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INTERNAL AMBIENCE OF BEEHIVES *Apis mellifera* WITH DIFFERENT COLORS AND ROOFING MATERIALS IN THE SUB MIDDLE OF THE SÃO FRANCISCO VALLEY

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ABSTRACT: The current study aimed to evaluate the influence of three colors and two types of roofing materials under the internal temperature of bee colonies *Apis mellifera*. The experiment was conducted at the Agricultural Sciences Campus at the Federal University of Sao Francisco Valley located in Petrolina-PE, in November and December 2013, using 24 colonies housed in Langstroth hives. The experiment was a completely randomized factorial design (3x2) with three colors of box (blue, white, and traditional) and two types of cover (with and without the use of plaster) with six treatments and four replications. The internal temperature dates of the colonies were hourly recorded, during 24 hours, and surface temperatures were hourly recorded between 08h00 and 17h00. The highest values for surface and internal temperature were registered in the blue painted boxes without the use of plasterboard, and the blue painted boxes covered with plasterboard respectively. However, the lowest values were found in the white painted hives and hives that have not received the plasterboard. It is recommended to paint boxes with bright colors, and the use of plasterboard had no effect in reducing the internal temperature.

KEYWORDS: thermal comfort, insects, temperature.

AMBIÊNCIA INTERNA DE COLMEIAS DE *Apis mellifera* COM DIFERENTES CORES E MATERIAIS DE COBERTURA NO VALE DO SUBMÉDIO SÃO FRANCISCO[1]

RESUMO: O presente estudo teve por objetivo avaliar a influência de três tipos de cores e dois materiais de cobertura sob a temperatura interna de colônias de abelhas *Apis mellifera*. O experimento foi conduzido no Câmpus de Ciências Agrárias da Universidade Federal do Vale do São Francisco, localizada em Petrolina-PE, em novembro e dezembro de 2013, utilizando 24 colônias alojadas em colmeias do tipo Langstroth. O delineamento experimental foi o inteiramente casualizado, em esquema fatorial (3x2), sendo três cores de caixa (azul, branca e tradicional) e dois tipos de tampa (com e sem o uso de gesso), com seis tratamentos e quatro repetições. Foram registrados dados de temperatura interna das colônias a cada hora, durante as 24 horas, e de temperatura superficial a cada hora, entre as 8 h e as 17 h. Os maiores valores de temperatura superficial e interna foram registrados em caixas pintadas de azul sem o uso da placa de gesso e em caixas pintadas de azul cobertas com placa de gesso, respectivamente. Já os menores valores foram encontrados em colmeias pintadas de branco e que não receberam a placa de gesso. Recomenda-se pintar as caixas de cores claras, e o uso da placa de gesso não influenciou na redução da temperatura interna das mesmas.

PALAVRAS-CHAVE: conforto térmico, insetos, temperatura.

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INTRODUCTION

The beekeeping activities has achieved great importance in agricultural production systems, since it presents an employment alternative and income for the farmer as well as being an activity of easy maintenance and low initial cost compared to other activities in rural areas (OMRAN, 2011).

The bees are affected directly by the ambient production, temperature variation, particularly with regard to the internal ambience creation in conventional boxes. So the environment is one of the factors that exert heat stress in animals. Even if it is carefully planned, some element cannot allow the insect be fully in a comfort situation. Among these elements, which can cause stress to the insects are the environmental variables such as temperature and humidity (BARBOSA FILHO, 2008).

The bee *Apis mellifera*, as well as other insects, is considered a heterotermic animal, however, the colony behaves as a homoeothermic organism, because it keeps the temperature constant in the region of the nest by about 33 to 36 ° C (SHAW et al., 2011), and this area where it cannot have large temperature variations, ranging to a maximum of 4 to 6 ° C for short periods from minutes to a few hours (BRASIL et al., 2013).

