



RESEARCH ARTICLE

Seasonal impact on the soil temperature and yield of baby corn (*Zea mays* L.) under different agronomic practices in tropics of India

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Abstract

Seasonal and diurnal variations in soil temperature play a critical role in baby corn production by influencing nutrient uptake and crop development. This study evaluated the effects of sowing windows, crop geometry and mulching on soil temperature dynamics and yield of baby corn. A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, during the winter (January–April) and kharif (June–September) seasons of 2022 using a split-plot design with 3 replications. Results revealed that sowing windows, crop geometry and mulching significantly affected soil temperature at both the surface and sub-surface (15 cm depth) during both seasons. Late sowing (D₃) consistently recorded the highest surface soil temperatures (27.5–29.1 °C at 7:22 hr and 40.1–41.2 °C at 14:22 hr) during winter and kharif, followed by mid (D₂) and early sowing (D₁). Wider spacing (60 × 30 cm) without mulching resulted in higher surface and sub-surface soil temperatures compared to closer spacing and mulched treatments. Sub-surface soil temperature at 15 cm depth was also highest under late sowing and wider spacing without mulching across both seasons. Correlation analysis indicated a significant negative relationship between soil temperature and baby corn yield, with correlation coefficients ranging from -0.57* to -0.98** in winter and -0.60* to -0.94** in kharif 2022. The study demonstrates that appropriate adjustment of sowing time, crop geometry and mulching practices can effectively regulate soil temperature and enhance baby corn productivity under varying seasonal conditions.

Keywords: baby corn; correlation coefficient; soil temperature; sowing windows

Introduction

Baby corn (*Zea mays* L.), a popular vegetable crop in tropical and subtropical regions, is cultivated for its tender, immature ears. In these climates, frequent temperature fluctuations and episodes of heat stress can adversely affect crop growth, development and yield. Soil temperature, a key component of the soil microclimate, is highly dynamic in tropical climates due to intense solar radiation, high diurnal temperature fluctuations and seasonal variations. In tropical soils, daily surface temperatures can rise sharply during the afternoon while sub-surface layers experience more moderated thermal regimes, creating complex interactions that influence root activity, nutrient availability and water uptake. Understanding soil thermal dynamics under such conditions is crucial for optimising

crop management practices, such as sowing time, crop geometry and mulching, which can modulate the soil microclimate and mitigate heat stress.

Baby corn yield is strongly influenced by plant populations, planting patterns, tillage types, water management, soil types, soil hydrological and chemical properties and other management practices (1). Plant density optimisation is the primary method for raising yield. Plants with high densities are more likely to be shaded, which hinders their ability to absorb light completely. This can lead to a decrease in their leaf development, leaf area index (LAI), leaf photosynthesis, premature total biomass output and reduced grain yield (2).

Seasonal temperature is a significant climatic component that can significantly impact agricultural productivity. Seasonal temperature variations primarily impact phenological development processes, which in turn impact grain yield. A varying reaction of temperature change (increase) to different crops has been seen under diverse production situations. Winter crops are particularly vulnerable to high temperatures during reproductive phases (3). Dates of sowing are crucial factors in crop production. The ideal planting date facilitates more efficient use of light, temperature, precipitation and other resources. In order to maintain crop productivity in the face of climate change scenarios, researchers are working to understand how climate change affects crop growth and yield. They are also trying to identify appropriate management strategies. In addition to being useful for studying climate change, crop growth models may be used to simulate the growth and production of crops under a variety of biotic and abiotic conditions. To assess the effects of climate change by tying it to future climate change scenarios, a thorough study of how crops respond to seasonal temperature fluctuations and other weather variations is necessary. It's also necessary to identify the modified agronomic management techniques that will aid in the crop's adaptation to the new surroundings (4).

Choosing the right planting date for corn is essential to production technology and it must be adjusted to accommodate variations (5). However, different results were drawn by researchers when identifying the best time to plant because climatic and soil conditions differ and agronomic tests conducted in different places cannot be replicated in space and time (6). Considering the above view, the present experiment was planned to study the effect of sowing windows, crop geometry and mulching on soil temperature and baby corn yield during winter and kharif. Aims of the examination: (i) How sowing windows, crop geometry and mulching affected the soil temperature at surface and sub-surface (15 cm)? (ii) How does influenced soil temperature affect the yield of baby corn?

