EFFECT OF THE INTERNAL SIZE AND THERMAL INSULATION OF THE HIVE ON BEE COLONIES STRENGTH AND PRODUCTIVITY

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(Manuscript received 12 January 2015)

Abstract

This study was conducted to investigate the effect of the internal size and thermal insulation of the hive on bee colonies strength (sealed brood area) and productivity (honey area, pollen area). Hives from Langstroth type were used containing honeybee colonies of equal strength from the species of hybrid carniolan. This study included three internal sizes of bee hives (0.024, 0.031 and 0.038 m^3); three insulation cases (without, with sackcloth and with foam); and three hive entrance direction (East, Southeast and South). The lowest mean hive temperatures recorded in the middle of January to be 18.3, 16.8 and 11.8°C with foam, sackcloth and without insulation, respectively. Average lower temperature were 20, 16.7 and 13.6 °C for internal hive sizes of 0.024, 0.031and 0.038 m^3, respectively. Average temperature were 17.3, 16.9 and 16.6 °C for hive entrance direction South, Southeast and East, respectively. The mean area of honey, pollen and sealed brood at the end of March were 826, 652 and 3561 cm^2, respectively when using foam insulator. And 884, 716 and 3626 cm^2, respectively at the end of March and with internal hive size 0.024 m^3. In case of south entrance direction the above areas were 845, 658 and 3542 cm^2, respectively at the end of March. Significant increase in hive temperature, honey area, pollen area, sealed brood area was detected When using the lowest internal beehives size and foam insulator.

Key words: Insulating, temperature, honey area, pollen area and sealed brood area.

