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The Biology and Management of Colonies in Winter

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The Biology of Wintering

In nature bees have two general methods for maintaining colony temperatures in winter: 1) selecting a protected and well-suited cavity (**Tab. 1**) and 2) clustering.

Clusters have a two-part structure (**Fig. 1**): 1) a ***dense outer mantle*** in which bees jam together, orienting their heads towards the center of the cluster and 2) a ***loose inner core*** where bees are free to move. The ***mantle insulates*** and, at its tightest, approaches the insulation of bird feathers or mammal fur (0.1 W/kg/ºC). Clusters move slowly from empty combs to ones full of honey. This movement is typically upwards and sideways, never downwards.

Before we go on, here are ***four critical temperatures*** you should know: 1) brood nest = **32-36ºC**, 2) minimum thorax temperature needed for flight = **27ºC**, 3) minimum temperature needed to pump flight muscles and warm up (analogous to mammal "shivering") = **18ºC** and 4) below which bees go into a "chill coma" = **6ºC**.

Bees ***begin clustering when temperatures fall below 18ºC***. Cluster size shrinks until -10ºC at which the cluster is tightest. The cluster shrinks 5-fold between 18ºC and -10ºC. Below -10ºC hive temperatures can only be maintained by increasing core heat production (**Fig. 2**). The ***core bees create this heat by "pumping" their flight muscles***. This process is ultimately fueled by honey which prompted WF Cheshire to write in 1888: "Each bee is a tiny furnace carrying on a process in its tissues and fluids which is the exact chemical equivalent of oxidizing honey ".

WORDS OF WISDOM - A hive's metabolic rate is lowest when temperatures are 5-10ºC. This is why beekeepers who winter bees indoors maintain their buildings at 5ºC: the bees use the least amount of honey at this temperature.

It is estimated that bees produce 0.68 kg of water per kg of honey they consume. This water is important to the bees and they use it to dilute honey, feed brood and flush metabolic wastes from their bodies. Nonetheless, some of this water escapes as a vapour, which in itself is important as brood develops best at 40% relative humidity. ***A problem occurs, however, when outside temperatures drop***. Cold air does not hold as much water as warm air, so as warm moist air leaves the cluster, it condenses on the comb. Bees can cope with some moisture outside the cluster, but ***if the moisture accumulates and begins dripping back on the bees it saps them of heat***. This issue is significant when we consider the role of the upper entrance in your colonies.

Bees reduce their energy consumption through the winter by ***"turning their thermostat down"***. They accomplish this by shutting down brood production in late fall and early winter (**Fig. 3**), which is thought to be triggered by shortening day length. Free of maintaining incubation temperatures (remember: 32-36ºC), the core bees lower their heat production and, thus, minimize their consumption of honey. ***Brood rearing begins slowly again after the winter solstice***. The high metabolic cost of late-winter brood rearing translates into higher honey consumption rates at the end of winter. In one study, colonies ate honey at twice the rate in March (0.84 kg per week) compared to December (0.42 kg per week).

Nest-site property	Frequency of occupation, given choice[a]
Apis mellifera	
Nest height from ground	5 m > 1 m
Nest exposure/visibility	Visible > hidden
Distance from parent nest	No preference (?)
Entrance area	12.5 cm^2 > 75 cm^2
Entrance location	Bottom > top
Entrance direction	Southward > northward (?)
Cavity volume	10 liters < 40 liters > 100 liters
Previous occupancy	Previously used > new
Nasanov pheromone	With pheromone > without pheromone
Cavity dryness	Damp sawdust = dry
Cavity soundness	Walls with holes = sound walls

Table 1. Nest site "checklist" for bees scouting for a new home (Seeley and Morse 1978).