Even with the ability to adapt to different environments, colonies of these insects can suffer major losses with changes in weather conditions. Although the adult bees are relatively tolerant to temperature variations, their offsprings are sensitive to small variations in the temperature of the nest (SOUZA, 2010). According to COSTA et al. (2007) any variation in weather conditions can influence the output of foraging bees foraging for nectar and polliniferous plants and consequently affect the productivity of the colony.

SALLES et al. (2003) evaluated the influence of two colors of box (blue and white), two types of coverage (asbestos and polyethylene), two types of protection height (single and double) and room temperature in honey production of *Apis mellifera* in the State of Rio de Janeiro during the winter period, found that the boxes painted with blue and covered with polyethylene tiles provided greater honey production.

In studies by BRASIL et al. (2010) in the State of Ceará was analyzed variation in internal temperature of an *Apis mellifera* beehive which was covered with a roof of long life milk cartons and with aluminized side (reflector) facing up. It was observed that these boxes had the lowest average values of internal temperature and humidity, being an inverse behavior to the boxes without this type of coverage.

To evaluate the influence on environmental factors and the material used to build the boxes used by the bees is essential for the best performance of the beehive and increase production, considering that studies directed to the beekeeping activities help obtaining higher quality products in ways that allow comfort and welfare for these insects. Thus, this study aimed to evaluate the influence of three colors and two beehives roofing materials under the internal temperature of colonies of *Apis mellifera*.

MATERIAL AND METHODS

The experiment was conducted in the apiary of Agricultural Sciences Campus of the Federal University of São Francisco Valley (09º19'26 "S, 40º33'36" W and altitude of 393 m) in the city of Petrolina-PE in the period of November and December, 2013. The average air temperature during the trial period was 27.5 °C and relative humidity of 56.1%, according to Meteorological Laboratory data of UNIVASF (LABMET). The climate, according to Köppen classification appears as tropical semi-arid, BshW type, characterized by the scarcity and irregularity of rainfall, with rainfall in the summer and strong evaporation as a result of high temperatures.

Twenty-four colonies of *Apis mellifera* were housed in beehives Langstroth type, sustained by an iron support, with spacing between them of approximately 2m. The colonies had uniform population with the same amount of offspring, and the supers were being added as needed.

The experimental design was completely randomized in a factorial 3 x 2, where were tested three housing colors (blue, white and traditional (unpainted)) and two types of cover (wood with addition of plaster and only wood cover) with six treatments and four replications: TACG: box painted blue and covered with wooden lid and plaster (A); TASG: box painted blue and covered with wooden cover (B); TBCG: box painted white and covered with wooden lid and plaster (C); TBSG: box painted white and covered with wooden cover (D); TSCG: traditional box covered with wooden lid and plaster (E); TSCSG: Traditional box covered with wooden lid (F). The boxes were named according to the treatment and repetition which they are designated and scattered randomly in the experimental area.

Following the arrangement of treatments, eight boxes were painted on the outside in white and blue colors and eight remained in the traditional way. The boxes that receiving the plaster lid were designed as follows: first the boxes were closed with a conventional timber and on that was placed the plaster board.

To study the influence of temperature and environmental variables in the internal ambience of the hives in the six treatments were recorded data of the surface temperature of the boxes through infrared thermometer during the experimental period. The data were always taken every hour, in two days weekly, from 8 am to 5 pm, giving a total of 10 days of data collection. Five records on surface temperature of the boxes (top (cover) and a reading by the side of the box) were obtained using the average temperature of each box. The wind speed was measured at the height of the boxes with the aid of a digital anemometer.

Environmental data were recorded every hour through the automatic weather station installed within the Federal University of São Francisco Valley at approximately 400 meters from the experimental area.

Mini data loggers were developed with temperature sensors to obtain the internal temperature of the boxes by storing the information every hour throughout the experimental stage inserted in the beehive nest area on the first day of the experiment, and remained until the end. To be placed inside the box, they were isolated by a closed plastic structure on both sides by a tulle fabric to prevent bee access to the sensor. Due to the size of the plastic structure, it was necessary to withdraw a frame from the nest area from all beehives so they could be inserted.

