Insect Visitors to Flowering Buckwheat, Fagopyrum esculentum (Polygonales: Polygonaceae), in North-Central Florida

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Insect visitors to flowering buckwheat, *Fagopyrum esculentum* (Polygonales: Polygonaceae), in north–central Florida

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Abstract

We provide the first extensive documentation of insect visitors to buckwheat (*Fagropyrum esculentum* Moench; Polygonales: Polygonaceae) in Florida. We visually surveyed eight 2 ha fields of buckwheat in north-central Florida and documented 5,300 visits by *Apis mellifera* L. (Hymenoptera: Apidae)—the western honey bee—and 3,422 non-*Apis* insect visits, with the majority of non-*Apis* visitors being wasps native to Florida or the southeastern United States (81.3%), followed by Diptera (12.5%) and non-*Apis* bees (5.8%). Sixteen families of insects composed of at least 62 species of flower visitors were observed within the buckwheat fields, with the most common species being the wasp *Scolia nobilitata* F. (Hymenoptera: Scoliidae). Most of the insect species were parasitoid wasps of various arthropod pests, and many parasitoids may also act as pollinators. Our data suggest that buckwheat attracts a great diversity of beneficial parasitoids, predators, and pollinators; thus, buckwheat possibly could be used as a cover crop to enhance biological control of various pest arthropods within cropping systems or augment local pollinator populations.

Key Words: Scoliidae; Tiphiidae; parasitoid; pollination

Resumen

Proveemos la primera extensa documentación de los insectos que visitan el alforfón (*Fagopyrum esculentum* Moench; Polygonales: Polygonaceae) en la Florida. Inspeccionamos visualmente ocho campos de alforfón cada uno de 2 hectáreas de en el centro-norte de Florida y documentamos 5.300 visitas de *Apis mellifera* L. (Hymenoptera: Apidae) — la abeja del oeste y 3.422 visitas de insectos no-*Apis*, con la mayoría de los visitantes que no son *Apis* siendo avispas nativas de la Florida o del sureste de los Estados Unidos (81,3%), seguido de Diptera (12,5%), y las abejas nativas (?) (5,8%). Se observaron dieciséis familias de insectos, compuestos por al menos 62 especies de visitantes florales dentro de los campos de alforfón con la especie más comun la avispa *Scolia nobilitata* F. (Hymenoptera: scoliidae). La mayoría de las especies de insectos fueron avispas parasitoides de diversas plagas de artrópodos o pueden actuar como polinizadores potenciales. Nuestros datos sugieren que el alforfón atrae a una gran diversidad de parasitoides, depredadores beneficiosos y polinizadores; por lo tanto, el alforfón, posiblemente, podría ser utilizado como un cultivo de cobertura para mejorar el control biológico de diversos artrópodos plaga dentro de los sistemas de cultivo o aumentar las poblaciones de polinizadores locales.

Palabras Clave: Scoliidae; Tiphiidae; parasitoide; polinización

Buckwheat (*Fagropyrum esculentum* Moench; Polygonales: Polygonaceae) is an Old World crop believed to have originated in China (Ohnishi 1998) and was introduced into the New World by European settlers in the 17th century (Treadwell & Huang 2008). Once a commonly planted crop in the United States, buckwheat production sharply declined in the 20th century due to the introduction of nitrogen fertilizer, which allowed for corn and wheat to become prevalent in the United States. In recent years, buckwheat has become more popular due to its newly discovered nutritional value (Cawoy et al. 2008). China, Russia, and Japan are currently the world's top producers of buckwheat (Treadwell & Huang 2008).

Buckwheat produces flowers that are distylous and self-incompatible, and can be pollinated by wind or insects (Sasaki & Wagatsuma 2007). There are 2 types of flower morphologies (pin or thrum), with pin flowers having long styles extending past their stamens and thrum flowers having long stamens that extend beyond the styles (Taki et al. 2009). In many distylous plants, the 2 differing flower structures allow for pollen to be carried on different parts of an insect's body, resulting in transfer of pollen between the 2 types of flowers (Darwin 1888, Beach & Bawa 1980). Buckwheat fields have approximately equal numbers of pin and thrum flowers (Quinet et al. 2004). In Florida, buckwheat blooms approximately 3–5 wk after planting and mature seeds form 6–8 wk after planting (Treadwell & Huang 2008).