ITRODUCTION

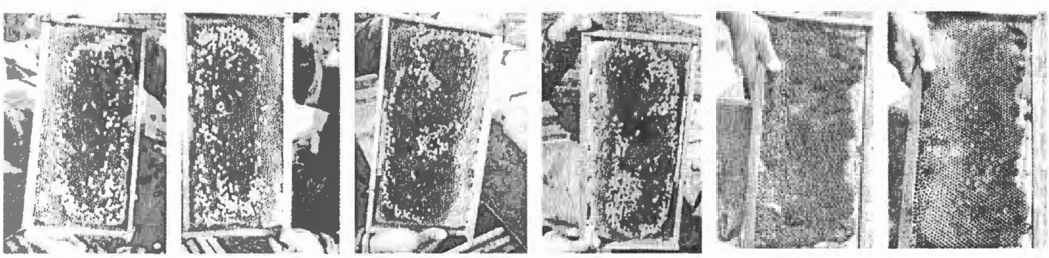
Temperature is an important factor affecting larval and pupal development of insects (Nylin and Gotthard, 1998). Honeybees can survive when the temperature of the external environment is between -20 and +48 °C and even -40 and +60 °C. However, they show the best performance at the temperatures between +21 and +35°C. If the temperature is extremely cold in winter (falls below +14°C) bees do not move around to collect honey (carbohydrate source) and pollen (protein source) and forming a ball (winter cluster). When the temperature falls below +6 °C, the hive has the appearance of an exact ball Adaptation to cold climates does not involve a state of dormancy or hibernation characteristic of most insects; honeybees remain active within the winter cluster. The cluster center, or core, in broodless colonies is generally maintained within the range of 20-30 °C. Maintaining a suitable range of temperature from 33 to 36 °C inside colonies is very important for honeybees (Petz *et. al.* 2004). This constant temperature is crucial for the normal growth and development of the brood. Deviation from this range can occur when the ambient air temperature changes and affect the developmental period of honey bee immature stages, 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). Moreover, very low temperature below 10 °C can prevent flight activity (Joshi and Joshi 2010). So crucial is the perception of temperature change to bees that an individual worker is able to pick up changes to within 0.25°C using receptors located on her antennae (Mathis and Tarpy, 2007). Honeybees are known to control their hive environment to survive drastic changes in the field environment (Jones and Oldroyd, 2007). During flight, the rather large flight muscles create heat, which must dissipate to brood area (Esch *et. al.,* 1991). The brood nest needs temperature of 30 - 36 °C to develop the brood Stabentheimer *et. al.,* 2003 used a new infrared technology, were able to measure the temperature of the individual parts of bees bodies, and show that there were also some workers who actually made heat (thermogenesis) by "shivering" (activating their wing muscles).Nest heating has an energetic cost: when ambient temperature drops from 28 – 17°C , the metabolic rate of a bee colony rises from 7 – 19 watt kg^{-1}. It has been demonstrated that, at low temperatures, workers spend more energy and time for thermoregulation than for brood care (feeding, building brood cells), which results in a reduced production of brood by the colony. Moreover, it has been shown that the production of brood cells is lower during cold periods of the year compared to hot periods (Velthuis *et. al.,*2000; Borges and Blochtein, 2006). Colonies even completely interrupt the production of brood cells during the period of winter (van Benthen *et. al.,*1995). At low ambient temperatures, whenever the brood temperature drops below the needed range of temperature, worker honeybees engage in different strategies to warm up the brood. One such strategy they employ is to heat their thoraces through muscular activity and press their warm thoraces onto capped brood cells for several minutes at a time (Bujok *et. al.,* 2002), such honeybees are referred as cap heating honeybees. The second strategy the worker honeybees employ is to warm themselves up, to enter empty comb cells among the brood, and to dissipate their body heat to the brood cells around them (Kleinhenz *et. al.,*2003); such honeybees are referred to as cell heating honeybees. In both the case of cell and the cap heating honeybees, the bees increase their body temperature by isometrical contraction of the bee flight muscles (Seeley, 1995 and Crane, 1990). In addition to these heating strategies, the honeybees also try to insulate and reduce the heat loss from the brood by crowding in the brood area. The main hypothesis to explain why brood production diminishes during cold periods is that workers spend more energy in heating the colony than with tasks related to brood production (Engels *et. al.,*1995; Vogt, 1996). Bees consume honey to rise inside the hive temperature in Worker bees contribute to the regulation of brood nest temperature by producing heat while sitting motionless on the caps of brood cells (Marco Kleinhenz *et. al.,* 2003). Increasing levels of metabolism (i e, honey consumption for heat production) are indeed associated with exposure to cold temperatures. The adult bees begin to generate their own heat by consuming carbohydrates (in the form of stored honey) and as a result they go hungry also in some cases they cannot feed themselves because honey within the hive freezes due to the cold. Starvation is a principal cause of colony losses; they cluster and starve because they eat the honey that stored. Therefore, if bees are short of honey, they should be fed a syrup of two parts granulated sugar to one part water that increase costs of production. Factors of external ambient and internal hive conditions are very important on the productivity honeybees (Cetin, 2004). Morse, 1990 mentioned that hives in cellar wintering, a technique that was often used at the turn of the past century. While only one of the variables of the equation, food consumption, is measured, the hive temperature increased, when they are moved to a relatively warmer place. When the hives are outside they consume 22.3 kilograms of honey during the season, but when they are placed in a cellar they only consume 6.8 to 13.2 kilograms. Starks *et. al.,*2000 observed that honeybees raise the temperature of the brood area regularly to increase the brood activities and protect themselves against predators. They have also stated that when Ascosphaera apis which is the pathogen of chalk brood contaminates to the colony at the temperatures below 30 ^{o}C, honeybees realize this and raise the temperature before the broods get sick. There have been many attempts to reduce the loss of honey bee colonies in winter, by improving the conditions of temperature inside the bee colonies, such as:(Furgala, and McCutcheon, 1992, Abrol, 2001,Wineman *et. al.,* 2003, Dodologlu, *et. al.,* 2004 and Erdogan, *et. al.,* 2009. 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. There are little researches about warming of beehives under Egypt condition. Bees or adult population was estimated in the rate of 2000 adult bees, which can cover a comb from both sides (Hauser and Lensky, 1994).

Therefore, the objective of the present study was to select the best internal size and thermal insulating of the hive that should be used to decrease both colony food consumption and mortality by improving hive conditions and maintaining the strength of colonies to produce citrus honey early during spring season.

