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Impact of Different Irrigation Techniques on Wheat Crop Micro-climate

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim of this experiment is to study the impact of irrigation techniques on microclimate of wheat crop in terms of temperature and humidity. Randomized block design is used on the wheat crop (*Triticum aestivum* L.) variety Karan Narendra (DBW 222) at research farm of ICAR-CSSRI, Karnal during the *Rabi* 2021-22. In conventional practice treatment, higher temperature fluctuation was observed and was 0.5-1°C cooler as compared to other plots. Drip irrigation treatment showed most stable crop microclimate in terms of canopy temperature and humidity dynamics. A sharp rise in

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temperature at maturity cause dryness in crop and leads to lower productivity. Except at physiological maturity, canopy was cooler than the ambient air, while relative humidity was higher both during morning and evening hour.

Keywords: Wheat; canopy; temperature; relative humidity.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) crop occupies an important position in Indian agricultural sector and overall financial system. It is the most important staple food of about two billion people (36% of the world population). In India, its cultivation is spread between 10°N to 37°N and cultivated under a wide range of agro-climatic conditions from Kashmir and other mountainous region to moist soils in the deltaic coastal areas and arid soils in Rajasthan [1]. It is the second staple food crop of India, cultivated in about 30.60 million hectares with a production of 102.28 million tonnes and productivity of 32.24 quintals per hectare. Climate variables viz. temperature, light, humidity, and rainfall in optimum conditions, exploit the full genetic potential of a particular variety by providing a suitable environment for crops and accounts for more than 20 percent of the variation in wheat yield [2]. Canopy temperatures provide a more realistic measure of microclimatic conditions and real conditions of crop stress exhibited in the field. Liu and Kang [3] also reported that microclimatic changes in winter wheat crops occurred due to different irrigation practices in North China plain. Canopy temperature depression had an important role to explore the physiological basis of the grain yield of wheat [4]. An increase in mean aerial temperature by 1°C resulted in a reduction of the vegetative period by about 3 days and reduction in grain yield of about 7 q ha^{-1}, reproductive period by 4.6 days [5], whereas temperature above 18.2 to 18.8°C cause a drastic reduction in grain yield by 23.2 to 42.2 per cent over the highest yield that achieved at the mean temperature of 18.2°C during reproductive phase of the crop [6]. Straw mulching doesn't only store water and retain soil moisture and reduced evapotranspiration [7], but also insulate temperature [8]. Mulch has warming effect from seedling stage to the turning green stage and, cooling effect from the jointing stage to the end of the ripening stage, which promotes the growth of the crop and ensures the yield [9]. Top-soil under strip-tillage had lower heat capacity and greater thermal conductivity than no-tillage due to lower moisture content hence have higher canopy temperature [10]. Keeping the foremost mentioned points in view, microclimate of wheat crop was studied under different irrigation techniques and tillage practices.

2. METHODOLOGY

2.1 Experimental site

The investigation was conducted during *Rabi* 2021-22 at the Research Farm of ICAR-Central Soil Salinity Research Institute, Karnal, situated at 29°43' N latitude, 76°58' E longitude and altitude of 245 meters.

2.2 Climatic Conditions of Experiment Site

The climate of Karnal is a typical semi-arid climate having hot and dry summer with desiccating winds. Maximum temperature is around 48ºC during the summer months of May to June and temperature below freezing point accompanied by frost in the winter months of December and January are common in Karnal. Fig. 1 depicts the weather conditions prevailed during the season at experimental area.

2.3 Experimental Layout

The experiment was conducted in randomized block design (RBD) with five replications. Treatments consist of conventionally tilled wheat with 6.5 cm surface irrigation provided at critical phenological stages (CRI, tillering, jointing, dough, and flowering) without straw mulch i.e farmers practice (T1); zero-tilled wheat with straw mulch and drip irrigation plot (T2); zero-tilled wheat with straw mulch and surface irrigation at critical phenological stages plot (T3); zero-tilled wheat with straw mulch and mini-sprinkler irrigation plot (T4). Full residue (1/3) of rice crop on surface was left over on surface as mulch. Karan Narendra (DBW 222) wheat variety was sown at recommended inter-row spacing of 22.5 cm. Total amount of irrigation applied in T1 is 26 cm, in T2 is 19.8 cm, T3 is 26 cm and T4 is 20.10 cm with rainfall of 12.42 cm.

