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The identity of crop pollinators helps target conservation for improved ecosystem services ☆

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ABSTRACT

Insect pollinated mass flowering crops are becoming more widespread and there is a need to understand which insects are primarily responsible for the pollination of these crops so conservation measures can be appropriately targeted in the face of pollinator declines. This study used field surveys in conjunction with cage manipulations to identify the relative contributions of different pollinator taxa to the pollination of two widespread flowering crops, field beans and oilseed rape. Flower visiting pollinator communities observed in the field were distinct for each crop; while field beans were visited primarily by a few bumblebee species, multiple pollinator taxa visited oilseed, and the composition of this pollinator community was highly variable spatially and temporally. Neither pollinator community, however, appears to be meeting the demands of crops in our study regions. Cage manipulations showed that multiple taxa can effectively pollinate both oilseed and field beans, but bumblebees are particularly effective bean pollinators. Combining field observations and cage manipulations demonstrated that the pollination demands of these two mass flowering crops are highly contrasting, one would benefit from management to increase the abundance of some key taxa, whilst for the other, boosting overall pollinator abundance and diversity would be more appropriate. Our findings highlight the need for crop specific mitigation strategies that are targeted at conserving specific pollinator taxa (or group of taxa) that are both active and capable of crop pollination in order to reduce pollination deficits and meet the demands of future crop production.

1. Introduction

Insect pollinators are important for the production of many fruit, vegetable and field crops (Klein et al., 2007) and their contribution to global agriculture has been valued at €153bn annually (Gallai et al., 2009). Like many European countries, insect pollination underpins some key sectors of UK agriculture, particularly the top and soft fruit industries but with increasing areas of insect pollinated field crops such as field beans and oilseed rape being grown, the current valuation of UK insect pollination services of £430 million per annum is set to increase (Smith et al., 2011). Driven by increasing demand for biofuels, the area of oilseed rape in the UK has increased by over 150,000 ha in the past decade (DEFRA, 2012) and with global coverage currently standing at 33.6 million ha (FAOStat, 2013), oilseed is rapidly becoming a crop of global significance.

Pollination of oilseed rape (*Brassica napus*) occurs through a combination of wind and insect vectors with considerable autogamy apparent (Delaplane and Mayer, 2000). Field and cage studies have shown positive effects of insect pollination on pod set and seed set (Jauker and Wolters, 2008; Manning and Wallis, 2005; Morandin and Winston, 2005; Stanley et al., 2013; Williams et al., 1987), with associated benefits to the yield and quality of production (Bommarco et al., 2012). These benefits are dependent on variety and the genetic origin of the oilseed, with some varieties showing increased yield responses to insects (Hudewenz et al., 2013; Steffan-Dewenter, 2003). Overall the contribution of insect pollination to oilseed production has been estimated to be around 18% of total yield (Bommarco et al., 2012).

Oilseed rape is visited by a variety of pollinating insects worldwide, including honey bees, solitary bees and hoverflies (Ali et al., 2011; Arthur et al., 2010). In the UK, bumblebees and honey bees were found to be active flower visitors in oilseed fields (Hayter

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and Cresswell, 2006) as well as *Andrena* spp., *Osmia* spp. and *Lasioglossum* spp. solitary bee species (Woodcock et al., 2013). The pollination efficiency of different taxa for oilseed has been shown to vary, *Osmia bicornis* increased pod set when compared to hoverflies (Jauker et al., 2012) and considerable variation between bee species in Pakistan was found (Ali et al., 2011). Furthermore, pollinator behaviour on oilseed flowers in terms of stigma contact and time spent foraging varies (Woodcock et al., 2013), and the amount of pollen carried by different oilseed flower visiting insects depends on taxa (Stanley et al., 2013). Given the variety of wild insects that visit oilseed flowers, and their potential impact on crop production, our understanding of the actual contribution of different taxa to crop pollination in the wider landscape of the UK remains limited.

With a total production area of 168,000 ha in the UK in 2010 (DEFRA, 2012) and 2.3 million ha grown worldwide (FAOStat, 2013), another important insect pollinated field crop is the field bean (*Vicia faba*). The positive effects of insect visits on the pollination of field beans has long been appreciated (Free, 1993), with associated increases in pod set, beans per pod and pod weight; positive impacts on pod distribution on the plant have also been observed (Aouar-Sadli et al., 2008; Benachour et al., 2007; Kendall and Smith, 1975). It has been suggested that only long-tongued bumblebees can access nectar due to the floral anatomy (Free, 1993) but legitimate visitation by honey bees (Kendall and Smith, 1975) and solitary bee species have been observed, although raiding behaviour by some bumblebee species and honey bees is common (Aouar-Sadli et al., 2008; Benachour et al., 2007; Tasei, 1976). Pollinator communities visiting bean flowers in the field have been characterised more recently in North Africa (Aouar-Sadli et al., 2008; Benachour et al., 2007), and in 1976 in France, honey bees, bumblebees and several solitary bee species were observed visiting field beans with varying proportions of legitimate and raiding visits (Tasei, 1976). A systematic survey of field bean visitors and their relative contribution to pollination in the UK has not been undertaken.

