Whitewashed Beehives during Summer

Summer Black Paned Beehives during Winter

Solar Heating of Honey Bee Colonies (Apis mellifera L.) During the Subtropical Winter and its Impact on Hive Temperature, Worker Population and Honey Production

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Abstract

We studied the impact of solar heating of bee colonies by placing beehives inside Infrared-Polyethylene (PE) covered enclosures, on: hive temperature, bee population, and spring honey production, during the subtropical winter (December 2000-March 2001) in Israel's Coastal Plain.

During this period, the ambient daily maximum temperature fluctuated between 12.8 and 23.1°C. Out of the 1192 light hours, only 90 hours were cloudy and cold (< 8°C). The precipitation was 176.8 mm rain, and the average wind velocity was 1.5 m/sec, above the threshold of bee foraging activities.

The temperature inside empty, non-covered hives was close to the ambient °t at 40 cm above the ground. However, on a bright day and clear night the °t inside empty, PE-covered hive was higher by 12.2 and 1.7°C, respectively, than that inside an empty, non-covered hive. The °t inside an empty, PE-covered hive resembled that inside PE tunnels and greenhouses, reaching maximum and minimum values during the noon and in the early morning, respectively. At all measuring positions, the °t was always higher in PE-covered colonies than in non-covered ones. The temperature outside the brood area in PE-covered hive was higher by 9.3 and 2.7°C during a bright day and clear night, respectively, than in non-covered ones. The brood area °t ranged between 34.8 and 36°C Brood area size in PE-covered hives increased by 59.2% (+ 2290 cm2) during the experimental period, but it went down by 8.4% (- 504 cm2) in non-covered hives (P=0.05). Adult bee population in PE-covered hives increased by 37.5% (3.8 occupied frames) during the winter, versus only 11.8% (1.8 occupied frames) in non-covered hives.

During the spring, PE-covered colonies produced ±20.8 kg honey/colony, while non-covered colonies produced only ±10.2 kg honey/colony (P=0.0004). We demonstrated that the temperature that prevailed in PE-covered populated hives was higher than non-covered ones, and resulted in a faster increase of the brood area size, colony population build-up and more spring honey per colony.

Introduction

In a honey bee colony, the worker bees maintain in the broodnest a steady temperature between 34.5

- 36.7°C, as long as it contains brood. Generally, in a subtropical climate queens lay eggs year-round, and the thermoregulation of the brood-nest is achieved as follows. During the summer, workers collect water at water sources, deposit the droplets inside comb cells, and evaporate them inside the hive to prevent the brood nest from overheating (Lindauer, 1955). During the winter, when ambient temperature drops below 18-19°C, workers cluster together and raise their metabolic rate in order to produce heat. The heat is dissipated from the thoracic flight muscles of workers that form the winter cluster in the brood area. Nest heating has an energetic cost: when ambient temperature drops from 28°C to 17°C, the metabolic rate of a bee colony rises from 7 to 19 Watt/Kg (Southwick, 1982). The "cluster" further contracts in the range of -5 to -18°C. Because of the harsh winter conditions of temperate climates, many bee colonies weaken or eventually die. Consequently, honey production is often reduced the following active season. Only strong bee colonies can produce high honey yields in temperate (Farrar, 1937) and subtropical (Hauser and Lensky, 1994) conditions.

Period / *Climatic factor*		*January*		*February*		*March*		*Annual*	
		01	*lta (*)*	*01*	*lta*	*01*	*lta*	*01*	*lta*
Ambient temp. (°C)	Max. (BD**)	20	19	19	19	25	24	25	24
	Min. (BD)	8	7.9	7.3	7.3	11	11	7.3	7
Precipitation (mm) (BD)		86	149	88	97	3	75	177	321
No. of rainy days		9		10		2			
Wind velocity (m/sec.)		1.3		1.8		1.5			

Table I: Temperature, rainfall, number of rainy days, and wind velocity in January-March 2001 (01) and longterm averages (lta) in Israel Central Coast Plain.
(*) Long-term averages cover the period of 1961-1990. (**) BD: Israel Meteorological Service, Bet-Dagan.

