Journal of Current Veterinary Research

*ISSN: 2636-4026*

Journal homepage: http://www.jcvr.journals.ekb.eg

***Animal production***

# Impacts of Climatic Factors on Milk Yield Performance and Mastitis Incidence in Holstein Cattle Reared under Subtropical Condition

Ahmed Dawod*

*Department of Husbandry and Animal Wealth Development, Faculty of Veterinary Medicine, University of Sadat City, Menofia, Egypt.*

**Corresponding author:* adawod@vet.usc.edu.eg *Received: 4/1/2022 Accepted: 1/2/2022*

## ABSTRACT

This study aimed to investigate the effect of climatic factors, including temperature-humidity index (THI) and rainfall level (RFL) regarding the parity on the incidence of mastitis, milk yield, and composition in Holstein cattle in Egypt. A total of 2496 lactating cows were used from different four dairy farms located in Egypt. One hundred dairy cows were selected from each dairy herd for detection of the effect of different climatic factors and parity on milk composition and somatic cell count (SCC).The data grouped according to parity into 1, 2, and >2 parity groups. Also, the animals grouped according to THI into low (<70), medium (70-80), and high (>80) THI level and regrouped according to RFL into low (<2 mm), medium (2-5 mm), and high (>5 mm) rainfall per month. The obtained results revealed an increase in daily milk yield, milk protein%, fat %, and SCC with the increase of parity. Also, high THI significantly (p≤ 0.05) decreased daily milk yield (29.45 kg) and increased SCC (415 × 103 cell/mL). In high THI and low RFL climatic conditions, multiparous cows were prone to the occurrence of clinical mastitis compared to primiparous ones (p≤ 0.001); especially during mid and late lactation stages. In conclusion, high THI and low RFL impaired dairy performance and increased the frequency of clinical mastitis.

**Keywords:** *Egypt; Holstein mastitis; temperature-humidity index; rainfall level milk yield; lactation.*

## INTRODUCTION

Currently, climatic conditions are important factors that influence the productive performance and disease incidence of animals (Lacetera, 2019). Dairy cattle are highly sensitive to environmental stress as a result of their high metabolic rate due to milk synthesis, which is equivalent to their production level (Beede & Shearer, 1991). In tropical, subtropical, and semi-arid countries, dairy cattle are subjected to high relative humidity, ambient temperatures, and solar radiation for long periods. This reduces the ability of the lactating cow to lose excess heat, leading to heat stress. Consequently, the animal develops several physiological mechanisms to cope with this stress. However, these responses have negative impacts on the productive and reproductive performance of the animal (Bouraoui *et al.*, 2002).

Rainfall level (RFL) is likely to have implications for livestock production, principally through its effects on forage and water resources, land sustainability, and animal health (Nardone et al. 2010). The extent of these impacts will depend on how rainfall is expressed in each livestock-producing region and the specific way in which it will probably affect both the quantity and quality of livestock production. Reduced productivity in marginal areas can be predicted and possibly higher productivity in higher rainfall regions (Rust & Rust, 2013). Linearly, a moderate positive correlation between the amount of rainfall and the quantity of milk production was reported in the Mweiga location, Kenya (Mirara and Maitho, 2013).

Clinical mastitis is one of the most serious diseases in dairy farms. This disease is one of the most costly multifactorial diseases (Halasa *et al.,* 2007). Many risk factors could be associated with the occurrence of clinical mastitis including production stage (Suriyasathaporn *et al.,* 2000), lactation number (Faye *et al.,* 1998), dairy herd management (Barkema *et al.,* 1999), and many environmental factors (Olde Riekerink *et al.,* 2007). Also, the genetic difference could be observed among mastitis susceptible and unsusceptible cows (Szyda *et al.,* 2019). Globally, the prevalence of clinical mastitis is reported to range between 16 to 48% (Kvapilik *et al.,* 2014), while the incidence of subclinical mastitis is estimated to be from 20 to 80 cases per 100 cows (Contreras & Rodríguez, 2011).

Holstein breed had a high incidence of diseases including mastitis rather than low producing breeds, this could be due to the intense selection pressure for improving milk yield (Curone et al. 2018). Holland, *et al. (2015)* reported that cow costs between $16.43 and $572.19 due to clinical mastitis incidence. Besides the economic aspects of mastitis, milk from cattle with mastitis accidentally can affect human health adversely via transmission of pathogenic microorganisms and antibiotic residues (Hameed *et al.,* 2007). Climatic factors such as temperature and humidity (Morse *et al.,* 1988) besides managerial conditions like season number, lactation stage, and frequency may play a significant role in the frequency of mastitis (Moosavi *et al.,* 2014). Little information is available on the relationship between the temperature-humidity index (THI) or rainfall level and milk production, fat, protein contents, and somatic cell count (SCC) (Bertocchi *et al.,* 2014). Therefore, this study was conducted to investigate the effect of parity, THI, and RFL on milk yield and composition as well as the occurrence of mastitis in Holstein dairy cattle in Egypt. These relationships would help to apply an effective general management strategy and mastitis control in dairy herds.

## MATERIALS AND METHODS

*Ethical Statement*

Animals were handled and cared according to the guidelines for the care and use of dairy cattle in researches. All protocols involving animals in this study were assessed and approved by the Institutional Animal Care and Use Committee (IACUC), Faculty of Veterinary Medicine, Sadat City University, Egypt.

