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Practices, knowledge and expectations of beekeepers and beehive suppliers regarding the wood material used for building beehives in the South of France

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1. Introduction

Humans first began to build hives in the shape of what seems to imitate the “ideal nest” found by wild honeybees in nature, cavities, including hollow trees and adopted the appropriate techniques to hollow tree trunks in order to raise their bee colonies (Crane, 2004; Marchenay, 1979; Fig.1a). Historical and ethnological studies have documented the worldwide diversity of beehive materials and shapes used over times (Marchenay, 1979; Crane, 1999; Tournernet and de Saint Pierre, 2015). But this diversity is gradually reduced during XIXth century and more especially after the Second World War leading to the actual period marked by the homogenization of beekeeping practices (Lehébel-Péron et al., 2016b; Schatz and Dounias, 2016). The invention of Father Langstroth movable frames in 1885 became rapidly the most frequently beehive model used world widely these days because this key element allowed beekeepers to breed, control and deeply boost the yield of their livestock production at least to tenfold. As an example, in the same apiary, the annual yield per sedentary Dadant hive averages 15 kg while that in hollow trunk hive is 2 kg (Figs.1b and 1c). From then on, the beehive must be rectangular-shaped with standard dimensions. All types of building materials are nowadays used to easily meet the first two requirements: wood remains the main building material (as when man sought to imitate nature), but its use is now threatened and it is gradually being replaced by plastic, polystyrene, although not renewable.



Fig.1. (a) Imitating nature by rearing colonies in hollowed tree trunks and (b) Apiary in Lozère (South of France) where man-made hollowed chestnut trunk hives dating from XIXth century stand alongside (c) Dadant standardised beehives (10 to 50 years old) made of spruce (source 1a.:

Encyclopedia Universalis)

But beekeeping is world widely facing nowadays mass extinction of honeybees (Oldroyd, 2007). In recent decades, annual global losses in Europe have been above the 10-15% previously considered as normal (IPBES, 2016) and are around 30% in the two survey regions of Southern France (Vallon 2015). The main causes are largely documented: the combined effects of pesticides, scarcity of natural resources, parasites and predators (*Varroa destructor* mite, Asian hornet *Vespa velutina*), pathogens (viruses, bacteria, fungi), genetic impoverishment of *Apis mellifera*, climate change (IPBES, 2016). Another cause, less known in the media, is the actual loss of beekeeping traditional practices and knowledge which is concerning because better resilience of technical production systems facing changes and successful ecosystem managements often depend on local and traditional knowledge systems (Berkes et al., 2000; Bérard et al., 2005; Gómez-Baggethun et al., 2013; Roué et al., 2015). In such an alarming context, all ways to enhance the bee health is relevant.

We address here the assumption that the evolution of modern beehives has been devoted to beekeeping practices focused only on the beekeepers' production needs. The accelerating current worldwide standardisation of beekeeping practices and the beehives models fail to take into account beekeepers' traditional knowledge and their current expectations around the nature of the beehive building material which could yet influence the living conditions of bees and help their resilience to the actual changes.

Some recent disciplinary studies have explored the beehive from the point of view of the physical influence of the building material on the in-hive hygrothermal climate (Abou-Shaara 2013; Lorenzon 2004; Dupleix et al., 2019b). For wood sciences, the number of cubic meters mobilised by beekeeping is certainly too low to attract the attention of researchers. In the field of social sciences, some ethnographic studies have locally described the relationship between humans and their beehives (Crane, 1999; Tourneret and de Saint-Pierre, 2016; in Cévennes: Lehébel-Péron 2014; Lehébel-Péron et al. 2015, 2016b; in Pyrénées: Bertrand, 2015; in Corse: Castelli, pers. com.). The approaches and hypotheses of our work have been inspired by one of those demonstrating the recurrence of a

statement made independently by various beekeepers in the South of France Cévennes region (Lehébel-Péron, 2014) that hollow chestnut trunk beehive improves the health status of bee colonies.

Our main objective is to analyse a variety of information on the knowledge and judgements from "*beehive users*" about beehive building material and in particular when it comes to wood material in order to: (1) determine from the point of view of beekeepers, holders of traditional knowledge, whether they perceive a real advantage for bees to live in a wooden habitat and how they describe this influence. (2) compare their traditional knowledge against the criteria of wood properties established by the scientific community and (3) compare the offer of sellers (beehive suppliers) with buyers' expectation (beekeepers), which involves understanding whether beekeepers are able to mobilize their knowledge when choosing their beehive supply or whether other factors guide them.

In this exploratory anthropological study, two kinds of "*beehive users*" have been interviewed: "*beehive suppliers*" who trade the beehive and "*beekeepers*" rearing colonies in the beehive to make a living from their production. Studying the beehive with the perspective cited above is only possible by conveying several disciplines in a multidisciplinary approach (Vinck, 2000): beekeeping training, wood sciences and social sciences. This approach is demanding, time-consuming and therefore still rare, which might also explain why beehives remained so far unexplored by scientists (Jullien et al., 2019). These difficulties also explain why this work is a first step that provides significant but not exhaustive results that will be completed during an extensive research process.

We will first specify the methodology, main stages and variables of our survey. Then, we describe the actual beehive market and the "*beehive users*" purchasing strategies function of their degree of dependence to the beehive supply. We will then detail the knowledge of wood specie and their properties considered as important by the stakeholders interviewed. These results finally lead us to identify possible collaborations between beekeeping and research actors in order to highlight the importance for bees and beekeepers of wood as beehive building material and raise the awareness on improving the practices around the beehive.

2. Material and methods

2.1. Acquisition of information

This exploratory anthropological survey has been introduced to the interviewees by saying that the topic was to “*explore the practices of beehive suppliers and beekeepers around the beehive building material*”. It has been conducted in two stages. The first survey of 11 beehive suppliers located all over the France has been conducted by the biannual National Union of French Beekeepers (UNAF, Union Nationale des Apiculteurs Français) Trade Show in Clermont-Ferrand on 27-30th October 2016. Such an event gathers stakeholders at national level; the suppliers surveyed there have been chosen because they are working in the region of the beekeepers interviewed during the second stage. In this strategic place, it has been possible to interview all the national market leaders (Fig.2b) as well as less powerful companies on the market. This panel of 11 beehive suppliers is therefore representative of the diversity of beehive suppliers in France. A questionnaire created *de facto* was completed by the researcher himself during the face-to-face interviews lasting a maximum of half an hour in the late afternoon when the beehive suppliers are available after the exhibition day. The second survey has been launched in July-August 2017 with face to face interviews of 23 beekeepers located in neighbouring departments (French administrative units smaller than regions) in the South of France: Hérault, Gard, Ardèche, Lozère, Aude and Drôme (Fig.2a). The departments have been chosen for their high beekeeping activity and for the local use of different kinds of wood. These departments are located in the two regions of southern France (Occitanie and Provence-Alpes-Côte-d’Azur), which represent nearly half of beekeepers and are the two largest regions in terms of volumes of honey produced (34% between them) (FranceAgrimer, 2018). These 23 individuals represent the different types of beekeepers according to the standard typology used by the researchers and only available at the beginning of the survey (Fig.3a). The semi-structured interviews were mainly conducted during farmers markets and sometimes directly at the farm. They were deliberately short (around 45 min) in order to fit the beekeepers tight schedule at this time of the year. All interviews have been transcribed:

text in italics and quotation marks are real expressions used during the interviews. In the rest of the article, *n* is the sample size.