Date	*Positions of temperature (t°C) measurement*							
	Ambient		*Empty hives center*		*Populated hives*			
					Brood area		*Inner side of astern hive wall*	
	40 cm above the ground	200 cm above the ground	PE-covered	Non-covered	PE-covered	Non-covered	PE-covered	Non-covered
25.01.2001 Cloudy day	10.7-17.1 (6.4)	11-15.1 (5.1)	11.7-25 (13.3)	10.8-17 (6.2)	34.8-35.5 (0.7)	35.2-35.5 (0.3)	17.3-25.1 (17.8)	14.6-18.6 (4)
27.01.2001 Sunny day	0.8-22 (20.2)	4.7-16.3 (11.6)	2.5-34.4 (31.9)	0.8-22.2 (21.4)	35.2-35.7 (0.5)	35.0-36.0 (1)	9.1-29.2 (20.1)	6.4-19.9 (13.5)

Table II: Minimum-maximum values of ambient temperature and temperature inside empty and populated hives on a cloudy and a sunny day, January 2001, Rehovot.
The values inside the parentheses indicate the fluctuation of the daily temperature (difference between maximum and minimum values).

Treatment		Bee colonies in non-covered hives (n=4)		Bee colonies in PE-covered hives (n=5)	
	Date	Range	Average±S.D.	Range	Average±S.D.
B.A. (cm^2 or %)	21.12.00	3480-6584	4910±1302	3075-5791	4870±1125
	01.03.01	3550-5137	4390±587	4793±8684	7160±1683
	Average increase (cm^2)	(-1447)-198	(-520) ±2391	(-998)-3609	2290±792
	Average increase (%), P=0.05	(-28.7)-4.43	(-8.4)±13.5	(-17.2)-182	59.2±74.1
A.P. (No. or %)	21.12.00	9-13	10.60±2.0	9-13	11.4±1.7
	01.03.01	9-16	12.4±2.5	13-19	15.2±2.4
	Average increase (No. of occupied frames)	(-0.5)-4.5	1.8±2.4	1-10	3.8±3.6
	Average increase (%) (P 0.49)	0-39.1	11.8±22.1	7.7-111.1	37.5±41.8
Total spring honey yield (kg/colony), P=0.0004		4.3-15.3	10.2±4.54	16.7-24.5	20.8±3.1

Table III: The growth of brood area (B.A.), adult bee population (A.P.) between 21 December 2000 and 1 March 2001, and total spring honey production of bee colonies in PE-covered and non-covered hives.

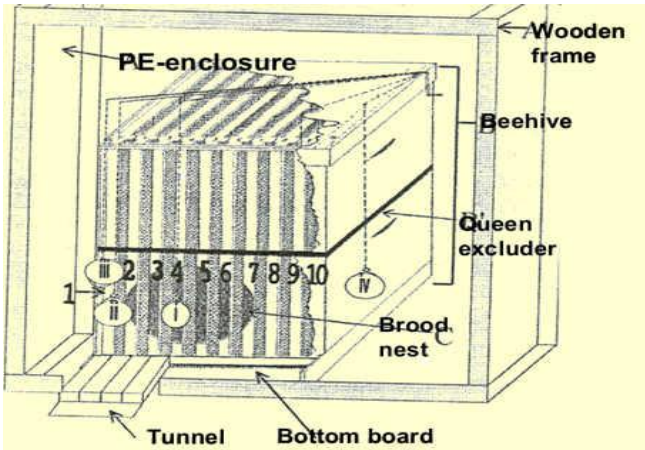
During the last century, researchers in the United States (Phillips and Demuth, 1914, Phillips and Demuth, 1918, Farrar, 1937, Owens, 1971, Detroy et al., 1982), Germany (Himmer, 1926, Büdel, 1968), France (Lavie, 1951), Norway (Villumstad, 1974) and in other countries, attempted to minimize winter losses of bee colonies by improving hive microclimatic conditions. They studied the effect of hive insulation on heat conservation inside the hive, reducing honey consumption from about 21 to 25% (Detroy et al., 1982), to up to 43% (Himmer, 1926). However, the relationship between hive insulation and the build-up of brood and adult bees and its impact on the spring honey production has not yet been fully explored. Some researchers have suggested solar heating of beehives: Morse (1999) recommended keeping bee colonies in the Northern U.S. during the winter in dark-painted hives and exposed to full sunlight, but provided no experimental data to indicate any beneficial effect of such a treatment. Indeed, one of the most debated and controversial topics of beekeeping in recent times has been that of the choice of the most desirable methods for wintering of bees in cold climates (Detroy et al., 1982). A major part of world honey and queen production is located in the subtropical zone (latitudes 23.5-34), which constitutes 22% of the earth's land surface where plants grow (Southern United States, Northern Mexico, Southern Australia, Northern Argentina and South Africa). In subtropical climates the day length changes less than in temperate zones and winters are milder. Hence, workers are foraging and queens are laying eggs almost year-round. In these regions, nectariferous plants supply nectar and pollen throughout the year and support a major part of the world honey and honey bee queen industry (Crane, 1990).