*Animals*

Four lactating dairy herds in a large agriculture company located at Giza Province, Egypt (latitude of 30° 16′ N and longitude 30° 36′ E, 43 m above the sea level) used in the present study. The dairy herds accommodated 2496 Holstein cattle (1st herd= 768, 2nd herd= 614, 3rd herd= 553, and 4th herd= 561) with an average milk yield of 9000 liters/season and 2.18 parity numbers (range 1-9 parity). The study was conducted during the period from June 2019 to November 2020, with atmospheric temperature, ranging from 17 to 36° C and relative humidity (Rh %) from 33 to 60%. The dairy animals were followed up for a complete lactation season. Cows were milked three times/day in a herringbone milking parlor equipped with automatic take-off systems and automatic recording systems (ALPRO, DeLaval, Kansas City, Missouri, USA). Milking practices and utensils management performed according to the standard management system used for Holstein dairy herds. The total mixed ration (TMR) was offered for the dairy cattle twice per day. The ration was adapted for the animals based upon their milk yield and body condition score. The ration was blended daily and prepared to match the optimal requirements of the dairy cows, also evaluated by a wet chemistry method (Table 1). The dry period feeding regime and requirements were adjusted based on guidelines of the National Research Council (USA) **(NRC, 2001).**

**Table 1.** The chemical composition of the ration

| Diet chemical analysis | |
|---|---|
| Neutral detergent fiber (%) | 25.94 |
| Crude protein (%) | 15.81 |
| Net energy for lactation (Mcal kg) | 1.80 |

Cattle housed in free-stall barns with 20% roofed area, open sides, and sandy floors, and grouped according to their level of milk production and stage of lactation. Dry cows were kept in a separate compartment and grouped into two groups (far off and close up). The dairy females were transferred to a close up group before their parturition due date by two weeks. All animals within the study were tested against tuberculosis and brucellosis and free cases were confirmed. Also, the dairy females were artificially inseminated after a voluntary waiting period of 50 days postpartum. The cows fed a total mixed ration (TMR) twice daily with 18% crude protein content on dry matter bases. The ration (dry matter/kg per day) was based on corn silage (14.0), grounded corn (3.0), alfalfa hay (3.0), soybean 46% (4.0), wheat bran (3.0), dried pulp root (3.25), extruded flaxseed (1.75), beaker yeast (0.10), and a mineral and vitamin supplement (Anavite Himix Dairy Cow Premix, ZAGRO Co., Singapore).

*Study design and animal grouping*

The study was divided into two main divisions; the first estimated the effect of climatic factors and parity on lactation performance, milk composition, and SCC, while the second described the effect of parity on the incidence of mastitis during different THI, RFL, and lactation stages in all dairy herds involved in the study.

The effect of climatic factors and parity on lactation performance, milk composition, and SCC was done on 400 dairy cows. Where one hundred dairy animals were randomly selected from each herd involved in the study. The obtained data were allocated into three categories according to the lactation parities, as 1, 2, and >2 parity groups. Moreover, the data were classified into three THI groups, including low (< 70), medium (70-80), and high (>80) according to Nasr and El-Tarabany (2017). Similarly, 3 RFL groups were recognized based on precipitation level as <2, 2-5, and >5 mm per month during the year-round.

The effect of the lactation parity on the incidence of clinical mastitis during different THI, RFL, and lactation stages was performed on all animals involved in the study (2496 dairy cows). After detection of the mastitis-affected cases, the mastitic cows were grouped according to their parity into 1, 2, and >2 parity groups. Moreover, based on the mastitis attack date, the mastitis affected cases were grouped according to the stage of lactation into fresh (0-14 days in milk), early (15-100 DIM), mid (100-200 DIM), and late (≥ 200 DIM) lactation stages.

Furthermore, to estimate the effect of clinical mastitis on 305 d milk yield and BCS, the dairy cows were divided into six groups according to the recurrence of clinical mastitis attacks as 0, 1, 2, 3, 4, > 4 times. Animals with incomplete records, affected by other diseases than mastitis or culled for any other reasons were excluded from the study.

*Milk somatic cell count and composition analysis*

Dairy cows were milked three times per day with 8 hours interval. Fresh milk samples were monthly collected from three consecutive milkings for the determination of SCC (cells/mL) with a fluoroopto-electronic counter (Fossomatic TM FC, Foss Electric, Hillerød, Denmark). Then the rest of the milk samples were stored at 4°C with a preservative (bronopol tablet; D&F Control System, San Ramon, CA, USA) till evaluation of protein and fat contents with FTIR spectrophotometry (MilkoScan™ FT 6000, Foss Electric, Hillerød, Denmark).

*Lactation performance and Clinical mastitis data*

Data of daily milk yield, 305-milk yield (MY), days in milk (DIM), and parity number were collected from on-farm recording system (dairy-Comb). The body condition score (BCS) of the dairy cows involved in the study was determined at 200 DIM on a 1-5 BCS scale, where 1=extremely thin and 5= extremely fat.

The dairy herds were subjected to strict milking hygiene practices and a mastitis control program. Clinical mastitis cases were identified throughout the appearance of clinical signs via milking personnel then confirmed by veterinarians. The diagnosis was confirmed throughout performing the California Mastitis Test for all suspected cases. The clinical signs including flaked milk, bloody milk or serous fluid, hotness, redness, hardness of one or more quarters, and appearance of sharp pain during palpation (Lima *et al.*, 2018). Mastitic animals were subjected to treatment via intra-mammary infusion with an antibiotic formula having spiramycin, neomycin, and flumethasone after each milking for three successive days. The data of the mastitic cows were determined, including the animal identification number, date and recurrence number of the affection, and DIM for each case.

