The pollinators of Echinacea angustifolia in Saskatchewan

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Abstract

Echinacea (Asteraceae) is grown as a nutraceutical crop and is one of the best selling medicinal plants on the North American market today, accounting for over 300 million dollars annually in sales. *Echinacea angustifolia* accounts for the majority of *Echinacea* produced in Saskatchewan and is native to the southern regions of the Canadian Prairies. *Echinacea* must be cross-pollinated to set seed, as is typical of members of the Asteraceae, and only insects can effect cross-pollination. An in-depth knowledge of *Echinacea's* pollination system is essential to developing *Echinacea* as a sustainable market crop.

E. angustifolia's native pollinators are being identified and their pollination efficiencies assessed by pollen-tube quantification after visiting previously unvisited inflorescences. Interestingly, the recent abundance of grasshoppers in Saskatchewan has supported large populations of potential pollinators of *E. angustifolia*. For instance, the grasshopper bee fly (*Systoechus vulgaris*) and the golden blister beetle (*Epicauta ferruginea*) were particularly abundant on *E. angustifolia* inflorescences in the summer of 2003 and their contributions to pollination are being assessed. Alfalfa leafcutting bees (*Megachile rotundata*) managed in Saskatchewan as pollinators of alfalfa (*Medicago sativum*) have the potential to be excellent managed pollinators of *Echinacea*; this project will evaluate their pollination efficiency.

Introduction

Plants of the genus *Echinacea* (Asteraceae) are harvested and used for their medicinal properties. The genus name comes from the root word *Echinos*, meaning "hedgehog", in reference to its showy inflorescence with its capitulum of sharp paleae that resemble the spiny back of a hedgehog. *Echinacea* is commonly known as the purple coneflower with different variations of the common name given to each species. For example, *Echinacea pallida* is commonly called the pale-purple coneflower due to its white pollen and *Echinacea angustifolia* is the narrow-leaved purple coneflower simply named for having leaves narrower than the other eight species.

Echinacea's medicinal value was first recognized hundreds of years ago by the American Indians and later passed along to European settlers (Kindscher, 1989). Preparations of *Echinacea* leaves and roots were used by the Native Americans to treat everything from colds to rattlesnake bites. Modern western medicine, with its focus on man-made drugs, had no place for an unproven herbal remedy so *Echinacea* was largely ignored. In the past decade there has been a resurgence of interest in using herbal treatments for common ailments like St. John's Wort for depression or Ginseng for increased energy levels. *Echinacea* is used as an immuno-stimulant to boost the body's natural immune system and reduce the duration and severity of colds and flu. *Echinacea's* popularity led to over-harvesting of wild stands and an ensuing decrease in its natural abundance. Supply far outpaced demand and farmers began to plant *Echinacea* as a specialty crop to fulfill that demand. *Echinacea angustifolia* accounts for 80% of the *Echinacea* grown in Saskatchewan, with *E. purpurea* making up the remaining 20% (Harbage, 2001). The root of *E. angustifolia* is harvested in its third or fourth year of growth when the bioactive ingredients are at their peak. The bioactive constituents of *Echinacea* plants are cichoric acid and echinacosids, which are derivatives of caffeic acid, and also alkamides, polyacetylenes, and glycoproteins/polysaccharides (Bauer et al*.,* 1998). There is debate about which compound has the most potent pharmacological activity, but all of the bioactive compounds should be used together to obtain their synergistic effect (Bauer et al., 1998). *E. angustifolia* is native to southern Saskatchewan, is drought tolerant and has a higher market value than other *Echinacea* species due to a higher concentration of bioactive ingredients (Li, 1998). These qualities make *E. angustifolia* a potential specialty crop for Saskatchewan growers looking to diversify their crop production.

