloom during the early spring months when queens are establishing nests is critical. In eastern states, a fall-planting mix that flowers in the spring, and a summer-planted mix (following wheat harvest) that flowers in the fall, will achieve this timing. Even low seeding rates can achieve floral displays that can effectively support pollinators. Avoid cover crop species related to squash or pumpkin that might harbor insects or pathogens that infest *Cucurbita* crops.

A Common Eastern Bumble Bee visiting vetch flowers in a spring blooming cover crop. *Photo: Hannah Balko, Pennsylvania State University.*

5. Practice no-till or minimum till agriculture: Squash bees and other ground-nesting bees often nest amid squash rows. Squash bees nest cells occur between 5 in and 20 in below the soil surface. Squash bee populations tend to be higher in areas with a lot of no-till agriculture. To control weeds between rows during nesting, instead of surface cultivation, use herbicide or burners if weed control is necessary during bloom. Avoid deep and frequent tilling in fields.

Avoid destroying ground nesting bees by minimizing soil disturbance. *Photo: Katharina Ullmann, The Xerces Society*

6. Support squash bees by making squash and pumpkin available every year: Squash bees depend exclusively on squash and pumpkin pollen for their offspring and prefer to nest below squash and pumpkin vines. Where squash and pumpkin are rotated annually, newly emerging bees need to be able to find new fields. Squash bee populations can build up on a farm when squash and pumpkin rotations are managed appropriately. Ensure that there is always a squash or pumpkin field within a ¼- 1 mile from the previous year's field. Doing so will allow emerging squash bees to find and colonize new fields. In the field that you had squash or pumpkin, no-till a cover crop or small grain with minimal soil disturbance until the squash bees have emerged. Planting squash or pumpkin in the same location every year can lead to pest and disease build up in the soil.

7. Minimize pesticide risks to pollinators: Use integrated pest management (IPM) to make targeted pest management decisions. Where possible, avoid insecticides using preventative measures. For example, row cover can create physical barriers that pests cannot penetrate. Additionally, cultivars that provide host-plant resistance, such as the squash cultivars resistant to aphid-transmitted viruses, or pumpkins with tolerance to powdery mildew, minimize disease risk. If using row covers, remove in the morning when flowers are in bloom. Choose selective options to control pests when possible, such as the selective aphicides to manage aphids when necessary. Avoid spraying blooming squashes or pumpkins with pesticides until late afternoon, after blooms have closed. This includes spraying fungicides, because certain fungicides can either be directly harmful to bees, or can increase the harm from contact with insecticides. Follow label instructions and guidelines. Whenever possible, select pesticides that are less toxic to bees and/or shorter-lived.

8. Minimize residues from systemic insecticides: Systemic insecticides have long been used to manage insect pests that transmit plant pathogens. Currently, these are neonicotinoids (imidacloprid, dinotefuran, thiamethoxam) or carbamates (oxamyl). Neonicotinoids largely replaced carbamates and provide much greater farm-worker safety, but residues are harmful to bees. Residues tend to be higher in pollen than nectar, and residue concentrations are affected by application method, environmental conditions, and plant stress. For neonicotinoids, seed treatments result in much lower residues compared to applications at planting through drip-irrigation, or transplant-applications. When neonicotinoids are needed to manage pests, limit them to seed-treatments to minimize residues and conserve your wild bees that are visiting squash/pumpkin in your farmscape.

Rotating squash and pumpkins from year to year prevents pest and disease build up, but fields should be within 0.25-1 mile from the previous year's field to support squash bees. *Photo: Katharina Ullmann, The Xerces Society.*

Case study: Pennsylvania cover cropping for bees

Researchers with Pennsylvania State University tested spring-flowering and fall-flowering cover crops from 2015-2017. Over 40 species of wild bees, in addition to managed honey bees, were found visiting the cover crop trials. These included important pumpkin pollinators like bumble bees, squash bees, long-horned bees, and sweat bees. Below are two cover crops mixes tested for the mid-Atlantic region; one is a fall blooming cover crop while the other is a spring blooming mix.