*Climatic data*

Meteorological data were obtained daily from the local weather station (Wadi El Natrun station, Egyptian General Meteorological Authority, Ministry of Civil Aviation, Egypt). Both temperature and relative humidity were measured at the farm and used to estimate the temperature-humidity index (THI). The daily THI was calculated using the following formula, according to Kendall and Webster (2009).

THI= (1.8xT+32)-[(0.55-0.0055xRH) x (1.8xT-26)]

where T = Ambient temperature (°C) and RH = Relative humidity (%).

***Statistical analysis***

The parametric data were enrolled in statistical analysis using the SAS software (2003, SAS Institute Inc., Cary, NC). Monthly data of each cow (daily milk yield, protein%, fat%, and SCC) were collected then the temperature, relative humidity, and rainfall values of the sampling day were estimated using the metrological data. The percentage data were subjected to Arcsine transformation, while the SCC data were logarithmically transformed to obtain normally distributed values. PROC GLM procedure of SAS was used to examine the effect of parity, THI, and RFL on daily-MY, milk protein%, fat%, and SCC according to the following statistical model:

$$Y_{ijklmnop} = \mu + P_i + T_j + R_k + (P*T)_l + (P*R)_m + (T*R)_n + (P*T*R)_o + E_{ijklmnop}$$

Where μ = overall mean; $P_i$ = parity, $_i$ = 1, 2 and >2; $T_j$ = THI effect, $_j$ = low, medium and high; $R_k$ = RFL effect, $_k$ = low, medium and high; $(P*T)_l$= interaction effect between parity and THI; $(P*R)_m$= interaction effect between parity and RFL; $(T*R)_l$= interaction effect between THI and RFL;$(P*T*R)_o$= interaction effect among parity, THI, and RFL; and $E_{ijklmnop}$ = random residual.

Results were expressed as least square means and standard error of the means (SEM). LSD test was carried out to detect the difference among means. Moreover, the effect of the clinical mastitis recurrence on dairy cattle BCS and 305-MY was done using one way ANOVA procedures of SAS, and the results expressed as the mean and standard error of means according to the following statistical model:

$$Y_{ij} = \mu + M_i + E_{ij}$$

Where μ = overall mean; $M_i$ = mastitis recurrence, $_i$ = 0, 1, 2, 3, 4 and >4; and $E_{ij}$= random residual.

The effect of parity on the clinical mastitis incidence at different THI, RFL, and stages of lactation was statistically analyzed with the Chi-square test. Values of $P \leq 0.05$ were considered significant.

## RESULS

*3.1. Impact of parity, THI, and RFL on lactation performance, milk composition, and somatic cell count*

Concerning dairy performance parameters Table 2, it was clear that milk yield, protein, fat, and SCC were significantly increased with the increase of the parity number of the dairy cows. Dairy cows of 2 parties or more sustained higher daily milk yield (32.77; 35.34 kg/day) compared with the young dairy cow (29.04 kg/day) (P=0.05). Same trend appeared in milk protein%, fat%, and SCC results (P=0.02; P=0.03; P=0.04). Moreover, different types of interactions among parity, THI, and RFL possessed no significant differences in milk yield, milk protein%, fat%, and SCC results (P>0.05).

**Table 2.** Effect of parity on Holstein milk yield, composition, and somatic cell count

| Parameters | Parity† | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **>2** | **SEM*** | **P-value** |
| Milk yield (kg/day) | 29.04$^{b}$ | 32.77$^{a}$ | 35.34$^{a}$ | 1.34 | 0.05 |
| Milk protein (%) | 3.12$^{c}$ | 3.21$^{b}$ | 3.34$^{a}$ | 0.01 | 0.02 |
| Milk fat (%) | 3.31$^{c}$ | 3.37$^{b}$ | 3.43$^{a}$ | 0.01 | 0.03 |
| SCC (×10$^{3}$ cell/mL)** | 335$^{c}$ | 371$^{b}$ | 445$^{a}$ | 2.58 | 0.04 |

†Parity: 1: First lactation; 2: Second lactation; >2: more than 2 lactations. *SEM: Standard error of the mean. **SCC: Somatic cell count. $^{a,b,c}$ Values within a row with different superscripts differ significantly at (P≤ 0.05).

Table 3 shows the effect of THI level on milk yield and composition together with the SCC of Holstein cattle. Cows reared under high and medium THI conditions showed a significant decrease in daily milk yield (P=0.02) besides milk protein (P=0.01) and fat percentages (P=0.01) compared with those reared under low THI conditions. Daily milk yield, milk protein, and milk fat percentages were reduced by 17.32, 5.97, and 4.89%, respectively in the high THI group relative to the low THI one. Also, the former parameters were reduced in the medium THI group but to a lesser degree than the high THI group. In contrast, medium and high THI atmospheric conditions led to a significant increase in SSC (P=0.03) by 12.10% and 19.60 %, respectively compared with low THI atmospheric conditions.

