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**GREAT DIVERSITY OF INSECT FLORAL ASSOCIATES MAY
PARTIALLY EXPLAIN ECOLOGICAL SUCCESS OF POISON IVY
(*TOXICODENDRON RADICANS* SUBSP. *NEGUNDO*
[GREENE] GILLIS, ANACARDIACEAE)**

David S. Senchina^{1*} and Keith S. Summerville²

ABSTRACT

Little is known about insect floral associates of poison ivy (*Toxicodendron radicans*, Anacardiaceae), despite the species' ubiquity and importance in nature and society. Poison ivy's pollination syndrome and results from prior studies suggest that the plant is not specialized for any particular pollinator type; however, a systematic survey exploring this hypothesis has been lacking. For this study, insect floral associates of *Toxicodendron radicans* subsp. *negundo* from a central Iowa site were observed during the flowering season of 2005. Thirty-seven distinct insect floral associates were observed: 8 coleopterans (beetles), 7 dipterans (flies), 2 hemipterans (true bugs), 19 hymenopterans (ants, bees, wasps), and 1 lepidopteran (butterfly). Hymenopterans appeared to be the most important contributors to poison ivy pollination on a per species basis; however, coleopterans and dipterans were also frequent associates. Poison ivy's ability to utilize a diverse assemblage of insect pollinators may partially explain its ecological success in varied habitats.

Toxicodendron radicans [L.] Kuntze (eastern poison ivy) is found commonly throughout the eastern half of the United States. Several subspecies are recognized (Gillis 1971). *T. radicans* is one of five members of the poisonous *Toxicodendron* P. Mill sect. *Toxicodendron* in North America, which also includes *T. rydbergii* [Small ex. Rydb.] Greene (Rydberg's or western poison ivy), *T. pubescens* P. Mill. (syn. *T. toxicarium* Gillis, Atlantic poison oak), *T. diversilobum* [Torr. & Gray] Greene (Pacific poison oak), and *T. vernix* [L.] Kuntze (poison sumac). On the American supercontinent, members of this clade span the continental United States and are found in Canada and Mexico; other *Toxicodendron* spp. stretch into South America (McNair 1925, Barkley 1937, Gillis 1971).

Insect-host interactions have been described for poison ivy previously (reviewed in Senchina 2008a). These have focused on herbivory (Howden et al. 1951; Steyskal 1951; Hicks 1952, 1955), insect-host interactions (Gillis 1971, Tietz 1972, Robinson et al. 2006), or simply ecological association (Isaak and Honda 2002). Due to known natural histories, some of these associations may be predicted to be floral associations (specifically some involving the Hymenoptera and Lepidoptera), though they are not always catalogued specifically as such. Many of the above observations do not relate to floral association and it is sometimes unclear which species of *Toxicodendron* is being reported due to the use of common names alone or confusion regarding scientific names. Thus, on several fronts, better data is needed regarding insect interactions with *T. radicans* in general, and insect pollination of the species in particular.

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An examination of the pollination syndrome of *T. radicans* suggests that it is not specialized towards one specific type of pollinator. The plant is dioecious (e.g., male and female flowers are borne on separate plants) though each contains reduced or rudimentary organs from the other (Gillis 1971). Poison ivy flowers are small, pentamerous cream-colored flowers arranged in thyrses that sprout from leaf axils and oftentimes hang from or are obscured by the leaves (when viewed from human height). The petals become more recurved as the flower ages. The corolla is flat and lacking depth, with the stigma slightly exert or parallel to the petal edge. The ovary of female flowers turns from white to black when it is no longer receptive to pollen (Gillis 1971). Inflorescences are variable in the number of flowers (Gillis 1971). For *T. radicans*, the inflorescences vary from a couple to several cm in length.

