Influence of Spring and Autumn Climatic Conditions on Brood Nest Temperature and Humidity in Different Honey Bee Strains

Waad .H. Al-Obaydi

[1]Department of Plant Protection, College of Agriculture, University of Anbar, Anbar, Iraq.
*Corresponding author's email: Waad.awaad@uoanbar.edu.iq

Abstract

The study was conducted during the autumn and spring seasons of 2022 in Anbar Governorate / Hit District. The results of the study on the effect of fluctuations in temperature and humidity between day and night hours during the study seasons on different honey bee strains, and their varying ability to maintain the temperature and humidity of the brood area, showed that bee colonies were able to maintain temperatures suitable for brood growth and development despite the fluctuations occurring in the surrounding environment. The results did not show significant differences between the strains at most times of the study. A major drop in temperature occurred in mid-March at 6:00 a.m., when the temperature of the control treatment, representing the external ambient temperature of the apiary, reached 5.4 °C, while the study treatments ranged — with no significant difference between them — between 34.15 – 35.45 °C for treatments C1 and C2, respectively. Meanwhile, treatment C4 gave the best humidity control, reaching 60.67%, compared with the control treatment of 71%, with a significant difference from treatments C1 and C3, which gave (90.5 and 87.5)%, respectively. In autumn, the strains did not show significant differences among themselves in controlling temperature and humidity, despite a large difference in temperatures compared with the control treatment. The results showed that the temperatures recorded for the treatments ranged between 34.1 and 35.2 °C, while the control treatment recorded only 7.3 °C during November.

Keywords: Honey bee, Carniolan bee strain, Brood area temperature, Climatic variability.

(It is not necessary that the keywords are taken from the title)

Introduction

The honey bee, *Apis mellifera* L., is distinguished from many other insects by its social life, as each colony consists of a single queen, thousands of workers, and several thousand drones living in an ideal manner and sharing their tasks among themselves. Nevertheless, many environmental conditions and internal colony factors may affect the behavior, survival, and development of these colonies, including temperature, humidity, and food [10,13] The internal temperature of a honey bee colony is vital for the sustainability of external activities, including the foraging behavior of workers and the flight of drones and queens[1] , whereas the internal processes of the colony, such as food storage, brood rearing, and social balance, occur within a reasonable thermal range[7] . Honey bee activity appears to decline when the temperature falls below 10 °C, while the maximum foraging activity has been observed at 20 °C [3]. [7] indicated that high humidity may negatively affect the activity of honey bee colonies, although its effect is less than that of high temperatures. Throughout their life cycle, honey bees are exposed to numerous environmental stresses, including those of physical, chemical, or biological origin, but they are able to survive through physiological adaptations [9] . The honey

bee possesses a range of adaptive regulatory mechanisms that improve its thermal tolerance traits, allowing bees to adapt to severe environmental changes [8] .Under heat stress, insect metabolism changes, such as an increased rate of carbohydrate consumption, increased lipid oxidation, and cholesterol concentration, which also leads to increased synthesis of certain polyols (sorbitol, mannitol). The accumulation of polyols in organisms is highly important for improving temperature tolerance, as it can stabilize the natural conformation of proteins and compensate for the harmful effects of high temperatures. Sorbitol and mannitol, which are six-carbon sugar alcohols, are important substances for organisms to resist heat and cold [4] .

Foraging activity in honey bees was also found to decrease at 43 °C. In changing environments, bees can maintain a balance between energy efficiency and the rate of food collected, and bees may live naturally for two to seventeen days at this temperature[5,14] . The honey bee, *Apis mellifera*, can regulate its body temperature socially, allowing it to maintain its colonies throughout the year, and the social balance of colony members regulates temperature to the level required for colony survival[6]. The foraging ability of bees and their foraging activity are directly affected by the temperature and humidity of the environment surrounding the apiary. [12] reported that the first recorded bee emergence for foraging and food collection occurred at 6.57 °C, while the best foraging activity was at 20 °C. Other studies found that foraging began at 10 °C and increased up to tenfold at 20 °C, while the lowest foraging activity was recorded at 43 °C [14]. The study aims to assess the capacity of different honey bee strains to maintain the temperature and humidity of the brood area, and, consequently, to examine their potential for survival and development throughout various times of the year.