Blooming cover crops provide pollinators with pollen and nectar. *Photo: Hannah Balko, Pennsylvania State University.*

Cover crops like blooming hairy vetch and crimsom clover can provide bees with extra pollen and nectar when squash, pumpkin, and gourds are not in bloom. For pumpkin fields in the mid-Atlantic, researchers think that cover crops that bloom in the spring and fall are especially important for bumble bees as they start to build nests or prepare to overwinter. In addition to providing floral resources for bees, cover crops can suppress pests and build soil health. The following mixes were developed for western Pennsylvania. Make sure to check what the planting date limitations are within your growing region in order to successfully establish a planting.

Seed this mix in early July for a fall blooming cover crop.	**Cover Crop**	**Variety**	**Species**	**Rate (lbs/acre)**
	Buckwheat	n/a	*Fagopyrum esculentum*	20
	Sunflower	cv. Perodovik.	*Helianthus annuus*	n/a
	Sunn Hemp	n/a	*Crotalaria juncea*	8
	White Mustard	Braco	*Sinapis alba*	5

Seed this mix in early September for a spring blooming cover crop.	**Cover Crop**	**Variety**	**Species**	**Rate (lbs/acre)**
	Canola	Wichita	*Brassica napus*	5
	Crimson Clover	Dixie	*Trifolium incarnatum*	20
	Hairy Vetch	Purple Bounty	*Vicia villosa*	15
	Oats*	Armor	*Avena sativa*	30

*Oats are used as a nurse crop in this mix. Nurse crops provide some cover and help at the micro-environment level during fall establishment. However, they die of in the winter and so do not compete with this spring mix.

A spring blooming cover crop in Pennsylvania. *Photo: Hannah Balko, Pennsylvania State University.*

Monitoring squash, pumpkin and gourd pollinators

The goals of this squash and pumpkin monitoring guide are to calculate the number of (1) different kinds of bees present and (2) bees per plant in your crop field.

By keeping track of these numbers you can determine what proportion of your pollination is coming from wild bees and see how their pollination changes across years or between fields. Researchers are currently determining what the minimum number of bees per plant are to get enough squash or pumpkin pollination. However, there is some indication that one bee per every three flowers may be enough bees for squash pollination.

To conduct this census you will estimate the average numbers of open flowers per plant and the number and kinds of bees present. The basic monitoring technique is a walking scan census, very much like the ones used to count birds. The idea is to know, at a given point in time, the densities of the various bee species at a given count of squash and pumpkin flowers. For the first bee census in your region, it would be useful to census bees at several time periods during the morning so as to fairly represent species that visit crop flowers at different times of the morning. The census should represent the bees visiting squash and pumpkin across the entire patch or field. In smaller patches, you might census all plants, but in larger fields, you should be sure to walk to different parts of the field to conduct your census (or walk across the field along two diagonals).

1. Choose the plants that you will census ahead of you, before you can see if there are bees or not.
2. Count all of the flowers and the bees that you see *in* those flowers on a day with good weather. Do not wait for bees to arrive or depart; this is meant to be the equivalent of a photographic snapshot of what is present at one moment.
3. Continue walking from plant to plant, keeping a running tally of open flowers present and bees found in those flowers. You should continue checking plants and counting bees until until at least 30 bees or 200 plants are included in the census, whichever comes first. There is no problem adding more bees or flowers if you like, as the work is generally quick. Obviously, in small plots with few bees, you will have less, but that is acceptable; do not include flowers twice in the same census.
4. Repeat throughout the season as time permits.