In the UK, there is increasing demand for insect pollination services, particularly as field crops reliant on wild pollinators, like oilseed rape, become more widespread (Breeze et al., 2011). With the continued decline of potential insect crop pollinators, both wild (Biesmeijer et al., 2006; Carvalheiro et al., 2013; Potts et al., 2010a) and managed (Potts et al., 2010b), possible associated impacts on production are a concern. If pollination services are to be sustainably managed to maintain crop productivity in the face of increasing demand and continued pollinator decline, it is essential that we identify those pollinators key to production of our most widely grown insect pollinated crops and quantify whether their activity in the field is adequate. Only then can pollination service management strategies be targeted at appropriate species in order to stabilise and improve crop production.

The aims of the present study were to use field surveys to identify insect pollinators which are floral visitors of two important UK flowering crops, field bean and oilseed, as well as establishing their relative level of activity in the field. Then, by using cage manipulation experiments, measure the crop pollination effectiveness of potentially important insect pollinators, thereby identifying those taxa that are currently primarily responsible for crop production and whether their activity in the field is meeting the demands of the crop. This is essential information to underpin pollination service management strategies for safeguarding crop production in the future.

2. Materials and methods

2.1. Pollinator communities of field bean and oilseed rape

For each crop, pollinator surveys were carried out in eight fields at least 2 km apart. Acknowledging that landscape structure affects the composition of pollinator communities (Kennedy et al., 2013), we used Corine Land Cover map (European Environment Agency, 2010) to characterise the local landscape and chose sites along a gradient of semi-natural habitat. Field bean fields varied between 0% and 46% semi-natural at a 2 km radius and oilseed varied between 0-37%. This ensured that the pollinator surveys in each of our crops would provide a good reflection of the variation in pollinator communities that might be expected in the wider landscape. In each field, two 150 m crop tramlines were selected at least 50 m from the field edge. At 50 m intervals along each tramline, three crop watch areas were established measuring 2 m by 1 m in bean fields and 2 m by 2 m in oilseed rape. At each location, 15 min crop watches were carried out three times during the season, at early, mid and late flowering. All floral insect visits, as well as the number of open flowers, within the crop watch area were recorded. Flower visitors were divided into five taxa: honey bees, bumblebees, solitary bees, hoverflies and others (which included other Diptera, Lepidoptera, Hymenoptera and Coleoptera). Where possible, pollinators were identified to species, and in beans, whether the visitor was nectar raiding or carrying out legitimate visits was recorded. Surveys were carried out only when temperatures were in excess of 15 °C and with no more than light wind. Flowering occurred throughout May for field beans and from the end of April to the end of May for oilseed. Field bean surveys were undertaken in 2011 in Berkshire on winter sown field beans, variety Wizard. Oilseed surveys were carried out in 2012 in Yorkshire on the restored hybrid varieties Excalibur and DK Expower.

2.2. Effect of different pollinators on field bean and oilseed rape pollination

To enable manipulation of both flowering crops and pollinators, flight cages were constructed at the University of Reading and University of Leeds experimental farms, using 2.4 by 2.1 m frames covered in polyethylene mesh with a gauge size of 1.33 mm. In separate flight cages, four potential crop pollinators were established: honey bees (*Apis mellifera*), bumblebees (*Bombus terrestris-audax* – a UK subspecies), a solitary mason bee (*O. bicornis*) and a hoverfly (*Episyrphus balteatus*). These pollinators were chosen because they are commercially available and represent four distinct flower visiting insect guilds which may be effective crop pollinators. Pollinators were provided with nesting and forage resources within the cage when not involved in experiments, thus encouraging natural foraging behaviour for the period of experimentation. *Apis mellifera*, through the use of a double entrance hive, was also given access both to the flight cage and the outside.

To compare the effects on pollination of our four pollinator species, flowering oilseed rape and bean plants were placed in a randomised block in flight cages with pollinators for a controlled number of visits per flower. Oilseed rape (cultivar: Heros) and field bean (cultivar: Clipper) plants were grown individually in pots. Experimental plants were planted in multiple temporal cohorts to ensure plants at the correct phenological stage were available for pollinator treatments and to enable repeated experimentation through time. During pollinator exposures, cages contained either 3 bean plants, or 10 oilseed plants, of which 5 were experimental. Within the cage, a focal plant was selected at random and all flower visits to that plant were recorded until a threshold number of visits was reached. By incorporating the total number of flowers within the cage, pollinator visitation rates to experimental plants could be manipulated by controlling the length of time plants were inside cages. Experimental visitation rates used were 1 (low) and 3 (high) visits on average per flower for oilseed, and 1 (low), 2 (medium) and 4 (high) visits on average per flower for field bean. Following exposure to pollinators, all flowers in anthesis on each of the experimental plants were marked with cable ties. Due to