EFFECT OF SHADING AND VENTILATION ON THE AMOUNT OF WATER CONSUMED FOR COOLING BEEHIVE DURING SUMMER SEASON

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ABSTRACT

This study was conducted to investigate the effect of apiary shading and ventilation of beehives on the amount of water consumed for cooling beehive, L/d. Ninety hives from Langstroth type were used containing honeybee colonies of equal strength from the species of hybrid carniolan. To study the effect of shading, hives were divided into three groups. The first group were shaded at a height of 2 m from the ground surface. The second group was covered with shaded material. The third group was un-shaded. To permit hive ventilation, four screened hive openings were studied [two holes (6 cm) at the bottom board; an opening with dimensions of 25 x 25 cm at the bottom board; two openings at the lower north side and two openings at the upper south side; two openings at the upper north side and another two opening on the same line; and all were compared with the un-opened hives]. The experimented hives were insulated inside with foam and compared with the un-insulated hives. It was observed that the minimum internal hive temperature (25.5 °C); the minimum internal relative humidity (36 %); the minimum amount of hive water consumption (0.220 L/d); high flight activity (216 workers per 5 minutes); the maximum amount of extracted honey per hive (8.2 kg/hive) and the minimum cost of production were achieved by using a ventilated hive with two screened holes (6 cm) at the bottom; shading height of 2 m and foam insulated hive. It is recommended to use a ventilated hive with two screened holes (6 cm) at the bottom; shading height of 2 m; and foam insulated hive to achieve best measurements.

Keywords: *shading; ventilation; temperature; humidity; water consumption; extracted honey, flight activity and costs.*

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1. ITRODUCTION

We all need water to live and bees are no exception. It was observed that bees clustering out at the front of the hive during very hot weather. This behavior coincides with the onset of the hot, humid days and nights from June to September. Bees fanning their wings to circulate air through the hive. Also they collect water for evaporative cooling. Droplets of water are placed inside the hive, then the bees stand in a line facing the hive entrance fanning their wings creating air currents that evaporate the water, thus cooling the hive. Whenever fanners are at the entrance, there are many inside the hive doing similar fanning to control the hive temperature, so we have to protect bees from intense sun during the summer month by shading, ventilation and insulation hives. This allows the bees to concentrate more of their efforts on raise brood, collect pollen and nectar instead of having to bring in water to cool the hive.

Temperature is an important factor affecting larval and pupal development of insects **(Nylin and Gotthard, 1998).** If the temperature in the beehive becomes higher the brood will die and combs will melt. Maintaining a suitable range of temperature from 33 to 36 °C inside colonies is very important for honeybees **(Petz Stabentheiner and Crailsheim, 2004).** If the in-hive temperature gets too hot, workers can fan hot air out of the hive and use evaporative processes by spreading collected water on comb surfaces. High temperatures outside the hive are compensated by bringing water into the hive and evaporating this by wing fanning. Environmentally induced temperature changes within the hive are compensated by individual honeybee workers via endothermic heat production or evaporation cooling **(Kleinhenz et al., 2003).** Workers position themselves on hot interior regions especially on the brood hive to prevent overheating. This constant temperature is crucial for the normal growth and development of the brood. Deviation from the optimum temperature range can occur when the ambient air temperature changes and affects the developmental period of honey bee immature stages and emergence rate **(Tautz et al 2003)** Also, ambient temperature has a great effect on foraging activity **(Al-Qarni, 2006)** and **(Blazyte-Cereskiene et al 2010).** Honeybees are known to control their hive environment to survive drastic changes in the field environment **(Jones,**

and Oldroyd, 2007). Factors of external ambient and internal hive conditions are very important on the productivity honeybees **(Cetin, 2004).** Langstroth beehives or otherwise known as movable frame hive is one of the types of hive designed for rearing honeybees for economic benefit. This type of hive is the most widely used hive in the world **(Ojeleye, 1999). Southwick and Moritz, 1992** reported that 580 calories are lost to each gram of evaporated water produced by the bees. There are little researches about shading or ventilation of beehives under Egypt condition so, this research was carried out for testing the hypothesis that ventilation, shading and insulation protects the bees from intense sun during the summer months. This allows the bees to concentrate more of their efforts on raise brood, collect pollen and nectar instead of having to bring in water to cool the hive.

