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IMPACT OF CLIMATE CHANGE ON BIOLOGICAL PERFORMANCE OF BARKI SHEEP RAISED IN NORTH WESTERN COASTAL ZONE OF EGYPT

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SUMMARY

The current study was conducted to characterize the changes of climatic parameters throughout the studied years from 2000 up to 2015 and quantify the biological responses of Barki sheep maintained in North Western Coastal Zone (NWCZ) of Egypt. A total number of 2692 accumulated records were collected over 14 successive breeding seasons. Biological and meteorological data were statistically analyzed to compare variations in biological performance of the flock as influenced by climate change. The considered years were partitioned (according to THI values trend) into two periods; the first period (P1) was from the year 2000 till the year 2007, while the second period (P2) was from the year 2008 up to year 2015. Analysis of the meteorological data revealed that there is a marked increase of annual air temperature (AT) and Temperature- Humidity Index (THI) values throughout the years under investigation particularly at P2. Also, the obtained results revealed that there is considerable evidence showing a substantial decline in the biological performance of the studied flock due to climate change. Generally, all the studied productive traits in P2 were significantly (P<0.001) lower than those of P1. Average birth weight, average weaning weight, average daily gain and survival rate were dropped by about 4.5%, 15.2%, 18.8% and 3.5%, respectively in comparison with those estimates in P1. While, estimate of number of ewes lambed per ewe joined (EL/EJ) was decreased in P2 by 5.3% less than that in P1. The obtained estimate of number of kilograms lambs weaned per ewe joined (KGW/EJ) during the P2 was less than that of P1 by about 9.4%. In conclusion, the current study underlines the importance to develop appropriate adaptation strategies to attenuate the adverse effects of climate change on Barki sheep raised in NWCZ of Egypt.

Keywords: Climate change, Barki sheep, biological performance, THI, Egypt

INTRODUCTION

The world population is projected to increase by more than one billion people within the next few years, reaching 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 (UN, 2015). Global demand for agricultural products will increase by about 70 % and for livestock products is expected to double by 2050 (FAO, 2009a). Many reports emphasized the increase in the earth's air temperature, which is known as the global warming. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the forecasted climate changes events are expected to have a dramatic impact on natural ecosystems and economy in many parts of the world (IPCC, 2007). Predictions relative to climate change effects consider the Mediterranean basin has categorized as a global warming hotspot and the anticipated rise in air temperature ranging from + 2°C to + 6.5°C by the end of the century (Giorgi 2006; Olesen and Bindi, 2002; Giorgi and Bi, 2005; Metzger *et al.*, 2006 and Segnalini *et al.*, 2013). Global warming is a critical issue due to its direct impact on agriculture and livestock production. Through its impacts on agriculture, climate changes threatens food availability by reducing the productivity of crops, livestock and fisheries, and hinder access to food by disrupting the livelihoods of millions of rural people who depend on agriculture for their incomes (FAO, 2016). The anticipated rise in temperature due to climate change is likely to aggravate the heat stress on livestock and adversely affecting their productive and reproductive performance and even death in extreme cases (Herrero *et al.,* 2012 and Nigm *et al.*, 2015).

It is a fact that the majority of worldwide ruminants are located in tropics and subtropics zones, especially in arid or semi-arid regions, where climate conditions limit animal productivity and yield (Herrero *et al.,* 2012). Barki sheep is the most recognized and predominant native sheep breed that is well adapted to the prevailing harsh conditions in the North Western Coastal Zone (NWCZ) of Egypt. The North Western Coastal Zone stretches about 500 kilometers along the Mediterranean coastline, west of Alexandria city to El-Salloum close to Libya state border. Barki sheep is raised mainly for lambs' production and play significant roles in the economy and food security for people living in that area. However, one of the major constraints to its productivity is climate conditions pertained in that area. A series of indexes has been suggested to describe the influence of thermal environment on animal biological response. The application of the Temperature Humidity Index (THI) is commonly used as an indicator for the degree of heat stress on farm animals caused by climate conditions, and still widely considered a useful tool to predict the effects of environmental warmth on farm animal's biological performance.

There is still limited research regarding the impacts of climate change on sheep production (IPCC, 2014). Up to the knowledge of the author, no published research works are available on the effect of global climate change on biological performance of Barki sheep under semi-arid conditions of Egypt. Therefore, the current study was conducted to characterize the changes of climatic parameters in NWCZ of Egypt focused on the years from 2000 up to 2015 and quantify the biological response of the impacts of climate change for several years on Barki sheep enterprise, having in mind to provide famers and policy makers with appropriate adaptation strategies to limit consequences of climate change on biological functions of Barki sheep in NWCZ.

MATERIALS AND METHODS

Location and climatological features

The present study was based on the data collected from Maryout Research Station on a Barki sheep flock. That research station belonging to Desert Research Center and located in North Western Coastal Zone of Egypt, some 30 km South West of Alexandria, at 30.90° North latitude and 29.55° East longitude, with the elevation of the area varies from 0 to 200 meter above sea level. This zone is classified in the more general sense as semi-arid erratic conditions. The climate characterizes by hot summer with an average daytime air temperature of 27°C and maximum air temperature of 32°C during summer time and with minimum air temperature of 10°C during winter time, while average relative humidity ranged between 63% in April and 70% in January. The annual rainfall is irregular and varies greatly from one year to another with an average of approximately 150-180 mm/year and maximum rainfall occurs during December-February (Bonnet *et al.,* 2014). Dynamics of monthly climate parameters derived from meteorological station are displayed in Figure (1).

