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Conserving wild bees for crop pollination

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Abstract
A substantial proportion of the worlds crops rely on insect pollination, yet for many we have little or no information as to which pollinators are most effective. Pollinator management has traditionally focussed exclusively on one species, the honeybee, *Apis mellifera*. Yet this bee is not able to adequately pollinate some crops, and is an unreliable pollinator in cold and wet climates. Natural populations of wild bee species and other insects probably contribute greatly to pollination of many crops. Yet many of these insects have declined greatly in the last 50 years as a result of agricultural intensification. It seems certain that the yield of some crops is now limited by inadequate pollination, and that opportunities for diversification into novel crops may be reduced through a lack of suitable pollinators. Agri-environment schemes provide an opportunity to enhance pollinator populations in farmland, but at present little is known as to which schemes are most suitable. Large-scale field trials are needed to assess how best to encourage and sustain populations of wild pollinators on farmland.

Key words: Bumblebee, floral resources, farmland biodiversity, crop yield.

Introduction

It is exceedingly hard to estimate the total value of bee pollination in crop production, but various estimates have been produced and all agree that the contribution made by bees is vast. Estimates for the USA vary from $1.6 billion to $40 billion per year[1,2]. Gill[3] estimated the value to be A$156 million for Australia, while Winston and Scott[4] put the value for Canada at C$1.2 billion. A comparable estimate for the EC suggests that insect pollination was worth 5 billion ECUs in 1989, of which 4.2 billion was ascribed to honeybees[5]. More than a third of all human food is thought to depend upon insect pollination[6]. Remarkably, we are ignorant of the pollination requirements of a great number of crops despite the fundamental and well-appreciated relationship between pollination and yield[7]. In Europe, a region better studied than most, about 250 plant species are grown as crops. Of these, about 150 are thought to be insect pollinated, but for most we do not know which insects pollinate them, or whether yields are being limited by inadequate pollination[7,8]. The current drive to diversify arable production is leading to the introduction of yet more crops, many of which require insect pollination, yet whether we have sufficient appropriate insects to pollinate them is unknown.The honeybee, *Apis mellifera*, is overwhelmingly the most widely managed pollinator of crops, and many farmers are entirely unaware that there are other insects that are capable of pollination. The economic value of pollination is often credited entirely to honeybees[9], and is frequently used to justify public subsidising of honey bee keeping. Even the scientific literature is frequently blinkered in this respect[10,11]. For example honeybees were promoted for pollination of alfalfa up until the 1980's even though Henslow noted in 1867 that honeybees were incapable of tripping the flowers. There is now growing appreciation that there are alternatives to the honeybee, and that in some situations the alternatives may be better[12]. In cold conditions, and when it is raining, honeybees will not forage[13]. In an unpredictable climate such as that of Northern and Western Europe this can be important, particularly when growing crops such as apples that flower early in the year when a spell of poor weather is likely. Honeybees are not able to adequately pollinate some crops, such as those with deep flowers (e.g. red clover) or those requiring buzz pollination (e.g. tomatoes and potatoes). Reliance on a single species for pollination of crops is an inherently risky strategy. This was made all too clear during the recent epidemic of the mite *Varroa destructor*, which all but exterminated the honeybee through vast parts of its range. Similarly, the invasion of the USA by Africanized honeybees has greatly reduced the availability of commercial hives for crop pollination[10].

In contrast, native pollinators are adapted to local conditions; for example bumblebees will forage in very cold conditions and even when it is raining[13]. Different wild pollinators suit different flowers, and between them they can pollinate a range of crops. For example short tongued bumblebee such as *Bombus terrestris* are important pollinators of oilseed rape, while species with medium or long tongues (*B. pascuorum* or *B. hortorum*) are needed to pollinate field beans and red clover[14]. Bumblebees and many other wild bee species are capable of buzz pollination.

