

RESPONSE OF TOMATO TO ELEVATED DAY AND NIGHT TEMPERATURE UNDER CONTROLLED STRESS CONDITIONS

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ABSTRACT

Climate change-induced temperature rise pose a significant threat to Tomato (*Solanum lycopersicum* L.) production by affecting plant growth, physiology, and reproductive development. A pot culture experiment was conducted at the Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, to assess the effects of Day stress, Night stress, and combined day and night stress (complete stress) across three transplanting windows (D₁ - 6 December, D₂ - 23 December, and D₃ - 6 January). The highest Leaf Area Index (3.25) occurred in the first transplanting under control at 45 days, while the lowest (1.23) occurred in the third transplanting under complete stress at 15 Days after transplanting (DAT). Photosynthetic rate declined from 18.5 to 12.7 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$, whereas proline increased from 178.9 to 469.9 $\mu\text{mol g}^{-1}$ under control and complete stress, respectively. Fertility coefficient decreased from 88% to 63%. Flowers and fruits declined from 32 to 21 and 28 to 15 plant⁻¹, respectively, in the first transplanting, with the lowest values (16 flowers and 10 fruits plant⁻¹) under complete stress in the third transplanting. Fruit yield declined from 2.5 kg plant⁻¹ under control to 0.8 kg plant⁻¹ under complete stress. The delayed transplanting window exacerbated negative consequences of heat stress. Complete stress significantly reduced tomato growth, physiology, and productivity, while an early transplanting window on 6th December (D₁), which falls under the 49th Standard Meteorological Week, emerged as a potential adaptation strategy to minimise heat-stress impacts under changing climatic conditions.

KEYWORDS: Diurnal Temperature Variation; Fruit Set; Proline; Tomato; Temperature Stress; Yield

INTRODUCTION

The global average temperature in 2025 was 1.19°C (2.14°F) above the 1951-1980 average, highlighting the continued warming of the Earth's climate system (1). One of the main abiotic factors limiting plant development and agricultural output is high temperatures (2). It can affect several crops, particularly in the flowering and grain-filling stages. Higher temperatures can shorten the growing season, stunt crop growth, and ultimately reduce total yield. Excessive heat can even cause crop failure in some regions. Intergovernmental Panel on Climate Change (IPCC) issues new estimates of the likelihood of exceeding the 1.5 °C or 2 °C global warming threshold in the upcoming decades unless immediate, rapid, and large-scale reductions in greenhouse gas emissions are implemented (3).

Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crop after potatoes. They are rich in essential nutrients and bioactive compounds, including lycopene, vitamin C, potassium, iron, folate, phenolic compounds (such as flavonoids and chlorogenic acid), and antioxidants like beta-carotene (4).

Tomatoes are a day-neutral plant and grow quickly, with a growing period of 90 to 150 days. However, yield is negatively affected by greater variation between daytime and nighttime temperatures. Yield declines when temperatures exceed 25°C, especially with high humidity and strong winds. Tomato plants employ a variety of adaptive strategies, including physiological, morphological, anatomical, and biochemical modifications, to mitigate the adverse effects of high temperatures (5). High temperatures will have a significant impact on several processes that reduce fruit yield, including seed germination, plant growth and development, morphology, physiology, and biochemistry (6).

Excessive temperature when compared to the optimum throughout the day or at night is thought to be the main factor restricting plant growth (7). Long-term exposure to temperatures over this range will more frequently and severely limit tomato growth and production (8). During cultivation, tomato plants often experience temperature fluctuations, and heat stress substantially affects fertilisation and reproduction, leading to crop failure and reduced fruit yield and quality (9). Several studies have examined the effects of heat stress on tomatoes, but little is known about the relative impacts of daytime and nighttime heat stress and their combined effects under different transplanting dates. It is essential to understand their interactions to develop climate-resilient production strategies. The current study assesses the effects of day and night heat stress and complete stress on the growth, physiological traits, fruit set, and yield in tomato.

MATERIALS AND METHODS

Study area

The experiment was carried out at the Agro Climate Research Centre (ACRC), Tamil Nadu Agricultural University (TNAU), Coimbatore (Fig. 1) Tamil Nadu is situated at latitude 11.0°N and longitude 77°E at an elevation of 427 meters above mean sea level.

Crop

Tomato hybrid 'Shivam', with a duration of 120 days, was used for the study. Healthy seedlings were raised for 25 days in nursery trays and transplanted under the respective transplanting windows. Fruit harvesting commenced at 55 days after transplanting and was carried out at weekly intervals. Therefore, weather interaction with crop performance was assessed for the first four to five pickings, which represent the economically important harvest period for farmers.

Experimental Design and Treatments

The experiment was conducted using a Factorial Completely Randomised Design (FCRD) with three transplanting windows, four temperature treatments, and three replications. For each treatment, three pots were maintained under both ambient and stress conditions. The primary objective of the study is to compare crop responses in the open environment and in a controlled environment, where the temperature was artificially elevated by 2°C above ambient levels, to assess the impact of heat stress during sensitive crop growth stages. Importantly, the study does not treat two separate climate control chambers as "control" and "treatment"; rather, the comparison is between ambient conditions and controlled elevated-temperature conditions.

Date of transplanting

Date of transplanting 1 (D₁): 6 December – 49th Standard Meteorological Week (SMW)

Date of transplanting 2 (D₂): 23 December- 51st SMW

Date of transplanting 3 (D₃): 6 January- 1st SMW

Heat Stress Imposition

The heat stress imposition details are given in Table 1. The heat stress treatments were applied during the reproductive phase, specifically from flowering to the fruit-setting stage, which is considered the most susceptible stages to temperature. The heat stress was imposed only on the crops by exposing them to +2°C above the ambient temperature during daytime (6 am to 5 pm) and nighttime (5 pm to 6 am), and one set of pots were kept completely under heat stress throughout the crop period in the Climate Control Chamber. The control plants were kept in the ambient environment. Automated sensors placed inside the Climate Control Chamber (CCC) were used to continuously measure the temperature conditions during the stress period.

