



# Relationship between Temperature-humidity Index and Milk Production of Dairy Cows in Tropical Climate

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10.18805/ajdfr.DR-213

## ABSTRACT

**Background:** Dairy cattle in many tropical, subtropical and semi-arid regions are subject to high ambient temperature and relative humidity for extended periods of time. This compromises the ability of the lactating cows to dissipate heat, resulting in heat stress and decreasing milk production. The objective of this study was to evaluate the effect of the temperature-humidity index (THI) on milk production in cows in the study area.

**Methods:** Data on monthly milk production (2017 to 2019) was collected from the Department of Animal Production and Health, Batticaloa District, Sri Lanka and the monthly weather data (2017 to 2019) required for the study was collected from the Meteorological Observatory Station in Batticaloa, Sri Lanka. SPSS version 26 was used to analyze interaction between milk production and weather parameters. The monthly THI values were determined for each year.

**Result:** Statistically significant negative relationship ( $p < 0.05$ ) was found between milk production and THI in 2017, 2018 and from 2017 to 2019 except 2019 due to the sudden death of cattle in Batticaloa district. Results of all three years indicated that milk production decreases as THI increases. It is concluded that the milk yield of cows is influenced significantly by heat stress during the dry season from April to August between 2017 and 2019, proper management strategies could be helpful to minimize heat stress to attain optimal performance of dairy cows.

**Key words:** Climate change, Dairy cattle, Heat stress, Milk production, Relative humidity, Temperature.

## INTRODUCTION

Heat stress is one of the most significant variables to be addressed in rearing livestock in tropical regions. In Sri Lanka, dairy farming is still a rural livelihood activity, mostly in small-scale operations for food and an extra source of income that can act as a cushion for income shocks from crop failure. The contribution of the livestock sector to overall GDP is currently about 1 per cent. Almost, the dairy cattle farms in Batticaloa district are practicing extensive cattle management systems with local cattle breeds. The cattle population in Batticaloa district of Sri Lanka was 9.56% of the country where as the milk production was recorded only 2.13% (DAPH, 2019). Several environmental factors such as temperature, relative humidity, solar radiation, air circulation, and precipitation are responsible for heat stress. The most recent animal heat stress studies have focused predominantly on temperature and relative humidity (Igono *et al.*, 1985; Igono and Johnson, 1990; Ravagnolo and Misztal, 2000; Bouraoui *et al.*, 2002).

The severity of stress increases as high temperatures is associated with increased relative humidity (Armstrong, 1994). A widely used bioclimatic index is the temperature-humidity index (Hahn *et al.*, 2003). The temperature-humidity index (THI) is an indicator to assess the level of stress caused by high ambient temperature and humidity, and THI values are examined to determine whether animals are in the comfort or stress zones (Bohmanova *et al.*, 2007). The production of dairy cattle in Sri Lanka has not reached its maximum levels. Thus, to supply the demand of the human

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**How to cite this article:** Narmilan, A., Puvanitha, N., Ahamed, A.S. and Senthirakumar, S. (2021). Relationship between Temperature-humidity Index and Milk Production of Dairy Cows in Tropical Climate. Asian Journal of Dairy and Food Research. 40(3): 246-252. DOI: 10.18805/ajdfr.DR-213.

**Submitted:** 05-12-2020 **Accepted:** 08-05-2021 **Online:** 11-06-2021

population, the country still relies on imports of dairy products importing 98,837.6 metric tons of milk and milk products in 2019. Furthermore, the global climate is changing and it is manifesting itself through various kinds of environmental changes. Extreme droughts, high ambient temperatures, heat waves, floods and freak storms occurred across the globe and affected agriculture and productivity of livestock systems, especially in tropical areas. Therefore, the primary objective of this study was to calculate the Temperature Humidity Index (THI) values for Batticaloa district, Eastern Province, of Sri Lanka using the available meteorological data for the past three years and to determine the impact of THI on milk production in dairy cows.

