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Stigmatic pollen delivery by flies and bees: Methods comparing multiple species within a pollinator community

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Abstract

A wide variety of insect species provide pollination services in natural and agricultural ecosystems, but in order to quantify their contribution it is necessary to evaluate their effectiveness. An important component of this is to determine their ability to transfer pollen to stigmas which typically requires observers to wait for insects to visit focal flowers (static approach); a time-consuming process not amenable to obtaining measures for pollinating species of low local abundance. An alternative method (active approach) is to detach test flowers and present them to the targeted flower visitor. This offers a number of advantages (*e.g.* increased speed and flexibility), but may alter insect behaviour. We compared pollen deposition within flowering onion crops using three bee (Apoidea) and three fly (Diptera) species. The two approaches resulted in similar numbers of pollen grains being deposited onto stigmas for each insect species, thereby supporting the validity of the active as an alternative to the static approach in our test crop. The ability to rapidly assess stigmatic pollen deposition of a broad range of insects using the active approach can greatly assist assessments of pollinator contribution within plant pollinator assemblages.

Keywords: Diptera; Hymenoptera; Eco-system services; Wild pollinators; Vegetable seed crops; Honey bees; Solitary bees; Blow flies; Hover flies; Pollinator diversity

Introduction

Numerous studies have demonstrated the contributions of diverse insect taxa to the pollination of many crop species (Kleijn et al. 2015; Rader et al. 2016), but fewer have compared the individual contributions of particular species. These assessments are necessary for developing applied interventions to support pollinators by maintaining or establishing suitable habitats (Howlett, Davidson, Mathers, & Pyke 2013; Sardiñas & Kremen 2015), developing new managed pollinators (Donovan, Howlett, & Walker 2010; Howlett 2012), prioritising management strategies to support more effective pollinators (Kleijn et al. 2015; Rodriguez & Kouki 2015; Scheper et al. 2013) and minimising the potential impacts of pest insect management (Biddinger & Rajotte 2015).

Measuring pollinator efficiency typically considers the rate at which viable pollen is deposited onto stigmas (Ne'eman, Juergens, Newstrom-Lloyd, Potts, & Dafni 2010; Rader et al. 2009). Although not a measure of successful ovule fertilisation, the measure is useful for assessing and comparing the ability of pollinators to deliver pollen to stigmas, a crucial step for the pollination of insect-pollinated plants. Collecting

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Table 1. Examples of studies using different approaches to assess single visit stigmatic pollen deposition by multiple pollinating species to different plant species. The approaches are static (waiting for an insect to visit a test flower left attached to the plant) or active (abcising the test flower from plant and presenting it to a chosen flower visitor).

Approach	Plant	Authors
Static	Turkcap (*Malvaviscus arboreus* Cav.)	King, Ballantyne, and Wilmer (2013)
Static	*Helicteres guazumifolia* Kunth	King et al. (2013)
Static	Meadow crane's-bill (*Geranium pratense* L.)	King et al. (2013)
Static	Foxglove (*Digitalis purpurea* L.)	King et al. (2013)
Static	Blueberry (*Vaccinium corymbosum* L.)	Cariveau, Williams, Benjamin, and Winfree (2013)
Static	Changunga [*Byrsonima crassifolia* (L.) Kunth]	King et al. (2013)
Static	Common agrimony (*Agrimonia eupatoria* L.)	King et al. (2013)
Static	Creeping thistle [*Cirsium arvense*(L.) Scop.]	King et al. (2013)
Static	Cranberry (*Vaccinium macrocarpon* Aiton)	Cariveau et al. (2013)
Static	Lesser knapweed (*Centaurea nigra* L.	King et al. (2013)
Static	Field scabious [*Knautia arvensis* (L.) Coult.]	King et al. (2013)
Static	Red clover (*Trifolium pratense* L.)	King et al. (2013)
Static	Morning glory [*Ipomoea trifida*(H. B. K.) G. Don.]	King et al. (2013)
Static	Hogweed (*Heracleum sphondylium* L.)	King et al. (2013)
Static	Blackberry (*Rubus fruticosus* L.)	King et al. (2013)
Static	Pak Choi [*Brassica rapa* var *chinensis* (L.) Hanelt]	Howlett et al. (2011) and Rader et al. (2009)
Static	Cashew (*Anacardium occidentale* L.)	Freitas and Paxton (1998)
Static	Cross-leaved heath (*Erica tetralix* L.)	Ballantyne et al. (2015)
Static	Bell heather (*Erica cinerea* L.)	Ballantyne et al. (2015)
Static	Common heather [*Calluna vulgaris* (L.) Hull]	Ballantyne et al. (2015)
Static	Common gorse (*Ulex europaeus* L.)	Ballantyne et al. (2015)
Static	Dwarf gorse (*Ulex minor* Roth.)	Ballantyne et al. (2015)
Static	Indian warrior (*Pedicularis densiflora* Benth. ex Hook.)	Sun et al. (2013)
Static	Orange jewelweed (*Impatiens capensis* Meerb.)	Young, Dunning, and von Hasseln (2007)
Static	Watermelon [*Citrullus lanatus* var. *lanatus* (Thunb.) Matsum. & Nakai]	Cariveau et al. (2013) and Winfree, Williams, Dushoff, and Kremen (2007)
Static	White clover(*Trifolium repens* L.)	Rodet et al. (1998)
Active	Almond [*Prunus dulcis* (P. Mill.)]	Thomson and Goodell (2001)
Active	Apple (*Malus domestica* Borkh.)	Park et al. (2016)
Active	Avocado (*Persea Americana* Mill.)	Perez-Balam et al. (2012) and Rader et al. (2016)
Active	Great yellow rattle (*Rhinanthus angustifolius* C.C. Gmelin)	Natalis and Wesselingh (2012)
Active	Field scabious [*Knautia arvensis* (L.) Coult.]	Larsson (2005)
Active	Kiwifruit (*Actinidia deliciosa* C.F.Liang & A.R.Ferguson)	Rader et al. (2016)
Active	Radish (*Raphanus sativus* L.)	Rader et al. (2016)
Active	Great yellow rattle (*Rhinanthus minor* L.)	Natalis and Wesselingh (2012)
Active	Muskmelon (*Cucumis melo* L.)	Goodell and Thomson (2007)
Active	Mustard (*Brassica rapa* L.)	Goodell and Thomson (2007)
Active	Carrot [*Daucus carota* subsp. *sativus* (Hoffm.) Schübl. & G. Martens]	Rader et al. (2016)
Active	Yellow jessamine (*Gelsemium sempervirens* (L.) J.St.-Hil.)	Adler and Irwin (2006)
Active	Twolobe larkspur (*Delphinium nuttallianum* Pritz. ex Walp.)	Waser (1988)

these data may be time-consuming when assessing multiple plant and pollinating species (Ballantyne, Baldock, & Willmer 2015).

To directly measure the amount of pollen transferred onto stigmas by insects, virgin test flowers (not previously exposed to insects) are monitored closely until immediately after a single visit. The stigma is then removed to assess pollen deposited. Two approaches have been used. In the 'static' approach the flower remains attached to the plant and the researcher waits until an insect visits. In the 'active' approach, a flower (or inflorescence) is removed from the plant and positioned by the researcher close to flowers currently being visited by the target pollinator.

Both approaches have been employed to test pollinator interactions with a wide variety of plant species and some examples are provided in Table 1. To our knowledge,