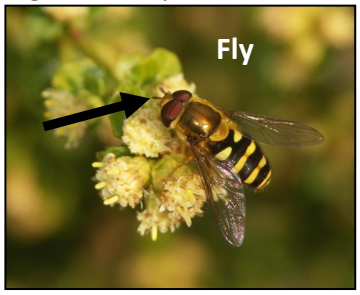
Walk down a row of squash and count all the bees you see in pumpkin flowers until you reach 30 bees or 200 plants, whichever comes first. *Photo: Nick Krause, Pennsylvania State University.*

Identifying squash, pumpkin and gourd pollinators

Although similar at first glance, **wasps** and **flies** are quite different from bees, a few key features to look for are:

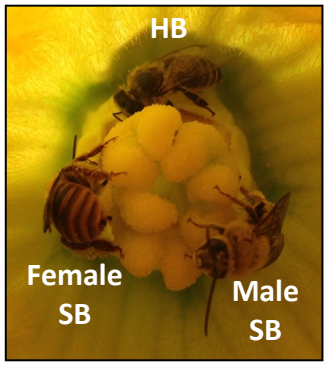
Wasps : Hairless body, skinnier with a "waistline"

Flies : One set of wings, little hair on legs and no "pollen baskets"

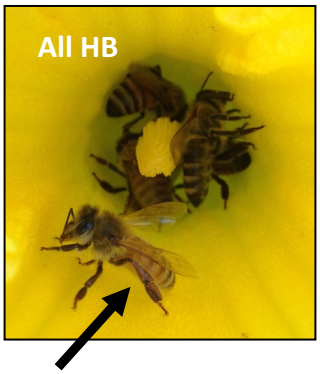


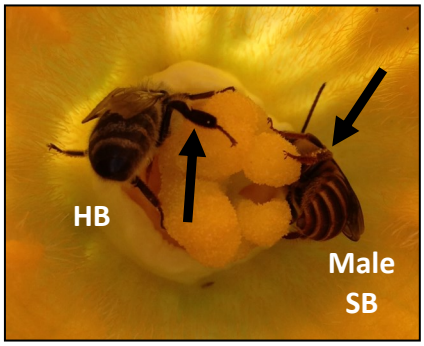
Squash bees (HB): Similar in appearance to honeybees with body shape; they lack a pollen basket, instead legs are covered in dense combs of (females). Look for distinct white stripes on abdomen.

Male vs. female squash bees Look for male squash bees in the closed flowers of pumpkin plants, their legs lack the distinct hairs of females as they don't collect pollen. You can often see a yellowish marking on their face.



Honey bee (HB): Look for a pollen "basket" on their legs and a striped abdomen, often honey colored. Their Stripes are much less distinct then those of squash bees.





Bumble bees: Size can vary, but they are often larger than honey bees and squash bees. There are 46 species found in North America. They are covered in hair and make a distinct and loud buzz.

Other bees: Diverse in their size and color, often metallic with a greenish hue. Look for two sets of wings to ensure it's a bee.

Photos taken by Katharina Ullmann, Jason Gibbs, Katie Ells, and Carley McGrady.

Squash, pumpkin and gourd pollinator monitoring data sheet

Name	Date	Total # of flowers	Honey Bees	Bumble Bees	Squash Bees	Other Bees	Total # of bees	Total Time (minutes)	Total bees/ flower
Jane Doe	7/3/2017	15	12	3	14	0	30	10 min	2 bees/ flower

Notes:

Additional Resources

Pollination of Pumpkin, Squash, and Zucchini
http://bit.do/cucurbita-factsheet

How to Reduce Bee Poisoning from Pesticides
http://bit.do/reduce-risk

USDA cost-share programs for pollinators
http://bit.ly/2fp8rRO

Squash and Pumpkin Pollination Webinar
https://youtu.be/liI63L7oBQQ

Wildflower Meadows for Pollinators in Pennsylvania
http://bit.do/pa-cons-cover

Center for Pollinator Research
http://bit.do/pa-poll-research

Pumpkin Pollinators
http://bit.do/pumpkin-polls

Cover Crops for Pollinators
http://bit.do/pa-cover-crops

Integrated Crop Pollination
http://projecticp.org

Clockwise from left to right: Female squash bee drinking nectar from female squash flower; Anther on male squash flower, mostly stripped of pollen; bumble bee exiting male squash flower; squash pollen sticking to the hairy legs of a squash bee. *All photos by Jim Cane, USDA-ARS.*

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