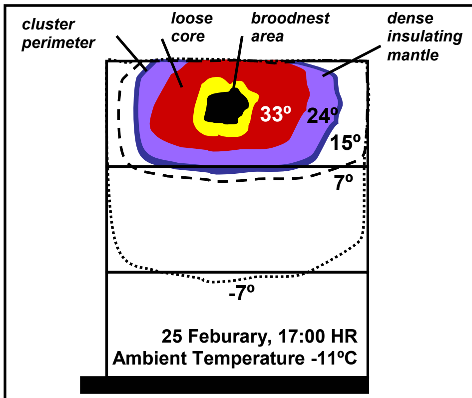

Figure 1. The two part structure of the winter cluster (Owen 1971, redrawn from Seeley).

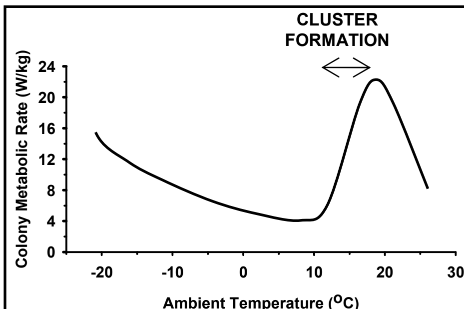

Figure 2. Colony metabolic rate as a function of ambient temperature (Southwick 1982, redrawn from Seeley).

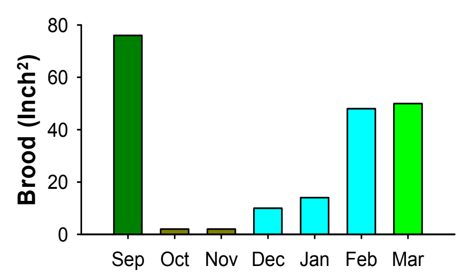

Figure 3. The amount of brood in colonies across the winter months in Aberdeen, Scotland (Jeffree 1956).

"Bees do not freeze to death in winter – they starve" - Herman Rauchfuss, Sr. ***<u>Make sure your bees have enough stored honey!</u>***

How much honey do bees consume (double brood nest)?

Location	Recommended Honey Stores
Saskatchewan	80-90 lb (36-40 kg)
Wisconsin, New York State	60-80 lb (27-36 kg)
Kentucky	55-60 lb (24-27 kg)
California, N. Carolina	30 lb (13 kg)

Weights are for honey only. The equipment and bees weigh ~60lb, so that in Saskatchewan for example, a colony should weight 120-140 lb after feeding.

"Thirty pounds more honey than the average colony uses is cheap insurance, compared with the risk of losing the best colonies because they have even one pound too little" – CL Farrar

How do colonies make it through a long Canadian prairie winter if they stop rearing brood? Shouldn't the colony gradually dwindle away? Although populations do shrink considerably from August to March, the colonies are able to maintain their numbers through the ***production of <u>winter bees</u>***. ***Winter bees live a lot longer (100+ d) than summer bees (~30 d)*** (**<u>Fig. 4</u>**). The trigger colonies use to switch from summer to winter bee production is unknown, but a leading hypothesis is that it is simply the cessation of brood rearing in the fall. Nursing, after all, is hard work and the bees born into a nest with no nursing jobs have it easy and live longer. Although the verdict on the trigger is still out, it is clear that winter bees differ physically: "newly emerged bees that overwinter have significantly greater dry weight, protein, fat, triglycerides, glycogen and glucose content than bees that do not survive to winter" (Matilla et al 2001).

How does a colony begin rearing brood in the middle of winter when there is no fresh pollen to collect? For one thing, ***bees can store a considerable amount of pollen in the comb before winter***. They appear to use this pollen to rear brood since colonies that store more pollen also have more bees in the spring (**<u>Fig 5</u>**): ***notice the 20,000 bee difference between colonies going into winter with a deficient or abundance of pollen.*** Bees also seem to be able to draw on stores of protein from their bodies in order to feed brood.

Bees should go into winter with 3 to 6 well-filled frames of pollen. In the last part of winter, Farrar (1936) says colonies can use up almost a frame of pollen a week. If colonies do not have much stored pollen, they will benefit from supplemental pollen up until natural pollen flows begin.

