Phenological evolution of nectar and pollen plants mobilized by the honeybee Apis mellifera l. within agricultural landscape structures in Gers (32, France): the relevant role of the woody component.

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Abstract:

This study was conducted between the 1st of April and the end of September 2011, in 6 areas and on 43 hives, on honeybee species *Apis mellifera L*. It provides information on honeybees and landscapes interactions. We evaluated the woody component production for pollen and nectar for the season, and we focused on food shortage periods (June and August). We studied these interactions using melissopalynological analysis.

The pollen and nectar needs for honeybee colonies vary according to the season and create a 'precarious' relationship with the landscape in an agricultural context. Firstly, the results reveal that the woody component and crops with weeds supply the greatest percentage of melliferous resources for the season. Secondly they reveal that landscape heterogeneity impacts on foraging strategies. The woody component is a strategic resource for brood development at the beginning of the season for all degrees of landscape heterogeneity. During the June shortage or food scarcity period, this component provides a strategic resource in the most heterogeneous areas. Moreover, the perennial nature of the woody component generates high landscape stability and an available food quality throughout the season (bramble, fruit trees). Hence honeybees are less reliant on single-crop farming. The herbaceous stratum associated with the woody component supplies a significant floral diversity throughout the season and a succession of flowering of these different strata.

Foraging strategies vary according to the season and the degree of landscape heterogeneity. Nevertheless the size of melliferous facies and the distance between them and the apiary does not explain the observed difference in terms of foraging strategies. Although the woody component does not provide pollen and nectar resources in sufficient quantities for the whole season, it supplies high quality melliferous resources. It also plays a compensatory role during food shortage periods. Thus, it is important to maintain and develop this component in agricultural landscapes.

1. Introduction

Studies about the interactions between the honeybee and its environment are mainly conducted in ecology, biology, chemistry laboratories and significantly less in geography. However, honeybees and other pollinators evolve in an environmental context with permanent mutations and are highly dependent on the surround landscapes environmental quality. The geographer is a specialist about the landscape and the spatial dynamics. Consequently, he is well positioned to contribute to provide knowledge on the analysis of the landscapes/honeybees interactions. Its position enables to give rise to new questions about the honeybees' relationships to space. That is why we propose in this study to question the spatio-temporal dynamic and the structural landscapes impacts on the honeybee foraging strategies of *Apis mellifera l.*.

Honeybees mobilize primarily nectar resources which supply carbohydrates, vitamins, trace elements and organic acids. They also mobilize pollen resources for proteins, amino-acids, fatty acids, vitamins and trace elements (Haydack 1970; Crailsheim 1990 ; Alaux 2010 ; Guerriat 2000). The low diversity of food resources generates a lack of amino acids. This induces physiological dysfunctions within the colony wich make it more vulnerable to diseases and predators (Haydack 1970; Keller et al. 2005, Brodschneider et al. 2010). The important single-crops farming areas with low crop diversity and short periods of flowering crops (Sunflower, Rapeseed, Corn…) are a constraint to the phenological and physiological colony development (Roman 2004).

On the one hand, the low protein in the pollen grains of Sunflower and Maize have a direct effect on the brood survival during the winter (Somerville 2001). On the other hand a greater source of food in the autumn (in quantity and quality) promotes the quality of oviposition and the brood survival until the spring (Keller et al. 2005). The supply of pollen and nectar to multi-floral origins is the guarantee of a balanced resources, able to promote the healthy honeybees development (Odoux et al. 2012; Alaux et al.2010). However the important transformations for more than 50 years in the agricultural landscape through the simplification of crop rotations, the hedgerows removal, the land consolidation and the use of phytosanitary products generated a strong depletion of the fauna and the flora agrobiodiversity. (Westerkamp et Gottsberger 2000; Tscharntke et al. 2005 ; Burel and al.2009) as well as the spatio-temporal and qualitative melliferous resources depletion (Fried et al 2009 ; Jauzein 2001 ; Kleijn et al 2006). Currently the presence of an important floristic agrobiodiversity, especially apart from the blooming periods of crops, is relegated to perennial semi-natural areas: isolated trees, hedges, woods, groves, forest edges... (Decourtye et a l. 2008 ; Decourtye et al. 2010 ; Hannon L et al. 2009 ; Baudry et al. 2000 ; Boutin et al. 2002). However the contribution of these landscape faciesfor the supply of pollen and nectar for honeybees is poorly known both in terms of spatio-temporal point of view and of floristic diversity.

