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BIOCLIMATIC ZONING FOR QUAILS IN THE RAIN SEASON IN THE STATE OF PARAÍBA, BRAZIL

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Abstract

This work aimed to perform bioclimatic zoning based on the temperature and humidity index (THI) for quails from the 3rd to the 5th week of life during the rainy season in the state of Paraíba, Brazil, in order to identify the most suitable mesoregions among the Zona da Mata, Agreste, Borborema and Sertão for the breeding of these birds and to propose mitigating measures for the thermal comfort of the animals. The monthly air temperature and relative humidity data for calculating the THI were obtained from conventional meteorological stations of the National Meteorological Institute of the Brazilian federal government from 1961 to 2015, in turn making maps with the spatial distribution of the index. The index ranged from 71 to 76 in the various mesoregions of Paraíba, with Agreste being the best mesoregion for breeding quails from the 3rd to the 5th week of life, thus providing a thermal comfort zone for birds and only requiring a few corrective measures in their facilities, when necessary, followed by the Sertão, Zona da Mata and Borborema mesoregions.

Keywords: Ambience. Comfort zone. Well-being.

1. Introduction

Brazil has an extensive territory with climatic diversities and particularities in each region. Therefore, there is a need to identify these diversities and to group the main bioclimatic zones in order to formulate constructive guidelines for installations for animals, such as quails (Amorim et al. 2017).

As a result, bioclimatic zoning emerges as an efficient tool, since it groups geographical areas with similar conditions, enabling to distribute animals presenting conditions to be produced in these environments, as well as the use of corrective strategies when necessary, aiming at greater productive efficiency (Tavares et al. 2016).

Bioclimatic zoning is developed in order to maximize the production of broiler chickens (Oliveira et al. 2019), goats (Pequeno et al. 2017) and cattle (Tavares et al. 2016). However, some limitations can be found in mappings such as the absence of complete historical climatic data series and a reduced number of studies on the theme in several Brazilian locations (Amorim et al. 2017).

Thus, expanding knowledge about bioclimatic zoning for quails can boost their production given that cotton farming is a promising poultry sector in which the birds have precocity, early sexual maturity and high productivity (Sakamoto et al. 2018), and present superior productive performance when raised within their thermal comfort zone (Ribeiro et al. 2016). Ambient temperatures above or below the thermal comfort zone can negatively affect zootechnical indices, bird performance and reproduction (Sousa et al. 2014b; El-Tarabany 2015).

Thus, the objective of the present work was to perform bioclimatic zoning based on the temperature and humidity index (THI) for breeding quails from the 3rd to the 5th week of life during the rainy season in the state of Paraíba in order to identify the mesoregions which are most suitable for their breeding. Furthermore, to propose mitigating measures for greater animal comfort when necessary.

2. Material and Methods

Bioclimatic zoning was carried out in the state of Paraíba. It has an area of 56,440 km², constituting 0.662 % of the Brazilian territory, and is located in the Northeast region of Brazil with a position between the parallels 6°02'12" and 8°19'18" latitude south and the meridians of 34°45'54"and 38°45'45" west longitude. The state of Paraíba is divided into four mesoregions: Zona da Mata Paraibana; Agreste Paraibano; Borborema and Sertão Paraibano (Nobrega et al. 2014), hereinafter referred to as Zona da Mata, Agreste, Borborema and Sertão (Figure 1).