There is ***genetically-based variation*** in the ability of bees to winter, although it is uncertain what specific traits are associated with this variation. The ***variation*** certainly ***runs along racial lines***. The ***<u>German Black Bee</u>*** of northern Europe (*A. mellifera mellifera*) has the best wintering ability of any other European race. Bees of this race, however, are hard to domesticate. Among domesticated races the high elevation ***<u>Carniolan</u>*** (*A. m. carnica*) and central European ***<u>Caucasian</u>*** (*A. m. caucasica*) bees are better at wintering than ***<u>Italian Bees</u>*** (*A. mellifera ligustica*).

Domestication has muddied most natural racial populations. Consequently, a bee that externally looks 'Italian' or 'Carniolan' may not winter like either race should. When purchasing queens you should always look past superficial

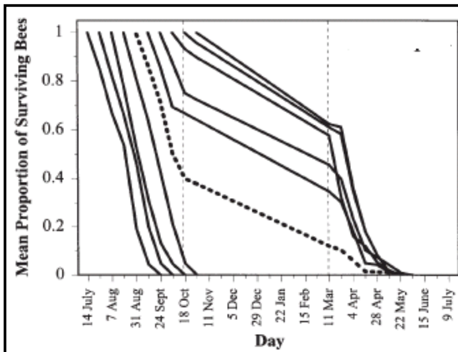

Figure 4. Mean survivorship curves for cohorts of bees introduced at 12-d intervals (from 14 July until fall brood rearing ceased). The graph shows a clear transition from ***short-lived summer bees*** and ***long-lived winter bees*** beginning with the cohort born on the 31 August (dotted curve). The data was collected by Harris in southern Manitoba and later analysed by Matilla et al. 2001.

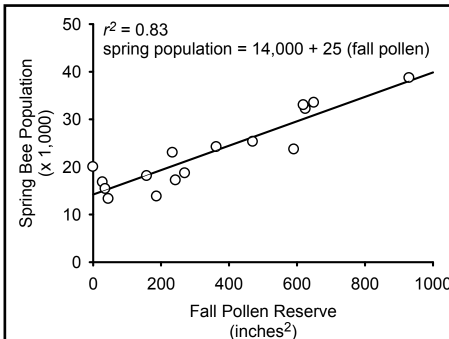

Figure 5. Relationship between stored pollen in a colony in the fall and the population of bees in the spring (late-March / early-spring). Data was collected over two years at Laramie, Wyoming. Farrar 1936.

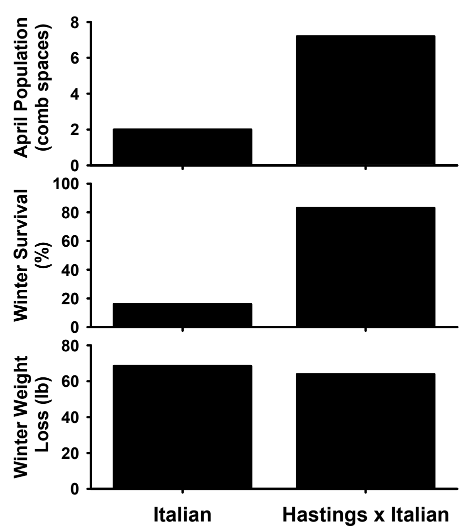

Figure 6. The amount of honey consumed (winter weight loss), the percentage of colonies surviving winter and spring adult populations between "Italian" commercial queens from California compared to hybrids of "Italians" crossed to "Hastings Carniolans". For all measures the hybrids were superior for wintering compared to the "Italians", suggesting the difference was genetic and dominantly inherited (from Szabo 1980)

resemblance, and instead, choose on the basis of proven performance under your conditions.