Material and Methods

A study was conducted to measure the effect of temperature and humidity in the environment surrounding the apiary on the temperature and humidity of the brood area for the local bee strain, the Carniolan bee strain, and the two strains resulting from natural mating between them, during the autumn and spring seasons. Bee colonies for all strains used in the study which were designated with the symbols (C1, C2, C3, and C4), namely (local strain, Carniolan strain, hybrid resulting from local queens mated with Carniolan drones, and Carniolan queens mated with local drones), respectively, Queens of each strain were reared using the Jenter system and mated naturally in isolated areas; the temperature and humidity of the apiary served as the control condition.. were prepared and distributed in the apiary in a single row with a distance of 0.5 m between each colony, and each colony was considered a replicate, Three replicates were used for each strain, with the exception of two strains for which only two replicates were used, due to the limited number of sensors in the device employed. A temperature and humidity measuring device developed specifically for this study was used, which obtained patent number (6561) in the year (2021) (SMTRB). The device was made by Chief Engineer Jameel Ibrahim Saleh / Ministry of Electricity. The device consists of two main parts: the receiver and the transmitter. In the first part, dual sensors are connected to measure temperature and humidity simultaneously, with a number of replicates, while keeping an additional sensor to measure the open area of the apiary. The sensors were connected with a

special cable to transfer data from the sensor to the receiver device, which is connected to another device to send data to the personal computer via a cable connected to a USB port to store data on the computer. The device draws its operating electrical power from the USB port itself, as shown in Diagram No. (1).

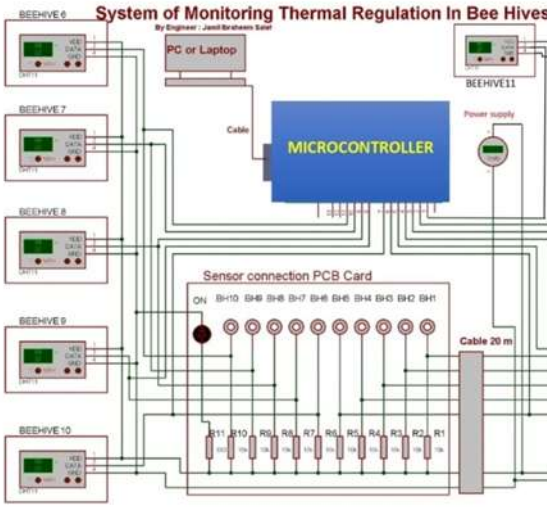


Figure (1) shows the parts of the thermometer and humidity measuring device for bee colonies.

Wooden bee hives with a capacity of 10 frames, based on the Langstroth system, made of wood of uniform thickness with a lid made of wood and coated with a layer of tin, were used for all replicates and all strains used in the study. The strains were introduced and housed in the designated hives, taking care to standardize the bee density for each replicate. The colonies were oriented toward sunrise and exposed to the same external factors of sunlight and air currents, as the colonies were kept in an apiary with a roof made only of metal sheets to provide somewhat harsh environmental conditions for all colonies at the same intensity For the purpose of conducting the study and calculating the effect of temperatures, one of the sensors of the measuring device was fixed in the apiary near the colonies at a height of one and a half meters above the apiary floor, while the remaining sensors were fixed in three colonies for each studied strain, except for two strains for which only two colonies were taken, in line with the number of receivers in the device used, considering each bee colony as a replicate. The sensors were fixed in the brood area after being placed in finger-shaped plastic cages, following smoking of the colonies to calm the bees and then smoking a second time to drive the bees away from the area where the sensors were to be fixed. After inserting the sensors, the frames were returned to their normal position in the colony, and then the upper lid of the hive was closed [2]. When the device begins operation, data recording usually does not start until at least one hour later, in order to give the bees an opportunity to adjust to disturbance in colony temperature resulting from opening the upper lid during the sensor installation stage. The data collection stage begins after the device is switched on and connected to the personal computer via the USB port to supply the device with operating power and collect data through the same cable. The data are transferred to the computer and analyzed immediately via a special program for operating the device, then saved in an Excel file for 24 hours per day. Readings were taken for a period of 6 months during the spring and autumn seasons of 2022 [2] The data obtained were analyzed using the SAS program according to one-way analysis of variance. The analysis included the effect of strains on the temperature and humidity of the brood area, following the General Linear Model, using the ready-made statistical SAS program, ninth edition.

