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Assessing the Variations in Canopy Temperature, Relative Humidity and Soil Temperature within the Canopy of Winter Maize in Bihar

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ABSTRACT

Variations in canopy temperature, relative humidity and soil temperature within crop micro-environment exert full control over plant's physiological processes and thereby over growth, development and yield of crop. These micro-meteorological parameters tend to significantly control the exchange of energy between the crop environment and the atmosphere. Keeping all this in view, a field experiment with winter maize (var. *Rajendra hybrid* 4) was conducted with five dates of sowing viz., 1 November (D1), 10 November (D2), 20 November (D3), 30 November (D4) and 10 December (D5) and three spacings viz., 60 X 20 cm (S1), 75 cm X 20 cm (S2) and 45 cm X 20 cm (S3) at the University farm of Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar during *rabi* season of 2021-22 to assess the variations in canopy temperature, relative humidity and soil temperature, as influenced by micro-environments and planting density. The experiment was laid out in split plot design with sowing dates as main-plots and spacings as split plots. Results revealed that canopy temperature was found to be the highest for the crop planted on D4 (30 November) with S2 (75cm X 20 cm) spacing, while the lowest was associated with the crop sown on D1 (1 November) with S3 (45 cm X 20 cm) spacing. Mean canopy temperature decreased from sowing to knee high stage, thereafter it increased with every phenological stage up to physiological maturity. Crop sown on D3 (20 November) having S3 (45 cm X 20 cm) spacing recorded maximum relative humidity. Highest soil temperature at 15 cm depth was recorded for D5 (10 December) sown and S2 (75cm X 20cm) spaced crop and the lowest for D2 (10 November) having S3 (45cm X 20cm) spacing. Information generated on the variation in canopy temperature, relative humidity and soil temperature at different phenophases of winter maize would be useful in managing abiotic stresses on crop production.

Keywords Winter maize, Micro-environment, Canopy temperature, Relative humidity, Soil temperature.

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INTRODUCTION

The variability of microclimatic factors plays utmost role in delineating crop-soil-micro-environment. The micro-environment near the near-ground or soil surfaces experiences spontaneous exchange of energy. Interaction between weather and plant behavior can be better understood by knowing behavior of 'within-canopy' variation in micro-climatic factors. Ahmed *et al*. (2020) concluded that microclimatic regimes caused significant variation in thermal days of maize. One of the important parameters is canopy temperature, which is the tangible manifestation of its energy and therefore, it is affected by environmental and plant factors. Canopy temperature is a very important tool for determining the water status of plant. Thus, it is an important factor for determination of grain yield. Kaur *et al*. (2019) measured canopy temperature in winter maize in Punjab and found significant relationship with grain yield.

Like canopy temperature, relative humidity plays the micro-climatic energy transfer processes. It has a direct influence on water retaining power of plants and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield. Omoyo *et al*. (2015) opined that field crop evapo-transpiration increased with rising temperature and low relative humidity and the rainfall in a season influences seed germination, grain filling and length of growing season of maize. Like canopy temperature and relative humidity, soil temperature has important role in crop life cycle especially in the initial stages of crop growth. Variable soil temperature affects the germination of seeds. Many soil organisms survive and function best at optimum soil temperature. Low soil temperature reduces water uptake as water viscosity lowers down and slows down rate of photosynthesis.

Maize (*Zea mays* L.), which is popularly known as "Corn" is grown for almost throughout a year due to its photo-thermo-insensitive character and the highest genetic yield potential among the cereals. It is predominately a *kharif* season crop. But in the past few years, *rabi* maize has gained a significant place in total maize production in India. In Bihar, *rabi* maize is grown in an area of 0.268 million hectares with a production of 1.64 million metric tonnes and productivity of 6.14 tonnes/ha. The information on canopy temperature, soil temperature and relative humidity within canopy are of utmost importance in developing cause and effect relationships. As information on this aspect in winter maize is almost non-existing for Bihar, it is essential that information on the variations these parameters are made available and hence, keeping this in view, objectives were set to evaluate the variations of these micro-meteorological parameters within winter maize canopy at different growing stages under different sowing environments.

MATERIALS AND METHODS

A field experiment with winter maize (var. *Rajendra hybrid* 4) was conducted with five dates of sowing viz., 1 November (D1), 10 November (D2), 20 November (D3), 30 November (D4) and 10 December (D5) and three spacings viz. 60 X 20 cm (S1), 75 cm X 20 cm (S2) and 45 cm X 20 cm (S3) at the University farm of Dr Rajendra Prasad Central Agricultural University, Pusa (25.98` N, 85.66` E, 52 m elevation), Samastipur, Bihar during *rabi* season of 2021-22. The experiment was carried out in split plot design with 5 dates of sowing as main plot and three levels of spacing as sub plot treatments. The region experiences sub-humid sub-tropical climate. The temperature tends to decrease significantly from November onwards. Appreciable fall in temperature is observed from 26.9°C in October to 21.9°C in November.