Details of Climate Control Chamber

A pot culture experiment was conducted in the Climate Control Chamber (CCC) at the Agro Climate Research Centre, TNAU. The chamber measured 7 m × 2.4 m × 2.4 m and was covered with polycarbonate sheets to maintain elevated temperature inside the chamber. Sensors installed inside and outside the chamber continuously recorded temperature at 10-minute intervals. Three foggers with four nozzles, controlled by threshold temperature, were used for stress imposition, while a fan regulated airflow. The system operated continuously, with temperature stress maintained during daytime using the pad-and-fan system (Fig. 2).

Observations

The following parameters were measured:

1. Growth Parameters

Leaf Area Index (LAI)

Leaf Area Index (LAI) Growth observations were recorded at 15, 30, and 45 Days After Transplanting (DAT). The ratio of leaf to ground area is known as the LAI. The third leaf from the top was measured for leaf length and breadth in the same tagged plants. In the same sampling plants, the number of leaves was counted, and the leaf area index was determined using the formula below, as given by (10),

$$LAI = \frac{(L \times W \times K \times \text{Number of leaves per plant})}{(\text{Land area occupied by the plant (cm}^2\text{)})} \quad \text{Eqn. 1}$$

Where,

L – Length of the third leaf from the top (cm),

B – Breadth of the third leaf from the top (cm), and

K – Constant (Constant is estimated using the proportion of the area of the leaf (sq. cm) calculated by the graphical (actual) method and using the Leaf Area Meter (exact area).

Leaf Area Meter (LAM): The third fully open leaf from the top of the tagged plant is freshly collected, and the area is estimated using the Leaf Area Meter (LAM). Graphical Method: The exact outline of the same leaf is imprinted on a graph sheet, and the area is calculated from the graph in square centimetres.

$$K = \frac{\text{Actual Leaf Area}}{\text{Calculated Leaf Area (L} \times \text{B)}} \quad \text{Eqn. 2}$$

2. Physiological Parameters

Photosynthetic Rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)

Three plant samples at 15, 30 and 45 DAT were recorded for the photosynthetic rate (P_n ; $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), using the Portable Photosynthetic System (PPS). The measurements were taken between 9:00 am and 11:00 am. The fully exposed leaf (third from the top) was inserted into the leaf chamber (3.0 cm^2) once the steady state was established inside the measurement chamber, and then the readings were taken. The time required for measuring each sample was approximately 15 minutes.

Proline Content ($\mu\text{mol g}^{-1}$ fresh weight)

The proline content is estimated from three plant samples collected from heat-stressed plants at 15, 30 and 45 days. The plant sample of 1 g was homogenised in 10 mL of 3% aqueous sulphosalicylic acid and centrifuged for 10 minutes at 3000 rpm. 2mL of glacial acetic acid and 2 mL of acid ninhydrin reagent were added to the supernatant. The solution was incubated in boiling water for 1 hr, and the reaction was terminated by immersing it in an ice bath for 10 minutes. The mixture was transferred to a separating funnel. The reaction mixture was then added to 4 mL of toluene and rapidly agitated for 20- 30 seconds. The toluene layer was obtained. The intensity of red colour was quantified in a spectrophotometer at 520 nm.

3. Reproductive Parameters

Fertility Coefficient

Fertility coefficient in tomato is calculated by dividing the number of fruits successfully formed by the total number of flowers produced on a plant or flower cluster and multiplying the result by 100.

Number of flowers per plant

The number of flowers produced per plant was recorded at the flowering stage by counting all fully opened flowers on each tagged plant. Observations were recorded for each heat-stress treatment and expressed as the number of flowers per plant (Nos. plant⁻¹).

Number of fruits per plant

The number of fruits per plant was recorded by counting all fully developed fruits on each tagged plant at the fruiting stage. The observations were recorded for each heat-stress treatment and expressed as number of fruits per plant (Nos. plant⁻¹).

4. Yield Parameters

Fruits were harvested at physiological maturity, and total fruit yield per plant (kg plant^{-1}) was recorded. For the study, yield observations were recorded from the plants under each treatment, and the mean yield value was calculated for statistical analysis.

5. Growing Degree Days

Growing Degree Days (GDD) were calculated using the mean temperature method as $\text{GDD} = \sum \left[\frac{(T_{\text{max}} + T_{\text{min}})}{2} - T_{\text{base}} \right]$, where T_{max} and T_{min} are the daily maximum and minimum temperatures ($^{\circ}\text{C}$), respectively, and T_{base} is the crop-specific base temperature (10°C for tomato). The Shivam tomato variety, a popular semi-determinate F1 hybrid, performs well under optimal daytime temperatures ranging from 20°C to 27°C and night time temperatures between 15°C and 20°C .

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Statistical Analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Completely Randomized Design. Treatment means were compared using the least significant difference (LSD) test at the 5% level of significance. Percentage reductions and increases over control were computed to assess the magnitude of heat stress effects on growth, physiological traits, reproductive performance, and yield of tomato.

RESULTS AND DISCUSSION

Effect of Heat Stress on Leaf Area Index (LAI)

Leaf Area Index (LAI) increased from 15 to 45 DAT under all treatments across the three transplanting dates. Control recorded the highest mean LAI (1.86, 2.43 and 3.13), while complete stress recorded the lowest mean values (1.42, 1.82 and 2.87) at 15, 30 and 45 DAT, respectively. The first (D1) recorded the highest LAI (1.79, 2.45 and 3.14) at the respective growth stages. DAT was non-significant at 15 DAT, whereas stress (S) and date of transplanting $\times$ stress ($D \times S$) showed significant differences with CD values of 0.39 and 0.67, respectively. At 30 days DAT, significant differences were observed for Date of Transplanting, stress, and $D \times S$, with CD values of 0.48, 0.55 and 0.95, respectively. Similarly, at 45 days after transplanting, Date of Transplanting, stress, and $D \times S$ recorded significant differences, with CD values of 0.56, 1.13 and 1.54, respectively (Table 2). The higher LAI under control and December 6 transplanting can be attributed to favourable temperatures for leaf initiation and expansion. Delayed transplanting and continuous heat stress likely restricted leaf expansion and photosynthetic activity, resulting in lower LAI. Overall,

delayed transplanting and complete heat stress adversely affected canopy development in tomato. The decline in leaf area under heat stress could be due to impaired cell division and expansion, increased transpiration loss, and reduced photosynthetic carbon assimilation, ultimately restricting leaf development. Similar reductions in vegetative growth under elevated temperature conditions have been reported by (11) and (12) that the agronomic characteristics of tomatoes, especially leaf area, were adversely affected by heat stress and heat shock. The present findings agree with (13), who reported that transplanting date significantly influenced growth parameters, including plant height and number of branches.