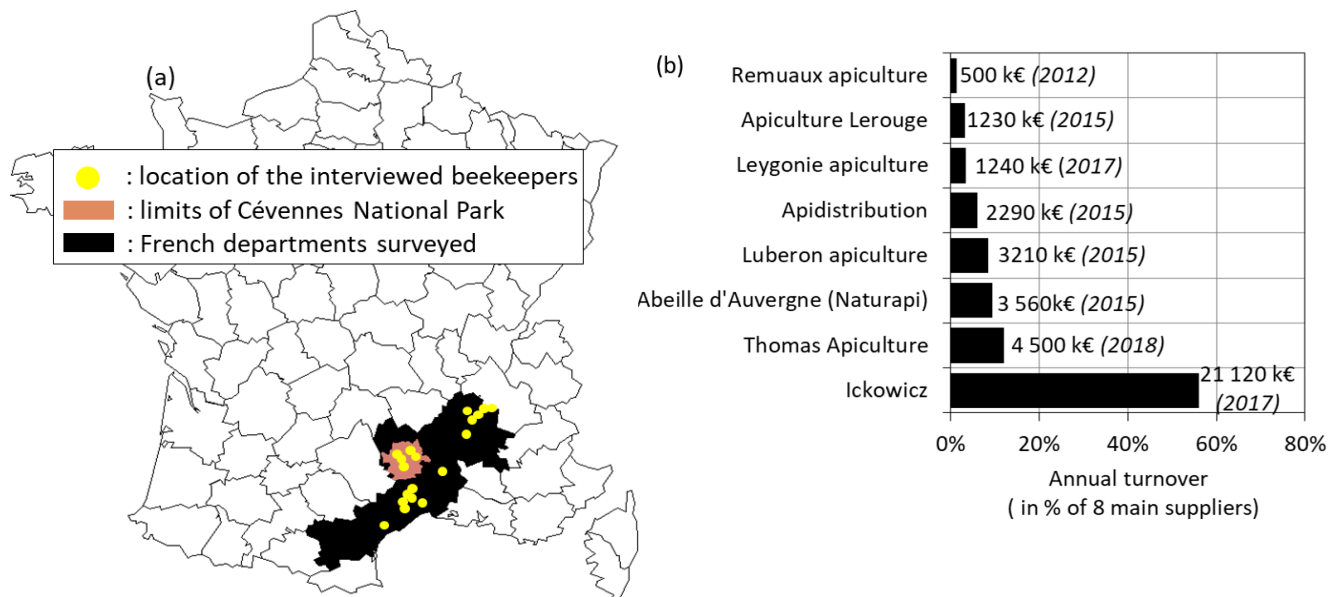


Fig.2. (a) Location of the interviewed beekeepers in the South of France; (b) Annual turnover of the French 8 major beehive suppliers with a market leader dominating the market (years are given;

source: societe.com)

2.2. Limitations of the survey

The interviewees' knowledge is often disclosed in statements and expressions which refer usually to lived knowledge acquired thanks to proper experiments (« *des savoirs vécus ou savoirs d'expériences* », Vermersch, 2016) but are also mixed with opinions or beliefs, which is hard to distinguish. Interviewees were also often hesitating when answering: they felt unsure admitting being "*worried about being wrong*", needing to think and requiring time to find the right words to describe a rather unformulated knowledge. The issues raised turned out to be in fact surprising because they were dealing with an unusual topic– the beehive building material and the practices concerning it – that no one ever mentioned anymore in today's beekeeping debate. The vocabulary used in the questionnaire revealed that beekeepers knowledge on the beehive is not declarative. As an example, the term « *interaction* » used in a closed-ended question such as « *do you think that there is interaction between wood (as beehive building material) and bees?* » did not bring anything to mind to 71% of the interviewed

beekeepers who answered negatively. And yet, their consecutive speeches report spontaneously the positive role of the “*smell of wood*” on bees’ health. This observation has clearly motivated to shift from the questionnaire first chosen to semi-structured interviews used in the second survey.

2.3. Data analysis

The information collected during the surveys has been submitted to a speech analysis¹, identifying the forms of judgments, qualifiers, terms and metaphors preferred by the actors to express their knowledge on wood properties and perception of wood material as a habitat for bees. All this information made it possible to build a typology of actors according to their degree of dependence to the beehive supply.

3. Results

3.1. Limits of standard typologies

In France, the activity level of the beekeeping sector is known thanks to statistics from the Ministry of Agriculture based mostly on figures from the powerful unions and the compulsory annual beehive declaration. These figures are nevertheless to be taken approximatively as the sector characterised by significant variability due to the nature of the activity and a few beekeepers preferring to remain conveniently vague about the production (Fert, 2015; Saddier, 2008). For the European Commission, a beekeeper who owns over 150 beehives is a “*professional*”; below 50 beehives he is a “*family beekeeper*” and in-between he is a “*multi-active beekeeper*”. Using the number of hives as the only criteria to define a beekeeper is also claimed by some beekeeping unions whose interest is to recognize that “*a beekeeper is someone who owns one hive*”. But it seems however insufficient when it comes to deepen the analysis and the recognition of beekeeper identities (Adam et al., 2017; Rondreux, 2016). In particular, it is hard to describe the “*plurality*” characterising French beekeeping and the “*several families of beekeepers*” featuring “*heteroclite*” practices in the words of one report from the

¹ This speech analysis does not involve any software

Ministry (Gerster, 2012). To provide a more comprehensive overview of the French beekeeping diversity, researchers suggest an enriched combined typology in which the quantitative amount of hives is tempered by the production economic purpose in order to describe 4 types of beekeepers: “professionals”, “big amateurs”, “small amateurs” and “family beekeepers” (Fig.3a, Milliet-Tréboux, 2017). The level of 10 beehives is usually used as the maximal limit under which the honey produced is considered for a family consumption. The level of 70 beehives is considered as a minimal limit to benefit from EU and French administrative unit (department or region) grants for this agriculture activity.

On the contrary, beehive retailing is an activity relatively unknown. There is no typology as for beekeepers nor historical study on the identity of beehive suppliers, despite figures publicly available from internet websites on annual turnovers showing the large predominance of one market leader over the others (Fig.2b). Through our investigations, we note that there is no specific training for becoming beehive supplier despite the highly specific nature of the equipment provided and most suppliers are former (or still active) beekeepers themselves. Their customers are “amateurs” beekeepers in majority, buying individually lower amounts of equipment than “professionals” but featuring higher purchase power and so tending to exceed professional customer sales turnovers - at least it is the case for the market leader.

3.2. Emergence of a new typology based on the degree of dependence to the beehive supply

The first information collected during the survey at UNAF Trade Show revealed among the “beehive suppliers” different degrees of dependence in their supply so that we could distinguish between three types: (1) the least autonomous “beehive suppliers” are “sellers” (either “representatives” of beekeeping market leaders brand or “cooperatives”²) who have no link with the manufacturers: they

² “Cooperatives” can sell multiple brands and differ from “representatives” who are committed to sell only one brand. The market leader has a large number of representatives for example.

just buy the hives they simply re-sell to others; (2) an intermediate type is the *"industrials"* who make beehives built by other industrial or semi-industrial beehive manufacturing factories being however linked to them by a certain degree of influence on the production and (3) the more autonomous are the *"manufacturers"* themselves: they have a low amount of production and feature low-automated production line but rather human-made operations (Fig.3c).