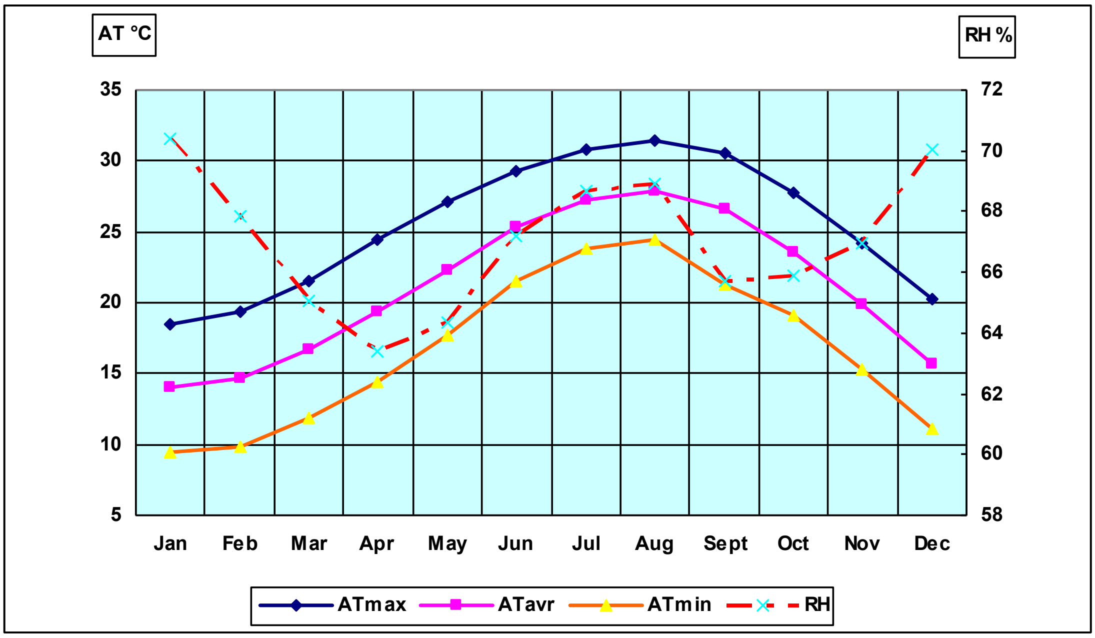

Figure 1. Monthly time series for meteorological parameters of the studied flock location

Biological data

Data utilized in the current study were obtained from a breeding flock of Barki sheep raised under semi-arid conditions at Maryout Research Station. A total number of 2692 accumulated records were collected over 14 successive breeding seasons from year 2000 up to year 2015 (data of breeding season 2012 was not available). Biological data considered were; number of lambing ewes, number of lambs weaned, birth weight of newborn lambs (BWT), weaning weight (WWT) at 90 days of age, daily gain of lambs from birth to weaning (ADG), and survival rate (SUR) of newborn from birth to weaning.

Flock management practices

Animals of the studied flock were housed in barns provided with open yards partially shaded with corrugated metal sheets. The flock normally shorn once a year in April. Flock performs controlled natural mating once a year. The mating season started in September and lasted for two estrous cycles. Lambing season took place on February and lasted for corresponding period of mating season. Lambs were kept with their dams for suckling up to weaning at approximately 90 days of age. The nutritional regime of the flock was applied through a standardized balanced rations of seasonal green fodders along with concentrate feed mix. Extra concentrate of 0.25 kg/head/day was offered two weeks prior mating season for flushing the ewes, in addition to, during late pregnancy and early lactation. Whenever available, sheep were allowed to graze on natural pastures in neighboring areas according to range conditions from sunrise until before sunset. Drinking water and mineral blocks were available all the daytime.

Meteorological data:

Meteorological data pertaining to the studied flock location with the corresponding studied years were provided by an automated meteorological station belonging to Desert Research Center and located at Maryout Research Station. The collected data were comprised of daily records of climate variables; dry bulb air temperature (°C) and air relative humidity (%) for the studied years from 2000 up to 2015. Monthly average dry bulb temperature (AT) and relative humidity (RH) were calculated from the daily meteorological records.

Temperature-Humidity Index:

Temperature-Humidity Index (THI) values were calculated using the formula designed for most sheep breeds raised in semi-arid and tropical environments and reported by Marai *et al.* (2007).

$THI = T_{db} - (0.31 - 0.0031 * HR) * (T_{db} - 14.4)$

Where:

$T_{db,}$ is the dry bulb air temperature (°C) and HR is the relative humidity (%).

The study adopted approach, to evaluate the annual THI dynamics over the studied years, was based on comparison of mean values of annual THI. In addition, a further assessment of THI values considering the summer season within each studied year was carried out, because summer season represents the major challenge for Barki sheep enterprise. Numerous publications have been undertaken to establish thresholds for heat stress in sheep on the basis of THI value. Marai e*t al.* (2007) defined four heat stress categories in relation to THI values as presented in Table (1).

Table 1. Definition of heat stress categories according to THI values.