Effect of Heat Stress on Photosynthetic Rate ($\mu\text{mol CO}_2/\text{m}^2/\text{s}$)

Photosynthetic rate declined from 15 to 45 days after transplanting across the stress treatments. Control recorded the highest photosynthetic rate (18.20, 17.73 and 17.47 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), while complete stress recorded the lowest values (13.87, 13.34 and 14.63 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) at 15, 30 and 45 days after transplanting, respectively. The first Date of Transplanting recorded the highest mean photosynthetic rate (16.20, 15.68 and 15.30 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) at the respective stages. Significant differences were observed for Date of Transplanting and stress at all three stages, while $D \times S$ was non-significant at 15 and 30 days but significant at 45 days after transplanting, with CD values of 0.109, 0.126 and 0.218, respectively (Table 3). Overall, complete stress caused the greatest reduction in photosynthetic activity, and the effect became more pronounced with delayed transplanting and longer stress exposure. These findings agree with those of (14) that gas exchange and photosynthetic efficiency are affected by stomatal conductance, which is influenced by net heat stress. (15) also observed that high temperatures had a detrimental effect on tomato seedlings' net photosynthetic rate, which decreased by 60.40% when compared to the control at ideal temperatures. The higher photosynthetic rate under control and December 6 transplanting can be attributed to favourable temperature conditions supporting efficient photosynthetic activity. In contrast, delayed transplanting and continuous heat stress likely reduced photosynthetic activity through impaired chloroplast function, restricted leaf expansion, and accelerated senescence (16;17;18).

Effect of Heat Stress on Proline Accumulation ($\mu\text{mol/g}$)

Proline content increased from 15 to 45 days after transplanting across the treatments. Complete stress recorded the highest proline content (2.86, 3.00 and 3.26), while the control recorded the lowest values (2.18, 2.28 and 2.40) at 15, 30 and 45 days after transplanting, respectively. The third Date of Transplanting recorded the highest mean proline content (2.63, 2.74 and 2.94) at the respective growth stages. At 15 days after transplanting, significant differences were observed for Date of Transplanting, stress, and $D \times S$, with CD values of 0.41, 0.48 and 0.83, respectively. Similarly, at 30 days after transplanting, Date of Transplanting, stress, and $D \times S$ recorded significant differences, with CD values of 0.46, 0.53 and 0.92, respectively. At 45 days after transplanting, significant differences were observed for Date of Transplanting, stress, and $D \times S$, with CD values of 0.37, 0.42 and 0.73, respectively (Table 4). Higher proline accumulation was observed under complete stress and the third transplanting date, indicating an adaptive response to elevated temperature. Increased proline accumulation under heat stress contributes to osmotic adjustment, maintenance of cellular water balance, and protection of plant tissues, thereby enhancing stress tolerance. Similar observations have been reported by (19) reported that high-temperature stress adversely affected tomato flower morphology and physiological metabolism, leading to alterations in the production and accumulation of metabolites such as proline, polyamines, and carbohydrates. Proline may help to mitigate heat stress in tomato plants, as seen by the differences between control and proline-treated heat-stressed plants (12).

Effect of Heat Stress on Fertility Coefficient (%)

Fertility coefficient (%) declined under heat stress treatments across all transplanting dates compared to the control. The fertility coefficient was influenced by both Date of Transplanting and temperature stress treatments. The control (S1) recorded the highest mean fertility coefficient (65.8), followed by S3 (61.9) and S2 (60.3), while complete stress (S4) recorded the lowest value (55.5). Among the dates of transplanting, D1 recorded the highest mean fertility coefficient (64.3), followed by D2 (60.8) and D3 (57.6). Date of Transplanting and stress significantly influenced the fertility coefficient, with CD values of 5.71 and 6.60, respectively, whereas their interaction ($D \times S$) was non-significant ($CD = 11.41$). Overall, the fertility coefficient was highest under the control condition and the first Date of Transplanting, while complete stress resulted in a considerable reduction in the fertility coefficient (Table 5). The fertility coefficient decreased under heat stress in the present study, likely due to reduced pollen viability and increased flower abortion, resulting in poor fruit set. Similar effects of heat stress on pollen fertility and fruit setting in tomato have been reported by (20) and (21). In tomato plants, high temperatures have been shown to cause floral abortion, which results in 80% flower loss and decreased fruit set (22). As a result of heat stress, annual crop losses are caused by a decrease in photosynthetic capacity and a decrease in fruit set (23).

Effect of Heat Stress on Flowers per plant (Nos)

The number of flowers decreased progressively with later transplanting dates, where the ambient temperature itself increased along with the heat stress imposed period. The control (S1) recorded the highest mean number of flowers (29), while complete stress (S4) recorded the lowest (19). Among the transplanting dates, DT1 recorded the highest mean number of flowers (27), followed by DT2 (24) and DT3 (21). Date of Transplanting and stress significantly influenced the number of flowers, with CD values of 0.84 and 0.97, respectively. The $D \times S$ interaction recorded a CD value of 1.69. Overall, the highest number of flowers was recorded under control conditions and the first Date of Transplanting, whereas complete stress at the later Date of Transplanting resulted in the lowest flower production (Table 6). The higher number of flowers per plant under the first transplanting date could be attributed to favourable

weather conditions during the vegetative and reproductive stages, promoting better growth and assimilate accumulation. Delayed transplanting exposed the crop to more than 35°C day time temperature resulting in reduced flower production. Similar findings were reported by (24) and (25).