Wintering of bee colonies in the subtropics has not been considered a problem. Several researchers and professional beekeepers in South Africa (Anderson et al., 1983), in Australia (Warhurst and Goebel, 1995), and in the United States (Eckert, 1954, Furgala and McCutcheon, 1992) suggested that bee colonies can successfully winter in the subtropics if they are healthy, have adequate food reserves, are headed by young productive queens, have reduced hive entrances and are placed in a sunny part of the bee yard. However, there is no study on wintering bee colonies, nor on the effect of warming them using solar radiation.

The subtropical climate of the Coastal Plain of Israel is Mediterranean, with average annual precipitation above 400 mm from October to May. This type of climate, which prevails around the Mediterranean coast line, along the Southern Coast of Australia and California, as well as the South African Cape of Good Hope, and part of Western Argentina, is characterized by mild and rainy winters followed by hot, dry summers (Cleveland, 1994). In such conditions, honey bees forage and rear brood throughout most of the year (Bodenheimer and Ben-Neria, 1937). In Israel, painting hives white for the summer prevented bee colonies from overheating (Lensky, 1958) and increased their honey production (Lensky, 1964). These results have been confirmed in South Perth, Western Australia (Smith 1964) and in Arizona (Murtadha, 1985). However, there is no data on the effect of increasing temperature inside beehives during the winter and its correlation with spring honey production.

We, therefore, studied the impact of solar heating by covering hives with Infra-Red Polyethylene (PE)-sheets during the winter of the Coastal Plain of Israel on:

a. hive temperature;
b. colony population;
c. spring honey production.



Methods and Materials

Bee colonies

We used nine bee colonies headed by one-month-old, openmated laying Italian queens (Apis mellifera L. var. ligustica Spinol.) obtained from Kona Queen Hawaii, Captain Cook, Hawaii. We hived the colonies inside Langstroth hives and placed them on a sunny site in the bee yard, with their entrances facing south. On 21 December 2000, adult workers occupied 9 to 13 frames, with about 4 to 9 combs of brood/colony. We carried out our observations from 21 December 2000 until 5 April 2001, on the Campus of the Faculty of Agriculture at Rehovot. Covering hives with Polyethylene (PE) sheets.

PE-covered enclosures. We studied the impact of PE-covering on bee colonies during the winter season by placing five populated hives and an empty one, each inside its own enclosure constructed from wooden frames (107x97x106 cm) and covered with PE-sheets as illustrated in Fig. 1. Another four not covered populated hives and an empty one served as controls.

Each enclosure was covered with a single layer of Anti Drip, Infra Red, (AD-IR) Diffused, 150-micron Polyethylene (PE) sheets, Ginegar Plastic Products Ltd., Kibbutz Ginegar, Israel (http://www.ginegar.com/). The PE sheets are used in Israel for covering greenhouses and tunnels. They reduce sensible, latent and radiative heat losses from the covered area to the atmosphere. Their physical characteristics are: light diffusion-50.8%, light transmisson-82.6% at nm 400-700, and 85% thermicity.

Entrance tunnels to covered hives. To ensure safe passage of bees from the beehive to the exterior, through the PE sheets covering the enclosure, we attached four plastic tunnels (27x3x1.5 cm) to the bottom board of the beehive at the right corner of each entrance. The tunnels extended 15 cm from the bottom board and passed through a slit in the PE sheets covering the enclosure, terminating in an opening to the outside. Thus, the bees had a safe path to walk into and out of the hive and could not become trapped inside the dead space between the hive and enclosure (Fig. 1, A).

Management

Feeding. We supplied each colony with at least two full combs of honey. Whenever necessary, we fed the colonies with a pollen substitute containing brewers' yeast (Saccharomyces cerevisiae, Bruggeman, Gent, Belgium). We did not feed any colony sugar syrup.

Monitoring and treating pests and diseases. We monitored Nosema apis and Varroa destructor every two months, and treated all the colonies, whenever necessary.