**Table 3.** Effect of the temperature-humidity index (THI) on Holstein milk yield, composition, and somatic cell count

| Parameters | Temperature-humidity index (THI)† | | | | |
|---|---|---|---|---|---|
| | **Low** | **Medium** | **High** | **SEM*** | **P-value** |
| Milk yield (kg/day) | 35.62$^{a}$ | 32.08$^{b}$ | 29.45$^{c}$ | 1.22 | 0.02 |
| Milk protein (%) | 3.35$^{a}$ | 3.17$^{b}$ | 3.15$^{b}$ | 0.01 | 0.01 |
| Milk fat (%) | 3.48$^{a}$ | 3.32$^{b}$ | 3.31$^{b}$ | 0.01 | 0.01 |
| SCC (×10$^{3}$ cell/mL)** | 347$^{c}$ | 389$^{b}$ | 415$^{a}$ | 2.96 | 0.03 |

†Low: THI less than 70; Medium: THI over 70 and less than 80; High: THI over 80. *SEM: Standard error of the mean.
**SCC: Somatic cell count. $^{a,b,c}$ Values within a row with different superscripts differ significantly at (P≤ 0.05).

As shown in Table 4, animals raised under high precipitation levels had the highest daily milk yield (P=0.05), milk protein (P=0.01), and milk fat percentages (P=0.01) by 24.46, 9.01, and 1.47%, respectively compared with that reared in low precipitation level. There were no significant differences regarding protein and fat contents of milk between medium and high RFL groups. SCC was significantly reduced by 28.98 and 16.37 in medium and high RFL, respectively compared with the low RFL group (P=0.04).

**Table 4.** Effect of rainfall level (RFL) on Holstein milk yield, composition, and somatic cell count

| Parameters | Rainfall level (RFL)† | | | | |
|---|---|---|---|---|---|
| | **Low** | **Medium** | **High** | **SEM*** | **P-value** |
| Milk yield (kg/day) | 27.92$^{c}$ | 32.27$^{b}$ | 36.96$^{a}$ | 1.89 | 0.05 |
| Milk protein (%) | 3.03$^{b}$ | 3.31$^{a}$ | 3.33$^{a}$ | 0.01 | 0.01 |
| Milk fat (%) | 3.34$^{b}$ | 3.38$^{a}$ | 3.39$^{a}$ | 0.01 | 0.01 |
| SCC (×10$^{3}$ cell/mL)** | 452$^{a}$ | 378$^{b}$ | 321$^{c}$ | 3.88 | 0.04 |

†Low: RFL less than 2mm per month; Medium: RFL over 2 mm and less than 5 mm per month; High: RFL over 5 mm per month. *SEM: Standard error of the mean. **SCC: Somatic cell count. [a,b,c] Values within a row with different superscripts differ significantly at (P≤ 0.05).

*3.2. Impact of THI and RFL on clinical mastitis occurrence*

Table 5 presents data on the occurrence of clinical mastitis as affected by increasing of the number of parity and THI level. The obtained results showed that clinical mastitis occurrence was significantly increased with increasing THI level ($P<0.001$). Multiparous cows showed a high rate of incidence of clinical mastitis compared to primiparous ones, throughout different THI groups. The highest occurrence of clinical mastitis was significantly detected in the multiparous cows of 3 or more lactation parity in high THI (17.7%) ($P<0.001$). The results of the occurrence of clinical mastitis during different RFL and parties are shown in Table 6. Clinical mastitis occurrence was significantly decreased with RFL increment, as the levels of the clinical mastitis were much high during low rainfall conditions ($P< 0.05$).

**Table 5.** Effect of parities during different temperature-humidity index (THI) on Holstein mastitis incidence

| Parity | N=2496 | Temperature-humidity index (THI) † | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | Medium | | High | |
| | | Freq. | % | Freq. | % | Freq. | % |
| 1 | 396 | 9 | 2.30 | 8 | 2.00 | 36 | 9.10 |
| 2 | 1016 | 39 | 3.80 | 88 | 8.70 | 76 | 7.50 |
| >2 | 1084 | 80 | 7.40 | 120 | 11.10 | 192 | 17.70 |
| Chi-square | | 21.41** | | 30.05** | | 55.53** | |
| P-value | | <0.001 | | <0.001 | | <0.001 | |

†Low: THI less than 70; Medium: THI over 70 and less than 80; High: THI over 80.

**Table 6.** Effect of parities during different rainfall level (RFL) on Holstein mastitis incidence

| **Parity** | **N=2496** | **Rainfall level (RFL) †** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Low** | | **Medium** | | **High** | |
| | | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** |
| 1 | 396 | 52 | 13.10 | 0 | 0 | 0 | 0 |
| 2 | 1016 | 104 | 10.20 | 68 | 6.70 | 32 | 3.10 |
| >2 | 1084 | 268 | 24.70 | 48 | 4.40 | 76 | 7.00 |
| Chi-square | | 83.02** | | 29.01** | | 40.18** | |
| P-value | | <0.001 | | <0.001 | | <0.001 | |

†Low: RFL less than 2mm; Medium: RFL over 2 mm and less than 5 mm; High: RFL over 5 mm.

*3.3. Impact of lactation stage on clinical mastitis occurrence*

Data presented in Table 7 showed that clinical mastitis occurrence of Holstein cows at early, mid, and late stages of lactation were significantly increased with increasing parity number (P< 0.001). During the early, mid, and late stages of lactation, multiparous cows showed a high rate of incidence of clinical mastitis compared to primiparous ones. However, the incidence of mastitis during the fresh stage (first 14 days of lactation) was insignificantly influenced by the parity number (P=0.08).