2.4 Observation Recorded

Micro-meteorological observations (canopy temperature and relative humidity) were recorded at 20 cm height from ground at 0700 (morning) and 1400 hours (afternoon) daily by a digital thermo-hygrometer (HTC-2). It was installed in the middle of every treatment to ensure the prevention of any outer disturbance.

3. RESULTS AND DISCUSSION

3.1 Influence of Irrigation Practices on Canopy Maximum Temperature

Canopy maximum temperature at 1400 hours (afternoon) among various treatments during the season is depicted in Fig. 2 along with maximum temperature of ambient. Highest canopy maximum was recorded in zero tillage mini-sprinkler irrigation treatment (T4) (47.16℃) followed by zero tillage surface irrigation treatment (T3) (46.26℃) and zero tillage drip irrigation treatment plot (T2) (43.07℃), whereas, lowest temperature was recorded in conventional tillage surface irrigation treatment plot (T1) (39.98℃) because of high transpiration cooling and heavy irrigation.

Canopy air temperature (Fig. 3) of all the treatments was higher than the ambient air temperature during winter period (tillering and booting stage), at par during anthesis and higher during warm period (late February to April) at milking and physiological maturity stages due to heat wave. It was observed that maximum canopy temperature in afternoon was lower than the ambient air temperature up to milking stage and thereafter it was higher. When canopy temperatures are high, too much energy is lost through the process of transpiration by the plants, and the reduced residual energy results in poorer grain formation and lower yields.

3.2 Influence of Irrigation Practices on Canopy Minimum Temperature

Canopy minimum temperature for morning among various treatments during the season is depicted in Fig. 4 along with minimum temperature of air. In morning, during winter period (post-jointing to anthesis), minimum canopy temperature was higher than the ambient minimum air temperature (Fig. 4). As the crop matured ambient air minimum temperature at morning was higher than the canopy minimum temperature. During jointing to anthesis stage lowest mean minimum morning temperature was recorded in conventional tillage T1 (4.1℃), while during anthesis to crop maturity period it was recorded in zero tillage mini-sprinkler irrigation treatment (T4) (15.43℃). Presence of mulch material over T2, T3 and T4 helped to trap more heat in canopy and buffered the canopy conditions which prevented fall in minimum temperature during winter period of crop growth cycle.