Results and Discussion

Study of the Effect of Temperature and Humidity Surrounding the Apiary on the Temperature and Humidity of the Brood Area for Different Honey Bee Strains in Spring Season

The data of the study on the effect of temperature and humidity on the brood area of different honey bee strains during the spring season, as shown in Table (1), indicated a major drop in temperature in mid-March at 6:00 a.m., where the temperature of the control treatment, representing the external ambient temperature of the apiary, reached 5.4 °C, while the study treatments ranged — with no significant difference among them — between (34.15 – 35.45) °C for treatments C1 and C2, respectively. The humidity of the control treatment reached 71%, compared with the study treatments (C1, C2, C3, C4), which ranged between (60.67 – 90.5)% for treatments C4 and C1, respectively. At 12:00 noon of the same period, an increase in the temperature of the control treatment was observed, reaching 18.6 °C, significantly different from the other treatments, which ranged between (34.9 – 36.16) °C for treatments C1 and C4, respectively, with no significant difference among them. As for humidity, despite its decrease in the environment represented by the control treatment to 26%, the high biological activities in the brood area led to the humidity percentage remaining high, reaching (95 and 93)% for treatments C1 and C3, respectively. At 6:00 p.m., the temperature of the control treatment dropped to 14 °C, while the results showed no significant differences for treatments C2, C3, and C4, which ranged between (35.33 – 35.6) °C for treatments C4 and C2, respectively. Treatment C1 gave a temperature of 34.25 °C, significantly different from treatment C2 only. As for humidity, the data showed a noticeable increase in the humidity of the brood area compared with the relative humidity of the external apiary environment represented by the control treatment, which reached 37%, while the lowest humidity rate appeared in treatment C4, reaching 68%, whereas humidity in the brood area reached 95% for treatments C1 and C3. At 12:00 midnight, the data from the same table showed a continued decrease in temperatures, with the control treatment recording 7.9 °C, while the temperature of the brood area for the study treatments ranged — with no significant difference among them — between (34.95 – 35.45) °C for treatments C1 and C3, respectively. As for relative humidity, despite the control treatment recording a relative humidity of 44%, treatments C1, C2, and C3 showed significant similarity among them, recording (95, 71.5, and 91)% respectively, while treatment C4 gave the lowest humidity rate of 61.67%, with no significant difference from treatment C2 and the control treatment. The data in mid-April at 6:00 a.m. showed the lowest temperature rate for the control treatment, reaching 10.7 °C, while the data showed no significant difference among treatments C1, C2, and C3, which reached (35, 34.95, and 34.9) °C respectively, significantly different from treatment C4, which reached 34.43 °C. As for relative humidity, the control treatment recorded 47%, with no significant difference from treatments C2 and C4, which reached (66 and 48)%, respectively, while treatments C1 and C3 recorded relative humidity of (81 and 94)%, respectively. At 12:00 noon, the temperature of the apiary environment rose to 35 °C, which did not differ significantly

from all studied treatments, which ranged (35.75 – 36.4) °C for treatments C1 and C3, respectively. Meanwhile, relative humidity decreased concurrently with the decrease in temperature to10%, significantly different from the rest of the study treatments (C1, C2, C3, and C4), which did not differ significantly among themselves, recording humidity ranging between 71.33 – 92.5 % for treatments C4 and C3, respectively. At 6:00 p.m., the control treatment recorded a temperature of 29.6 °C, while the other treatments recorded temperatures ranging between (35.4 – 36.15) °C for treatments C4 and C2, respectively. Meanwhile, the humidity of the external environment continued to decrease, recording 12%, while the humidity of the other treatments ranged from 54.67 to 84.5 % for treatments C4 and C3. Temperatures dropped again at 12:00 midnight, with the control treatment recording 12.8 °C, while the other treatments gave a brood area temperature of (34.1 and 35.5) °C for treatments C4 and C3, respectively. As for relative humidity, the control treatment recorded 29%, with no significant difference from treatment C4, which recorded 43%, while treatments C1, C2, and C3 recorded (76, 69, and 85)%, respectively. In mid-May at 6:00 a.m., the control treatment recorded a temperature of 21.5 °C, while treatments C1, C2, and C3 were very close in brood area temperature, recording (35.3, 35.35, and 35.35) °C respectively, while treatment C4 recorded a temperature of 31.33 °C, with no significant difference from the other treatments. As for humidity, the control treatment did not differ significantly from the other treatments in the recorded humidity percentage, which reached 60%, while the other treatments ranged between (65 – 74)% for treatments C4 and C3, respectively. At 12:00 noon, the temperature of the control treatment rose to 38 °C, exceeding the normal level for brood area temperature, while the other treatments ranged — with no significant difference among them — (35 – 36) °C for treatments C4 and C1, respectively. The data also showed a decrease in humidity level at this time of day, with the control treatment recording 31%, compared with the study treatments, which gave humidity percentages ranging between (51.5 – 74)% for treatments C2 and C1, respectively, with no significant difference among them. At 6:00 p.m., the apiary environment temperature recorded 33.9 °C, a temperature close to the brood area temperature, as the other treatments recorded similar temperatures with no significant difference among them, ranging between (35.46 – 35.75) °C for treatments C4 and C1, respectively. As for relative humidity, the control treatment recorded 32%, compared with relative humidity that did not differ significantly among treatments C2, C3, and C4, which ranged between (55.5 – 69)% for treatments C2 and C4, respectively. At 12:00 midnight, the temperature of the control treatment dropped to 24.4 °C, significantly different from the other treatments, which were significantly similar among themselves and ranged between (33.5 – 35.25) °C for treatment C4 and treatments C2 and C3, respectively. As for relative humidity, the results showed no significant difference among all studied treatments, which recorded percentages ranging between (62 – 71)% for treatments C2 and C1, respectively, compared with the control treatment of 42%. From the table, the high ability of honey bee colonies to maintain a suitable temperature in the brood area is evident, despite the large difference