Pacific poison oak (*T. diversilobum*) has been used as the model for floral anatomy in this genus. The pollen is bright yellow and produced only by male flowers despite the presence of rudimentary stamens in female flowers (Copeland and Doyel 1940). Nectar is secreted from the disk epidermis (Copeland and Doyel 1940, Gillis 1971); however, to the best of our knowledge, no one has reported whether or not nectar is produced by male flowers of *T. radicans* specifically. Investigations of closely related genera may provide some insight. *Rhus* is a genus of nonpoisonous sumacs closely related to *Toxicodendron* (Yi et al. 2004). Wheeler (2001) reports that both male and female flowers of staghorn sumac (*Rhus hirta* [L.] Sudworth) produce nectar, though the males produce much less. Young (1972) states that both male-sterile and hermaphroditic flowers in the gynodioecious *Rhus integrifolia* (Nutt.) Benth. & Hook f. ex. Brewer & S. Wats and *Rhus ovata* S. Wats produced nectar. For the more distantly-related andromonoecious cashew plant (*Anacardium occidentale* L.), both the male and hermaphrodite flowers produced nectar though the hermaphrodite flowers produced significantly more (Wunnachit et al. 1992). These results from other genera suggest that *Toxicodendron* spp. likely produce nectar in both male and female flowers, but that production in male flowers is likely reduced compared to female flowers. Historically, botanists have commented that *Toxicodendron* flowers emit a scent similar to lily-of-the-valley (Miller and Martyn 1809) or jasmine and hyacinth (McNair 1921). Others refute this (Gillis 1971). Given the well-characterized morphological plasticity of the genus, scent too may be a variable trait.

Little is known about the pollination ecology of poison ivy despite its ubiquity and importance in nature and human society. In his monograph on *Toxicodendron* spp., Gillis (1971) gives only *Apis mellifera* L. (Hymenoptera: Apidae, the honeybee) specifically as a pollinator of poison ivy, and adds, "Other visitors that appear to transport pollen include other Hymenoptera and several Coleoptera." Poison ivy pollen is nonallergenic and is a major component of honey in Iowa (Pammel and King 1930) as well as other states (Lieux 1981). More recently, Kraemer and Favi (2005) have identified the blue orchard or orchard mason bee, *Osmia lignaria* Say (Hymenoptera: Apoidea: Megachilidae), as another pollinator. Mulligan and Junkins (1977) named several other Hymenopteran floral associates. Senchina (2005, 2008b) described specific behaviors from Coleoptera and Lepidoptera. Table 1 gives an overview of all purported poison ivy pollinators and nectar-seekers known prior to the present investigation, but does not include taxa that are merely listed (or implied) as floral associates/visitors. No systematic survey of insect floral associates of poison ivy has yet been conducted, and it is unknown whether other insect orders (such as Diptera and Hemiptera) are also important floral associates.

The objective of this study was to better characterize insect floral associates of poison ivy by cataloguing floral visitors to a Midwestern population of *Toxicodendron radicans* subsp. *negundo* (Greene) Gillis. Findings from this investigation were combined with previous data to obtain a better understanding of the ecology of poison ivy.

MATERIALS AND METHODS

Study Populations. All observations were conducted at East River Valley Access (ERVA) in Ames, IA. ERVA is a mixed ash (*Fraxinus* spp. L.: Oleaceae)/elm (*Ulmus* spp. L.: Ulmaceae) floodplain forest with some linden (*Tilia americana* L.: Tiliaceae), hackberry (*Celtis occidentalis* L.: Ulmaceae), maple (*Acer* spp. L.: Aceraceae/Sapindaceae), and oak (*Quercus* spp. L.: Fagaceae). Prevalent shrub- and herb-layer species (intermingled with *T. radicans*) include Virginia creeper (*Parthenocissus quinquefolia* [L.] Planchon: Vitaceae), frost or river grape (*Vitis riparia* Michx.: Vitaceae), gooseberry (*Ribes missouriense* Nutt.: Grossulariaceae), raspberry (*Rubus* sp. L.: Rosaceae), wild parsnip (*Pastinaca sativa* L.: Apiaceae), and various grasses. The site experienced a severe and prolonged flood in 1993 from which the flora has been recovering.