MATERIALS AND METHODS

Bees from a private apiary at Meet-Salseel, EL- Daqahliyah governorate, Egypt, were used in this study. 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). A total of 21 Langstroth enclosure beehives (outside measures: 53cm x 43 cm x 25cm and wall thickness: 2 cm) with removable tops contents honey bees (hybrid carniolan), that had been established 8 months prior to the onset of the experiment on a sunny site in the bee yard, with their entrances far from the common wind direction and rain. Beehives 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 (6 combs). Nosema apis and Varroa destructor were monitored every 12 days throughout the winter season, and treated whenever necessary. The present study carried out from 1 December until 30 March.

The studied factors included three internal sizes of beehives (0.024, 0.031and 0.038 m^3); three insulation cases (without, with sackcloth and foam); and three hive entrance direction (East, Southeast and South). There were two ventilation small holes located under the cover to permit ventilation and allow moisture exchange. A digital thermometer was used to determine internal hive temperature in the bee yard. The number of sealed brood cells located at the lower edge or sides of the comb, honey stored along the top edge of the comb and pollen stored along the sides of the comb. Each colony was monitored by taking photos of the new sealed brood, honey and pollen cells after shaking the bees off (fig. 1). Comparing consecutive the number of new sealed brood, honey and pollen cells photos could be assessed. The nearest areas of capped brood, honey and pollen cells were determined in all the experimental colonies by considering 4 cells per sq. cm of comb. This investigation was carried out every 12 days throughout the winter season of 12 December, 24 December, 5 January, 17 January, 29 January, 10 February, 22 February, 6 March, 18 March and 30 March.



Comb$_1$-side$_1$ **Comb$_1$-side$_2$** **Comb$_2$-side$_1$** **Comb$_2$-side$_2$** **Comb$_3$-side$_1$** **Comb$_3$-side$_2$**

Fig. 1. Some combs inspected in winter season.

RESULTS AND DISCUSSION

1- The climate of tested region.

Data illustrated in figures from 2 to 4 show the mean monthly climatic factors for the 4 months (December 2013, January 2014; February 2014 and March 2014). The range of minimum temperature fluctuated between 10.7 °C in January and 14.9

°C in March Maximum temperature fluctuated between 18.8 °C in January to 22.8 °C in March. The aerage temperature during night time in December, January, February and March was 15.4, 13.4, 15 and 16.8 °C, respectively. The mean temperature during daytime in December, January, February and March was 17.9, 15.9, 17.5 and 19.7 °C, respectively. Out of 1294 possible sunshine duration hours during the study so, the ambient temperature was higher than 8 °C. In general, workers cease flying when ambient temperature is below 8 °C (Crane, 1990), hence, the winter of 2013-2014 was quite favorable for foraging activities of field bees. The minimum value of mean rainfall was 0 mm in February and March; and the maximum value was 32 mm in January. The average wind velocity during December, January, February and March was 3.2, 3.4, 3.5 and 4.1 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 average Relative humidity, % during December, January, February and March was 75, 76, 74 and 67 %, respectively as illustrated in Figs (2,3 and 4).

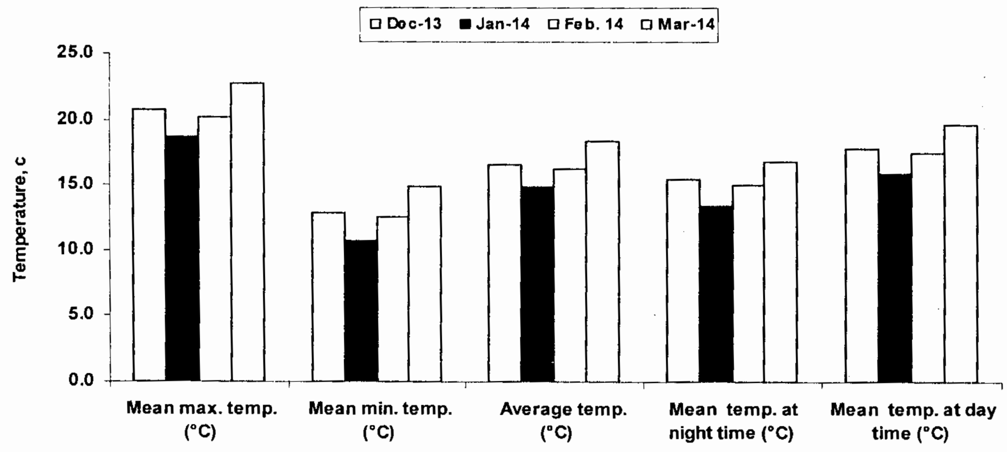


Fig. 2. The mean temperatures during the study.