between it and the external environment temperature, as the highest difference was recorded during March, April, and May, reaching (30, 24.3, and 14.85) °C respectively. As for relative humidity, the results showed a large difference in relative humidity between the control treatment and the other treatments, with the highest humidity difference recorded during March, April, and May reaching (69, 82.5, and 42.67)% respectively. The variation in brood area humidity may be due to the different numerical densities of the studied bee strains, which caused the apparent difference in the table as a result of increased brood area and bee density, leading to increased biological activities, which in turn produced greater CO_2 gas, accompanied by an increase in relative humidity inside the brood area concurrently with a decrease in temperatures. This makes it difficult to dispose of excess humidity through evaporation, because that would lead to a decrease in brood temperature, which does not align with what the colony requires. The large increase in humidity levels in the brood area during mid-March at 6:00 a.m. for treatments C1 and C3 is attributed to the high numerical density of colony individuals of the strains, along with the high brood density, as indicated in life activity experiments, with the great influence of biological activities such as respiration of brood and adults and feeding processes leading to an increase in humidity percentage with a decrease in temperatures, which hinders the bees from reducing it.

Table 1. Effect of temperature and humidity on the brood area of different honey bee strains during the spring season

Month	Time in hours	Parameter	Strain C1	C2	C3	C4	Control	LSD
March	6 a.m.	T B	34.15	35.45	35.3	34.96	5.4	1.45
		H B	90.5	73	87.5	60.67	71	23.25
	12 p.m.	T B	34.9	36	35.35	36.16	18.6	2.3
		H B	95	83	93	70	26	30.15
	6 p.m.	T B	34.25	35.6	35.4	35.33	14	1.25
		H B	95	81.5	95	68	37	32.22
	12 a.m.	T B	34.95	35.2	35.45	35.36	7.9	1.93
		H B	95	71.5	91	61.67	44	27.99
April	6 a.m.	T B	35	34.95	34.9	34.03	10.7	0.89
		H B	81	66	94	48	47	19.6
	12 p.m.	T B	35.75	36.35	36.4	36.06	35	2
		H B	77	86	92.5	71.33	10	34.6
	6 p.m.	T B	36	36.15	35.75	35.4	29.6	0.33
		H B	69.5	76	84.5	54.67	12	38.33
	12 a.m.	T B	34.7	34.8	35.05	34.1	12.8	0.69
		H B	76	69	85	43	29	20.18
May	6 a.m.	T B	35.3	35.35	35.35	31.33	21.5	4.7
		H B	71.5	66.5	74	65	60	23.24
	12 p.m.	T B	36	35.9	35.8	35	38.2	1.28
		H B	74.5	51.5	67	73.67	31	43.15
	6 p.m.	T B	35.75	35.6	35.6	35.46	33.9	0.63
		H B	68.5	55.5	68	69	32	44.73
	12 a.m.	T B	34.9	35.25	35.25	33.5	24.4	2.66

H B	71	62	70	64.33	42	27.89

The letter C refers to the bee strain:(C1) local strain (C2) Carniolan strain, (C3) local queens * Carniolan drones, (C4) Carniolan queens * local drones. The symbol (TB) and (HB) ature and humidity of the brood area, respectively

Study of the Effect of Temperature and Humidity on the Brood Area of Different Honey Bee Strains in Autumn Season

