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THERMOREGULATION WITHIN HONEY BEE *Apis mellifera* COLONY

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ABSTRACT

Thermoregulation within the honey bee, *Apis mellifera jemenitica*, and colony was monitored at the apiary belonging to the Agriculture Research Center, Ministry of Agriculture and Fisheries, Muscat, Sultanate of Oman during September, 2007. The temperature and the relative humidity were recorded at 1-hour intervals / 24 hours for period of 5 days by using HOBO RH & Temp data logger. Three groups of colonies (according to its status and strength) were considered: the 1st headed with good queen and received perfect colony management (bees covered 10 combs); the 2nd had a high inbreeding value (bees covered 6 combs) and the 3rd comprised laying workers (bees covered 4 combs).

In the 1st group the outdoor (outside the hive) temperature and humidity throughout the day recorded an average of 30.21±2.38 ^{o}C & 43.53±5.11%, respectively. The worker bees regulated the colony conditions inside the hive to reach thermal equilibrium. Whereas the average ambient temperature and humidity were 35.51±0.24 ^{o}C & 54.34±2.31%, respectively for sealed brood, 34.46 ±0.27 ^{o}C & 57.94 ±0.41%, respectively for open brood / eggs and 33.49±0.49 ^{o}C & 53.21±1.27, respectively for empty / honey comb .

In the 2nd group, the mean outdoor temperature was 31.73±1.53 ^{o}C and humidity was 59.46±6.79% throughout the day. The sealed brood, which included in between open brood and empty cells according to the degree of inbreeding, the worker bees tried to reach the temperature and humidity to the allowable limits which recorded 34.56±0.31 ^{o}C and 53.42±2.31%, respectively. The corresponding values for the open brood / eggs was 33.13 ±0.17 ^{o}C & 53.26±2.77%, respectively and for empty / honey comb was 31.05±1.59 ^{o}C & 41.07±1.13%, respectively.

In the 3rd group, which had laying workers, the temperature and humidity were 31.04±1.75 °C & 60.65±4.52% in outdoor 31.88±1.16 °C & 41.59±1.21%for remaining brood / eggs 31.76±1.36 °C & 44.89±0.93% for eggs / empty and 31.09±1.54 °C & 48.82±0.75% for empty / honey, respectively.

INTRODUCTION

The individual worker of honey bee *Apis mellifera* is heterothermaic (cold blooded), but the honey bee colony looks like homeothermic (warm blooded) as a superorganism (Grodzicki and Caputa 2005). Worker bees regulate brood nest temperature via alternating warming and cooling periods while transferring its body heat to the brood nest by either sitting on the surface of sealed brood cells or making several longitudinal visits to the open brood cells (Levin & Collison 1990; Watmough & Camazine 1995 and Kleinhenz *et al* 2003). Moreover the genetic variance also play a role for regulating brood nest temperature where brood nest temperatures in genetically diverse colonies tend to be more stable than in genetically uniform ones (Jones *et al* 2004 and Graham *et al* 2006). According to the type of tasks for colony needed to regulate its climate, bees foraging to collect either nectar (Kovac and Schmaranzer 1996) or water (Schmaranzer 2000).

At low temperature the worker bees manage to regulate the nest temperature to the thermal adequate by crowding together in a cluster as the mantle and endothermic bees arrange themselves in the core and towards the surface of the cluster (Fahrenholz *et al*, 1989; Myerscough 1993; Akimoto 2000 and Stabentheiner *et al* 2003 b).

The present work aimed to find out the actual temperatures needed for worker brood either sealed or open. Moreover, eggs and honey in normal colonies and comparing it with default colonies either by queen (inbreeding) or by beekeeper (laying worker).

KeyWords:honeybee- *Apis mellifera*- thermoregulation– inbreeding-laying worker

MATERIALS AND METHODS

Thermoregulation within the honey bee *Apis mellifera jemenitica* colony was achieved at the apiary belonging to the Agriculture Research Center, Ministry of Agriculture and Fisheries, Muscat, Sultanate of Oman during September, 2007.

Nine colonies situated under the shadow of huge ziziphus tree were chosen which were divided into three groups comprising three colonies each according to their status and strength. The 1st group was headed with good queens and had perfect colony management, the hive had 10 combs and the bees covered all combs. The 2nd group was headed with inbreed queens and received moderate colony management, the hive had 8 combs and the bees covered 6 combs. The percentage of inbreeding was calculated by counting the number of holes among the brood cells in an area of one inch^2, replicated ten times per colony. The 3rd group had laying workers and received bad colony management where the colonies were dequeening and the open brood combs were elevated for ten days before starting the experiment, the hive had 6 combs and the bees covered 4 combs.

The temperature and the relative humidity were measured at 1-hour intervals for a period of 5 days in three different locations within each colony of each group. This work was carried out by using the apparatus of HOBO RH & Temp data logger (Onset Computer and Technical Support, Bourne, USA). The recorded data was downloaded, analyzed and figured graphically using BoxCar Pro4 software for the fluctuations in relative humidity and temperature of the surroundings. It was difficult to tabulate in detail the obtained data, therefore, the 24 hours of the day were divided into 5 categories: 1- Midnight to Sunrise (0–5am), 2- Morning (6am – 10am), 3- Midday (11am – 2pm), 4- Afternoon (3pm – 6pm) and 5- Sunset to Midnight (7pm – 23pm).

Ten apparatus were used, one was located outside the hives and the other nine were placed inside the colonies of each group, i.e. three per colony for the three hives as follows: The first group was carried out from 15 to 19 / 9 / 2007. The 1st apparatus was inserted between sealed brood combs, the 2nd was inserted between open brood / eggs combs and the 3rd was inserted between empty / honey combs and repeated in the same manner as in the other two colonies.The second group was carried out from 20 to 24 / 9 / 2007. The 1st apparatus was inserted within sealed brood combs which included in between eggs or open brood according to the degree of inbreeding. The 2nd was inserted between open brood / eggs and eggs / empty combs and the 3rd was inserted between empty / honey combs and repeated in the same manner as previous the two colonies.The third group was carried

out from 25 to29 / 9 / 2007, the 1st apparatus was inserted between brood / eggs combs, the 2nd was inserted between eggs / empty combs and the 3rd was inserted between empty / honey combs and repeated in the same manner as in the other two colonies.

RESULTS AND DISCUSSION

Generally workers of the honey bee *Apis mellifera* and moreover *A m jemenitica* race tend to stabilize the climate, i.e. temperature and relative humidity inside the colony nest by thermoregulation either by fanning and collecting water in hot weather or by clustering in cold weather. The data of the present work show that the thermal behaviour differed according to the colony status.

Group1: Good queen and perfect colony management

As shown in Table (1) & Fig. (1), the outdoor temperature, relative humidity and dew point fluctuated during the day. The worker bees in colonies headed with good queens and aided by perfect management tended to regulate the nest climate within the required thermal equilibrium needed for each developmental stage and general colony status throughout the day.