There is also ***variation within races***. This variability is used by queen breeders to select for improvements on wintering. A notable example of this is the work of bee breeder Everett Hastings (Birch Hills, Saskatchewan). In the 1940s Hastings obtained the remnants of a Mountain Grey Caucasian stock originally imported from Russia to the US in the early 20th Century. Following years of selecting this stock under his harsh winter conditions, he began incorporating Carniolan genetics in 1963. This hybrid population was selected to be very winter hardy and extremely productive in prairie environments. Although his stock is no longer maintained, it has been incorporated into notable breeding populations worldwide, most notably the New World Carniolan population in Ohio. These bees ***use less honey to winter, have bigger spring populations and have a higher rate of winter survival*** than commercial "Italian" queens from California (**Fig 6**).

Management of Colonies in Winter

In ***most regions of the USA and a few warm regions of Canada (eg southern BC and Ontario) winter management is a simple affair***: **1)** make sure colonies have ***enough honey and pollen***, **2)** use ***bee stock adapted to the area*** and **3)** provide a way ***for excess moisture to escape*** the colony. In ***colder areas, colonies benefit from more intensive management***. These regions include the rest of Canada, the Northwest states east of the Rocky Mountains, Midwest states north of Kansas and the Northeast states north of Pennsylvania.

The best way to vent extra moisture from wintering colonies is with an upper entrance. This entrance is **VERY IMPORTANT!** A study from northern Alberta, for example, demonstrated that either a 1 x 1.5 cm top entrance built into the inner cover or a 2.5 cm diameter hole in drilled into the middle of the upper brood box greatly increased colony strength, health and decreased the consumption of honey stores (**Fig. 7**).

In colder areas of N. America colonies benefit from some level of protection. There are ***two general designs for protecting colonies*** wintered outside. The first involves wrapping colonies in black-coloured, wind-proof sleeves (***solar wraps***). The black surfaces of solar wraps passively warm colonies on sunny winter days ***causing them to break their cluster at lower ambient temperatures than normal***. Although wraps were traditionally homemade from tar-paper or roofing felt, industrially produced waxed cardboard sleeves are now becoming more common. The second method involves wrapping the colonies with a layer of insulation (***insulated wraps***). These wraps help ***colonies retain heat when temperatures are extremely low***, but in turn prevent colonies from warming on sunny days.

The kind of wrap that you should use depends on where you live. Solar wraps increase colony productivity in some places with fairly mild winters. A study from Israel, for example, demonstrated that colonies that were enclosed in a black plastic tent achieved brood rearing temperatures a month earlier than colonies painted white, and as a consequence, were able to double their honey production during the first honey flow in March (**Fig. 8**). More traditional solar wraps also perform well in relatively colder climates. The best way to winter colonies in Minnesota, for example, is as triple brood nests with solar wraps (tar paper) rather than the insulated double brood nest 4-packs (**Fig. 9**). Solar wraps, however, are not used under the more extreme conditions found on the Canadian prairies. Although a number of studies in this region have concluded that ***insulated 4-Packs***

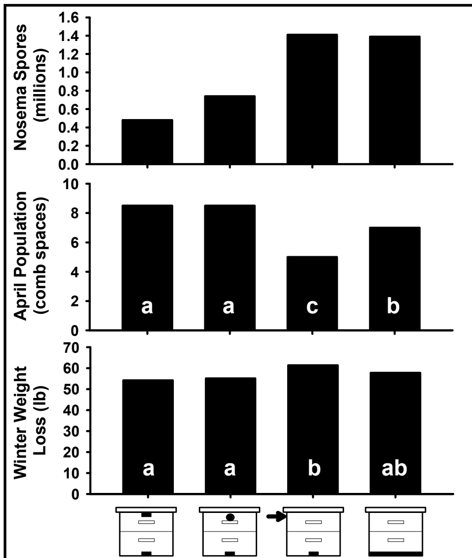

Figure 7. The amount of honey consumed (winter weight loss), spring adult populations and nosema levels among colonies with different types of entrances: 1) bottom and top entrances 1 x 1.5 cm each, 2) bottom (1 x 1.5 cm) and top (2.5 cm dia in middle of 2nd chamber), 3) bottom and side (1 x 1.5 cm each) and 4) fully open bottom entrance and no top (from Szabo 1982). Different letters mean averages were significantly different.