The data of the study on the effect of temperature and humidity, as indicated in Table (2), showed that temperatures and humidity differed somewhat among the different strains compared with the control treatment, which represents the temperature and humidity of the apiary environment. The data in mid-September showed that the brood area temperature ranged between (35.2 and 30) °C for treatments C3 and C1, respectively, with no significant difference among the treatments, while the control treatment reached 21.2 °C, with a significant difference from the other treatments at 6:00 a.m. The humidity levels of the treatments did not differ significantly among themselves and ranged between (48 and 35.33)% for the control treatment and treatment C2, respectively. At 12:00 noon, all treatments did not differ significantly among themselves and ranged between (35 and 35.75) °C for treatments C4 and C3, respectively, while the control treatment differed significantly from them, reaching 37.4 °C. Also, all treatments did not differ significantly among themselves in the brood area humidity, ranging between (39 and 45.66)% for treatments C1 and C4, respectively, significantly different from the control treatment, which reached only 15%. At 6:00 p.m., the data showed no significant difference in temperatures for all treatments, which ranged between (35.5 and 36.45) °C for treatments C4 and C1, respectively, compared with the control treatment of 34.6 °C. Also, all treatments did not differ significantly among themselves in humidity, which ranged between (39.5 and 44.66)% for treatments C1 and C2, respectively, significantly different from the control treatment, which reached 13%. At 12:00 midnight, the results showed no significant difference among treatments (C1, C2, C3, and C4), with a significant difference from the control treatment, which reached 24.7 °C. The results also showed no significant difference in humidity levels for treatments C1, C3, and C4, which differed significantly from treatment C2, which reached 34%, and which in turn did not differ significantly from the control treatment.

In mid-October, the table shows significant similarity among all treatments in temperatures at 6:00 a.m., which ranged between (31.16 – 34.9) °C for treatment C2 and treatments C1 and C4, respectively, compared with the control treatment, which differed significantly from the other treatments and reached 15.7 °C. Treatments C2, C3, and C4 did not differ significantly among themselves in humidity, which ranged between (38.5 – 39)% for treatment C3 and treatments C2 and C4, significantly different from

treatment C1, which reached 25%, while the control treatment gave 48%. At 12:00 noon, all treatments did not differ significantly from each other in brood area temperature, which ranged between (33.36 – 35.3) °C for treatment C2 and treatments C1 and C4, respectively, while the control treatment gave the lowest temperature of 31 °C. Also, all treatments did not differ significantly among themselves in brood humidity, which ranged between (36 – 38)% for treatments C1 and C3, respectively, compared with the control treatment, which reached only 9%. At 6:00 p.m., the data in the table below showed no significant difference among all treatments in temperature, which ranged between (34.53 – 35.56) °C for treatments C2 and C4, respectively, compared with the control treatment of 22.7 °C. Also, the brood humidity did not differ significantly among treatments and ranged between (40 – 48.33)% for treatments C2 and C4, respectively, compared with the control treatment of 28%. At 12:00 midnight, the treatments were also equal among themselves in brood area temperatures, which ranged between (32.26 – 35.26) °C for treatments C2 and C4, respectively, while the control treatment reached 17.5 °C. Treatments C2, C3, and C4 were also equal in brood area humidity, which reached 40%, with no significant difference from treatments C1 and the control, which reached 32 and 39 % respectively.

In mid-November at 6:00 a.m., the data showed a decrease in temperature in the control treatment, which reached 7.3 °C, while the brood area temperature for the same day did not differ significantly among treatments and ranged between (34.1 – 35.2) °C for treatments C1 and C3, respectively. The humidity of the apiary environment, represented by the control treatment, reached 88%, while treatments C2, C3, and C4 did not differ significantly among themselves in relative humidity, which ranged between (44 – 55)% for treatments C2 and C3, respectively, with a significant difference between treatments C3 and C1, which reached only 35%. At 12:00 noon, the apiary temperature represented by the control treatment rose to 24.3 °C, while C1, C2, C3, and C4 did not differ significantly among themselves in brood area temperatures, which ranged between (34.15 – 35) °C for treatments C1 and C2, respectively. As for humidity, the humidity of the apiary environment decreased significantly at the same time, reaching only 26%, while the other treatments did not differ in brood area humidity, which ranged between (51 – 57.66)% for treatments C3 and C4, respectively. At 6:00 p.m., temperatures decreased again in the control treatment to reach 16.7 °C, while the brood area temperature did not differ among treatments and ranged between (34.63 – 35.45) °C for treatments C4 and C1, respectively. Also, the studied treatments did not differ from the control treatment in the recorded humidity levels, which ranged between (48 – 56)% for treatments C1 and C4, respectively. At 12:00 midnight, the apiary environment temperature decreased further to reach 10.3 °C, while the brood temperature for treatment C2 reached 35.8 °C, significantly superior to treatments C1, C3, and C4, which reached 34.8, 35, and 34.9 °C respectively. The apiary humidity at 12:00 midnight recorded 82%, and brood humidity ranged with a significant difference from the control treatment and with no significant difference among

themselves, ranging between (44.5 – 56)% for treatments C2 and C4, respectively.