Therefore, the objectives of the present study were to select the best shading position and the optimum ventilation place, that should be used to decrease internal hive temperature, ˚c; relative humidity,%; water consumption and consequently increase fight activity (number of workers/5 minute) by improving hive conditions and maintaining the strength of colonies to produce more honey.

2. MATERIALS AND METHODS

This paper were conducted in a private apiary at Meet-Salseel, EL-Daqahliyah Governorate, Egypt in the summer season of 2016 from June until September to study the shading position and the ventilation place for beehives

2.1. Materials:

2.1.1 Colonies bees:

Experimented colonies were equal in the strength, food stores (Honey - pollen), queen's age (about 8 months old) and number of combs covered with bees from both sides. Colonies were free from *Nosema apis* and *Varroa* destructor.

2.1.2 Colonies structure:

A wooden Langstroth enclosure beehives (outside measures: 53 x 43 x 45cm and sides thicknesses of 2 cm) with removable tops content honey bees (*hybrid carniolan*) were used. Ninety hives were placed in groups in parallel rows, with their larger entrances (summer entrance) face East direction. All openings except the entrance were closed with wire screen from inside to prevent foreign insects for entering the hive, so no robbing would occur. Openings were closed with a piece of wood from the outside when the weather turns cooler. The distance between hives was about 0.5 meter. Hives were painted white to reduce overheating by reflecting the sun heat in the summer months. A plastic frame feeder is a narrow vessel resembling a standard frame with dimensions of 42 x 7.7 x 11cm and its capacity was 3 litters. It was hanged inside the hive like a frame. It is also a leak-proof, one-piece molded plastic and roughened interior surface to provide a foothold for bees. It was filled with artificial feeding (sugar syrup) in cold weather, but we used it for providing bees with pure water in the hot summer; bees have direct access to it. The photograph of plastic frame feeder is shown in figure 1. Pieces of reed barriers were used for shading the bee yard as shown in fig. (2).

Fig. (1) Plastic frame feeder

Fig. (2) Reed barriers

Fig. (3) Two top side opening

Fig.(4) Lower part

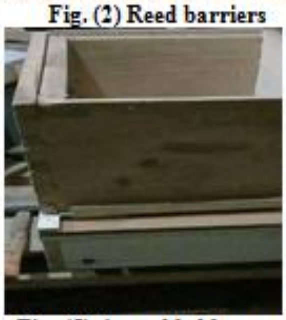

Fig. (5) Assembled lower part

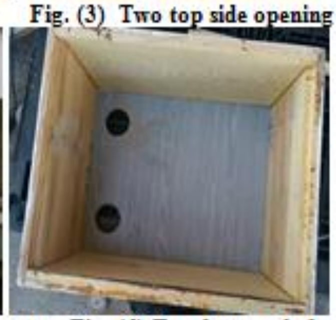

Fig. (6) Two bottom holes

Fig.(7) Two screened bottom holes

Fig.(8) Screened bottom board

Fig. (9) Assembled bottom board

The Reed barriers used for shading the bee yard were hanged on steel wires. The steel wires were placed at two meter heights on removable posts. The wires were attached in S hooks to be removed as we need. The top and bottom parts of the hives were outside dimensions of (53 x 43 x 25cm and wall thickness of 2 cm) with studied openings were designed according to Langstroth hive dimensions (figures 3, 4 and 5). The hives were bored from the bottom (figures 6 and 7). Also some hives have square open from the bottom with (25 x 25 cm) dimension (figures 8 and 9).