Materials and methods

Study location

The study was conducted in Field No.37F of Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore. The study area is geographically situated at 11° N, 76° E and 426.7 m mean sea level of latitude, longitude and altitude which comes under Western Agro Climatic Zone of Tamil Nadu (Fig. 1). The nutrient status of the experimental soil was low in organic carbon (0.45 %) and available nitrogen (213 kg ha^{-1}), high in available phosphorus (31.0 kg ha^{-1}) and potassium status (640 kg ha^{-1}). Also, study soil was clay loam in texture and black in type with calcareous nature.

Experimental details

The field experiments were conducted during winter (January–April) and kharif, (June–September) 2022 seasons. Where thermal time approach was studied under different sowing windows, crop geometries with mulching and the field trial was conducted in split-plot design with three replications. Recommended agronomic practices were engaged as per the Tamil Nadu Agricultural University crop production guide (7). The variety F1 Sunder was used for the field trails and the crop was harvested after the silk colour turned pinkish from milky white by leaving border sample rows. Details of the experiments employed

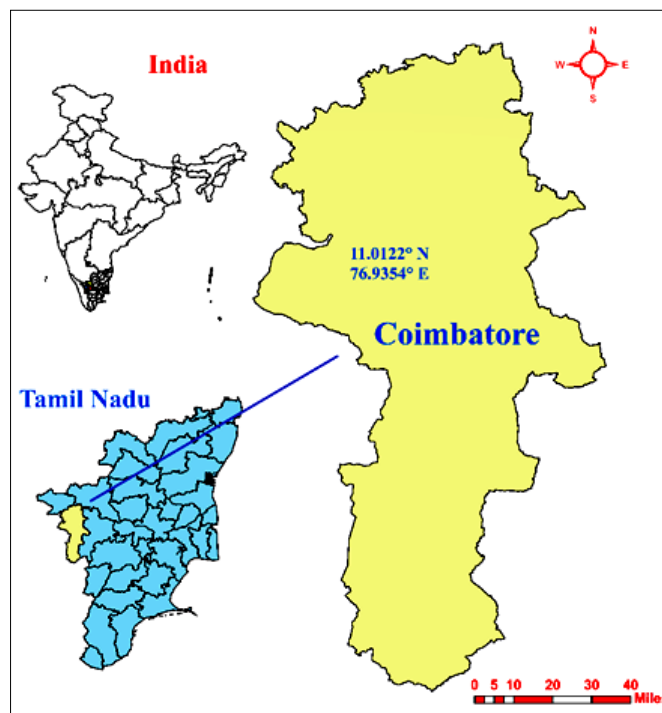


Fig. 1. Location map of the experimental study area.

Table 1. Details of the experiment combinations for the cropping seasons.

Main Plot: Sowing windows		Sub plots: Crop geometries and mulching	
Experiment - I (Winter season):			
D ₁	I FN of 21 st January 2022	S ₁ M ₀	60 x 30 cm ² without mulching
D ₂	I FN of 5 th February 2022	S ₁ M ₁	60 x 30 cm ² with mulching (paddy straw)
D ₃	II FN of 20 th February 2022	S ₂ M ₀	60 x 20 cm ² without mulching
Experiment - II (Kharif season):		S ₂ M ₁	60 x 20 cm ² with mulching (paddy straw)
D ₁	I FN of 15 th June 2022	* FN - Fortnight	
D ₂	II FN of 30 th June 2022		
D ₃	I FN of 15 th July 2022		

for both the seasons are given in Table 1.