## MATERIALS AND METHODS

### Study area

The study was carried out in Batticaloa district in the Eastern Province of Sri Lanka belongs to the dry zone (Fig 1). The average annual maximum and minimum temperatures were respectively  $31.7 \pm 2.2$  and  $25.6^\circ\text{C} \pm 1.0$  and the annual rainfall was approximately  $< 1750$  mm. The climate of the study area covers the wet season (Maha season) from September to March with high North-East monsoon and 2<sup>nd</sup> inter monsoon precipitations, the dry season (Yala Season) from April to August with low South-West monsoon and 1<sup>st</sup> inter monsoon precipitations (Meteorological Department, Batticaloa, 2019).

### THI and ambient temperature

Temperature humidity index (THI) is an indicator of heat stress. It can be used to estimate the cooling requirements for dairy cattle to improve productivity and efficiency of management strategies (Zimbelman, 2008). The temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity, associated with the level of thermal stress (Bohmanova *et al.*, 2007). This index is widely used in hot areas all over the world to assess the effect of heat stress on dairy cows (Brown-Brandl *et al.*, 2003). Indeed, the heat stress is related to decreased milk production and an altered composition (Gantner *et al.*, 2011). Also, a cow's health has the biggest impact on the quality of the milk it produces. Just like humans, cows can catch illnesses such as a cold or flu. They're also susceptible to irritation or inflammation of their udders if stall conditions are poor.

### Feeding practices

The farmers in the study area were rearing the local cattle breeds and crossbreeds in their herds. The animals were managed extensive system, by feeding on communal grazing lands during the day time and brought back home in the evening and kept in a paddock near the farmers' dwellings. The usual grazing lands were catchment areas of the village tank beds, shrub jungle, paddy fields after the harvest and rangelands. In many situations, the animals were named to walk faraway places in search of grazing lands.

### Data collection

Data on monthly milk production (2017 to 2019) was collected from the Department of Animal Production and Health,

Batticaloa District, Sri Lanka and the monthly weather data (2017 to 2019) required for the study was collected from the Meteorological Observatory Station in Batticaloa, Sri Lanka.

### Data analysis

SPSS version 26 was used to analyze interaction between milk production and weather parameters. The monthly THI values were determined for each year. For the THI estimation, the following equation of Bernabucci *et al.*, 2014 was used:

$$\text{THI} = (1.8 \times \text{AT} + 32) - (0.55 - 0.55 \times \text{RH}) \times [(1.8 \times \text{AT} + 32) - 58]$$

Where,

THI= Temperature humidity index.

AT = Ambient temperature ( $^\circ\text{C}$ ).

RH = Relative humidity (%).

$(1.8 \times \text{AT} + 32)$  = Accounts for the conversion of temperature data from degrees celsius to degrees Fahrenheit and the correlation between milk production.

## RESULTS AND DISCUSSION

### Weather conditions during the experimental period

The higher average air temperature was recorded in the dry season (from April to August) at  $30.1^\circ\text{C}$ ,  $29.9^\circ\text{C}$  and  $30.3^\circ\text{C}$  in 2017, 2018 and 2019, respectively. However, the lower relative humidity was found in the dry season in 2017, 2018 and 2019, which was 74.8%, 75.3% and 74.6% respectively (Table 1). The average highest temperature was found for June indicating higher heat stress on dairy cows between 2017 and 2019 followed by July, August, and the lowest in January (Fig 2). The average highest relative humidity was recorded in November followed by December, October and no significant variation was observed from January to May between 2017 and 2019. Furthermore, the highest relative humidity was found in November indicating higher heat stress on dairy cows during this month followed by July, August and the lowest in January between 2017 and 2019 (Fig 2). Broucek *et al.* (2009) and St. Pierre *et al.* (2003) stated that a higher temperature may reduce milk production and adversely affect the fertility of cows. Furthermore, high temperatures coupled with high relative humidity make this process difficult and the cow's body temperature increased (Allen *et al.* 2015). This may result in impaired thermoregulation