A plastic frame feeder was placed in the hive after filling with pure water to determine the amount of cooling water, litter/day consumed by every hive in the bee yard at 5 pm.

2.2. Methods:

To study the effect of shading, hives were divided into three groups. The first group were shaded at a height of 2 m from the ground surface. The second group were covered with the shaded material (there is no distance between reed barriers shaded material and the hive top cover). The third group were the un-shaded, named S_1, S_2 and S_3, respectively.

To permit hive ventilation, four screened hive openings were studied (figure 10) as follow:-

- Two holes with a diameter of 6 cm for each were bored or located in the side bottom board (named A_1).
- A screened square open (25 x 25 cm) were bored at the middle bottom board (named A_2).
- Two openings with a diameter of 6 cm for each were bored at the lower north part and two openings were bored at the upper south part (named A_3).

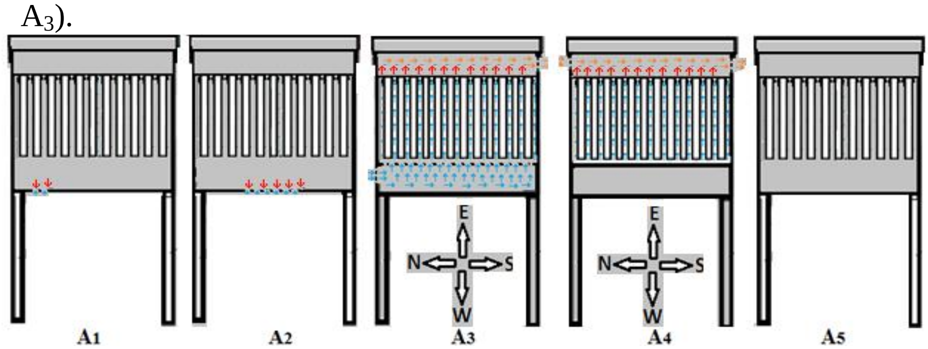

Fig. (10): Schematic diagram illustrate the hive openings.

- Two openings with a diameter of 6 cm for each were bored at the upper north part and another two opening were bored on the same line at the south direction (named A_4).
- All of these ventilated hives were compared with the traditional hives (without ventilation, named A_5).

Some hives were inside insulated with foam and compared with the un-insulated hives, named I1 and I2, respectively.

2.3: Measurements:

The measurements include the; internal hive temperature and relative humidity; water consumption; flight activity; amount of honey and total ventilated hive cost.

2.3.1: Internal hive temperature, ˚C and relative humidity, %: which measured with a digital thermometer with an accuracy of 0.1 ˚C. Air temperature outside the hives was taken by a thermometer placed in in a shaded place in the apiary.

2.3.2: Water consumption: which estimated by refilling the plastic frame feeder with a standard flask.

2.3.3: Flight activity (number of workers per 5 minutes): which scored at the entrance of the hives every five minutes at 12.00 a.m.

2.3.4: Amount of honey per hive, kg: which estimated by extracting every hive with an electric honey- extractor. A digital scale was used to determine the weight of honey (kg) with an accuracy of 0.01 gram.

2.3.5: Ventilated hive cost: The cost of each ventilated hive was estimated according to the recent price in Egypt and compared with the normal hive without ventilation.

2-4 Statistical analysis:-

All obtained data were presented in figures and was analyzed statistically by using a computer program (Minitab Release 1.5) for estimating the probability at levels 1 and 5%. The graphs were drawn using the Microsoft excel window 2013.

