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INSECT POLLINATION AND CROP PRODUCTION: A EUROPEAN PERSPECTIVE

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ABSTRACT

The dependence of crop production in Europe on pollination by insects is reviewed. The botanical diversity of the 140 crop species, identified as benefiting from insect pollination, requires a diversity of insect pollinators. The native European honey bee is undoubtedly the insect species that contributes most to crop pollination, a contribution (to 30 selected crops only) evaluated at *ca.* 4250 million dollars a decade ago. Species of bumble bee are also of considerable importance, both to field crops, when sufficiently abundant and, because they can now be reared commercially, for the managed pollination of many protected crops. The contribution of native species of solitary bees is poorly understood. The main concerns of pollination scientists in relation to sustainable pollination are outlined. Population density and agriculture are exerting major pressures on land use. There is much documented evidence that European bee fauna is diminishing largely due to habitat deterioration and bee disease; the consequences for pollination are feared to be severe. More research into the pollination requirements of plants and the development of land use strategies and agricultural policies sympathetic to bee populations is being called for. Although the European Commission recognises the need for more environmentally-friendly agricultural policies, it does not appear to appreciate the crucial role of pollinator diversity to the functioning of agricultural production systems to ensure continuity of supply of high quality and varied food for Europe or the dangers of over-dependence on the services of a single pollinator, the honey bee.

Terms of reference

The Terms of Reference of this International Workshop on '*The Conservation and Sustainable Use of Pollinators in Agriculture, with Emphasis on Bees'* (defined by the Conference of the Parties of the Convention on Biological Diversity in Annex 3 of its Decision 111/11) are to: 1. Monitor the loss of pollinators world wide, 2. Identify specific causes of pollinator decline, 3. Estimate the economic cost associated with reduced pollination of crops, 4. Identify and promote best practices and technologies for more sustainable agriculture, 5. Identify and encourage conservation practices to maintain or re-establish pollinators. During the last decade, similar issues have been considered by pollination scientists in Europe. Here, I review briefly their concerns, findings and recommendations, and implications of these for agri-environmental policies needed to ensure conservation and sustainable use of pollinators for European agriculture.

Population density and agriculture

Population density and agriculture exert major pressures on land use in Europe. The 15 current member states of the European Union (EU) have a population of *ca.* 332 million and a land area of 324 million hectares of which 44% is utilised agricultural area and 33% is woodland; furthermore much of the non-cultivated land is also man-managed. Eastward enlargement of the EU is expected to increase the population by 100 million and expand the agricultural area by 50%. The

agriculture is diverse and intensive, supplying a variety of high quality food and other products for its multicultural population.

Which crops need pollinators?

Crop production in Europe is highly dependent on pollination by insects. At least 264 crop species from 60 plant families are grown in the EU; nothing has been published about the pollination requirements of a third of these species but of the remainder, 84% depend on, or benefit from, insect pollination (Williams 1994).

Which insects pollinate crops?

The botanical diversity of morphology, degree of self-compatibility and sexuality of the flowers of crops grown requires a diversity of insect vectors for efficient pollination (Williams 1994, 1996). The flowers of most outdoor crops are visited by an assemblage of insects, typically including the honey bee, several species of bumble bee, a few species of solitary bee, and on more open flowers species of flies, beetles, butterflies, or thrips. Some beetles pollinate cucurbits and oilseeds, butterflies pollinate blackberry, clovers and tobacco while some flies are used commercially to pollinate protected crops of onion, chive, carrot, strawberry and blackberry. However, on the basis of abundance and foraging behaviour, bees are the most important pollinators.

The native European honey bee (*Apis mellifera*) is undoubtedly the insect species that contributes most to crop pollination (Williams 1994). It is abundant and readily available; in the EU there are estimated to be *ca.*7.5 million colonies managed by *ca.*500,000 beekeepers. It is the only pollinator available for supplementary pollination of field crops. As a generalist feeder, it visits and pollinates most of the crops grown, yet on a single foraging trip is highly constant to species making it a reliable cross-pollinator, although not necessarily the most efficient one for all crops.

Bumble bees are important too (Osborne and Williams 1996). They are efficient pollinators of crops wherever they are sufficiently abundant and particularly important in northern Europe in weather too cool for honey bees. They are generalists with a broad flower choice but species differ in tongue length and hence flower preferences; long-tongued species, such as *Bombus hortorum* and *Bombus pascuorum* are important pollinators of crops with deep corollas such as field bean and red clover. Because of their ability to buzz-pollinate, they are better pollinators than honey bees of solanaceous and ericaceous crops. Since methods for the continuous rearing of bumble bees were developed in the late 1980s, the use of bumble bees (*Bombus terrestris* L.) for the managed pollination of protected fruit crops of aubergine, blueberry, melon, raspberry, red currant, strawberry, sweet pepper and tomato and of protected seed crops of carrot, cauliflower and brussels sprout has grown dramatically and their potential for the pollination of some high value outdoor field crops, such as almond, apple, blueberry, cherry, cranberry, peach, pear and plum is being assessed.