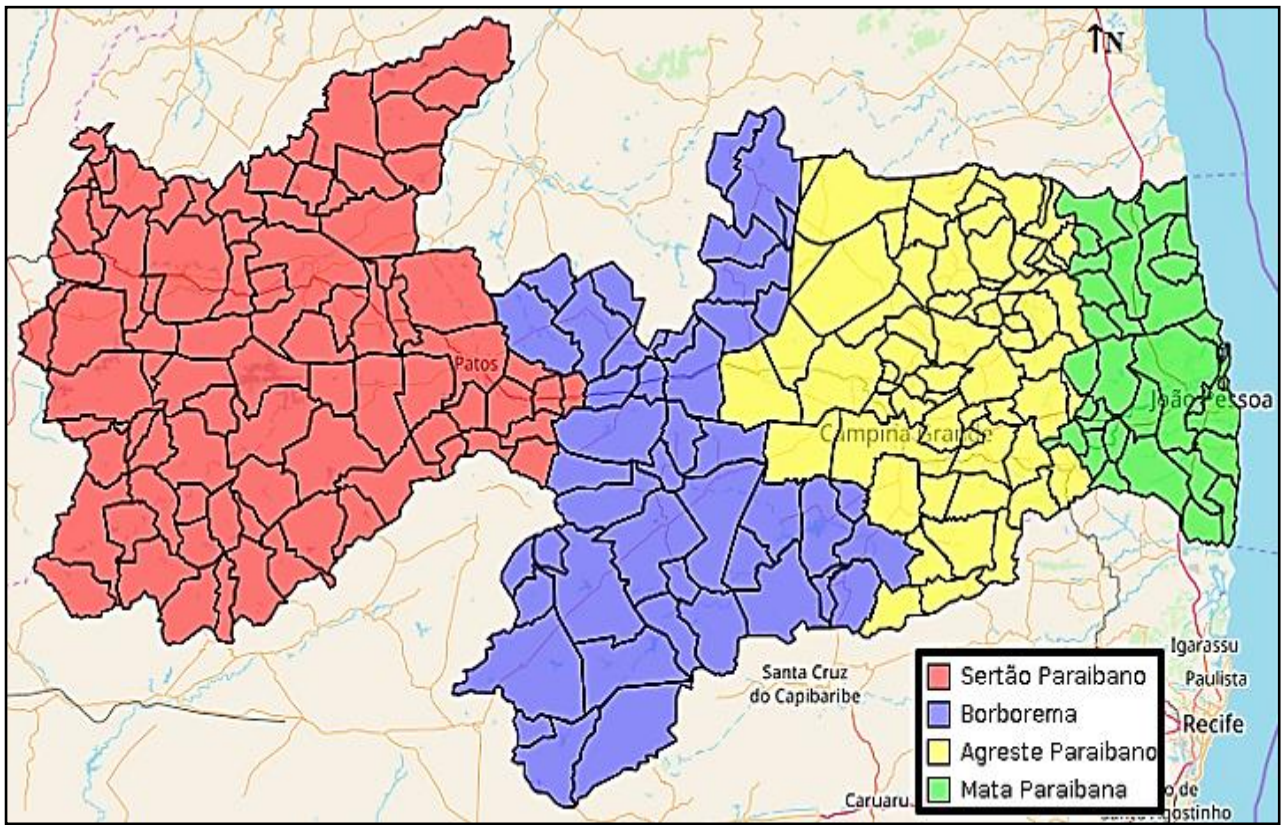

Figure 1. Mesoregions of the state of Paraíba. Source: Aesa, 2018.

Paraíba has four climate types: Aw (451.52 km²), which characterizes the region as tropical, with a dry season in winter; Am (677.28 km²), characteristic of monsoon regions and is the climate related to regions with a high annual volume of precipitation such as the Zona da Mata; As (32,340.12 km²), found in the Zona da Mata, Agreste and Sertão, which is characterized by a tropical climate with dry summer; and Bsh (22,971.08 km²), characterized by a dry semi-arid climate with low latitude and altitude, being characteristic of the Borborema mesoregions and part of the Sertão.

The climatic data were obtained from conventional meteorological stations of the National Institute of Meteorology (INMET) of the Brazilian federal government, available in the Meteorological Database for Teaching and Research (BDMEP), with the variables used for calculating the THI being the monthly

averages of air temperature (T, ºC) and relative humidity (RH, %) from 1961 to 2015. The stations are located in the municipalities of Areia, Campina Grande, João Pessoa, Monteiro, Patos and São Gonçalo.