Similar features were revealed during beekeepers' interviews: some of them buy while others build their hives. It was then possible to use the same typology than for *"beehive suppliers"* based on the degree of dependence to the beehive supply and we could distinguish two types of *"beekeepers"*: the least autonomous being the *"buyers"* who buy the hives they use and the most autonomous being the *"handymen"* who build themselves the hives they use (Figs. 3c, 3d). Having a common typology based on the degrees of autonomy over beehive supply is helpful to compare the actual practices, knowledge and expectations around the beehive building material among the *"beehive suppliers"* and *"beekeepers"*. In our sample of 11 interviewed *"beehive suppliers"*, eight are simple *"sellers"* (72%), two are *"industrials"* (18%) and one is a *"manufacturer"* (10%) (Fig.3c). In our sample of 23 interviewed beekeepers, eight are *"handymen"* and 15 are *"buyers"* (Fig.3d). Although the distribution is not uniform and the sample is small, it is representative of each of the types of actors in the field (Fig.3).

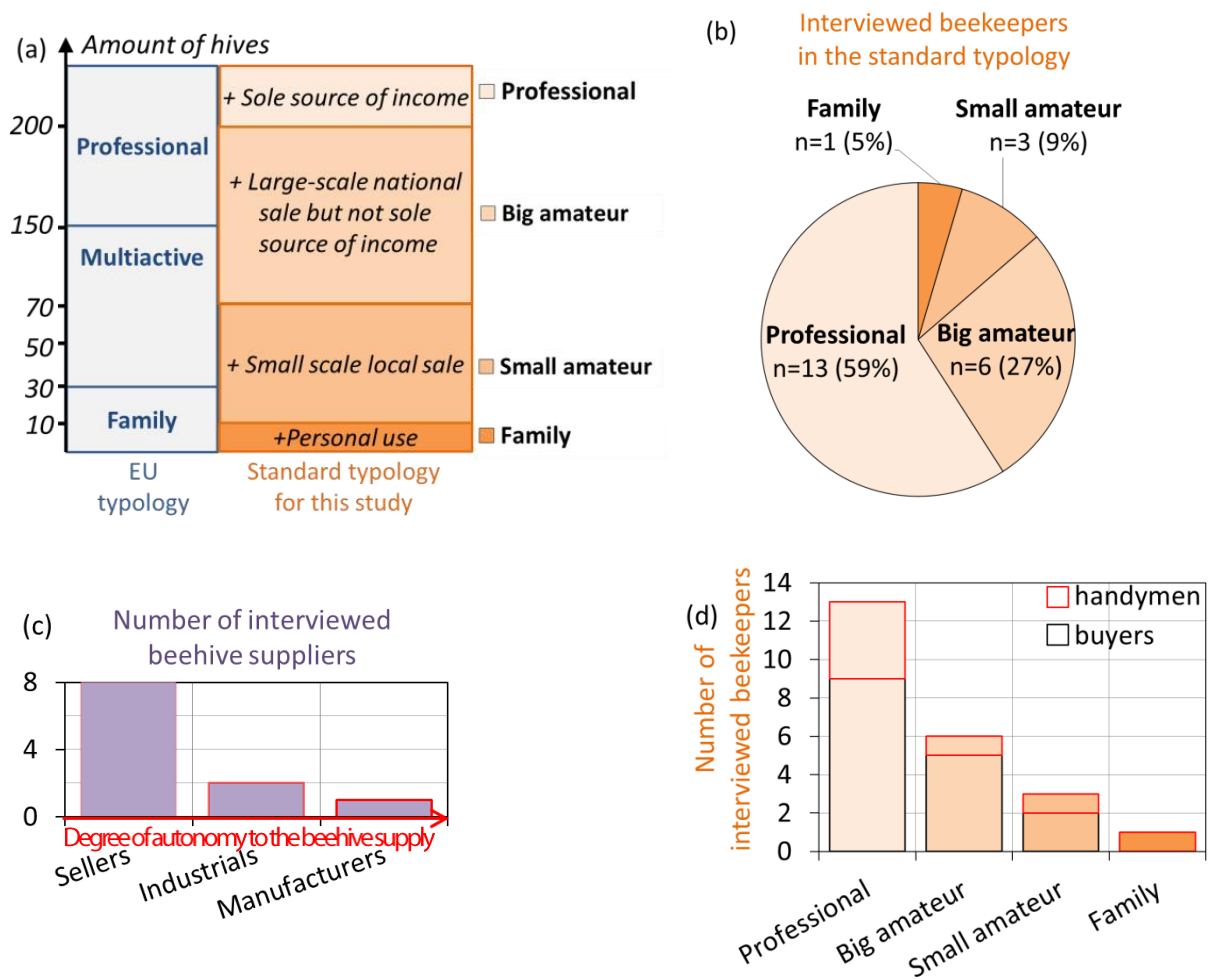


Fig.3. (a) Comparison of typologies used by EU (3 types of beekeepers based only on one criteria: the amount of hives) and researchers (4 types of beekeepers based on two criteria: the amount of hives and the economic purpose). The typologies are in bold colours and the criteria in italic black. (b) Repartition of the interviewed beekeepers in the standard typology. (c) Repartition of the interviewed beehive suppliers and (d) beekeepers in the new typology based on the degree of dependence to the beehive supply. The red arrow indicates the increasing degree of autonomy over beehive supply.

3.3. Motivations for building hives

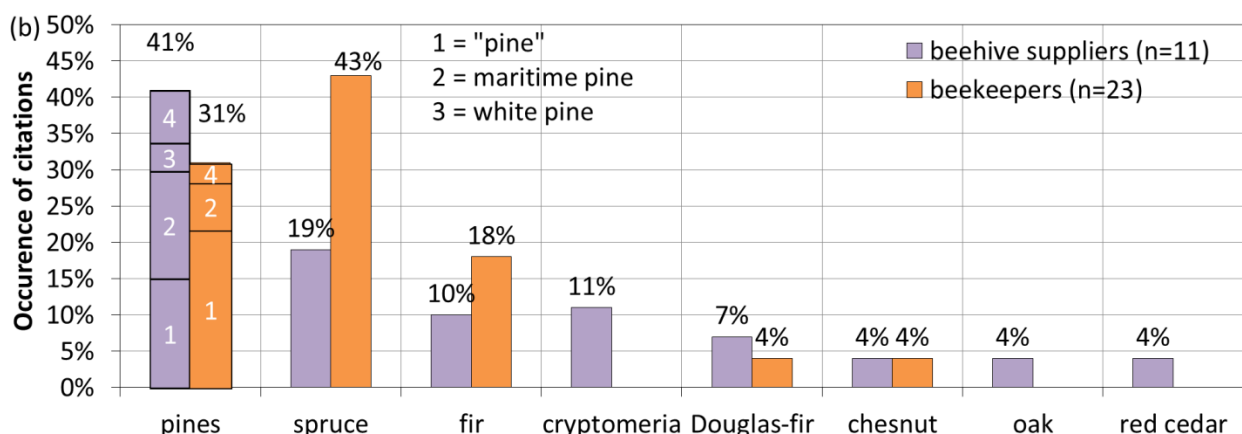
Looking at the repartition of beekeepers in the typology based on the degree of dependence to the beehive supply (Fig.3d), the sample size for *"family"* and *"amateurs"* is too small to confirm the representativeness of results that would seem to indicate that they buy or build without clear distinction. *"Professionals"* and *"big amateurs"* tend to buy their hives (resp. n = 9 out of 13: 69% and n = 5 out of 6: 83%) given their high number of hives and the economic objectives for *"professionals"* which result in a lack of *"time, investment, place and know-how"*. But still some of them are *"handymen"* showing that beehive building can be economical in certain professional contexts when the technical needs are particular, such as the production of royal jelly which requires larger hives, or when the treatment methods are specific (use of *"anti-Varroa chestnut flying board"*). The sources of motivation among the professionals are often also more personal and the interviews have revealed their wide diversity: 1) habit of manufacturing prior to becoming *"professional"*, 2) personal attraction for handy work: *"I always enjoyed handwork [...] winter time is less busy, time permits"*, 3) mistrust and demands regarding the quality and lifetime of the beehives sold in the market, raised for example when *"look[ing at the state] of the flying board"*, combined to the wish of local timber, 4) search for wood specie *"adapted"* to outdoor uses in order to avoid wood chemical treatments, harmful to bees, 5) proximity of *"a carpenter friend"*. However, it is remarkable that the quality or choice of wood specie is already emerging among these sources of motivation.