Effect of Heat Stress on the number of fruits (Nos/Plant)

The number of fruits decreased with successive DAT and increasing temperature stress. The control (S1) recorded the highest mean number of fruits (24 nos), while complete stress (S4) recorded the lowest (13 nos). Among the transplanting dates, D1 recorded the highest mean number of fruits (22 nos), followed by D2 (19 nos) and D3 (15 nos). Date of Transplanting and stress significantly influenced the number of fruits, with CD values of 1.11 and 1.29, respectively. The $D \times S$ interaction recorded a CD value of 2.23. Overall, the highest number of fruits was recorded under control conditions at the first Date of Transplanting (28 nos), whereas complete stress at the third Date of Transplanting recorded the lowest value (10 nos). Irrespective of the temperature regime, fruit number declined with delayed transplanting, indicating that elevated temperatures, particularly combined day and night heat stress, adversely affected fruit development and yield potential in tomato (Table 7). Fruit yield was reduced under heat stress in the present study, indicating the sensitivity of tomato productivity to elevated temperature. This finding is consistent with (26), who reported significant effects of transplanting date on tomato yield and observed a decline in tomato yield with increasing temperature. Reduced photosynthetic activity and assimilate availability under heat stress may further contribute to lower fruit production (27).

Effect of Heat Stress on Yield (Kg/Plant)

Fruit yield (kg plant^{-1}) was significantly reduced under heat stress treatments across all transplanting dates. The control (S1) recorded the highest mean yield (2.0 kg/plant), while complete stress (S4) recorded the lowest (1.0 kg/plant). Among the transplanting dates, D1 recorded the highest mean yield (1.9 kg/plant), followed by D2 (1.5 kg/plant) and D3 (1.2 kg/plant). Date of Transplanting and stress significantly influenced yield, with CD values of 0.19 and 0.22, respectively. The $D \times S$ interaction recorded a CD value of 0.39. Overall, the highest yield was recorded under control conditions at the first Date of Transplanting (2.5), whereas complete stress at the third Date of Transplanting recorded the lowest yield (0.8 kg/plant) (Table. 8). Heat stress significantly reduced tomato yield in the present study, which may be attributed to reduced pollen viability, increased flower abortion, and poor fruit set. High temperature can also impair fruit development and maturity, further contributing to yield reduction (19). Daytime heat stress may cause greater damage since it coincides with active photosynthesis, stomatal regulation, transpiration, and reproduction, whereas reduced metabolic activity at night may improve heat tolerance.

Impact of Growing Degree Days

Impact of Growing Degree Days

Under the simulated +2°C warming scenario, cumulative GDD during the first 45 days after transplanting followed the same increasing trend as the optimum condition, rising to 724.9, 738.6, and 755.0 GDD for D₁ (6 December), D₂ (23 December), and D₃ (6 January), respectively (mean daily GDD: 16.11, 16.41, and 16.78 °C Day). Although later transplanting dates accumulated marginally higher thermal units, this was driven largely by elevated maximum temperatures - frequently exceeding 33-36.5°C during January-February, well above the optimum range of 20-27°C for Shivam tomato - rather than favourable warming. Such supra-optimal heat exposure can impair photosynthesis, leaf expansion, and reproductive development, offsetting any apparent benefit of higher GDD under D₂ and D₃. D₁ continued to experience the mildest thermal conditions during early crop establishment, even after the +2°C adjustment. Thus, 6 December (D₁) remains the optimum transplanting date under the warming scenario, minimizing heat stress risk during critical early growth stages, while delayed transplanting increases vulnerability to compounded thermal stress under projected climate warming (Fig. 3).

Impact of Diurnal Variation of Temperature on tomato

On the first date of sowing, LAI developed well initially, but fluctuations in diurnal temperature caused mild stress, potentially reducing leaf expansion. Proline levels also rose as temperature stress increased in January and February. Dec 6th transplanting window may be more favourable for overall growth but still faces stress in later growth stages. Dec 23rd transplanting window experiences moderate stress but may be optimal in balancing growth and fruiting. Jan 6th transplanting window faces the most significant stress due to wider diurnal variation of more than 10°C leading to lower yield and quality. Based on the results of (28), more attention should be paid to the potential effect on tomato growth posed by DIF (difference between day and night temperatures); positive DIFs have a stronger positive influence than negative DIFs, and 6°C DIF is best for tomato growth. The possibility of extreme heat stress in the future is highlighted by predictions that the average surface temperature will rise by 0.2 °C every decade for the next three decades (Fig 4). Heat stress negatively impacts tomato development, restricts food availability, hinders photosynthesis, interferes with reproduction, denatures proteins, distorts signalling pathways, and destroys cell membranes, according to earlier research (11).

CONCLUSION

Tomato growth, physiology, reproductive efficiency, and yield were all negatively impacted by heat stress. Leaf Area Index and photosynthetic rate decreased progressively with increasing heat stress intensity, with the greatest reduction under complete day and night stress, particularly in delayed transplanting. In contrast, proline accumulation increased under stress, indicating its involvement in physiological adaptation to elevated temperatures. Heat stress also reduced the fertility coefficient, number of flowers and fruits per plant, resulting in considerable yield losses. Among the stress

treatments, day and night stress caused comparatively lower reductions, whereas complete stress had the most severe effects. Overall, delayed transplanting combined with continuous heat stress resulted in maximum reduction in tomato growth and productivity. Early transplanting and avoidance of prolonged heat exposure may therefore help improve tomato performance under warming conditions.