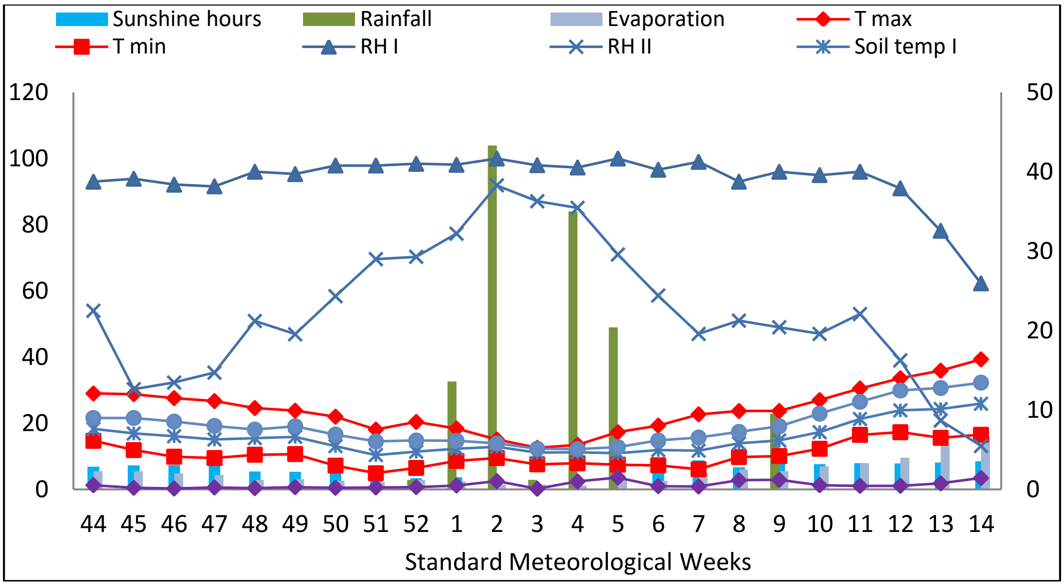

Fig. 1. Mean weekly values of weather parameters during *Rabi* (2021-22)
Temperature (°C), relative humidity (%), bright sunshine hours (hrs), wind speed (kmph) (left margin); rainfall (mm), evaporation (mm) (right margin)

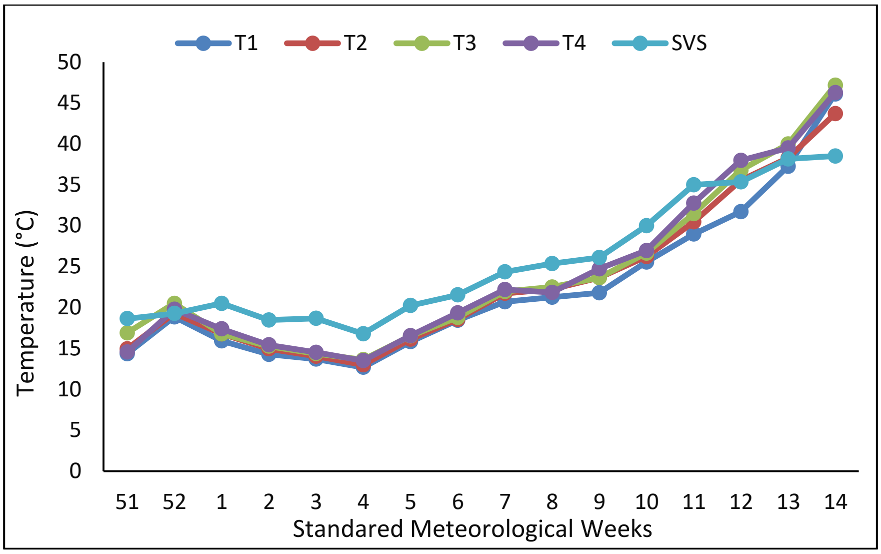

Fig. 2. Canopy maximum temperature (1400 hours) during *Rabi* (2021-22)
Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

Comparatively higher canopy temperature was recorded in T4 as it drains out the surplus water quickly because of higher infiltration rate (1.35 cm hr^{-1}), too much energy and water losses because of evapotranspiration and canopy interception, followed by T3, T2 and least in T1 because of high transpiration cooling and heavy irrigation. Due to more canopy cover and good crop stand, T1 was able to maintain a lower canopy temperature which was also observed by Dhaliwal et al., [11] in his work. Presence of mulch over T2, T3 and T4 trapped more heat in canopy and raised the temperature during winter period. Terminal heat stress was more pronounced in T4 and T3 because of higher solar radiation interception due to low canopy covers, mulch, higher soil temperature and moisture due to sensible heat transfer from soil to crop canopy via canopy interception and conduction, which in later crop growth stages increased crop canopy temperature. The effect of mulch was observed up to 100-110 days after sowing. A sharp rise in canopy temperature of T4 accompanied by hot winds during the grain growth period caused forced maturity of the crop resulting in the production of immature and shriveled grains and reduced production. In T1, higher temperature fluctuation was observed and was 0.5-1°C cooler as compared to other plots.