Measurement of soil temperature

Digital thermometers (Model KUSAM MECO - 936) attached with a probe consisting of a thermocouple sensor was employed to measure the soil temperature at weekly intervals (20, 27, 34, 41, 48 and 55 DAS) during 7:22 hr and 14:22 hr since the physiological maturity of the baby corn reached 55 days and 60 days in the winter and kharif, 2022 seasons, respectively. Soil temperature was recorded at 7:22 hr to represent the minimum or night-retained soil temperature and at 14:22 hr to represent the maximum or peak diurnal soil temperature. These time points were selected to capture the daily extremes of soil thermal variation under different treatments. The experiment comprised 12 treatments with three replications, resulting in a total of 36 plots (plot size – 25 m²). Soil temperature was measured at 3 randomly selected locations within each plot at both the surface (0 cm) and sub-surface (15 cm) layers during 7:22 hr and 14:22 hr, yielding a total of 216 observations per

standard week

Statistical analysis

Correlation between baby corn yield and soil temperature (surface and sub-surface) was done using SPSS software to investigate the effect of thermal time approach on baby corn yield. The significant differences between mean values were evaluated using least significant difference (LSD) at 5% probability level as suggested by previous researchers (8). Stepwise regression analysis was performed to examine the relationship between daily soil temperature at different depths (surface and 15 cm) and baby corn yield.

Results and Discussions

Effect of treatments on surface soil temperature (°C) at 7:22 hr.

The result inferred that the sowing window and crop geometry with mulching had significant influence on the surface soil temperature (°C) of 7:22 hr during both the cropping seasons and it was ranged from 23.0 °C to 30.1 °C and 23.5 °C to 33.5 °C during winter and kharif 2022, respectively (Fig. 2).

Among the sowing windows, late sown plants (D_3) recorded maximum surface soil temperature (27.5 °C and 29.1 °C during winter and kharif 2022, respectively) followed by mid (D_2) and early sown (D_1) crops. The ideal sowing date for a particular location varies depending on a number of factors, including the local climate and related micrometeorological fluctuations. The findings unequivocally showed that delaying sowing increasing the air temperature compared to early sowing (9).

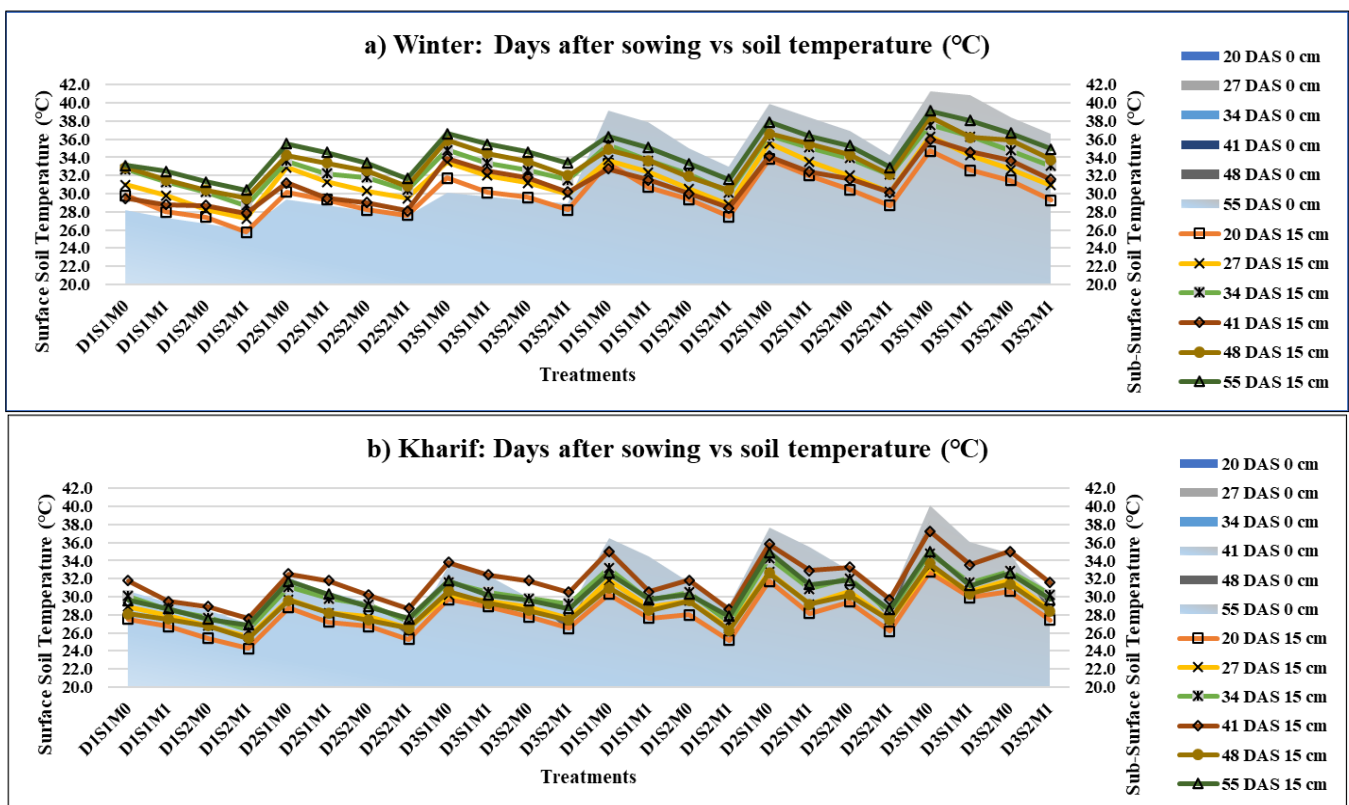
Wider spacing (S_1 - 60 x 30 cm) without mulching (M_0)