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Table 1. Experimental Details

S. No	Treatment Details
1.	Date of transplanting 1 (D1) + Control- (S1)
2.	Date of transplanting 1 (D2) + Day stress (+2°C)-S2
3.	Date of transplanting 1 (D3) + Night stress (+2°C)-S3
4.	Date of transplanting 1 (D4) + Complete stress(+2°C)-S4
5.	Date of transplanting 2 + Control
6.	Date of transplanting 2 + Day Stress(+2°C)
7.	Date of transplanting 2 + Night Stress(+2°C)
8.	Date of transplanting 2 + Complete stress(+2°C)
9.	Date of transplanting 3 + Control
10.	Date of transplanting 3 + Day Stress(+2°C)
11.	Date of transplanting 3 + Night Stress(+2°C)
12.	Date of transplanting 3 + Complete stress(+2°C)

Table. 2. Impact of Heat stress on LAI

	LAI 15				LAI 30				LAI 45			
	DT 1	DT 2	DT 3	Mean	DT 1	DT 2	DT 3	Mean	DT 1	DT 2	DT 3	Mean
Control	1.92	1.90	1.76	1.86	2.61	2.48	2.20	2.43	3.25	3.17	2.96	3.13
Day stress	1.75	1.57	1.49	1.60	2.45	2.23	2.13	2.27	3.14	3.05	2.87	3.02
Night stress	1.84	1.69	1.53	1.68	2.50	2.36	2.19	2.35	3.19	3.10	2.91	3.07

Complete stress	1.65	1.39	1.23	1.42	2.22	1.31	1.95	1.82	2.98	2.86	2.77	2.87
Mean	1.79	1.64	1.50		2.45	2.10	2.12		3.14	3.04	2.88	
	D	S	DxS		D	S	DxS		D	S	DxS	
SED	0.16	0.18	0.32		0.23	0.27	0.46		0.27	0.32	0.77	
CD	NS	0.39	0.67		0.48	0.55	0.95		0.56	1.13	1.54	

*Date of Transplanting - DT

Table 3 . Impact of Heat stress on Photosynthetic Rate ($\mu\text{mol CO}_2/\text{m}^2/\text{s}$)

	Photosynthetic rate – 15 DAS				Photosynthetic rate – 30 DAS				Photosynthetic rate – 45 DAS			
	DT 1	DT 2	DT 3	Mean	DT 1	DT 2	DT 3	Mean	DT 1	DT 2	DT 3	Mean
Control	18.5	18.3	17.8	18.2	17.8	17.89	17.5	17.73	17.5	17.6	17.3	17.47
Day stress	15.8	16	15.7	15.83	15.31	15.5	15.2	15.34	15	15.2	14.8	15
Night stress	16.5	16.6	16.3	16.47	16.1	16.2	15.9	16.07	15.7	15.8	15.5	15.67
Complete stress	14	13.8	13.8	13.87	13.5	13.21	13.31	13.34	13	18.2	12.7	14.63
Mean	16.2	16.18	15.9		15.68	15.7	15.48		15.3	16.7	15.08	
	D	S	D × S		D	S	D × S		D	S	D × S	
SED	0.082	0.094	0.163		0.059	0.069	0.119		0.053	0.061	0.105	
CD	0.169	0.195	NS		0.123	0.142	NS		0.109	0.126	0.218	

Table. 4. Impact of Heat stress on Proline ($\mu\text{mol/g}$)

	Proline 15				Proline 30				Proline 45			
	DT	DT	DT	Mean	DT	DT	DT 3	Mean	DT	DT 2	DT	Mean

	1	2	3		1	2			1		3	
Control	2.07	2.13	2.33	2.18	2.17	2.2	2.47	2.28	2.30	2.3	2.57	2.40
Day stress	2.37	2.37	2.73	2.49	2.47	2.50	2.73	2.57	2.57	2.60	2.87	2.68
Night stress	2.27	2.30	2.47	2.34	2.43	2.37	2.57	2.46	2.47	2.50	2.67	2.54
Complete stress	2.67	2.90	3.00	2.86	2.83	2.97	3.20	3.00	2.90	3.20	3.67	3.26
Mean	2.34	2.43	2.63		2.48	2.51	2.74		2.56	2.66	2.94	
	D	S	DxS		D	S	DxS		D	S	DxS	
SED	0.20	0.23	0.40		0.22	0.26	0.45		0.18	0.20	0.35	
CD	0.41	0.48	0.83		0.46	0.53	0.92		0.37	0.42*	0.73	

Table. 5. Impact of Heat stress on Fertility Coefficient in (%)

Fertility Coefficient				
	D1	D2	D3	Mean
S1	70.3	65.9	61.2	65.8
S2	63.6	60.0	57.3	60.3
S3	65.5	61.2	59.0	61.9
S4	57.8	55.9	52.8	55.5
Mean	64.3	60.8	57.6	
	D	S	DxS	
SED	2.77	3.19	5.53	
CD	5.71**	6.6**	11.41	

Table. 6. Effect of Heat Stress on Flowers per plant (Nos)

Flowers				
	D1	D2	D3	Mean
S1	32	29	26	29
S2	25	23	20	23
S3	29	26	21	25
S4	21	19	16	19
Mean	27	24	21	
	D	S	DxS	
SED	0.41	0.47	0.82	
CD	0.84**	0.97**	1.69	

Table. 7. Effect of Heat Stress on the number of fruits (Nos/Plant)

Fruits				
	D1	D2	D3	Mean
S1	28	24	20	24
S2	20	17	14	17
S3	24	20	16	20
S4	15	13	10	13
Mean	22	19	15	
	D	S	DxS	
SED	0.54	0.62	1.10	
CD	1.11**	1.29**	2.23	

Table. 8. Impact of Heat Stress on Yield (Kg/Plant)

Yield				
	D1	D2	D3	Mean
S1	2.5	2.0	1.6	2.0
S2	1.6	1.4	1.0	1.4
S3	2.1	1.7	1.3	1.7
S4	1.2	1.0	0.8	1.0
Mean	1.9	1.5	1.2	
	D	S	DxS	
SED	0.09	0.11	0.19	
CD	0.19**	0.22**	0.39	