3. RESULTS AND DISCUSSION

3.1: Factors affecting internal hive temperature, °C:-

The mean value of internal hive temperature, ˚C (figure 11) decreased in August from 37.3 ˚C with un-ventilated (control) hives (A_5), un-shaded hives (S_3) and un-insulated hives (I_2) to 25.5 ˚C with bottom holed hives (A_1), shading height of 2 m (S_1) and foam insulated hives (I_1), while the outside air temperature at the apiary was 38.5 ˚C. This is due to the non-flow of the outside hot air to the inside of the ventilated hives (A_1) and consequentially less thermal retention inside hive; less thermal conductivity for foam insulated hives (I_1); and non-sun radiation and good air flow above the hives with shaded hives (S_1). The mean percentage of hive internal temperature, ˚C decreasing about 31.6 % at A_1, S_1 and I_1. It was noticed that hive internal temperature, ˚C decreased with the ventilated, shaded and insulated hives according to the following descending order descending order ($A_1 > A_2 > A_3 > A_4 > A_5$), ($S_1 > S_2 > S_3$) and ($I_1 > I_2$), respectively.

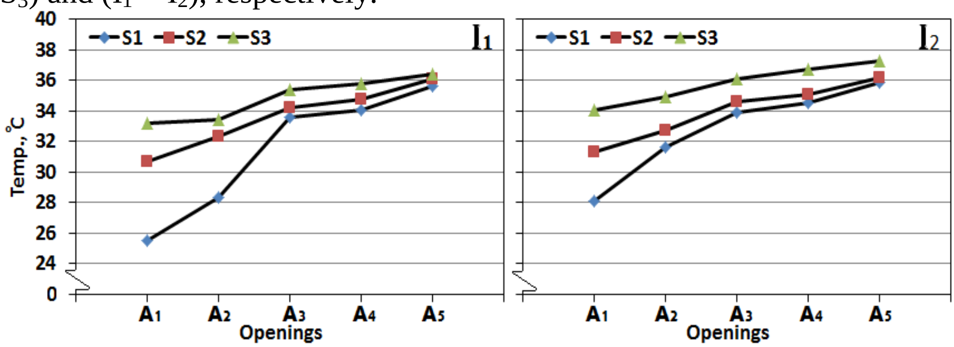

Fig. (11): Factors affecting internal hive temperature.

3.2: Factors affecting internal hive relative humidity, %:-

Fig. (12) shows the effect of studied factors on the internal hive relative humidity, % during August. The maximum mean value of relative humidity of 49.1% was observed with un-ventilated hives (A_5), un-shaded hives (S_3) and un-insulated hives (I_2).

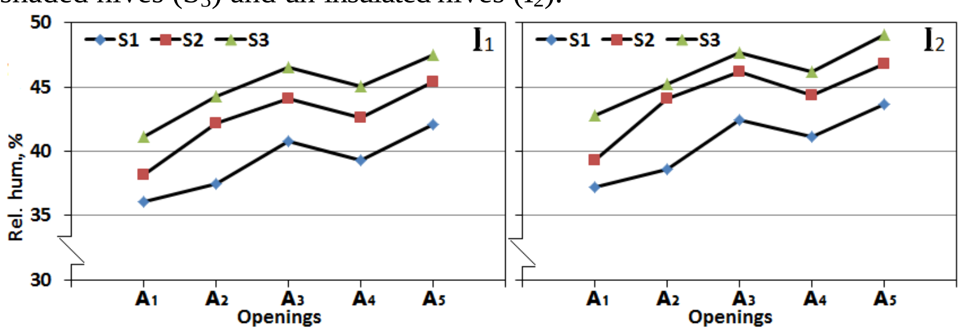

Fig. (12): Factors affecting internal hive relative humidity.

This is due to high temperature led bees to collect much water for evaporative cooling under un-ventilated hives, direct sun shine and with less insulating material (wood). It was observed that internal relative humidity, % increased with A_1, A_2, A_3 and A_5, respectively and decreased with A_4. This is due to direct air flow from north to south that remove excess vapour and consequently, decrease internal relative humidity,%. The mean percentage of internal relative humidity decreasing about 26.5 % at A_1, S_1 and I_1. It was noticed that relative humidity, % decreased with the ventilated, shaded and insulated hives according to the following descending order ($A_1 > A_2 > A_4 > A_3 > A_5$), ($S_1 > S_2 > S_3$) and ($I_1 > I_2$), respectively.