THI value	Heat stress category
THI < 22.2	Absence of heat stress
22.2 ≤ THI < 23.3	Moderate heat stress
23.3 ≤ THI < 25.6	Severe heat stress
THI ≥ 25.6	Extreme severe heat stress

Reference: Marai e*t al.* (2007)

Due to heat stress thresholds reported by Marai *et al.* (2007), the calculated THI values of the current study were split into two categories, THI value < 22.2 units and THI value ≥ 22.2 units. On the other hand, on the basis of results obtained for the current metrological data and climate conditions, the studied years were partitioned into two periods; the first period (P1) was from the year 2000 till the year 2007, while the second period (P2) was from the year 2008 up to year 2015.

Statistical analysis:

Data collected on productive and reproductive performance of the studied flock were statistically analyzed using least squares procedures as described by SAS (2004) to compare variations in biological performance of the flock as influenced by climate change and estimate correlation coefficients among THI and studied biological traits. The current study adopted number of kilograms of lambs weaned per ewe joined (KGW/EJ) as one of the most indicative parameters for measuring productivity of sheep flock. The biological traits which suppose to be relevant to KGW/EJ were; number of ewes lambed per ewe joined (EL/EJ), average daily gain from birth up to weaning age (ADG) and lambs survival rate up to weaning age (SUR). While the productive traits were; average birth weight of newborn lambs (BWT) and average weaning weight (WWT). The following fixed effect linear model was applied to analyze the above mentioned traits.

$$Y_{ijkl} = \mu + T_i + P_j + A_k + (TP)ij + (TA)_{ik} + (PA)_{jk} + e_{ijkl}$$

Where:

Y_{ijkl} = is the observation,

μ = is the overall mean,

Ti = is the effect due to I^{th} THI value, i = 1, 2, where 1 = < 22.2 and 2 = ≥22.2,

Pj = is the effect due to J^{th} period, j = 1, 2, where 1 = (2000 – 2007) and 2 = (2008 – 2015) years

A_k = the effect due to K^{th} age of ewe, k= 2, 3, 4, 5, 6, 7, >7,

(TP)ij = the effect due to interaction between THI and period,

$(TA)_{ik}$ = the effect due to interaction between THI and age of ewe,

$(PA)_{jk}$ = the effect due to interaction between period and age of ewe and

e_{ijkl} = the random error, associated with the individual observation, assumed to be normally independently distributed with mean = 0 and variance = ∂^2e.

The significant differences among means of biological traits were tested using Duncan's Multiple Rang Test (Duncan, 1955).

RESULTS AND DISCUSSION

Meteorological parameters

The distribution of annual average ambient air temperature and the corresponding THI values dynamics during the studied years are presented in figure (2). Analysis of the meteorological data revealed that there is a marked gradual increase of both annual AT and THI values throughout the years under investigation. Furthermore, the annual average of THI values in P1 (2000-2007) were mostly less than the minimum threshold of heat stress (< 22.2

units) with an average of 21.7 units. Meanwhile, THI values for P2 (2008 – 2015) were higher than threshold of heat stress with an average of 22.3 units, and exceeded those in P1 by 2.8 %.

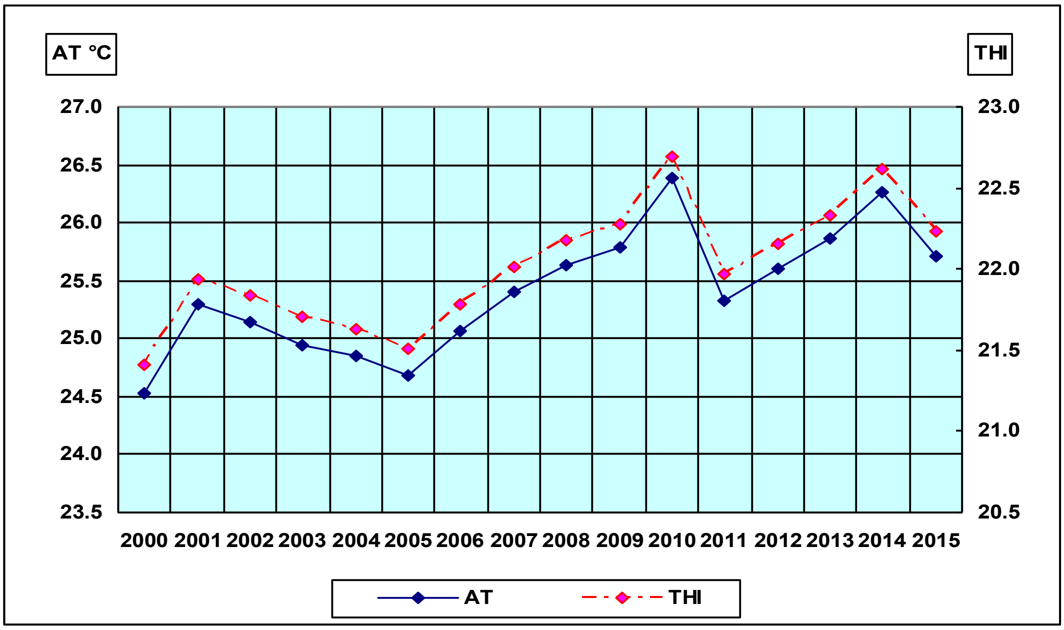

Figure 2. Mean values of annual average air temperature and temperature humidity index for the studied years

In addition, analysis of meteorological data during the summer months (June – September) showed a real elevation of both AT and THI every year starting from year 2008 (Figure 3) and bridge the threshold of heat stress. The averaged annual variation of THI values during summer months showed a severe heat stress (THI ≥ 23.3 units) was observed, this may due to hot waves throughout summer months. When the produced time series of THI values were compared between P1 and P2, it indicated that the frequency of occurrence of THI categories during summer season revealed a clear shift to higher categories was observed particularly in P2 and the maximum THI values were identified on years 2010 and 2015 and reached about 23.3 units. The obtained meteorological results are considered as a real evidence of climate change from moderate heat stress (22.2 ≤ THI < 23.3) in P1 to severe heat stress (23.3 ≤ THI < 25.6) in some years of P2.