To raise the crop, recommended dose of fertilizers and four irrigations were applied to the crop for each treatment. Micrometeorological observations such as canopy temperature, relative humidity and soil temperature at 15 cm depth were recorded at critical phenological stages of winter maize. Canopy temperature was measured remotely by infrared thermometer (Model Raytek, USA). The thermometer was viewed on the top of canopy at an angle of 45 degrees from horizontal avoiding bare soil. Four reading were taken in each plot in four directions to negative directional bias. Assmann Psychrometer was used in the experimental field for taking observation of relative humidity. Instrument was placed at mid height of the canopy for recording observations. Dry bulb and wet bulb temperatures were noted down and these readings were converted to relative humidity. Soil temperature was recorded on each observation day throughout the growing period of winter maize at 15 cm depth by Digital soil thermometer (Model TM-9126).

RESULTS AND DISCUSSION

Variation in canopy temperature

Mean canopy temperatures measured at different phases spanning over 21 days after sowing (DAS) to harvesting stages of winter maize, grown under different dates of sowing and spacings presented in Table 1 revealed that the differences in sowing dates brought about statistically significant differences in mean canopy temperature recorded over all the phases of growth under study. The difference in spacings gave rise to significant difference in mean canopy temperatures recorded over milking, dough and physiological maturity phases, while in the remaining phases, the difference in canopy temperatures were non-significant. The interaction between dates of sowing and spacings caused significant differences in mean canopy temperatures recorded at milking, dough and physiological maturity phases, while in

Table 1. Canopy temperature of winter maize for different dates of sowing and spacing at different phenological stages.

Treatments	Phenological stages								
	21 DAS	Knee high	Tasseling	Silking	Milking	Dough	Physiological maturity	Harvesting	Mean
Sowing dates									
D1 (01.11.2021)	29.5	19.5	19.9	21.7	27.2	31.7	35.6	32.9	27.3
D2 (10.11.2021)	26.5	20.3	26.5	28.5	28.4	31.6	31.8	32.7	28.3
D3 (20.11.2021)	25.8	21.9	28.2	31.6	30.8	33.4	33.4	33.7	29.9
D4 (30.11.2021)	26.3	26.1	32.0	32.2	31.2	33.0	32.4	32.7	30.7
D5 (10.12.2021)	20.2	26.4	31.6	29.7	33.8	31.4	31.9	32.1	29.6
Mean	25.6	22.8	27.6	28.7	30.2	32.2	33.0	32.8	
SEm (±)	0.7	0.3	0.1	0.4	0.1	0.1	0.1	0.1	
CD (p=0.05)	2.3	1.0	0.4	1.4	0.4	0.4	0.5	0.5	
Spacing									
S1 (60 cm x 20 cm)	25.7	23.0	27.7	29.1	30.4	32.4	33.1	31.9	29.2
S2 (75 cm x 20 cm)	25.9	22.6	27.6	28.7	30.6	32.6	33.3	32.6	29.2
S3 (45 cm x 20 cm)	25.5	22.9	27.7	28.4	29.8	31.7	32.7	31.9	28.8
Mean	25.7	22.8	27.6	28.7	30.2	32.2	33.0	32.1	
SEm (±)	0.3	0.1	0.1	0.3	0.1	0.1	0.1	0.1	
CD (p=0.05)	NS	NS	NS	NS	0.3	0.3	0.3	NS	
Interaction (DxS)									
D1 S1	29.7	19.3	19.9	23.6	27.1	31.9	35.3	32.9	27.5
D1 S2	30.0	19.4	19.9	21.5	27.7	31.4	36.0	33.0	27.4
D1 S3	28.8	19.8	19.9	20.1	26.8	31.6	35.8	33.0	27.0
D2 S1	26.7	20.2	26.5	28.4	28.3	31.9	32.3	32.6	28.4
D2 S2	27.1	20.4	26.9	28.8	28.5	31.4	32.2	32.8	28.5
D2 S3	25.7	20.3	26.3	28.4	28.6	31.6	30.9	32.8	28.1
D3 S1	25.5	22.3	28.6	31.8	30.9	33.8	33.8	34.1	30.1
D3 S2	25.6	21.7	28.0	31.7	31.2	34.0	34.0	34.2	30.1
D3 S3	26.3	21.8	28.2	31.5	30.4	32.6	32.6	32.9	29.5
D4 S1	26.6	26.5	32.0	32.1	31.4	33.6	32.4	32.8	30.9
D4 S2	27.3	25.3	31.9	32.1	31.6	33.5	32.4	32.7	30.9
D4 S3	26.0	26.6	32.1	32.5	30.8	32.0	32.5	32.8	30.7
D5 S1	19.9	26.7	31.6	29.6	34.5	31.3	31.7	31.9	29.7
D5 S2	19.9	26.4	31.5	29.8	34.2	31.9	32.3	32.6	29.8
D5 S3	20.9	26.2	32.0	29.9	32.7	31.2	31.7	31.9	29.6
Mean	25.7	22.8	27.6	28.7	30.3	32.2	33.0	32.8	
SEm (±)	1.2	1.2	0.2	0.7	0.2	0.2	0.2	0.2	
CD (p=0.05)	NS	NS	NS	NS	0.7	0.6	0.8	NS	