The rainy season was determined by the average rainfall of the four rainiest months, with the municipalities of Patos and São Gonçalo having rainy periods from January to April, Monteiro from February to May, and Areia, Campina Grande and João Pessoa from April to July. The dew point temperature (Td) in Eq. 1 was calculated from the collected climatic data, and the temperature and humidity index (THI) values in each weather station were calculated using the equation proposed by Thom (1958) (Eq. 2):

$$T_d = \frac{237{,}3\left(\log R_H + \frac{7{,}5t}{237{,}3+t}\right)}{7{,}5 - \log R_H - \frac{7{,}5t}{237{,}3+t}} \qquad \text{(Eq. 1)}$$

In which: t ≥ 0 and the fraction of RH.

$$THI = T + (0.36 \times Td) + 41.5 \qquad \text{(Eq. 2)}$$

Next, maps with spatial distribution were prepared from the THI values using the Surfer® software version 13.6 for the state of Paraíba in the rainy season, with the data interpolation done by the kriging method.

The climatological data obtained were compared with the ideal thermal comfort conditions for quails in order to identify the bioclimate indicated for their production. The temperature and relative humidity recommendations mentioned by Sousa et al. (2014a) were used to assess quails' thermal comfort zone in the third week, while the quotes by Sousa et al. (2014b) were used for the fourth and fifth weeks, and then these variables were used to determine the thermal comfort zone for quails from the third to the fifth week of life in relation to the THI (Table 1).

Table 1. Thermal comfort range in relation to temperature, relative air proportion and temperature and temperature index for quails up to a fifth week of life.

	Variables		
Weeks	T (ºC)	RH (%)	THI- Calculated
3[a]	23 – 24.6	52.6 – 64.4	69 – 72
4[a]	26.1 – 27.3	53.8 – 66.6	73 – 76
5[a]	25 – 26.1	56.2 – 65.2	71 – 75

Mapping using the temperature and humidity index (THI) means in the rainy season were used to identify the areas which would present lower, ideal and higher values of THI than those recommended for quails in the third, fourth and fifth week of life.

3. Results

The temperature and humidity index in the state of Paraíba varies from 71 to 76 in the rainy season, with ranges from 72 to 74 in Zona da Mata, 71 to 72 in Agreste, 71 to 75 in Borborema and 74 to 76 in Sertão (Figure 2).

The THI values in the Agreste mesoregion would be within the ZCT (71 - 72), where the historical T ranges from 22 to 24 ºC and RH 76 to 82%; most of the forest zone would be under heat stress (72 - 74), with T ranging from 23 to 25 ºC and RH from 79 to 82%, with ideal THI (72) being observed in the territorial boundary with the Agreste, corresponding to 23% of the mesoregion's territory (Figure 3).

The T and RH variables in the Borborema mesoregion oscillate between 22-26 ºC and 64 to 79%, respectively, resulting in heat stress, THI between 71-75, except in the transition to Agreste, where comfort would be present in 27.3% of the territory, while the Sertão presents an environment under heat stress, THI between 74-76, with T ranging from 25-27 ºC and RH from 64-76% (Fig.1).

The ideal THI range for quails in the fourth week of life is between 73 to 76, with temperature ranging from 26.1 to 27.3 ºC and relative humidity from 53.8 to 66.6% (Sousa et al. 2014b), in which quails present optimized zootechnical performance. Therefore, the THI is found within the TCZ (74 to 76) in the Sertão, in 77% of the territorial area of the Zona da Mata (73 to 75), 72.7% of Borborema (73 to 74), and cold stress would predominate (71 to 72) in Agreste due to low temperatures and high relative humidity (Figure 4).