Using melissopalynological data, this study aims to understand the woody component interest in terms of supply of pollen and nectar resources for the season and specially for the food scarcity periods (June and August). These data are analyzed from a phenological and spatial point of view. .

In agricultural landscape context, the pollen and nectar availability fluctuate a lot for the season. We assume that the woody component supplies regular melliferous resources for honeybee colonies and that it is a strategic landscape element, particularly in times of food scarcity.

2. Methodology

This study was conducted in open fields, on 6 sites (Fig 1.) with a 3 km radius (average foraging distance estimated for the honeybee foragers). These sites are spaced at least 10 km (from the center of the first site to the outer edge of the second closest site) in order to avoid mutual influences. (Steffan-Dewenter et al. 2002; Seeley 1995; Beekman and Ratnieks 2000).

They are located in the southwest of France, from East to West of the Gers Department (32) in a hill agricultural landscape context with the same soil and plant conditions. These sites are characterized by a predominance of agricultural activities with field crops and crop-livestock farming systems. They are divided into 3 types, according to a gradient of landscape heterogeneity: very heterogeneous, heterogeneous or intermediate and homogeneous sites. Landscape heterogeneity correspond to the woody component recovery degree, the landscape elements diversity and the complex relationships between these elements (Burel and Baudry 1999).

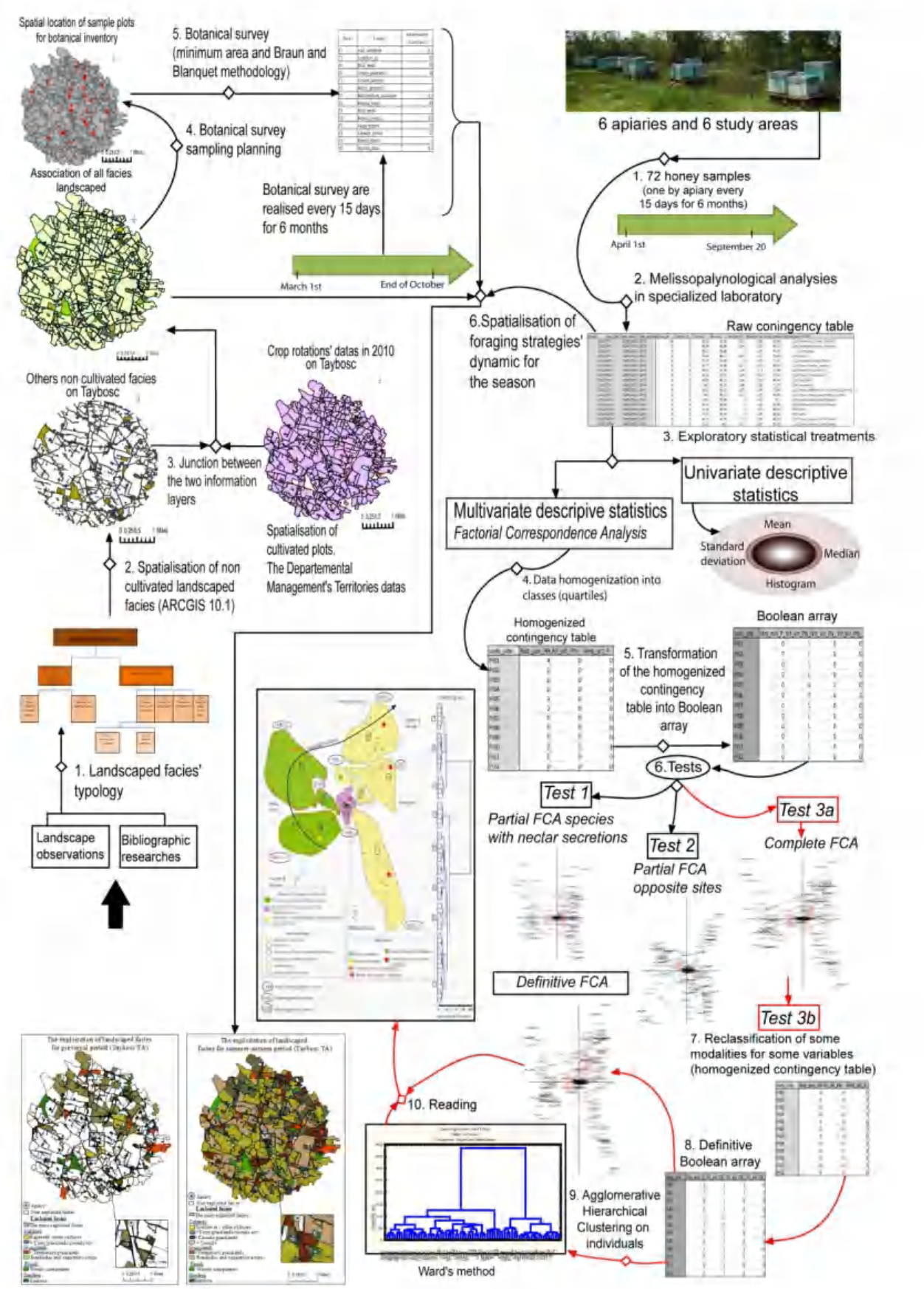

Figure 1 *: Overall methodological approach to the study of the interactions honeybee/landscape through melissopalynologic data analysis*

In order to provide knowledge about honeybees and landscape interactions; an apiary with 7 hives has been positioned in the center of each 6 sites for a total of 42 hives. Various parameters of the evolution of the Life History Traits have been observed between early April and late September 2011: worker broods surfaces, male broods surfaces, the weight of the hives, the weight of the honey harvested in honey super, samples of pollen pellets etc.