3.4. Choosing the wood specie

All the beehive suppliers and beekeepers interviewed were able to name the wood specie used for their hives. They mention mainly softwood specie: pine and spruce in majority, but also two hardwoods: oak and chestnut, although in minority. The way they designate wood is particularly uneven: a whole genus is sometimes mentioned (*"pine"*, *"spruce"*, *"fir"*, *"chestnut"* or *"oak"*) while other times the specie names are specified (such as Scots pine, maritime pine, etc., Tab.4a). Some of

them easily mix up hardwoods with softwoods (one “buyer” states “not to use softwoods” and then says that his hives are made of spruce) and specie (another one tells us he uses “pine...well, fir” as if these two genera are the same). From a taxonomic point of view, the *Pinus* genus is composed in France of 110 pine specie (Gernandt et al., 2005) while *Pinus* and *Abies* are two distinct genera from the *Pinaceae* family. The interviewees are certainly not aware of such botanical differences among woods; the variation in results among beekeepers and beehive suppliers confirms the lack of knowledge precision (Fig.4b). Asking beekeepers and beehive suppliers to name the wood specie they use may not accurately represent the reality of the market but gives its general trend.

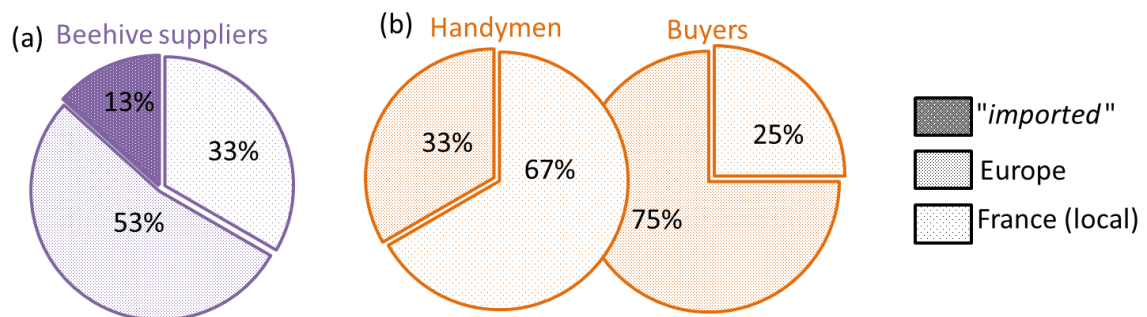
Wood specie cited by beehive users		Corresponding taxonomic names		
In French (cited)	English translation	Family	Genus	Specie
Softwoods				
« pin »	pine	<i>Pinaceae</i>	<i>Pinus</i>	N/A
« pin sylvestre »	Scot pine	<i>Pinaceae</i>	<i>Pinus</i>	<i>sylvestris</i>
« pin maritime », « pin des Landes »	maritime pine	<i>Pinaceae</i>	<i>Pinus</i>	<i>pinaster</i>
« pin Weymouth »	white pine	<i>Pinaceae</i>	<i>Pinus</i>	<i>strobus</i>
« épicéa »	spruce	<i>Pinaceae</i>	<i>Picea</i>	<i>abies</i>
« sapin blanc »	fir	<i>Pinaceae</i>	<i>Abies</i>	<i>alba</i>
« douglas »	Douglas-fir	<i>Pinaceae</i>	<i>Pseudotsuga</i>	<i>menziesii</i>
« red cedar »	red cedar	<i>Cupressaceae</i>	<i>Thuja</i>	<i>plicata</i>
« cryptomeria »	cryptomeria	<i>Taxodiaceae</i>	<i>Cryptomeria</i>	<i>japonica</i>
Hardwoods				
« châtaignier »	chestnut	<i>Fagaceae</i>	<i>Castanea</i>	<i>sativa*</i>
« chêne »	oak	<i>Fagaceae</i>	<i>Quercus</i>	<i>robur*</i>



Tab.4. (a) Name of the specie as used by beehive suppliers and beekeepers and corresponding scientific names of specie genus or names (* indicated cases when this term is assumed); Fig.4. (b) Occurrence of citations for the cited specie found in beehive suppliers and beekeepers' speeches.

3.5. Wood supply

One third of the beehives sold by suppliers are said to be made in France and more than a half to come from other European countries, especially eastern ones (Romania, Serbia, Bulgaria) and Portugal. Two species are "imported" (13%): cryptomeria originated from Japan and now imported from Azores, and red cedar from Northern America (Fig.5a). Only the interviewed "manufacturer" can be precise about the wood resource he is working with: he buys standing trees directly in the surrounding forests during ONF sales (French National Forest Organisation) because he is aware of the importance of choosing trees for the quality of his wood. He is the only one to say using "local" wood. Among the two types of beekeepers distinguished, there are strong differences in the wood supply origin: "handymen" declared that they are using mostly wood coming from France (67%) and 75% of "buyers" that their hives come from Europe (Fig.5b). It should be noted that none of this information on the geography of the wood can be confirmed because it is mainly lost in the sales process. There is practically no mention of the building material, the wood species itself or his origin in the "seller" catalogues. Hive models are often identified according to their size (number of frames) and geometry (Dadant, Langstroth, Warré): example, "10 Dadant frames" or their type of joint: "tenon" or "half-lap joint". Only "plastic hives" are referred to by their construction material.