**Table 7.** Effect of parities during different stages of lactation on Holstein mastitis incidence

| Parity | N=2496 | Lactation stage† | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fresh | | Early | | Mid | | Late | |
| | | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| 1 | 396 | 4 | 1.00 | 16 | 4.00 | 20 | 5.10 | 12 | 3.00 |
| 2 | 1016 | 16 | 1.60 | 36 | 3.50 | 68 | 6.70 | 84 | 8.30 |
| >2 | 1084 | 28 | 2.60 | 96 | 8.90 | 132 | 12.2 | 136 | 12.50 |

| Chi-square | 4.91 | 29.55** | 27.92** | 33.30** |
|---|---|---|---|---|
| P-value | 0.08 | <0.001 | <0.001 | <0.001 |

† Fresh: First 14 days of lactation; Early: 14-100 days of lactation; Mid: 100-200 days of lactation; Late lactation: 200-300 days of lactation.

*3.4. Impact of recurrence of mastitis attack on Holstein performance parameters*

As displayed in Table 8, throughout the 305d milk yield, the attack recurrence of mastitis was significantly influenced. The lowest 305d milk yield (9447.1 kg) was recorded in the cows with more than four times of mastitis recurrence. In contrast, healthy cows had significantly higher values of 305d milk yield (10408.54 kg) compared to the attacked ones. Holstein cows affected by mastitis once had the highest mastitis incidence (16.80%), while the lowest incidence attained in those attacked more than four times. The results of body condition score showed no significant differences among different mastitis attack frequencies.

**Table 8**. Effects of recurrence of mastitis attack on some dairy Holstein performance parameters.

| Parameters | The recurrence of the mastitis attack | | | | | | SEM | P-value |
|---|---|---|---|---|---|---|---|---|
| | Once | Twice | Three times | Four times | > Four times | Healthy | | |
| Mastitis incidence (%) | 16.8 | 4.4 | 1.5 | 1.2 | 0.5 | - | | |
| Body condition score | 3.47 $^{a}$ | 3.50 $^{a}$ | 3.54 $^{a}$ | 3.50 $^{a}$ | 3.50 $^{a}$ | 3.49 $^{a}$ | 0.02 | 0.10 |
| Total milk yield (kg) | 9854.36 $^{b}$ | 9754.07 $^{b}$ | 9646.25 $^{b}$ | 9447.14 $^{c}$ | 9426.67 $^{d}$ | 10408.54 $^{a}$ | 167.68 | 0.04 |

SEM: Standard error of the mean. $^{a,b,c}$ Values within a raw with different superscripts differ significantly at (P≤ 0.05).

## DISCUSSION

Climatic conditions predominantly impact the general health and productive performance of livestock (Hill & Wall, 2015). Also, parity affected the milk yield and composition of Holstein dairy cows. The improvement of the milk yield, milk protein% and fat% with the increase of parity number could be due to the continuous increase of the dairy cow weight over the years together with completion of the udder tissue development. These findings were supported by (Yang *et al.*, 2013). Temperature humidity index is a reliable measure of heat stress and the subsequent impact on the productive and reproductive performance of farm animals (Habeeb *et al.*, 2018). The increase in atmospheric temperature is associated with production losses in livestock farms due to ongoing and predicted environmental changes (Smith *et al.*, 2013, Hill & Wall, 2015). Our results confirmed this trend as there was a decrease in daily milk production and milk composition during high THI compared to low THI. The obtained result was in agreement with (Bouraoui *et al.*, 2002; Nasr and El-Tarabany, 2017; Tamami *et al.*, 2018) who reported lower daily milk yield, composition, and higher SCC values in high THI compared with low THI levels. Bouraoui et al. (2002) detected a significant decrease in milk, protein, and fat yields during summer days of THI = 78 rather than spring days of THI= 68. The opposite of this trend was reported in SCC in Holstein dairy cows under the same condition. Linearly, Renna et al. (2010) reported a drop in milk yield, protein, and fat in the hottest summer months. Moreover, a reduction in milk protein and fat by 0.009 kg and 0.012 kg was reported for each unit increase of THI above the threshold level of 72 (Ravagnolo *et al.*, 2000).

Cows with high milk production are often sensitive to heat stress, especially in hot conditions, because of the increase of metabolic heat production intended for milk production (West *et al.*, 2003). High THI may irritate the neuroendocrine system leading to a negative impact on energy and water balance, hormonal equilibrium, and body temperature, which ultimately disturbed the growth, reproduction, milk production, and the immune system (Cappa, 1998).

SCC in milk is an essential parameter used as a marker for milk quality and healthy mammary tissue (Li *et al.,* 2014). Results obtained throughout this study indicated that the SCC increased with the increase of parity. The same finding was reported by (Yang *et al.,* 2013). Linearly, Tančin et al. (2007) observed that the milk SCC was affected with either internal or external parameters including parity, stage of lactation, teat placement, and milk flow kinetic.

High THI level was linked to the increase of SCC. There are conflicting results for the impact of different environmental conditions on SCC. Yang, et al. (2013) observed a notable decreased in SCC in the milk of dairy Holstein cows in hot weather and the opposite was recorded in cold weather. In contrast, Bernabucci et al. (2015) mentioned the opposite, which supported our findings. Linearly, Bertocchi et al. (2014) reported a progressive relationship among THI, SCC, and total bacterial count in the udder tissue. The increase of SCC in Holstein milk during high THI weather could be due to various types of stress. Moreover, during the summer the count and species of bacteria are increased in animal bedding material due to the appropriate humidity and temperature, which facilitates overexposure of teat ends to various infections (Bouraoui *et al.,* 2002). Generally, the increase of SCC was accompanied by a decrease in mammary gland synthetic performance (Harmon, 1994). On the other hand, the increase of RFL was associated with the increase of dairy performance and the decrease of SCC, as this may be due to the positive correlation between milk yield and high rainfall (Msechu *et al.,* 1995). In contrast, Morse et al. (1988) could not find an association between RFL and the incidence of mastitis in dairy cattle in USA.