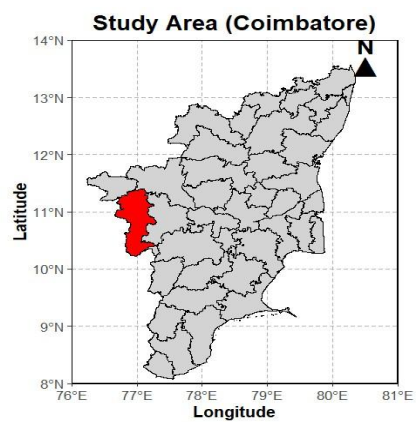


Fig. 1. Study area – ACRC, TNAU, Coimbatore

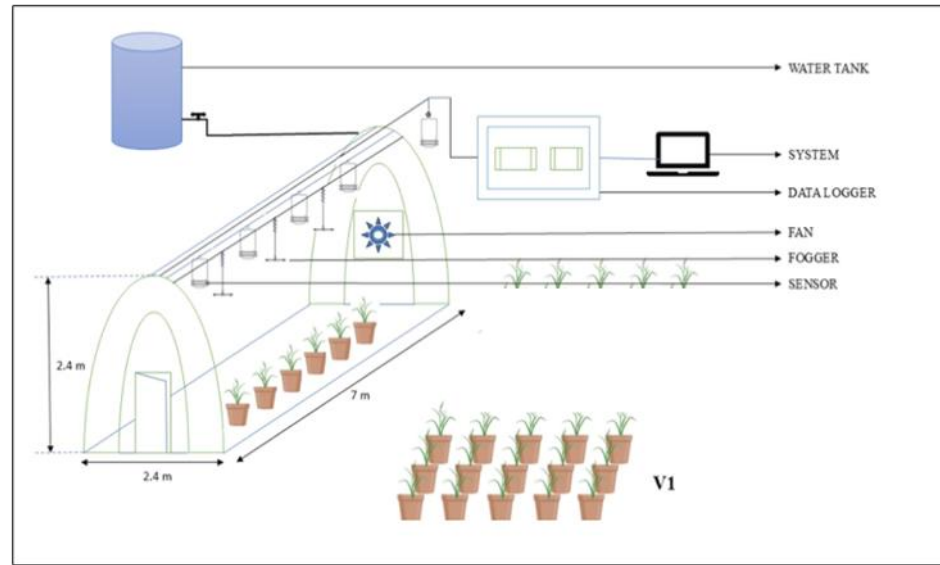


Fig. 2. Climate Control Chamber

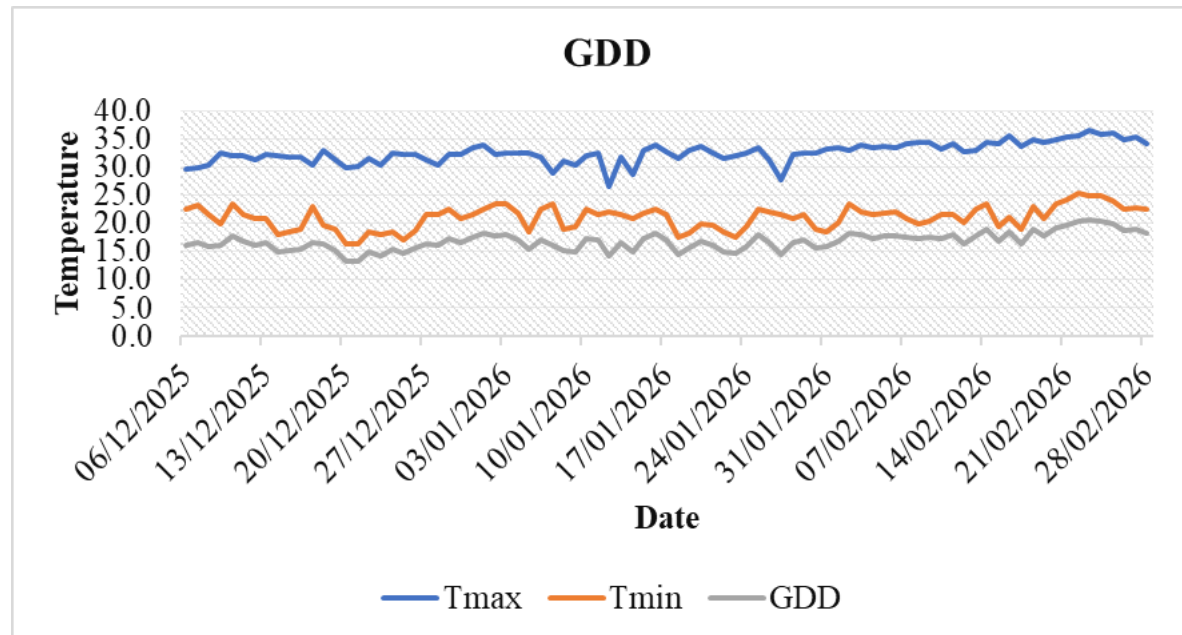