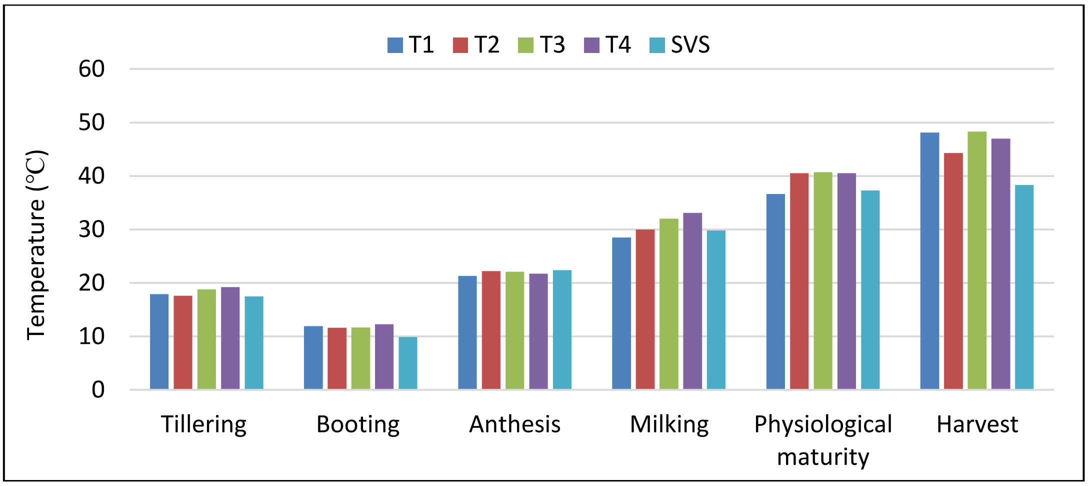

Fig. 3. Canopy maximum temperature at various growth stages of wheat
Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

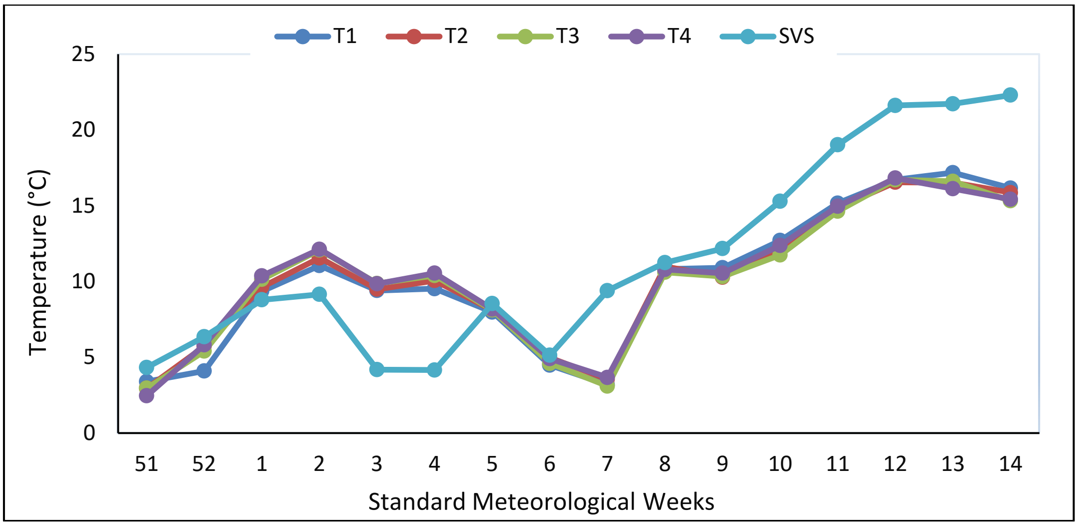

Fig. 4. Canopy minimum temperature (0700 hours) during *Rabi* (2021-22)
Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