The increase of parities was accompanied by a high frequency of mastitis episodes. These findings were in agreement with those of (Roche, *et al.,* 2009; Sinha *et al.,* 2021). The outcome could be due to the widening of the teat canal together with the elongation of teat shape in advanced parities (Sinha *et al.,* 2021). On the contrary, Kadarmideen and Pryce (2001) reported that parity does not affect mastitis incidence. The result might be attributed to the high susceptibility of glandular tissues of older animals to infection. This high susceptibility could be formed by high milk production, and a higher tendency of the udder to become pendulous by age (Radostits *et al.,* 2006). Of note, it was reported that the immune functions are more active in younger cows than older ones (Fleischer *et al.,* 2001, Dego & Tareke, 2003). Obtained results indicated that dairy cattle with high parity (> 2) subjected to high THI showed the highest incidence of mastitis. In agreement, Morse *et al.,* (1988) reported that high THI was a predisposing factor for mastitis. Moreover, the results suggested that the increase of RFL was associated with a decrease in the incidence of mastitis in both primiparous and multiparous cows. In contrast, Sinha et al. (2021) reported a significant increase in clinical mastitis cases in high producing Karan Fries and Sahiwal cows during the rainy season and this could be due to high levels of droplet infection, dampness, and muddy floors.

Concerning the effect of the party on clinical mastitis incidence among different lactation stages, the results showed an increase in the incidence of mastitis in mid and late lactation stages. In concordance with these results reported by Steeneveld, *et al. (2008)*, who reported that mid-lactation and late lactation stages were subject to increased incidence of mastitis in multiparous cows than primiparous ones. Also, Patel and Trived (2018) reported an increase in subclinical mastitis cases during early and late lactation stages.

The BCS possessed no significant differences between mastitic cows and healthy ones. A similar BCS between mastitis-affected and healthy cows has been reported by many researchers (Ruegg & Milton, 1995, Berry *et al.,* 2007). In contrast, Roche et al. (2009) reported that higher mastitis incidence in primiparous cows induced higher BCS in cattle reared under the Korral Koo cooling system. Moreover, current results showed that mastitis-affected cows produced less milk than healthy ones. These results are in concordance with those reported by Hagnestam, *et al.* (2007). Decreased milk yield with increased mastitis incidence and recurrence might be attributed to many factors including higher energy required for the immune system to face the infection, reduction of the appetite as a result of excessive inflammation and pain (Oudah, 2009), impairment of synthesis and ejection of milk from the mammary gland due to the inflammation (Dodd & Booth, 2000), reduction of the synthetic activity of the mammary epithelium in the infected udder together with the reduction in fat and lactose production (Teleb *et al.*, 2014) and passage of lactose from udder milk into the blood (Shuster *et al.*, 1991).

## CONCLUSION

High temperature-humidity index and low rainfall conditions were associated with a decrease in dairy performance indices including daily milk yield, milk protein, and fat percentages, and an increase of somatic cell counts. Multiparous Holstein cows were more susceptible to mastitis than primiparous ones. Also, High THI and low RFL are considered as predisposing factors for mastitis incidence in Holstein herds. The mid and late lactation were recognized as periods for mastitis incidence in multiparous Holstein cows, as these stages correlated with high mastitis incidence. Clinical mastitis harms milk yield and this affects magnitude with its recurrence. Therefore, the mastitis control program should focus on multiparous cows in their late lactation phase especially during high THI and low RFL to achieve the reasonable strategy of mastitis prevention in Holstein dairy herds, under the subtropical condition of Egypt.

## REFERENCES

Barkema, H.W., Schukken, Y.H., Lam, T.J., Beiboer, M.L., Benedictus, G., & Brand, A. (1999). Management practices associated with the incidence rate of clinical mastitis. Journal of dairy science, 82 (8), 1643-1654. https://doi.org/10.3168/jds.S0022-0302(99)75393-2.

Beede, D. & Shearer, J. (1991). Nutritional management of dairy cattle during hot weather. IV. Agri-Practice, 12, 164–170.

Bernabucci, U., Basiricò, L., Morera, P., Dipasquale, D., Vitali, A., Cappelli, F.P., & Calamari, L. (2015). Effect of summer season on milk protein fractions in Holstein cows. Journal of dairy science, 98, 1815-1827.

Berry, D.P., Lee, J.M., Macdonald, K.A., Stafford, K., Matthews, L., & Roche, J.R. (2007). Associations among body condition score, body weight, somatic cell count, and clinical mastitis in seasonally calving dairy cattle. Journal of dairy science, 90, 637-648. https://doi.org/10.3168/jds.S0022-0302(07)71546-1.

Bertocchi, L., Vitali, A., Lacetera, N., Nardone, A., Varisco, G. & Bernabucci, U. (2014). Seasonal variations in the composition of Holstein cow's milk and temperature-humidity index relationship. Animal : an international journal of animal bioscience, 8, 667-674. https://doi.org/10.1017/s1751731114000032.

Bouraoui, R., Lahmar, M., Majdoub, A., & Belyea, R. (2002). The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research, 51, 479-491.

Cappa, V. (1998). Dairy cows milk yield and quality in hot climate conditions. Zootecnica e Nutrizione Animale, 24, 233–238.

