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Comparing the performance of native and managed pollinators of Haskap (*Lonicera caerulea*: Caprifoliaceae), an emerging fruit crop

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ABSTRACT

Fruit set in many crops is dependent on pollinating insects, but the pollination performance of floral visitors can vary tremendously among taxa. *Apis mellifera* L. is the primary managed pollinator used for most crops, but alternative managed bee species or wild pollinators may be more effective and efficient pollinators. In this study, we compared the performance of *A. mellifera* to commercial *Osmia lignaria* Say and wild *Bombus* spp. as pollinators of Haskap (*Lonicera caerulea* L.), an early flowering fruit crop grown in northern regions of North America, Europe, and Asia. We conducted field experiments that compared single visit pollen deposition (SVD), foraging behaviour, and pollen load composition among the three taxa. We found that individual *Bombus* spp. had the highest SVD levels, visited the most flowers per time interval, had high floral constancy, and could tolerate the colder temperatures often experienced during Haskap flowering. *Apis mellifera* had the lowest SVD levels, spent three times as long per flower as *Bombus* spp., and were not active during cooler temperatures. However, their potential for high densities in good weather and their affinity for Haskap suggest that as a colony they are important for Haskap pollination. *Osmia lignaria* rarely visited Haskap when alternative forage such as willow (*Salix*) was available and therefore contributed very little to Haskap pollination. These results emphasize the economic importance of wild bees in agro-ecosystems, and we conclude that pollination in Haskap orchards can be optimized by providing year-round forage and nesting habitat for wild *Bombus* spp., in addition to pollination by *A. mellifera*.

1. Introduction

Pollination services for insect pollinated crops can be provided by the introduction of managed bee species, or by wild populations of native pollinators. *Apis mellifera* L. (Hymenoptera: Apidae), the honey bee, is the most widely used managed pollinator, and many crops directly depend on its use (Klein et al., 2007; McGregor, 1976). As social, generalist, and commercially available foragers, *A. mellifera* can be a practical solution for avoiding pollination deficits when native pollinators are scarce (Klein et al., 2007). However, it is well known that *A. mellifera* workers are inefficient pollinators of some crops, and in many cases alternative managed or wild species may do a better job (e.g. reviewed by (Klein et al., 2007; Westerkamp and Gottsberger, 2000); almond (Bosch and Blas, 1994); blueberry (Javorek et al., 2002); coffee (Klein et al., 2003); raspberry and blackberry (Cane, 2005); tomatoes (Putra and Kinasih, 2014); cherry (Bosch and Kemp, 1999); pear (Monzón et al., 2004)). Even when *A. mellifera* are effective pollinators, native bees increase crop yields and buffer against commercial colony losses (Garibaldi et al., 2013, 2011; Klein et al., 2003; Rader et al., 2013; Winfree et al., 2007). For many crops the performance of different species of pollinators is still unknown, and *A. mellifera* is often used by default even when they are not the most effective or efficient option.

Haskap (*Lonicera caerulea*: Caprifoliaceae), also known as blue honeysuckle or honeyberry, is a temperate fruiting shrub that is visited by *A. mellifera*,*Bombus* spp. (i.e. bumble bees; Hymenoptera: Apidae), and a variety of solitary bees (Bożek, 2012). Haskap is native to northern regions of North America, Europe, and Asia, and it has recently gained popularity as a commercial crop in North America (Hummer et al., 2012). Haskap production is increasing in North America due to potential health benefits of eating the fruit (e.g. Lefèvre et al., 2011; Rupasinghe et al., 2012; Svarcova et al., 2007), and the slightly tart flavour of its blue berries, which are eaten fresh or used in a wide variety of food products (Hummer et al., 2012). However, very little is known about Haskap pollination biology,

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though it is known to be mostly self-incompatible (Bors et al., 2012; Hummer et al., 2012) and to require animal pollinators (Bożek, 2012). In Canada, *A. mellifera* is the primary managed pollinator used for Haskap production, with most orchards receiving some level of pollination services from local apiaries. Recently, *Osmia lignaria* Say (Hymentopterae: Megachilidae), known commonly as the blue orchard bee, has also been considered as a potential pollinator of Haskap. Native *Bombus* spp., solitary bees (e.g. *Lasioglossum* spp., *Osmia* spp. *Halictus* spp.), and syrphid flies (Diptera: Syrphidae) are also regular visitors of Haskap in Canada; however, the pollination efficacy of both managed and wild floral visitors of Haskap is entirely unknown.

Haskap flowers have a pale yellow tubular corolla, less than 2.5 cm in length, and grow in two flowered cymes that are typical of other *Lonicera* species. Many inflorescences are produced per branch and the flowers nod downwards. The flowering period for Haskap lasts 2 to 3 weeks and occurs very early in the spring before the plant leafs out, and the flowers are able to tolerate frosts down to at least −7 °C (Bors, 2008; Hummer et al., 2012). Only a few insect pollinators can fly during periods of low temperature characteristic of spring at high latitudes, potentially suggesting a dependence on cold-tolerant pollinators such as *Bombus* spp., whose large queens can fly in temperatures as low as 0 °C (Heinrich, 2004). Fruit development in Haskap is unusual compared to other crops; the bracteoles subtending the flowers have fused together around the two ovaries (Fig. 1a), and the Haskap berry (actually a multiple fruit) forms from these combined structures (Fig. 1b and c). The development of the Haskap fruit may depend on the successful pollination of both flowers in the inflorescence, so pollinator behaviour (e.g. how likely a species is to visit both flowers) may be especially important for the production of high quality fruit (Woodcock et al., 2013).