For superficial and internal temperature were obtained average values from each time for all treatments. Correlation analysis between the surface and internal temperatures was accomplished by the Pearson's method and its statistical probability given by the "t" test at 1%. We conducted analysis of variance for each date, and the means were compared by Tukey test at 5% probability through the statistical program SISVAR (Version 5.3).

RESULTS AND DISCUSSION

Figures 1 and 2 show the average values of temperature and relative humidity during the trial period. There was a thermal variation during the 24 hours of observation. At 6 a.m. it was the lowest temperature (22.8 ° C), occurring a gradual increase in these values until it reaches the peak at 4 p.m. (32.1 °C), returning soon afterwards, to fall to 25.8 °C at 11 p.m. (Figure 1). Regarding data on air relative humidity it can be observed that the highest value was at 6 a.m. (73.8%). From that time these values began to decline, until 4 p.m. when it was verified the lowest value (36.3%) then a rise of such data registering 58.8% at 11 p.m (Figure 2).

These results corroborate with MACHADO et al. (2011) which state that in the early hours of the day there has been always lower air temperatures and higher relative humidity values. This fact is due to the energy balance, which short-wave radiation (UV) gained during the day is largely dissipated during the night when there is no sunlight in the form of long wave radiation (IR).

These climatic variables act directly on the maintenance and control of the internal temperature within the colonies, influencing the development of the offspring (CARVALHO, 2009).

For WINSTON (2003), temperature above 36 ° C for any time period are detrimental to *Apis mellifera* offspring and excess of 1 to 2 ° C can cause developmental abnormalities and death. During the experimental period, it was observed that the air temperature has not exceeded the mean value of 36 ° C, then not been considered detrimental to development of the offspring.

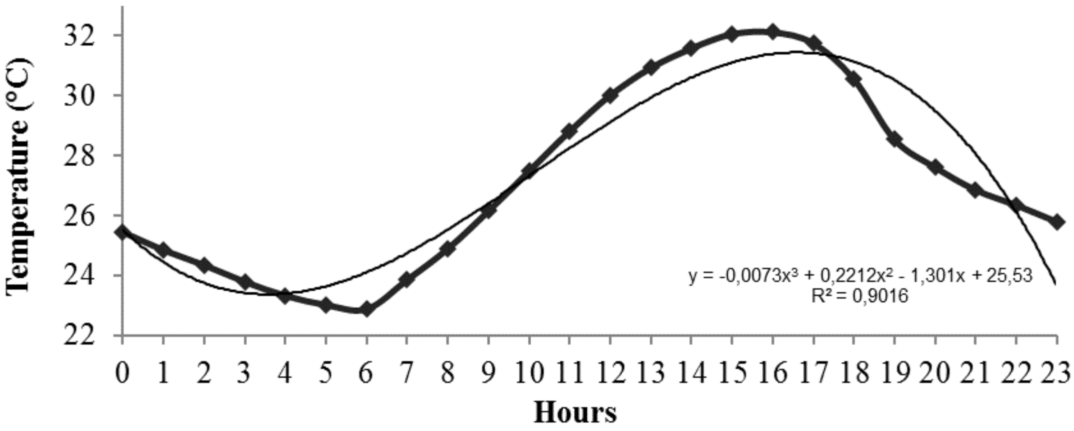

FIGURE 1. Average values of air temperature recorded in 24 hours during the experimental phase.

