Chapter 32

Effect of Hive Design on Internal Hive Temperature: A New Application of Temperature Data Loggers

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Introduction

Apis cerana like other *Apis* species thermoregulates to keep its thoracic temperature between 30 and 36°C (Underwood 1991). In order for brood to develop properly, honeybees maintain high temperatures (30–36°C) in the centre of the cluster where the brood nest is located (see reviews by Seeley 1985, Winston 1987, Roubik 1989, Crane 1990 and Graham 1992). Thermoregulation by bee colonies (Simpson 1961, Kronenberg and Heller 1982 and Heinrich 1985) has a high energetic cost, so insulation provided by beehives can have a strong influence on the rate of food consumption, work allocation of workers and ultimately colony survival. Hence, microclimatic suitability of hives for local bees is important in designing appropriate beehives.

In the current study, the thermal qualities and performance of bee colonies in different hives have been tested in conjunction with trials to ascertain the suitability of the hives from the point of view of local farmers in two sites: Jumla, a remote part of mid-Western Nepal (2500–3100 m); and Godavari in the Kathmandu Valley (1500 m). Jumla is a stronghold of traditional beekeeping with log hives. It is isolated from motorable roads by 5-days walk and hence nails and other hive-making materials are not affordable to local people. Godavari, on the other hand, lying only 15 km outside Kathmandu, is relatively developed with availability of ready-made 'modern' beekeeping equipment, and nails and machine-cut wood.

Methods

Temperature and bee performance data were collected in demonstration apiaries in Karnali Technical School, Jumla, and ICIMOD testing and demonstration site Godavari from May 1996 – March 1998 inclusive, and will be ongoing until November 1998. Hive types were tested as follows: traditional log hive, modified log top-bar hive, straw hive, Newton hive, and the 'Jumla' hive (a square cross-section log top-bar hive). The latter was tested in Jumla only, being particularly suited to the Jumla situation.

Maximum-minimum temperatures and details of the colony performance were recorded, but results will be presented in later publications. In each hive type, internal hive temperature of occupied and empty hives was compared by placing ONSET 'Stowaway' temperature-data loggers inside hives. The data-loggers were set to record at 30-min intervals 24 hours a day over periods of several months. Distance of the loggers from the hive clusters was difficult to control, but as long as the hive cavity was not completely full of bees they were placed at the side of the hive not directly adjacent to a cluster. This was to avoid the loggers measuring the temperature of the bee cluster, which should not vary between hive types.

Hive types were assumed to vary in their response to ambient temperature and solar warming at different times of day, so time-slots were set for analysis of hive temperatures. Mean temperatures were calculated over four-hour periods as follows: 0600–1000, 1000–1400, 1400–1800, 1800–2200, 2200–0200, 0200–0600 h. One-way ANOVAs were conducted for each time slot to determine whether the differences between mean hive temperatures in different hive types and between mean hive temperatures and ambient were significant or not. Duncan's test was used to determine which means were significantly different from one another.

Examples of data for periods when occupied hives of all the different types were available with sufficient levels of replication were chosen as follows: in Jumla between 18 and 31 May 1996 in the warmest time of year, and in Godavari between 18 August and 30 September 1997 in the late monsoon. In Jumla, colony deaths and absconding due to Thai Sac Brood Virus Disease (TSBV) and European Foul Brood (EFB) disrupted data collection in 1996 and 1997. In Godavari in 1996, insufficient replication caused insignificant results. Hence, to give meaningful results, data has been selected in Jumla before colonies died and in Godavari after logger replication was sufficient.

Results

Between empty hives, in both Jumla and Godavari, differences in internal hive temperature were not significant. In occupied hives however, differences were significant in some cases but not others. Mean temperatures over the sampling periods chosen for each hive type and for ambient temperature in each time slot are shown in Fig. 1 for Jumla and Fig. 2 for Godavari.

In Jumla, the straw hive was warmest most of the time, followed by log top-bar, log and Newton. The Jumla hive was warmest at night but cool in the morning. The significance of the differences, listed pair-wise between hive types at different time slots in Jumla is shown in Table 1.

Due to low night temperatures in this high altitude area, all the hives were significantly warmer than ambient overnight (1800–0600), and all, except the straw hive, equilibrated with ambient once the sun came up. The straw hive

Table 1. Comparison of different hive types (occupied by bees) at different times of day (time slots) in Jumla over the period from 18 May to 31 May 1996.