**Table 1:** Climatic conditions during the experimental periods.

Parameters	Periods					
	Wet season (Maha)			Dry season (Yala)		
	2017	2018	2019	2017	2018	2019
Minimum temperature ( $^\circ\text{C}$ )	$24.5 \pm 0.3$	$24.5 \pm 0.3$	$24.8 \pm 0.2$	$26.3 \pm 0.2$	$26.0 \pm 0.1$	$26.6 \pm 0.2$
Maximum temperature ( $^\circ\text{C}$ )	$30.1 \pm 0.6$	$29.9 \pm 0.5$	$30.2 \pm 0.5$	$33.8 \pm 0.4$	$33.7 \pm 0.5$	$34.0 \pm 0.3$
Average temperature	$27.3 \pm 0.4$	$27.2 \pm 0.4$	$27.5 \pm 0.3$	$30.1 \pm 0.2$	$29.9 \pm 0.3$	$30.3 \pm 0.2$
Minimum RH (%)	$76.7 \pm 1.4$	$78.0 \pm 1.6$	$79.4 \pm 1.4$	$67.4 \pm 1.5$	$67.6 \pm 2.9$	$67.8 \pm 1.5$
Maximum RH (%)	$87.4 \pm 1.3$	$87.7 \pm 1.3$	$88.4 \pm 1.1$	$82.2 \pm 1.5$	$83.0 \pm 2.5$	$81.8 \pm 1.2$
Average RH (%)	$82.1 \pm 1.2$	$82.9 \pm 1.4$	$83.9 \pm 1.1$	$74.8 \pm 1.3$	$75.3 \pm 2.7$	$74.6 \pm 1.3$

and heat stress (Rhoads *et al.* 1992). Therefore, temperature and relative humidity are the very critical factor which determines the milk production.

### THI pattern in Batticaloa district in Sri Lanka

THI value for every month in 2017, 2018, and 2019 are presented in (Table 2) while Fig 3 shows the differences between THI in both seasons (Wet and Dry) between 2017 and 2019. THI values in all years were increased gradually from January to June and decreased from July to December between 2017 and 2019. No significant difference in mean THI was estimated (80.2, 80.0 and 80.7 in 2017, 2018, and 2019, respectively) during the experimental period. The highest THI value (83.2) was recorded in June 2019 while the lowest (76.1) in January 2017 and 2018. Overall, the highest THI was recorded in May, June and July in all three years and higher THI was estimated in the dry season compared with the wet season in Batticaloa district.

Kadzere *et al.* (2002) concluded that THI <70 points to the lack of heat stress, THI values of 75-78 point to heat stress and THI >78 means a serious threat to cow welfare. Most commonly, it is assumed that heat stress occurs when THI values exceed 72 since milk production begins to decrease (Akyuz *et al.* 2010). According to the findings of similar studies, the THI value was high from 2017 to 2019 in

the study period. Therefore, it will lead to an increase in the heat stress of cows in the study area. Ultimately it affects the milk production in Batticaloa district. Hence, livestock farmers have to take mitigation techniques to overcome this issue, especially during the dry season.

### Milk production (2017-2019) in Batticaloa district, Sri Lanka

The highest annual milk production was recorded in 2017 while the lowest was in 2019 in the study area (Fig 4). Milk production in all years decreased from January to July and increased gradually from August to December from 2017 to 2019. However, the results indicated that milk production decreased suddenly from April to June in 2017 and 2018 in Batticaloa district. The average highest milk yield (1.2 Million liters) was recorded in January 2017 and the lowest (0.1 million liters) was in July 2019. Even though, similar milk production trend was found in all three years.

Cattle farmers, all over the world are facing the problem of heat stress in dairy cattle. Air velocity and intensity of solar radiation, particularly in unshaded areas of a barn, coupled with the temperature and relative humidity, increase the effect of heat stress (Angrecka and Herbut, 2016). Suitable temperature, humidity conditions, ventilation and ammonia concentration are particularly important as they affect the cows' rest conditions, their behavior, hormonal and metabolic changes and milk production (Herbut *et al.* 2015). The milk yield of cows may also be further improved by providing shade to the cows in the pre milking area of the milking facility (Wildridge *et al.*, 2017). Hot weather conditions are associated with reductions in dairy cows feed intake and milk yield (Garner *et al.*, 2017).