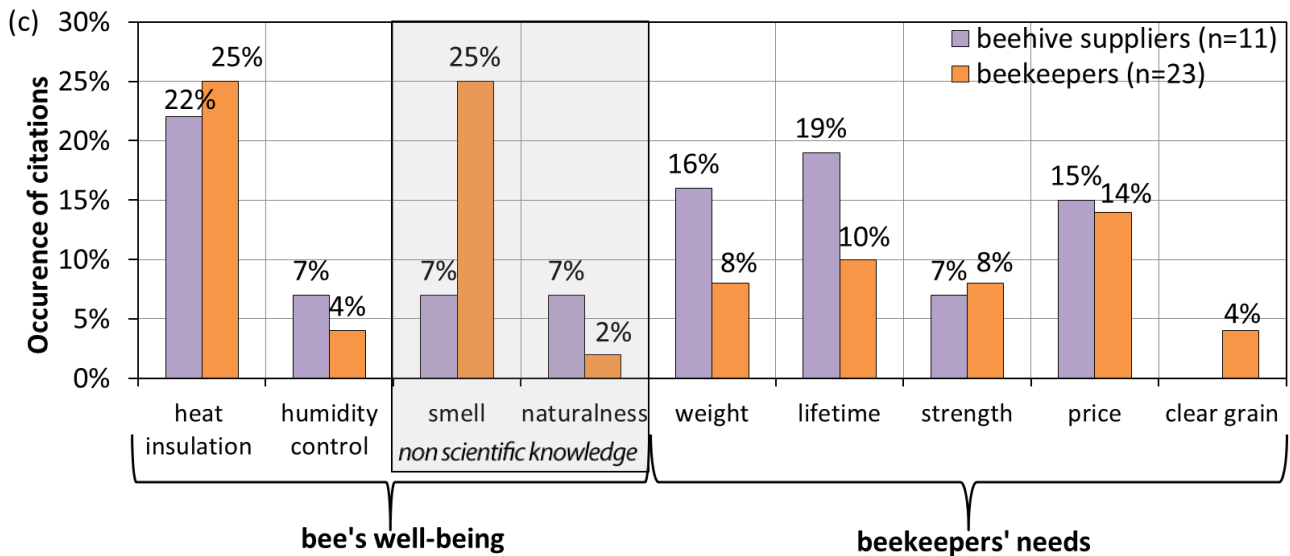


Fig.5. Geographical origin of the wood specie used for their hives according to (a) beehive suppliers and (b) beekeepers; (c) Occurrence citations of the choice factors for using wood material for their hives among beehive suppliers and beekeepers classified according to scientific and non-scientific knowledge and their target: bee's well-being or beekeepers' needs.

However, when asked, nearly 50% of our sample of beehive suppliers and beekeepers are aware of the fact that the wood specie are chosen by the manufacturing factories because of their proximity to manufacturing sites and not for any other reason related to the intrinsic quality of wood. Only the market leader assumes the relocation of manufacturing abroad to reduce costs, he says. It even makes it an opportunity to convey a positive social image of the company acting as a "lord" over manufacturing factories abroad: he says to "visit the factories[it owns in part] regularly", "take care of wages" and even allow better working conditions in the face of the local economic situation.

3.6. Non-scientific knowledge

Clearly, interviewees expressed a common preference for using wood material for their beehives. Only one "buyer" among the 23 interviewed beekeepers and one "industrial", the Nicotplast supplier³ prefers plastic to wood for the following reasons they mention: lighter and cheaper considering the

³ Nicotplast is a famous French brand located in Jura selling plastic beehives the founder of which, M. Nicot, has given his name to the Nicot plastic hive: <http://www.nicotplast.fr>

time saved because plastic is “not moving”, “not aging”, “easier to clean and disinfect with water, bleach or high-pressure hose” and requires “no [protective] treatment”.

There are several reasons performed by suppliers and by beekeepers for choosing wood for the hives “beyond the[ir] [expressed] pleasure to work with wood”. Heat insulation, price and strength are used with the same importance by suppliers and beekeepers (Fig.5b). However, suppliers’ sales arguments for wood differ at some points from the beekeepers’ views. The highest differences concern the “smell” of wood mentioned as an important factor by 25% of beekeepers and 7% of beehive suppliers and wood “naturalness” to be more important in the suppliers’ views (7%) than for beekeepers (2%). Both are non-scientific knowledge, compared to other wood properties that are quantitatively measurable physically or chemically (weight, lifetime, etc.), and these differences are not surprising since non-scientific knowledge relies on proper experiments (“savoirs d’expériences”, Vermersch, 2016). In their speeches, beehive suppliers make refer to wood as the only material to “deliver a natural function”, creating “a natural environment” and “promoting a natural symbiotic relationship” with the bees. Beekeepers also mentioned some wood specie for their ability to release a “smell” able to influence bees’ behaviours; one of them even stating that “whatever wood is used as long as it smells good”. Beekeepers cite fir (*Abies*) and basswood (*Tilia*) as good examples of wood attractiveness to bees: “fir smells good” and basswood is used to catch wild swarms (in Iran, Javaremi A., and in center regions of France (Creuse), Thévenin T., pers. com) while cryptomeria would threaten bees to fly out because “*Cryptomeria [which] smells bad*”. Truly, bees are known to be driven by their olfactory sense with no evidence of any limitation to a single chemical cue (Dillier 2006) and wood natural chemicals release volatile organic compounds (VOCs) giving the material its smell (Venet and Keller, 1986). Literature mentions for example VOCs’ antifungal and antibacterial effects of Scots pine and spruce (Rautio et al., 2007), VOCs’ physiological relaxation for humans of sugi (Japanese name for *Cryptomeria*) (Matsubara and Kawai, 2014) and VOC’s *Cyressus* and *Eucalyptus* against insect pests of stored food grains or flies (Bett et al., 2016; Lee et al., 2015). But as for the red cedar and “*cyress*” cited to “control the population of wax moth” and chestnut to control the population of *Varroa*, there

is still no demonstrated scientific study proving any effects of hive wood smell on bees nor on its parasites. Apart from a previous ethnological study reporting the repellent effect of chestnut on *Varroa* among local traditional beekeeper practices in Cévennes (South of France) (Lehébel-Péron et al., 2015, 2016b), scientific studies are hitherto lacking. But driven by promising therapeutic effects in apitherapy, the complex smell combination creating the “*smell of the hive*” is coming to the interest of bee ecology scientists to understand its variability, sources and roles. For sure, the “*smell of the hive*” is due to wood’s contribution but not only and beekeepers are aware of it, one of them saying that “*old hives are attractive to bees because of their smell of propolis and wax*”.

3.7. Scientific knowledge

3.7.1. Wood for bees’ well-being

However, there are scientific arguments as to why beekeepers prefer wood that can be classified into two categories: some wood properties play a role in the well-being of bees and others meet the needs of beekeepers (Fig.5c). First and foremost, wood is interesting for its thermal insulating properties, which are moreover equivocally mentioned, by 22% of beehive suppliers and 25% of beekeepers, because it can help bees “*to improve the hive heating management*”. Two beekeepers are even able to link wood anatomy outright as an empirical “*rule of thumb*” that wood with “*lower density leads to a better insulation*”. For them, spruce which is less dense can better insulate than pine specie or Douglas-fir. Wood anatomical cross-sections show a porous structure with ligno-cellulosic material located in the cell wall forming a tube while inside cells are hollowed (Fig.6a). The less dense the wood, the more cells can be filled with a mix of air and water (depending of the degree of saturation of the cell wall material) which, being locked (not circulating), creates a thermal barrier like in double-glazing: therefore, the more porous, the more resistant to heat in steady state (Kollmann et al., 1968; Duplex et al., 2014). Another choice factor for wood is humidity control but to a lesser extent. Wood is mentioned by 7% of suppliers and 4% of beekeepers for “*helping hive breathing*” which is important as humidity is known to be regulated and crucial for bees (Decourtye et al., 2018). Wood is used “*at*

least, for the bottom of the hive” because: *“fir, being soft, restores better humidity to the hive”*. Behind the word *“restore”* lies the wood ability to absorb and give water back which can be measured in terms of *“impregnability”*. Scientific knowledge has linked wood softness and impregnability with density (or porosity). Softer wood specie (*i.e.* in wood sciences, less resistant to localised indentation known as *“Monnin hardness”*) have more porous structures (with a lower amount of cell wall material) which are more likely to collapse against mechanical shocks (and some marks would be left) and are more accessible to hydroxyl (-OH°) sites responsible for H-bonds between cell wall cellulose and water (H₂O) molecules (Figs. 6a and 6b). Another supplier has reached by observation the same conclusions: lighter wood means also softer. That is why he sells light specie (such as cryptomeria and red cedar) for *“amateur”* or *“family”* uses rather than to *“professionals”* who are more worried about its weakness when knocked. The interviewees certainly lack the underlying scientific background to explain their *“savoirs d’expériences”* built on observations which are however obviously quite appropriate (even if *silver fir* is not a typical soft specie: Monnin hardness = 2.5, Fig.6b)