recorded the maximum surface soil temperature of 7:22 hr (27.4 °C and 29.7 °C during winter and kharif 2022, respectively) in crop geometry with mulching, whereas it was minimum in the closer spacing (S_2 - 60 x 20 cm) with mulching (M_1) treatment. In combination with all the treatments, the higher surface soil temperature of 7:22 hr (28.4 °C and 31.1 °C during winter and kharif 2022, respectively) was recorded in the late sown plants and wider spacing without mulching ($D_3S_1M_0$) whereas it was minimum (24.4 °C and 24.6 °C during winter and kharif 2022, respectively) in the early sown plants and closer spacing with mulching ($D_1S_2M_1$). Surface soil temperature was significantly decreased by mulching due to the cooler environment created in the soil as compared to non-mulched plots. More precisely, mulching has been observed to impact the temperature of the topsoil at different stages of baby corn growth (10).

The results of weekly interval data revealed that the surface soil temperature of 7:22 hr was increased till 34 DAS then reduced at 41 DAS and thereafter it was increased up to the harvest of the baby corn during winter, 2022. Whereas, during kharif 2022, it was increased till 41 DAS then reduced at 48 DAS and thereafter it was increased up to the harvest. In the entire growing cycle, higher surface soil temperature of 7:22 hr was recorded at 55 DAS (28.3 °C) and 41 DAS (29.8 °C) during winter and kharif, 2022 respectively. This study showed that the soil temperature increased gradually with the advancement of growth and delayed sowing up to the tasselling stage of baby corn, but thereafter gradually decreased until physiological maturity. The similar result was found by previous researchers (11).

Effect of treatments on surface soil temperature (°C) at 14:22 hr.

Fig. 2 showed the significant influence of sowing window and crop



Winter: D_1 - Jan. II FN (21.01.2022) D_2 - Feb. I FN (05.02.2022) D_3 - Feb. II FN (20.02.2022)

S_1 - 60 x 30cm; S_2 - 60 x 20cm;
NS - Not Significant.

Kharif: D_1 - June I FN (15.06.2022) D_2 - June II FN (30.06.2022) D_3 - July I FN (15.07.2022) M_0 - Without mulching; M_1 - With mulching.

Fig. 2. Temporal variation in soil temperature of baby corn as influenced by different treatments over crop growth period.

geometry with mulching on the surface soil temperature ($^{\circ}\text{C}$) of 14:22 hr during both the cropping seasons. The soil temperature of 14:22 hr was ranged from 29.2 $^{\circ}\text{C}$ to 41.2 $^{\circ}\text{C}$ and 25.3 $^{\circ}\text{C}$ to 40.1 $^{\circ}\text{C}$ during winter and kharif 2022, respectively.