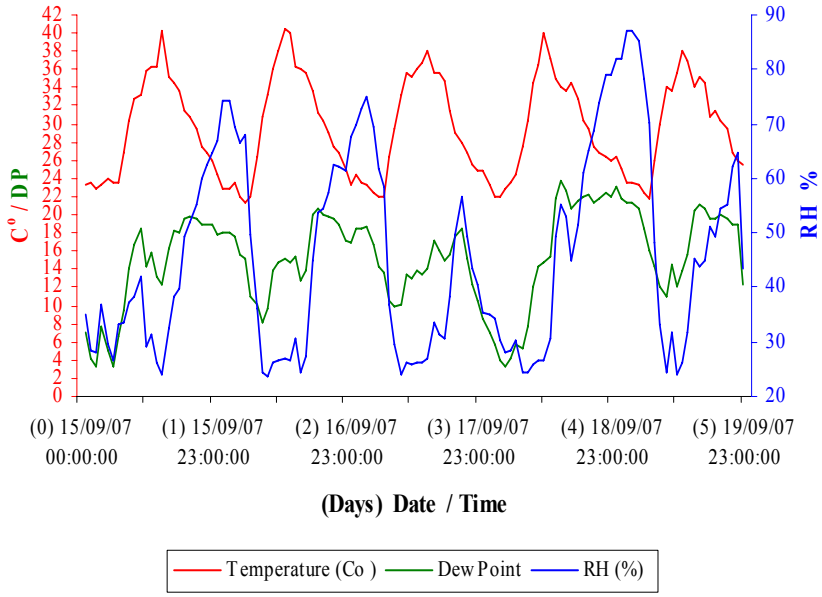

Fig.(1): Daily outdoor temperature , humidity and dew point during 15-19/9/2007

Table(1): The outdoor temperature, humidity and dew point at different periods within a day during 15-19/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	23.43 ±0.40	30.72 ±4.18	5.12 ±1.83	29.32 ±4.08	36.90 ±3.64	13.06 ±5.02	37.18 ±2.01	27.7 ±3.23	13.86 ±1.50	33.7 ±1.61	40.05 ±7.08	18.06 ±1.40	28.08 ±1.97	58.9 ±5.23	19.22 ±0.40	30.34 ±2.36	38.85 ±5.47	13.86 ±2.48
2nd	22.86 ±1.09	69.88 ±3.56	17.05 ±1.32	29.69 ±5.56	32.08 ±10.99	10.58 ±2.08	38.68 ±1.92	27.67 ±2.02	14.98 ±0.38	34.13 ±2.30	37.55 ±14.03	16.78 ±4.07	27.77 ±2.01	29.52 ±3.52	19.13 ±1.16	30.61 ±2.71	40.53 ±4.56	17.29 ±2.28
3rd	23.18 ±0.82	69.38 ±4.58	17.24 ±1.64	29.36 ±5.40	35.08 ±13.92	11.47 ±1.81	36.56 ±1.20	26.40 ±0.37	13.55 ±0.53	34.44 ±1.99	33.42 ±3.47	15.96 ±0.89	26.82 ±1.74	47.94 ±6.19	14.80 ±3.40	30.07 ±2.45	41.90 ±1.62	17.85 ±2.65
4th	23.12 ±1.02	31.90 ±3.44	5.43 ±1.99	30.65 ±4.96	26.18 ±2.38	8.99 ±3.93	36.57 ±2.66	40.40 ±13.92	18.91 ±4.56	32.77 ±1.78	52.70 ±6.65	21.72 ±0.84	27.21 ±1.41	73.18 ±6.24	21.94 ±0.47	30.06 ±2.31	40.25 ±8.99	17.19 ±5.80
5th	24.08 ±1.41	83.60 ±3.56	21.11 ±1.51	29.03 ±5.23	41.66 ±18.16	13.55 ±2.06	36.17 ±1.75	31.87 ±9.44	15.49 ±3.60	32.98 ±2.21	47.45 ±3.51	20.28 ±0.8	27.61 ±2.16	56.00 ±8.31	17.92 ±3.23	29.97 ±2.10	52.12 ±8.80	17.67 ±1.42
Mean ± s.e.	23.33 ±0.21	57.10 ±10.83	13.19 ±3.31	29.61 ±0.28	34.38 ±2.57	11.53 ±0.83	37.03 ±0.44	30.81 ±2.57	15.36 ±0.96	33.60 ±0.32	42.23 ±3.47	18.56 ±1.07	27.50 ±0.22	53.11 ±7.17	18.60 ±1.15	30.21 ±2.38	43.53 ±5.11	15.45 ±1.41

In the sealed brood, the daily averages of ambient temperature were 35.51±0.24 ^{o}C ranging between 34.92±0.05 ^{o}C from midnight to sunrise and 36.11±0.17 ^{o}C during midday. The average relative humidity was 54.34±2.31 % ranging from 53.19±3.72 % from sunset to midnight to 56.26±3.17% during the morning (Table, 2 & Fig., 2).

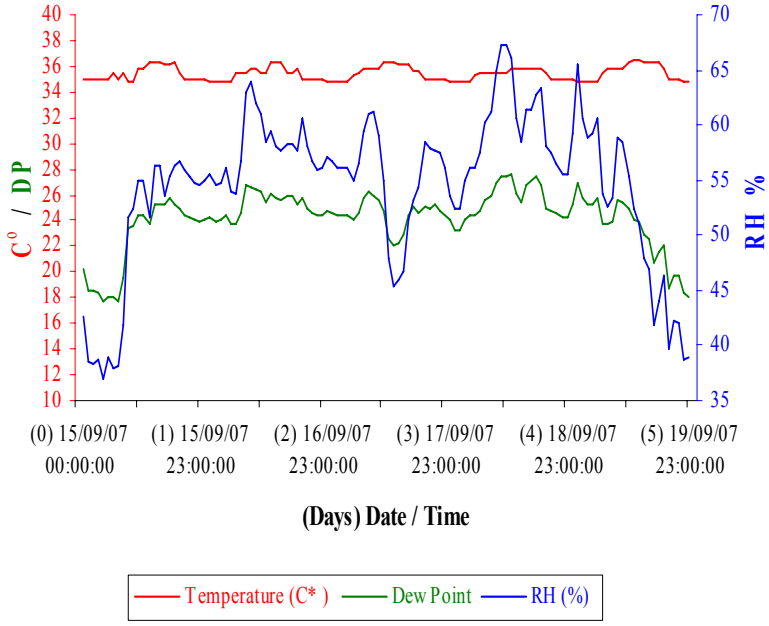

Fig.(2): Daily ambient temperature, humidity and dew point for sealed worker brood during 15-19/9/2007

Table(2): The ambient temperature, humidity and dew point for sealed worker brood at different periods within a day during 15-19/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.
1st	35.01 ±0.17	40.27 ±1.55	18.90 ±0.70	35.11 ±0.35	44.36 ±7.15	20.47 ±2.88	36.06 ±0.24	54.47 ±2.01	24.48 ±0.61	36.20 ±0.52	55.38 ±7.52	25.36 ±8.05	35.09 ±0.17	55.44 ±0.88	24.28 ±0.42	35.79 ±0.26	49.18 ±2.95	21.90 ±1.09
2nd	34.87 ±0.00	55.02 ±0.79	24.07 ±0.24	35.60 ±0.23	59.86 ±4.40	25.61 ±1.38	35.85 ±0.24	58.97 ±1.43	25.90 ±0.36	35.74 ±0.21	57.97 ±0.38	25.65 ±0.27	35.01 ±0.29	56.50 ±0.42	24.52 ±0.13	35.41 ±0.20	57.66 ±0.86	25.15 ±0.36
3rd	34.92 ±0.00	57.12 ±2.03	24.70 ±0.59	35.77 ±0.23	59.48 ±1.91	25.61 ±0.64	36.33 ±0.25	48.55 ±4.38	22.92 ±1.28	35.91 ±0.43	51.37 ±3.34	24.27 ±0.94	35.01 ±0.19	53.96 ±1.62	23.82 ±0.52	35.59 ±0.27	54.09 ±1.95	24.26 ±0.45
4th	34.92 ±0.17	57.37 ±0.86	24.84 ±0.32	35.43 ±0.00	62.24 ±3.87	26.12 ±1.05	35.94 ±0.21	63.10 ±4.24	26.64 ±1.02	35.85 ±0.41	62.20 ±0.96	27.04 ±0.34	35.09 ±0.03	60.98 ±2.67	25.79 ±0.72	35.45 ±0.21	61.18 ±1.01	26.09 ±0.38
5th	34.88 ±0.00	57.08 ±1.44	24.69 ±0.42	35.77 ±0.19	55.36 ±2.99	24.47 ±0.96	36.35 ±0.25	51.70 ±3.12	23.99 ±0.84	36.16 ±0.21	44.77 ±2.33	21.72 ±0.79	34.95 ±0.23	39.06 ±2.10	18.69 ±0.96	35.62 ±0.33	49.59 ±3.38	22.71 ±1.13
Mean ± s.e.	34.92 ±0.05	53.37 ±3.30	23.44 ±1.14	35.54 ±0.28	56.26 ±3.17	24.46 ±1.03	36.11 ±0.17	55.36 ±2.58	24.79 ±0.67	35.97 ±0.20	54.34 ±2.79	24.81 ±0.89	35.03 ±0.07	53.19 ±3.72	23.42 ±1.23	35.51 ±0.24	54.34 ±2.31	24.02 ±0.77

It was noticeable, that the daily ambient temperature for the open worker brood and eggs were less by about one degree than in the sealed brood as it recorded an average of 34.46±0.27 ^{o}C ranging between 33.73±0.08 ^{o}C from midnight to sunrise - 35.34±0.31 ^{o}C during midday. Moreover, the relative humidity was slightly higher as it was an average of 57.94±0.41% (56.77±0.36% from midnight to sunrise and 59.20±1.14 during the midday), Table (3) & Fig. (3).

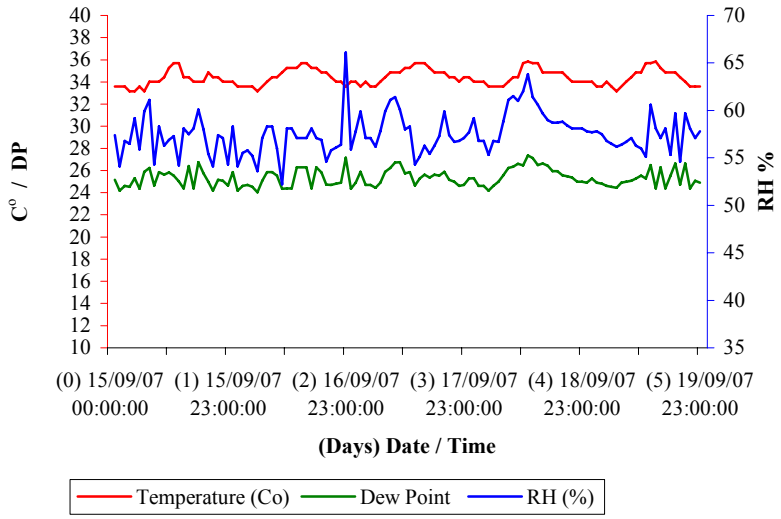

Fig.(3): Daily ambient temperature, humidity and dew point for open worker brood and eggs during 15-19/9/2007