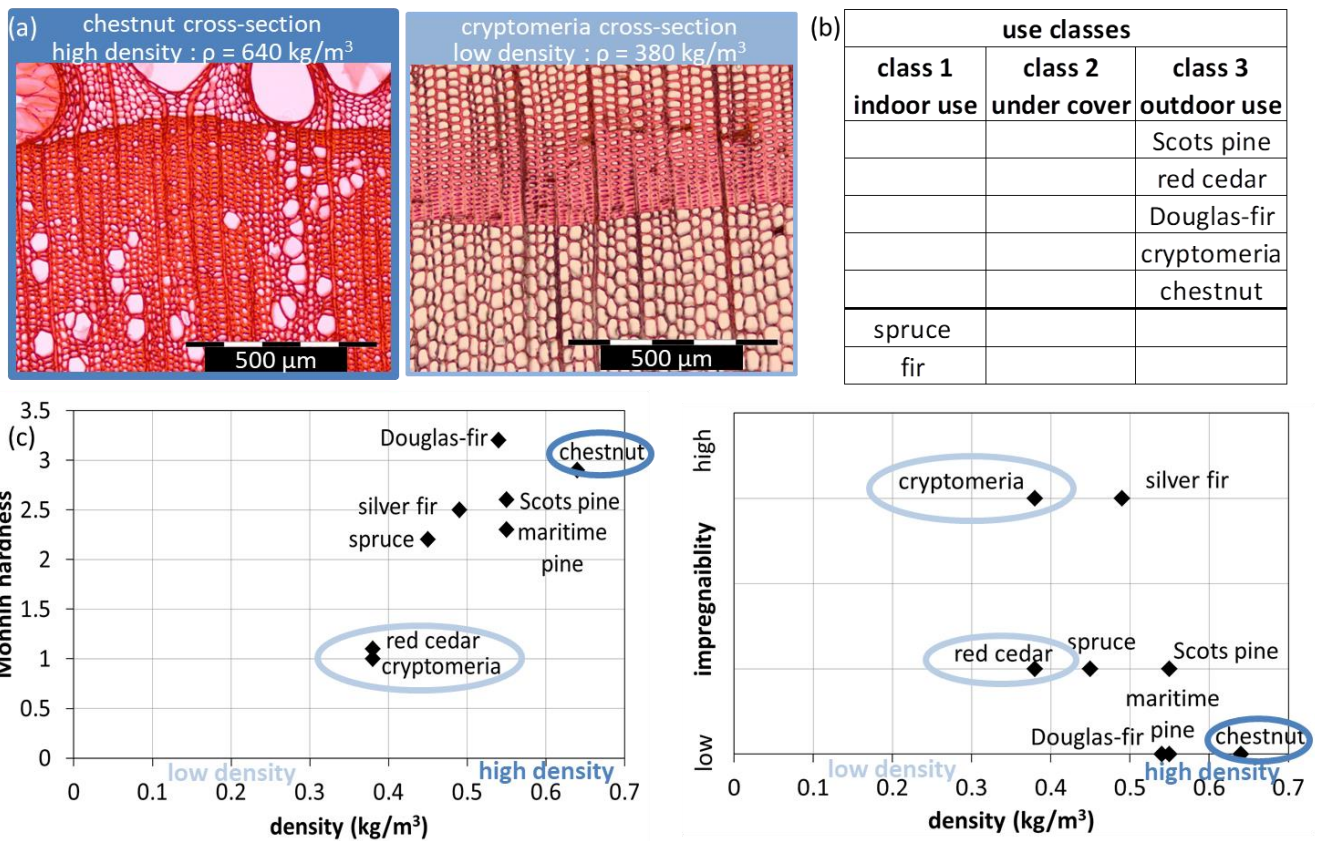


Fig.6. (a) Anatomical cross-sections of chestnut and cryptomeria showing the differences of density which influence; (b) Wood use allocation as specified in European standard EN 460 according to their natural durability (EN 350) and the use class in which they are in service (EN 335); (c) Wood specie hardness and impregnability (Paradis et al. 2015, credits: M.C. Trouy)

3.7.2. Wood for beekeepers' needs

Other choice factors are mentioned to fulfill the beekeepers' needs for their hives: beehive "weight" and "lifetime" are mostly cited and beehive "strength" to a less extent. These three factors have an economic background of justification. Beehive weight is essential since the practice of "transhumance" (transporting hives to follow blossoms) has become extremely common to increase productivity but it impacts on operating costs since it increases truck fuel consumption. Beehive lifetime and strength influence the renewal term of hives which plays also on investments such as the beehive "price" discussed in the last section. When talking about beehive "weight", "lifetime" and "strength", beehive users refer in fact to wood properties, from which they result, and which are subject of scientific

knowledge formalized by wood sciences. Beehive *“weight”* results from wood density (in kg/m³). Beehive *“lifetime”* from the inclusive notion of wood *“durability”* which in wood sciences combines biological durability (to insects, fungi, etc.), physico-chemical resistance of wood to abiotic factors (UV, temperature and humidity variations) and wood mechanical resistance. Beehive *“strength”* results from wood mechanical resistance (including hardness mentioned earlier but also rupture strength, etc.) and mechanical strength of joint due to the joint type itself. *“Weight”* and *“lifetime”* are choice factors mentioned about twice as much by beehive suppliers as by beekeepers (16% vs 8% and 19% vs 10%, respectively). Beehive suppliers are slightly more specific when talking about wood density and biological durability than beekeepers who have basic enough knowledge but quite broad without hardly any range of distinction: specie are either *“light”* or *“heavy”*, *“rot-proof”* or not. Despite the wide variability of density within one single tree (due to the different kinds of wood present such as earlywood, latewood, etc.) and from one specie to another, scientific databases give mean density values for each specie which confirm that chestnut (640 kg/m³) and pine (550 kg/m³) are *“heavy”* - chestnut being even the heaviest wood specie to build hives - while cryptomeria, red cedar (less cited certainly because it is a niche market) and spruce are light and *“easy to handle”* (resp. 380 kg/m³, 380 kg/m³ and 450 kg/m³, Fig.7a). Fir and Douglas-fir are more confusing, they are cited to be either *“heavy”* or *“light”* ; they feature indeed average density values (Douglas-fir: 540 kg/m³ ; fir: 490 kg/m³) such as spruce (450 kg/m³), though. As a consequence, a beehive can weight from 4.8 kg to 8.1 kg for a common 22 mm thickness when it is built out of cryptomeria or chestnut. Of course, weight will increase far much in case of chestnut when increasing the thickness of the hive than in the case of cryptomeria (Fig.7b). In the same way, one beehive user says that pine is *“able to last”*, another one that cryptomeria is *“imperishable”* and also that red cedar *“prone to resist decay”*. This information lack the precision which is yet publicly available in European standards: Fig. 6b details the 5 different *“use classes”* (EN 335) used to qualify each wood specie *“durability”* function of the service situations to which wood can be exposed to how long wood will last in service in order to find "the right wood for the right place". Use class 1 is for indoor use (wood is not exposed to the weather of wetting), use