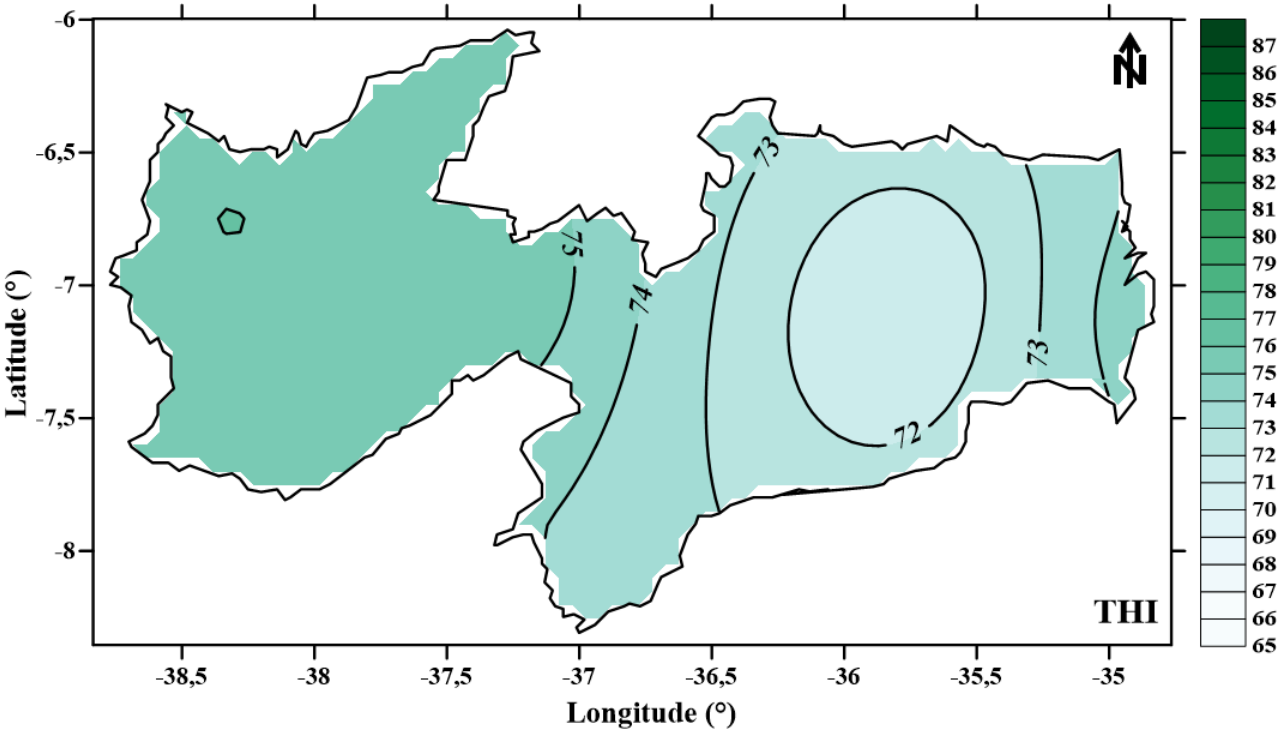

Figure 2. Spatial distribution of THI in the rainy season.

