Effect of coatings radiative properties on the temperature of a Dadant hive

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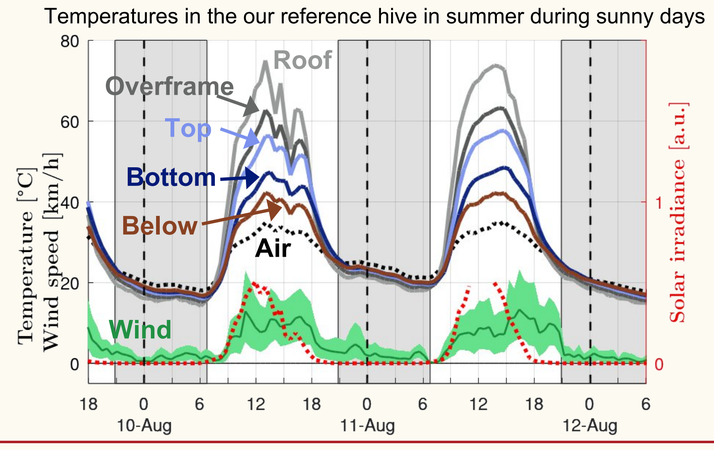
CONTEXT

Due to extreme temperature events, beekeepers have experienced wax frames collapsing in their hives. Indeed, pure bee wax melts around 65°C while in the south of France, the hive roof temperature can reach 70°C to 80°C. These temperature also affect the normal behavior and the health of bee colonies resulting in financial losses due to mortality and reduced productivity. **The hive temperatures depend on several parameters :**

- colony activities,
- weather conditions (solar irradiance, cloud covering, air temperature, sky temperature, wind speed/direction),
- close environment properties (surroundings objects, reliefs, ground type),
- beehive materials and coverings / beehive configuration (feeders, supers, closed/opened floor, vent holes, etc.).

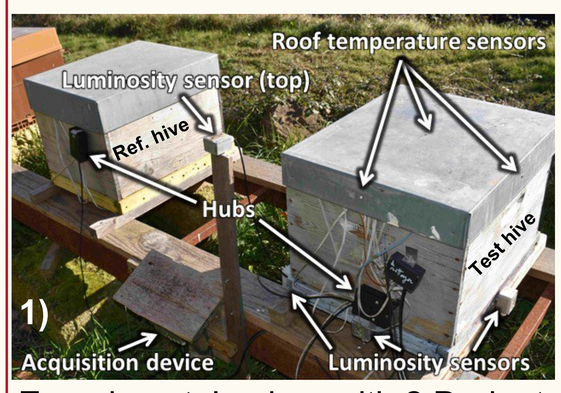
This study focuses on measuring quantitative data of the thermal efficiency of some beehive coatings used by beekeepers to limit the effect of solar radiation on their hives.
The final objective is to help beekeepers to adapt their hives to local environmental factors.