Among the sowing windows, maximum surface soil temperature of 14:22 hr were recorded under late sown plants (D_3) (41.2 $^{\circ}\text{C}$ and 40.1 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) followed by mid (D_2) and early sown (D_1) crops. The higher surface soil temperature of 14:22 hr (38.2 $^{\circ}\text{C}$ and 35.3 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) was recorded in the wider spacing (S_1 - 60 x 30 cm) without mulching (M_0) and the minimum was observed in the closer spacing (S_2 - 60 x 20 cm) with mulching (M_1) treatment. In combination with all the treatments, maximum surface soil temperature was recorded under the late sown plants and wider spacing without mulching ($D_3S_1M_0$) and the lowest values was observed in the early sown plants and closer spacing with mulching ($D_1S_2M_1$). The soil temperature distribution at different soil depths depends on radiation absorption, reflection and permeation. The maximum air temperature was increased under delayed sowing which increased the surface soil temperature than early sowing window. Also, mulches and their amounts affect the radiation received at the soil surface. The results were agreed with those obtained by previous researchers (12).

Among the weeks, the highest surface soil temperature of 14:22 hr were observed in the 55 DAS (37.6 $^{\circ}\text{C}$) and 41 DAS (33.9 $^{\circ}\text{C}$) during winter and kharif, 2022 respectively. The lowest value was observed in the early growing stages. The highest growing cycle was recorded in the early sowing window and it was reduced in the delayed sowing. Also, the growing duration was higher in the kharif season as compared to winter season. Temperature and light are the main ecological factors affecting the length of crop growing cycle. Similarly, there was faster growth and earlier development of corn under delayed sowing compared with others (13).

Effect of treatments on sub-surface soil temperature ($^{\circ}\text{C}$) at 7:22 hr.

Fig. 2. showed the results of sowing window and crop geometry with mulching influence on the sub-surface soil temperature ($^{\circ}\text{C}$) of 7:22 hr during both the cropping seasons which was ranged from 25.7 $^{\circ}\text{C}$ to 36.6 $^{\circ}\text{C}$ and 24.3 $^{\circ}\text{C}$ to 33.8 $^{\circ}\text{C}$ during winter and kharif 2022, respectively.

Like the surface soil temperature, the higher sub-surface soil temperature was recorded under the late sown plants (D_3) (32.6 $^{\circ}\text{C}$ and 30.1 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) followed by mid (D_2) and early sown (D_1) crops. In crop geometry with mulching, wider spacing (S_1 - 60 x 30 cm) without mulching (M_0) recorded the maximum sub-surface soil temperature of 7:22 hr (32.9 $^{\circ}\text{C}$ and 30.4 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) whereas it was minimum in the closer spacing (S_2 - 60 x 20 cm) with mulching (M_1) treatment. In combination with all the treatments, late sown plants and wider spacing without mulching ($D_3S_1M_0$) recorded the higher sub-surface soil temperature of 7:22 hr (34.4 $^{\circ}\text{C}$ and 31.3 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) whereas the early sown plants and closer spacing with mulching ($D_1S_2M_1$) crops recorded the minimum values (28.2 $^{\circ}\text{C}$ and 26.0 $^{\circ}\text{C}$ during winter and kharif 2022, respectively). Soil temperature was effectively modified using paddy straw mulch and early sown crop is usually exposed by a low soil temperature as well as high soil moisture conditions, creates favourable climatic conditions for crop growing (14).

Among the growing weeks, the sub-surface soil temperature of 7:22 hr was increased upto 34 DAS then reduced at 41 DAS and thereafter it was increased upto the harvest of the baby corn. Where, the maximum value was observed at 55 DAS (33.6 $^{\circ}\text{C}$) and 41 DAS (29.3 $^{\circ}\text{C}$) during winter and kharif, 2022 respectively. The results from this study also suggest that factors that reduce soil temperature, such as mulching reduced the crop growing duration (15). Furthermore, soil temperature controls the rate of development in corn crops until the 6-leaf stage because the plant meristem is below ground level until this stage (16).

Effect of treatments on sub-surface soil temperature ($^{\circ}\text{C}$) at 14:22 hr.

Data of the influence of sowing window and crop geometry with mulching on the sub-surface soil temperature ($^{\circ}\text{C}$) of 14:22 hr during both the cropping seasons was shown in Fig. 2. The result showed that the value ranged from 27.5 $^{\circ}\text{C}$ to 39.1 $^{\circ}\text{C}$ and 25.2 $^{\circ}\text{C}$ to 37.2 $^{\circ}\text{C}$ during winter and kharif 2022, respectively.