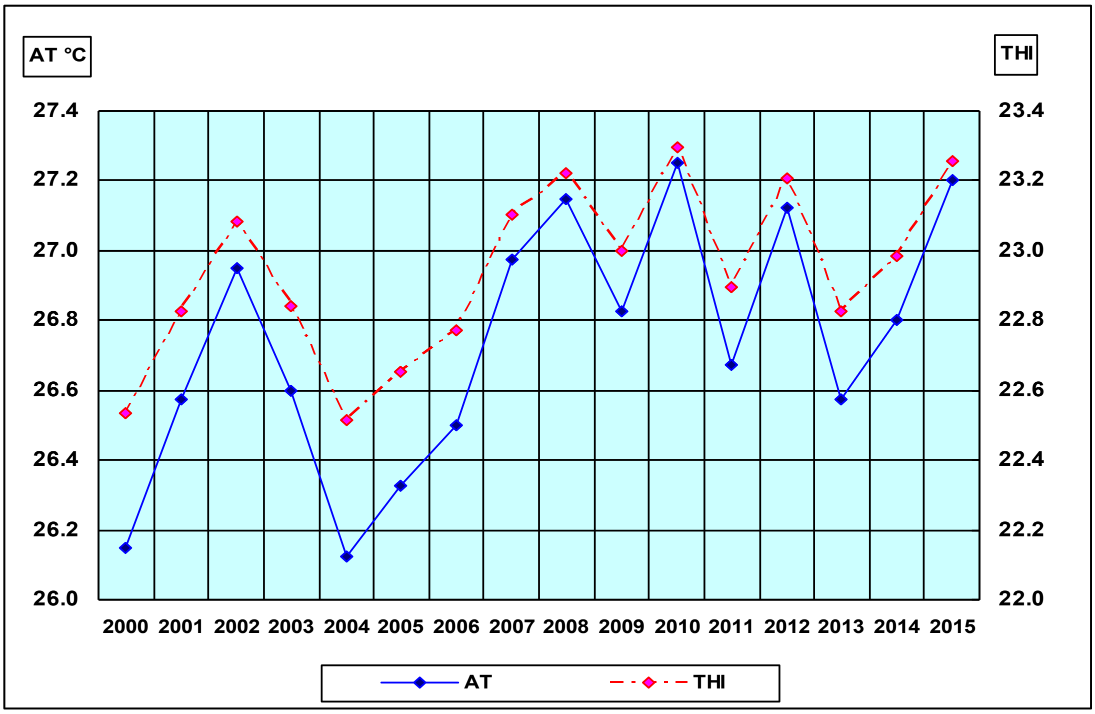

Figure 3. Time series of average air temperature (AT) and temperature humidity index (THI) for months (June – September) for the studied years

Partial correlation matrix

The phenotypic correlation coefficients among the studied biological variables and THI values are presented in Table (2). In fact, the correlation analysis demonstrated that considered biological traits and meteorological factors were moderate and inversely associated with R^2 estimate of 0.935. It could be observed that the obtained correlation coefficients were moderate with the highest negative estimate of -0.493 between average birth weight and THI, and lowest negative estimate of -0.014 was between survival rate and THI. While the correlation coefficient for KGW/EJ was estimated as -0.458. Therefore, exposure of sheep to such heat stress evokes a series of drastic changes in the biological functions, which include a decrease in feed intake efficiency and utilization, disturbances in water, protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites. The obtained meteorological results are in agreement with those reported by Nigm *et al.* (2015).

Table 2. Pearson correlation coefficients among studied biological traits and THI values

Variables	BWT	WWT	ADG	SUR	EL/EJ	KGW/EJ	THI
BWT	**1.000**	0.463	0.538	0.309	0.159	0.533	-0.493
WWT		**1.000**	0.893	0.312	0.619	0.797	-0.341
ADG			**1.000**	0.306	0.341	0.729	-0.350
SUR				**1.000**	0.505	0.738	-0.014
EL/EJ					**1.000**	0.771	-0.421
KGW/EJ						**1.000**	-0.458
THI							**1.000**

BWT; average birth weight, WWT; average weaning weight, ADG; average daily gain from birth up to weaning age, SUR; lambs survival rate up to weaning, EL/EJ; number of ewes lambed per ewe joined and KGW/EJ; kilograms of lambs weaned per ewe joined.

Bio-meteorological correlation

The relationship between average daily gain of the growing lambs and THI values of the current study are displayed in figure (3). The ADG distribution obviously declared the negative correlation coefficient (-0.350) between average daily gain and THI values. The average daily gain curve showed a markedly decline in ADG particularly during P2 years (2008 – 2015) when climate starts to change and the annual THI values were higher than 22.2 units.