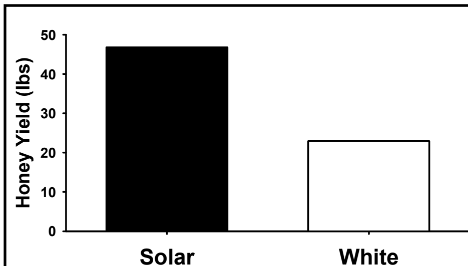

Figure 8. The amount of honey collected from colonies in Israel during the earliest honey flow (March) if they were painted white or enveloped in a black plastic tent (solar) (Wineman et al 2003).

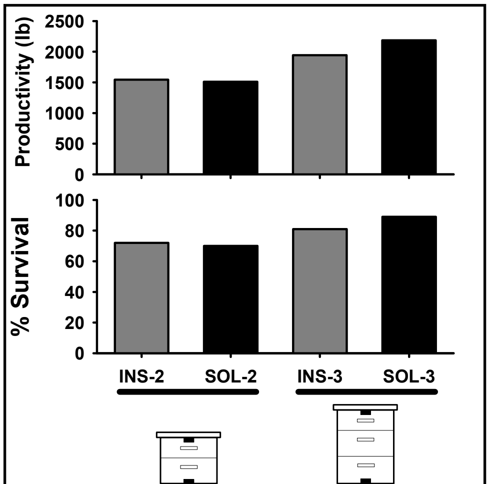

Figure 9. The percent survival and productivity of colonies wintered using four different methods: packs of four colonies wrapped together with insulated wraps, that were either 2 (INS-2) or 3 (INS-3) brood chambers in size or individual solar wrapped colonies in 2 (SOL-2) or 3 (SOL-3) brood chambers. Productivity = (The Number of Colonies Surviving Winter) x (Average Honey Production of Parent Colonies + Ave. Honey Production of Splits) (Sugden et al. 1988)

(**Fig. 10**) are superior to solar wrapped double brood nest colonies, I am not aware of any comparisons of 4-Packs to solar wrapped triple brood nests. Potentially solar wrapped triples might work well on the prairies, particularly with the trend to warmer winters.

Honey bee colonies are also ***wintered indoors*** (**Fig 11**) in temperature controlled buildings. Indoor wintering is only practiced in the Canadian prairies, in Quebec and in the Maritime Provinces. Bees are typically moved indoors when daytime temperatures are below freezing (typically at the end of October on the prairies). ***Colonies stay indoors for 5 to 6 months***. Some beekeepers winter a few thousand colonies in a single building.

As I mentioned in the Wintering Biology section, colonies winter most efficiently at 5ºC. ***Keeping wintering buildings at 5ºC is tricky because: 1) colonies give off heat and 2) outdoor temperatures fluctuate.*** In the late fall the heat produced by the bees is greater than the amount required to keep the room temperature at 5ºC. ***The excess heat is removed by exhausting the warm storage air and replacing it with cool outdoor air***. This air is exhausted using thermostatically controlled fans. The ***exhausting also removes CO_2 and moisture***, both of which are harmful to bees at high levels. Exhaust fans are typically tied into a reticulating polyethylene duct system that ensures the air moves uniformly throughout the room (**Fig. 12**).

When the outdoor temperature is very cold the bees are able to generate only enough heat to keep the building at 5ºC. In this situation the exhaust fans remain closed. ***To prevent CO_2 and moisture from building up, a low level exhaust runs to ensure just enough fresh air is brought in***. It is a task to adjust the exhausting system so that it can keep the air fresh and temperature regulated (**Fig 13**). Consequently, I urge you to consult with your provincial apiculturalist before you begin construction. If temperatures fall lower still, ***backup heat*** is used to warm the building. In warmer climates, such as in Quebec, buildings are also equipped with ***refrigeration systems to cool buildings down*** when temperatures begin to rise in the spring.