remaining phases the data were not statistically significant. The lowest canopy temperature of 19.3°C was observed in crop sown on 1 November with 60 cm x 20 cm spacing at knee height stage, whereas the highest canopy temperature of 36.0°C was measured in crop sown on 1 November with 75cm x 20 cm spacing at physiological maturity stage.

In crop sown on 1 November, canopy temperatures varied from 19.5°C at knee high stage to 35.6°C at physiological maturity stage; in crop sown on 10 November, it was found to vary from 20.3°C at knee high stage to 32.7°C at harvesting stage; in crop sown on 20 November, it extended from 21.9°C at knee height stage to 33.7°C at harvesting stage; in crops sown on 30 November , it ranged between 26.1°C at knee high stage and 33.0°C at dough stage in crop sown on 10 December, it was found to be as low as 20.2°C at 21 DAS to as high as 33.8°C at milking stage. When averaged over all the dates of sowing, which ranged between 27.3°C and 30.7°C, increased with delay in sowing dates. In crops sown on 1 and 10 November, it was observed that canopy temperatures were lesser than 30°C up to milking stage, whereas in crop sown on 20 November, it was lesser than 30°C up to tasseling stage. The crop sown on 30 November and 10 December were found to experience canopy temperatures being lesser than 30°C up to knee high stage. Greater than 30°C canopy temperatures are experienced by the crops, sown on 1 and 10 November, during dough and harvesting stages, the crop sown on 20 during tasseling and harvesting stages. The crops grown under the delayed dates of sowing, i.e., 30 November and 10 December, were found to experience higher than 30°C canopy temperatures during reproductive and ripening phases (tasseling to harvesting).

Mean canopy temperatures recorded in crops grown under 60 cm x 20 cm spacing varied from 23.0°C at knee high stage to 33.1°C at physiological maturity stage; in crops grown under 75 cm x 20 cm spacing, it was found to vary from 22.6°C at knee high stage to 33.3°C at physiological maturity stages; crops grown under 45 cm x 20 cm spacings, it extended from 22.9°C at knee height stage to 32.7°C at physiological maturity stage. When averaged over all the 3 spacings, mean canopy temperatures were found to be range between 22.8°C at knee height and 33.0°C at physiological maturity stage. When averaged over all the phases of growth , mean canopy temperature were found to vary within very narrow range 29.2°C under 60 cm x 20 cm and 75 cm x 20 cm spacings to 28.8°C under 45 cm x 20 cm spacings. In addition, when averaged over all the phases of growth, the lowest canopy temperature of 27.0°C was recorded in treatment combination comprising the crop sown on 1 November with spacing of 45 cm x 20 cm, whereas the highest temperature of 30.9°C was noted in treatment combination having the crop sown on 30 November with the spacings of 60 cm x 20 cm and 75 cm X 20 cm. In general, higher canopy temperature was recorded for the crop sown at 75 cm X 20 cm spacing for all dates of sowing. The higher canopy temperature in sparsely spaced maize crop in comparison to closer spacing might be due to penetration of higher amount of radiation in the crop (Kaur *et al*. 2019). On the other hand, better canopy coverage in densely planted crop enhanced evapotranspiration, leading to lower canopy temperature.