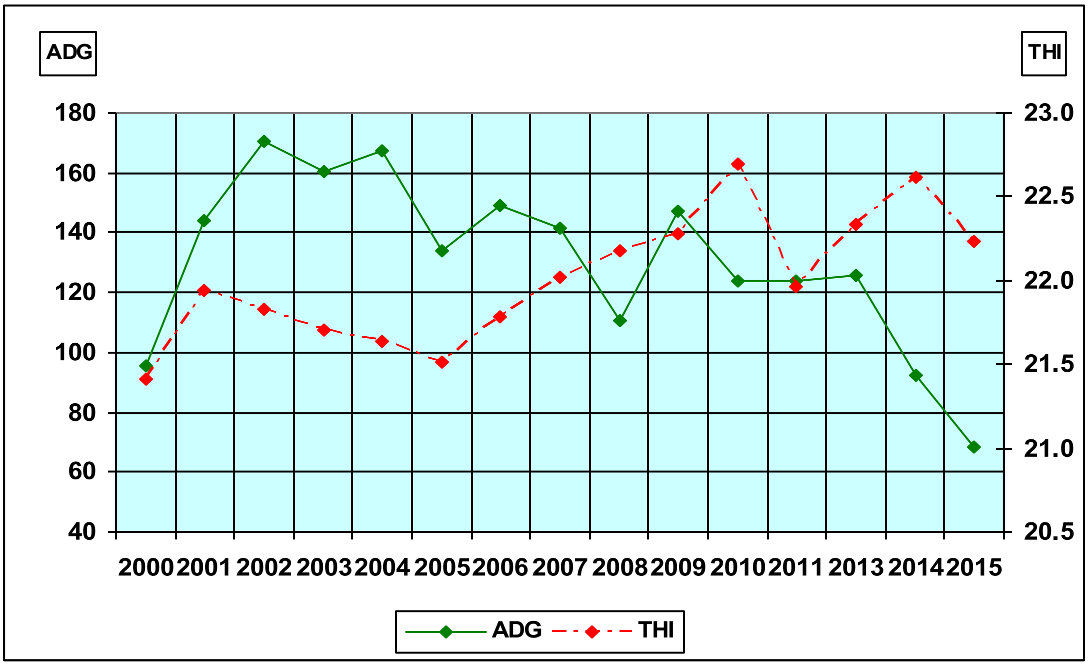

Figure 3. Average daily gain (ADG) of the growing lambs during the studied years in relation to THI values

In the same context, the obtained EL/EJ and THI values distributions of the considered years obviously illustrated the negative correlation coefficient (-0.421) between lambing rate and THI value (figure 4). As a result, diminishing trend of flock performance. The current findings emphasis the adverse impact of climate change throughout P2 in comparison with P1 on the studied Barki flock performance.

On the other hand, KGW/EJ is considered a conclusive measure of flock productivity, since it combines ewe and ram fertility as well as daily gain of lambs and lambs' survival into one index as reported by Younis *et al.* (1990). It is of interest to notice that, results of analysis of correlation (Table 2) revealed that there are moderate positive correlation coefficients among EL/EJ and ADG with KGW/EJ of estimates +0.771 and +0.729, respectively. Subsequently, any negative change in these relevant biological traits, due to the occurrence of climate change throughout P2 years, will drop the obtained quantity of KGW/EJ as shown in figure (5).

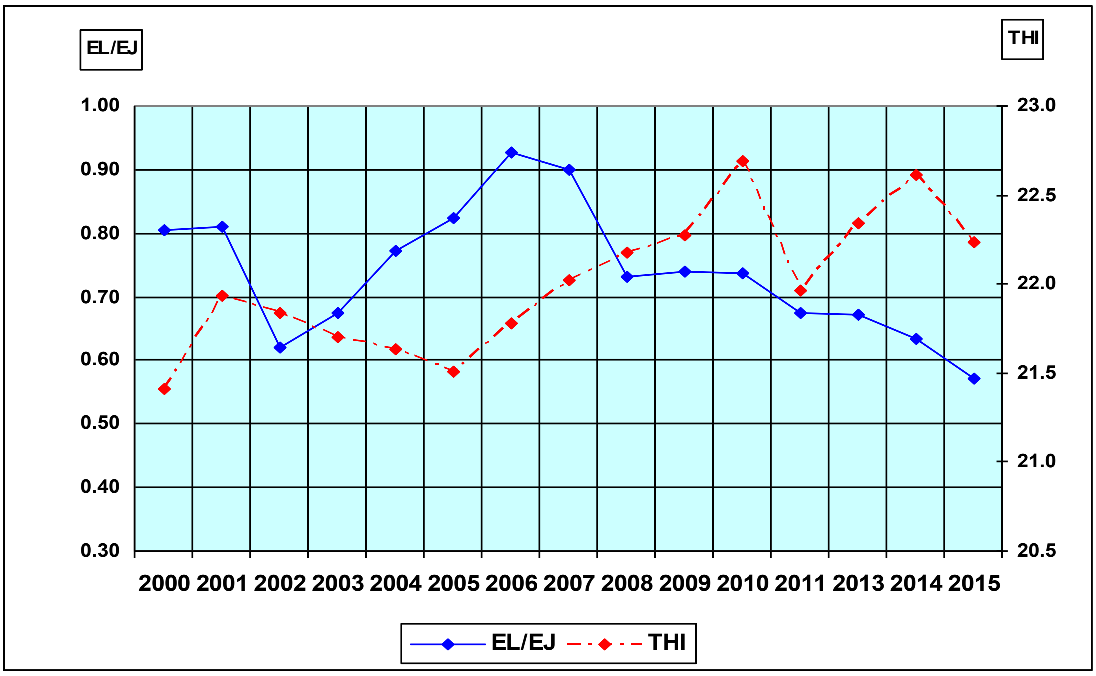

Figure 4. Distribution of lambing rate of the studied flock in relation to THI values for the studied years