Microclimate Measurement
We used a Campbell Scientific Micrologger 21x (Campbell Scientific, Logan, Utah, U.S.A) connected to two Multiplexes (AM 32-32, 64 channels, Campbell Scientific) to retrieve and store the data (temperature, solar radiation and wind velocity). The Micrologger retrieved data from all measuring positions at 1-min. intervals and presented them every 30 minutes as averages. For temperature measurements, we used thermocouples (copper-constantan, ±0.2°C) that were fixed with metal clamps to the center of all combs and hive walls mentioned:

I. A comb of brood near the nest center;
II. the inner side of comb # 1 (1 cm from the brood area);
III. the outer side of comb #1, which faced the western hive wall (4 cm from the brood area);
IV. the eastern hive wall (at least 6.5 cm from the brood area). The latter position is furthermost from the brood area, and thus, is least affected by the bees' thermoregulation.

In empty hives, we fixed the thermocouples to the center of:

i. the hive, 20 cm above the bottom board;
ii. the external northern hive wall, outside the hive, 40 cm above the ground.

For global radiation measurements, we used CM6 Solarimeter (Keep and Zonen, Delft, The Netherlands, ±7W/m2), placed 10 cm above the ground. For wind velocity measurements we used wind speed sensor (Met-One Instruments, Grants Pass, Oregon, U.S.A., ±0.2m/sec). Precipitation data were obtained from the Israel Meteorological Service, Bet-Dagan.

Nectariferous Plants
During the winter and the early spring season the following nectariferous plants flowered in Rehovot: Citrus spp, Eucalyptus rostrata, Eriobotrya japonica, Persea gratissima, Ceratonia siliqua, Sinapis arvensis, Raphanus raphanistrum, Senecio vernalis and various ornamental plants. The contribution of Citrus flowers to the nectar flow was minor, because most of the orchards near the Faculty of Agriculture Campus, Rehovot, had either been uprooted or dried out during the last 20 years.

Brood, adults and honey production
We measured the brood area size, calculated it and estimated the population of adult bees by counting the occupied frames on: 21 December 2000, 18 January 2001, 1 February, 8 February, 1 March and 23 March.

Brood area. We measured the brood area that contained eggs, larvae, and pupae on the combs in each bee colony and calculated its size (cm2) using the ellipse formula (Fresnaye and Lensky, 1961).

Adult bee population. We measured the size of adult bee population in each bee colony by estimating the number of frames that were covered with adult workers (Hauser and Lensky, 1994). The ratio of brood area/adult bee population. We calculated this ratio by dividing the average brood area size (cm2/100) by the number of populated frames.

Honey production. We raised supers that contained empty honey combs above the brood chambers after the beginning of the experiment. On 5 April 2001, we weighed all combs of honey in the honey supers of each colony, after shaking the bees off. We subtracted 11 kg, which represents the weight of a super containing 10 empty honeycomb frames, from the total weight of each super examined. We did not remove any combs of honey from the brood chamber. The result is the net honey weight in kg/ colony at that moment.

Results and Discussion
The climate of Israel's Coastal Plain: winter 2000-2001 The minimum-maximum temperature during January, February and March 2001 matched in general the long-term average in Table I. The daily maximum temperature fluctuated between 19 and 25°C, and resembled the long-term average of 19-24°C. Out of 1192 light hours, 1102 hours were sunny and warm (ambient ºt> 8°C). Workers cease flying when ambient temperature is below 8ºC (Crane, 1990), hence, the winter of 2000-2001 was quite favorable for foraging activities of field bees. The precipitation level in January was lower than the long-term average. In February it was close to the long-term average, however in March rainfall

was only three mm, whereas the long-term average was 75 mm. The total amount of precipitation for January, February and March 2001 was 177 mm, versus the corresponding long-term average of 321 mm. Due to scarcity of precipitation in the spring, the blooming period of nectariferous plants was shorter than normal.

The average wind velocity during January, February and March was 1.3, 1.8 and 1.5 m/sec., respectively. In general, the activity of foragers stops at wind velocities above nine m/sec. (Hoopingarner and Waller, 1992), but wind velocity never reached that value during the study.

The short, mild winter and the long, dry and hot summer coupled with continuous foraging activity of field bees was in general typical for the subtropical Mediterranean climate of Israel’s Central Coastal Plain.

The climate near the ground in the bee yard

The beehives were placed on sandy soil covered with scattered vegetation composed of perennial shrubs and annuals. The temperature fluctuations during a cloudy and a sunny day at 200 cm above the ground were lower than those recorded at 40 cm above the ground at the level of the beehives (Table II). The higher the measuring site above the ground, the narrower was its daily fluctuation. Figure 2 shows the daily fluctuations of ambient. temperature at 40 cm and at 200 cm above the ground compared to those of the global radiation on 25-27 January 2001. The maximum temperature at 40 cm above the ground was higher on sunny days than on cloudy days (22 versus 17.1°C), and the maximum global radiation was 740 and 551 Watt/m2, respectively.