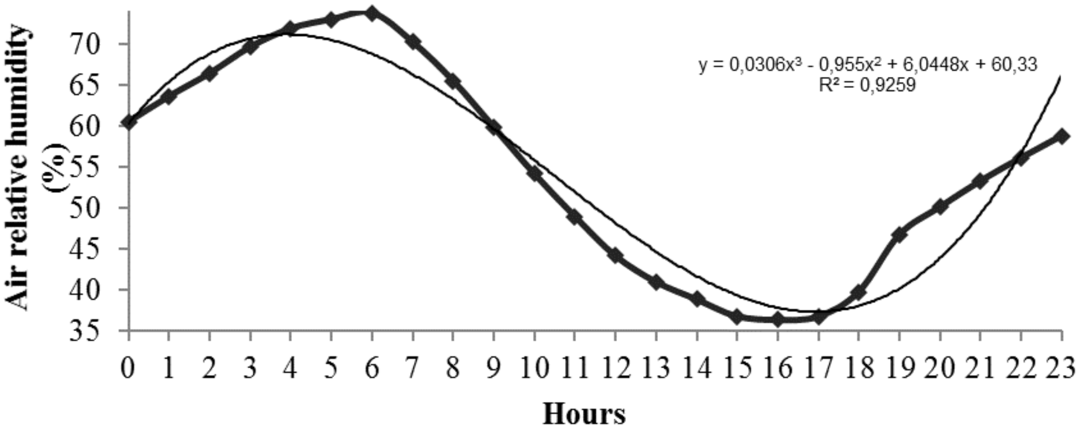

FIGURE 2. Average values of relative humidity of the air recorded in 24 hours during the experimental phase.

There was statistical difference (P <0.05) when the boxes surface temperatures were compared with different colors and lids at all times. Treatment with boxes painted blue without the use of plasterboard (TASG) was no different (P>0, 05) from treatment TACG, but significant different (P <0.05) between the other treatments. Yet TBCG was similar (P> 0.05) to the treatments TSCG and TSCSG, differing (P<0, 05) from TACG, TASG and TBSG (Figure 3).

The higher surface temperature values were recorded in TASG where early in the morning, the average temperature was 29.7 ° C, increasing gradually, and its peak was at 3 p.m., 48.8 ° C and after this time there was a gradual decrease in temperatures up to 5 p.m. In contrast, lower temperature values were recorded in white beehives without the use of plaster board (TBSG), which differed significantly from the others (P<0.05). From 2 p.m., the boxes belonging to the TSCSG treatment also showed low values of surface temperature (Figure 3). This difference was due to the colors used in the experimental boxes, like the blue color that absorbed more solar radiation compared to white colors, providing increased surface temperature in these boxes, which corroborates with suggestions by SALLES et al. (2003), that rational boxes of *Apis mellifera* should be externally painted white to conserve better their material, ensuring durability. Also, light colors best reflect the radiation, helping to keep the internal temperature of the beehives near to the comfort in warmer periods. The results also show that the plaster did not influence the amount of radiation absorbed by beehives, causing no reduction in the surface temperature of the same.