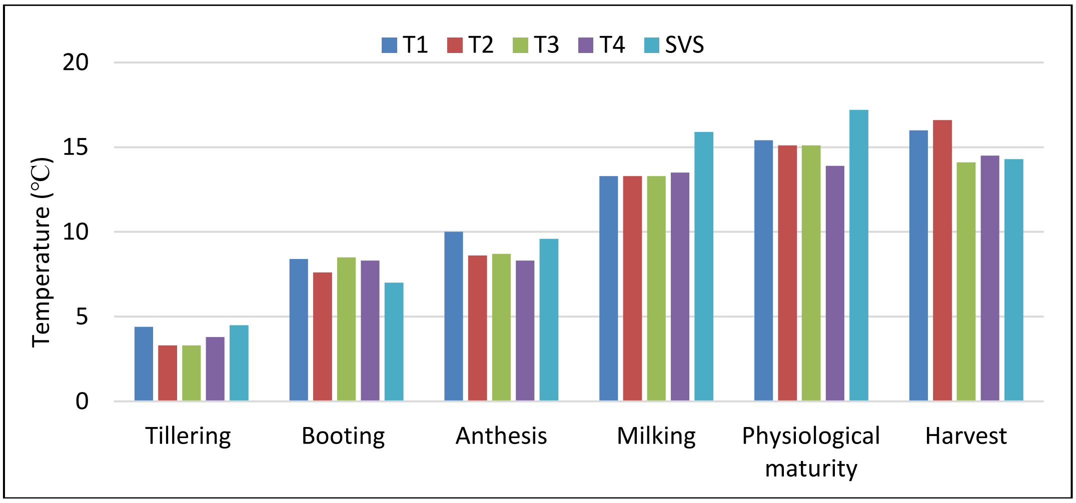

Fig. 5. Canopy minimum temperature at various growth stages of wheat
Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

3.3 Influence of Irrigation Practices on Canopy Relative Humidity

Crop canopy was warmer and retains higher relative humidity (>20-30%) than ambient air. Relative humidity at 0700 hours (RH-I) was higher in T1 (99.7%) due to which leaf temperature of crop in T1 was lowest (24.9℃) (Fig. 6). Relative humidity at 1400 hours (RH-II) was higher than air relative humidity throughout the crop growth period (Fig. 7). Mulching aids in maintaining a good amount of humidity near soil surface. In T4, RH falls sharply because of high canopy temperature (44-46°C), heat wave incidence, lower crop coefficient (K_c) (0.40) and amount of irrigation.

Highest mean canopy relative humidity (RH-I) during morning hours was recorded at booting stage (99%), while lowest was observed at harvest (40%) depicted in Fig. 8. From jointing to milking stage there was a little difference in RH-I among the different treatments. In these growth stages RH-I was higher in conventionally surface irrigation method treatment and least in sprinkler irrigation system treatment (T4) (54%). Canopy relative humidity for afternoon (RH-II) among various treatments is depicted in Fig. 9 along with relative humidity of air at same time. Maximum mean canopy relative humidity during afternoon hours was recorded during heading stage because of high rainfall, and was observed highest in T2 (98%) followed by T4 (98%), T3 (98%) and T1 (94%), while lowest was recorded during harvest in T1 (13%), followed by T4 (31%), T3 (25%) and T2 (34%). It was observed that in mini-sprinkler irrigation treatment relative humidity fall sharply in later stages of the crop development.

3.4 Influence of Irrigation Practices on Stomata Conductance, Transpiration and Photosynthetic Rate

At maximum vegetative growth, transpiration and photosynthetic rates depicted in Table 1 were significantly higher in T1 due to abundance water availability and lower relative humidity of canopy, while lesser stomata conductance was responsible for minimum water losses, which results in lavish growth of crop under the plot.

Experimental area faced high temperature (around >5°C) than normal during grain filling stage. Heat wave of 7 days stroked the crop which desiccated the crop and soil, reduced grain moisture and yield reduction of around 20-25%. Grain yield of T1 (47.35 qha^{-1}) was higher followed by T2 (45.92 qha^{-1}), T4 (43.66 qha^{-1}) and T3 (41.67 qha^{-1}), whereas, the harvest index significantly varied under different treatments. T2 had significantly higher harvest index (38.30%) as compared to T3 (37.50%), T4 (37.46%) and T1 had lowest (36.34%).