Although pollination can occur by wind (Marshall 1969), most pollination is considered to be accomplished by insects, which may be necessary for successful pollination (McGregor 1976). Despite numerous insects being documented visiting buckwheat, the study of insect pollination and visitation on buckwheat is incomplete (Sasaki & Wagatsuma 2007), and findings appear to differ in various parts of the world. For example, western honey bees (*Apis mellifera* L.; Hymenoptera: Apidae) comprised 80% of all insect visitations in Australia (Goodman et al 2001), 95% in central New York (Björkman 1995) and Poland (Banaszak 1983), 97% in Belarus (Kushnir 1976), and 18 to 51% in Belgium (Jacquemart et al. 2007). Alternatively, Sasaki & Wagatsuma (2007) found

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that 2 *Bombus* species (Hymenoptera: Apidae) accounted for over 75% of insect visitation in Japan and were presumed to be the most important pollinators of buckwheat in that study. In a cage experiment, *Apis cerana* F. (Hymenoptera: Apidae) (the Asian honey bee) was found to be an important pollinator in India (Rahman & Rahman 2000). Other authors have documented other insect groups (e.g., Syrphidae, Sphecidae, Crabronidae, Vespidae, and Scoliidae) as common visitors (Bugg & Dutcher 1989; Carreck & Williams 1997; Ambrosino et al. 2006).

Although buckwheat is not a major crop planted in the southeastern United States, its potential as a cover crop to bring in entomophagous insects and as a weed suppressor has been explored in southern Georgia (Bugg & Dutcher 1989) and Florida (Huang 2009), respectively. Little is known about the attractiveness of buckwheat to pollinating and other beneficial insects in the southeastern United States. Here, we present insect survey data from 8 buckwheat fields planted in north-central Florida.

Materials and Methods

Eight 2 ha (5 acre) buckwheat fields were established in north-central Florida (Fig. 1) from seed (Hancock Seed Company, Dade City, Florida) between 15 and 29 Jun 2015. The seeding rate was 113.4 kg per field (50 lbs/acre) per label instructions, and the seeds were the cultivar 'Mancan.' Nitrogen fertilizer was applied to 2 fields to ensure growth and flowering of plants, whereas the other 6 fields did not require any fertilizer. Nitrogen fertilizer is needed to improve growth in soil that is nitrogen limited (Myers & Meinke 1994). Four out of the 8 fields had a systemic pesticide (Sivanto™, Bayer Crop Science) applied to them for a separate study, and 3 colonies of managed honey bees were located in close proximity (<10 m) to each of the 8 fields. Two foliar applications of Sivanto™ were applied at pre- and full-bloom, each at the maximum application rate of 409.5 g/ha (0.365 lb/acre).

We began flower insect visitor surveys when it was observed that at least 20% of a field was flowering. Only insects that visited flowers were captured or counted; thus, insects visiting other portions of the plant were excluded from our surveys. The surveys entailed 1 or 2 researchers walking 2 random 100 m linear transects within the field on a given day. If 1 researcher was present, he/she walked both 100 m transects; if 2 researchers were present, both walked 1 of the 100 m transects. Each 100 m transect walk lasted 30 min. To minimize edge effects, transects were begun approximately 10 m from the field edge and directed towards the center of the field. During the flowering period (20 Jul to 19 Aug 2015), we conducted 54 transect walks (27 total hours) within the 8 buckwheat fields. All transects were accomplished between 9:00 a.m. and 4:00 p.m. on days when weather was appropriate for pollinator activity during this time of year (i.e., no rain and temperatures above 30 °C). Representative insect samples were collected with sweep nets and identified to the lowest taxonomic level possible. Insects that could be identified positively in the field were not collected. A *t*-test was done to determine whether any differences in abundance or species richness of non-*Apis* insects existed between Sivanto™-treated fields and non-treated fields (Statistix 9 Program, Analytical Software, Tallahassee, Florida).