The minimum temperature at both heights above the ground were higher on cloudy days than on sunny days because the clouds absorbed the long-wave radiation from the ground and radiated part of it back, thus reducing heat loss from the ground. The effect of PE on the temperature of empty and populated hives.

On a cloudy day, the minimum-maximum temperature inside PE-covered empty hives were higher by 8°C (25 versus 17°C) and 0.9°C (11.7 versus 10.8°C), espectively, than in the non-covered hive (control). On a sunny day, the minimum-maximum temperature inside PE-covered, empty hive was higher than in the noncovered hive (control) by 12.2°C (34.4 versus 22.2°C) and 1.7°C (2.5 versus 0.8°C), respectively (Table II).

Daily temperature fluctuations inside empty PE-covered and non-covered (control) hives during a cold period (25-27 January 2001) are shown in Fig. 3. The temperature difference between the center of the empty hive and the ambient one at 40 cm above the ground was usually smaller than 0.5°C (Figs. 2 and 3) and it resembled that of the air layer near the ground, where its daily fluctuation was the widest. The temperature inside PE-covered hives reached its peak between 12:00 and 14:00 hrs (Fig.3). The transparent PE-cover over the enclosure acts like a greenhouse, mainly, by reducing heat losses through sensible and latent heat fluxes from the covered area. The PE-cover also reduces radiative heat losses by preventing part of the long-wave radiation from leaving its surface. The PE absorbs the IR radiation and radiates back part of it into the enclosure.

One way to increase the temperature inside a hive is to paint it dark. The temperature inside an empty, black painted hive in Rehovot in March at noontime was higher by 14.5°C than that inside a white painted hive (Lensky and Seifert, 1979). During the night, the PE-cover contributed to a 0.9 -1.7°C higher hive temperature, while the black painted hive did not.

Daily temperature fluctuations at the eastern inner walls of populated hives. Table II shows that inside PE-covered and populated hives the maximum temperature was higher by 6.5°C (25.1 versus 18.6°C) on a cloudy day and by 9.3°C (29.2 versus 19.9°C) on a sunny day, than the °t inside non-covered and populated hives. The min. value inside PE-covered hives was 2.7°C (17.3 versus 14.6°C) higher on cloudy night and 2.7°C higher on a clear night than (9.1 versus 6.4°C) in the control hives. This difference is higher than inside empty hives (0.9 and 1.7°C, respectively), because of the thermoregulation by the workers inside populated hives.

Hive insulation or exposure to solar radiation in the winter? The insulation of a beehive is supposed to minimize the heat-losses from the hive, and thus to reduce the thermoregulative effort of honey bee workers. However, insulation can contribute to moisture being retained in a colony; and damage can result where bees reside in a moist environment. Water can evaporate, then condense and freeze inside colonies in temperate regions (Sanford, 2002, personal communication). Phillips and Demuth (1914, 1918) recommended insulating hives during the winter. They did not report on the effect of insulation with regard to colony performance during the subsequent spring.

Hive insulation resulted in 7°C ºt increase around the winter cluster versus non-insulated hives (Owens, 1967). That could have a positive effect at nighttime, when the hive cools down. During the day, the effect of insulation might be negative. Insulation slows down the rate of energy exchange between the hive and the environment; also, it could slow down the penetration into the hive of heat that was generated through solar radiation. In our trials, the PE-enclosure served as an insulator during the night, yet during the day it increased the rate of hive heating. Therefore, whenever ambient temperature reaches 23°C at 200 cm above the ground, we recommend removing the PE-enclosure from the beehives to prevent their overheating.