3.3: Factors affecting hive water consumption, litter/day:-

Fig. (13) shows the effect of studied factors on hive water consumption during August. It was decreased from 0.575 L/d with un-ventilated hives (A_5), un-shaded hives (S_3) and un-insulated hives (I_2) to 0.220 L/d with bottom holed hives (A_1), shading height of 2 m (S_1) and foam insulated hives (I_1). This is due to best internal condition with bottom holed hives, that permit the remover of excess heat and vapour without outside hot air direct flow. There was less opportunity of changing the hot air which comes from hives at low shading heights (S_2) so, high shad (S_1) and well insulated hives (I_1), improves the internal hive condition and consequently, decreases the amount of water consumption. The mean amount of water consumption, L/d decreasing about 61.7 % at A_1, S_1 and I_1. It was noticed that hive water consumption, L/d decreased with the ventilated, shaded and insulated hives according to the following descending order ($A_1 > A_2 > A_3 > A_4 > A_5$), ($S1 > S_2 > S_3$) and ($I_1 > I_2$), respectively.

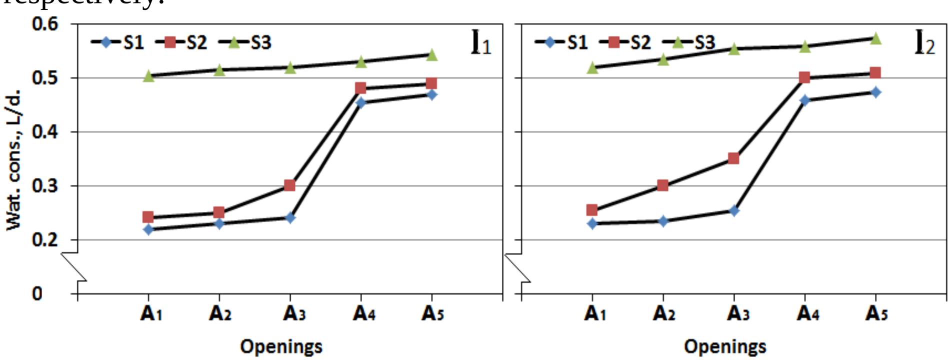

Fig. (13): Factors affecting hive water consumption.

3.4: Factors affecting flight activity (number of workers per 5 minutes):-

Fig. (14) shows the effect of studied factors on flight activity (number of workers/5 minutes). The number of workers per five minutes recorded at the enterance of hive was decreased from 216 workers/5 minutes with bottom holed hives (A_1), shading height of 2 m (S_1) and foam insulated hives (I_1) to 111 workers/5 minutes with un-ventilated (A_5), un-shaded (S_3) and un-insulated (I_2) hives. This is due to high inside temperature, that needs more workers for inside thermal regolation and ventelation; and conseqently decreases in collected pollen and nectar. The mean number of workers/5 min. increasing about 48.6 % at A_1, S_1 and I_1. It was noticed that flight activity (number of workers/5 min.) increased with the ventilated, shaded and insulated hives according to the following descending order descending order ($A_1 > A_2 > A_3 > A_4 > A_5$), ($S_1 > S_2 > S_3$) and ($I_1 > I_2$), respectively.

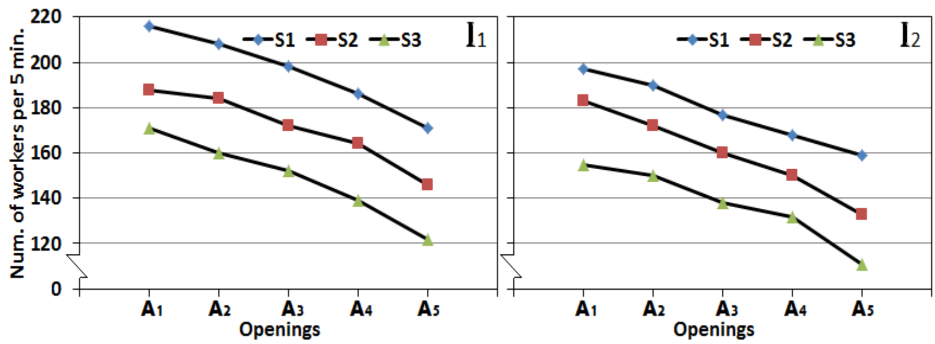

Fig. (14): Factors affecting flight activity (number of workers per 5 minutes).