Table(3): The ambient temperature, humidity and dew point for open worker brood and eggs at different periods within a day during 15-19/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	•C	RH %	D.P.	•C	RH %	D.P.	•C	RH %	D.P.	•C	RH %	D.P.	•C	RH %	D.P.	•C	RH %	D.P.
1st	33.52 ±0.72	56.65 ±1.68	24.68 ±0.45	33.92 ±0.23	57.98 ±2.73	25.65 ±0.60	35.27 ±0.07	56.62 ±1.69	25.18 ±0.64	34.11 ±0.36	58.42 ±1.15	25.81 ±1.05	34.35 ±0.35	55.66 ±1.54	24.81 ±0.40	34.23 ±0.29	57.07 ±0.58	25.23 ±0.22
2nd	33.59 ±0.17	55.42 ±1.56	24.65 ±0.64	34.26 ±0.29	56.38 ±2.52	25.33 ±0.63	35.38 ±0.16	57.60 ±0.58	25.33 ±1.11	35.27 ±0.21	57.30 ±0.54	25.69 ±0.91	34.18 ±0.36	57.80 ±4.69	25..25 ±1.06	34.54 ±0.34	56.90 ±0.44	25.25 ±0.17
3rd	33.80 ±0.17	57.33 ±1.43	24.83 ±0.56	34.59 ±0.23	59.82 ±2.04	25.95 ±0.76	35.48 ±0.35	61.95 ±1.36	26.85 ±0.45	35.16 ±0.25	59.02 ±0.78	26.24 ±0.35	34.43 ±0.19	57.58 ±1.32	25.07 ±0.51	34.69 ±0.29	59.14 ±0.84	25.79 ±0.37
4th	33.94 ±0.17	57.10 ±1.29	24.76 ±0.44	34.01 ±0.22	59.82 ±2.04	25.95 ±0.66	35.08 ±0.35	61.95 ±1.36	26.85 ±0.45	34.85 ±0.25	59.02 ±0.47	26.24 ±0.35	34.26 ±0.19	58.30 ±0.31	25.28 ±0.27	34.42 ±0.23	59.28 ±0.81	25.82 ±0.36
5th	33.80 ±0.17	57.35 ±0.56	24.83 ±0.26	34.01 ±0.59	56.54 ±0.36	24.93 ±0.31	35.52 ±0.25	57.87 ±3.63	25.49 ±0.76	34.95 ±0.36	57.55 ±1.84	25.71 ±1.00	33.84 ±0.30	57.46 ±1.86	25.74 ±0.88	34.42 ±0.35	57.35 ±0.22	25.34 ±0.19
Mean ± s.e.	33.73 ±0.08	56.77 ±0.36	24.75 ±0.04	34.16 ±0.16	58.11 ±0.75	25.56 ±0.19	35.34 ±0.31	59.20 ±1.14	25.94 ±0.37	34.67 ±0.23	58.26 ±0.36	25.94 ±0.12	34.21 ±0.12	57.36 ±0.45	25.23 ±0.15	34.46 ±0.27	57.94 ±0.41	25.48 ±0.23

The averages temperature between empty and honey combs was 33.49 ± 0.49 °C ranging from 32.13±0.05 °C during night - sunrise to 34.94±0.11 °C during midday. The relative humidity was 53.21±1.27% giving a law of 49.60±3.57% during midday, and a high 56.38±1.18% from midnight to sunrise, (Table 4 & Fig., 4).

The dew point is the temperature in which air must be cooled in order to reach saturation i.e. where vapor begins to condense. The present data showed that bees tend to regulate the colony climate according to the status within the hive by regulating the dew point between allowable narrow limits. It was slightly higher in open brood 25.48±0.23 °C followed by sealed brood 24.02±0.77 °C and finally empty and honey comb 22.19±0.15 °C.

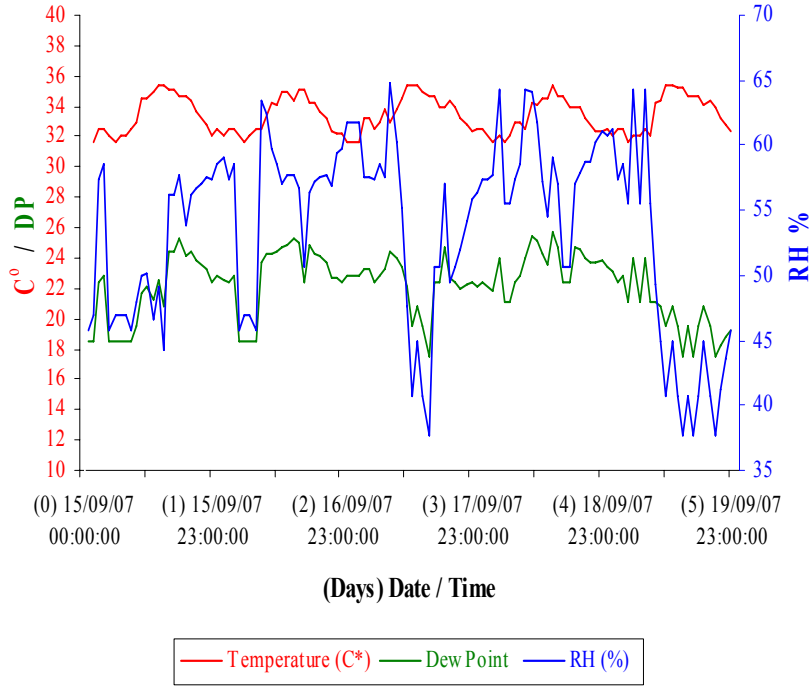

Fig.(4): Daily ambient temperature, humidity and dew point for empty and honey combs during 15-19/9/2007

Table(4): The ambient temperature, humidity and dew point for empty and honey combs at different periods within a day during 15-19/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	32.03 ±0.36	50.22 ±6.02	19.84 ±2.12	32.86 ±1.02	47.50 ±1.58	19.32 ±1.42	35.03 ±0.40	47.52 ±2.60	21.72 ±0.76	34.44 ±0.24	56.00 ±1.57	24.56 ±0.50	33.18 ±0.93	56.96 ±0.52	23.79 ±0.73	33.51 ±0.54	51.64 ±2.04	21.85 ±1.04
2nd	32.21 ±0.33	54.37 ±6.24	21.25 ±2.18	32.93 ±0.82	55.66 ±8.61	21.82 ±3.09	34.82 ±0.53	57.80 ±0.62	24.81 ±0.38	34.23 ±0.48	55.25 ±3.05	24.14 ±1.23	32.35 ±1.05	58.28 ±1.25	23.10 ±0.74	33.31 ±0.52	56.27 ±0.76	23.02 ±0.67
3rd	32.30 ±0.80	59.57 ±2.34	22.93 ±0.30	33.59 ±0.70	59.28 ±3.60	23.58 ±0.66	35.24 ±0.21	43.52 ±3.44	20.48 ±1.24	33.91 ±0.21	49.05 ±8.14	21.73 ±3.01	33.45 ±1.01	52.42 ±2.54	22.33 ±0.26	33.70 ±0.47	52.77 ±3.07	22.21 ±0.53
4th	32.01 ±0.36	58.12 ±3.14	22.27 ±0.94	32.93 ±0.77	59.96 ±4.02	23.13 ±1.62	34.61 ±0.53	58.15 ±3.00	24.69 ±0.94	34.02 ±0.24	53.90 ±3.69	23.52 ±1.37	32.92 ±0.70	59.36 ±1.30	23.94 ±0.36	33.30 ±0.46	57.90 ±1.06	23.51 ±0.40
5th	32.11 ±0.33	59.63 ±3.15	22.82 ±0.97	33.27 ±1.47	53.92 ±7.31	21.63 ±1.31	35.01 ±0.40	41.02 ±3.00	19.34 ±1.34	34.33 ±0.40	41.02 ±3.00	19.34 ±1.34	33.43 ±1.01	41.82 ±3.06	18.65 ±0.78	33.63 ±0.49	47.48 ±3.90	20.36 ±0.79
Mean ± s.e.	32.13 ±0.05	56.38 ±1.18	21.82 ±0.58	33.12 ±0.14	55.26 ±2.24	21.90 ±0.74	34.94 ±0.11	49.60 ±3.57	22.21 ±1.10	34.19 ±0.10	51.04 ±2.78	22.66 ±0.96	33.07 ±0.20	53.77 ±3.21	22.36 ±0.97	33.49 ±0.49	53.21 ±1.27	22.19 ±0.15

Group2: Inbreed queens and moderate colony management

The outdoor temperature, relative humidity and dew point are exhibited in Table (6) & figure (5). In this group the average percentage of inbreeding was 30.1 % ranging from 26.9% to 33.4%, Table (5).

Table (5): Number of sealed worker brood and their empty cells / inch^2 in *Apis mellifera jemenitica* colony during 20 to 24 / 9 / 2007.

Colony no.	No. of cells	No. of empty cells	% of inbreeding
1st	27.6±1.69	8.1±2.77	29.3
2nd	27.1±1.78	7.3±1.94	26.9
3rd	28.1±1.54	9.4±1.76	33.4
mean± s.e.	27.6±0.29	8.3±0.61	30.1