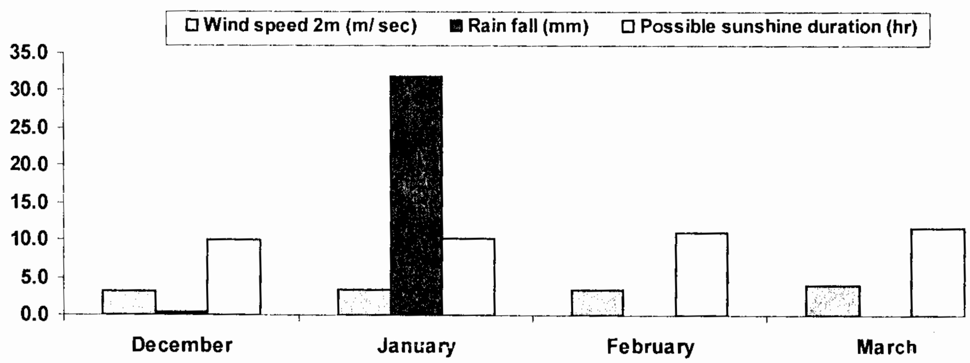


Fig. 3. The mean wind speed (m/s), rainfall (mm) and possible sunshine duration (hr) during the 4 months.

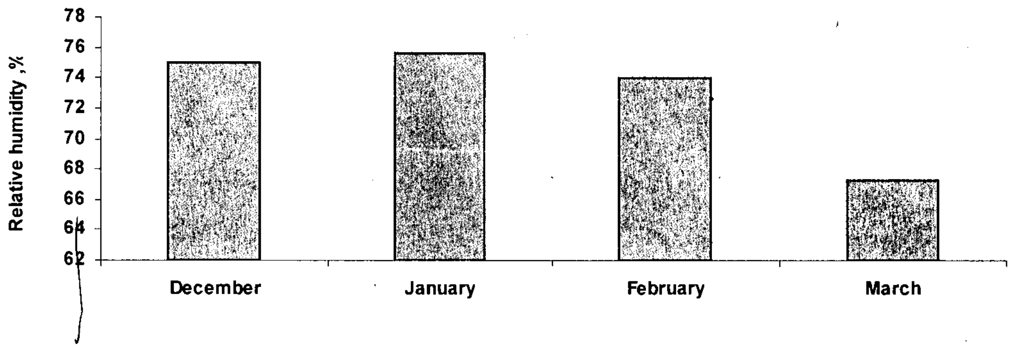


Fig. 4. The mean relative humidity, % during the 4 months.

Data illustrated in Figs (5 to 8) show the comparative magnitude of values of hive temperature (T, °C), honey area, (H_a, cm^2), polen area, (P_a, cm^2) and sealed brood (Sb_a, cm^2) .

2- Effect of the internal hive size, insulator type and hive entrance direction on hive temperature, °C.

Fig. 5 shows the effect of internal hive size, insulator type and hive entrance direction temperature. There was an increasing in temperature when decreasing hive internal size and by using foam insulator with South entrance direction. The mean temperature on the middle of January increases from 13.6 °C at hive internal size 0.038 m^3 to 20°C at hive internal size 0.024 m^3. The mean temperature on the middle of January increases from 16.8 °C with sackcloth insulator to 18.3 °C with foam insulator, however sackcloth insulator prevents any foreign insect from interning the hive and absorb vapor from the evaporation process. The lower mean temperature on the middle of January was 11.8 °C without using insulator. The mean temperature on the middle of January increases from 16.6 °C at East entrance direction to 17.3 °C at South entrance direction. In general, the average values were decreased for all from the first day of experiment (12 December, 2013) up to the nearly middle of January (17 January, 2014) then increased from the end of January (29 January, 2014) up to the end of experiment (30 March, 2014). This is due the effect of changes in ambient temperature during the study. It was noticed that T, °C increased; with internal hive sizes, insulator types and entrance direction, according to the following descending order (0.038 m^3 < 0.031 m^3 < 0.024 m^3); (without insulator < Sackcloth < Foam) and (East < Southeast < South), respectively.