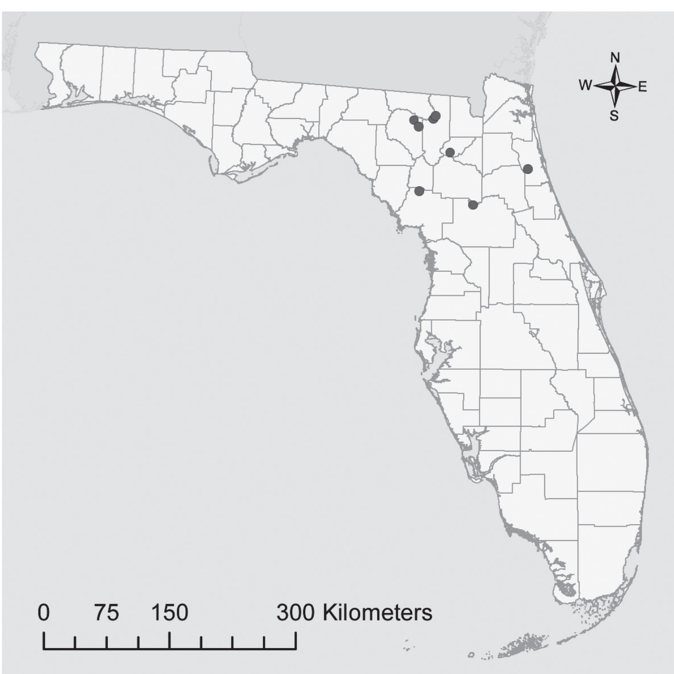

Fig. 1. Map depicting location of eight 2 ha buckwheat fields utilized for this study in north-central Florida.

Results

During the bloom and survey period, 3,422 insect flower visitors (excluding honey bees) were documented to visit buckwheat flowers. Honey bees accounted for an additional 5,300 flower visits (61% of overall flower visits) during our survey work. Honey bee activity was relatively high during mornings but largely disappeared within the buckwheat fields in the afternoons. Native wasps and other flower-visiting insects were active within the buckwheat fields during mornings and afternoons. Native wasps comprised the majority of non-*Apis* flower visitors (81.3%; n = 2,782), followed by Diptera (12.5%; n = 427), native bees (5.8%; n = 197), and beetles (0.47%; n = 16). Most of the non-*Apis* flower visitors were parasitoid wasps. Excluding Apidae, Scoliidae (n = 1,080) and Tiphiidae (n = 628) were the most commonly observed families, with *Scolia nobilitata* F. (Hymenoptera: Scoliidae) (n = 948) being the most common species observed in the buckwheat fields. Excluding the honey bee, only 7 native bee species (superfamily Apoidea) were found to visit buckwheat flowers. A list of the flower visitors is given in Table 1. Although we did not enumerate, at least 15 butterfly species were observed during our surveys utilizing buckwheat flowers (Table 2). It was difficult to identify some of the species of Lepidoptera (e.g., Hesperiidae) in the field because they moved away quickly from the transect path when a researcher approached. We did, however, collect unknown species with a sweep net for identification purposes. Therefore, we chose to document butterfly presence within the buckwheat fields rather than quantifying them.

Neither species abundance (F = 0.06; df = 1,26; P = 0.44) nor richness (F = 0.03; df = 1,26; P = 0.86) differed between fields treated with Sivanto™ or not treated at all. All of the abundant flower visitor species were present at all locations, although some of the individual species abundances differed among fields ($P \leq 0.05$).

Discussion

Buckwheat is well known for its attractiveness to honey bees and its ability to yield a large amount of honey (Myers & Meinke 1994). The majority of flower visitors in our study were honey bees; however, we expect these visitations would be much lower without the presence of managed honey bee hives nearby. Honey bees were extremely com-

Table 1. List of all insect species (except Lepidoptera) observed to visit buckwheat flowers during the survey period (20 Jul to 19 Aug 2015). We also placed insects into ecological guilds (Pa = parasitoid, Pr = predator, D = detritivore, H = herbivore) and relative abundance categories (A = abundant with 50+ observations, C = common with 11–49 observations, R = rare with ≤10 observations) within the buckwheat fields planted in north-central Florida. *Apis mellifera* was excluded from this list.