Toxicodendron radicans subsp. *negundo* is the only poison ivy species inhabiting this site and this region of Iowa (Eilers and Roosa 1994). ERVA includes both climbing and nonclimbing individuals, as well as populations on the forest edge and the forest interior. For this particular site, climbing individuals were found only in the forest interior and nonclimbing individuals only along the forest edge. Nonclimbing individuals constituted the bulk of the sample and were clustered in three major groups. Group 1 was east-facing and approximately 18 × 4 m in size. Group 2 was directly 16 m west of Group 1, west-facing (i.e., on the other side of a narrow strip of forest), and approximately 24 × 4 m in size. Group 3 was directly 48 m north of Group 2, on the same west-facing forest edge, and approximately 38 × 3 m in size. Group 1 is bordered by a footpath to the east side and vegetation on all other sides, whereas Groups 2 and 3 are bordered by a footpath to the west side and vegetation on all other sides. Younger and shorter individuals tend to occupy areas closer to the footpath, whereas older and taller individuals tend to occupy areas closer to the forest interior. Consequently, the number of flowering individuals increased with distance away from the footpath (*Toxicodendron* spp. do not flower until their third year [Gillis, 1971]). From observations made in previous field seasons, it can be noted that approximately equal numbers of males and females inhabit the site. Some general measurements were taken during mid-July 2008 to determine population characteristics. Within the area specified for Group 1, poison ivy plants were clustered in dense patches, occupying approximately 50% of the total area. Their average spacing within these patches was about 25 cm, with an average height of 60 cm. In contrast, within the areas specified for Groups 2 and 3, poison ivy plants were more or less contiguous and occupied approximately 80% of the total area and were variably spaced 10 cm (closer to the footpath) to 20 cm (closer to the forest interior), with an average height of 65 cm. These differences may be the result of sunlight exposure (east- vs. west-facing). Hundreds of individuals were thus included in these areas. Only two nonclimbing individuals could be located for inclusion in the study (northwest of the three nonclimbing groups in a contiguous portion of the forest). Both climbing and nonclimbing individuals and both genders were included in the study. We did not distinguish between visits to male vs. female plants or climbing vs. nonclimbing in our records.

Observations and Specimen Identification. All field observations were conducted daily from 5 to 21 June 2005 by the same lone observer except for on days of continuous rain (8, 10, and 20 June). These dates represent the first and last days in which poison ivy was found flowering. In total, over 50 hrs of observations were amassed. Each observational period lasted a minimum of 1 hour (20 total observational sessions, average = 1.8 hrs, range = 1-5 hrs). The time of day during which observations were conducted was varied to include morning (no earlier than 3 hrs. after sunrise), afternoon, and evening hours (no later than 30 min before sunset), though the bulk of sessions (13 out of 20) were conducted in the afternoon as this appeared to be the time of greatest pollinator activity.

The goal during observation was to identify as many floral visitors as possible; since there was a lone observer and oftentimes multiple, simultaneous pollinators, it was difficult to record factors such as number of flowers visited or length of visit for each individual insect (though this was attempted). An Olympus D-540 camera was used to photograph or video insect floral associates. For this investigation, we opted not to collect insects due to the allergenic nature of the plant and the stability (Bogue 1894) of its allergenic element (urushiol). Photographs were compared to specimens collected throughout Iowa from the Drake University and Iowa State University entomological collections and also print and Internet resources (Yanega 1996, Borror and White 2004, Triplehorn and Johnson 2006).

RESULTS

Insects from several different orders were found to be floral associates at this study site (Table 2). In total, we observed 37 distinct insects that were identifiable to the level of family: 8 coleopterans, 7 dipterans, 2 hemipterans, 19 hymenopterans, and 1 lepidopteran. Coleopteran floral associates included 6 members of Cerambycidae (the long-horned beetles), 1 member of Cantharidae (soldier beetles), and 1 member of Cleridae (checkered beetles). Dipteran floral associates included 4 members of Syrphidae (hoverflies) and 1 each from Anthomyiidae, Asilidae (robber flies), and Bombyliidae (bee flies). Two hemipteran floral associates from the Lygaeidae (seed, milkweed, or cinch bugs) were observed. Hymenopteran floral associates were the most abundant and diverse on both individual insect visitor and total insect species levels. We recorded flower visits from 6 members of Andrenidae (mining bees), 4 members of Apidae (bumble bees and honeybees), 1 member of Chalcidoidea (parasitoid wasps), 3 members of Halictidae (sweat bees), 2 members of Sphecidae (mud-daubers and sandwasps), and 3 members of Vespidae (paper and potter wasps). Only one lepidopteran, the summer azure, *Celastrina neglecta* W. H. Edwards (Lycaenidae, the gossamer-winged butterflies), was observed; a more thorough treatment of this insect's association with poison ivy may be found elsewhere (Senchina 2008b).

On a per species basis, the greatest diversity of insect floral associates was observed at the beginning of the observational period (specifically 8 and 9 June). Similarly, the total number of insects seen visiting poison ivy flowers on a per day basis was greatest at the beginning of June and subsequently dwindled. By mid-June, the same species observed associating with poison ivy had shifted toward servicing neighboring plants, mainly wild parsnip and white clover (*Trifolium repens* L.; Fabaceae).