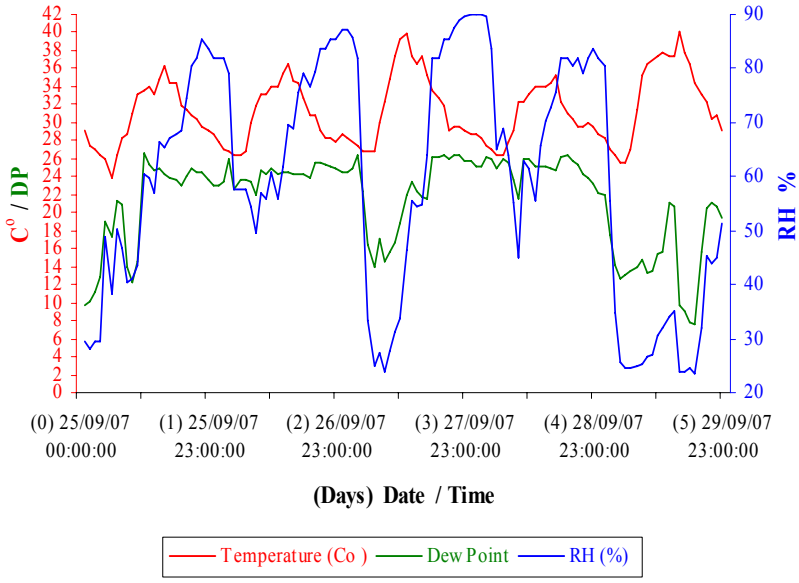

Fig.(5): Daily outdoor temperature , humidity and dew point during 20-24/9/2007

Table(6): The outdoor temperature, humidity and dew point at different periods within a day during 20-24/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH %	D.P.	°C	RH%	D.P.
1st	26.66 ±1.72	33.95 ±8.09	13.40 ±3.90	29.53 ±2.65	44.46 ±3.96	16.63 ±4.23	33.91 ±0.67	60.92 ±3.94	25.37 ±0.80	34.26 ±1.78	67.15 ±1.36	23.71 ±0.48	30.23 ±0.96	81.14 ±4.08	24.36 ±0.48	30.92 ±1.43	57.52 ±8.33	20.69 ±2.39
2nd	27.19 ±0.94	73.33 ±12.20	23.58 ±1.19	30.98 ±2.73	54.9 ±3.29	23.69 ±1.07	34.97 ±1.18	62.07 ±5.66	24.58 ±0.28	33.12 ±1.81	75.1 ±4.32	24.21 ±0.26	28.87 ±1.12	83.40 ±2.41	25.31 ±0.33	31.03 ±1.40	69.76 ±5.04	24.27 ±0.32
3rd	27.65 ±0.81	71.92 ±22.35	23.17 ±3.57	32.25 ±4.17	27.04 ±2.81	15.60 ±1.34	38.30 ±1.57	47.47 ±9.99	21.65 ±1.98	34.76 ±2.07	70.6 ±13.55	23.84 ±2.58	29.83 ±1.19	87.38 ±1.96	26.20 ±0.34	32.56 ±1.86	60.88 ±10.59	22.09 ±1.78
4th	27.83 ±0.92	88.07 ±2.93	25.49 ±0.54	29.61 ±2.68	59.82 ±0.20	24.49 ±1.91	33.80 ±0.42	63.35 ±6.21	25.30 ±0.44	33.29 ±1.90	78.02 ±4.63	25.53 ±0.87	29.74 ±0.36	81.36 ±1.67	24.49 ±1.03	30.85 ±1.15	74.12 ±5.40	25.06 ±0.24
5th	27.01 ±1.49	50.45 ±26.27	16.89 ±4.36	33.52 ±4.18	24.58 ±0.16	13.82 ±0.53	37.55 ±0.22	32.85 ±2.01	18.23 ±3.17	37.26 ±2.40	23.87 ±0.42	8.53 ±1.01	31.13 ±1.63	43.46 ±7.12	19.50 ±7.26	33.29 ±1.98	35.04 ±5.23	15.39 ±1.96
Mean ± s.e.	27.27 ±0.21	63.54 ±9.52	20.51 ±2.29	31.18 ±0.77	42.16 ±7.13	18.85 ±2.19	35.71 ±0.94	53.33 ±5.86	23.03 ±1.38	34.54 ±0.74	62.95 ±9.94	21.16 ±3.17	29.96 ±0.37	75.35 ±8.05	23.97 ±1.16	31.73 ±1.53	59.46 ±6.79	21.50 ±1.71

According to the degree of inbreeding, depicted by either and / or eggs and open brood in the holes among the sealed brood. Therefore, the bees become confused for heating behaviour and try to manage the thermal requirement for the different developmental stages. So the ambient temperature for inbreed sealed worker brood (lie inbetween sealed and open brood) recorded an average of 34.56±0.31 ^{o}C ranging from 33.69±0.11 ^{o}C during midnight – sunrise to 35.53±0.10 ^{o}C during midday. The average relative humidity was found to be 53.42±2.31% a law of 51.73±3.03% from midnight to sunrise to a high of 55.71±2.31% during the morning, (Table7&Fig 6).

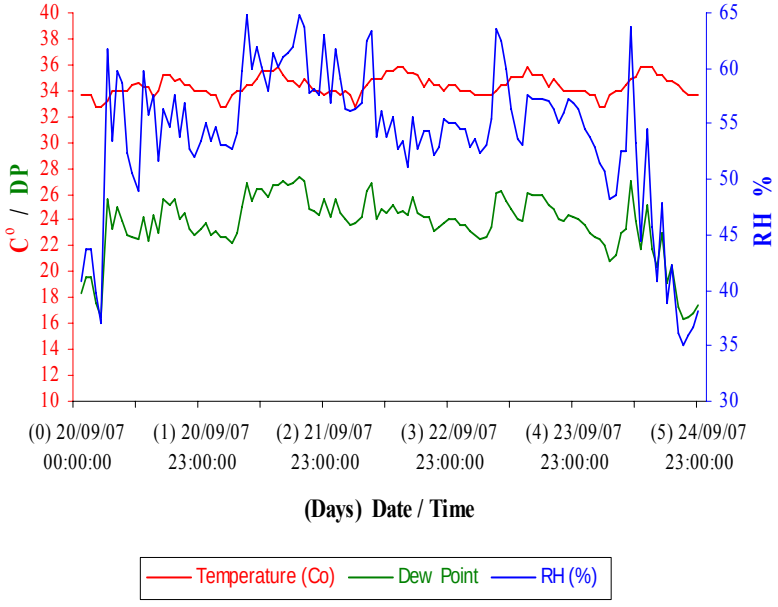

Fig.(6): Daily ambient temperature, humidity and dew point for inbreed sealed worker brood during 20-24/9/2007

Table(7): The ambient temperature, humidity and dew point for inbreed sealed worker brood at different periods within a day during 20-24/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	▪C	RH %	D.P.	▪C	RH %	D.P.	▪C	RH %	D.P.	▪C	RH %	D.P.	▪C	RH %	D.P.	▪C	RH %	D.P.
1st	33.31 ±0.34	40.05 ±3.41	17.84 ±1.65	33.63 ±0.76	47.82 ±8.92	20.66 ±3.53	35.37 ±0.41	48.80 ±3.05	22.74 ±1.30	34.77 ±0.60	55.10 ±2.54	24.87 ±1.23	34.55 ±0.35	53.80 ±1.82	23.61 ±0.74	34.33 ±0.35	49.11 ±2.66	21.94 ±1.23
2nd	33.59 ±0.27	53.68 ±0.98	22.89 ±0.51	34.46 ±0.48	60.14 ±3.96	25.38 ±1.50	35.58 ±0.21	59.92 ±1.41	26.40 ±0.47	34.77 ±0.35	62.30 ±1.77	26.95 ±0.64	34.38 ±0.48	60.10 ±3.07	25.30 ±1.03	34.56 ±0.29	59.23 ±1.45	25.83 ±0.70
3rd	33.80 ±0.23	57.73 ±2.21	24.28 ±0.72	34.70 ±0.37	58.54 ±4.14	25.24 ±1.22	35.68 ±0.25	53.90 ±1.28	24.71 ±0.28	35.20 ±0.60	53.45 ±1.97	24.76 ±0.71	34.73 ±0.30	53.98 ±1.37	23.76 ±0.45	34.82 ±0.28	55.52 ±1.08	24.55 ±0.25
4th	33.94 ±0.32	53.87 ±1.03	23.27 ±0.57	34.31 ±0.42	58.92 ±4.49	24.79 ±1.61	35.26 ±0.42	55.17 ±2.17	24.70 ±0.98	34.99 ±0.42	57.17 ±0.05	25.71 ±0.42	34.46 0.38	56.30 ±0.86	24.31 ±0.35	34.59 ±0.31	56.28 ±0.86	24.56 ±0.39
5th	33.80 ±0.23	53.32 ±2.05	22.96 ±0.74	34.26 ±0.66	53.14 ±6.29	23.04 ±2.44	35.78 ±0.41	49.50 ±5.13	23.14 ±1.66	34.89 ±0.25	42.47 ±3.89	20.73 ±1.60	33.94 ±0.37	36.40 ±1.18	16.85 ±0.47	34.53 ±0.33	46.97 ±3.29	21.34 ±1.21
Mean ± s.e.	33.69 ±0.11	51.73 ±3.03	22.25 ±1.13	34.27 ±0.18	55.71 ±2.31	23.82 ±0.89	35.53 ±0.10	53.46 ±2.03	24.34 ±0.65	34.92 ±0.08	54.10 ±3.07	24.60 ±1.04	34.41 ±0.13	52.12 ±4.09	22.77 ±1.51	34.56 ±0.31	53.42 ±2.31	23.64 ±0.86

The open brood and eggs recorded an average temperature of 33.13±0.17 ^{o}C ranging from 30.68±0.19 ^{o}C during midnight – sunrise to 34.83±0.32 ^{o}C during midday. The relative humidity averaged 53.26±2.77 % ranging from 48.69±4.04 % during midday to 57.18±3.63 % during the morning, (Table 8 & Fig. 7).