The trend of milk production suddenly declined in 2019 especially in the mid of the year due to climate change of trough compared with the rest of the years of the months in this area. Cattle affected by heat stress showed a reduction in feed intake and milk yield and shift metabolism, resulting in reduced their milk production efficiency (Dahl *et al.*, 2016). Moreover, another important reason for the lowest production might be the death of animals due to various factors such as climate changes, poor management practices, lack of

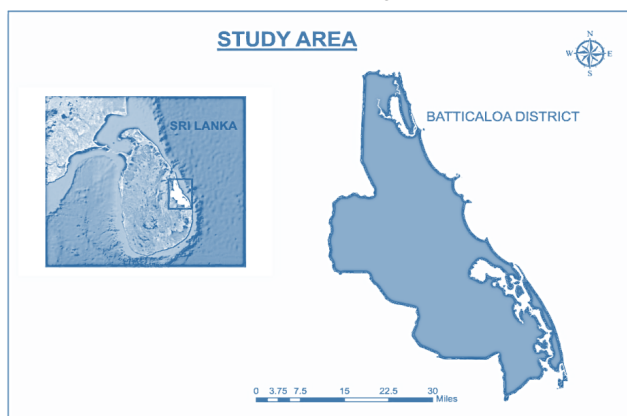


Fig 1: Study area : Batticaloa district in the Eastern Province of Sri Lanka.

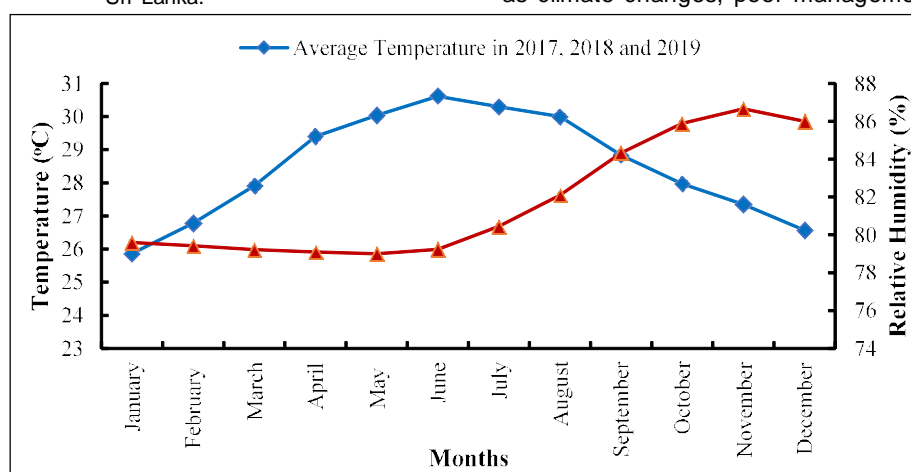


Fig 2: Air temperature and relative humidity from 2017 to 2019.

pasture and fodders and so on. Most probably the temperate climates with milder seasons put less stress on cows than climates with more extreme weather. Geography is closely tied to weather climate and farmer management. For example, the large number of the cattle population is extensively raising with the ineffective environment such a parcel land, water, vaccine and other facilities during this period (Santhirakumar and Narmilan, 2020). When cows do not have comfortable places to rest, space to graze, and farmers' malpractices resulted in decreased quality and quantity of milk.

#### Interaction between THI and milk production

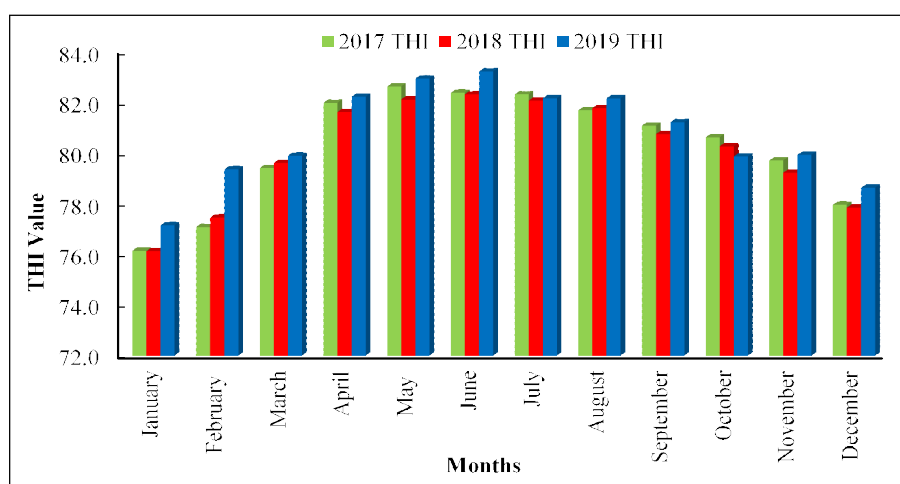
A significantly negative relationship ( $p < 0.05$ ) was observed between milk production and THI in 2017, 2018 and from

2017 to 2019 except 2019 due to the sudden death of cattle in Batticaloa district (Fig 5). The highest correlation ( $-0.899^{**}$ ) was estimated between milk production and THI in 2018 (Table 3). No statistically significant relationship was found in 2019 due to several other reasons which are mentioned under milk production.