Order	Family	Species	Abundance (# observations)	Pa	Pr	D	H
Hymenoptera							
Bees	Apidae	*Bombus* spp., including *B. bimaculatus* Cresson	C(27)				x
		Xylocopa virginica (L.)	C(13)				x
		Xylocopa micans Lepeletier	A(71)				x
	Halictidae	*Agapostemon* spp., including *A. splendens* (Lepeletier)	A(76)				x
		Augochlorella aurata (Smith)	R(5)				x
		Halictus spp., including *Halictius poeyi* Lepeletier	R(5)				x
Wasps	Chrysididae	*Hedychrum confuses* du Buysson / *H. violaceum* Brullé	R(2)	x			
	Crabronidae	*Bicyrtes* sp.	R(3)	x			
		Cerceris bicornata Guérin-Méneville	A(128)	x			
		Cerceris spp.	C(15)	x			
		Crabro sp.	R(1)	x			
		Larra analis F.	R(3)	x			
		Stictia carolina (F.)	C(30)	x			
		Stizoides renicintus Say	R(2)	x			
		Tachytes spp.	A(214)	x			
		Tribe *Larrini*	C(17)	x			
	Mutillidae	*Timulla* sp.	R(7)	x			
	Pompilidae	*Anoplius* sp.	R(2)	x			
		Poecilopompilus interrupta Say	R(2)	x			
		Pompilidae sp. 1	R(8)	x			
		Pompilidae sp. 2	R(1)	x			
		Pompilidae sp. 3	C(11)	x			
	Scoliidae	*Campsomeris quadrimaculata* (F.)	R(10)	x			
		Campsomeris plumipes fossulana (F.)	C(128)	x			
		Scolia nobilitata F.	A(948)	x			
		Scolia bicincta (F.)	C(13)	x			
		Trielis octomaculata hermione (Banks)	A(81)	x			
	Sphecidae	*Ammophila* spp., including *A. fernaldi* (Murray)	C(22)	x			
		Isodontia spp.	R(1)	x			
		Prionyx atratus (Lepeletier)	R(5)	x			
		Prionyx parkeri Bohart and Menke	C(13)	x			
		Sphex ichneumoneus (L.)	C(17)	x			
		Sphex habenus Say	R(8)	x			
	Tiphiidae	*Myzinium* spp.	A(628)	x			
	Vespidae	*Euodynerus maegera* Lepeletier	R(8)	x			
		Euodynerus sp.	R(1)	x			
		Eumenes smithii de Saussure	R(2)	x			
		Pachodynerus erynnis (Lepeletier)	R(5)	x			
		Polistes spp.	A(442)		x		
		Vespula squamosa (Drury)	R(2)		x		
		Zethus sp.	R(2)	x			
Diptera	Bombyliidae	Anthracinae sp.	R(1)	x			
		Villa sp.	R(1)	x			
		Xenox sp.	R(1)	x			
	Stratiomyidae	*Hedriodiscus binotatus* (Loew)	R(5)			x	
		Stratiomys sp.	R(1)			x	
	Syrphidae	*Copestylum* sp.	R(1)			x	
		Eristalis saxorum Wiedemann	R(1)			x	
		Eristalis spp., including *Eristalis tenax* (L.)	A(342)			x	
		Meromacrus acutus (F.)	R(3)			x	
		Milesia virginiensis (Drury)	R(1)			x	
		Ocyptamous spp.	C(13)			x	
		Ornidia obesa (F.)	R(1)			x	
		Palpada furcata (Wiedemann)	R(4)			x	
	Tachinidae	*Belvosia* spp.	R(10)	x			
		Tachinidae spp.	C(30)	x			
		Trichopoda spp.	C(12)	x			

Table 1. (Continued) List of all insect species (except Lepidoptera) observed to visit buckwheat flowers during the survey period (20 Jul to 19 Aug 2015). We also placed insects into ecological guilds (Pa = parasitoid, Pr = predator, D = detritivore, H = herbivore) and relative abundance categories (A = abundant with 50+ observations, C = common with 11–49 observations, R = rare with ≤10 observations) within the buckwheat fields planted in north-central Florida. *Apis mellifera* was excluded from this list.