EXPERIMENTS

METHODOLOGY

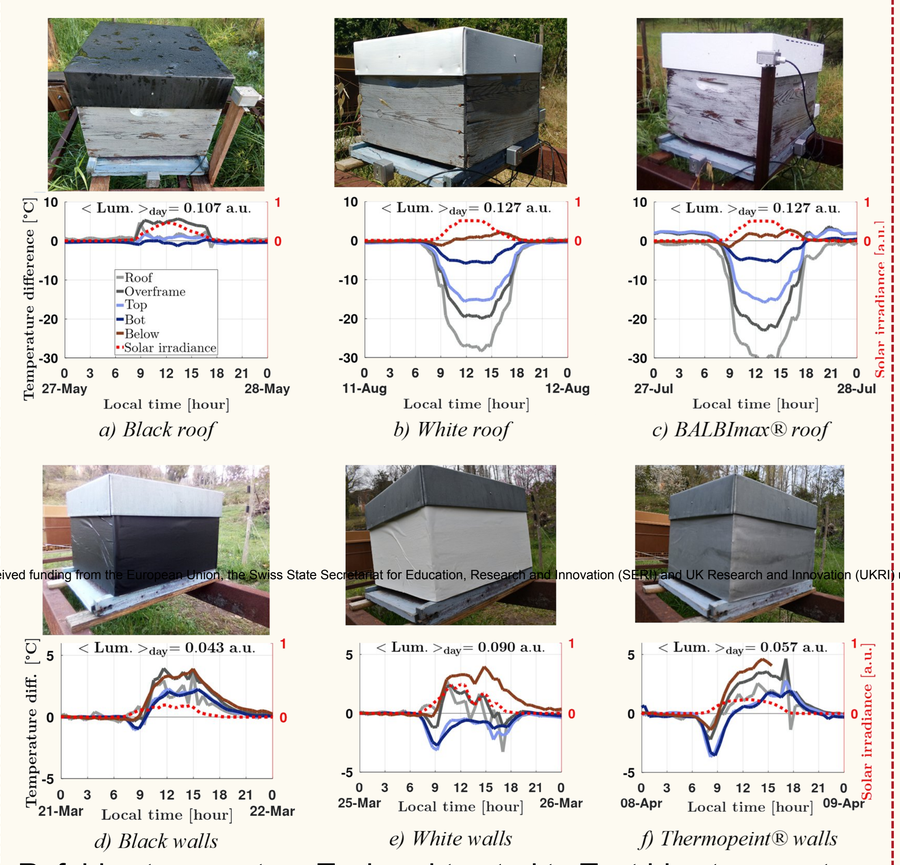
Experimental parametric study to estimate the effect of paints on the in-hive temperatures.



Experimental apiary with 2 Dadant hives (figure 1) equipped with 8 temperature sensors (NCT75 and TC74, figure 2). Luminosity (VEML7700 sensor) is measured on each of the 6 sides. A weather station measures air temperature and wind speed.

One hive is kept unchanged during the experiments (Reference hive), the other hive (Test hive) undergoes successive modifications.

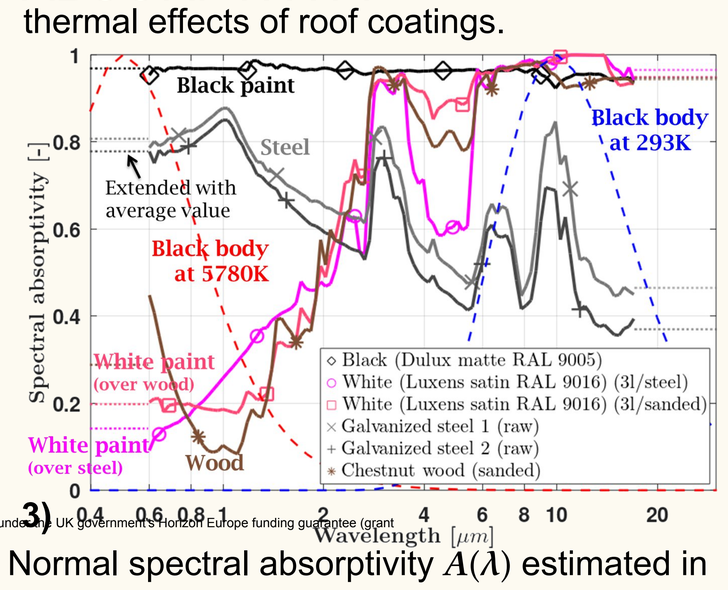
HIVE CONFIGURATION



Ref. hive temperature T_{ref} is subtracted to Test hive temperature T_{test} for better visualization of results when analyzing data.

SPECTRAL ABSORPTIVITY

Measurements realized to understand the thermal effects of roof coatings.