The variation in canopy temperature across different dates of sowing revealed that the canopy temperature decreased from 21 days after sowing (DAS) to knee height stage except in 10 December sown crop (D5). This may be attributed to the fact the air temperature was comparatively lower when crops sown on D1, D2, D3, D4 reached knee height stage in the month of November and December, compared to the crop sown on D5, which reached knee height stage in the first week of March, thus having higher canopy temperature for the crop sown on D5. These results are in conformity with findings of Luan and Vico (2020), who observed that there is an increase in canopy temperature from cooler temperature and wetter soil to warmer temperature and drier soil. Variation in canopy temperature for different dates of sowing and different spacings showed increase in canopy temperature from knee high to physiological maturity phase, because temperature and solar radiation kept on increasing after knee high stage in *rabi* crops. S2 (75 cm x 20 cm) spacing recorded the highest canopy temperature at all stages as widely spaced crop allows more penetration of radiation within the crop canopy. It could be observed that canopy temperature for D1 date of sowing decreased from 21 DAS to knee height stage and further increased up to physiological maturity stage. The variations of canopy temperature for D2 and D3, D4 and D5 showed similar trends except that the canopy temperature decreased from silking to milking stage for all three spacing (Fig.1). Majumder *et al*. (2016) measured canopy temperature in maize under different modified soil environment.

Variation in relative humidity within maize canopy

Significant differences in mean values of relative humidity from knee height to harvesting stage were recorded (Table 2). These values were significant in knee height, silking, dough, physiological maturity and harvesting stages. It was highly significant in dough stage. Considering spacing factor, relative humidity was significant in all phenological stages and highly significant in tasseling stage. For the interaction effect, the difference in values of relative humidity were found to be significant except at milking stage and it was found to be highest in tasseling stage.

While considering the date of sowing, for the crop sown on 1 November, relative humidity decreased from knee high to tasseling and further increased at silking stage. It ranged from 66.3% in dough stage to 76.8% in silking stage; in crop sown on 10 November, relative humidity decreased from

Table 2. Relative humidity (%) within canopy of winter maize for different dates of sowing and spacings at different phenological stages.

Treatments	Phenological stages							
Sowing dates	Knee height	Tasseling	Silking	Milking	Dough	Physiological maturity	Harvesting	Mean
D1 (01.11.2021)	75.0	70.8	76.8	75.5	66.3	75.6	74.6	73.5
D2 (10.11.2021)	75.2	72.3	75.8	75.2	68.9	77.9	73.9	74.2
D3 (20.11.2021)	75.6	72.1	71.9	73.8	74.6	76.6	75.3	74.3
D4 (30.11.2021)	76.8	70.2	71.1	74.8	75.8	76.3	68.4	73.3
D5 (10.12.2021)	72.4	70.1	79.2	75.3	75.3	69.7	75.6	73.9
Mean	75.0	71.1	74.9	74.9	72.1	75.2	73.5	
SEm (±)	0.5	0.6	0.5	0.9	0.6	0.5	0.3	
CD (p=0.05)	1.66	NS	1.82	NS	2.06	1.66	1.31	
Spacing								
S1(60 cm x 20 cm)	75.9	72.9	76.4	77.2	74.5	77.5	75.8	75.7
S2 (75 cm x 20 cm)	67.8	62.8	65.6	64.8	63.18	65.9	64.6	65.0
S3 (45 cm x 20 cm)	81.2	77.6	82.9	82.9	78.9	82.1	80.3	80.8
Mean	74.9	71.1	74.9	74.9	72.1	75.1	73.5	
SEm (±)	0.3	0.4	0.3	0.3	0.2	0.2	0.3	
CD (p=0.05)	0.94	1.20	1.00	0.97	0.85	0.86	0.89	
Interaction (DxS)								
D1 S1	74.6	71.8	77.4	78.9	67.7	79.5	77.9	75.4
D1 S2	70.8	62.5	69.6	64.9	58.8	63.7	63.8	64.9
D1 S3	79.6	78.0	83.4	83.0	72.7	83.5	82.1	80.3
D2 S1	76.4	74.6	78.7	76.9	70.4	80.5	75.5	76.1
D2 S2	69.1	62.1	66.4	65.1	60.5	68.5	65.5	65.3
D2 S3	80.2	80.4	82.5	83.7	75.9	84.7	80.8	81.2
D3 S1	75.6	74.1	74.4	75.1	78.2	79.3	76.7	76.2
D3 S2	67.6	65.9	61.2	64.4	65.0	66.5	68.9	65.6
D3 S3	83.5	76.3	80.1	82.1	80.8	84.0	80.6	81.1
D4 S1	79.4	72.3	72.5	76.4	79.0	77.8	69.3	75.2
D4 S2	67.4	62.4	60.6	64.9	65.4	70.2	60.6	64.5
D4 S3	83.8	76.0	80.4	83.3	83.2	81.0	75.4	80.4
D5 S1	73.6	72.1	79.0	78.6	77.6	70.7	79.7	75.9
D5 S2	64.6	61.2	70.2	64.8	66.2	60.9	64.1	64.6
D5 S3	79.1	77.3	88.4	82.6	82.1	77.6	83.1	81.5
Mean	75.0	71.1	75.0	75.0	72.2	75.2	73.6	
SEm (±)	0.7	0.9	0.8	1.1	0.8	0.7	0.6	
CD (p=0.05)	2.38	3.05	2.58	NS	2.58	2.28	2.10	