Alongside these observations, melissopalynologic analysis have been performed on samples of honey collected from each apiary every 15 days between early April and late September 2011 (Fig.1. point 1 at the top right).
A detailed mapping of the landscaped facies and an important botanical inventory have been made for each of the 6 sites (Fig 1. points 1 to 5 - on the left side). The coupling of the botanical, spatial and melissopalynologic data enable understanding the landscape impact on the spatio-temporal dynamic of foraging strategies. Furthermore it enables to map privileged areas for research of pollen and nectar resources (Fig 1. point 6 – centre of the figure).
In parallel, important exploratory statistical treatments (Factorial Correspondence Analysis Ward method and Agglomerating Hierarchical Clustering) have provided some understanding of honeybees foraging strategies for the season according to the landscape heterogeneity degree. (Fig 1. paragraphs 2 to 10 left).

Results summarized in this article exhibit only one part of a more global research program on honeybees / landscapes interactions. That is why the results from the observation of the honeybee colonies' Life History Traits are not reflected.

3. Results

3.1. The predominant position of the woody component and crops

In the agricultural landscape context of the Gers Department, 78 species and or plant families have been mobilized for the season. Only a few are predominant. The most mobilized are Sunflower to 26%, Rapeseed to 13% and Mercurial .to 11% Willow and blackberry are also significant and equal to 9%. The largest amounts of pollen and nectar stored in the hive depend only on a few dominant floristic species and or families. The 'crops' (i.e. land cover classes) and the 'woody' supra-facies are the most mobilized for the season to 56% and to 31.5% on average (Fig 2.). 'Grasslands' and 'gardens' occupy a significantly lower place averaging of 9.5% and 3%. (Fig 2).