Among the treatments, the higher sub-surface soil temperature of 14:22 hr were recorded in the late sown plants and wider spacing without mulching ($D_3S_1M_0$) (39.1 $^{\circ}\text{C}$ and 34.5 $^{\circ}\text{C}$ during winter and kharif 2022, respectively) whereas the early sown plants and closer spacing with mulching ($D_1S_2M_1$) crops recorded the minimum values (29.5 $^{\circ}\text{C}$ and 26.9 $^{\circ}\text{C}$ during winter and kharif 2022, respectively). Among the crop growing cycle, the sub-surface soil temperature of 14:22 hr was maximum at 55 DAS (35.6 $^{\circ}\text{C}$) and 41 DAS (32.9 $^{\circ}\text{C}$) during winter and kharif, 2022 respectively. The temperature at sub-surface (15 cm) is consistently lower during the growing season than the surface temperature because of the thermal insulation of the soil. The choice of sowing day is mainly driven by meteorological factors and soil temperature (17). Previous researchers pointed out that early sown corn plant was associated with potentially under-optimal soil and weather planting conditions while delayed sowing exposes crops to a reduced growing season length and high soil temperatures (18, 19).

Influence of soil temperature on corn yield

Fig. 3 depicts that cob yield ranged from 5.5 to 11.4 t ha⁻¹ during winter 2022 and from 7.7 to 17.7 t ha⁻¹ during kharif 2022. Yield was significantly influenced by sowing windows, with early sowing (D_1) recording the highest cob yield of 11.2 t ha⁻¹ in winter 2022 and 18.3 t ha⁻¹ in kharif 2022. Crop geometry also had a marked effect on yield, as closer spacing (S_2 : 60 x 20 cm) produced significantly higher cob yields (8.4 t ha⁻¹ and 12.9 t ha⁻¹ during winter and kharif 2022, respectively) compared to wider spacing (S_1 : 60 x 30 cm) in both seasons. Mulching further enhanced baby corn productivity, with paddy straw mulching (M_1) resulting in higher cob yields (8.2 t ha⁻¹ in winter 2022 and 12.4 t ha⁻¹ in kharif 2022) than non-mulched treatments (M_0). Among interaction effects, significant variation in cob yield was observed for D_1S_2 during the winter season, while during kharif 2022, significant interactions were recorded for cob yield (D_1M_1), corn yield (D_1S_2) and fodder yield (D_1S_2 , D_1M_1 and $D_1S_2M_1$).

Correlation between soil temperature and baby corn yield depicted in the Table 2. In particular, negative and highly significant correlations were found between the baby corn yield and soil temperature (surface and 15 cm depths) during both the cropping seasons. The correlation coefficient was ranged from -0.57* to -0.98** and -0.60* to -0.94** for winter and kharif 2022, respectively. From the regression analysis, it is confirmed that the higher negative

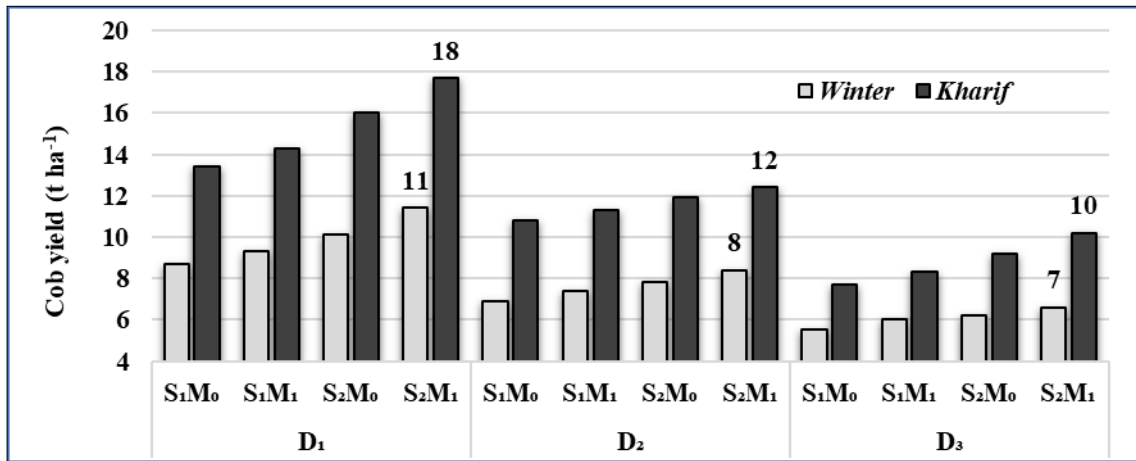


Fig. 3. Influence of treatment interaction effect on cob yield (t ha^{-1}) of baby corn.