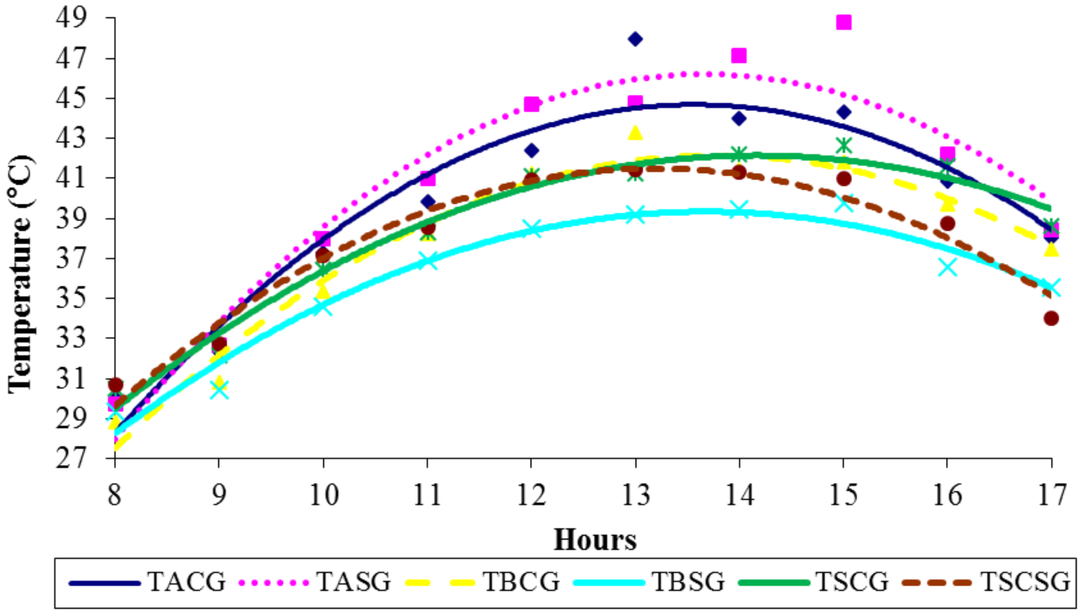

FIGURE 3. Average surface temperature of hives of *Apis mellifera* at 8 a.m. to 5 p.m., within treatments: TACG (treatment with boxes painted blue with use of plasterboard); TASG (boxes painted blue without the use of plasterboard)); TBCG (boxes painted white using the plasterboard)); TBSG (boxes painted white without using the plasterboard); TSCG (boxes that were not painted and received plasterboard) and TSCSG (boxes that were not painted and did not receive plasterboard) in the period from November to December 2013.

To minimize the effect of solar radiation on the boxes raising the surface temperature and thus transmitting heat to inside, we can make use of shading, taking into account that the lack of shading is one of the factors that contribute to low productivity and high dropout rate from beehives in the Brazilian Northeast (LOPES et al., 2011).

LOPES et al. (2009) recommend that the beehives are installed under high coverage enabling better ventilation to minimize the thermal sensation of the colonies. The experimental beehives were installed in an area with vegetation size from low to medium, hindering ventilation, and in addition these plants lose their leaves in the dry season and do not provide full shading for the beehives. The wind speed data measured at the height of beehives, recorded average values of 3.3km / h, the highest value observed during data collection was 9.3 km / h.

The data showed that the internal temperature and the TACG and TBSG treatments differed from each other (P <0.05), and the first was significantly higher. These two treatments are similar (P> 0.05) with TASG, TBCG, TSCG and TSCSG, which also did not differentiate between them (P> 0.05).

From the first observation time, was noted that there was an increase in internal temperature, being recorded high values in the hottest hours of the day in the treatment with boxes painted blue and plasterboards under its cover (TACG), reaching 37.5 °C at 2 p.m. Lower temperatures were recorded in boxes painted white, and in the ones that had not received the plasterboard (TBSG), where the highest value was 35.7 ° C at 2 p.m. (Figure 4). Beehives belonging to TSCSG treatment, from 3 p.m., also had internal temperature in acceptable range for the proper development of the offspring, which should be around 36 °C (SHAW et al., 2011). Under the influence of surface temperature, internal temperature values were higher in boxes painted with dark colors, due to the fact that these absorb more solar radiation, increasing the thermal load and raising the internal temperature, unlike light colors, which reflect more solar radiation. It can be seen that once again, the plaster did not provide the necessary insulation to retain heat.