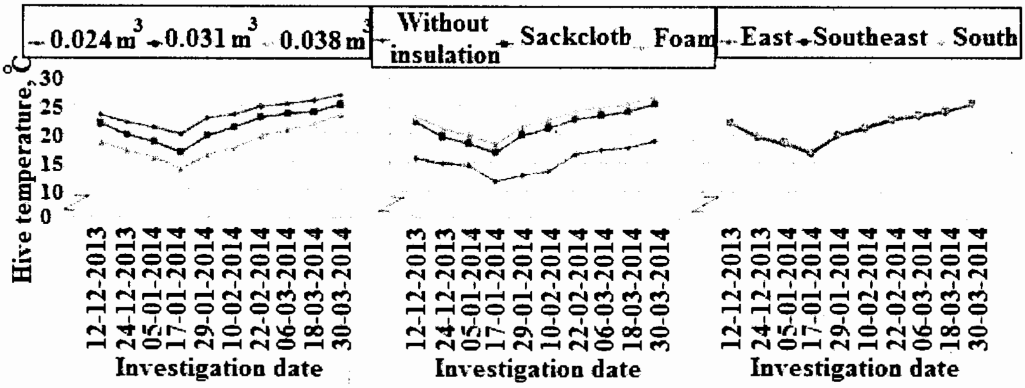


Fig. 5. Effect of the internal hive size, insulator type and hive entrance direction on hive temperature, °C

3- Effect of the internal hive size, insulator type and hive entrance direction on honey area.

The mean value of honey area, cm^2 Fig. 6 increased on the end of March from 555 cm^2 at hive internal size 0.038 m^3 to 884 cm^2 at hive internal size 0.024 m^3. The mean honey area, cm^2 on the end of March increases from 126 cm^2 with sackcloth insulator to 128 cm^2 with foam insulator. The mean honey area, cm^2 on the end of March was 284 cm^2 without using insulator. The mean honey area, cm^2 on the end of March increases from 800 cm^2 with East entrance direction to 845 cm^2 with South entrance direction. In general, the average values were decreased for all from the first day of experiment (12 December, 2013) up to the nearly middle of January (17 January, 2014) and started to increase from the end of January (29 January, 2014) up to the end of experiment (30 March, 2014). This is due the effect of changes in ambient temperature during the study. It was noticed that honey area, cm^2 increased; with internal hive sizes, insulator types and insulator thicknesses, according to the following descending order (0.038 m^3 < 0.031 m^3 < 0.024 m^3); (without insulator < Sackcloth < Foam) and (East < Southeast < South), respectively.

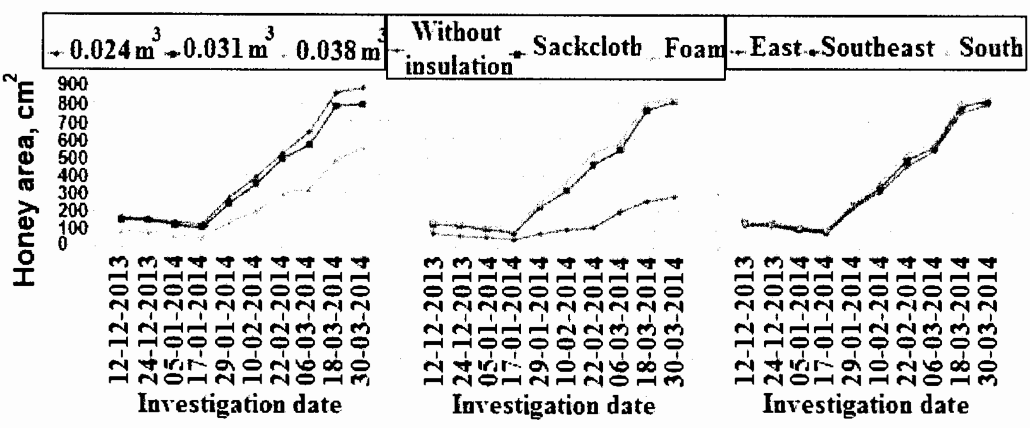


Fig. 6. Effect of the internal hive size, insulator type and hive entrance direction on honey area, cm^2

4- Effect of the internal hive size, insulator type and hive entrance direction on pollen area.