Contreras, G.A., & Rodríguez, J.M. (2011). Mastitis: comparative etiology and epidemiology. Journal of mammary gland biology and neoplasia, 16, 339-356.

Curone, G., Filipe, J., Cremonesi, P., Trevisi, E., Amadori, M., Pollera, C., Castiglioni, B., Turin, L., Tedde, V., Vigo, D., Moroni, P., Minuti, A., Bronzo, V., Addis, F. & Riva, F. (2018). What we have lost: Mastitis resistance in Holstein Friesians and in a local cattle breed. Res. Vet. Sci. 2018, 116, 88–98.

Dego, O.K., & Tareke, F. (2003). Bovine mastitis in selected areas of southern Ethiopia. Tropical animal health and production, 35, 197-205. https://doi.org/10.1023/a:1023352811751.

Dodd, F. & Booth, J. (2000). Mastitis and milk production. In The health of dairy cattle., Andrews, A.H., Ed. Blackwell Science Ltd:

Oxford, 213-255.
Faye, B., Perochon, L., Dorr, N., & Gasqui, P. (1998). Relationship between individual-cow udder health status in early lactation and dairy cow characteristics in Brittany, France. Veterinary research, 29, 31-46.
Fleischer, P., Metzner, M., Beyerbach, M., Hoedemaker, M., & Klee, W. (2001). The relationship between milk yield and the incidence of some diseases in dairy cows. Journal of dairy science, 84, 2025-2035.
Habeeb, A., Gad, A., & Atta, A. (2018). Temperature-humidity indices as indicators to heat stress of climatic conditions with relation to production and reproduction of farm animals. Intl. J. Biotech. Recent Adv, 1, 35-50.Halasa, T.; Huijps, K.; Østerås, O.; Hogeveen, H. (2007). Economic effects of bovine mastitis and mastitis management: a review. Veterinary Quarterly, 29, 18-31.
Hagnestam, C., Emanuelson, U., & Berglund, B. (2007). Yield losses associated with clinical mastitis occurring in different weeks of lactation. Journal of dairy science, 90, 2260-2270. https://doi.org/10.3168/jds.2006-583.
Hameed, K.G.A., Sender, G., & Korwin-Kossakowska, A. (2007). Public health hazard due to mastitis in dairy cows. Animal Science Papers and Reports, 25, 73-85.
Harmon, R.J. (1994). Physiology of mastitis and factors affecting somatic cell counts. Journal of dairy science, 77, 2103-2112. https://doi.org/10.3168/jds.S0022-0302(94)77153-8.
Hill, D.L., & Wall, E. (2015). Dairy cattle in a temperate climate: the effects of weather on milk yield and composition depend on management. Animal: an international journal of animal bioscience, 9, 138-149. https://doi.org/10.1017/s1751731114002456.
Holland, J.K., Hadrich, J.C., Wolf, C.A., & Lombard, J. (2015). Economics of measuring costs due to mastitis-related milk loss. 2015 AAEA & WAEA Joint Annual Meeting, Las Vegas, San Francisco, CA.
Kadarmideen, H., & Pryce, J. (2001). Genetic and economic relationships between somatic cell count and clinical mastitis and their use in selection for mastitis resistance in dairy cattle. Animal Science, 73, 19-28.
Kendall, P.; Webster, J. (2009). Season and physiological status affect the circadian body temperature rhythm of dairy cows. Livestock Science, 125, 155-160.
Kvapilik, J., Hanus, O., Syrucek, J., Vyletelova-Klimesova, M., & Roubal, P. (2014). The economic importance of the losses of cow milk due to mastitis–A meta-analysis. Bulgarian Journal of Agricultural Science, 20, 1501-1515.
Lacetera, N. (2019). Impact of climate change on animal health and welfare. Animal Frontiers, 9, 26-31.
Lima, S.F., Bicalho, M.L.S., & Bicalho, R.C. (2018). Evaluation of milk sample fractions for characterization of milk microbiota from healthy and clinical mastitis cows. PloS one, 13 (3), 0193671. https://doi.org/10.1371/journal.pone.0193671.
Li, N., Richoux, R., Boutinaud, M., Martin, P., & Gagnaire, V. (2014). Role of somatic cells on dairy processes and products: a review. Dairy science & technology, 94, 517-538.
Mirara, A., & Maitho, T. (2013). Monitoring rainfall data to estimate milk production in Mweiga location, Nyeri County, Kenya. Livest. Res. Rural Dev, 25, 1-8.
Moosavi, M., Mirzaei, A., Ghavami, M., & Tamadon, A. (2014). Relationship between season, lactation number and incidence of clinical mastitis in different stages of lactation in a Holstein dairy farm. In Proceedings of Veterinary research forum, 13.
Morse, D., DeLorenzo, M.A., Wilcox, C.J., Collier, R.J., Natzke, R.P., & Bray, D.R. (1988). Climatic effects on occurrence of clinical mastitis. Journal of dairy science, 71 (3), 848-853. https://doi.org/10.3168/jds.S0022-0302(88)79626-5.
Msechu, J.K., Mgheni, M., & Syrstad, O. (1995). Influence of various climatic factors on milk production in cattle in Tanzania. Tropical animal health and production, 27, 121-126. https://doi.org/10.1007/bf02236324.
Nardone, A., Ronchi, B., Lacetera, N, Ranieri, .M. S. & Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. Livest. Sci., 130, 57–69.
National Research Council, N.R.C. (2001).

Nutrient requirements of dairy cattle. Subcommittee on Dairy Cattle Nutrition. Publ. Natl. Acad. Press, Washington, DC.