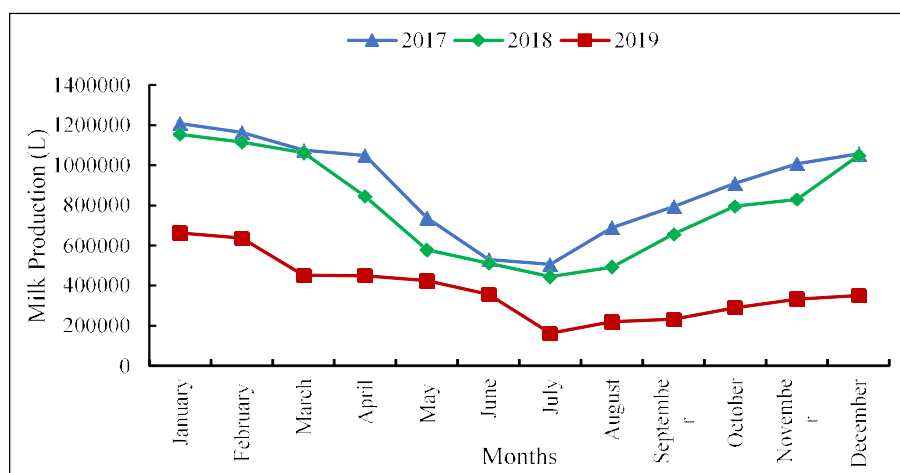
Also, a cow's health has the biggest impact on the quality of the milk it produces. Just like humans, cows can catch illnesses such as a cold or flu. They're also susceptible to irritation or inflammation of their udders if stall conditions are poor. Exposure to mud, manure and runoff can expose the herd to more pathogens, increasing incidents of infection in the Batticaloa district in 2019, therefore, increasing THI value decreased Milk production in the experimental area during this period.

**Table 2:** Seasonal differences of THI.

Year	THI					
	High	Low	Mean $\pm$ SE	SD	Wet season	Dry season
2017	83.0	76.0	80.2 $\pm$ 0.6	2.2	79.0 $\pm$ 0.7	82.0 $\pm$ 0.2
2018	82.0	76.0	80.0 $\pm$ 0.6	2.1	79.0 $\pm$ 0.6	82.0 $\pm$ 0.5
2019	83.0	77.0	80.7 $\pm$ 0.5	1.9	79.0 $\pm$ 0.5	83.0 $\pm$ 0.2