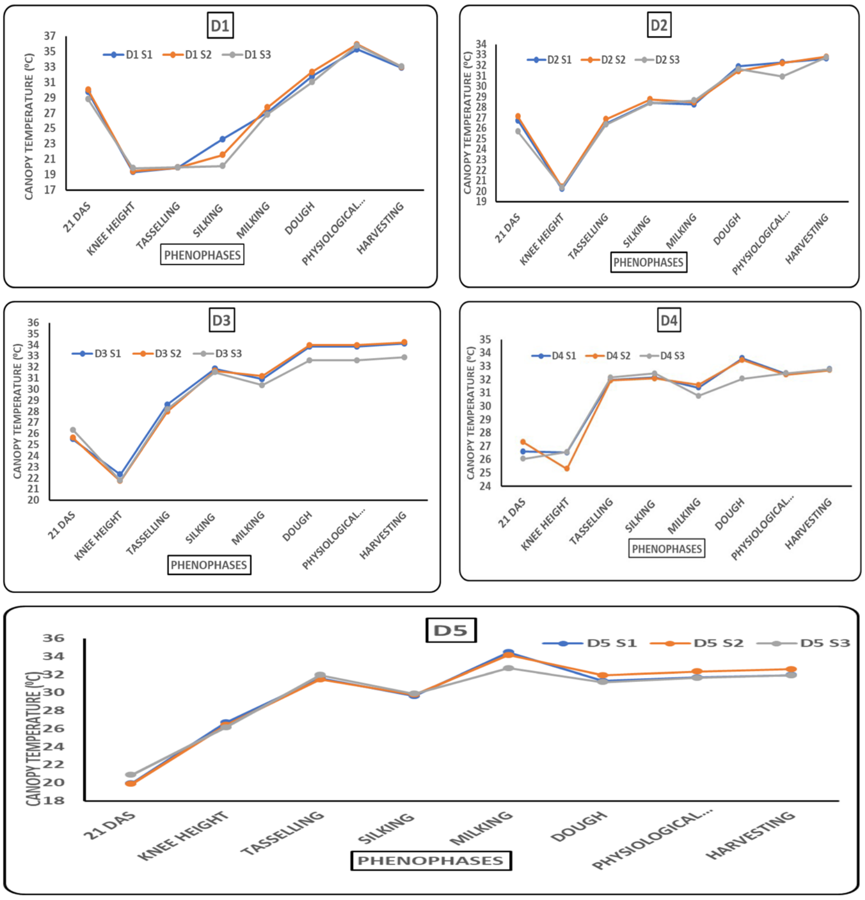

Fig.1. Variations in canopy temperature of winter maize at different spacings for D1, D2, D3, D4 and D5 dates of sowing.

knee high to tasseling stage and increased in silking stage. For both 1 and 10 November sown crops, the relative humidity was found to be the lowest in dough stage. In crop sown on 10 November, the relative humidity varied from 68.9 % in dough stage to 77.9 % in physiological maturity stage; for crop sown on 20 November, relative humidity tended to decrease from knee high to silking stage and thereafter, increased in milking stage up to physiological maturity stage. The values of relative humidity in 20 November sown were found to vary from 71.9% in silking stage to 76.6% in physiological maturity stage; for 30 November sown crop, the relative humidity decreased from knee high to tasseling stage and increased from silking to physiological maturity stage. The crop sown 30 November experienced relative humidity ranging from 68.4% in harvesting to 76.8% in knee high stage; for crop sown on 10 December, initial trend in relative humidity was found to be similar to that of other sowing dates. It decreases from knee high to tasseling stage and increases again in silking stages. After that relative humidity values were found to decline up to physiological maturity stage. The range of relative humidity varies from 69.7% in physiological maturity stage to 79.2% in silking stage. When averaged, it was observed that mean relative humidity was observed to be the lowest in tasseling stage and the highest value was recorded in physiological maturity stage. When averaged over all phases of growth, it was found that the crop sown on 20 November experiences the highest mean value of relative humidity throughout the growing season and, the lowest was associated with the crop sown on 30 November.

