BEE-FRIENDLY PLANT BREEDING

BEE LIFE PROPOSALS TO IMPROVE POLLINATORS ENVIRONMENT IN AGRICULTURAL AREAS AND ENSURE NUTRITIONAL RESOURCES

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Introduction

Pollinators, and bees in particular, are essential constituents of our ecosystem, first of all as bio-indicators of environmental health and second of all as providers of a variety in food production, contributing to well-balanced diets and human health (as many crops, and particularly fruits and vegetables, depend on insect pollination).

It is well evidenced that pollinators are facing many threats worldwide and are in dire need for protection. The latest report of the IPBES on pollination, pollinators and food production has recently echoed this fact[1].

Furthermore, beekeepers across Europe have increasingly reported a decline in bee's attractiveness towards usually melliferous crops or a decrease in honey production from usually highly melliferous crops, such as sunflower for example. As a result, the crops that were an important source of food for pollinators in agricultural areas are losing this potential.

Scientific background

Research studies have described on the one hand, that nectar produced by plants varies, sometimes greatly, depending on the variety [2-5]; and on the other hand that honey bees are more attracted to some varieties than others[6]. Similar observations have been done for wild bees[7].

No specific reason/s has/have been found yet to explain these differences in attractiveness. However, there are a number of traits proposed to be involved in these attractiveness, including pollen and nectar production.

Following beekeepers observations, there are now studies looking into the reasons of this loss of attractiveness or honey production potential, like the project "Répondre aux nombreuses interrogations sur la miellée de tournesol et ses pertes de rendement" steered by F. Allier and Cyril Vidau from ITSAP, the French Technical Institute for beekeeping and pollination services. Unfortunately, no specific reason has been identified for the moment.

However, one plausible explanation could be that by focusing plant breeding primarily on criteria such as yields, productivity, pathogen resistance or stability in production, the resulted varieties might have decreased their melliferous characteristics, nectar production, crop attractiveness or even cross-pollination character[8].

Lately the commercialisation of self-pollination varieties have been proposed to overcome the shortage of pollinators. This loss of dependence to entomophilous pollination can also be a result from breeding (for stability for example). However, no studies linked this characteristic to a loss of attractiveness, despite of the fact that one study performed on sunflower actually shows that self-pollination rate of a plant does not influence its attractiveness to bees[4].

Considering the tendencies in pollinators mainly in agricultural areas and the risk this involves for food security, the active selection of attractive varieties/varieties with high nectar or pollen production could be a way to support the establishment of a food web for pollinators in the agricultural landscape. In doing so, not only crops' pollination and crop yields will be promoted, but honey yields will be[9].

Legal background

In the EU, for a seed to be cultivated and marketed it must be:

- registered in the common catalogue (EU database of registered plant varieties, two of them: vegetable species and agricultural plant species)
- certified by official bodies

To be registered, a plant variety (and so the seed it comes from) must comply with standards based on four criteria:

- Distinctness, i.e. it is clearly distinct from any other variety known in the EU (due to one or several important characteristics).
- Uniformity, i.e. plants of this variety are similar or genetically identical, except for some rare occurrences, in their specific characteristics.
- Stability, i.e. after reproduction and/or multiplication the plant still presents its essential characteristics.
- Value for cultivation and use (for agricultural crops), i.e. if it presents specific characteristics, such as yields, resistance to harmful organisms, quality, response to the environment. These apply only to agricultural crops i.e. varieties of beet, fodder plant, cereal, potato and oil and fibre plant.

The common catalogue for agricultural plant species is regulated by the Directive 2002/53/EC. The definition of value for cultivation can be found in paragraph 4 of article 5:

> "*The value of a variety for cultivation or use shall be regarded as satisfactory if, compared to other varieties accepted in the catalogue of the Member State in question, its qualities, taken as a whole, offer, at least as far as production in any given region is concerned, a clear improvement either for cultivation or as regards the uses which can be made of the crops or the products derived therefrom. Where other, superior characteristics are present, individual inferior characteristics may be disregarded.*"

The certification is an additional guarantee on the seed quality. Certification is based on three aspects:

- varietal quality (varietal identity and purity)
- technical quality (analytical purity, germination)
- health quality (e.g. no harmful organisms)

Twelve Directives regulate the European legislation on the marketing of seeds and plant propagating material, one relates to the Common catalogue and the others relate to the requirements for the marketing of seeds and plant propagation material. These Directives are divided between categories of plant (e.g. Directive on the marketing of beet seed, Directive on the marketing of cereal seed, etc.)

See here for the Commission website:
http://ec.europa.eu/food/plant/plant_propagation_material/legislation/eu_marketing_requirements/index_en.htm

The Commission tried to review the seed regulation in 2013 to simplify the directives and reduce their number
(http://ec.europa.eu/food/plant/plant_propagation_material/legislation/review_eu_rules/index_en.htm) however it stirred up so many different interests and passions that the Commission decided to drop the dossier in 2015.