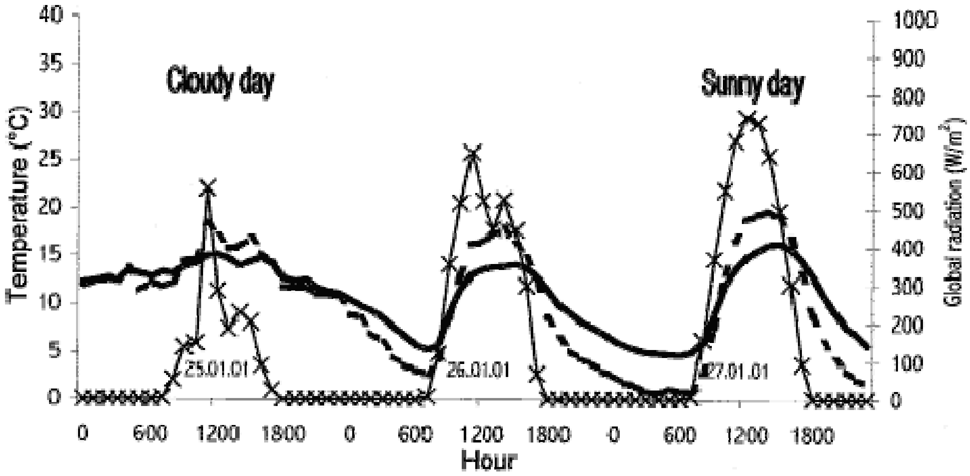


Fig. 2: Diurnal cycles of ait temperature at 40 cm and at 200 cm above the ground, and of global radiation, 24-28 January 2001

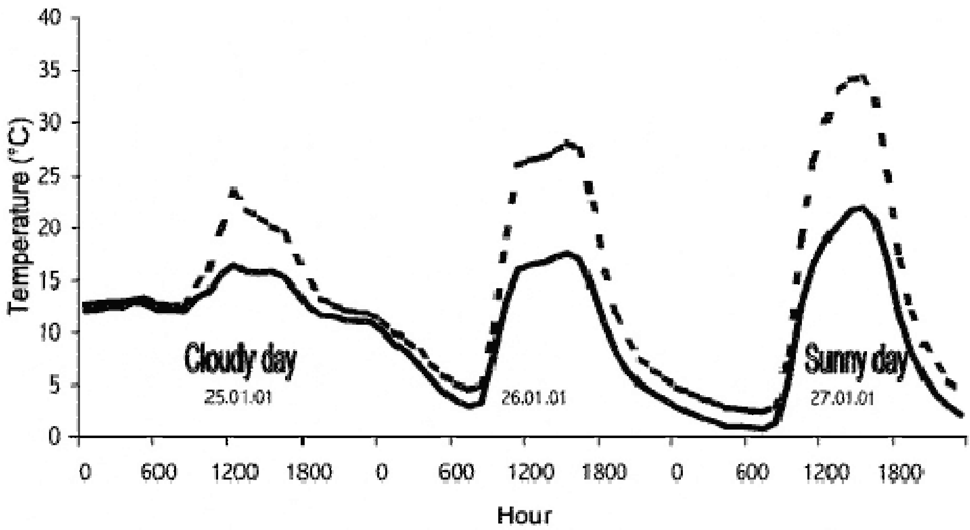


Fig. 3: Diurnal cycles of ait temperature in an empty hive inside PE-enclosure and an empty, non covered hive, 25-27 January 2001

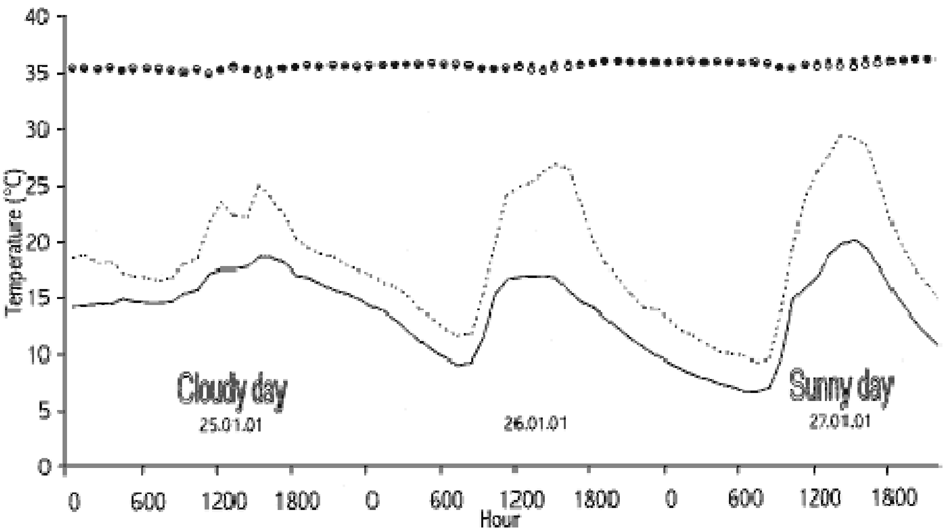


Fig. 4: Diurnal cycles of ait temperature in a populated hive inside PE-enclosure and a populated, non covered hive, 25-27 January 2001