Table 2. Correlation between soil temperature ($^{\circ}\text{C}$) and corn yield of baby corn

Days after sowing (DAS)	Surface (0 cm)				Sub-surface (15 cm)			
	Winter, 2022		Kharif, 2022		Winter, 2022		Kharif, 2022	
	7:22 hr	14:22 hr	7:22 hr	14:22 hr	7:22 hr	14:22 hr	7:22 hr	14:22 hr
20	-0.84**	-0.57*	-0.94**	-0.72**	-0.84**	-0.67*	-0.84**	-0.70*
27	-0.81**	-0.60*	-0.82**	-0.71**	-0.87**	-0.72**	-0.80**	-0.63*
34	-0.96**	-0.77**	-0.84**	-0.69*	-0.86**	-0.81**	-0.82**	-0.66*
41	-0.97**	-0.82**	-0.71*	-0.60*	-0.86**	-0.87**	-0.84**	-0.70*
48	-0.98**	-0.87**	-0.89**	-0.77**	-0.89**	-0.87**	-0.83**	-0.66*
55	-0.97**	-0.78**	-0.80**	-0.69*	-0.92**	-0.84**	-0.76**	-0.64*

** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level.

Model 1: Y (Winter 2022) = $67252.115 - 190.304$ (Morning ST 0 cm) ($R^2=0.89$).

Model 2: Y (Kharif 2022) = $415259.263 - 170.886$ (Morning ST 0 cm) ($R^2=0.74$).

correlation found in the morning soil temperature (7:22 hr) as compared to afternoon soil temperature (14:22 hr) during both the cropping seasons.

Among the individual factors, crop geometry had higher influence on the physiological gas exchange parameters followed by sowing windows and mulching during both the cropping periods. Early sown (D_1) recorded higher physiological gas exchange parameters than late sowing (D_3). Wider spaced (S_1 - 60 x 30 cm) crops with mulching had higher rate as compared to closer spaced (S_2 - 60 x 20 cm) crops during both the cropping seasons. In combinations, the higher gas exchange parameters were observed

in early sowing (D_1) with wider spacing (S_1 - 60 x 30 cm) and mulched plot during both winter and kharif 2022. Among the sowing windows, early sowing window had higher LAI (4.3 and 5.1) and light interception (63.1 and 76.8 %) which increased the physiological gas exchange as compared to delayed sowings. Soil temperature varied significantly with sowing dates, crop spacing and mulching treatments throughout the crop growth period. Fig. 4 depicts that early sowing resulted in comparatively lower soil temperature during the initial vegetative stages, whereas late sowing experienced elevated soil temperature, particularly during mid-day hours. Wider crop spacing recorded higher soil temperature due to greater soil surface exposure, while closer spacing moderated soil