Order	Family	Species	Abundance (# observations)	Pa	Pr	D	H
Coleoptera	Ripiphoridae	*Macrosiagon cruenta* Germar	R(1)	x			
		Ripiphoridae sp. 1	R(1)	x			
	Scarabaeidae	*Euphoria sepulcralis* (F.)	R(1)			x	
		Trigonopeltastes delta (Forster)	C(13)			x	

mon during the morning hours but noticeably absent during the afternoon hours. Hedtke & Pritsch (1993) also found insect abundance to be highest during the morning hours in buckwheat but did not discriminate between honey bees and other flower visitors. Presumably, this is because buckwheat begins producing nectar in the morning (Lee & Heimpel 2003) and is exhausted by honey bees within just a few hours, at which time the honey bees begin to forage elsewhere. Honey bees have been shown to be an effective pollinator of buckwheat because they collect both pin and thrum pollen on a single trip, promoting contact with stigmas (Björkman 1995). Whether other insect visitors regularly collect both types of pollen is not known fully, but any insect that frequently visits buckwheat could be a potential pollinator. The majority of the other flower visitors did not seem impeded by honey bee presence and were observed visiting buckwheat flowers throughout the day, presumably gathering pollen and/or nectar that buckwheat produced after honey bees were foraging elsewhere.

There was a relatively overall low abundance of native bees within the buckwheat fields compared with the abundance of other insect groups. Most native bees mass provision pollen for their offspring. Thus, the large number of honey bees within the fields in the morning may have depleted pollen and nectar availability quickly, consequently causing buckwheat fields to be unappealing to native bees. Alternatively, there could be a lack of coevolution between buckwheat and native bees, making it a less attractive plant to native bees. In China, the probable country of origin for buckwheat (Ohnishi 1998), native non-*Apis* bees and syrphid flies accounted for over 50% of insect visits (Wang & Li 1998), suggesting an evolutionary linkage compared with areas outside of buckwheat's natural range. Although buckwheat's origin is China, it quickly spread to Europe and Asia about 5,000 yr ago (Myers & Meinke 1994). Honey bees are native to Europe, and buckwheat is an Old World crop; therefore, honey bees have been exposed to this crop on a much longer evolutionary timescale than have native North American bees. Therefore, honey bees could have coevolved with this Old World crop making them highly attracted to the nectar and pollen.

Table 2. List of Lepidoptera observed to feed from buckwheat flowers during the survey period (20 Jul to 19 Aug 2015).

Family	Species
Erebidae	*Utetheisa ornatrix* L.
Hesperiidae	*Epargyreus clarus* Cramer
	Erynnis spp.
	Hylephila phyleus Drury
	Urbanus proteus L.
Nymphalidae	*Agraulis vanillae* L.
	Anartia jatrophae L.
	Danaus gilippus Cramer
	Phyciodes tharos Drury
Papilionidae	*Eurytides marcellus* Cramer
	Papilio cresphontes Cramer
	Papilio glaucus L.
	Papilio palamedes Drury
	Papilio troilus L.
Pieridae	*Phoebis sennae* (L.)

Buckwheat has been explored for use as a cover crop that can harbor potential biological control agents of various herbivorous insects (Bugg & Dutcher 1989; Bowie et al. 1995; Platt et al. 1999; Lee & Heimpel 2005), for weed control (Treadwell & Huang 2008), and for pollinator enhancement (Carreck & Williams 2002). We documented at least 43 species of potential parasitoid or predatory insects, most of which feed on problematic arthropods, that are attracted to buckwheat flowers. The majority of these parasitoids attack Coleoptera or Lepidoptera larvae and Orthoptera nymphs but also could act as potential pollinators as adults. Along with these parasitoids and predators, we documented at least 18 other potential beneficial insect species (e.g., potential pollinators) that fed from buckwheat flowers. Our survey data suggest that buckwheat attracts a multitude of beneficial insects in Florida, which potentially could maintain and enhance localized populations of these beneficials. Although buckwheat has been shown to attract some insect pests (e.g., various herbivorous Hemiptera and Homoptera), the pests can serve as food for the beneficials (Bugg & Dutcher 1989). Due to the large number of parasitoid wasps observed visiting buckwheat, it potentially could be used as a cover crop to attract (and potentially augment) entomophagous insects within cropping systems. Little is known about the biology of Scoliidae and Tiphiidae, the 2 most commonly observed insect families in the buckwheat fields. However, both families are known to be solitary ectoparasitoids of scarab beetles ("white grubs") (O'Neill 2001). Chemical control of scarab larvae has been difficult because they live underground (Cherry 1991), making biological control the most promising solution. In Florida, scarab larvae feed on a wide variety of plant roots including many turf grasses, ornamentals, and vegetable crops (Buss 1993). Presence of scarab larvae can also attract small mammals and birds that dig into the ground to consume them, which can exacerbate damage to plants (Buss 1993). Buckwheat grown near some of these crops could attract and potentially enhance parasitoid abundance.