Options for an improvement of the situation

There are a number of options to improve the situation, all sharing as objective to maintain the melliferous potential of plants. On the one hand, there is the legislative approach, which aims at fixing as criterion for the inclusion in the official catalogue the melliferous potential of melliferous crops. The way forward is explain in the sub-section "Legislative approach". On the other hand, there is the commercial option, which aims at fixing the same criterion which is to be included into quality or certification schemes.

Legislative approach

Contrarily to the current trends in plant breeding, encouraging the selection of varieties with high nectar/pollen production and/or melliferous characteristics would participate in supporting pollinators' populations by providing food for them[3,8,9]. Alternatively, even if high nectar/pollen production are not maximize, future plant varieties should at least not lose their nectar or pollen potential.

Therefore, on the basis of these observations and in order to increase quantity and quality food resources for pollinators in European landscape and to maximise their pollination services, Bee Life proposes to include the article mentioned below in the following Directives:

- Directive 2002/53/EC on the common catalogue of varieties of agricultural plant species, in article 5, after paragraph 4 as paragraph 5.
- Directive 2008/90/EC on the marketing of fruit plant propagating material and fruit plants intended for fruit production, in article 3 as paragraph 2 or in article 7, as part of paragraph 5.

Article:

A variety shall be accepted for certification and marketing only if it has been established by official or officially controlled examinations, particularly growing trials or laboratory tests, that:

- *in the case of plant species depending on entomophilous pollination, of beekeeping interest and of nutritional importance for bees, the variety remains attractive to insect pollinators in terms of quality and quantity of nectar and pollen, as well as in terms of accessibility of flowers to these insects.*

- *in the case of plant species depending on entomophilous pollination, of beekeeping interest and of nutritional importance for bees, the pollen and nectar of the plant variety does not present toxicity to insects.*
- *in the case of plant species of beekeeping interest and of nutritional importance for honey bees, the foraging activity of honeybees on the variety does not imply a loss in value for beehives products.*

Appendix 1 includes a non-comprehensive list of plant species dependent on insect-born pollination, or with interest for honey production or with nutritional interest for bee nutrition in Europe.

Commercial approach

Specific quality or certification schemes linked to or involving plant breeding selection could include criteria related to nectar and pollen productivity. Selection programmes of traditionally melliferous plants would then be complemented with the interest for pollinators and could be one more marketing tool or decision-making criteria. As a result, varieties of melliferous plants included into the catalogue would satisfy the above mention criteria (distinctiveness, uniformity, stability and value for cultivation and use). In parallel, seed certification could include the melliferous capacity together with other criteria like varietal, technical or health quality.

References

[1] Summary for Policy Makers of the Thematic Assessment of Pollininators, Pollination and Food Production, available on the IPBES website : http://www.ipbes.net

[2] Jivan AR. Research on Production Growth, Achieved by Honey Bee Families at Different Autumn Rape Varieties. Scientific Papers Animal Science and Biotechnologies. 2013 May 31;46(1):281-5.

[3]Pierre J, Mesquida J, Marilleau R, Pham‐Delegue MH, Renard M. Nectar secretion in winter oilseed rape, Brassica napus—quantitative and qualitative variability among 71 genotypes. Plant Breeding. 1999 Dec 1;118(6):471-6.

[4] Ion N, Ştefan V, Ion V, Fota V, Coman R. Results concerning the melliferous characteristics of the sunflower hybrids cultivated in Romania. Scientific Papers Animal Science and Biotechnologies. 2007 Oct 31;40(2):80-90.

[5] Gupta SK, editor. Breeding Oilseed Crops for Sustainable Production: Opportunities and Constraints. Academic Press; 2015 Sep 25.

[6] Cerrutti N, Pontet C. . Differential attractiveness of sunflower cultivars to the honeybee Apis mellifera L.. OCL - 2016, 23(2) D204. ; Gupta SK, editor. Breeding Oilseed Crops for Sustainable Production: Opportunities and Constraints. Academic Press; 2015 Sep 25.

[7] Somme, L., Vanderplanck, M., Michez, D., Lombaerde, I., Moerman, R., Wathelet, B., Wattiez, R., Lognay, G., and Jacquemart, A.-L. (2014). Pollen and nectar quality drive the major and minor floral choices of bumble bees. Apidologie *46*, 92–106.

[8] Cerrutti N, Pontet C. . Differential attractiveness of sunflower cultivars to the honeybee Apis mellifera L.. OCL - 2016, 23(2) D204.

[9] Kamler F, Jas S. Nectar production of selected winter rape cultivars. Journal of Apicultural Science. 2003;47(2).