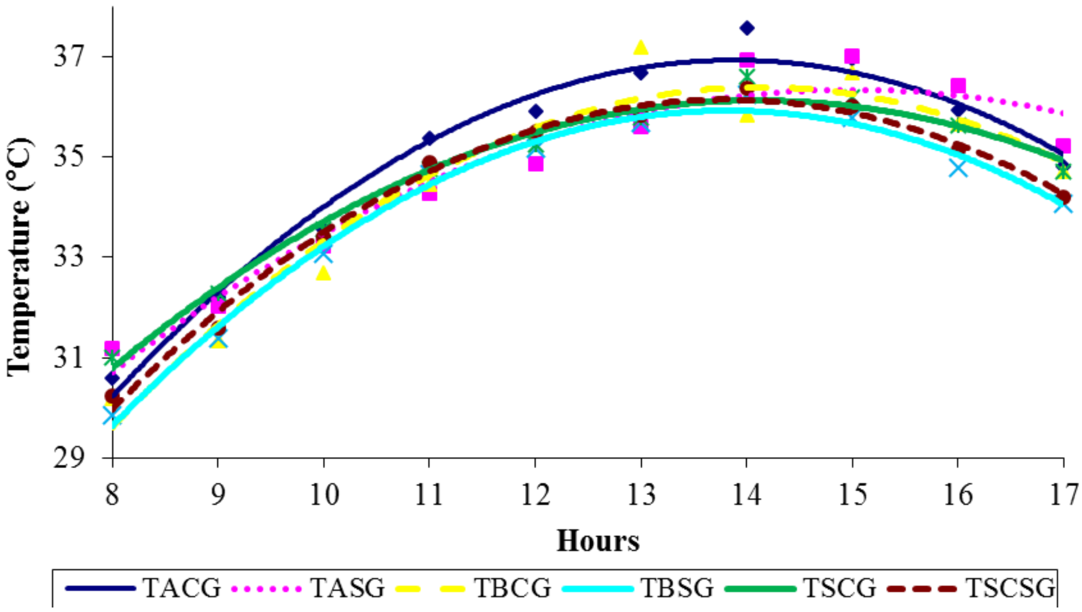

FIGURE 4. Average internal temperature of hives of Apis mellifera at 8 a.m. to 5 p.m. within treatments: TACG (treatment with boxes painted blue with use of plasterboard); TASG (boxes painted blue without the use of the plasterboard); TBCG (boxes painted white using the plasterboard); TBSG (boxes painted white without using the plasterboard); TSCG (boxes that were not painted and received plasterboard) and TSCSG (boxes that were not painted and did not receive plasterboard) in the period from November to December 2013.

High temperatures damage the colonies, so in hot regions is necessary boxes painted with light colors. Even with this practice, many boxes have failed to remain with internal temperature below 36 ° C, necessitating other measures to minimize the effect of temperature, such as shading. LOPES et al. (2011), in a study on internal ambience variance of boxes on offspring area, found that the beehives remained under natural shade (trees) benefited from food storage and increased offspring, as well as the microclimate under the trees canopy was favored by better ventilation providing better thermal comfort for these insects.

Similar study was developed by PONTARA et al. (2012) monitoring internal temperature through the data logger system in *Apis mellifera* nest in the summer period, with two types of coverage, they found internal temperature values for the boxes covered with PET tile and fiber cement at 35.40 °C and 36.40 °C, respectively.

Unlike the data from this study, SALLES et al. (2003), in studies conducted in the winter period in the city of Seropédica-RJ, found no significant differences regarding the internal temperature data in boxes painted blue and white, obtaining average values of 35.50 °C and 35.46 °C, respectively.

According to TAN et al. (2010), when there is increasing in room temperature, the nest cooling becomes essential for the development of the colony. To keep the nest in comfort conditions, the bees perform various actions like causing ventilation through the movement of its wings at beehive entrance, as verified in this experiment at the hottest times of the day, from 1 p.m. to 3 p.m., where the internal temperature was around 37 ° C and the ambient temperature was an average 34 °C. This behavior was observed more frequently in colonies housed in boxes painted blue without the use of plasterboard.

Worker bees spend a lot of time and effort to make the process of colonial thermoregulation, time which could be used for activities aimed to the production of the colony as collecting pollen and nectar. In situations where this effort exceeds the bee capacity in the colony can present problems in its development, and also to abandon the beehive, or even lead to the swarm death (MACIEIRA & PRONI, 2004).