class 2 for outdoor use under cover (wood is not exposed to the weather - particularly rain - but where occasional wetting can occur), use class 3 for outdoor use (wood is exposed to the weather, particularly rain and two sub-classes define whether or not wetting is maintained), use class 4 for direct contact with ground and fresh water, use class 5 for permanently or regularly submerged in salt water. Surprisingly, spruce and fir, yet cited to be “not durable” by beekeepers, are still sold in the market while they should be avoided to build hives because they are not able to resist outdoor uses (use class 1, Fig. 6b). For beehive use, instead choose a specie classified in use class 3 (pine, red cedar, cryptomeria, Douglas-fir, chestnut).

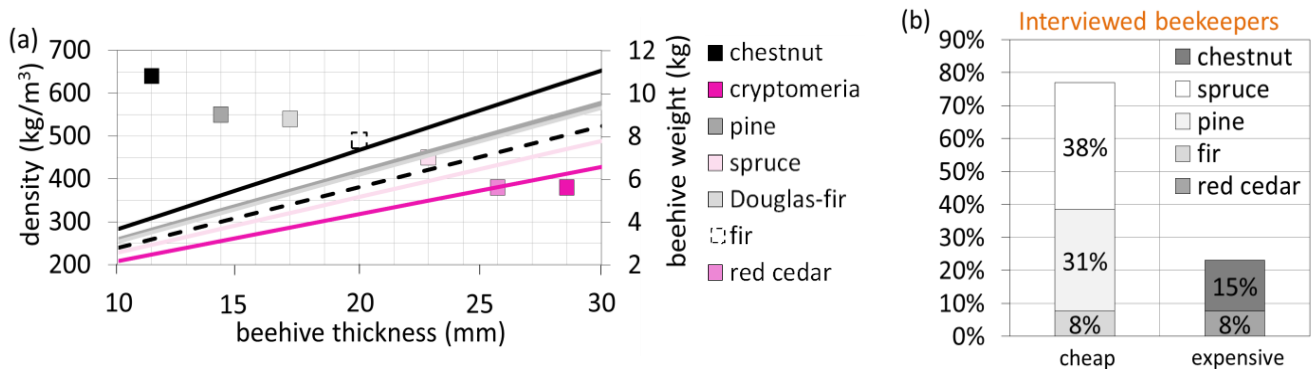


Fig.7. (a) Mean densities of wood specie in standard conditions (65% of Relative Humidity, 20°C) (squares) and variation of beehive weight according to beehive thickness (lines); (b) Grading of cheap versus expensive beehives according to beekeepers.

When describing the beehive “strength”, suppliers argue only on the joint type: the two joints used to build hives are either “tenons” or “half lap joint”, which can then be tightened with glue, nails or screws. “Tenons” form the end of a board to fit into a square hole cut into the other corresponding board (Fig.8A). “Half lap joint” refers to joints with uprights and struts cut in deeply so as to put them above each other on the same level (Fig.8B). The screwed “tenon” joint is always mentioned as the most solid one. But apart from the “manufacturer” who reveals a specific know-how, there is hardly no mention of other factors yet known in wood sciences and woodworking to influence hive strength such as: wood specie mechanical strength, wood shrinkage behaviour, presence of knots (beyond aesthetic objectives of having wood “clear grain” claimed by 4% of beekeepers). The “manufacturer”

chooses carefully the orientation grain of the piece of wood used in order to build a “robust and durable” beehive: he draws sketches to explain that “the pith [the center of the tree] should be oriented outwards” (Figs.8a and 8b). But all beehives are not built this way and it is common to find in the market beehives built with no consideration of wood shrinkage behaviour which is affected by annual growth rings (Fig.8c). Wood is indeed an anisotropic and hygroscopic material which shrinks (and swells) about twice as much in the direction tangential to the annual growth rings (tangentially) as across the rings (radially). The combined effects of shrinkage behaviour, annual growth rings orientation, moisture variation and mechanical fastening (which is the case when building hives) can distort the shape of wood pieces leading to openings in beehive structure such as in (Fig.8d).

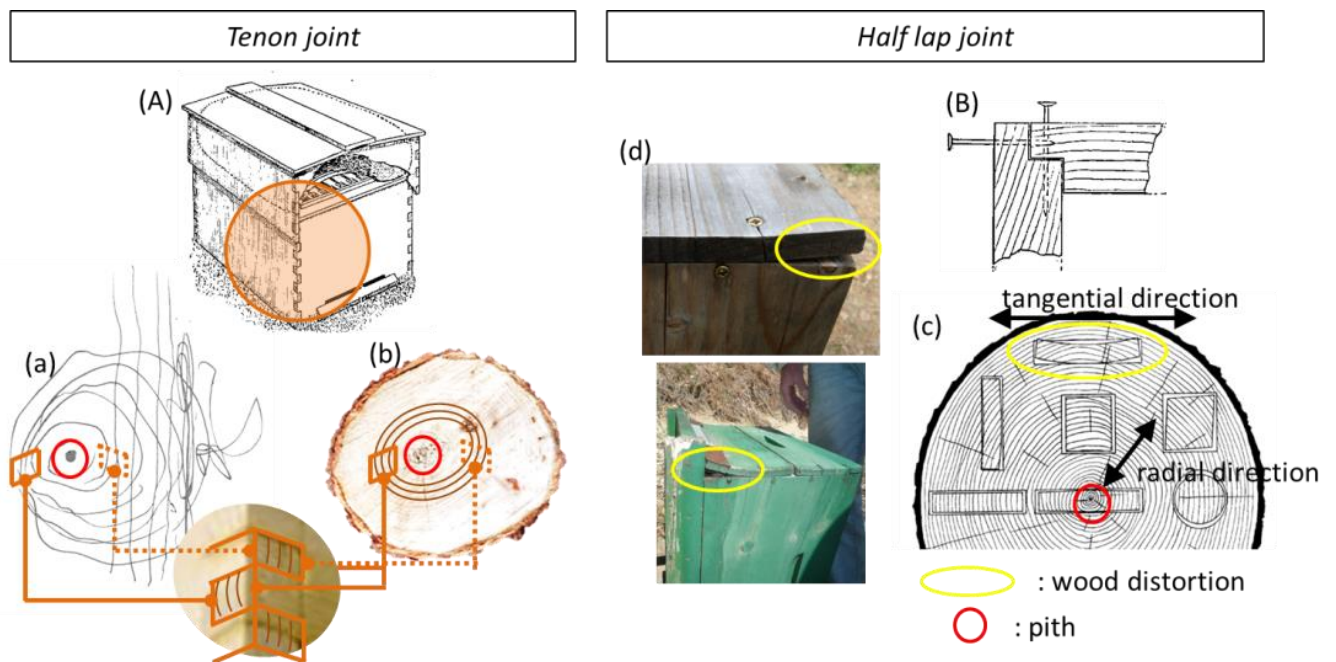


Fig.8. (A) tenon joint; (B) half-lap joint; (a) Sketch drawn by the manufacturer during the interview showing a cross-section of wood with a decentered pith; (b) Corresponding picture of wood cross-section. The location of the “tenon” joint represented in the cross section is built in the respect to the orientation of the wood annual rings looking outwards, the pith being outside the joint; (c) shrinkage and distortion of wood pieces are affected by direction of growth rings and (d) consequences on beehive openings (sources: (a) Boissellerie Petite, (d) Duplex A., (c) Glass and Zelinka, 2010)