The purpose of this study was to assess the pollination performance of commercially managed *A. mellifera* and *O. lignaria* relative to wild *Bombus* spp. on Haskap crops in Saskatchewan, Canada. Specifically, we compared single visit pollen deposition, visit symmetry, visit duration, and pollinator density. In addition, we analyzed the pollen load composition from female *O. lignaria*; although *A. mellifera* and *Bombus* spp. are known to forage on Haskap (Bożek, 2012), it is unclear whether *O. lignaria* shows a preference for the crop. We hypothesized that because *Bombus* spp. are active in lower temperature ranges that correspond with flowering, they are likely the most effective and efficient pollinators of Haskap. We predicted that *A. mellifera*, which is a non-native species that prefers warm weather and is unlikely to co-exist with Haskap under natural conditions, would be less effective and efficient. *Osmia lignaria* is known to be an effective pollinator of other fruit crops (Bosch and Kemp, 2001), and is a native North American species that is well adapted to cool temperatures, so we expected it to be similar to *Bombus* spp. in performance. These taxa have never been assessed as pollinators of Haskap, and the information obtained from this study will help Haskap orchard managers to implement pollination strategies that optimize fruit yield in a sustainable manner.

2. Methods

2.1. Study site

Our research was conducted in the spring of 2014 within a 30 ha organic Haskap orchard in Birch Hills, Saskatchewan, Canada (52.97 N, −105.42 W). The study orchard was bordered on two sides by a narrow shelter-belt of trees. The surrounding area was largely agricultural and consisted mostly of crops such as canola, alfalfa, and wheat. Plants in the area that flowered concurrently to Haskap were primarily willow (*Salix*, Salicaceae) and dandelion (*Taraxacum*, Asteraceae). A variety of insects were frequently observed visiting Haskap flowers within the orchard, including over 10 species of *Bombus* (Appendix A, supplementary material). The orchard was established in 2008 and grows four Haskap cultivars developed in the University of Saskatchewan's fruit breeding program. Our research focused on the varieties 'Tundra' and 'Indigo Gem', which were chosen because they were well-represented within the orchard by mature plants. Each row within our study area contained approximately 400 plants of the same cultivar, spaced 1 m apart, with adjacent rows being different cultivars and a row of pollinizers (a distantly related cultivar that provides a compatible source of pollen to the desired cultivars) located every 5th row. The cultivars 'Tundra' and 'Indigo Gem' were represented by a total of 13 and 14 rows, respectively.

For the purpose of our experiments, 12 full-strength colonies of *A. mellifera* provided by a local apiarist were placed on the eastern edge of the orchard. In addition, 12 nesting boxes of *O. lignaria* were obtained from Mason Bee Central (Black Creek, BC, Canada) for our experiments, with 220 bees (2:1 female to male ratio) in each.

2.2. Single visit deposition

To assess pollen deposition by each pollinator taxa, we covered branches of unopened flowers with pollinator exclusion bags. Once the flowers had opened we removed the bags and removed the whole branch from the bush and placed it into a single-stem flower

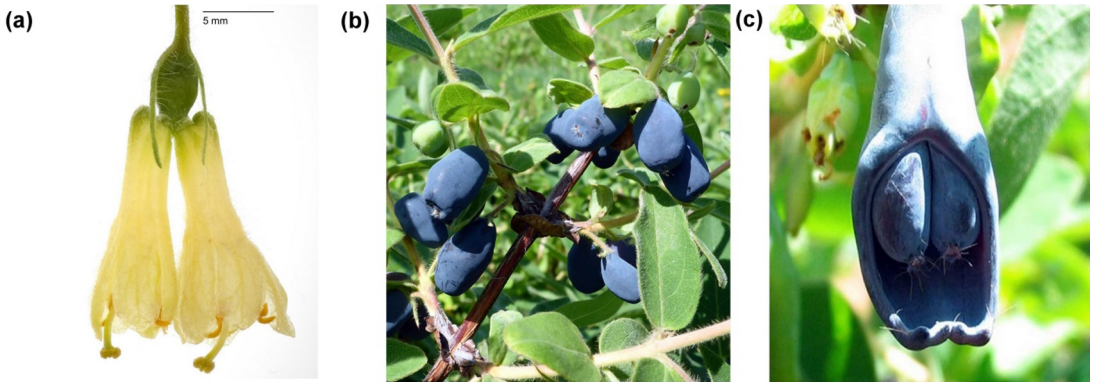

Fig. 1. Haskap (*Lonicera caerulea* L.) flowers and fruits. (a) Typical Haskap inflorescences. The two perfect flowers each have five petals, five stamens and one stigma; the ovaries of both are enclosed by bracteoles which are fused into a cupule and are subtended by two bracts. The ovaries and bracteoles develop into a single compound fruit. (b) Normal compound fruit produced by Haskap. A single fruit results from each two-flowered inflorescence. (c) Haskap fruit in which the bracteoles have not fused around the ovaries, showing the two distinct berries which make up the fruit (Photo credit: Logie Cassells, LaHave Natural Farms, Nova Scotia, Canada).