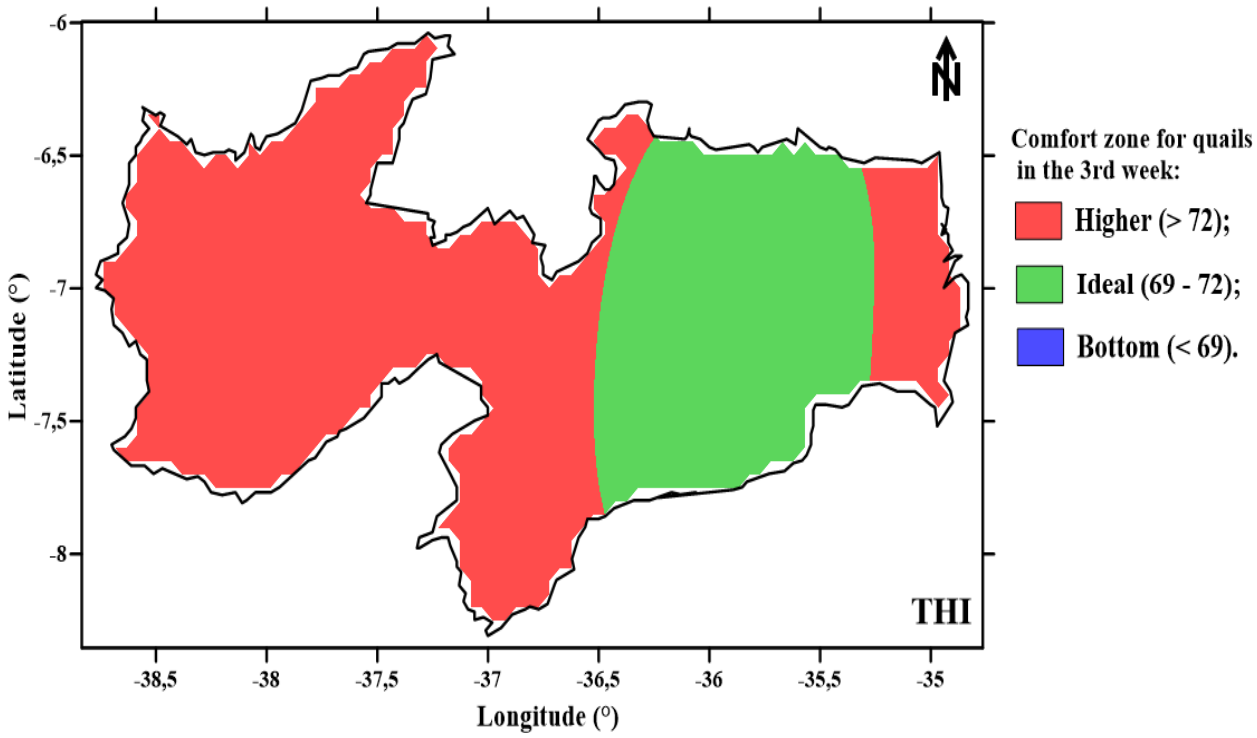

Figure 3. Spatial distribution of the temperature and humidity index ranges for quails in the 3rd week in the rainy season.

The ideal THI range for quails in the fifth week of life ranges from 71 to 75, with temperatures between 25 and 26.2 ºC and relative humidity of 56.2 to 65.2%. Therefore, the THI within that zone is

found in the territorial areas of Zona da Mata (72 - 74), Agreste (71 - 72), Borborema (71 - 75), and there is a reduced transition area (76) between comfort and heat stress in 99.5% of the Sertão (74 - 75) (Figure 5).