3.4: Factors affecting the honey amount (kg/hive):-

Fig. (15) shows the effect of studied factors on the amount of honey (kg/hive). The amount of honey at the end of season was increased from 2.33 kg/hive with un-ventilated (A_5), un-shaded (S_3) and un-insulated (I_2) hives to 8.2 kg/hive with bottom holed hives (A_1), shading height of 2 m (S_1) and foam insulated hives (I_1).

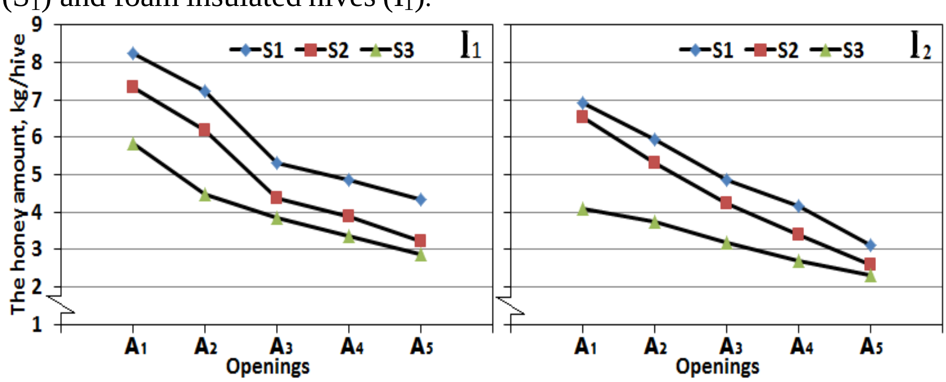

Fig. (15): Factors affecting the honey amount.

This is due to the improvement of hive conditions. It was noticed that the amount of honey increased with the ventilated, shaded and insulated hives according to the following descending order descending order ($A_1 > A_2 > A_3 > A_4 > A_5$), ($S_1 > S_2 > S_3$) and ($I_1 > I_2$), respectively.

3.4: Factors affecting the cost production:-

The total cost production was estimated according to recent prices in Egypt. Table (1) represents a comparison between ventilated hives (A_1, A_2, A_3 and A_4) costs and the traditional hive (without ventilation, named A_5).

Table 1: Comparison between the cost production of ventilated and the traditional hives.

Specification	Price				
	A_1	A_2	A_3	A_4	A_5
- Super	90	90	90	90	90
- Nest from 9 frames	400	400	400	400	400
- Addition upper part	----	----	60	60	----
- Addition lower part	----	----	60	----	----
- Cover, bottom board and stand	80	80	70	70	70
- Total hive cost	570 L.E.	570 L.E.	680 L.E.	620 L.E.	560 L.E.

The cost of one sunshade contains 10 hives under it was 800 L.E. and the total insulation costs for 10 hives were 50 L.E., so the total costs of the 10 ventilated hives (A_1) plus the cost of the sunshade and insulation material equal 6550 L.E.. The expected live of ventilated hives, sunshade and insulation materials were 5 years, so the actual annual cost equal 1310 L.E. The cost of one kilogram of honey equal 60 L.E. and the amount of honey produced from ventilated hives at the optimum treatments equal 8.2 kg / hive, so the total price of honey produced from 10 hives equal 4920 L.E. The total price of honey produced from the un-treated hives (A_5) equal 1398 L.E., so the saving money equal 3522 L.E. represents about 250 %.