Figure 10. The ***Peer 4-Pack*** from Saskatchewan consists of four double brood nest colonies pushed together and wrapped in black plastic that contains ***R-12*** batt insulation. The top of the pack contains ***R-20*** insulation batts, again in plastic to prevent the insulation from getting wet. The roof is made of a piece of plywood and upper entrances are fastened by wooden blocks.

Figure 11. An indoor wintering building pictured as colonies are being moved in. Notice the ***recirculating fans*** and ***return duct*** on the ceiling and one of the ***cold air intakes*** with ***light trap*** on the right wall. This building holds about 1,000 single brood nest colonies and is operated by Jack and Dorathee Cage.

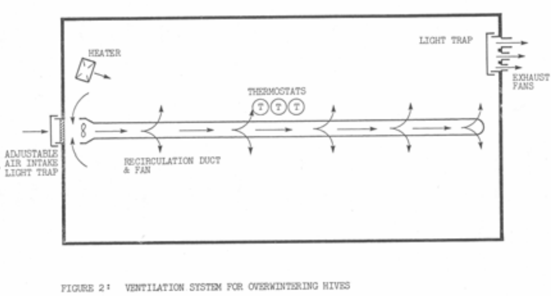

Figure 12. A simplified schematic of the ventilation, exhaust and heating systems used in indoor wintering buildings. ***Notice that all exhausts are equipped with light traps to ensure that no light enters the building.*** Although lights disturb indoor wintering bees ***beekeepers employ red lights, which are invisible to bees, for routine maintenance***. The recirculating fans and ducts ensure that air in the building is ***well mixed***. The ***heater*** is only used when outside temperatures are so low that the heat generated by the bees can no longer maintain the room temperature at 5ºC.

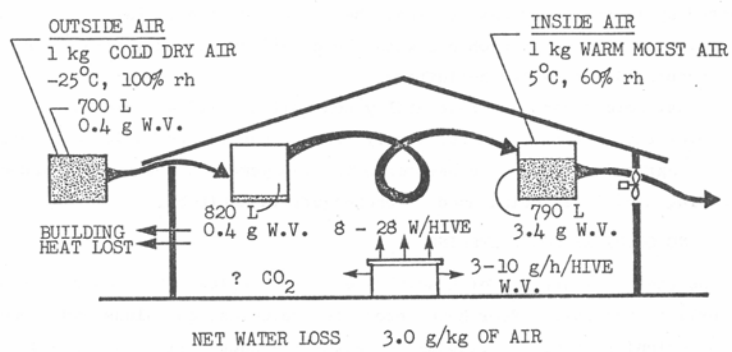

Figure 13. Winter ventilation for overwintering hives. **EXAMPLE.** ***Each colony in the building generates 3-10 g of water vapour per hour and 8-28 watts of heat***. Imagine if we brought 1 kg of outdoor air into the building. This air is at -25ºC and 100% relative humidity (RH), and thus, contains only 0.4 g of water vapour (remember cold air does not hold much water). When that 1 kg of outdoor air is brought into the 5ºC building (60% RH), it can now hold 3.4 g of water. Thus for each kg of 5ºC air (60% RH) exhausted there is a net loss of 3.0 g of water vapour. To move that 3.0 g/kg of water 0.25 L/s of air must be exhausted from our theoretical building. If we bring this amount of cold air into the building we will need to produce 13 W per hive to keep the building at 5ºC. We also loose 4 W of heat through the walls of the building, so now we need 13 + 4 = 17 W to keep the building at 5ºC. Let's say the colonies are only producing 12 W. We therefore need another 5W per hive from the heater. Phew! ***Save yourself the trouble and get an expert when planning a wintering building.***