Nasr, M.A., & El-Tarabany, M.S. (2017). Impact of three THI levels on somatic cell count, milk yield and composition of multiparous Holstein cows in a subtropical region. Journal of thermal biology, 64, 73-77. https://doi.org/10.1016/j.jtherbio.2017.01.004.

Olde Riekerink, R.G., Barkema, H.W., & Stryhn, H. (2007). The effect of season on somatic cell count and the incidence of clinical mastitis. Journal of dairy science, 90 (4), 1704-1715. https://doi.org/10.3168/jds.2006-567.

Oudah, E. (2009). Non-genetic factors affecting somatic cell count, milk urea content, test-day milk yield and milk protein percent in dairy cattle of the Czech Republic using individual test-day records. Livest. Res. Rural Dev., 21, 1-25.

Patel, Y.G., & Trivedi, M.M. (2018). Effect of stage of lactation and parity on occurrence of subclinical mastitis. International Journal of Science, Environment and Technology, 7(1), 250 – 253.

Radostits, O.M., Gay, C.C., Hinchcliff, K.W., & Constable, P.D. (2006). Veterinary Medicine E-Book: A textbook of the diseases of cattle, horses, sheep, pigs and goats; Elsevier Health Sciences.

Ravagnolo, O., Misztal, I., & Hoogenboom, G. (2000). Genetic component of heat stress in dairy cattle, development of heat index function. Journal of Dairy Science, 83, 2120–2125.

Renna, M., Lussiana, C., Malfatto, V., Mimosi, A., & Battaglini, L. M. (2010). Effect of exposure to heat stress conditions on milk yield and quality of dairy cows grazing on Alpine pasture. In Proceedings of 9th European IFSA Symposium (pp. 1338–1348). Vienna, Austria

Roche, J.R., Friggens, N.C., Kay, J.K., Fisher, M.W., Stafford, K.J., & Berry, D.P. (2009). Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. Journal of dairy science, 92, 5769-5801. https://doi.org/10.3168/jds.2009-2431.

Ruegg, P.L., & Milton, R.L. (1995). Body condition scores of Holstein cows on Prince Edward Island, Canada: relationships with yield, reproductive performance, and disease. Journal of dairy science, 78, 552-564. https://doi.org/10.3168/jds.S0022-0302(95)76666-8.

Rust, J., & Rust, T. (2013). Climate change and livestock production: A review with emphasis on Africa. South African Journal of Animal Science **2013**, 43, 255-267.

SAS (2000) User's Guide: Statistics, Version 8.1 Edition. SAS Inst. Inc., Cary, NC.

Sinha, R., Sinha, B., Kumari, R., Vineeth, M.R., Verma, A., & Gupta, I. D. (2021). Effect of season, stage of lactation, parity and level of milk production on incidence of clinical mastitis in Karan Fries and Sahiwal cows, Biological Rhythm Research, 52:4, 593-602. https://doi.org/ 10.1080/09291016.2019.1621064

Shuster, D.E., Harmon, R.J., Jackson, J.A., & Hemken, R.W. (1991). Suppression of milk production during endotoxin-induced mastitis. Journal of dairy science, 74, 3763-3774. https://doi.org/10.3168/jds.S0022-0302(91)78568-8.

Smith, D.L., Smith, T., Rude, B., & Ward, S. (2013). Comparison of the effects of heat stress on milk and component yields and somatic cell score in Holstein and Jersey cows. Journal of dairy science, 96, 3028-3033.

Steeneveld, W., Hogeveen, H., Barkema, H.W., van den Broek, J., & Huirne, R.B. (2008). The influence of cow factors on the incidence of clinical mastitis in dairy cows. Journal of dairy science, 91, 1391-1402. https://doi.org/10.3168/jds.2007-0705.

Suriyasathaporn, W., Schukken, Y.H., Nielen, M., & Brand, A. (2000). Low somatic cell count: a risk factor for subsequent clinical mastitis in a dairy herd. Journal of dairy science, 83, 1248-1255. https://doi.org/10.3168/jds.S0022-0302(00)74991-5.

Szyda, J., Mielczarek, M., Frąszczak, M., Minozzi, G., Williams, J., & Wojdak-Maksymiec, K. (2019). The genetic background of clinical mastitis in Holstein-Friesian cattle. Animal, 13(10), 2156-2163. https://doi.org/10.1017/S1751731119000338

Teleb, D., Hafasa, F., El-Baz, A., & El-Sherbieny, M. ( 2014). Relationship between somatic cell count and udder health in Damascus goats. Egyptian Journal of Sheep and Goat Sciences, 9, 31-42.

Tančin, V., Ipema, A. H., HOGEWERF, P. (2007). Interaction of somatic cell count and quarter milk flow patterns. J. Dairy Sci., 90, 2223- 2228.

Tamami, F. Z., Hafezian, H. , Mianji G.R. , Abdullahpour R. , & Gholizadeh, M. (2018). Effect of the temperature-humidity index and lactation stage on milk production traits and somatic cell score of dairy cows in Iran. Songklanakarin J. Sci. Technol., 40 (2), 379-383.

West, J., Mullinix, B., & Bernard, J. (2003). Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. Journal of dairy science, 86, 232-242.

Yang, L., Yang, Q., Yi, M., Pang, Z., & Xiong, B. (2013). Effects of seasonal change and parity on raw milk composition and related indices in Chinese Holstein cows in northern China. Journal of dairy science, 96, 6863-6869.