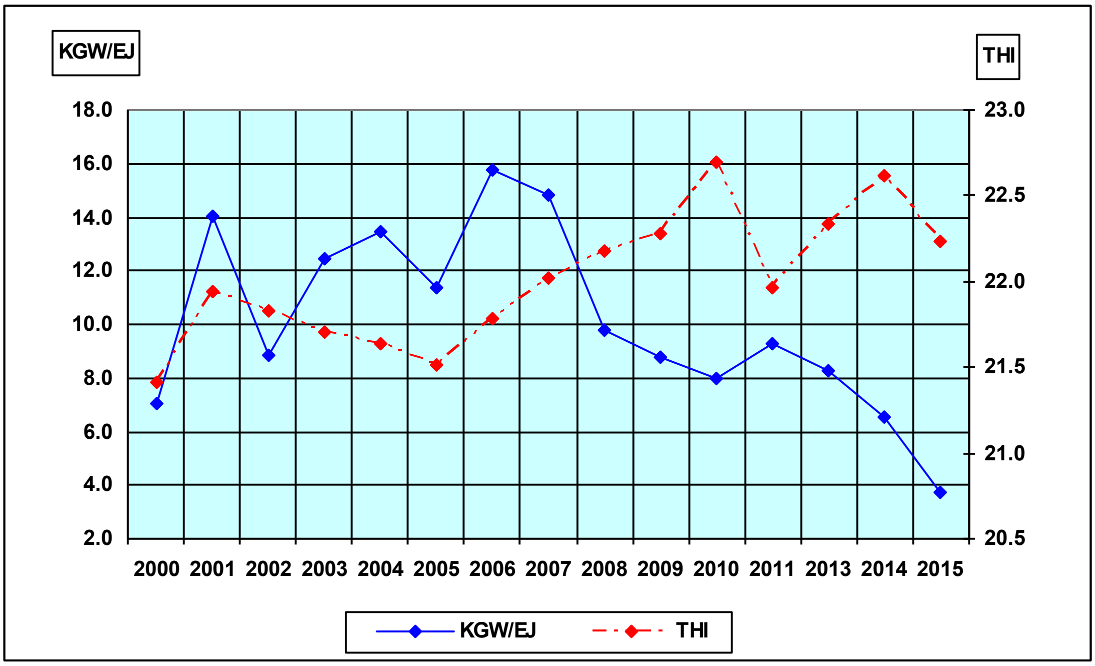

Figure 5. Distribution of KGW/EJ and THI values during the investigated years

Biological indicators

The obtained results of analysis of variance for the current study revealed that there is considerable evidence showing a substantial decline in the biological performance of the studied flock due to climate change (Table 3). Generally, some of the studied productive traits were significantly ($P<0.001$) affected by both period and THI effects incorporated into the statistical model. All studied productive traits in P2, where THI values were high, were significantly (P<0.001) lower than those of P1. Average birth weight, average weaning weight and average daily gain were dropped by about 4.5%, 15.2% and 18.8%, respectively in comparison with those estimates in P1. On the other hand, average survival rate of lambs in P2 decreased by about 3.5% than that of P1. Similar results were reported in previous publications, Marai *et al.* (2007) reported that exposure of sheep to heat stress is accompanied by changes in the biological functions. Heat stress has an effect on utrine environment, substantially reduces the total embryo cell number and placenta size resulting in smaller birth weight of lambs.

Similarly, the same influence was markedly observed due to THI value. When THI values were greater than 22.2, the flock was exposed to heat stress; therefore, all the above mentioned traits were declined as well by about 8%, 14.3% and 15.8%, respectively. These findings revealed that the negative impact of heat stress may be attributed to the reduction in feed intake and utilization and/or metabolic hormones (Rhoads *et al.,* 2009, Rhoads *et al.,* 2010 and Wheelock *et al.,* 2010). On the other hand, the effect of high THI value on average daily gain induced by the decrease of the anabolic activity and increase in tissue catabolism as reported by Marai *et al.* (2007). This decrease in anabolism is essentially caused by a decrease in voluntary feed intake of main nutrients. In the same time, the increase in tissue catabolism occurs mainly in fat depots and/or lean body mass. In the same context, the interaction between THI and period showed a significant effect (P < 0.05) on BWT and highly significant effect (P < 0.001) on the other productive traits (Table 3).