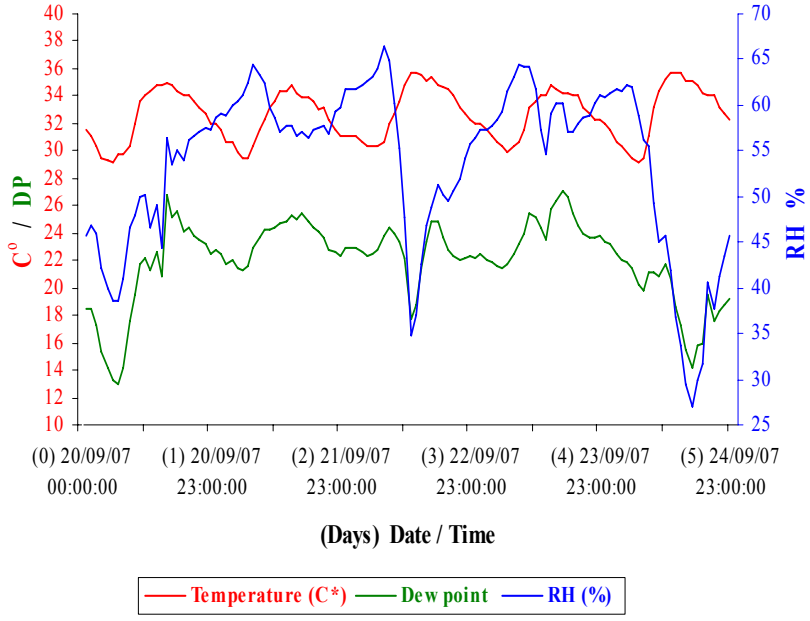

Fig.(7): Daily ambient temperature, humidity and dew point for open worker brood and eggs during 20-24/9/2007

Table(8): The ambient temperature, humidity and dew point for open worker brood and eggs at different periods within a day during 20-24/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	30.04 ±1.13	43.23 ±3.45	16.15 ±2.24	30.57 ±2.22	44.82 ±4.77	17.17 ±3.66	34.53 ±0.40	47.52 ±2.61	21.72 ±0.76	34.53 ±0.46	54.70 ±1.22	25.45 ±1.13	33.18 ±0.93	56.96 ±0.52	23.49 ±0.73	32.87 ±1.14	49.45 ±2.72	20.80 ±1.79
2nd	30.71 ±0.92	59.67 ±1.01	21.96 ±0.62	31.37 ±1.48	62.50 ±1.74	23.33 ±1.14	34.32 ±0.53	57.80 ±0.62	24.81 ±0.38	33.74 ±0.53	56.82 ±0.35	24.61 ±0.45	32.35 ±1.05	58.28 ±1.25	23.10 ±0.74	32.70 ±1.78	59.01 ±0.98	23.56 ±0.52
3rd	30.78 ±0.39	62.18 ±0.60	22.70 ±0.22	31.86 ±1.37	62.16 ±4.50	23.67 ±0.65	35.59 ±0.34	40.50 ±5.80	19.99 ±2.09	35.32 ±0.42	49.30 ±1.88	24.19 ±0.77	33.43 ±1.01	52.42 ±2.54	22.33 ±0.26	33.65 ±1.09	53.31 ±4.11	22.58 ±0.73
4th	31.25 ±0.66	57.78 ±1.01	21.94 ±0.36	31.12 ±1.29	63.48 ±1.22	23.37 ±1.43	34.11 ±0.53	58.15 ±3.00	24.69 ±0.94	34.31 ±0.19	58.60 ±1.79	26.41 ±0.71	32.92 ±0.69	59.36 ±1.30	23.94 ±0.36	33.04 ±0.89	59.47 ±0.45	24.07 ±0.74
5th	30.64 ±0.94	61.62 ±0.53	22.42 ±0.75	31.46 ±2.31	52.96 ±5.66	20.62 ±0.57	35.59 ±0.21	39.47 ±5.38	19.59 ±2.05	34.84 ±0.41	29.52 ±1.99	15.35 ±0.83	33.43 ±1.01	41.82 ±3.06	18.65 ±0.78	33.41 ±1.06	45.05 ±5.57	19.33 ±1.17
Mean ± s.e.	30.68 ±0.19	56.90 ±3.50	21.03 ±1.23	31.28 ±0.21	57.18 ±3.63	21.63 ±1.24	34.83 ±0.32	48.69 ±4.04	22.16 ±1.12	34.55 ±0.26	49.79 ±5.3	23.20 ±1.20	33.06 ±0.20	53.77 ±3.21	22.30 ±0.95	33.13 ±0.17	53.26 ±2.77	22.07 ±0.88

According to the moderate (less experience) colony management, beekeepers tend to insert more empty combs in wrong situation inside the hive. The surplus of this combs disarrange the thermal equilibrium, where the ambient temperature for the empty and honey combs recorded an average of 31.05±1.59 °C (from 27.06±0.23 °C during night – sunrise to 34.90±0.16 °C during the midday**.** The average relative humidity was 41.07±1.13 % (from 33.79±1.95% during midday to 44.03±1.26 % from sunset to midnight, (Table 9 & Fig. 8).

The dew point in this group varied according to the status, it was within reasonable limits in both sealed brood (23.64±0.86 °C) and open brood and eggs (22.07±0.88 °C), but much lower for empty and honey combs (16.56±0.44 °C).

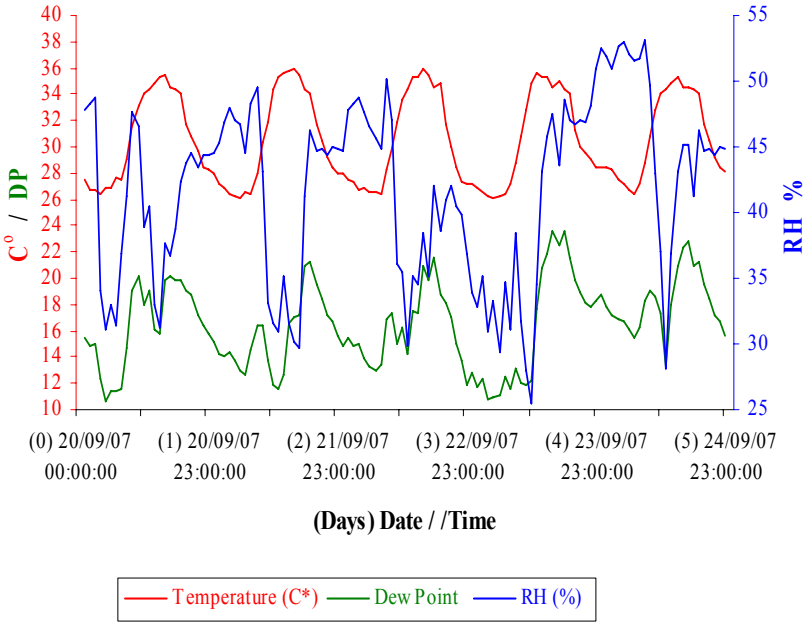

Fig.(8): Daily ambient temperature, humidity and dew point for empty and honey combs during 20-24/9/9/2007

Table(9): The ambient temperature, humidity and dew point for empty and honey combs at different periods within a day during 20-24/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH%	D.P.	°C	RH %	D.P.
1st	26.88 ±0.59	40.50 ±8.57	11.79 ±3.71	29.81 ±2.70	40.78 ±6.80	14.75 ±4.98	34.64 ±0.54	35.88 ±4.45	17.23 ±1.56	34.64 ±1.26	38.85 ±2.50	19.89 ±0.18	29.79 ±1.46	44.10 ±0.46	17.46 ±1.44	31.15 ±1.52	40.02 ±1.34	16.22 ±1.37
2nd	26.86 ±1.07	46.42 ±1.24	14.10 ±0.71	28.61 ±2.68	43.76 ±6.47	17.73 ±1.66	35.30 ±0.73	26.53 ±3.39	13.18 ±2.31	34.97 ±1.55	36.80 ±8.23	19.04 ±2.30	29.52 ±1.46	44.76 ±0.23	17.48 ±1.54	31.05 ±1.72	39.65 ±3.67	16.31 ±1.13
3rd	27.13 ±0.89	47.28 ±1.45	14.58 ±0.79	28.61 ±2.60	44.76 ±5.26	15.15 ±2.02	34.64 ±0.80	32.98 ±4.13	16.32 ±1.51	35.18 ±1.34	38.58 ±2.78	20.24 ±1.26	28.93 ±1.87	40.08 ±1.95	15.17 ±2.53	30.90 ±1.67	40.74 ±2.49	16.29 ±1.03
4th	26.52 ±0.81	32.58 ±2.12	8.12 ±1.49	29.13 ±2.63	32.78 ±3.94	11.01 ±1.89	35.27 ±0.35	37.25 ±9.17	18.12 ±4.34	34.53 ±1.12	46.70 ±2.16	22.80 ±0.98	29.66 ±1.06	47.94 ±1.79	18.56 ±0.82	31.02 ±1.66	39.45 ±3.32	15.72 ±2.68
5th	27.9 ±1.04	52.15 ±0.68	17.24 ±0.94	29.13 ±2.63	49.80 ±3.99	17.52 ±1.51	34.64 ±0.54	36.32 ±6.21	17.37 ±3.11	34.40 ±0.95	44.42 ±2.21	21.79 ±0.90	29.56 ±1.42	44.76 ±0.23	17.48 ±1.54	31.13 ±1.41	45.49 ±2.73	18.28 ±0.88
Mean ± s.e.	27.06 ±0.23	43.79 ±3.36	13.17 ±1.53	29.06 ±0.22	42.38 ±2.80	15.23 ±1.22	34.90 ±0.16	33.79 ±1.95	16.44 ±0.86	34.74 ±0.14	41.07 ±1.90	20.75 ±0.68	29.49 ±0.15	44.03 ±1.26	17.23 ±0.56	31.05 ±1.59	41.07 ±1.13	16.56 ±0.44

Group 3: Laying workers and bad colony management

In queenless colonies and in case of absence of open brood, the reproductive system in the older worker bees become active and such workers start to lay eggs. The percentage of these laying workers increase gradually as the time progress Therefore some worker bees become unguided and the work inside the colony becomes disturbed according to the state and strength of the colony.

As the results of bad beekeeping management and the unguidance of the worker bees, the attention to thermal equilibrium for the sealed worker brood and eggs becomes less, and the colony climate was nearly similar to that of the outside, Tables (10, 11,12 and 13) & figures (9, 10, 11 and 12).