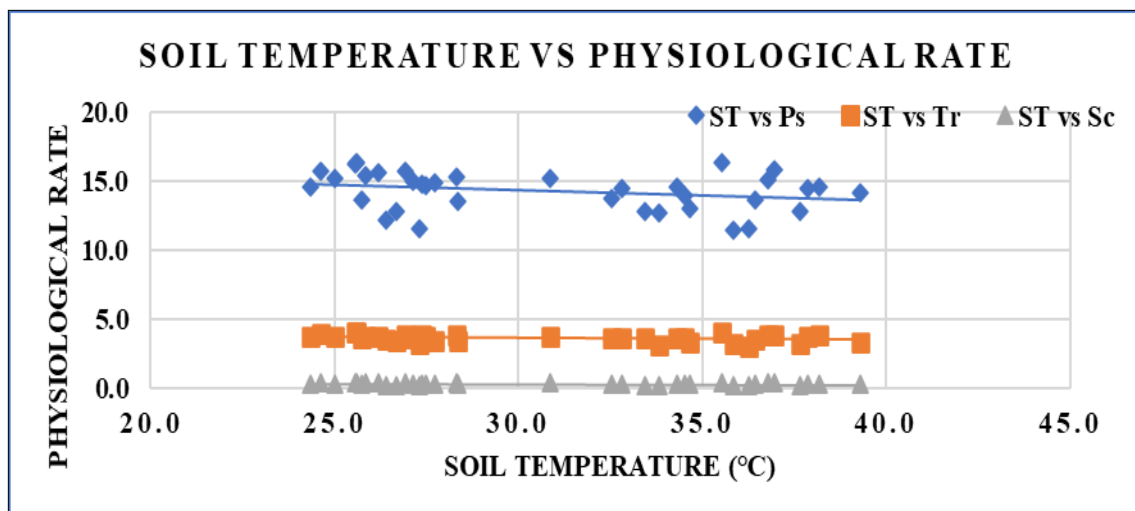


Fig. 4. Relationship between soil temperature and physiological rates of baby corn.

ST- Soil Temperature; Ps- Photosynthetic rate; Tr- Transpiration rate; Sc- Stomatal Conductance ($n = 144$, cumulative of both seasons).

temperature through canopy shading. Application of paddy straw mulch significantly reduced soil temperature and minimised diurnal temperature fluctuations by insulating the soil surface and reducing direct solar radiation. These observations are in agreement with earlier findings that mulching and canopy cover play a critical role in regulating the soil thermal regime. Similar results were reported earlier, that physiological rates (Pn, Gs and E) was higher at early sowing of corn than delayed sowing (20). Baby corn plants showed higher physiological gas exchange at wider spacing than closer spacing which was due to proper availability of spacing for the gas exchange at wider spacing. Similar result was observed by previous researchers found the higher photosynthetic intensity at wider row spacing also observed greater consumption of photosynthetic gas exchange in the wider row spacing (21). Mulching had significantly increased the physiological gas exchange parameters as compared to non-mulching which was due to higher LAI recorded in mulched plots. Straw mulching increased the photosynthetic rate, respiration rate, transpiration rate of corn plants were reported earlier (22). Changes in seasonal temperature affect the baby corn yield, mainly through phenological development processes. Soil temperature influences water uptake. Optimal root function maintains turgor and stomatal opening, allowing efficient gas exchange and carbon assimilation. Among the seasons, winter crops are especially vulnerable to high temperature during reproductive stages and differential response of temperature change under different sowing windows. The similar finding was reported in previous studies that higher soil temperatures reduced the duration of corn reproductive growth and accelerated root and leaf senescence, leading to small root/shoot biomass accumulation (12). The negative correlation between the canopy temperature, growth attributes and grain yield of corn was reported previously (23). However, early sowing window can be conflicted by low soil temperatures and delayed sowing and poor emergence can significantly reduce the yield (24).

Conclusion

The study revealed a significant negative relationship between soil temperature and baby corn yield, with a stronger effect observed during morning hours (7:22 hr) than in the afternoon. Late sowing and wider spacing without mulching resulted in higher surface and sub-surface soil temperatures, whereas early sowing combined with closer spacing and mulching maintained a favourable soil microclimate. It is concluded that early sowing (II fortnight of February and I fortnight of June) with closer spacing (60 × 20 cm) and mulching is optimal for regulating soil temperature, improving nutrient uptake and enhancing baby corn productivity to meet the increasing demand for fodder and table vegetables. The study demonstrates that soil temperature management through agronomic practices has a clear and measurable influence on the growth and productivity of baby corn. Overall, the evaluated practices modified the soil thermal regime by increasing soil temperature during the early stages of crop growth and reducing excessive fluctuations as the crop canopy developed. This moderated soil temperature created a more favourable root environment, enhancing physiological processes such as nutrient uptake, photosynthesis and dry matter accumulation.

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Authors' contributions

ST contributed to research idea conceptualisation, conducted the experiments and participated in writing, reviewing and editing of the manuscript. RSP, DGA and JD contributed to research idea conceptualisation and were involved in writing, reviewing, and editing of the manuscript. RB, DR, GT and TT contributed to writing, reviewing, and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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