Table 3. Least squares means (X) and standard errors (SE) of biological traits for the studied flock

Classification	BWT (KG)	WWT (KG)	ADG (gm)	SUR
	X ± SE	X ± SE	X ± SE	X ± SE
Overall mean	3.45 ± 0.01	15.5 ± 0.09	133 ± 1.02	0.85 ± 0.07
THI	***	***	***	**
< 22.2	3.61[a] ± 0.02	16.8[a] ± 0.13	145.8[a] ± 1.42	0.87[b] ± 0.01
≥ 22.2	3.32[b] ± 0.01	14.4[b] ± 0.12	122.7[b] ± 1.35	0.83[a] ± 0.01
Period	NS	***	***	*
P1	3.52[a] ± 0.02	16.5[a] ± 0.12	144[a] ± 1.42	0.86[a] ± 0.01
P2	3.36[b] ± 0.03	14.0[b] ± 0.13	117[b] ± 1.35	0.83[a] ± 0.01
Age	NS	*	**	NS
2	3.37[b] ± 0.03	15.0[cb] ± 0.20	129[a] ± 2.20	0.84[b] ± 0.02
3	3.42[b] ± 0.03	15.7[ab] ± 0.20	137[a] ± 2.10	0.88[b] ± 0.02
4	3.55[a] ± 0.03	15.9[a] ± 0.25	136[a] ± 2.60	0.84[b] ± 0.02
5	3.48[ab] ± 0.03	15.7[ab] ± 0.25	135[a] ± 2.60	0.87[b] ± 0.02
6	3.45[ab] ± 0.04	15.8[a] ± 0.31	137[a] ± 3.30	0.83[b] ± 0.03
7	3.45[ab] ± 0.06	14.3[c] ± 0.39	119b ± 4.10	0.75[a] ± 0.04
> 7	3.49[ab] ± 0.05	14.4[ab] ± 0.29	132[a] ± 3.04	0.88[b] ± 0.02
THI X Period	*	***	***	***
THI X Age	NS	NS	NS	NS
Period X Age	NS	NS	NS	NS

BWT; average birth weight, WWT; average weaning weight, ADG; average daily gain from birth up to weaning age and SUR; lambs survival rate up to weaning.

[a,b,c] Means within the same column with different superscripts are significantly different (P < 0.05)

* P < 0.05, ** P < 0.01, *** P < 0.001, NS; non significant.

The obtained least squares means of EL/EJ of the studied flock showed a markedly decreased in P2, where THI value was ≥ 22.2 unit, in comparing with P1 and scored estimates of 0.67 and 0.72, respectively. Kadokawa *et al.* (2012) reported that heat stress reduces the length and intensity of estrus besides increases incidence of anestrous and silent heat in farm animals. Also, Lacerda and Loureiro (2015) reported that heat stress decreases fertility by diminishing quality of oocytes and embryos through direct and indirect embryonic growth and development.

The analysis of variance showed a highly significant effect (P < 0.001) of the considered effect of THI and significant effect (P < 0.05) of period on KGW/EJ of Barki flock as shown in Table (4). The obtained estimate of KGW/EJ during the P2, where THI exceeded 22.2 units, was less than that of P1 by about 9.4%. While, THI values also, negatively influenced KGW/EJ which showed up to 27.4% losses where THI was ≥ 22.2. These marked effects of THI on KGW/EJ is quite surprising, considering that small ruminant should be less sensitive to heat stress than large ruminants.

In the same context, analysis of variance showed a highly significant effect (P<0.001) of interaction between THI and period on flock biological performance expressed in terms of KGW/EJ as shown in Table (4). On the other hand, comparing the estimate of KGW/EJ in P2, revealed a drastic decline by about 29 % lower than that of P1 in case of absence of heat stress (THI < 22.2) as shown in figure (6). This may due to that the studied flock exposed to a longer duration of severe heat stress (23.3 ≤ THI < 25.6) in some years of P2 than in P1 as indicated before in Figure (3). In addition, comparing the flock biological performance under the both considered THI values in P1 and P2, figure (6) declared that the difference between the estimates of KGW/EJ in P1 is larger than that of P2 as a result of climate change.

Table 4. Least squares means (X) and (SE) of EL/EJ and KGW/EJ

Classification	N	EL/EJ	KGW/EJ
		X ± SE	X ± SE
Overall mean	2692	0.74 ± 0.08	10.2 ± 0.17
THI		***	***
< 22.2	1421	0.80[a] ± 0.01	11.7[a] ± 0.23
≥ 22.2	1271	0.67[b] ± 0.01	8.5[b] ± 0.22
Period		NS	*
P1	1522	0.76[a] ± 0.01	10.6a ± 0.23
P2	1170	0.72[b] ± 0.01	9.6[b] ± 0.22
Age		***	**
2	618	0.72[b] ± 0.02	9.4[d] ± 0.03
3	493	0.78[a] ± 0.02	10.7[ab] ± 0.37
4	479	0.80[a] ± 0.02	11.2[a] ± 0.40
5	411	0.72[ab] ± 0.02	10.8[abc] ± 0.45
6	272	0.67[b] ± 0.03	9.4[bcd] ± 0.55
7	199	0.76[a] ± 0.03	9.6dc ± 0.56
> 7	220	0.70[ab] ± 0.03	9.4abcd ± 0.62
THI X Period		**	***
THI X Age		**	NS
Period X Age		***	**

EL/EJ; number of ewe lambed per ewe joined, KGW/EJ; number of kilograms of weaned lambs per ewe joined.
[a,b,c] Means within the same column with different superscripts are significantly different (P < 0.05).
* P < 0.05, ** P < 0.01, *** P < 0.001, NS; non significant.