Echinacea must be cross-pollinated to produce seed (McGregor, 1968) and uses a strictly entomophilous pollination system where insects are required to transfer pollen from plant to plant (Leuszler et al., 1996). The production of seed can be profitable for a grower as a commodity or as a means to expand their planted acreage and replace harvested plants. It is recommended that 319,000 seeds (approximately one kilogram) are required to plant one hectare of *E. angustifolia* (Oliver et al., 1995). Each *Echinacea* "flower" is actually a composite inflorescence of many smaller florets similar to the inflorescence of sunflower. The central area of the inflorescence is the cone shaped capitulum of bisexual disc florets where the achenes (fruits) are produced. Surrounding the capitulum is a whorl of sterile ray florets each with a strap shaped corolla that gives the appearance of petals around the inflorescence.

The objectives of this research are twofold. The first objective is to discover the native insects that are pollinating *Echinacea angustifolia* in central Saskatchewan and assess their individual pollination efficiencies. The second objective is to evaluate the efficiency of the Alfalfa leafcutting bee (*Megachile rotundata*) as a managed pollinator for *E. angustifolia* fields which will be important if native pollinators are not sufficient to ensure complete cross-pollination.

Materials and Methods

Two field sites were chosen for their proximity to the University of Saskatchewan to simplify the transport of materials and enable regular monitoring of insect activities. The largest field site lies at the southwest corner of Saskatoon near the South Saskatchewan River. This site approximates a native stand of *E. angustifolia* with most of the plants having sprung up from root remains and shed seeds of a crop harvested years ago. The plant density is lower than would be found in an agricultural planting of comparable size. The second, smaller plot is more of an agricultural planting with one fairly dense area of *E. angustifolia* that sits alongside a meadow and a wooded area. This site is several kilometres outheast of Saskatoon. At each field site, single insect visits to previously unvisited inflorescences were recorded. Bags of fine mesh netting were placed over the inflorescences before anthesis (flower opening) to ensure that the inflorescence remained untouched by visiting insects. The bags were removed when at least three whorls of disc florets had matured and the first insect visitor was observed. After the insect visit, the inflorescence was re-bagged and harvested 24 hours later to count the number of pollen tubes started by the single visit as described in Davis (1992).

To assess the contribution of insect groups based on body size, eight wooden cages (120cm x 120cm x 120cm) were placed over an average of ten unvisited inflorescences. Four of the cages were made of a fine tent screen mesh that excludes all insects. This group represents a control group without any insect visitors and thus, theoretically, no opportunity for cross-pollination. Two cages of this type were placed at each field site. The next treatment excluded large insects with a metal mesh and allowed small-bodied insects to enter through holes with openings of approximately 9.6mm^2. Two of each of these cages were placed at each site. The third treatment was an open pollination treatment where inflorescences were left open to insect visits throughout the duration of flowering. Seed heads from each of these treatments were shattered and their achenes counted and weighed. To standardize each sample, the weight of the achenes from each inflorescence were extrapolated to 1000 achenes and then compared. Achenes from each treatment will then be germinated to assess their viability.

The diversity and abundance of native insect visitors were recorded by regular observations of inflorescences along a transect line. Transect observations began on July 8, 2003, and continued until August 8, 2003, when the majority of inflorescences had finished flowering. The transect at the larger field site encompassed thirty inflorescences while the smaller field site had twenty inflorescences per transect. On several days, transects were performed in the morning, afternoon and evening to observe any temporal differences in the abundance of pollinators. A total of 33 transect observations were made at the large field site and 5 at the small field.

Alfalfa leafcutting bees were released at the large site on July 18, 2003 and allowed to nest in blocks within a plastic hut. Their foraging behaviour on inflorescences was observed and their pollination efficiency is to be assessed by the same single insect visit criteria as the native pollinators.

Results and Discussion

The single insect visits allowed for observations on the feeding behaviour of the pollinating insects and gave a general impression of which insects were visiting many inflorescences during a foraging trip. Pollen tube analysis will reveal whether these single visits resulted in compatible pollen deposition on the stigma and will thus reveal how efficient the insect was at transmitting pollen. This lab work is ongoing.