The mean value of pollen area, cm^2, Fig. 7 increases on the end of March from 477 cm^2 at hive internal size 0.038 m^3 to 716 cm^2 at hive internal size 0.024 m^3. The mean pollen area, cm^2 on the end of March increases from 574 cm^2 with sackcloth insulator to 652 cm^2 with foam insulator. The mean pollen area, cm^2 on the end of March was 406 cm^2 without using insulator. The mean pollen area, cm^2 on the end of March increases from 619 cm^2 with East entrance direction to 658 cm^2 with South entrance direction. In general, the average values were decreased for all from the first day of experiment (12 December, 2013) up to the nearly middle of January (17 January, 2014) and started to increase from the end of January (29 January, 2014) up to the end of experiment (30 March, 2014). This is due the effect of changes in ambient temperature during the study. It was noticed that pollen area, cm^2 increased; with internal hive sizes, insulator types and insulator thicknesses, according to the following descending order (0.038 m^3 < 0.031 m^3 < 0.024 m^3); (without insulator < Sackcloth < Foam) and (East < Southeast < South), respectively.

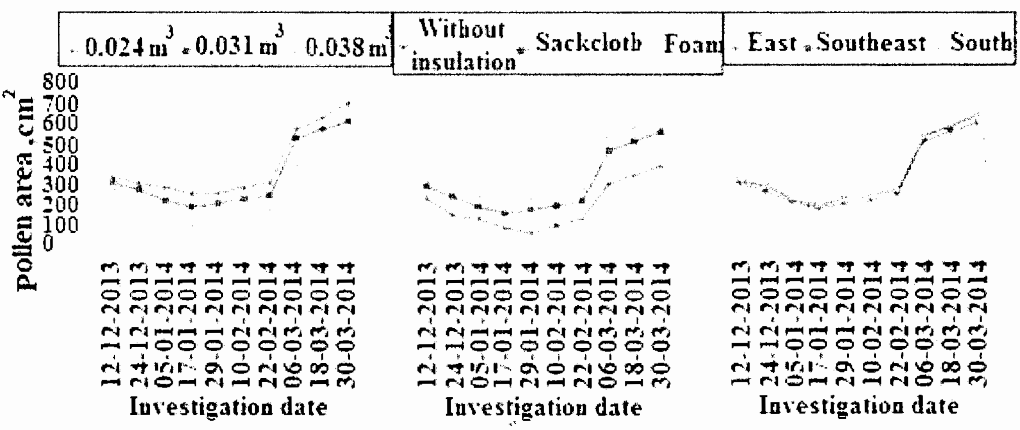


Fig. 7 . Effect of the internal hive size, insulator type and hive entrance direction on pollen area, cm2

5- Effect of the internal hive size, insulator type and hive entrance direction on sealed area brood, cm^2.

The mean value of sealed brood area, cm^2, Fig. 8 increases on the end of March from 3168 cm^2 at hive internal size 0.038 m^3 to 3626 cm^2 at hive internal size 0.024 m^3. The mean sealed brood area, cm^2 on the end of March increases from 3503 cm^2 with sackcloth insulator to 3561 cm^2 with foam insulator. The mean sealed brood area, cm^2 on the end of March was 2710 cm^2 without using insulator. The mean sealed brood area, cm^2 on the end of March increases from 3452 cm^2 with East entrance direction to 3542 cm^2 with South entrance direction. In general, the average values were decreased from (24 December, 2013) up to the nearly end of January (29 January, 2014) and started to increase from the end of January (29 January, 2014) up to the end of experiment (30 March, 2014. It was noticed that sealed brood area, cm^2

increased; with internal hive sizes, insulator types and insulator thicknesses, according to the following descending order (0.038 m^3 < 0.031 m^3 < 0.024 m^3); (without insulator < Sackcloth < Foam) and (East < Southeast < South), respectively.