Fig. 3. Impact of GDD on Tomato crop

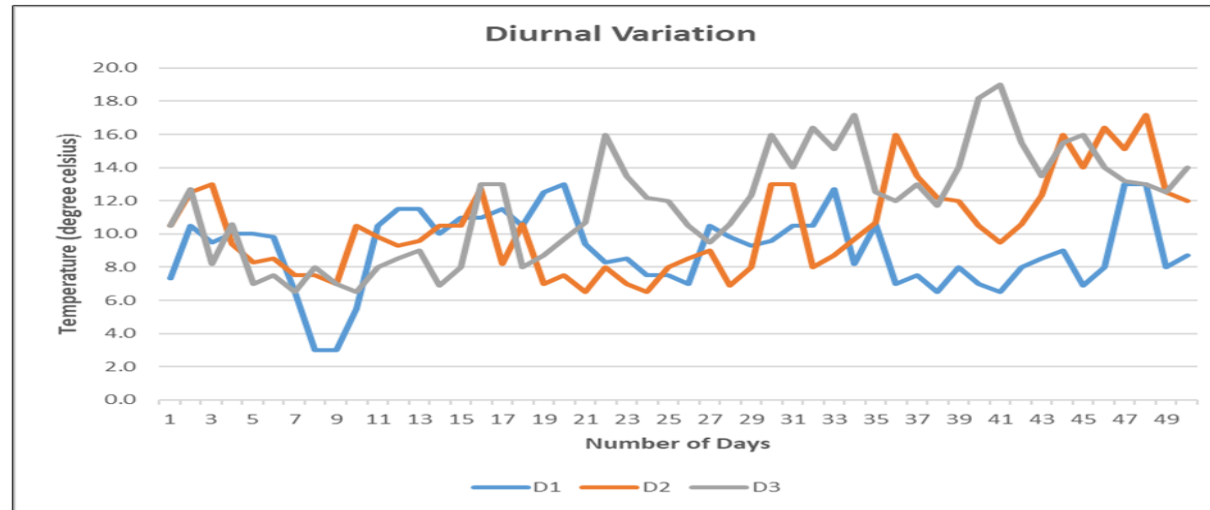


Fig. 4. Impact of diurnal variation on Tomato crop variation on Tomato crop

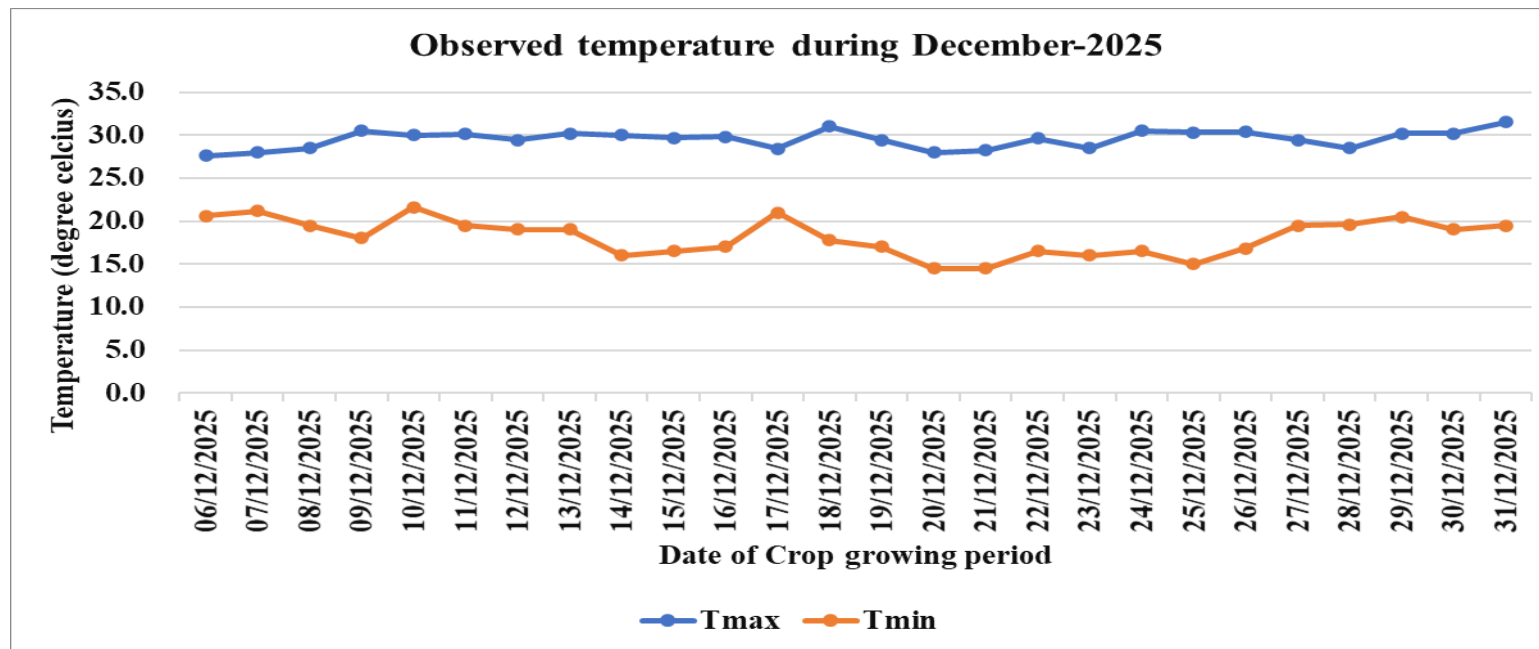