The internal temperature of the beehives, according to WINSTON (2003) affects also the longevity of Africanized bees since it can be a great physical wear of the foragers probably due to increased water collection and ventilation behavior in the offspring area, to minimize the negative effects of temperature.

The data from this study show that, in the hottest hours of the day, there was an improvement in the internal ambience of the colonies with boxes painted white without the presence of plasterboard (TBSG) that presented internal temperature data in the comfort range for bees, up to 36 ° C, as stated by SHAW et al. (2011).

In TASG treatment was observed that even at high surface temperatures reaching values up to 48 °C, the bees were able to maintain the internal temperature of the beehive in acceptable range (36 ° C) till 1 p.m., where it was raised to 1 ° C to reach its peak at 3 p.m (Figure 4).

The highest air temperature at the observation time and days on the surface temperature was recorded between 3 p.m and 4 p.m, reaching 34 °C at 4 p.m. These temperatures negatively reflected inside TACG treatment boxes, where were noted the highest values. In contrast, TBSG treatment of beehives did not suffer from the high air temperatures, remaining in temperature considered optimal for the survival of the colony. This fact can be explained by light colors reflect more heat than dark colors. It was found, therefore, that the presence of plasterboard on the lid of beehives for *Apis mellifera* did not affect the amount of radiation that has passed into the interior of the beehive not been necessary its use for the conditions of this experiment.

Considering the used material for covering the boxes it was observed that the highest surface temperature values were recorded in boxes receiving the plasterboard on its lid in boxes painted white, and the those ones not painted. However, in blue boxes these values were higher in those that did not receive the plasterboard on its cover. For the internal temperature values, these were higher, regardless of the color of the boxes, in which received the plasterboard on its cover.

The average internal temperature of the beehives during the 24 hours is displayed on Figure 5. The treatments behaved in a similar manner at all times, with higher values in times between 1 p.m and 2 p.m verified that the TACG, in the hottest hours of the day showed the highest internal temperature values, reaching 35.4 °C at 1 p.m. During the night (between 10 p.m and 4:00 a.m.) the highest values were observed on TASG and the lower temperatures at that same range were recorded in beehives belonging to TBSG treatment (25.2 °C). Thus, even in the early hours there were not registered very low internal temperatures which according to WINSTON (2003), workers bee begin to heat the nest when the internal temperature drops below 18 °C. Therefore, within 24 hours of data collection on internal temperature the boxes that were painted blue had less efficient with respect to the variable studied. In contrast, the TBSG provides better thermal environment for bees, recording the lowest average internal temperature.