For spacing factor, it was observed that the mean values of relative humidity averaging over different growth phases, the lowest mean value was associated with crops grown under S2 (75 cm x 20 cm) spacing and the highest value was for most dense canopy, pertaining to the crop grown with S3 (45cm x 20 cm) spacing. For S1(60 cm x 20 cm) spacing, it was observed that the initial trend was the same as in case of date of sowing factor i.e., relative humidity decreases from knee high to tasseling stage. The highest value of relative humidity (77.5%) prevailed at physiological maturity stage and the lowest (72.9 %) was found to be associated with tasseling stage; for S2 (75 cm x 50 cm) spaced crop, the initial pattern of relative humidity was almost similar to that of S1 spaced crop, following which it varied from 62.8% in tasseling stage to 67.8% in knee height stage ; for S3 (45 cm x 20 cm) spacing, which is the densest canopy among all, the initial trend is same as that of other two spacings i.e., relative humidity value decreases from knee high to tasseling stage. The relative humidity varied from 77.6% from tasseling stage to 82.9% in both silking and milking stage. When the values of relative humidity was averaged for different phenological stages, it was observed that the lowest mean value of relative humidity was 71.1%, which was observed in tasseling stage and the highest of 75.1% was recorded in physiological maturity stage of the crop. Difference in values of relative humidity was highly significant (1.20) in tasseling stage.

Considering the interaction between both the factors, it was observed that the crop sown on 10 December with 45 cm x 20 cm spacing i.e., D5S3 treatment experienced the highest (81.5%) mean value of relative humidity and the lowest value of relative humidity (64.5%) was found in crop sown on 30 November with spacing of 75 cm x 20 cm

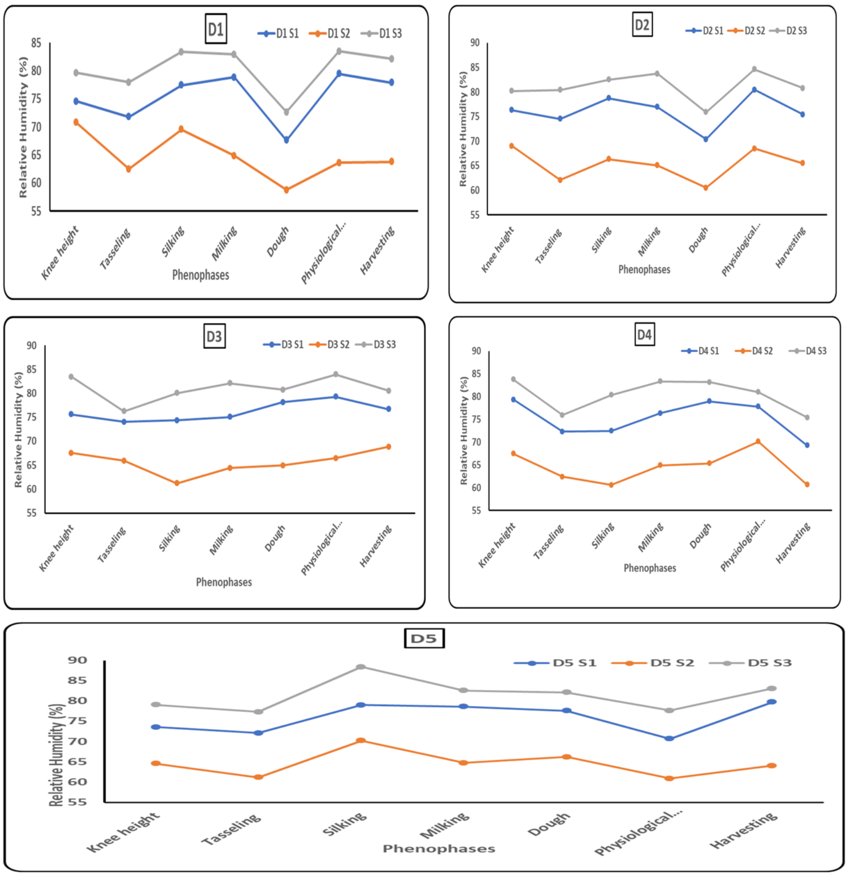

Fig. 2. Variations in relative humidity in winter maize canopy at different spacings for D1, D2, D3, D4 and D5 dates of sowing.

i.e., D4S2 treatment. The differences in relative humidity of all the treatments was highly significant in tasseling stage. Also, it was observed that relative humidity tended to fall from knee high to tasselling stage and thereafter showed an increasing trend for other phenophases due to rise in air temperature. Rising temperature and low relative humidity promote evapotranspiration in crops and grain filling in maize plant (Omoyo *et al*. 2015).