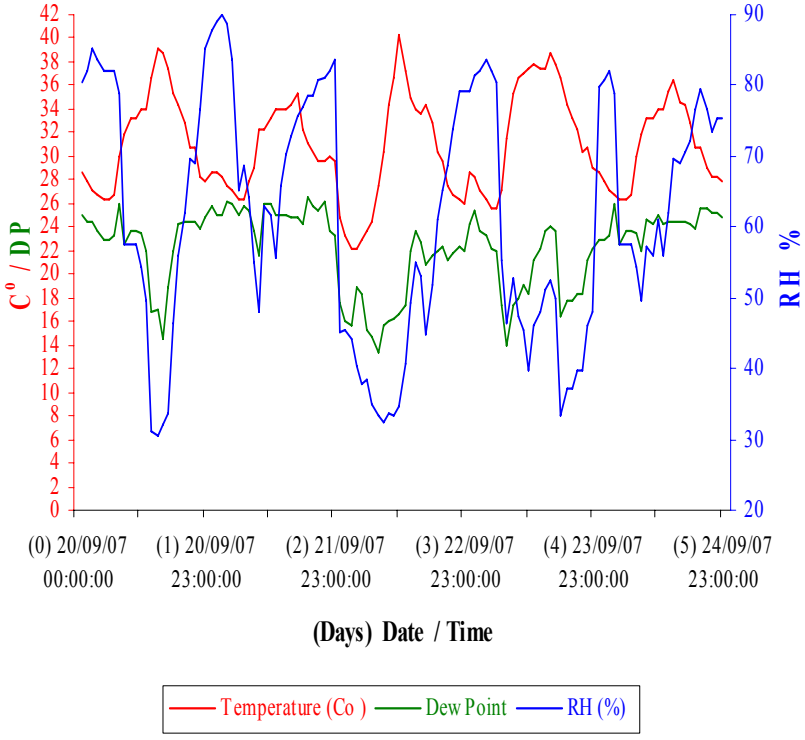

Fig.(9): Daily outdoor temperature , humidity and dew point during 25-29/9/2007

Table(10): The outdoor temperature, humidity and dew point at different periods within a day during 25-29/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	27.19 ±0.94	82.48 ±8.36	23.94 ±0.84	30.98 ±2.73	66.78 ±6.74	23.84 ±1.23	35.95 ±2.49	40.60 ±7.12	19.80 ±3.41	36.48 ±1.98	40.00 ±13.99	19.93 ±4.23	30.08 ±1.99	72.50 ±8.87	24.39 ±0.37	32.14 ±1.78	60.47 ±8.61	22.38 ±1.03
2nd	27.78 ±0.95	84.07 ±9.52	25.49 ±0.54	29.59 ±2.71	59.82 ±8.19	24.49 ±1.91	33.80 ±0.42	63.35 ±6.21	25.30 ±0.44	33.29 ±1.90	75.95 ±2.45	25.10 ±0.94	29.74 ±0.36	81.20 ±1.78	24.84 ±1.24	30.84 ±1.16	72.88 ±4.82	25.04 ±0.17
3rd	23.12 ±10.2	41.90 ±3.54	16.93 ±0.68	30.65 ±4.96	33.58 ±2.98	15.20 ±1.04	36.62 ±2.75	41.15 ±12.98	18.91 ±4.56	32.77 ±1.78	52.70 ±6.65	21.72 ±0.84	27.19 ±1.42	73.18 ±6.24	21.94 ±0.47	30.07 ±2.31	48.50 ±6.88	18.94 ±1.32
4th	26.93 ±1.35	81.37 ±1.47	23.48 ±1.27	23.50 ±4.17	49.54 ±4.28	17.15 ±1.91	37.15 ±0.22	46.25 ±4.87	21.34 ±2.25	36.91 ±1.88	43.20 ±9.29	20.43 ±3.94	31.13 ±1.63	48.12 ±4.75	19.55 ±2.03	31.12 ±2.70	53.70 ±6.99	20.39 ±1.04
5th	27.19 ±0.94	73.33 ±12.20	23.58 ±1.19	30.98 ±2.73	54.90 ±3.29	23.63 ±1.07	34.97 ±1.18	62.07 ±5.66	24.58 ±0.28	33.12 ±1.91	72.10 ±3.32	24.21 ±0.26	28.87 ±1.12	76.00 ±2.18	25.31 ±0.33	31.03 ±1.40	67.68 ±3.97	24.26 ±0.32
Mean ± s.e.	26.44 ±0.84	72.63 ±7.90	22.68 ±1.48	29.14 ±1.43	52.92 ±5.61	20.86 ±1.94	35.70 ±0.59	50.68 ±5.01	21.99 ±1.27	34.51 ±0.89	56.79 ±7.36	22.28 ±1.02	29.40 ±0.66	70.20 ±5.73	23.21 ±1.08	31.04 ±1.75	60.65 ±4.52	22.20 ±1.14

Inside the hive, the temperature was an average of 31.88±1.16 ^{o}C ranging from 28.46±0.20 ^{o}C during midnight – sunrise to 34.71±0.10 ^{o}C during the afternoon for brood and eggs combs, (Table 11 & fig. 10).

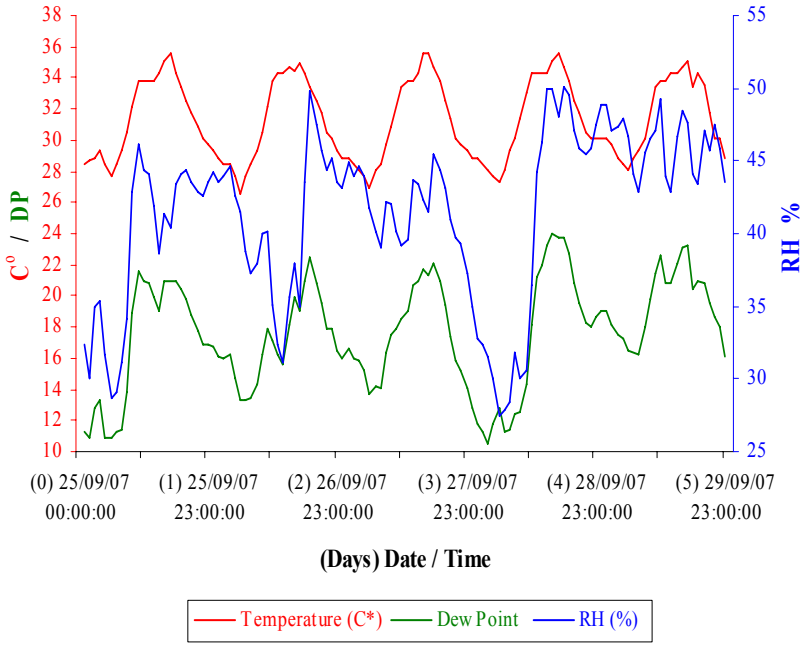

Fig.(10): Daily ambient temperature, humidity and dew point for worker brood / eggs combs during 25-29/9/2007

Table(11): The ambient temperature, humidity and dew point for worker brood *I* eggs comb at different periods within a day during 25-29/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	28.43 ±0.64	31.18 ±2.64	11.07 ±1.77	30.87 ±2.16	36.68 ±7.44	15.05 ±5.02	33.96 ±0.21	42.28 ±2.63	20.20 ±0.87	34.60 ±0.95	42.33 ±1.72	20.80 ±0.25	32.03 ±1.18	43.38 ±0.69	18.01 ±1.24	31.98 ±1.11	39.17 ±2.32	17.03 ±1.80
2nd	28.24 ±1.00	43.42 ±1.18	15.52 ±1.28	29.64 ±1.76	38.84 ±1.27	15.04 ±1.96	34.27 ±0.35	33.58 ±2.12	16.80 ±1.07	34.82 ±1.18	41.55 ±6.53	20.57 ±1.48	31.86 ±1.31	45.28 ±1.48	18.54 ±1.68	31.77 ±1.27	40.53 ±2.04	17.29 ±1.02
3rd	28.17 ±0.77	43.73 ±1.14	15.56 ±1.01	29.88 ±1.69	40.74 ±1.38	15.99 ±1.77	33.85 ±0.34	41.48 ±2.40	19.79 ±1.18	34.92 ±0.82	43.43 ±1.85	21.53 ±0.49	31.64 ±1.34	40.10 ±2.18	16.39 ±2.04	31.69 ±1.24	41.90 ±0.72	17.85 ±1.19
4th	28.24 ±0.65	31.53 ±2.57	10.59 ±1.78	30.38 ±1.89	29.74 ±1.60	11.58 ±2.24	34.27 ±0.00	44.23 ±5.74	21.15 ±2.20	34.81 ±0.73	49.43 ±0.92	23.56 ±0.59	32.02 ±1.10	46.34 ±0.90	19.06 ±1.11	31.94 ±1.22	40.25 ±4.02	17.19 ±2.60
5th	29.24 ±0.86	47.82 ±0.93	17.94 ±1.03	30.70 ±1.88	45.24 ±1.73	18.39 ±2.26	34.06 ±0.24	45.73 ±2.87	21.58 ±0.96	34.38 ±0.73	45.90 ±2.52	21.93 ±1.46	31.70 ±1.47	45.92 ±1.56	18.62 ±1.71	32.02 ±0.98	46.12 ±0.44	19.69 ±0.85
Mean ± s.e.	28.46 ±0.20	39.54 ±3.43	14.14 ±1.42	30.29 ±0.23	38.25 ±2.55	15.21 ±1.09	34.08 ±0.08	41.46 ±2.11	19.90 ±0.84	34.71 ±0.10	44.53 ±1.43	21.68 ±0.53	31.85 ±0.08	44.20 ±1.14	18.12 ±0.46	31.88 ±1.16	41.59 ±1.21	17.81 ±0.46

These temperature were relatively similar for eggs and empty combs (Table 12 & fig. 11), and honey combs (Table 13 & fig. 12), i.e. an average of 31.76±1.36 ^{o}C (from 28.04±0.32 ^{o}C during midnight – Sunrise to 34.86±0.07 ^{o}C during afternoon) and 31.09±1.54 ^{o}C (from 26.80±0.52 ^{o}C during midnight – Sunrise to 34.56±0.06 ^{o}C during afternoon), respectively.