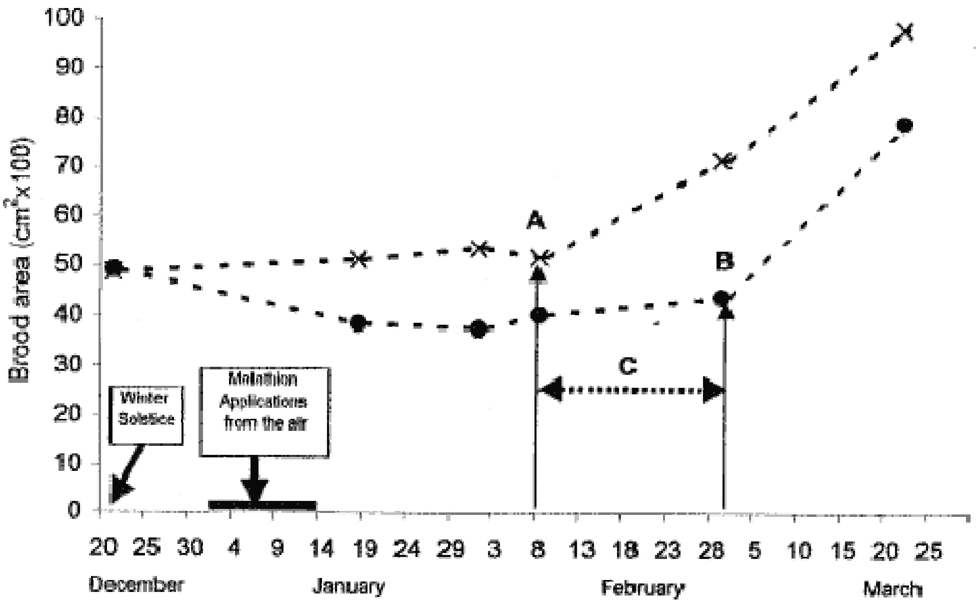
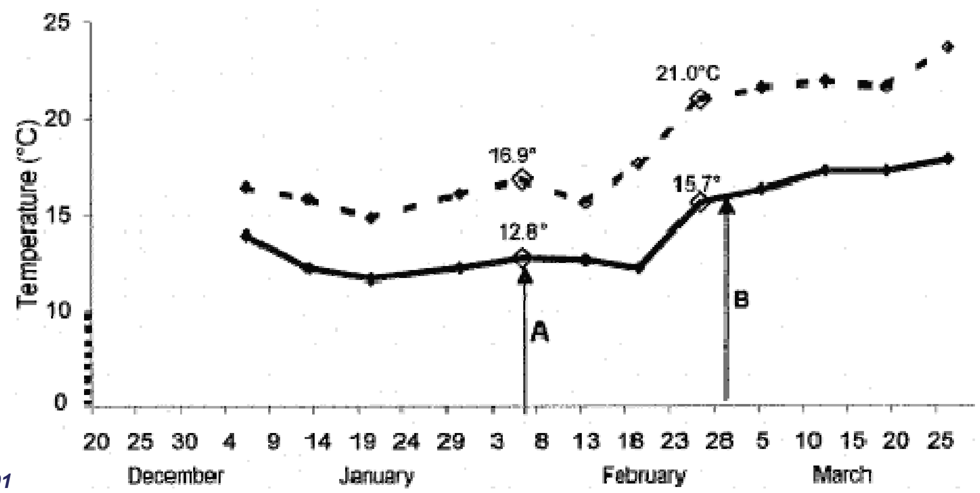


Fig. 5: Changes in brood aeras of bee colonies in covered and non-covered hives. A and B indicate the date of the beginning of a fast built-up of the brood aera in the spring inside PE-enclosures and in non-covered hives, respectively. 21 December 2000



- 22 March 2001

Fig. 6: The average weekly temprature in PE-covered and no-covered empty hives.A and B indicate the date of the onset of the t increase of brood area inside covered and non-covered hives, respectively. 6 January 2000 - 22 March 2001

The effect of PE on brood, adult bee population, and honey production

Brood area dimensions. Bee hives covered with PE-enclosures increased brood area by 59%. In non-covered hives there was a decrease of 8.4% brood area (Table III). The fluctuations of the measured brood area appear to reflect increased queen's egg laying activity by the queen and increased nursing activity by the worker bees.