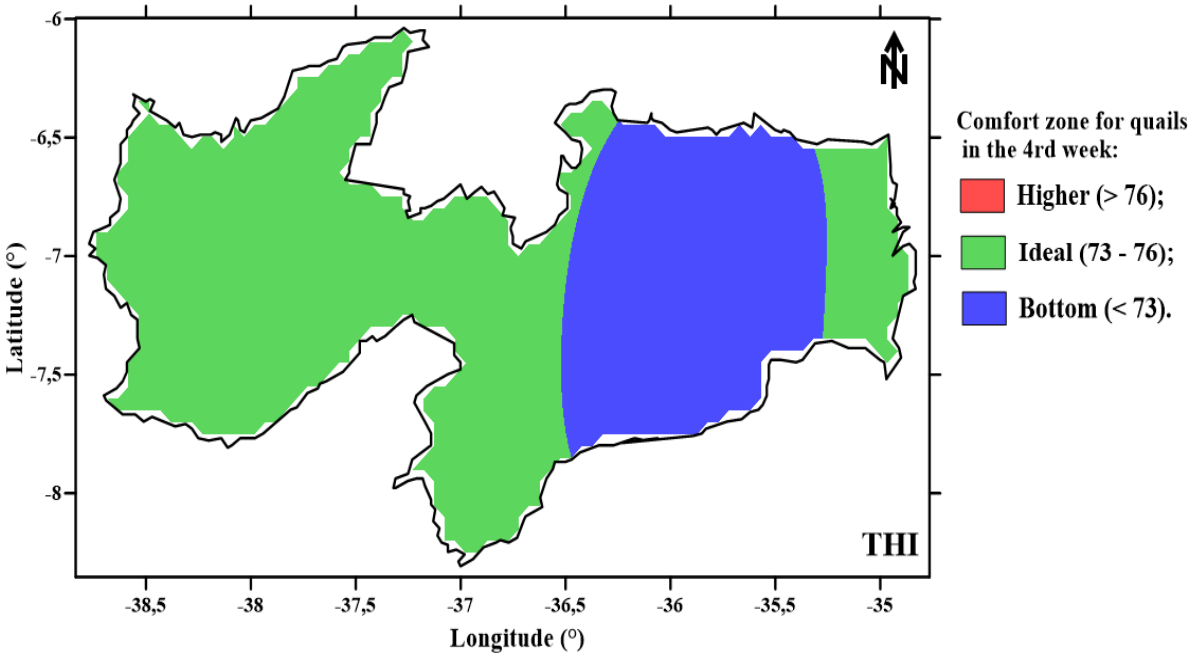

Figure 4. Spatial distribution of temperature and humidity index ranges for quails in the 4th week in the rainy season.

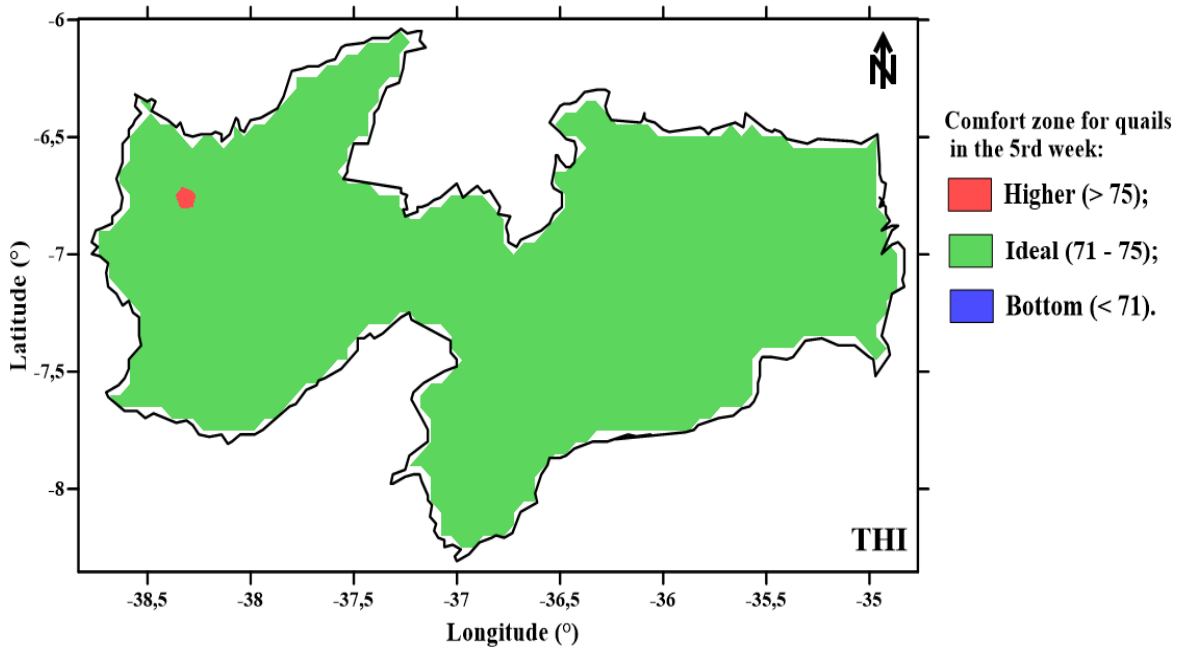

Figure 5. Spatial distribution of temperature and humidity index ranges for quails in the 5th week in the rainy season.