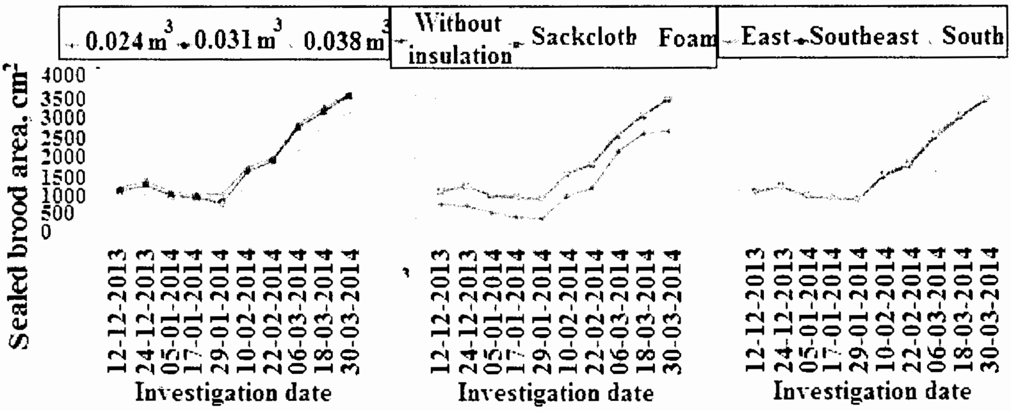


Fig. 8. Effect of the internal hive size, insulator type and hive entrance direction on sealed brood area, cm^2

CONCLUSION

It was observed that the maximum values of hive temperature, area of honey, pollen and sealed brood were achieved by using the lowest internal beehives size (0.024 m^3) and the South entrance direction.

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تأثير الحيز الداخلي والعزل الحراري للخلية علي قوة وإنتاجية طوائف النحل

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أجريت الدراسة لملاحظة تأثير الحيز الداخلي والعزل الحراري للخلية علي قوة طوائف النحل وذلك بتقدير مساحة الحضنة المنتجة وكذلك إنتاجية طوائف النحل من خلال معرفة مساحة كلا من العسل وحبوب اللقاح المخزنة بالبراويز بالإضافة إلي ملاحظة التغير في درجات الحرارة داخل الخلية.لإجراء ذلك استخدمت خلايا من نوع لانجستروس تحتوي طوائف نحل من النوع الهجين الكرنيولي . تم دراسة ثلاث أحجام داخلية للخلية هي علي الترتيب (٠,٠٢٤، ٠,٠٣١، ٠,٠٣٨ م^{٣}) وثلاث حالات للعزل هي (بدون عزل ، خيش ، فوم) وثلاث اتجاهات لباب الخلية هي (شرقي، جنوب شرقي ، جنوبي) لوحظ أن درجات الحرارة المتوسطة داخل الخلية هي ١٨,٣، ١٦,٨ ، ١١,٨°م عند الحالات بدون عزل وباستخدام خيش وباستخدام فوم علي الترتيب علي حين كانت ٢٠، ١٦,٧ ، ١٣,٦ °م عند حجم داخلي ٠,٠٢٤ ، ٠,٠٣١، ٠,٠٣٨م^{٣} وكانت ١٧,٣، ١٦,٩، ١٦,٦ عند الاتجاهات التالية لباب الخلية (جنوبي ، جنوب شرقي ، شرقي) وذلك تقريبا في منتصف شهر يناير. متوسط مساحة أعين العسل المغلقة وحبوب اللقاح والحضنة كانت ٨٢٦- ٦٥٢-٣٥٦١ سم^{٢} علي الترتيب وذلك في نهاية شهر مارس وعند استخدام الفوم العازل. و كانت ٨٨٤-٧١٦- ٣٦٢٦ سم^{٢} علي الترتيب وذلك في نهاية شهر مارس و عند حجم داخلي ٠,٠٢٤ م^{٣}. وكانت ٨٤٥ ٦٥٨ ٣٥٤٢ سم^{٢} علي الترتيب وذلك في نهاية شهر مارس وعند الاتجاه الجنوبي لباب الخلية. لذا فانه عند استخدام اقل حجم داخلي للخلايا والفوم كمادة عازلة فان هناك زيادة في درجة حرارة الخلية الداخلي ومساحة أعين العسل المغلقة وحبوب اللقاح والحضنة.