The brood area in PE-covered colonies increased slowly until the beginning of February (A), whereas in the non-covered hives during this period the area diminished by 1100 cm2 (Fig. 5). From the beginning of February the brood area increased rapidly in PEcovered hives. In the non-covered hives rapid expansion of the brood area took place only three weeks later, namely at the beginning of March (B). Line (C) represents the time difference between the fast increase of brood area in PE-covered and noncovered hives.

Fast brood development took place in colonies belonging to non-covered (control) and covered hives when the average weekly temperature in an empty hive reached 15.7 and 16.9°C respectively (Fig. 6). PE-covered empty hives reached that critical temperature about three weeks earlier than non-covered ones.

During the winter, the brood area in PE-covered hives increased 67.6% (increase of 59.2 versus a decrease of 8.4%) faster in area than in the non-covered hives. This increase might be explained by the following hypotheses:

A given number of workers may be able to tend and feed a limited number of developing bees including larvae. Since the winter cluster expands as temperature rises from -5 to +18°C (Wilson and Milum, 1927), it appears that within and above this range, bee colonies are able to rear brood. Indeed, in March, the ratio of brood area/number of frames occupied by adult workers in the PEcovered hives was larger than that in the non-covered controls. Winter clusters inside hives heated by an electric tape (140 W), were more dispersed than those inside insulated or standard noncovered hives (Owens, 1967). It is possible that the clusters inside insulated hives did not expand because of low temperature that was due to a reduced conductivity of solar energy through the insulated hive walls.

In the PE-covered hives outside the brood area, the temperature, as well as the activity of the workers and the queen, might have been higher than in the controls.

Insulative Effects: Northern United States' bee colonies that have been insulated during the winter had 70% more brood than the non-protected colonies (Owens, 1971). In Norway, bee colonies hived during the winter inside double-walled hives produced in the spring 14% more brood than the control ones (Villumstad, 1974). In North India in Jammu and Kashmir Provinces, hive insulation contributed to a 122% larger brood area than in controls (Abrol, 2001). In Wisconsin, colonies inside hives covered with semi-transparent plastic plates produced 10% more brood than the controls (Detroy et al. 1982).

Adult bee population inside non-covered and PE-covered hives increased by 11.8 and 37.5%, respectively (Table III). The ratio between the size of the brood area (in 100 x cm2) and the size of adult bee population (No. occupied frames) in PE-covered and in non-covered hives on 21 December 2000 was 4.3 {(4870/100cm2)/11.4 occupied frames} and 4.6 {(4910/100cm2)/10.6 occupied frames}, respectively. On 1 March 2001, the ratio was 4.7 {(7160/100cm2)/15.2 occupied frames}, which was 30% higher than that of 3.5 {(4390/100cm2)/12.4 occupied frames} in non-covered hives.

Spring honey production. The colonies inside PE-covered hives produced twice as much as the colonies inside non-covered hives: 20.8±3.1 Kg honey/bee colony, versus 10.2±4.5 Kg honey/bee colony, respectively ($P=0.0004$) (Table III).

We can make hypotheses about the increased honey yields harvested during the spring from the PE-covered hives as follows: The warmer environment inside the PE-covered hives may have resulted in swifter build-up of worker bee population, which produced higher honey yields, both in temperate (Farrar, 1937) and in subtropical climates (Hauser and Lensky, 1994). The high temperature around of the brood area could have enhanced several activities of the workers, including ripening of the honey crop.

The higher temperatures that prevailed inside the PE-covered hives than in the controls, may have saved thermoregulatory energy expenditure by the workers, and consequently reduced their honey consumption. When ambient temperature decreases from 35 to 10°C, the oxygen consumption of a single worker bee increases from 4-to 44-ml. oxygen/gram body weight/hour (Southwick, 1991).

Some reports from temperate regions indicate that hive insulation may cause a decrease in honey consumption: In Germany, wintering bee colonies in an insulated and in control hive consumed 1.87 and 3.3 kg honey, respectively (Himmer, 1926). In Wisconsin, colonies covered with semi-transparent plastic consumed 25% less honey than those inside control hives (Detroy et al. 1982).

The above studies referred only to honey consumption, but did not reflect honey production, thus leaving the economic importance of hive insulation in temperate climates unclear on that point.

The results of this study show that even in subtropical climates covering honey bee colonies promotes greater brood rearing and, subsequent honey production. It is recommended that beekeepers at least experiment with this technique to see if it fits with their particular management style.

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