4. Discussion

THI ranges of 69-72, air temperature between 23-24.6 ºC and the relative humidity between 52.6 to 64.4% can provide the birds with better thermal conditions for the third week of life, and present better zootechnical performance (Sousa et al. 2014a).

It is observed heat stress for quails in this phase (3rd week) in 77% of the territory of Zona da Mata, 72.7% of Borborema and 100% of Sertão, with the use of mitigating measures being necessary to avoid reduction in the productive performance of quails, considering that inadequate environmental conditions within the facilities result in reduced productive efficiency of the birds (Oliveira et al. 2016).

Quails use physiological mechanisms to maintain their body temperature under heat stress from 24 ºC such as a reduction in food intake. This reduction is around 18 g bird^{-1} day^{-1} in the transition from 24 to 27 ºC, consequently causing a drop-in weight gain, around 8 g bird^{-1} day^{-1}. There may be a decrease in weight at slaughter, carcass yield of around 4.5 %, resulting from the bird's attempt to reduce internal heat production, thus proving that the animal's performance is closely related to the thermal conditions of the environment to which they are submitted (Sousa et al. 2014a).

Considering that the relative air humidity is above the thermal comfort zone (TCZ) in this period in the Zona da mata and Borborema mesoregions, corrective measures must be taken in order to minimize the deleterious effects for breeding quails in the third week of life such as cross ventilation. This is a strategy which can be adopted in conventional installations equipped with curtains and allows opening when necessary, enabling the removal of excess heat and humidity through the renewal of air inside the installation, improving the quality of air, the performance of birds, and providing a reduction in production costs (Santos et al. 2017).

While the T and RH in this period in the Sertão would be above the TCZ for the third week of life of the birds, some mitigating measures can assist animals in the dissipation of body heat such as water supply and cooling and the use of fans in order to facilitate the dissipation of excess heat, improving the thermal sensation of the microenvironment of the installations (Silva et al. 2015; Schiassi et al. 2015; Castro et al. 2017) and the use of the surrounding landscaping for avoid reflection of the sun's rays.

Thus, cold stress would predominate in 23% of the Zona da Mata territory and in 27.3% of Borborema; a situation which can cause physiological and behavioral disorders in birds given that their thermoregulatory apparatus is still underdeveloped, making them sensitive to the cold when young (Schiassi et al. 2015).

Birds tend to maintain or increase food consumption in situations of cold stress. However, they divert part of the energy that would serve for tissue deposition for maintenance, decreasing their productive performance and there is an increase in the relative weight of the organs, with an associated need for greater body heat production (Sousa et al. 2014b). Therefore, it becomes necessary to apply mitigating measures to avoid stress and reduce production.

Curtains can be kept in semi-open installations at times when the temperature is mild in order to increase the internal T in an attempt to minimize the effects of temperature below comfort and the high relative humidity of the air which can impact the performance of birds (El Kholy et al. 2017), thus enabling air to be renewed inside by means of natural ventilation and thereby reducing humidity (Santos et al. 2017).

The T in Borborema, Zona da Mata and Agreste would be below the recommended level and the RH above comfort in the fourth week of life, but the same corrective measures could be adopted in all of them.

The T and RH would be above the TCZ for the fifth week of life of the birds in the rainy season in the Sertão, and the same mitigating measures adopted for the third week can assist these animals in dissipating body heat.