Declines in Pollinator Populations

At a time when appreciation that wild insects can be important as crop pollinators is growing, these insects are declining in abundance. The available evidence suggests that many wild pollinators have declined dramatically in recent decades, both in the UK, in continental Europe and in North America[15-18]. These declines are almost certainly the result of intensification of farming practices during the latter half of the 20th century[15,19]. Notable changes include the loss of unimproved flower-rich grasslands (formerly valued as pasture and for hay production), loss of hedgerows, and the widespread use of insecticides and herbicides (the latter removing food sources for insects). Boyle and Philogène[20] counted only 5 bumblebees in a 3-year census of orchard pollinators in Ontario. Bumblebees are abundant in other parts of Ontario, but are thought to have been driven from the fruit-growing regions by intensive use of pesticides. These crops now rely solely in pollination by honeybees. Similarly, native populations of bumblebees are rarely adequate to pollinate cranberries in North America[21,22]. Cranberry farmers are forced to rent honeybees colonies to effect pollination[1], but, as with tomatoes, honeybees do not favour cranberry flowers and from preference will forage elsewhere[22]. If field sizes are very large then there may simply not be enough wild bees to go around[23]. Farms with large field sizes necessarily have a low proportion of hedgerows or other field margins, and since these are the places that provide nest sites and floral resources for wild pollinators when crops are not flowering, then farms with large fields will have relatively few pollinators (regardless of the pesticide regime adopted). Yield of crops may be limited if there are insufficient bees to visit all of the flowers. For example in fields exceeding 12 ha in size the yield of field beans was reduced through inadequate pollination by long-tongued bumblebees[24]. Similarly, if field sizes exceeded 5 ha then yield of red clover in New Zealand declined through a shortage of bumblebees[25]. At present the area of land in the EC and USA under entomophilous crops is increasing, and some researchers have predicted that we will soon be facing a serious shortage of both wild and managed bees[5,26]. Ifpollination is inadequate then farmers may be tempted to switch to growing crops that do not require insect pollination[27]. For example red clover is now rarely grown for seed production in Europe because yields are poor, probably because of a lack of appropriate pollinators. The introduction of novel crops may also be limited by pollinator availability. A diversity of new crops have been introduced in Europe in recent years, as yet grown only on a small scale. Many are insect pollinated; for example lupins (*Lupinus* spp.), borage (*Borago officinalis*), camelina (*Camelina sativa*), cosmea (*Cosmea maritima*), cuphea (*Cuphea* spp.) and niger (*Guizotia abyssinica*)[7]. The potential of these crops may never be realized if yields are limited by a paucity of suitable insects needed to pollinate them.

Encouraging Native Pollinators

Government policies in Europe now place emphasis on combining the goals of agriculture and conservation[28,29], and subsidies are currently available to remove land from arable production. The primary aim of these schemes when they were first introduced was to reduce agricultural production, but there is growing emphasis on using land that is taken out of production to encourage farmland biodiversity. In the UK, farmers can now choose to adopt any of a range of schemes which aim to reduce yields and increase farmland wildlife. Similar schemes are in operation elsewhere. Options include new hedge-planting, repair of existing hedgerows, conservation headlands (field margins that are not treated with fertilizers or pesticides), beetlebanks (strips of tussock-forming grasses planted across fields), uncropped field margins (either allowed to regenerate naturally or sown with wildflower seed mixtures), and set-aside, whereby the land is left fallow for variable periods of time[30-32]. As yet little is known as to the relative value of these various forms of management for wildlife, and they are likely to differ between faunal or floral groups. However, there is no doubt that broadly the schemes do benefit wildlife. For example hedgerows and beetlebanks provide overwintering sites for beetles, and so boost the overall populations on farmland[29]. They also provide a home for small mammals and nesting sites for bird[33,34]. Conservation headlands have been shown to increase abundance of farmland butterflies and hoverflies[35,36]. All of these schemes increase the abundance and diversity of flowers that are available. For example studies of uncropped field margins (6 m wide field margins that are not sown with crops or treated with agrochemicals) have found that they support approximately six times as many flowering plant species, ten times as many flowers, and attract ten times as many foraging bumblebees as equivalent cropped field margins[37]. Any form of management that increases floral resources and reduces the area of crop is likely to benefit wild pollinators. Appropriate management of uncropped areas to encourage wild pollinators may prove to be a cost-effective means of maximising crop yield. Depending on the crops that they grow, farmers may wish to encourage particular species. For example if they grow field beans in the UK then they require healthy populations of the long-tongued bumblebees *B. pascuorum* and *B. hortorum*. To encourage them, the farmer might sow wildflower strips containing deep flowers such as white deadnettle (*Lamium album*) and red clover (*T. pratense*)[38]. Of course the crops themselves provide vast areas of forage, but only for short periods. However, planting a succession of crops that flowered at different times could greatly enhance pollinator abundance while simultaneously maximising yields. Management of farmland with the specific aim of enhancing wild pollinator populations is in its infancy, and at present is largely based on educated guesswork. Large scale experimental trials are urgently needed to establish which methods are most cost effective, and must take in to account the costs of lost crop area and establishment and management of bee resources, versus the financial benefits gained through improved yields. Enhancing populations of wild bees is likely to be most successful if it is carried out at a landscape scale, which would require cooperation and coordination at a regional level.

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