**Fig 3:** THI value from 2017 to 2019 in the study area.



**Fig 4:** Milk production from 2017 to 2019 in study area.

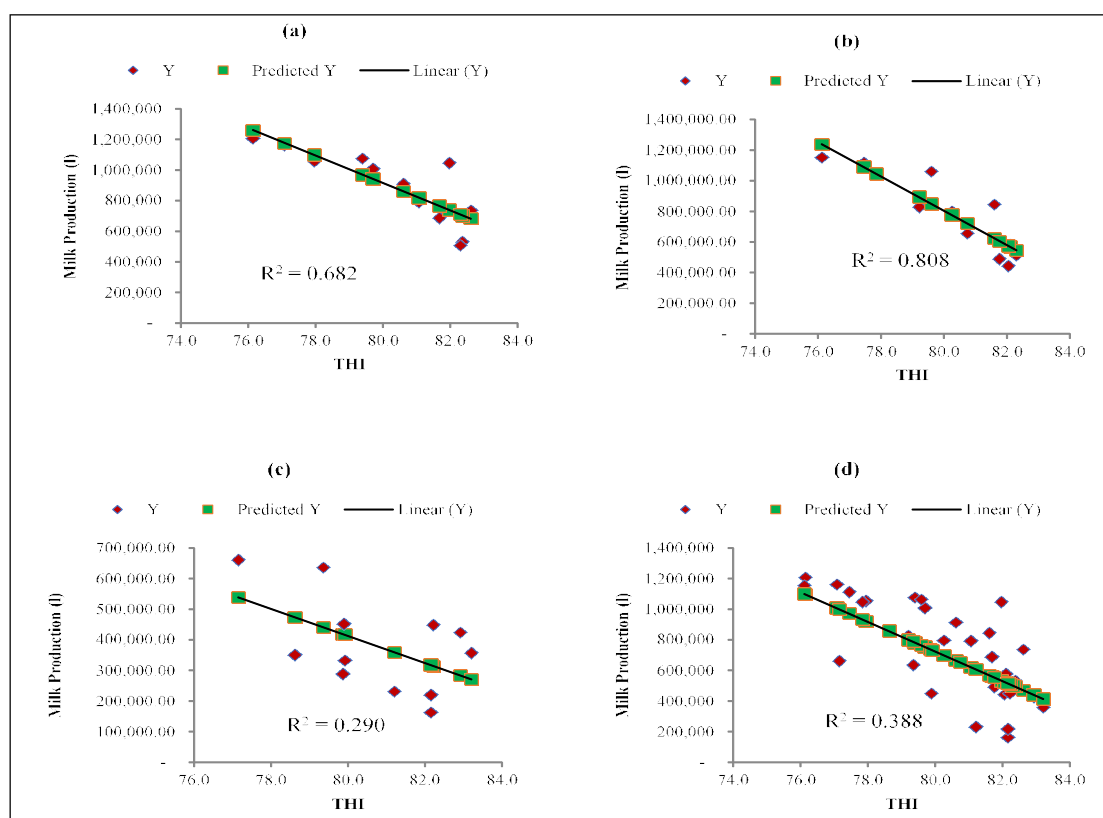


Fig 5: Interaction between THI and milk production - (a): 2017, (b): 2018 and (c): 2019.

Table 3: Correlation between THI and milk production.

	Items	2017	2018	2019	2017-2019
Mean	THI	80.25	80.08	80.70	80.34
	Milk production (l)	893986.17	794834.67	380834.5	689885.1
S.D	THI	2.20	2.09	1.87	2.02
	Milk production (l)	238830.93	258105.41	154936.06	311792.47
Correlations	Pearson correlation	- 0.826**	- 0.899**	- 0.538	- 0.623**
	Sig. (2-tailed)	0.001	0.000	0.071	0.000

Correlation is significant at the 0.05 \*\*. level (2-tailed).

### Regression model between THI and milk production

The highest temperature was recorded for June indicating the highest heat stress on dairy cows and the highest relative humidity was recorded in November from 2017 to 2019. There was no significant difference in mean THI (80.2, 80.0, and 80.7 in 2017, 2018 and 2019, respectively) during the experimental period. Overall, the highest THI values were recorded in May, June and July in all three years (Fig 6 and Table 4). The highest milk yield (1.2 million liters) was recorded in January 2017 and the lowest (0.1 million liters) was in July 2019. Though, similar milk production trend was found throughout all three years. A negative significant relationship ( $p < 0.05$ ) was observed between milk production and THI in 2017, 2018 and from 2017 to 2019 except 2019 due to sudden death of cattle in Batticaloa district. Therefore, increased THI value decreased milk production in the

experimental area during this period. The negative slope of the regression line in all three years indicated that milk production decreased as THI increased. The value of this relationship for predictive purposes is relatively high, as depicted by an  $R^2$  value of 0.808 in 2018 and the lowest (0.290) in 2019. Tousova *et al.* (2017) mentioned that to cool their bodies, cows increased their respiration rates and consumed less feed during hot weather, which in turn caused a decline in milk production. During hot weather, cows were often less active (West *et al.*, 2003) as their body temperature increased in response to locomotion (Schutz *et al.*, 2011). Cows suffered from heat stress, if the mean daily THI exceeds 68 when the minimum daily THI is greater than 65 or both (Carter *et al.*, 2011).