The birds tend to stay most of the time at rest, increase water consumption and reduce food consumption when they are under thermal stress in order to minimize their body heat production. Greater thermal discomfort for quails occurs with high temperature and high relative humidity, since the main heat dissipation mechanism of birds is through the respiratory tract evaporation, and its activation influences the cardiorespiratory frequency (Bueno et al. 2017).

In quails in the fifth week of life submitted to a temperature transition from 26 to 30 ºC above the TCZ there is an average decrease of 5.0 g bird^{-1} day^{-1} in feed consumption, a reduction in weight gain of 13.0 g bird^{-1} day^{-1}, which may reach a decrease of 19.0 g bird^{-1} day^{-1} if the temperature rises to 33 ºC (Sousa et al. 2014b). In view of the occasional discomfort within the Sertão mesoregion, it is necessary to use possible mitigating measures, thus seeking to alleviate discomfort throughout the territory.

From this stage, the animals are destined for laying or cutting, and it is necessary to pay even more attention to sudden changes in climatic variables, especially the high temperature which causes problems with the use of feed, and consequently with the growth rate, weight gain and productivity.

According to El Tarabany (2015), laying quails subjected to temperature variation from 24 ºC to 32 ºC, in addition to decreasing feed consumption (4.2 g bird^{-1} day^{-1}) and weight gain (15 g bird^{-1} day^{-1}), show a decline in egg production (6.7%), egg weight (0.25 g bird^{-1} day^{-1}), egg hatchability (4.5%), as well as reducing egg quality and their internal characteristics. Bonfim et al. (2016) mention that quails destined for cutting submitted to a temperature variation from 26 ºC to 32 ºC reduce feed consumption (15.8%), weight gain (5.7%), in addition to suffering changes in quality meat, carcass characteristics and weight of some organs, such as the heart with a 0.12% reduction in size.

The facilities are responsible for the internal microclimate in the aviaries, with the most common models for breeding quails in Brazil being opened on the sides with the use of ceramic or fiber cement tiles, curtains and mini curtains which allow their total closure when necessary (Silva et al. 2015). Appropriate materials must be used in the construction of new facilities to promote the thermal comfort of quails, in order to avoid thermal stress since this can cause negative impacts and economic losses (Silva et al. 2015; Ribeiro et al. 2016; Santos et al. 2019).

When choosing the orientation of conventional installations, one should opt for the construction of the largest dimensions in the East-West direction when possible, considering that direct solar radiation will affect their weight and its coverage most of the day, avoiding the incidence inside. The ceiling height should vary between 2.8 - 3.5 m when the maximum widths are from 8 to 10 m in relation to the location of the terrain. It is preferable that the soil is firm and has good drainage, avoiding that they have little insolation and irregularity in the movement of air, facilitating the emergence and spread of pathogenic microorganisms (Lopes Neto 2017).

The population density of quails is also of fundamental importance for the success of the breeding, as large groups generate competition for space and food, leading to reduced performance, further intensifying with rising temperatures (Braga et al. 2018). Knowledge about the elements which endanger the welfare of birds will enable the producer to reformulate or rebuild the facilities, making them more efficient (Silva et al. 2015).

5. Conclusions

Based on the temperature and humidity index within the state of Paraíba, the mesoregions that would present greater comfort in the rainy period for quails in the third week of life would be Agreste, followed by the Zona da Mata, heat stress would occur in the other mesoregions, and may be used as a means of mitigation the supply of chilled water, cross ventilation, use of fans and surrounding landscaping.

For quails in the fourth week of life, comfort would be found in the Sertão, followed by Zona da Mata and Borborema, while in Agreste cold stress would predominate, and as a way of mitigation, keeping the curtains in the semi-open facilities allowing natural ventilation. For those in the fifth week of life, the comfort zone would be found in the Agreste mesoregion, followed by Borborema, Zona da Mata and Sertão.

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