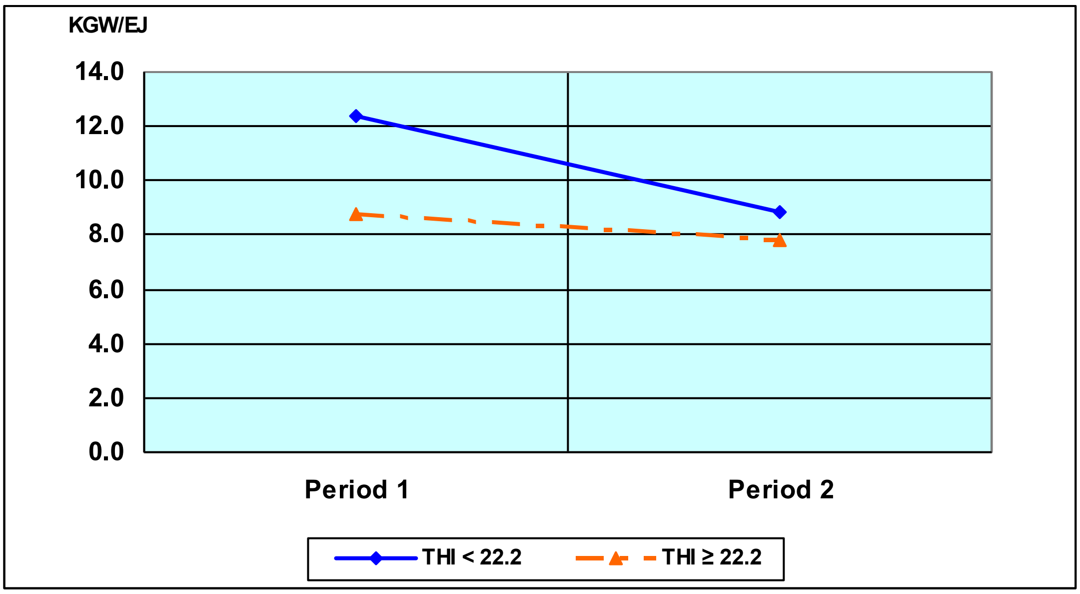

Figure 6. Effect of interaction between THI and Period on KGW/EJ of the studied flock

CONCLUSION

In conclusion, meteorological indicators obtained from the current study confirmed a marked change in climate of the considered NWCZ of Egypt, expressed in the elevation of THI values. The findings of the current study revealed that there are adverse effects on all the biological studied traits. Farmers, pastoralists and community depend on activities that are intimately and inextricably linked to climate are also the most vulnerable to climate change. In the same context, with the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. Further, researches efforts are needed to evaluate the economic losses due to climate change. The current study underlines the importance to develop appropriate adaptation strategies to attenuate the adverse effects of climate change in Barki sheep.

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أثر التغيرات المناخية على الأداء الحيوى للأغنام البرقى المرباة فى منطقة الساحل الشمالى الغربى بمصر

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أجريت الدراسة الحالية لتوصيف تغير المناخ خلال سنوات الدراسة من عام ٢٠٠٠ حتى عام ٢٠١٥، وتقدير الإستجابات الحيوية للأغنام البرقى المرباة فى منطقة الساحل الشمالى الغربى بمصر. تم جمع ٢٦٩٢ سجلاً خلال ١٤ موسم تربية متوالى. تم إجراء التحليل الإحصائى للبيانات البيولوجية والمناخية لمقارنة الإختلاف فى الأداء الحيوى للقطيع نتيجة لتغير المناخ. تم تقسيم سنوات الدراسة إلى فترتين، الفترة الأولى (P1) من عام ٢٠٠٠ حتى عام ٢٠٠٧، بينما الفترة الثانية (P2) من عام ٢٠٠٨ حتى عام ٢٠١٥. كشفت نتائج تحليل بيانات الأرصاد الجوية إلى أن هناك زيادة ملحوظة فى درجة حرارة الجو ودليل الحرارة والرطوبة وبصفة خاصة خلال (P2). بشكل عام، أظهرت النتائج أن هناك إنخفاض ملحوظ فى الأداء الحيوى للقطيع تحت الدراسة بسبب تغير المناخ. كانت متوسطات جميع الصفات الإنتاجية المدروسة أقل خلال (P2) عنها فى (P1) على مستوى معنوية (P<0.001). إنخفض متوسط وزن الميلاد، متوسط وزن الفطام، معدل النمو اليومى ومعدل البقاء بنحو ٤.٥%، ١٥.٢%، ١٨.٨%، و ٣.٥%، على الترتيب. بالمقارنة بالمتوسطات فى (P1). فى حين انخفض عدد النعاج الوالدة بالنسبة لعدد النعاج الداخلة فى (P2) بنسبة ٥.٣% عن (P1). كان معيار عدد كيلوجرامات المفطومة بالنسبة لعدد النعاج الداخلة فى الفترة الثانية (P2) أقل من (P1) بنحو ٩.٤%. تؤكد الدراسة الحالية على أهمية وضع استراتيجيات ملائمة للتخفيف من الآثار السلبية لتغير المناخ على الأغنام البرقى المرباة فى منطقة الساحل الشمالى الغربى.