The highest relative humidity was associated with the crop sown with 45 cm X 20 cm spacing and the lowest with the crop sown with 75 cm X 20 cm, probably due to greater heating as result of thinner foliage and also dense canopy leads to higher transpiration rate that increases evaporation rate which ultimately leads to decrease in soil temperature, thus increases relative humidity. Crops sown on 20 November exhibited the highest relative humidity (74.3%). Fig. 2 depicts the variations in relative humidity for different sowing environments and spacings. Sattar *et al*. (2003) observed the influence of air temperature on the profiles of relative humidity within crop canopy.

Variation in soil temperature at 15 cm depth

Table 3. Soil temperature at 15 cm depth in winter maize for different dates of sowing and spacings at different phenological stages.

	Phenological stages							
Treatments Sowing dates	21 DAS	Knee height	Tasseling	Silking	Milking	Dough	Physiological maturity	Mean
D1 (1.11.2021)	28.6	20.0	30.1	25.7	28.5	29.6	30.1	27.5
D2 (10.11.2021)	24.7	19.8	25.7	24.3	22.2	29.4	29.9	25.1
D3 (20.11.2021)	24.7	19.7	27.6	30.0	29.8	31.5	32.0	27.9
D4 (30.11.2021)	19.3	24.4	29.2	22.1	29.8	34.7	35.2	27.8
D5 (10.12.2021)	20.7	24.4	29.2	29.4	30.7	36.2	36.7	29.6
Mean	23.6	21.7	28.4	26.3	28.2	32.3	32.8	
SEm (±)	0.4	0.1	0.1	0.1	0.1	0.1	0.1	
CD (p=0.05)	1.1	0.3	0.3	0.4	0.4	0.3	0.3	
Spacing								
S1 (60 cm x 20 cm)	23.6	21.7	28.1	26.4	28.1	32.3	32.8	27.6
S2 (75 cm x 20 cm)	24.3	22.4	29.6	27.1	29.0	33.0	33.5	28.4
S3 (45 cm x 20 cm)	23.0	20.9	27.4	25.4	27.5	31.5	32.0	26.8
Mean	23.6	21.7	28.4	26.3	28.2	32.3	32.8	
SEm (±)	0.3	0.1	0.1	0.1	0.1	0.1	0.1	
CD (p=0.05)	0.9	0.2	0.2	0.3	0.3	0.2	0.2	
Interaction (DxS)								
D1 S1	28.4	20.2	29.8	26.4	28.1	29.4	29.9	27.5
D1 S2	30.0	20.9	31.3	26.3	29.3	30.6	31.1	28.5
D1 S3	27.3	19.0	29.3	24.4	28.0	28.9	29.4	26.6
D2 S1	24.9	19.9	25.9	24.3	22.2	29.3	29.8	25.2
D2 S2	25.1	20.5	26.6	25.1	22.8	30.2	30.7	25.9
D2 S3	24.1	19.1	24.6	23.5	21.5	28.6	29.1	24.4
D3 S1	24.3	19.8	27.3	29.8	29.7	31.6	32.1	27.8
D3 S2	25.3	20.2	28.4	30.8	31.2	32.4	32.9	28.7
D3 S3	24.4	19.3	27.2	29.3	28.4	30.5	31.0	27.2
D4 S1	19.4	24.5	29.1	21.9	29.6	34.7	35.2	27.8
D4 S2	19.7	25.3	30.5	22.5	30.5	35.4	35.9	28.5
D4 S3	18.7	23.5	27.9	21.8	29.4	34.0	34.5	27.1
D5 S1	20.7	24.3	28.5	29.5	30.8	36.3	36.8	29.6
D5 S2	21.2	25.3	31.1	30.6	31.2	36.7	37.2	30.5
D5 S3	20.1	23.5	28.0	28.2	30.2	35.5	36.0	28.8
Mean	23.6	21.7	28.4	26.3	28.2	32.3	32.8	
SEm (±)	0.67	0.15	0.18	0.23	0.23	0.16	0.16	
CD (p=0.05)	NS	NS	0.53	0.67	0.68	NS	NS	