Appendix 1

List of plant species dependent on insect-born pollination

- Category fodder plants:
    - Lucerne (*Medicago sativa* L.; *Medicago varia* Martyn)
    - White clover (*Trifolium repens* L.)
    - Red clover (*Trifolium pratense* L.)
    - Crimson clover (*Trifolium incarnatum* L.)
    - Alsike clover (*Trifolium hybridum* L.)
    - Berseem/Egyptian clover (*Trifolium alexandrinum*)
    - Persian clover (*Trifolium resupinatum*)
    - Sainfoin (*Onobrychis sativa* L.; *Onobrychis viciifolia*)
    - Birdsfoot trefoil (*Lotus corniculatus*)
    - Vetches and beans (*Vicia* sp.: *Vicia faba* L., *Vicia pannonica*, *Vicia sativa* L., *Vicia villosa* Roth)
    - Lupin (*Lupinus albus* L., *Lupinus angustifolius*, *Lupinus luteus* L.)

- Category oil and fibre plants:
    - Swede rape (*Brassica napus* L.)
    - Field mustard *(Brassica rapa* subsp*. campestris)*
    - Fodder kale *(Brassica oleracea)*
    - White mustard (*Brassica alba* or *sinapis alba* L.)
    - Black mustard (*Brassica nigra* (L.))
    - Brown mustard (*Brassica juncea*)
    - Sunflower (*Helianthus annuus* L.)
    - Safflower (*Carthamus tinctorius* L.)
    - Soya bean (*Glycine max* (L.))
    - Flax, linseed (*Linum usitatissimum* L.) highly self-pollinating but bees visit the flowers
    - Poppy (*Papaver somniferum*)
    - Groundnut (peanut) (*Arachis hypogea*) self-pollination and insects
    - Cotton (*Gossypium* spp.)
    - Sesame (*Sesamum indicum* L.)

- Category vegetable plants:
    - Broad bean (*Vicia faba* L.)
    - Chili or pepper (*Capsicum annuum* L.)
    - Aubergine or eggplant (*Solanum melongena* L.)
    - Melon (C*ucumis melo* L.)
    - Cucumber, gherkin (*Cucumis sativus* L.)
    - Gourd (*Cucurbita maxima* Duchesne)
    - Marrow or courgette (*Cucurbita pepo* L.)
    - Tomato (*Lycopersicon lycopersicum*, *Lycopersicon esculentum*, *Solanum lycopersicum*)

- Category fruit plants:

- Actinidia (*Actinidia chinensis* Planch.)
- Almond tree (*Prunus amygdalus* Batsch)
- Apple tree (*Malus x domestica* Mill) almost always self-incompatible
- Apricot tree (*Prunus armeniaca* L.)
- Cherry tree (*Prunus avium* (L.) self-incompatible but breeding towards self-pollinating species; P*runus cerasus* L. self-compatible)
- Citrus (*Citrus* sp. L., *Fortunella* sp. (kumquat), *Poncirus* sp. Raf.)
- Genus of the blueberry plant (*Vaccinium* sp. L.)
- Genus of the gooseberry, currant plant (*Ribes* sp. L.) self-compatible but benefiting from insect pollination
- Genus of the raspberry, blackberry bush (*Rubus* sp. L.)
- Peach tree (*Prunus persica* (L.) Batsch) mainly self-compatible but bees are beneficial
- Pear tree (*Pyrus communis* L.) breeding towards more and more parthenocarpy
- Plum tree (*Prunus domestica* L.) many self-compatible varieties but still benefiting from insect pollination ; Mirabelle plum tree (*Prunus insititia* L.) self-compatible ; Cherry / Myrobalan plum tree (*Prunus cerasifera*) self-compatible ; Japanese plum tree (*Prunus salicina* Lindley) self-compatible but still benefiting from insect pollination
- Quince tree (*Cydonia oblonga* Mill.) self-compatible but bees are beneficial
- Strawberry plant (*Fragaria x ananassa* L.)

- Category cereals:
  - Buckwheat (*Fagopyrum esculentum*)

List of plant species with interest for honey production:

- Lavender (*Lavandula angustifolia* Mill., *L. stoechas*, *L. latifolia*, *L. vera*)
- Buckwheat (*Fagopyrum esculentum*)
- Acacia (*Acacia* sp.)
- Hawthorn (*Crataegus*)
- Heather (*Erica arborea*, *Calluna vulgaris*, among others)
- Cherry tree (*Prunus avium* L., *Prunus cerasus* L.)
- Thistle (plants of the genera of *Asteraceae*, species like *Carduus* sp., *Cirsium* sp., *Onopordum* sp.)
- Sweet chestnut (*Castanea sativa*)
- Orange tree (*Citrus sinensis* L.)
- Rapeseed (*Brassica napus* L.)
- Eucalyptus (*Eucalyptus* sp.)
- Raspberry bush (*Rubus idaeus*)
- Ivy (*Hedera helix*)
- Lucerne (*Medicago sativa* L. + *Medicago varia* Martyn)
- Dandelion (*Taraxacum* sp.)
- Rosemary (*Rosmarinus officinalis*)
- Blackberry bush (*Rubus fruticosus*)
- Sainfoin (*Onobrychis sativa* L.; *Onobrychis viciifolia*)
- Pine tree (*Abies* sp.)
- Thyme (*Thymus vulgaris*)

- Lime tree (*Tilia* sp.)
- Sunflower (*Helianthus annuus* L.)
- Clover (*Trifolium* sp.)