The motion of the bees inside the hive may be the reason for decreasing the relative humidity percentages. The recorded relative humidity was quite low as it was an average between 41.59±1.21% (from 38.25±2.55% during the morning to 44.53±1.43% during afternoon, 44.89±0.93% (from 42.06±3.36% during the morning to 49.67±1.18% during afternoon and 48.82±0.73% (from 46.01±1.73% during afternoon to 53.88±1.88% during the morning) for brood / eggs combs, eggs / empty comb and honey comb, respectively. The higher humidity was mostly detected during the afternoon and the lower humidity percentage was during the morning.

As the same manner the dew point recorded a less degree than the outdoor temperature, where it was 17.81±0.46 ^{o}C for brood / eggs comb, 18.27±0.44 ^{o}C for eggs / empty comb and 19.16±0.30 ^{o}C for honey comb

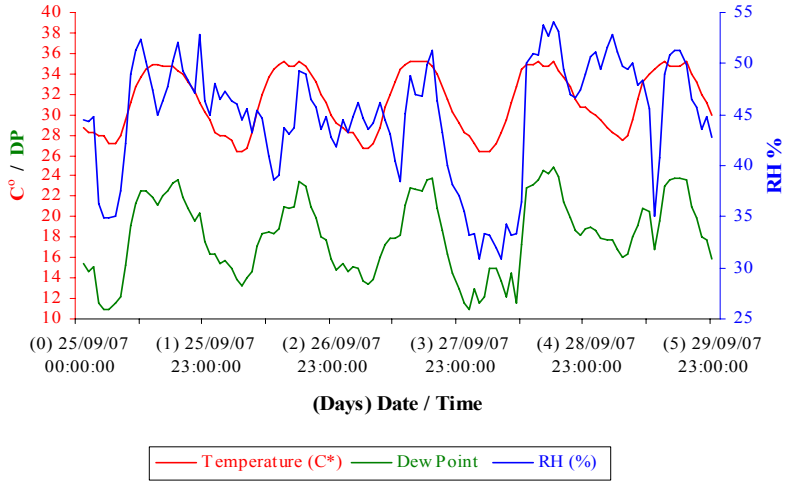

Fig.(11): Daily ambient temperature, humidity and dew point for eggs / empty combs during 25-29/9/2007

Table(12): The ambient temperature, humidity and dew point for eggs / empty combs at different periods within a day during 25-29/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.	°C	RH %	D.P.
1st	28.04 ±0.54	39.95 ±5.05	13.01 ±2.30	29.68 ±2.31	43.00 ±7.00	15.65 ±4.59	34.43 ±0.59	48.72 ±3.69	22.03 ±0.66	34.66 ±0.21	49.10 ±2.56	22.85 ±0.72	32.19 ±1.50	48.76 ±2.53	20.02 ±1.62	31.80 ±1.36	45.91 ±1.87	18.71 ±1.89
2nd	27.91 ±1.03	46.55 ±1.06	15.41 ±0.93	28.72 ±2.38	44.64 ±0.92	15.48 ±2.19	34.53 ±0.72	40.55 ±2.33	19.17 ±1.27	34.88 ±0.21	46.27 ±3.33	22.05 ±1.31	32.03 ±1.63	44.68 ±1.50	18.48 ±1.96	31.61 ±1.50	44.54 ±1.07	18.06 ±1.27
3rd	28.11 ±0.85	44.20 ±1.49	14.77 ±0.60	29.03 ±2.25	44.32 ±1.18	15.66 ±1.98	34.43 ±0.91	43.22 ±4.63	20.05 ±2.37	35.09 ±0.21	48.75 ±2.21	23.12 ±0.62	31.54 ±1.94	40.94 ±3.80	16.63 ±3.17	31.64 ±1.46	44.29 ±1.27	18.05 ±1.55
4th	27.06 ±0.88	32.58 ±2.23	9.20 ±1.68	29.76 ±2.23	29.24 ±4.47	9.79 ±1.32	34.85 ±0.34	47.10 ±7.14	21.75 ±2.95	34.77 ±0.35	53.40 ±0.60	24.35 ±0.45	31.86 ±1.28	47.90 ±1.22	19.44 ±1.33	31.66 ±1.55	42.04 ±4.70	16.91 ±3.12
5th	29.10 ±0.94	51.12 ±1.09	17.97 ±0.75	29.92 ±2.40	49.08 ±0.94	18.06 ±1.97	34.64 ±0.54	42.57 ±6.06	19.95 ±2.55	34.88 ±0.21	50.85 ±0.66	23.64 ±0.07	32.03 ±1.63	44.68 ±1.51	18.48 ±1.96	32.11 ±1.24	47.66 ±1.72	19.62 ±1.06
Mean ± s.e.	28.04 ±0.32	42.88 ±3.14	14.07 ±1.45	29.42 ±0.23	42.06 ±3.36	14.93 ±1.37	34.58 ±0.08	44.43 ±1.51	20.59 ±0.55	34.86 ±0.07	49.67 ±1.18	23.20 ±0.38	31.93 ±0.11	45.39 ±1.39	18.61 ±0.57	31.76 ±1.36	44.89 ±0.93	18.27 ±0.44

Table(13): The ambient temperature, humidity and dew point for empty / honey combs at different periods within a day during 25-29/9/2007

Days	Duration (Time)																	
	Midnight – Sunrise (0 – 5am)			Morning (6am – 10am)			Midday (11am – 2pm)			Afternoon (3pm – 6pm)			Sunset – Midnight (7pm – 23pm)			Mean ± s.e.		
	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.	°C	RH%	D.P.
1st	25.21 ±0.53	50.27 ±6.86	15.35 ±2.59	28.73 ±2.71	50.92 ±3.57	17.55 ±3.48	34.12 ±0.72	46.75 ±1.52	21.10 ±0.35	34.37 ±0.21	46.10 ±1.40	21.82 ±0.38	31.78 ±1.50	47.40 ±0.80	19.21 ±1.22	30.84 ±1.73	48.29 ±0.97	19.01 ±1.18
2nd	27.13 ±1.19	53.82 ±2.61	16.87 ±0.40	28.01 ±2.50	54.64 ±2.84	17.10 ±1.79	34.12 ±1.05	40.53 ±2.91	18.78 ±1.77	34.69 ±0.43	40.16 ±5.46	21.62 ±1.00	31.62 ±1.62	47.10 ±0.84	18.95 ±1.46	31.11 ±1.54	47.25 ±3.11	18.66 ±0.85
3rd	27.26 ±1.10	52.78 ±1.81	16.76 ±0.52	28.25 ±2.47	55.98 ±4.74	18.58 ±1.92	34.01 ±1.08	44.40 ±1.81	20.15 ±1.40	34.58 ±0.41	45.05 ±4.41	21.59 ±1.77	30.81 ±1.99	42.92 ±0.93	16.74 ±1.49	30.98 ±1.47	48.23 ±2.58	18.76 ±0.95
4th	26.15 ±1.01	47.53 ±4.55	14.07 ±1.37	28.49 ±2.81	48.58 ±2.98	16.58 ±2.21	34.64 ±0.54	46.25 ±4.87	21.34 ±2.25	34.48 ±0.60	50.43 ±1.26	23.40 ±0.72	31.37 ±1.37	50.88 ±1.75	19.96 ±0.78	31.03 ±1.64	48.73 ±0.87	19.07 ±1.67
5th	28.24 ±1.02	57.02 ±1.52	18.91 ±0.65	28.88 ±2.20	59.28 ±3.99	20.10 ±1.16	34.33 ±1.05	47.68 ±3.89	21.58 ±2.00	34.69 ±0.43	48.32 ±2.74	22.88 ±1.02	31.37 ±1.37	45.62 ±3.15	18.12 ±0.29	31.50 ±1.32	51.58 ±2.74	20.32 ±0.87
Mean ± s.e.	26.80 ±0.52	48.68 ±3.57	16.39 ±0.81	28.47 ±0.16	53.88 ±1.88	17.98 ±0.62	34.24 ±0.11	45.12 ±1.27	20.59 ±0.51	34.56 ±0.06	46.01 ±1.73	22.26 ±0.37	31.39 ±0.16	46.78 ±1.29	18.60 ±0.55	31.09 ±1.54	48.82 ±0.73	19.16 ±0.30

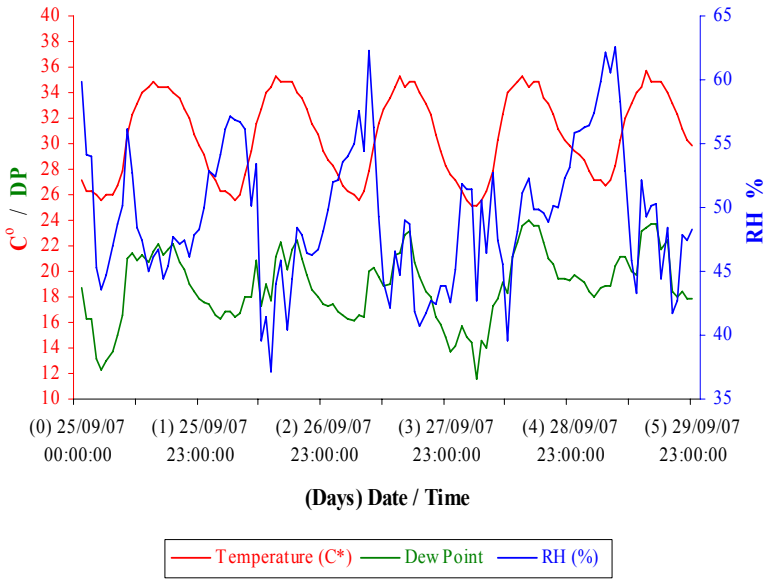

Fig.(12): Daily ambient temperature, humidity and dew point for empty / honey combs during 25-29/9/2007

Because bees live in colony consisting of thousands of individuals (social), behavioural thermoregulatory responses of a single bee serve not only its own body temperature but also that of the entire colony as well. Such social behaviour results in a permanent thermal stabilization of the colony. Most social insects' species are able to regulate the temperature within their nest. Honey bee colony is able to maintain brood nest temperatures within the range of 33-36 ^{o}C even when the ambient temperatures ranges well below freezing or above 45 ^{o}C (Fahrenholz *et al* , 1989). Worker bees tend to regulate their own body temperature between allowable limits by turnover of their energy metabolism (Crailsheim *et al* 1999 and Stabentheiner *et al* 2003 a). Worker bee warms its body temperature in spring and evaporative heat loss in summer to reach the thermal equilibrium (Roberts and Harrison 1999).