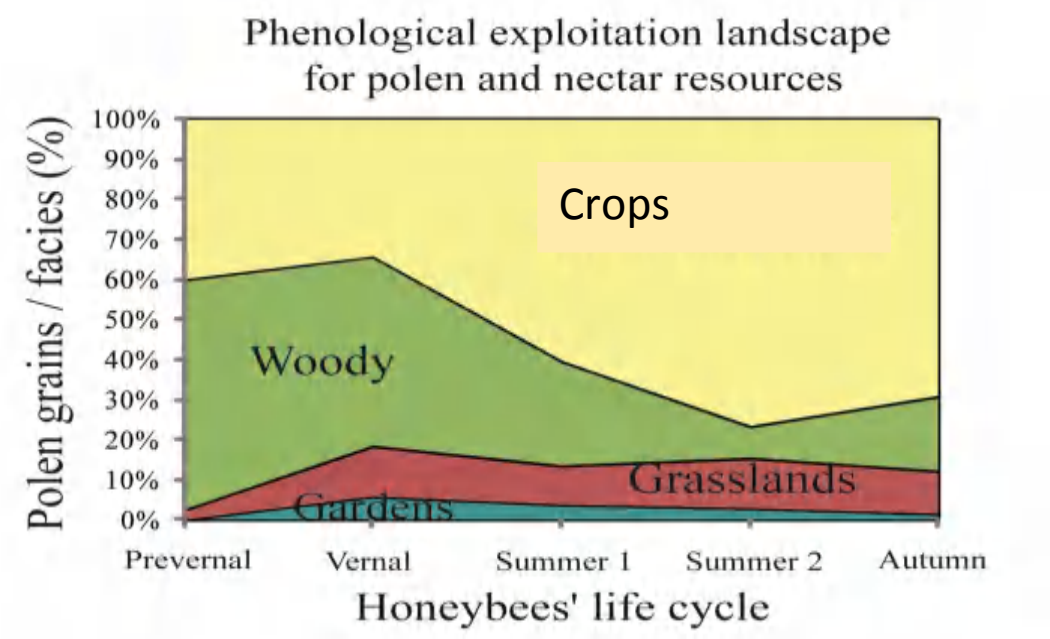

***Figure 2** : Phenological contribution of the main landscaped supra-facies, for the 'active' honeybee season (P: Prevernal, February / March;) V: Vernal, April / June; S1: Summer, early July; S2: Summer 2, mid July / mid-August; A: Autumn, mid / end of October).*

The honeybee colonies interest to the different supra-facies landscaped is not linear during the season (Fig 2.). The woody component plays a strategic role in the spring, during the first scarcity period in June (prevernal and vernal periods) and at the end of the season (estivo-autumnal period). During the summer its low contribution is explained by the late bloom of many plant resources and the strong attractiveness of the Sunflower and the Mercurial. The large presence of bramble in the hedges, the forests edges, the groves and the wastelands is the main woody resource with a significant presence during the same period. The herbaceous strata associated with the woody component take mainly part from the end of the spring period. It supplies a diverse floristic resource, especially at the end of the blossoming tree and tree strata (trefoil, clover, St John's wort etc.).

Crops and weeds prevail for the summer and estivo-autumnal periods while initiating a phase of regression. From mid-September it is the end of key crops blooming except for Maize. This enables a renewed interest for the woody component through the Ivy and the bramble. Grasslands and gardens are secondary but compensate the blooming deficiency of the woody component during the summer and the beginning of the estivo-autumnal periods, notably through the White clover, the Birdsfoot trefoil, the Lucerne, the Thistle and the Knapweed.