DISCUSSION

Only a few hymenopteran and coleopteran species were known to be *T. radicans* pollinators or nectar-seekers prior to this study (Table 1). Here we report findings from the first systematic survey of insect floral associates of poison ivy (Table 2), conducted during the 2005 field season. To the best of our knowledge, this study is the first to report the existence of both dipteran and hemipteran floral associates for this species, and supplies further information on additional coleopteran and lepidopteran floral associates as well as hymenopteran floral associates other than the honeybee or blue orchard bee. Together, Tables 1 and 2 represent the currently known catalogue of insect floral associates of *Toxicodendron radicans*. Data on beetle floral associates at the same site is also available from 2004 (Senchina 2005). Four of the five beetle floral associates witnessed in 2004 were also observed in 2005.

From the present data and known life histories, it appears that Hymenoptera may be the most important order of insects for poison ivy pollination. Thus data

Table 1: Known poison ivy pollinators and nectar-seekers prior to this study.

Order	Family	Species	Study
Coleoptera	Cantharidae	<i>Chauliognathus marginatus</i> (Fabricius)	Senchina, 2005
Coleoptera	Cantharidae	<i>Chauliognathus pennsylvanicus</i> (DeGeer)	Senchina, 2005
Coleoptera	Cerambycidae	<i>Analeptura lineola</i> (Say)	Senchina, 2005
Coleoptera	Cerambycidae	<i>Strangalia acuminata</i> (Olivier)	Senchina, 2005
Coleoptera	Cleridae	<i>Enoclerus rosmarus</i> (Say)*	Senchina, 2005
Hymenoptera	Andrenidae	<i>Andrena</i> spp. Fabricius	Mulligan & Junkins, 1977
Hymenoptera	Apidae	<i>Apis mellifera</i> L.	Gillis, 1971
Hymenoptera	Halicitidae	<i>Agapostemon viriscens</i> (Fabricius)	Mulligan & Junkins, 1977
Hymenoptera	Halicitidae	<i>Augochlora pura</i> (Say)	Mulligan & Junkins, 1977
Hymenoptera	Halicitidae	<i>LasioGLOSSUM</i> spp. Curtis	Mulligan & Junkins, 1977
Hymenoptera	Megachilidae	<i>Osmia lignaria</i> Say	Kraemer & Favi, 2005
Lepidoptera	Lycaenidae	<i>Celastrina neglecta</i> (W. H. Edwards)	Senchina, 2008b

* = This insect was previously identified as *Thanasimus dubius* but is more likely *Enoclerus rosmarus* (Dr. Jonathan Mawdsley, U.S. Fish & Wildlife Service, personal communication, October 2005).

Table 2: Insect floral associates of poison ivy (*Toxicodendron radicans* subsp. *negundo*) observed during the 2005 flowering season at a site in Ames, Iowa.

Order	Family	Species	# of Days Observed
Coleoptera	Cantharidae	<i>Chauliognathus pennsylvanicus</i> (DeGeer)	6
Coleoptera	Cerambycidae	<i>Analeptura lineola</i> (Say)	1
Coleoptera	Cerambycidae	<i>Euderces picipes</i> (Fabricius)	1
Coleoptera	Cerambycidae	<i>Molorchus</i> sp. Fabricius	1
Coleoptera	Cerambycidae	<i>Strangalia acuminata</i> (Olivier)	5
Coleoptera	Cerambycidae	Unidentified cerambycid 1	1
Coleoptera	Cerambycidae	Unidentified cerambycid 2	1
Coleoptera	Cleridae	<i>Enoclerus rosmarus</i> (Say)	1
Diptera	Anthomyiidae	Unidentified anthomyiid	1
Diptera	Asilidae	<i>Laphria</i> sp.	6
Diptera	Bombyliidae	<i>Anthrax analis</i> Say	1
Diptera	Syrphidae	<i>Eupeodes americanus</i> (Weidemann)*	1
Diptera	Syrphidae	Unidentified syrphid 1	8
Diptera	Syrphidae	Unidentified syrphid 2	1
Diptera	Syrphidae	Unidentified syrphid 3	1
Hemiptera	Lygaeidae	<i>Lygaeus kalmii</i> Stål	1
Hemiptera	Lygaeidae	Unidentified lygaeid 1	1
Hymenoptera	Andrenidae	<i>Andrena</i> sp. Fabricius	2
Hymenoptera	Andrenidae	Unidentified andrenid 1	3
Hymenoptera	Andrenidae	Unidentified andrenid 2	5
Hymenoptera	Andrenidae	Unidentified andrenid 3	5
Hymenoptera	Andrenidae	Unidentified andrenid 4	1
Hymenoptera	Andrenidae	Unidentified andrenid 5	1
Hymenoptera	Apidae	<i>Apis mellifera</i> L.	3
Hymenoptera	Apidae	<i>Bombus fervidus</i> (Fabricius)	2
Hymenoptera	Apidae	<i>Xylocopa</i> sp. 1 Latreille	1
Hymenoptera	Apidae	<i>Xylocopa</i> sp. 2 Latreille	1
Hymenoptera	Chalcidoidea	Unidentified chalcidoid 1	3
Hymenoptera	Halictidae	<i>Agapostemon virescens</i> (Fabricius)	3
Hymenoptera	Halictidae	Unidentified halictid 1	1
Hymenoptera	Halictidae	Unidentified halictid 2	1
Hymenoptera	Sphecidae	<i>Sceliphron caementarium</i> (Drury)	1
Hymenoptera	Sphecidae	Unidentified sphecid 1	1
Hymenoptera	Vespidae	<i>Eumenes fraternus</i> Say	2
Hymenoptera	Vespidae	<i>Vespula</i> sp. 1 Thomson	6
Hymenoptera	Vespidae	<i>Vespula</i> sp. 2 Thomson	1
Lepidoptera	Lycaenidae	<i>Celastrina neglecta</i> (W. H. Edwards)	3