In the present work, the climate in a well maintained bee colony comprising a good queen and well beekeeping management as in the first group the temperature was in the ranged between 33.49 ± 0.49 ^{o}C and 35.51 ± 0.24 ^{o}C (outside 30.21 ± 2.38 ^{o}C) & relative humidity averaged from 53.21 ± 1.27 % to 57.94 ± 0.41 % (outside 43.53 ±

5.11 %). Meanwhile, these temperatures ranged between 31.05 ± 1.59 ^{o}C and 34.56 ± 0.31 ^{o}C (outside 31.73 ± 1.53 ^{o}C) & relative humidity ranged from 41.07 ± 1.13% to 53.42 ± 2.31 (outside 59.46 ± 6.79 %) in the second group where it comprised inbreed queens and received moderate beekeeping management. So the rate of heat production of adult workers is strongly dependent upon the number of bees together in a group, Fahrenholz *et al* (1989).

On the other hand in the third group; a climate condition inside the hive (temperatures ranged between 31.09 ± 1.54 ^{o}C and 31.88 ± 1.16 ^{o}C & relative humidity ranged from 41.59 ± 1.21% to 48.82 ± 0.73%) was nearly equaled outside climate conditions (temp. 31.04 ± 1.75 ^{o}C & RH 60.65 ± 4.52 %), as a result of absence of queen and poor beekeeping management. In this later case the misguidance of worker bees lead them in disarray for the thermoregulation of their hive. Moreover, slightly atypical brood rearing temperature can affect the behaviour of the bees as adults Tautz *et al* (2003).

In general, the beekeeper must aid the bee colony to regulate their thermal stabilization for high performance by good colony management i.e. good queen, keep the colony strong, offering food requirements at the dearth periods, protect the colony from the direct sun rays, offering water nearby the colony, arranging the combs inside the hive, elevate the surplus of combs and good wintering.

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REFERENCES

Akimoto, T. (2000). Winter temperature in the exposed nest of Japanese honeybee, *Apis cerana japonica*. Honeybee Science. 21: 1, 31-34.

Crailsheim, K.; A. Stabentheiner; N. Hrassnigg and B. Leonhard (1999). Oxygen consumption at different activity levels and ambient temperatures in isolated honeybees (Hymenoptera: Apidae). Entomologia Generalis. 24: 1, 1-12. (CAB Abs. 19990506265).

Fahrenholz,L.; Lamprecht,I. and Schricker,B. (1989). Thermal investigations of honey bee colony. J. Compar. Physiol. Biochem. 159: 5, 551-560.

Graham, S.; M.R. Myerscough; J.C. Jones and B.P. Oldroyd (2006). Modelling the role of intracolonial genetic diversity on regulation of brood temperature in honey bee (*Apis mellifera* L.) colonies. Insectes Sociaux. 53: 2, 226-232.

Grodzicki, P.and M. Caputa(2005). Social versus individual behaviour: a comparative approach to thermal behaviour of the honeybee *Apis mellifera* L and the American cockroach *Periplaneta americana* L. J. Insect. Physiol. 51: 3, 315-322.

Jones, J.C.; M.R. Myerscough; S.Graham and B.P. Oldroyd (2004). Honey bee nest thermoregulation: diversity promotes stability. Science 305: 5682, 402-404. (CAB Abs. 20043131597)

Kleinhenz, M.; B.Bujok; S.Fuchs and J. Tautz (2003). Hot bees in empty brood nest cells: heating from within. J. Experim. Biol.206: 23, 4217-4231.

Kovac, H. and S. Schmaranzer (1996). Thermoregulation of honeybees (*Apis mellifera*) foraging in spring and summer at different plants. J. Insect Physiol.,42:11, 1071-1076.

Levin, C.G. and C.H. Collison(1990). Broodnest temperature differences and their possible effect on drone brood production and distribution in honeybee colonies. J. Apic. Res. 29: 1, 35-45.

Myerscough. M.R. (1993). A simple model for temperature regulation in honeybee swarms. J. Theore. Biol..162: 3, 381-393

Roberts, S.P.and J.F. Harrison (1999). Mechanisms of thermal stability during flight in the honeybee *Apis mellifera*. J. Exp. Biol. 202: 11, 1523-1533.

Schmaranzer, S.(2000). Thermoregulation of water collecting honey bees (*Apis mellifera*). J. Insect. Physiol.,46:8, 1187-1194.

Stabentheiner, A.; J. Vollmann; H. Kovac and K.Crailsheim (2003 a). Oxygen consumption and body temperature of active and resting honeybees. J. Insect Physiol.,49(9) 881-889.

Stabentheiner, A.; Pressl, H.; Papst, T.; Hrassnigg, N.; Crailsheim, K. (2003 b). Endothermic heat production in honeybee winter clusters .J. Exp. Biol. 206: 2, 353-358.

Tautz,J.; S. Maier; C. Groh; W. Rossler and A. Brockmann (2003). Behavioural performance in adult honey bees is influenced by the

temperature experienced during their pupal development. Proc. Nat.Acad.Sci.USA 100, 7343-7347.

Watmough,J.and S.Camazine(1995). Self-organized thermoregulation of honeybee clusters. J. Theore. Biol. 176: 3, 391-402

تنظيم درجات الحرارة داخل طائفة نحل العسل

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تم رصد تنظيم درجات الحرارة داخل طائفة نحل العسل اليمنى ***Apis mellifera jemenitica*** فى منحل مركز البحوث الزراعية ، وزارة الزراعة والثروة السمكية، مسقط ، سلطنة عمان خلال شهر سبتمبر 2007 . سجلت درجات الحرارة والرطوبة كل ساعة على مدار 24 ساعة خلال 5 أيام عن طريق جهاز **HOBO RH & Temp data logger**. تم تقسيم الطوائف إلى 3 مجموعات طبقا لقوة وحالة الطائفة. المجموعة الأولى (النحل يغطى 10اقراص) وتحتوى على ملكة جيدة وعمليات نحالة جيدة. المجموعة الثانية (النحل يغطى6 أقراص) وتحتوى على ملكة لها نسبة تربية داخلية عالية وعمليات نحالة متوسطة. المجموعة الثالثة (النحل يغطى 4 أقراص) وتحتوى على أمهات كاذبة.

في المجموعة الأولى : سجلت متوسطات درجات الحرارة والرطوبة خارج الخلايا 30.21 ±2.38 °م و43.53 ± 5.11 % على التوالي. تهيأ شغالات النحل الطائفة من الداخل لتصل إلى التوازن الحراري المطلوب حيث سجلت متوسطات درجات الحرارة والرطوبة 35.51 ±0.24 °م و54.34 ± 2.31 % على التوالي للحضنة المقفولة و 34.46 ±0.27 °م و57.94 ± 0.41 % على التوالي للحضنة المفتوحة والبيض و 33.49 ±0.49 °م و53.21 ± 1.27 % على التوالي لأقراص العسل و الفارغة.

في المجموعة الثانية : سجلت متوسطات درجات الحرارة والرطوبة خارج الخلايا 31.73 ±1.53 °م و59.46 ± 6.79 % على التوالي. نظرا لوجود تربية داخلية، فان الحضنة المقفولة تحتوى فيما بينها على عيون سداسية فارغة وأحيانا تحتوى هذه العيون على حضنة مفتوحة، لذا تحاول الشغالات أن تصل درجات الحرارة والرطوبة لها إلى مستوى مناسب حيث سجلت متوسطات درجات الحرارة والرطوبة 34.56 ±0.31 °م و53.42 ± 2.31 % على التوالي و 33.13 ±0.17 °م و53.26 ± 2.77 % على التوالي للحضنة المفتوحة والبيض و 31.05 ±1.59 °م و41.07 ± 1.13 % على التوالي لأقراص العسل و الفارغة.

في المجموعة الثالثة : سجلت متوسطات درجات الحرارة والرطوبة خارج الخلايا 31.04 ±1.75 °م و60.65 ± 4.52 % على التوالي. نظرا لاحتواء الطائفة على أمهات كاذبة سجلت متوسطات درجات الحرارة والرطوبة 31.88 ±1.16 °م و41.59 ± 1.21 % على التوالي للحضنة والبيض و 31.76 ±1.36 °م و44.89 ± 0.93 % على التوالي لأقراص البيض و الفارغة و 31.09 ±1.54 °م و48.82 ± 0.75 % على التوالي لأقراص العسل و الفارغة.