Overall, numerous syrphid flies and other Diptera also were observed visiting buckwheat flowers. Despite being often overlooked as pollinators, Syrphidae are efficient pollinators of many plants and can act as important predators in agricultural settings (Ssymank et al. 2008). Although many syrphid flies feed on aquatic bacteria or dead plant material, many other species are aphidophagous. Various flowering plant species have been shown to attract and sustain populations of aphidophagous Syrphidae in agricultural settings (Miller et al. 2013). Syrphid flies are strong fliers and, combined with their hovering ability, are very adept at locating small aphid colonies (Horn 1981). Other, non-syrphid Diptera have been shown to be highly abundant and diverse within agricultural ecosystems and provide pollination services in these ecosystems (Orford et al. 2015).

Our study supports previous studies that found buckwheat is attractive to foraging honey bees (e.g., Björkman 1995; Goodman et al. 2001). Due to the warm climate in Florida, buckwheat also could be grown late in the season in north-central Florida and even during the winter in south Florida (Treadwell et al. 2008), thus potentially helping sustain bee colonies when few plants are flowering and temperatures begin to decline. Consequently, the short generation time for buckwheat could be capitalized on as a supplemental forage crop for honey bee colonies in agricultural settings or planted during times when nectariferous plants are scarce. Overall, buckwheat is advantageous as an attractive plant to honey bees, native pollinators, and potential biological agents that could control some agricultural pests.

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References Cited

Ambrosino MD, Luna JM, Jepson PC, Wratten SD. 2006. Relative frequencies of visits to selected insectary plants by predatory hoverflies (Diptera: Syrphidae), other beneficial insects, and herbivores. Environmental Entomology 35: 394–400.

Banaszak J. 1983. Occurrence and numbers of bees (Apoidea) on some cultivated crop plants in the Wielkopolska region (W. Poland). Polish Journal of Entomology 53: 623–631.

Beach JH, Bawa KS. 1980. Role of pollinators in the evolution of dioecy from distyly. Evolution 34: 1138–1142.

Björkman T. 1995. Role of honey bees (Hymenoptera: Apidae) in the pollination of buckwheat in eastern North America. Journal of Economic Entomology 88: 1739–1745.

Bowie MH, Wratten SD, White AJ. 1995. Agronomy and phenology of "companion plants" of potential for enhancement of biological control. New Zealand Journal of Crop and Horticultural Science 23: 423–427.

Bugg RL, Dutcher JD. 1989. Warm-season cover crops for pecan orchards: horticultural and entomological implications. Biological Agriculture and Horticulture 6: 123–148.

Buss E. 1993. White grub management in turf. University of Florida IFAS Extension Document ENY-321 (LH037).

Carreck NL, Williams IH. 1997. Observations on two commercial flower mixtures as food sources for beneficial insects in the UK. Journal of Agricultural Science 128: 397–403.

Carreck NL, Williams IH. 2002. Food for insect pollinators on farmland: insect visits to flowers of annual seed mixtures. Journal of Insect Conservation 6: 13–23.

Cawoy V, Kinet J, Jacquemart A. 2008. Morphology of nectaries and biology of nectar production in the distylous species *Fagopyrum esculentum*. Annals of Botany 102: 675–684.

Cherry RH. 1991. White grubs in Florida sugarcane. University of Florida IFAS Extension Document ENY-664 (SC012).

Darwin C. 1888. The different forms of flowers on plants of the same species. Facsimile ed., 1986. University of Chicago Press, Chicago, Illinois.

Goodman R, Hepworth G, Kaczynski P, McKee B, Clarke S, Bluett C. 2001. Honey bee pollination of buckwheat (*Fagopyrum esculentum* Moench) cv. Manor. Australian Journal of Experimental Agriculture 41: 1217–1221.

Hedtke C, Pritsch G. 1993. Qualitative and quantitative investigation of insects foraging on buckwheat (*Fagopyrum esculentum* Moench). Apidologie 24: 476–477.

Horn D. 1981. Effect of weedy backgrounds on colonization of collards by green peach aphid, *Myzus persicae*, and its major predators. Environmental Entomology 10: 285–296.

Huang P. 2009. Optimal conditions for buckwheat (*Fagopyrum esculentum* Moench) production as a cover crop for weed suppression in Florida. Master's thesis. Horticultural Sciences Department. University of Florida, Gainesville, Florida.