	Newton vs LTB	Newton vs log	Newton vs Straw	Newton vs Jumla	Newton vs Outside	LTB vs Log	LTB vs Straw	LTB vs Jumla	LTB vs Outside	Log vs Straw	Log vs Jumla	Log vs Outside	Straw vs Jumla	Straw vs Outside	Jumla vs Outside
06 to 10	Y	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	Y	N
10 to 14	N	N	Y	Y	N	N	N	Y	N	Y	N	Y	Y	N	Y
14 to 18	N	N	Y	N	N	N	Y	N	N	Y	N	N	Y	Y	N
18 to 22	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y
22 to 2	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y
2 to 6	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y

(Y indicates that the difference is significant and N indicates that the difference is insignificant. LTB means Log top-bar hive and Outside means outside ambient temperature.)

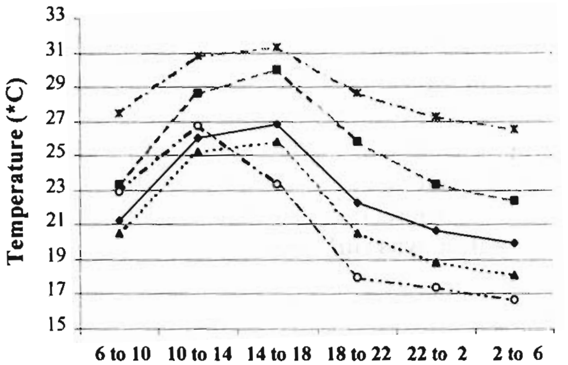

Fig. 1. Mean Temperature by hive type and time slot for Godavari from 16 Aug 1997 to 30 Sep 1997

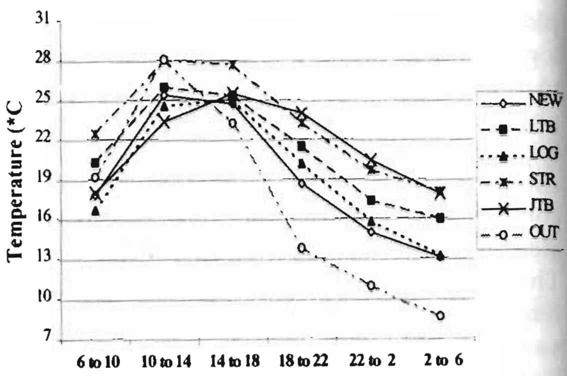

Fig. 2. Mean Temperature by hive type and time slot for Jumla from 18 May 1996 to 31 May 1996

was significantly warmer than ambient at all times, except when it converged with ambient around midday. The Jumla hive was significantly cooler than ambient in the midday period whereas the Newton hive and log top-bar hive were not significantly different from ambient during daytime (0600–1800). The log hive was significantly colder than ambient in the morning (0600–1000). The straw hive was significantly warmer than the Newton and log hives in all time slots, and than the Jumla hive in the day (0600–1800). However, it was not significantly different than the Jumla top-bar hive overnight (1800–0600). It was significantly warmer than the log top-bar hive between 1400 and 1800 hours, at 2200–0200 hours, and again around dawn (0200–0600) but not at other times. The Jumla hive was significantly warmer than the Newton hive, except in early morning and late afternoon, and was significantly warmer than the log overnight. The Newton hive was significantly colder than all others overnight (1800–0600) with the exception of the log hive. This did not differ significantly from the Newton hive except between 1800 and 2200 when the log hive was colder. The log top-bar hive was significantly warmer than the Newton (1800–1000), Jumla (0600–1400) and the log (0200–1000), but was significantly cooler than the Jumla hive at night (1800–0200). In late afternoon (1400–1800) and around dawn (0200–0600) there was no significant difference between the log top-bar and Jumla hives. The log hive was not significantly different from either the Jumla and Newton hives in the day (0600–1800) or the log top-bar hive between 1000 and 0200 hours. It was significantly colder than the log top-bar hive from 0200–1000 hours.

In Godavari, a similar pattern emerged: all pair-wise differences were significant except between log top-bar and ambient (outside) at 0600–1000 hours, when hive temperature almost equilibrated to ambient due to overnight cooling. The straw hive was significantly warmer than all others and ambient in all time slots. The log top-bar hive was next warmest, then the Newton and lastly the traditional log. Log and Newton hives were cooler than ambient outside temperature in the morning and between 1000 and 1400 hours. For the remainder of the time slots and hive types, hive internal temperature exceeded ambient temperature.