Beehives are sold and bought without any kind of technical datasheet on the hive characteristics (weight, lifetime, wood strength, wood hardness) while we have seen that these factors are important to beekeepers and beehive suppliers. We may assume that, as confirmed also by the production sites location, factories do not care on building quality beehives which would require to invest on improving knowledge on wood properties, but are rather driven by the only price factor.

3.8. Market identity

Despite an attachment to wood material, purchasing, selling and production strategies are nowadays guided by economic interests leading to a beehive market dominated by low-cost wood specie: spruce, pine and fir, chosen for building hives at the cheapest price, whatever the wood quality is. Asked to cite declaratively the cheapest versus the most expensive specie (Fig.7b), beekeepers declared that pine and spruce are cheaper (for respectively 38% and 31% of interviewed beekeepers) and chestnut or red cedar (at 15% and 8%) more expensive. In the podium of beehive suppliers catalogue (in terms of turnover), pine (undetailed specie) and spruce beehives are indeed sold around 30€ (on average for only the hive body) but red cedar and chestnut 4 to 5 times more (120€ / 150€). Spruce, pine (undetailed specie) and fir beehives largely dominate the market for their low price despite the poor durability of spruce and fir which makes these beehives unable to fit the usual beehive working conditions such as outdoor uses. Still, a niche market identified for chestnut and red cedar has managed to emerge (both adapted to use class 3 for outdoor uses; chestnut being heavier but harder and red cedar lighter but softer) but only limited to “*amateur*” beekeepers because of unaffordable prices for “*professionals*”. This niche market might explain why red cedar and chestnut are less mentioned in the price investigation.

Some critics are raised about the recent beehive quality and lifetime drop: *“before, a beehive would last for life”* – so at least 40 years, a professional exercise term – but *“now, its use is limited to 5 to 10 years at best”*. The fact that beehive quality may be different according to the production location is shared among 33% of suppliers and 21% of beekeepers. Some beekeepers blame suppliers for their carelessness to relocate production in low-labour cost countries where no consideration is given to valuable practices for them such as: 1) all year round timber cutting while ancient skills, considered as better, would cut trees in winter time devoid of sap, 2) selection of trees and wood specie for their price, 3) fast kiln-drying and manufacturing methods leading to *“badly dried wood improper after 3 years”*, *“insufficient glued joint”* prone to handling damage as regards the preferred *“tenons”*. In response, one *“industrial”* supplier tries to promote the *“beehive product”* arguing, as already described above, that he can control beehive quality in the relocalised factories he owns. But truly, the relatively partial knowledge about wood properties among *“industrials”* and *“sellers”* is not convincing. They seem to be rather oriented by the maximum gain, being aware that their customers have no choice but to buy what they offer: beehive is at present a market where offer controls demand. One *“industrial”* supplier for example has optimised his business model by offering only two types of beehives: cryptomeria for *“amateur”* users (low weight but soft) and maritime pine for *“professionals”* (heavier but more robust and able to regular handling).

A general feeling from the interviews is that the beehive has lost its original key status of *“combining bees and hive ecology, environmental conditions for breeding, and beekeepers’ know-how with economic and historical backgrounds”* (Lehébel-Peron et al., 2016b). The beehive has become nowadays, together with bees, a means of production (*“a consumable goods”* in the word of one *“seller”*) in a production-driven system controlled by humans to produce quantitatively more (honey, queens, pollens, propolis, etc.) with less working time. Under the current economic pressure, beekeepers and suppliers’ knowledge about the advantages to use specific wood specie for their valuable properties turns into a minor key at the time of choosing while wood sciences demonstrate that each wood specie have a right use which fits it. To sidestep market rules, a possible solution is to

become “*handymen*” for beekeepers. But rare are those who can change habits because manufacturing beehives oneself is dually seen both an investment and a risk (as seen, technical knowledge and required skills are crucial for the beehive durability and mechanical strength). Only one interviewed beekeeper has chosen to start manufacturing himself again while others prefer to “*deal with the market offer*” to save time and money.

4. Conclusion

This first exploratory anthropological survey conducted on a few beehive users (beekeepers and beehive suppliers) in the South of France has revealed that beehive supply is a discriminatory factor among the actors. A new typology based on the fact that some buy or build the hives they use or sell has emerged to reflect these different degrees of autonomy related to the beehive supply. Looking at the objectives of the study, we are now able to state that: All actors choose their hives primarily on the basis of factors that meet the needs of beekeepers (“*weight*”, “*strength*” and “*lifetime*”) even if nowadays the market offer does not meet all their needs (particularly in terms of the lifetime of the beehives). A few of beekeeping stakeholders perceive a benefit of wooden habitat on the bees’ well-being for the following reasons that they can analyse: heat insulation, humidity control, “*naturalness*” and smell, the two first being founded on scientific arguments. In any case, the overall actors’ knowledge on wood properties is mostly relative, qualitative, based on “*savoirs d’expériences*” but lack of scientific background – even if some trends (on weight and durability for example) are scientifically correct. So, the knowledge of the material does not yet guide the supply or choice of beehives. Only a minority of the market is indeed composed of man-made beehives built by “*manufacturers*” or “*handymen*” beekeepers to fulfill their specific needs. The beehive market shows nowadays a loss of traditional knowledge in front of the domination of low quality industrial hives mostly made of softwood specie chosen for economic reasons but not for wood quality or specific desired properties dominated. More in-depth knowledge would promote demand that can influence the market and reverse the current trend in which supply controls demand. In particular, amateur beekeepers mostly

buy professional equipment which is not adapted to their less productive practices. However, a niche market has emerged for some specie chosen for their beneficial properties on bees' health (repulsive to bees' parasite such as *Varroa* or wax moth) although no scientific studies have confirmed yet those statements based on observations.

These results lead to work towards improving the technical information provided to beehive users and the education on wood properties in order to enable users to make an informed choice (choosing to foster one hive property or another thanks to specific wood specie that they find valuable or significant for their practices). Scientific researches are necessary to look at the beehive as the indispensable third party in the human-bees relationship, which can act, beyond its protective role, as a "*habitat*" (Dupleix et al., 2019a) with building material properties creating a physical and chemical environment enhancing the colonies living conditions and contributing to their health, comfort (Matsubara and Kawai, 2014) and thus production. We also encourage the scientific study of the survey findings to identify potential sources of innovation for the survival of bees while promoting the local market for wood and certain specie. It is with this in mind that we are investigating in particular the relationships between the smell emitted by the different woods used to build the hive and the behaviour of bees and their pathogens (Jullien et al., 2019).

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