Adapting foraging strategies in the landscape context

A more precise spatial approach across the 6 study sites enables to identify different foraging strategies according to the landscape heterogeneity degree. In the spring, species mobilized are very similar between these sites: fruit trees, Willow, and Rapeseed. However the percentage of pollen grains varies for the different taxas. Despite the spatial prevalence of Rapeseed on sites, fruit trees and Willows predominate within heterogeneous and highly

heterogeneous landscape structures. The honey type produced during this period is mainly a flower honey. On homogeneous sites, there is mainly a rapeseed. honey type. The woody component predominance on very heterogeneous and heterogeneous sites facilitates the brood start with a supply of protein-rich pollen and an early blooming.

Differences in terms of foraging strategies are significantly more pronounced during the first scarcity period in June. During this period, honeybees have mainly mobilized BlackBerry and Clover or woody component and pastures on very heterogeneous sites, and have produced a flower honey.. On heterogeneous sites they have mainly mobilized the Chestnut and the Sunflower for the honeydew production. The same phenomenon is observed on the homogeneous sites but only the Sunflower is strongly mobilized. During scarcity periods, the woody component supplies diversity and most interesting melliferous resources from a qualitative point of view than those located on crops areas.

Finally during the summer and estivo-autumnal periods, the blooming Sunflower has impacted all sites, as well as some weeds such as the Mercurial or Lamb's quarters. Crops are the most mobilized landscaped facies. However, the woody component plays a complementary role through the bramble. It is foraged until the end of the beekeeping season on heterogeneous sites even if the proportion of pollen grains is decreasing over time. On heterogeneous sites the woody component knows a renewed interest for estivo-autumnal period.

From the summer period the role of crops and weeds is predominant. However the woody component keeps a significant attractiveness. This phenomenon makes honeybess less dependent on non-perennial landscaped facies on heterogeneous and very heterogeneous sites. Although grassland play a secondary role, is complementary and is a strategic facies. Indeed it supplies and maintains an important floristic diversity through the Alfalfa, the Clover, the Trefoil etc.

3.2.Landscape dynamics impacts on foraging strategies

This study demonstrates that the variability of land cover classes and the land use, influence the floristic resources diversity and quantity for honeybees between very heterogeneous and homogeneous landscape structures.

From the beginning (prevernal) to the end of the season (estivo-autumnal), the surface of landscaped facies with melliferous interest is most important and perennial in a very heterogeneous landscape context. It is the same for the diversity of melliferous facies. This landscape stability is due to the strong presence of pastures and the woody component. It supplies a more regular intake of pollen and nectar resources within the colony throughout the season. The risk of scarcity is less important. Conversely, the strong presence of crops areas in homogeneous landscape context generates instability and a restricted spatiotemporal availability of food resources. This “landscaped imbalance” creates more important and recurrent risks of stress within the colony.

According to the statistical non-parametric tests (Spearman R), average distance and the melliferous landscaped facies areas don't seem to explain the proportion in which these facies are mobilized all along the season. Finally we observed that the average distance between facies resources and the apiary does not vary significantly between homogeneous and heterogeneous landscape structure whatever was the periods of the season.

4. Conclusion

The woody component and crops, supplemented by the role of weeds, are the most mobilized landscaped "supra-facies" or land cover classes. On the very heterogeneous sites, the woody component appears as a strategic resource for the brood start at the beginning of the season like for scarcity periods. It supplies the provision of rich melliferous resources from a qualitative point of view (fruit-trees, brambles). Moreover its perennial character generates a landscape stability and continuity. By consequence, honeybees are less dependent on the single crops farming rhythm of blooming and areas. The complementary of the herbaceous strata with the woody component maintains a diversity of plant species throughout the season. It also enables an alternating of blooming according to the vegetation strata.

Foraging strategies vary according to the season and depend on the landscape heterogeneity degree. However neither "melliferous facies"areas nor their distance from the apiary, seem to explain differences in terms of honeybees landscape exploitation.

Although the woody component is not sufficient to supply nectar and pollen resources throughout the season, it is a strategic landscape element. Indeed, its contribution due to its qualitative resources as well as its compensatory effect for scarcity periods makes the woody component development necessary within agricultural landscapes.

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