Preliminary results from the exclusion experiment support the literature's view that *E. angustifolia* requires insect cross-pollination to set viable seed. Achenes from cages where all insects were excluded had much lower weights than those in the open pollination trial, indicating that the achene was an empty husk without a viable seed inside. The combined mean of all the total exclusion treatments is 1.147 g while the combined mean of the open pollinated achenes is 2.637 g. Achenes from the excluder treatment that shattered during extraction were found not to contain seeds and were indeed just empty husks. Shattered achenes from open pollinated

inflorescences revealed a small white seed that could sometimes be induced to germinate even without the protection of the achene shell.
Germination results are not available yet.

Transect data revealed that grasshopper bee flies, *Systoechus vulgaris*, (Diptera: Bombyliidae) were the most plentiful insect visitors to *E. angustifolia* in the summer of 2003 around Saskatoon, comprising 69% of the total suspected pollinators at the first field site and 74% at the second. Insects found on inflorescences that are not commonly regarded as pollinators, like grasshoppers and ants, were excluded from the total counts of potential pollinators. At the beginning of the field study, the number of bee flies was astounding. Every open inflorescence in the field had at least two bee flies foraging on it. The first transect of 30 inflorescences had 208 bee flies foraging along it. One inflorescence was observed with seventeen bee flies in attendance. After a few days these extraordinary numbers decreased dramatically and levelled off to between ten and twenty bee flies per transect. At the large field site golden blister beetles, *Epicauta ferruginea*, (Coleoptera: Meloidae) were present as the second largest group of visitors with 23% of the total, but they were completely absent at the second field site. The reason for this discrepancy is unknown but it may be that the dispersal abilities of bee flies are superior to those of blister beetles. Light and scanning electron microscope studies of bee flies and blister beetles collected while foraging showed that their body hairs were ideal for carrying *Echinacea* pollen grains, so physically both of these insects can vector pollen. Bee flies are common wildflower pollinators and were probably the most efficient *Echinacea* pollinators in the field. They can carry thousands of pollen grains on their hairy bodies and heads and often visit many inflorescences as they forage for nectar. The blister beetles are less likely to be efficient pollinators because they do not travel quickly between plants but tend to stay on inflorescences for an extended period of time, especially if there is abundant pollen for them to feed on.

Butterflies of the families Pyridae and Satyridae (Lepidoptera) were the third largest group of visitors making up 5% (large site) and 10% (small site) of the total visits, respectively. Hymenopteran pollinators were present but in much smaller percentages than expected. Only 3% of potential pollinators to inflorescences at the large field site were made by hymenopterans represented by bumblebees, halictid bees and megachilid bees. Evening and late night transects revealed that the vast majority of pollinating insects were not present on the inflorescences after sunset. In fact, the bee flies and butterflies did not even forage during extended cloudy periods in the afternoons or late mornings.

It is interesting to find such high numbers of bee flies and blister beetles on *Echinacea* inflorescences. Upon investigating the life cycle of these two insects, it was found that in the larval stage both bee flies and blister beetles are predators of grasshopper egg. One larva of either species can destroy an entire egg pod of the clear-winged grasshopper (*Camnula pellucida*) or half of the egg pod of the two-striped grasshopper (*Melanoplus bivitattus*) (Swan and Papp 1972). Both of these grasshoppers are serious crop pests on the prairies. This common larval food source explains the abundance of the adult stages in the field. The grasshopper numbers around Saskatoon were severe for the summer of 2003. For more information on the life histories of these insects and their relationship to grasshoppers, see Gillott et al. (2003). Grasshoppers were ever present in the two field sites but were especially abundant at the larger site. An interesting note is that even with these high population numbers the grasshoppers did not feed on the leaves or stem of the *E. angustifolia* plants.

Observations of the foraging behaviour of the Alfalfa leafcutting bees on the inflorescences bode well for their future as managed pollinators of *E. angustifolia*. The female bees rapidly collected pollen from the staminate disc florets that were presenting pollen and in doing contacted the stigmas of the florets in the receptive pistillate stage with their feet and abdomen, probably transferring pollen. Each bee worked furiously and showed a floral constancy in that they quickly moved from one *E. angustifolia* inflorescence to the next without foraging on a different flowering species in between. Future study may definitively answer the question of whether Alfalfa leafcutting bees can be used as managed pollinators for *E. angustifolia* crops.

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