The contribution of the several hundred species of native solitary bees in the pollination of field crops is less well understood (Williams 1996). Solitary bees are rarely as numerous on crops as the honey bee and bumble bees and their abundance is restricted by the proximity of suitable nesting sites. Nevertheless some species of *Andrena, Osmia* and *Anthophora* can make a useful contribution to early flowering fruit when other bees are scarce and species of *Megachile* are important pollinators of legumes. Associated with their short flying season and seasonality is a synchronisation of their foraging activity to a limited number of

plant species that flower at that time and have accessible pollen and nectar. Most have short tongues (*Hylaeus, Colletes, Andrena, Halictus, Sphecodes*) whereas others have tongues longer than that of the honey bee (e.g. *Anthophora).* Solitary bee species can be especially useful pollinators of particular crops; the alfalfa leaf-cutting bee (*Megachile rotundata* Fab.) is used on a small scale for the pollination of lucerne and white clover and management methods are being investigated for a few species of stem-nesting *Osmia* and *Megachile*, for use in the pollination of selected orchard and soft fruits, field legume and seed crops (Williams 1996).

Economics of crop pollination by bees

An economic evaluation of the contribution of bee pollination to the production of 30 insect-pollinated crops was published more than a decade ago (Borneck and Bricout 1989). These authors attributed to each crop a value, 'the coefficient of incidence', based on its dependence on insect pollination and attributed 85% of insect pollination to honey bees. They calculated that the crops had a combined annual market value of 65,000 million ecus, that insect pollination contributed 5000 million ecus and that pollination by honey bees contributed 4250 million ecus (1 ecu = *ca.* 1$). There is a need to update this evaluation and include more than 30 of the 177 crops grown in the EU that benefit from bee pollination. More recently, the value of honey bees and bumble bees as pollinators of major selected UK crops for which market statistics are available, has been estimated to be £172 million for outdoor crops (rape, beans, tree and soft fruit) and £30 million for glasshouse crops (tomatoes and sweet peppers) (Carreck and Williams 1998).

Loss of pollinators and causes for decline

European bee fauna is diminishing (Banaszak 1995). Habitat deterioration and bee disease have been identified as major causes of decline. In response to the concern that changes in land use and beekeeping practice within the Community may result in a shortage of bees for crop and wild flower pollination, the Scientific and Technical Options Assessment (STOA) of the European Parliament commissioned a desk study on `Bees and the pollination of crops and wild flowers: changes in the European Community' (Corbet, Williams and Osborne 1991a). This examined: 1. which crops and wild flowers in the Community depend on bees for their pollination and how the role of bees as pollinators can be assessed (Corbet, Williams and Osborne 1991b), 2. recent changes in habitats and land use and their predicted effects on bee pollination (Osborne, Williams and Corbet 1991), 3. recent changes in the numbers and distribution of honey bees and wild bees and their consequences for crop production and the reproductive success of wild flowers (Williams, Corbet and Osborne 1991).

The STOA report documents serious regional losses of bumble bee species, marked decreases in the numbers of managed honey bees and the listing of numerous species of solitary bee in national Red Data Books. It recognises that: a) the distribution and abundance of bees depends largely on the availability of a seasonal succession of forage flowers and nest sites; b) fragmentation and destruction of semi-natural habitats, particularly open biotypes such as garique, heaths, unimproved grassland and undisturbed areas of farmland, is a cause of the decline of wild bee populations and of reduced food supply for honey bees; c) intensively cultivated arable land is an inhospitable environment for bees.

It warns that the impact of inadequate populations of pollinators will be far reaching. If bee pollinated flowers do not set seed, the integrity of europe's remaining semi-natural vegetation will be destroyed. This in turn will deprive many other herbivorous or seed-eating insects, birds and small mammals of their host plants and/or food, with consequent further loss of species diversity. Crops

dependent on pollination by bees will give decreased yields and may no longer be grown profitably. Their loss will cause further depletion of nectar resources for the remaining bees. This vicious circle, resulting from the mutual interdependence of bee-pollinated plant and pollinator, makes the future survival of both inextricably linked.' it concludes that appropriate agricultural and environmental policies and co-ordinated research and development programmes are needed urgently to ensure adequate pollination of bee-pollinated crops and wild flowers in the European Union.

Further data on recent quantitative and qualitative changes in bee fauna composition as a consequence of changes to ecosystem management and environmental pollution, were presented at an international colloquium convened in Poland to discuss 'Trends of changes in the fauna of wild bees in Europe' (Banaszak 1995). These included data from various countries and habitats of Europe, including many from Central and Eastern Europe.