Discussion

Since only small subsets of the data are being used here, cautious interpretation is necessary. Later ICIMOD publications will present all the data (including colony performance data) collected during the year in the two sites and confirm whether these sample data sets are representative of the general situation. The insignificant differences between different hive types when empty is attributable to the shading effect of the hives upon the loggers and the lack of warming from inside. The assumption that the thermal properties of hives can be determined by measuring temperature of empty hives was incorrect when only small sample data sets were used. To perform better controls in the future, heating devices with a fixed temperature of 35°C (to mimic the heat generated in the centre of the bee cluster) need to be placed inside hives without bees. Loggers would then be placed at a fixed distance (e.g., 20 cm) from the device and the same comparisons made.

Straw hives provide better insulation than hives made of wood, even when the wooden walls are 5–6 cm thick. This probably has a positive effect in winter but may cause overheating in the summer at lower altitudes. Although the straw walls are probably most important in providing insulation, hive volume is also much smaller in the straw hive than the Jumla and log hives. Hives with larger volumes (especially traditional logs) show generally lower temperatures than those with smaller volumes (Newton, straw and log top-bar). In both Jumla and Godavari, the log top-bar hive was significantly warmer than the traditional log (the hive design from which it is adapted). This difference is probably due to the decrease in internal hive volume by around one third that occurs when the hive is adapted. The smaller hive cavity warms up more quickly in response to the temperature of the bee cluster. The higher temperature of the Newton hive at night in comparison to the log in Godavari is also probably attributable to this volume consideration. In Jumla where cooling from outside is more extreme, the thin wooden Newton hive cooled more quickly than the log in the afternoon/evening despite the smaller volume. The two hive temperatures then converged around dawn but once the sun came up the Newton hive responded more rapidly to solar heating. Although rapid temperature increase due to solar heating in the morning may be positive, since bees may emerge more quickly to forage, rapid cooling when the sun goes down renders Newton hives inappropriate in mountain conditions (2600 m) especially in winter. The thick-walled wooden Jumla hive holds the heat well overnight. Although it responds slowly to solar heating, this may protect against overheating in summer and perhaps also against too much solar warming in winter. It is questionable whether too much heat in winter may have a negative effect by causing higher consumption of honey by bees that would otherwise remain alive but dormant. Winter honey stores may be finished too quickly and the bees starve later. In future analyses, the hive volume and size of the cluster will also be taken into account.

Although this paper has looked specifically at the thermal properties of different types of hive, selection of a hive for use in beekeeping extension programmes must depend more on the preferences of the local farmers and the availability of materials and tools to make hives than on this one factor. Hence although straw hives are on average warmer than Jumla log top-bar hives, the latter has been accepted by the Jumla farmers while the former has not. The straw hive is disliked because of susceptibility to pest attack (especially pine martens and ants) and its tendency to hold moisture; also traditional threshing techniques break the straw into small pieces, and the press for making the hives is expensive and cannot be made in the village. Similarly, the Newton hive is not accepted by Jumla farmers because of its poor insulating properties, the need for exact measurements and the lack of availability of machine-cut wood and nails. This clearly demonstrates that appropriate technology needs to grow from the resources and technologies already in use, using participation of the local people in order to succeed.

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References

Crane, E. 1990. *Bees and Beekeeping: Science, Practice and World Resources*. Heinemann Newnes. Oxford.

Graham, J.M. (Ed.). 1992. *The Hive and the Honeybee*. Dadant and Sons. Hamilton, Illinois.

Heinrich B. 1985. The social physiology of temperature regulation in honeybees. *Fortschritte de Zoologie*, **31**: 398-406.

Kronenberg F. and Heller H.C. 1982. Colonial thermoregulation in honeybees (*Apis mellifera*). *J. Comp. Physiol.* **148**:65-76.

Roubik D.W. 1989. *Ecology and Natural History of Tropical Bees*. Cambridge University Press. UK.

Seeley T.D. 1985. *Honeybee Ecology: A Study of Adaptation in Social Life*. Princeton University Press, Princeton, New Jersey.

Simpson J. 1961. Nest climate regulation in honeybee colonies. *Science*, **133**, 1327-1333.

Underwood B.A. 1991. Thermoregulation and energetic decision-making by the honeybees *Apis cerana*, *Apis dorsata* and *Apis laboriosa*. *J. Exp. Biol.* **157**: 19-34.

Winston M.L. 1987. *The Biology of the Honeybee*. Harvard University Press. Harvard.