Table 2: ANOVA Analysis

Changeable factor	Measurements				
	Internal hive temperature, ˚C	Internal hive relative humidity, %	Water consumption , litter/day	flight activity (number of workers per 5 min.)	Amount of honey (kg/hive)
Ventilation (A)	**	**	*	*	**
Shading (S)	*	**	**	**	**
Insulation, (I)	**ns**	**ns**	**ns**	**ns**	**ns**

**, highly significant at 1% level; *, significant at 5% level; ns, non-significant

4. CONCLUSION

It was observed that the minimum internal hive temperature (25.5 °C); the minimum internal relative humidity (36 %); the minimum amount of hive water consumption (0.220 L/d); high flight activity (216 workers per 5 minutes); the maximum amount of extracted honey per hive (8.2 kg/hive) and the minimum cost of production were achieved by using a ventilated hive with two screened holes (6 cm) at the bottom; shading height of 2 m and foam insulated hive. The direct outside air current increase internal hive temperature, so it is recommended to use ventilated hive with two screened holes (6 cm) at the bottom; shading height of 2 m and foam insulated hive, that workers can fan hot air out of the hive without external hot air entrance or exchanger. It is recommended also to use a piece of sackcloth under the cover of foam insulated hives to prevent any foreign insect to inter the hive and absorb excess vapor from the evaporation process.

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الملخص العربي

تأثير التظليل والتهوية على كمية المياه المستهلكة في تبريد خلية النحل خلال الموسم الصيفي

محمد علي إبراهيم الراجحي*

تم إجراء هذه الدراسة من اجل ملاحظة تأثير التظليل والتهوية على كمية المياه التي تستهلكها شغالات النحل في تبريد الخلية. استخدمت في الدراسة ٩٠خلية من نوع لانجستروس تحتوي على نحل من النوع الهجين الكرنيولي المتساوي في القوة (عدد براويز النحل وعمر الملكة). لدراسة تأثير التظليل تم تقسيم الخلايا الي ثلاث مجموعات. المجموعة الاولي تم تظليلها على ارتفاع ٢ م من سطح الارض وفي الثانية تم وضع مادة التظليل علي أظهر الخلايا مباشرة وتم وضع المجموعة الثالثة في الشمس بدون تظليل. ولعمل تهوية للخلايا تم عمل أربع اوضاع للفتحات كلها مغلقة بشبك سلك من الداخل وهي ثقبان بقاع الخلية بقطر ٦ سم وفتحة مساحتها ٢٥ * ٢٥ سم اخري بقاع الخلية وفتحتان في الجانب الشمالي السفلي بقطر ٦سم واثنتان اخريان في الجزء الجنوبي العلوي وكذلك فتحتان في الجزء الشمالي العلوي يقابلهم فتحتان علي نفس المسار في الجزء الجنوب العلوي. وتم مقارنة جميع هذه الخلايا بالخلايا العادية الغير مهواه. وتم عزل الخلايا من الداخل بالفوم لمقارنتها بالخلايا الغير معزولة. ولوحظ ان أقل درجة حرارة داخل الخلية خلال شهر اغسطس (٢٥.٥ °م) واقل رطوبة نسبية (٣٦ %) وأقل كمية مياه مستهلكة (٠.٢٢٠ لتر/يوم) وأكبر عدد للنحل السارح كل خمس دقائق (٢١٦ نحلة كل خمس دقائق) وأكبر كمية للعسل المفروز في نهاية الموسم (٨.٢ كيلوجرام/خليه) عند استخدام خلايا بها ثقبان من أسفل بقطر ٦ سم وارتفاع تظليل قدرة ٢ م وخلايا معزولة من الداخل بالفوم. لذا ينصح باستخدام خلايا بها ثقبان من أسفل بقطر ٦ سم وارتفاع تظليل قدرة ٢ م وخلايا معزولة من الداخل بالفوم للحصول على افضل قياسات.

***باحث بمعهد بحوث الهندسة الزراعية.**