Appendix 2

Summary of some of the relevant scientific studies on the subject

Jivan AR. Research on Production Growth, Achieved by Honey Bee Families at Different Autumn Rape Varieties. Scientific Papers Animal Science and Biotechnologies. 2013 May 31;46(1):281-5.

Study of honey production from three different varieties of oilseed rape: two hybrids and one cultivar (Adriana): honey production was higher for bees that foraged on the cultivar (Adriana). Depending on the variety, bees collect different amounts of pollen and nectar on rape crops. Oilseed rape is a melliferous plant but breeding result in a decrease of nectar quantity produced by flowers in hybrids of new generation.

Cerrutti N, Pontet C. . Differential attractiveness of sunflower cultivars to the honeybee Apis mellifera L. OCL - 2016, 23(2) D204.

Different cultivars of sunflower do not attract bees the same way. This observation raises the question of differences in the melliferous potential of sunflower plants due to their genetics (in quality, quantity and accessibility). Sunflower breeding focusing on yield stability might have led to a decrease of sunflower dependence on entomophilous pollination.
Cultivating melliferous varieties of sunflower would have positive consequences on sustaining pollinators' population, which are in decline today, and on supporting the beekeeping activity.

Ion N, Ştefan V, Ion V, Fota V, Coman R. Results concerning the melliferous characteristics of the sunflower hybrids cultivated in Romania. Scientific Papers Animal Science and Biotechnologies. 2007 Oct 31;40(2):80-90.

The glucidic index (i.e. amount of sugar in nectar per flower) of nectar differs among plant species and plant varieties within species. This paper shows though that the rate of self-pollination in sunflower crops does not affect honey bee production, honey bee production solely depends on the variety, indifferently from the fact that a variety rely much or not on self-pollination. The variety with the highest glucidic index results in the biggest honey production (in general).

Pierre J, Mesquida J, Marilleau R, Pham‐Delegue MH, Renard M. Nectar secretion in winter oilseed rape, Brassica napus—quantitative and qualitative variability among 71 genotypes. Plant Breeding. 1999 Dec 1;118(6):471-6.

There are differences in nectar production between genotypes of oilseed rape (nectar production can vary because of other factors as well). It is possible to select oilseed rape genotypes on the basis of the criterion of nectar production, though not on the basis of sugar concentration (depend a lot on the environment). The objective of the study was to estimate variability in nectar production and sugar composition of different oilseed rape varieties and genotypes.

Gupta SK, editor. Breeding Oilseed Crops for Sustainable Production: Opportunities and Constraints. Academic Press; 2015 Sep 25
Chapter 4 – Sunflower
"Breeding for bee attractiveness in sunflower"

Genetic factors influence bee visit and attractiveness of sunflower ("yellow-colored ray flowers and disk florets, aromatic substances, corolla length longer than 4.2mm, less sticky substances,

and larger nectar amount", stomata number and location). Nectar production in sunflower species is a genetic trait and can be bred for.

Kamler F, Jas S. Nectar production of selected winter rape cultivars. Journal of Apicultural Science. 2003;47(2).

Breeding for higher nectar secretion can increase the attractiveness of varieties for bees and also yields for rapeseed crops. Honey yield as well can be increased by the selection of cultivars producing a lot of nectar. In the cultivars studied, GM cultivars did not produce less nectar than the others.

ITSAP Project – Expérimentation contrôlée sur la miellée de tournesol : relations entre la sécrétion nectarifère de différents cultivars de tournesol et la production de miel par des colonies d'abeilles domestiques – étude dans sa deuxième année

Significant honey yield declines have been observed in the sunflower. Two hypotheses are proposed to explain this phenomenon: the decline in sunflower honey production is (1) the result of a decrease in quantity and quality of pollen and nectar production by flowers; or (2) a problem in honey bee colony population dynamics before and during flowering sunflowers.

So far observations have been done regarding differences of variety attractiveness. However, it is not possible to link these observations to the production of nectar and/or the size of capitula. The study continues.

In the end, all the data will be analysed by modelling with the aim to identify the relationship between honey production and flower visits, accessibility of nectar, nectar volume produced between different varieties.