Jacquemart A, Gillet C, Cawoy V. 2007. Floral visitors and the importance of honey bee on buckwheat (*Fagopyrum esculentum* Moench) in central Belgium. Journal of Horticultural Science and Biotechnology 82: 104–108.

Kushnir LG. 1976. Role of bees as honey collectors and pollinators of buckwheat and clover seed plants under conditions in Gomel District, pp. 64–68 *In* Kozin RB [ed], Pollination of Entomophilous Crops by Bees. Amerind, New Delhi, India.

Lee JC, Heimpel GE. 2003. Nectar availability and parasitoid sugar feeding. pp. 220–225 *In* Proceedings of the 1st International Symposium on Biological Control of Arthropods, 14–18 Jan 2002, Honolulu, Hawaii.

Lee JC, Heimpel GE. 2005. Impact of flowering buckwheat on lepidopteran cabbage pests and their parasitoids at two spatial scales. Biological Control 34: 290–301.

Marshall HG. 1969. Description and Culture of Buckwheat. Bulletin 754. Pennsylvania State University, College of Agriculture, Agricultural Experiment Station, University Park, Pennsylvania.

McGregor SE. 1976. Buckwheat. Insect Pollination of Cultivated Crop Plants. Agricultural Handbook No. 496. Agricultural Research Service, United States Department of Agriculture.

Miller N, Al-Dobai S, Legaspi J, Sivinski J. 2013. Estimating attraction of Syrphidae (Diptera) to flowering plants with interception traps. Biocontrol Science and Technology 23: 1040–1052.

Myers RL, Meinke LJ. 1994. Buckwheat: a multi-purpose, short-season alternative. University of Missouri Extension G4306.

Ohnishi O. 1998. Search for the wild ancestor of buckwheat III. The wild ancestor of cultivated common buckwheat, and of tartary buckwheat. Economic Botany 52: 123–133.

O'Neill KM. 2001. Solitary Wasps: Behavior and Natural History. Cornell University Press, Ithaca, New York.

Orford KA, Vaughan IP, Memmott J. 2015. The forgotten flies: the importance of non-syrphid Diptera as pollinators. Proceedings of the Royal Society B 282: 20142934.

Platt JO, Caldwell JS, Kok LT. 1999. Effect of buckwheat as a flowering border on populations of cucumber beetles and their natural enemies in cucumber and squash. Crop Protection 18: 305–313.

Quinet M, Cawoy V, Lefevre I, Miegroet FV, Jacquemart A, Kinet J. 2004. Inflorescence structure and control of flowering time and duration by light in buckwheat (*Fagopyrum esculentum* Moench). Journal of Experimental Botany 55: 1509–1517.

Rahman A, Rahman S. 2000. Effect of honeybee (*Apis cerana indica*) pollination on seedset and yield of buckwheat (*Fagopyrum esculentum*). Indian Journal of Agricultural Sciences 70: 168–169.

Sasaki H, Wagatsuma T. 2007. Bumblebees (Apidae: Hymenoptera) are the main pollinators of common buckwheat, *Fagopyrum esculentum*, in Hokkaido, Japan. Applied Entomology and Zoology 42: 659–661.

Ssymank A, Kearns CA, Pape T, Thompson FC. 2008. Pollinating flies (Diptera): a major contribution to plant diversity and agricultural production. Biodiversity and Agriculture 9: 86–89.

Taki H, Okabe K, Makino S, Yamaura Y, Sueyoshi M. 2009. Contribution of small insects to pollination of common buckwheat, a distylous crop. Annals of Applied Botany 155: 121–129.

Treadwell D, Huang P. 2008. Buckwheat: a cool-season cover crop for Florida vegetable systems. University of Florida IFAS Extension Document HS1135

Treadwell D, Klassen W, Alligood M. 2008. Annual cover crops in Florida vegetable systems Part 1. Objectives: Why grow cover crops? University of Florida IFAS Extension Document HS387.

Wang R, Li CA. 1998. Insect pollinators and yield of common buckwheat, pp. 25–28 *In* Campbell C, Przybylski R [eds.], Proceedings of the 7th International Symposium on Buckwheat, Advances in Buckwheat Research, 12–14 Aug, Winnipeg, Manitoba, Canada.