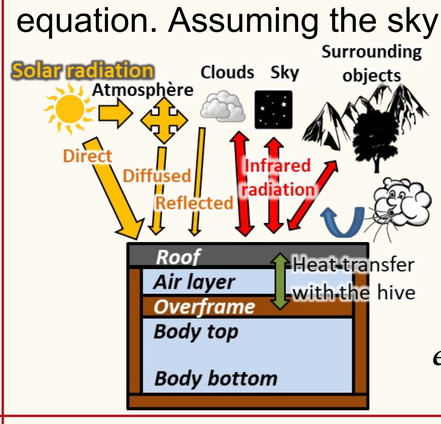
Normal spectral absorptivity $A(\lambda)$ estimated in CEMHTI lab. (Orléans, France) using the measurements of normal hemispherical spectral reflectivity and transmittivity:

$$A(\lambda) = 1 - R(\lambda) - T(\lambda)$$

It involves two integrating spheres:
1) In the visible range (0.6 to $1.5\mu m$)
2) In the infrared range (1 to $17\mu m$).

THERMAL MODELING OF HIVE ROOF

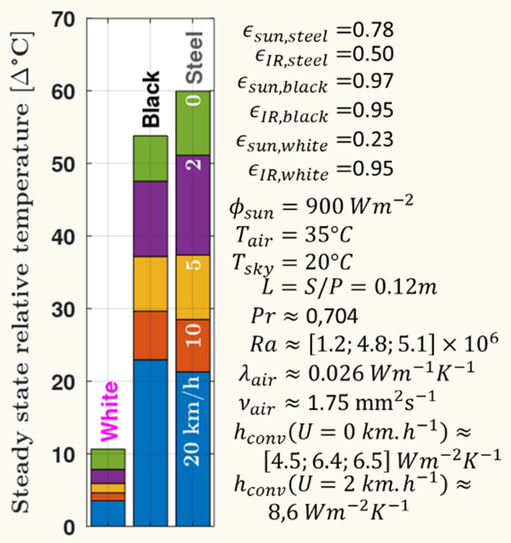
The steady state temperature of the hive roof exposed to sunlight is estimated by solving the energy conservation equation. Assuming the sky is a black body at temperature T_{sky} and is the only object visible from the roof:



$$0 = \epsilon_{sun}.\phi_{sun} + \epsilon_{IR}.\sigma\left(T_{sky}^4 - T_r^4\right) + h_{conv}\left(T_{air} - T_r\right) + g\left(T_{hive} - T_r\right)$$

- $\epsilon_{sun}.\phi_{sun}$: **Solar radiation absorbed by the roof**
- ϵ_{IR} : **Hemispherical emissivity for the sun**
- $\epsilon_{IR}.\sigma\left(T_{sky}^4 - T_r^4\right)$: **Hemispherical emissivity for IR at ambiant temperature**
- $h_{conv}\left(T_{air} - T_r\right)$: **Convection coefficient**
- $g\left(T_{hive} - T_r\right)$: **Conductance between the roof and the hive.**

ϵ_{sun} and ϵ_{IR} estimated by integrating the normal spectral absorptivities $A_x(\lambda)$ - Figure 3).



RESULTS

Hive part	Coating	Experimental result	Comment
Roof	White paint	Significant reduction of the roof temperature (up to -28°C around midday and -9°C on average) in summer	As shown by the normal spectral absorptivities, this is due to the low absorptivity (23%) in the visible range and the high emissivity in the infrared range (95%).
	Galvanized steel	Roughly equivalent to black roof	The steel roof has a higher absorptivity in the visible range (78%) than in the infrared range (50%) which led to potential overheating issue.
	Balbimax®	Close to white roof	Insulating effect during the night lower the in-hive cooling performance
Walls	White paint	Minor effect compared to the unpainted wood	
	Thermopeint®	No temperature decrease observed	
	Black paint	Measurable effect by increasing the temperature of the body part by about 2°C	

A steady state model of the hive roof is developed to predict the roof temperature based on radiative and convective properties.

- The model predictions are confirmed by the observations on instrumented hives.
- The model confirms the potential overheating of a Dadant hive with a standard galvanized steel roof
- With strong solar irradiance, the overheating issue encountered by beekeepers is unlikely to occur in windy weather.

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