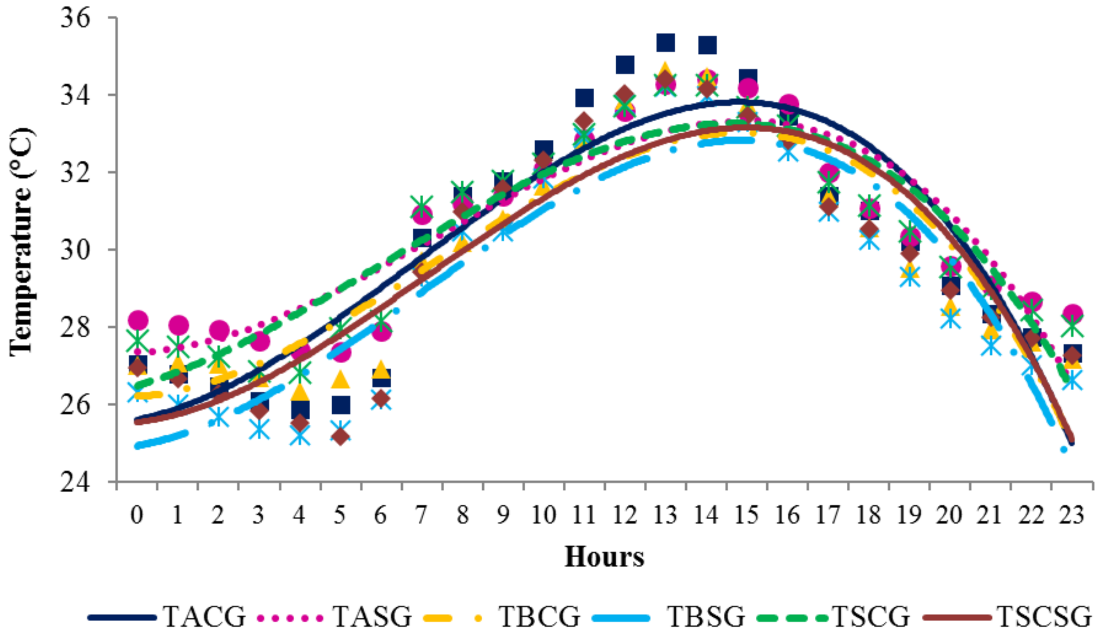

FIGURE 5. Average internal temperature for 24 hours the colonies on the TACG (blue boxes painted without the use of the plasterboard) treatment; TBCG (boxes painted white using the plasterboard); TBSG (boxes painted white without using the plasterboard); TSCG (boxes that were not painted and received plasterboard) and TSCSG (boxes that were not painted and did not receive plasterboard) in the period from November to December 2013.

The results of the correlation analysis by the Pearson method, between the average surface temperature and internal temperature of beehives showed that the correlation coefficient (r = 0.8061 **) was significant at 1% probability by the "t " Test indicating that there is a positive correlation between the two variables (Figure 6).

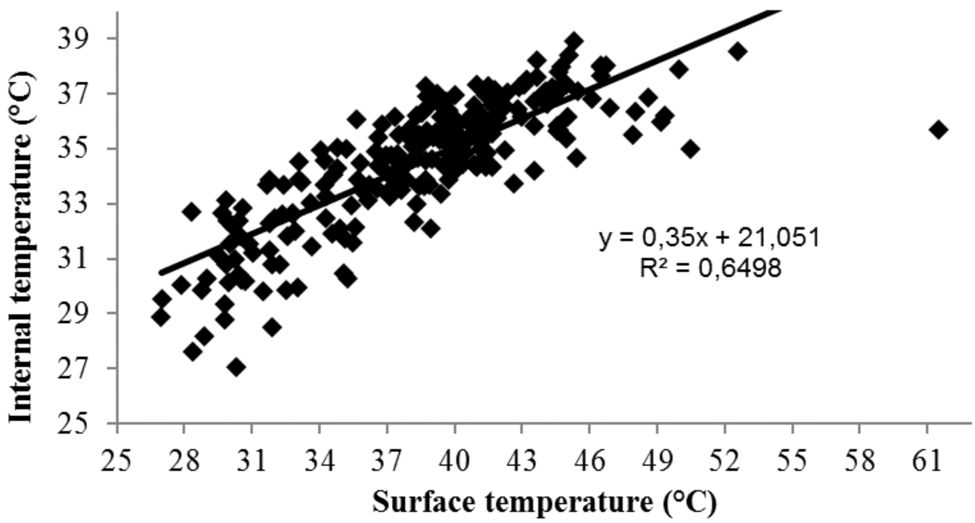

FIGURE 6. Regression and dispersion equation on average data of surface and internal temperature of beehives *Apis mellifera* during five days of experimental period.

CONCLUSIONS

Boxes painted white and without the presence of plasterboard on its lid provide more appropriate thermal environment for the development of offspring, being more suitable for semi-arid region.

The use of plasterboard had no effect on lowering the temperature, not interfering with the amount of radiation received and transmitted into the beehive.

It is recommended to paint the boxes externally in light colors so, that more reflect the incoming solar radiation.

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