Table 1. Influence of different irrigation practices on various physiological parameters at maximum vegetative growth in wheat

Treatments	Transpiration rate (mmol m^{-2} s^{-1})	Photosynthetic rate (µmol m^{-2} s^{-1})	Stomata conductance (mol m^{-2} s^{-1})
T1	16.23^{A}	0.33^{A}	1.11^{C}
T2	13.58^{B}	0.26^{B}	1.20^{B}
T3	12.99^{B}	0.21^{C}	1.30^{A}
T4	13.27^{B}	0.22^{C}	1.28^{A}
General Mean	14.02	0.26	1.22
p-Value	0.0167	<.0001	0.0007
CV (%)	6.56	4.67	2.42
SE(d)	0.751	0.01	0.024
LSD at 5%	1.8383	0.0238	0.0592

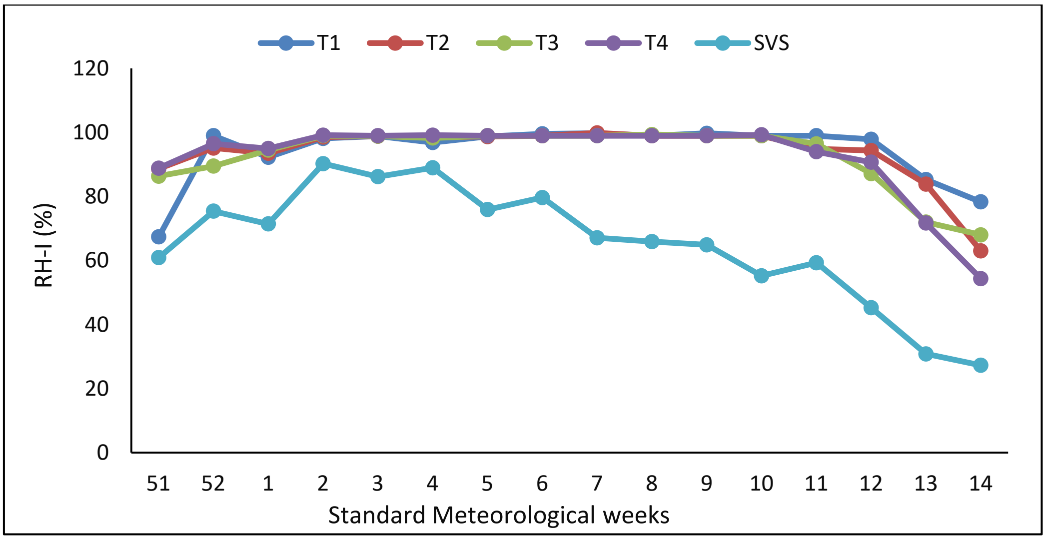

Fig. 6. Canopy relative humidity at 0700 hours

Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

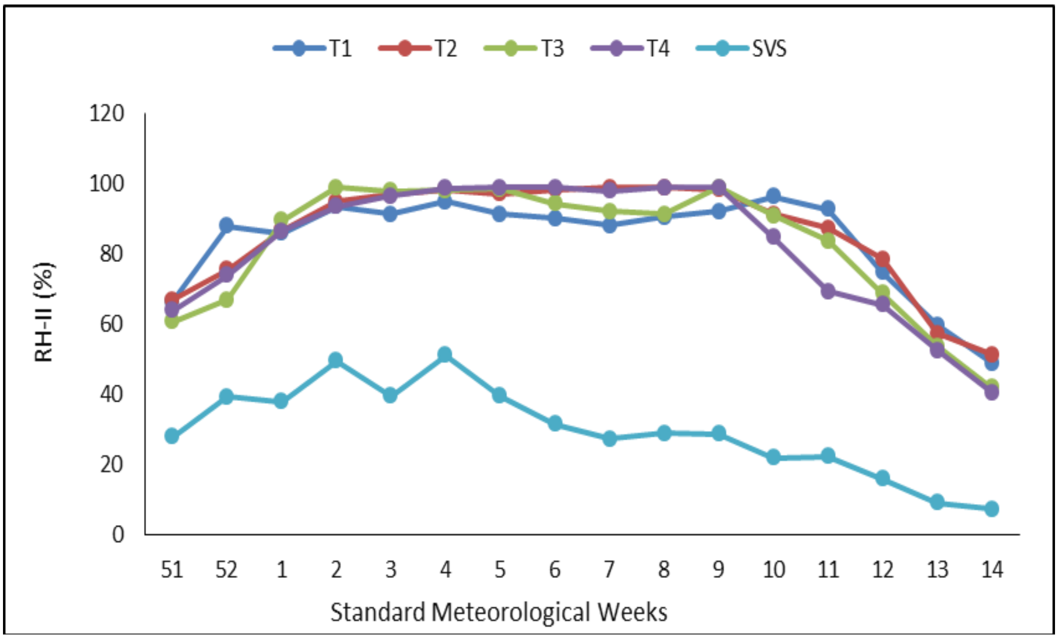

Fig. 7. Canopy relative humidity at 1400 hours

Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen temperature

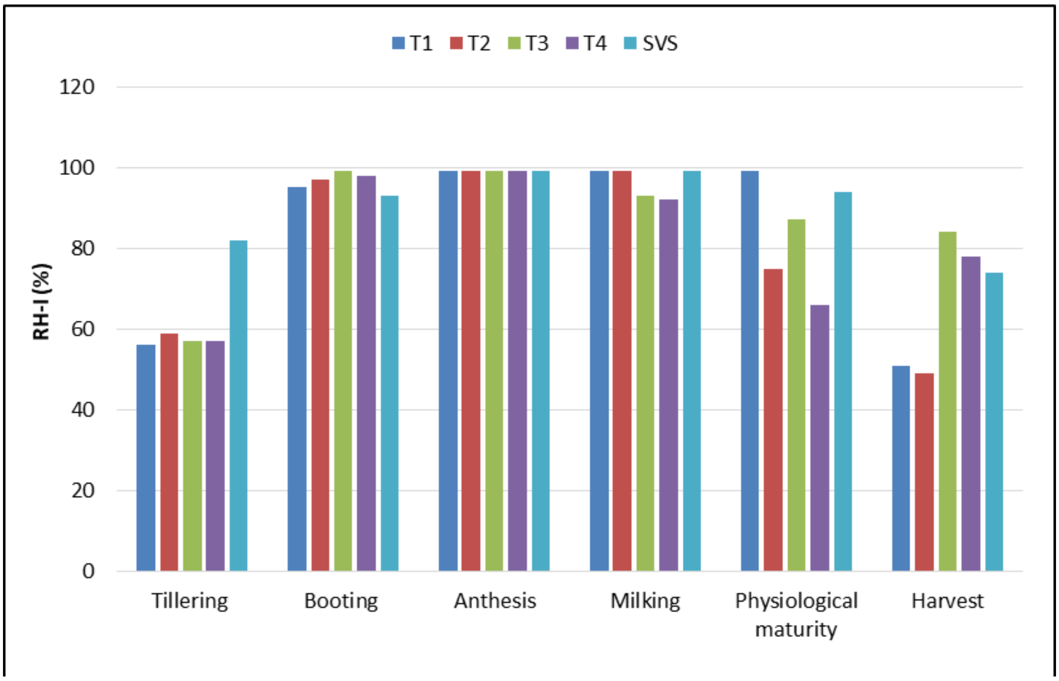

Fig. 8. Canopy relative humidity at 0700hrs of growth stages of wheat crop

Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen RH

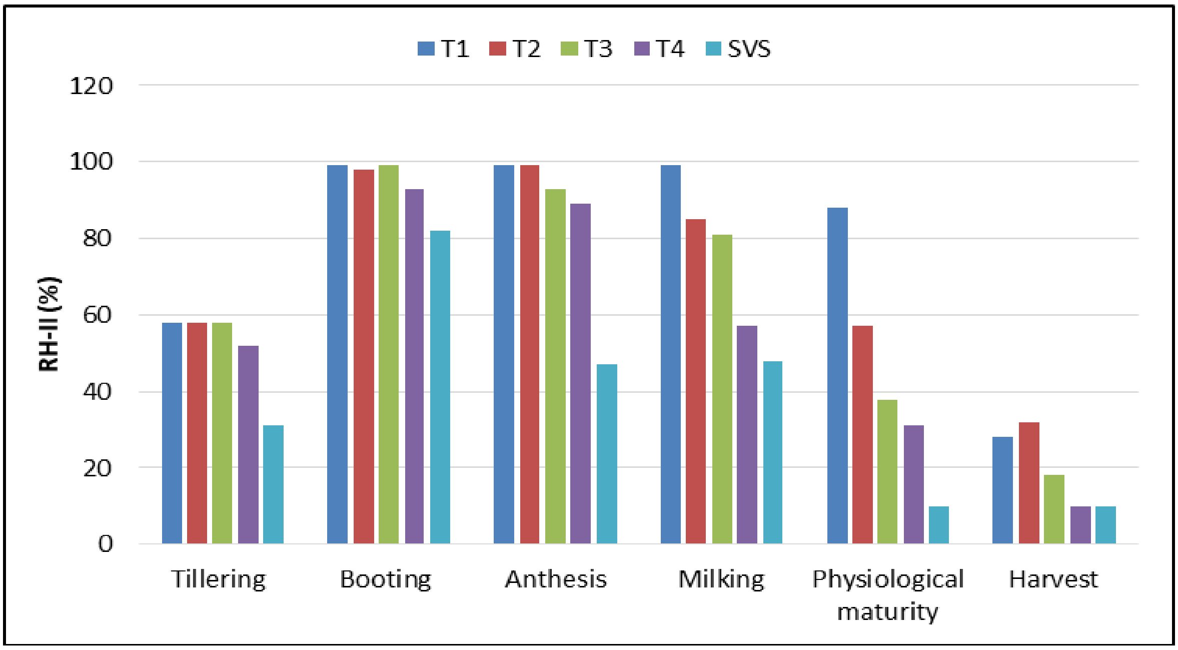

Fig. 9. Canopy relative humidity at 1400hrs of growth stages of wheat crop

Where, SMW- Standard meteorological weeks, T1- conventional irrigation plot, T2- drip irrigation plot, T3- surface irrigation plot with straw mulch, T4- mini-sprinkler irrigation plot, SVS- Stevenson's screen RH

4. CONCLUSION

Field microclimate was affected by different types of irrigation methods not only during the period of irrigation but also during all irrigation intervals. Drip irrigation plot (T2) showed most stable crop microclimate in terms of soil and canopy temperature dynamics. A strong association of canopy temperature and humidity is seen with the method of irrigation applied. Deficit irrigation application in T4 with higher evapotranspiration losses and infiltration rates in zero tilled plots (T4 and T3) faced heat stress at maturity. T4 recorded to have highest canopy temperature at 1400 hours because of deficit irrigation and higher solar radiation interception in canopy, while T1 has lowest canopy temperature because of heavy irrigations and dense canopy cover. Crop canopy was warmer and retains higher relative humidity (>20-30%) than ambient air. Mulches helped in warming the air near soil surface, resulting in higher (2-5 °C) canopy temperature.

CONFERENCE DISCLAIMER

Some part of this manuscript was previously presented in the conference: 3rd International Conference IAAHAS-2023 "Innovative Approaches in Agriculture, Horticulture & Allied Sciences" on March 29-31, 2023 in SGT University, Gurugram, India. Web Link of the proceeding: https://wikifarmer.com/event/iaahas-2023-innovative-approaches-in-agriculture-horticulture-allied-sciences/

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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