The *Varroa* mite, which entered Germany in 1977 and had invaded Greece, Italy, France and Holland by 1992, continues to spread and devastate honey bee populations on mainland Europe. In 1992, it was discovered in England and has since spread throughout the UK; beekeepers are increasingly unable to meet the demand from growers for colonies for pollination. In 1998, *Varroa* was reported from Ireland.

Current status and future pollination needs

Following the STOA report, the EU Commission convened a workshop of EU pollination experts in Brussels, to discuss further the current status of bees as pollinators of EU crops and native plants and the future pollination needs of European agriculture (Bruneau 1993). This workshop recommended (Williams 1993) that:

1. **Research** be encouraged to determine which crops and wild flowers are bee pollinated, which bee species pollinate them best and at what densities and the economic benefits of bee pollination per crop and per region.

2. Relevant **research and development and agricultural policies** be adopted to ensure adequate populations of appropriate pollinators for different crops in different regions. Particular attention should be given to develop and improve techniques for the rearing of solitary bees and bumblebees, support bee taxonomic research, promote a thriving beekeeping industry and pollination services and advice to growers, encourage the use of native rather than exotic bees, monitor movement of commercially reared bees and the impact of *Varroa*, and investigate the impact of honey bee introductions on native bee populations.

3. **Land use policies** be promoted to encourage appropriate management of agricultural, forested, semi-natural, conservation and amenity areas to improve habitats for wild and managed bees. Particular attention should be given to conserve and restore natural vegetation, minimise soil surface disturbance which destroys nest sites, promote perennial herbaceous vegetation, bee forage seed mixtures and legumes and develop pesticides safe for bees.

Concern that interspecific competition for food (pollen/nectar/oil) resources between honey bees and other bee species was leading to reduced reproductive success of wild bees and loss of diversity was the subject of a workshop convened in the Netherlands in 1997. The workshop concluded that there was insufficient

published data on competition between honey bees and wild bees in Europe to allow general conclusions to be made on the existence or absence of harmful competition. Most studies were small scale experiments, of short duration and without sufficient replication. It recommended more research on the ecology and taxonomy of bees to include key factors (food and nest site availability, parasites, diseases, predators) affecting the population dynamics of wild bee species and the richness and abundance of bee communities in different habitats. Landscape scale studies on the foraging ranges and behaviour of different species, particularly in relation to the temporal and spatial arrangement of resources, their quantity and quality were also recommended.

Land management for bees

Conservation of bees in agroecosystems depends on habitat management sympathetic to their survival. Available land management options have been explored in at least three recent meetings, all convened in the UK. In 1993, a symposium (Matheson 1994) explored EU and UK Government land use policies, especially as they affect bee forage plants through land use changes, set-aside programmes, management of hedgerows, field margins and woodland and the planting of forage crops specifically for bees. Another symposium in 1995 (Matheson *et al.* 1996), was organised around four themes: a) the effects of habitat degradation on bees and opportunities for improvement of different habitat types, b) the importance of bee diversity to crop, wild plant and rare plant genetic diversity, c) the effects on native bee faunas and floras of introducing honey bees and bumble bees and d) the key role of bee systematics as a vital scientific discipline enabling the monitoring and understanding of bee diversity. In 1998, a workshop examined specific examples of habitat restoration for wildlife and bee diversity improvement (Jones 1998).

EU agri-environmental policies

Agenda 2000 - Agriculture, the policy document of the European Commission, which outlines its Common Agricultural Policy (CAP) into the first decade of the next century acknowledges 'the crucial role that agriculture plays, in producing high quality food, in maintaining a living countryside, in protecting landscapes and preserving cultural values' It recommends increasing budgetary resources and co-financing of 'services which call for an extra effort by farmers, such as organic farming, maintenance of semi-natural habitats, traditional orchards or hedgerows, alpine cattle keeping, upkeep of wetlands, buffer strips along rivers or field margins.' Improved management of such farming systems and habitats could bring benefits for bees.

However, there is no evidence that the EU Commission has taken note of the concerns and recommendations made by its pollination scientists as outlined above. Lobbying by the beekeeping industry has resulted in some increased funding to support beekeeping and, in particular, to fund research into *Varroa*. But there appears to be little recognition of the dependence of EU crop production on a diversity of bees or of the dangers of over-dependence on the services of a single pollinator, the honey bee. Hopefully, by highlighting these issues at International Fora, this Workshop will help focus the attention of the EU Commission on the crucial role of pollinator diversity to the functioning of agricultural production systems and foster its support for research and policy development to conserve and promote the sustainable use of pollinators in Europe.

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