Heat stress caused economic losses because it decreased milk yield and growth performance in both dairy



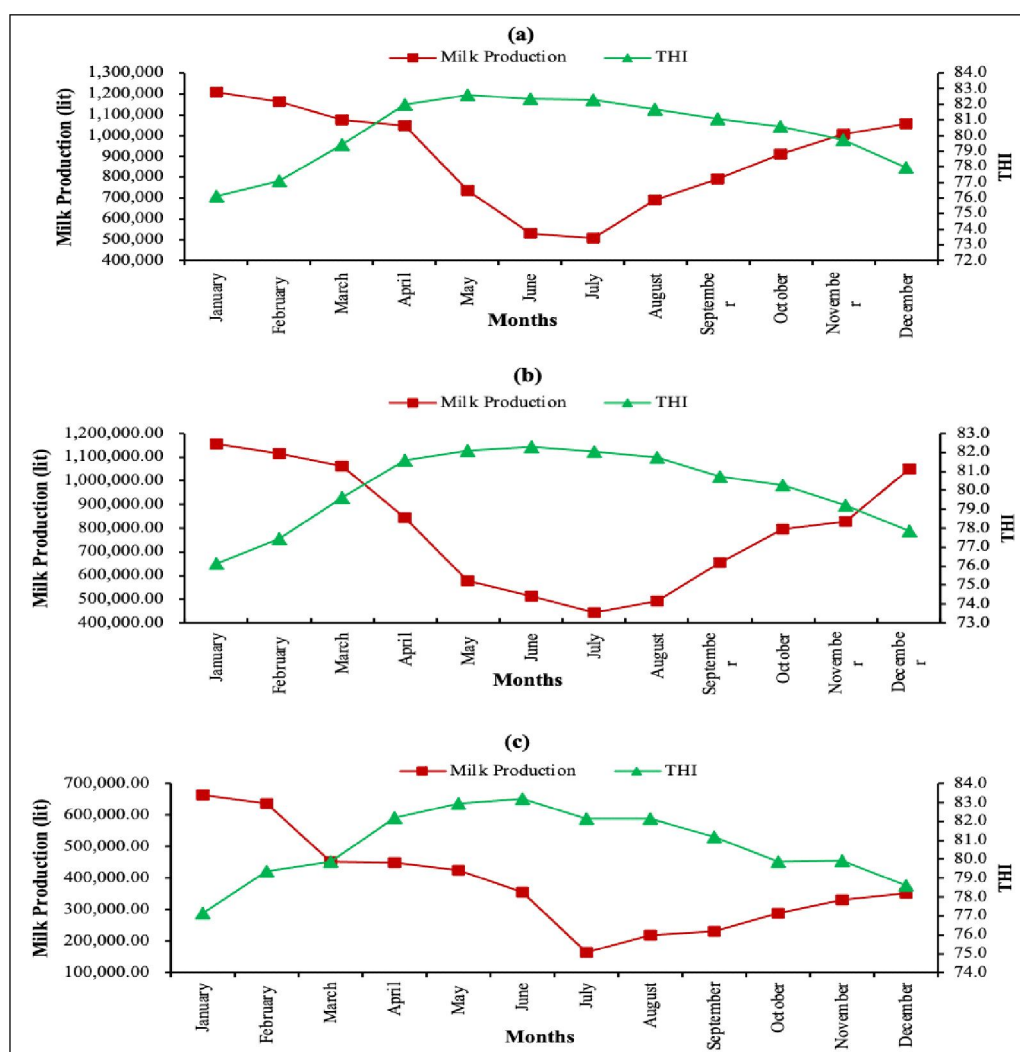


Fig 6: Regression analysis between THI and milk production - (a): 2017, (b): 2018, (c): 2019 and (d): 2017 - 2019.

**Table 4:** Regression model summary between THI and milk production from 2017 to 2019.

Period	R	R Square	Adjusted R Square
2017	0.826	0.682	0.650
2018	0.899	0.808	0.789
2019	0.538	0.290	0.218
2017-2019	0.623	0.388	0.369

and beef cattle (St-Pierre, 2003). Therefore, farmers are advised to focus on the heat stress of cows to increase milk production in the study area.

## CONCLUSION

It is concluded that the milk yield of cows was influenced significantly by heat stress during the dry season from April to August from 2017 to 2019. Therefore, the farmers are advised to focus on proper management strategies which could be helpful to minimize heat stress to attain optimal milk production of dairy cows.

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