The previous results show the large range of thermal difference between the external environment of the colonies and the brood area temperature, which reached its highest difference of (14, 19.2, and 27.9) °C for (September, October, and November), respectively. This indicates the high ability of honey bee colony members to control a suitable temperature to preserve the safety of eggs and brood from decreasing. Bee density also has the greatest influence, along with wintering procedures, in controlling thermal balance inside colonies, and the expansion of brood area depends primarily on increasing bee density to control its temperature. As for relative humidity, we generally notice the ability of bee colonies to modify relative humidity. When temperature decreases and humidity rises in the apiary environment, as is the case in November, where it reached 7.3 °C and 88% for temperature and humidity, respectively, we find that the colonies were able to reduce the humidity level to a range between 35–55 % to maintain a suitable temperature, since humidity is a conductor of temperature, and when it rises, it negatively affects temperatures. On the other hand, when temperatures rise, humidity decreases in the environment, as was evident in October at 12:00 noon, where the temperature reached 31 °C while humidity reached only 9%; we find that the colonies raised the humidity percentage to reach a range between 36–38%. The appearance of results most times with no significant differences, can be attributed to two reasons: bees can maintain brood temperature through clustering behavior, which is an instinctive behavior to raise temperatures when the external apiary temperature decreases [5] and the second reason is due to the degree of thermal variation, which is somewhat close to the bees' requirements, especially during spring and mid-autumn. This helps bees control the temperature and humidity of the brood area better, which is contrary to what was found by[2] .

Table (2): Effect of Temperature and Humidity on the Brood Area of Different Honey Bee Strains in Autumn Season

Month	Time in hours	Parameter	Strain C1	C2	C3	C4	Control	LSD
September	6 a.m.	T B	30	32.63	35.2	34.1	21.2	5.77
		H B	37.5	35.33	43	44.33	48	12.09
	12 p.m.	T B	35.05	35.53	35.75	35	37.4	1.29
		H B	39	40	45.5	45.66	15	15.11
	6 p.m.	T B	36.45	36.36	35.95	35.5	34.6	1.06
		H B	39.5	44.66	42.5	43.66	13	14.32
	12 a.m.	T B	31.75	33.8	35.35	34	24.7	3.86
		H B	40	34	49	44.33	33	9.6
October	6 a.m.	T B	34.9	31.16	34.6	34.9	15.7	5.5
		H B	25	39	38.5	39	48	8.98
	12 p.m.	T B	35.3	33.36	35	35.3	31	2.4
		H B	36	37.33	38	37.66	9	12.19
	6 p.m.	T B	35.1	34.53	35.25	35.56	22.7	1.61
		H B	46	40	48	48.33	28	9.6
	12 a.m.	T B	34.9	32.26	34.4	35.26	17.5	3.92
		H B	32	40	40	40	39	11.36
November	6 a.m.	T B	34.1	35.05	35.2	34.66	7.3	1.09
		H B	35	44	55	46.66	88	13.25
	12 p.m.	T B	34.15	35	34.7	34.43	24.3	1.04
		H B	53	52	51	57.66	26	9.23
	6 p.m.	T B	35.45	34.95	35.2	34.63	16.7	1.81
		H B	48	53	52	56	53	9.39
	12 a.m.	T B	34.8	35.8	35	34.9	10.3	0.68
		H B	51.5	44.5	52.66	56	82	11.71

The letter C refers to the bee strain:(C1) local strain (C2) Carniolan strain, (C3) local queens * Carniolan drones, (C4) Carniolan queens * local drones. The symbol (TB) and (HB) ature and humidity of the brood area, respectively

Conclusion

It can be concluded from the study that large fluctuations in temperature have a direct impact on colony vitality, the ability of colonies to survive, and the maintenance of live brood. Furthermore, the hybrid bee strain produced from local queens mated with Carniolan drones exhibits the highest control over climatic fluctuations, owing to its high reproductive capacity, and consequently displays better regulation of the temperature and humidity of the brood area.

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