* = This species has alternatively been classified as *Metasyrphus americanus* Weidemann.

from this study may be useful to beekeepers or other individuals in the honey production business, as the honeybee as well as several other bee species were found to be common pollinators of poison ivy. Coleopterans, dipterans, hemipterans, and lepidopterans might also play important roles. The degree to which these different insects efficiently move poison ivy pollen from one flower to another likely varies tremendously. For example, *Chauliognathus* spp. (Coleoptera: Cantharidae) as well as longhorned beetles (Coleoptera: Cerambycidae) are known to be pollenivores of *Toxicodendron* spp., whilst anthomyiid, asilid, and syrphid flies (Diptera) are also pollen-feeding (McAlpine 1987, MacRae and Rice 2007). During the process of feeding, they may only tangentially transfer pollen from one plant to another. In contrast, the activities of the hymenopterans (such as *A. mellifera* and *O. lignaria*), who receive nectar rewards from poison ivy, may be considered much more significant to pollination from the perspective of the plant. Further research may help define a relative continuum by which pollen transfer efficiency among these floral associates could be compared.

Poison ivy populations are widely found throughout multiple habitat types, such as fields, forests, urban areas, and waste places (Gillis 1971). Its ecological success may be partially explained by the pollinator plasticity documented here: because it is not reliant on a single species or single order of insects for pollination, poison ivy is capable of reproducing in multiple ecosystem types, and may be capable of recruiting novel pollinator species when it spreads into new habitats.

Importantly, we also discovered additional herbivores during our investigation. One hemipteran (an unidentified species from Family Thyreocoridae, the negro bugs) was observed daily feeding off poison ivy leaves both in the 2004 and 2005 field seasons. A coleopteran (an unidentified species from Family Curculionidae, the weevils) was observed on a few days during the 2005 season. We occasionally observed one hymenopteran herbivore (an unidentified species from Family Tenthredinidae, the sawflies).

Beyond its empirical value to botanists, ecologists, entomologists, and natural history interpreters, data from this study may also have direct application for natural areas managers. In general, herbicides have failed to control unwanted poison ivy populations and alternative strategies have been sought. Natural areas managers are considering biological control agents such as fungi, arthropods, birds, and mammals (reviewed in Senchina [2008a] based on effectiveness, selectivity, practicality, and indirect or side effects). The identification of floral associates may offer some assistance. Floral associates could be used as vectors for spreading a virus, bacterium, or fungal agent that is specific for poison ivy. Although in theory one could diminish the presence of a particular pollinator and thus adversely influence a plant's reproductive capacity, this is not a very viable option for poison ivy because its pollinators are known to interact with several plant species. A more tenable alternative may be to augment herbivore (such as those discussed in the preceding paragraph) or pollenivore populations. Certain members of the Cerambycidae, for example, may interact with *Toxicodendron* spp. in such a way that their low interindividual pollen transfer rate is outweighed by heavy pollen feeding and possible damage to adjacent reproductive structures, thus negatively impacting poison ivy reproduction overall. Controlled greenhouse and laboratory studies would be the first step in determining the feasibility of such endeavors. However, given how little research exists on this topic, it is likely that many more ecological associates for *Toxicodendron* spp. have yet to be identified, and more extensive field research is necessary to both catalogue and characterize such interactions.

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