Fig.5 Observed Temperature during December

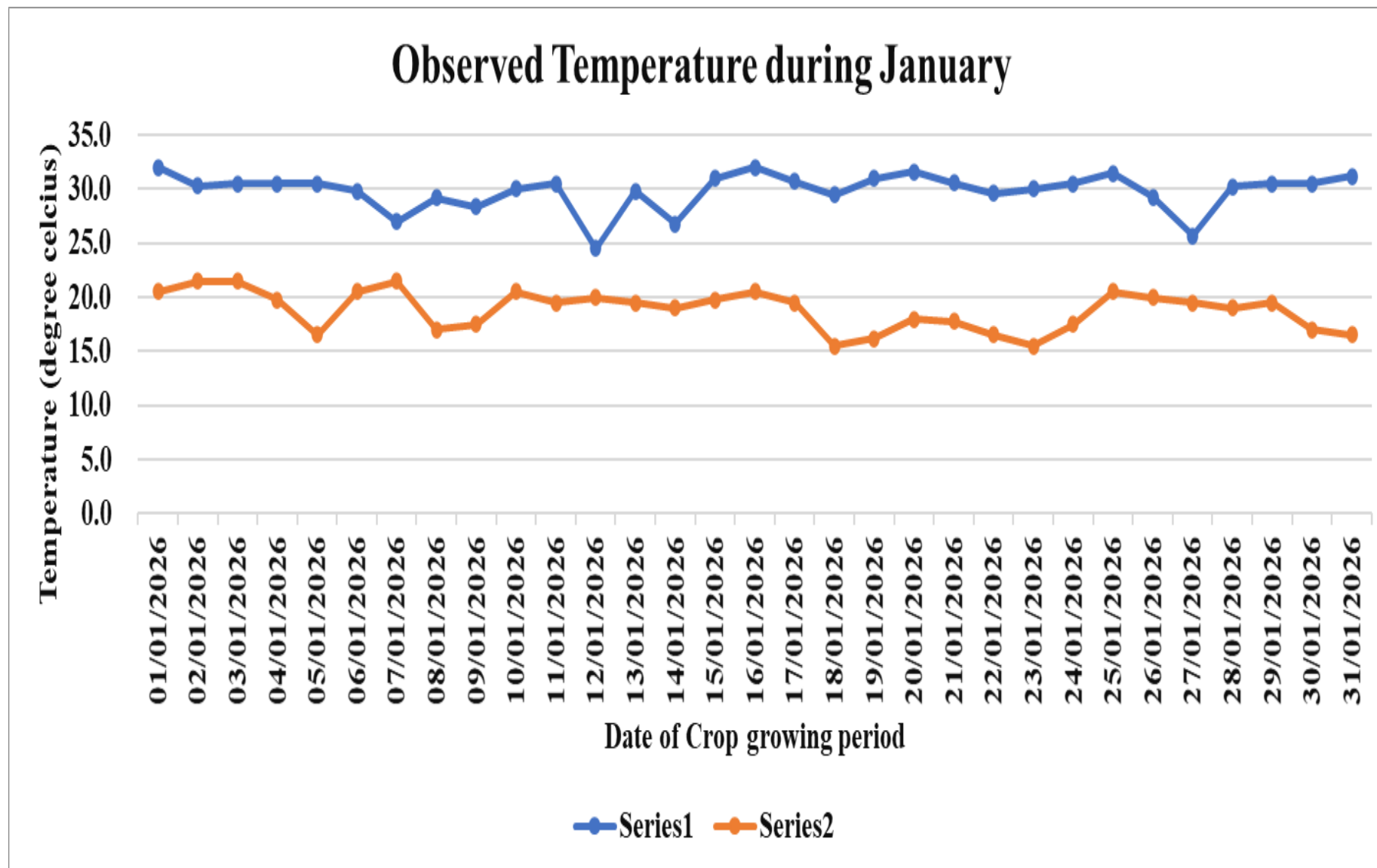


Fig.6 Observed Temperature during January -2026

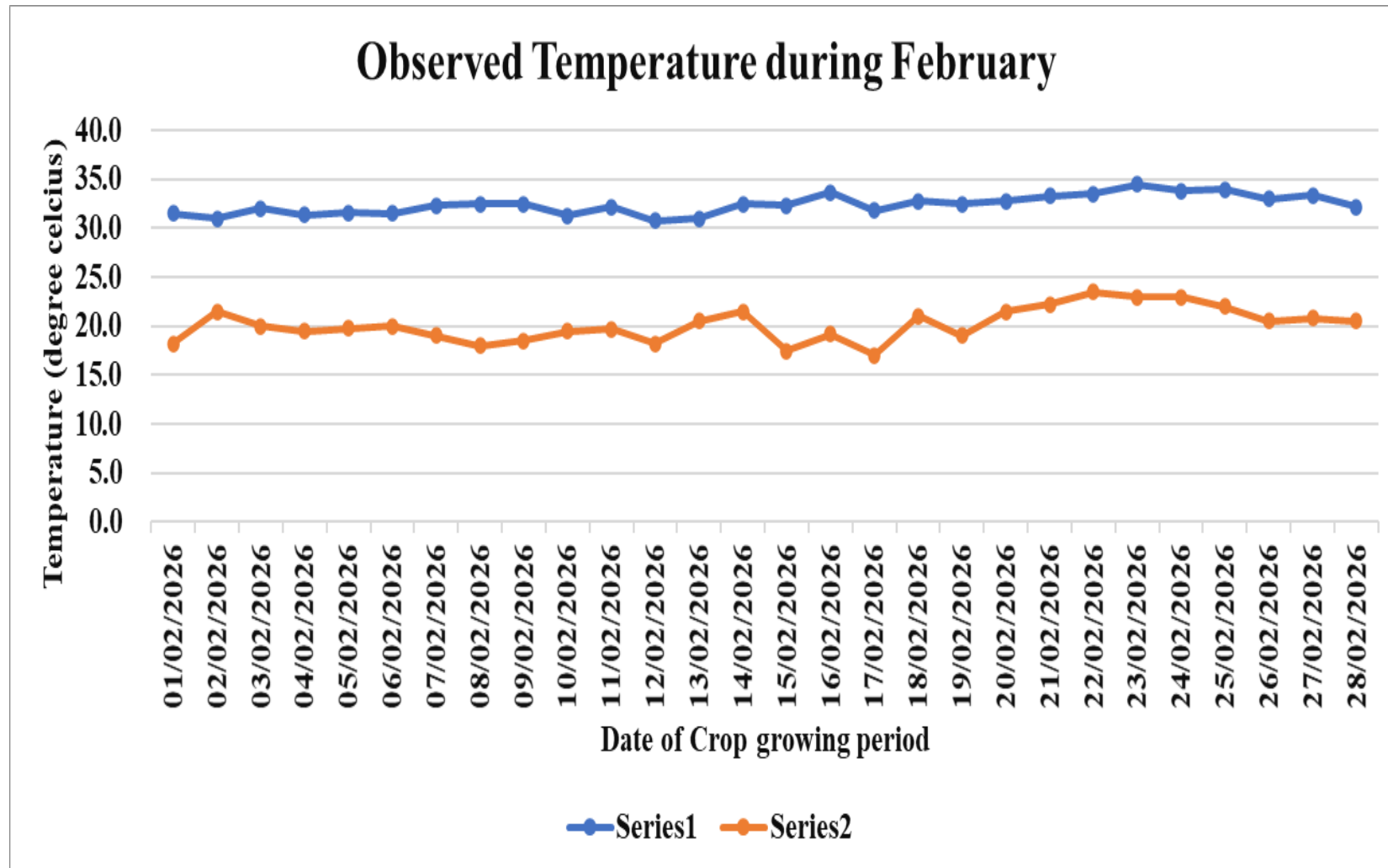


Fig.7 Observed Temperature during February -2026