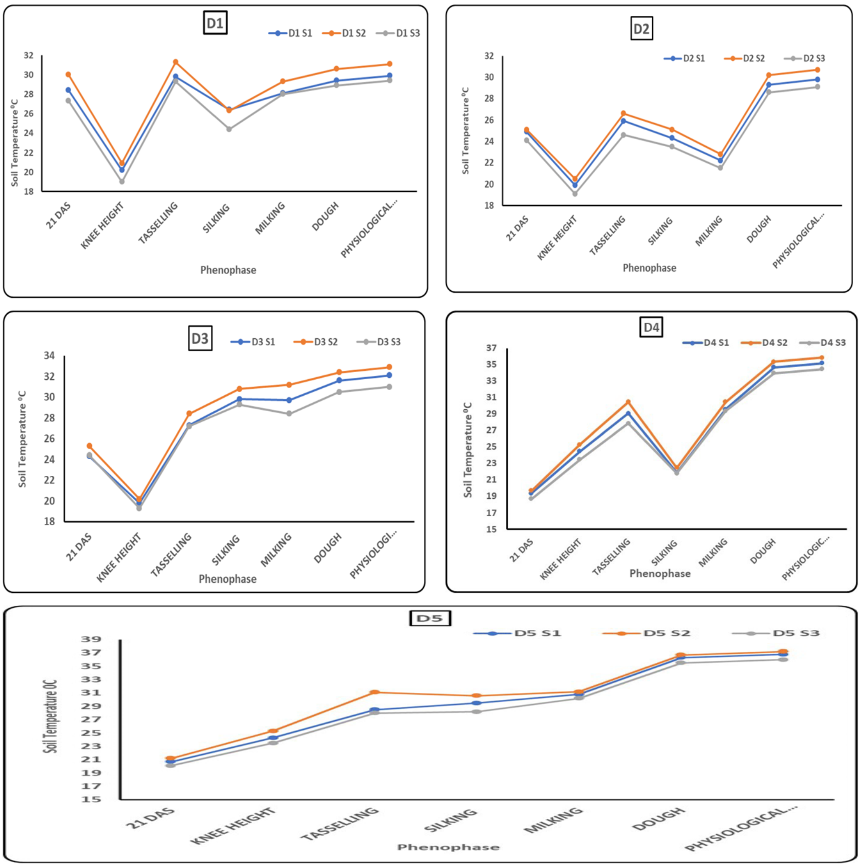

Fig. 3. Variation in soil temperature at 15 cm depth in winter maize at different spacings for D1, D2, D3, D4 and D5 dates of sowing.

Soil temperature at 15 cm depth at different phenological stages varied significantly with different sowing dates (Table 3). Similar observations were recorded for different spacings, where difference was significant in all the phenological stages. For interaction between different dates of sowing and spacings, it was observed that the difference was non-significant in 21 DAS, knee height stage, dough stage and physiological maturity stages and significant for tasseling, silking and milking stages.

Crops were sown on five different dates starting from 1 November to 10 December at an interval of 10 days. It was observed that the soil temperature at 15 cm depth varied between 20.0°C at knee height stage to 30.1°C at physiological maturity stage for the crop sown on 1 November (D1). Considering the trend in the variation of soil temperature at 15 cm depth for different phenological stages, it was observed that soil temperature decreased from 21 DAS to knee height stage and then increased in tasseling stage. For the crop sown on 10 November (D2), it was observed that the soil temperature varied from 19.8°C in knee height stage to 29.9°C in physiological maturity stages. The trend of variation in soil temperature remains similar in D2 sown crop i.e., values of soil temperature decreased from 21 DAS to knee height stage and again increased in tasseling stage. For crops sown on 20 November (D3), it varied from 19.7°C at knee height stage and 32°C at physiological maturity stage. Similar trend in variation of soil temperature was observed with crop sown on D4. Crop sown on 30 November (D4) had the lowest temperature (19.3°C) at 21DAS and the highest (35.2°C) was recorded at physiological maturity stages. Soil temperature increased from 21 DAS to physiological maturity stage. For 10 December sown crops, it was observed that the soil temperature varied from 20.7°C at 21DAS to 36.7°C at physiological maturity stages. Trends in variation were found to be similar as in D4. When averaged over different phenophases, it was found that the crop sown on 10 November exhibited the lowest soil temperature of 25.1°C. On the other hand, maximum temperature was observed for the crop sown on 10 December. Soil temperature did not cross 30.0°C upto knee height stage. Statistically, the difference of soil temperature among different dates of sowing was highly significant at 21 DAS.

For different spacings, there was significant difference among all the spacings at every phenological stage. For crops having spacing of 60 cm x 20 cm (S1), soil temperature varies from 21.7°C at knee height stage to 32.8°C at physiological maturity stage. Variation in soil temperature for different phenological stages was found to be similar as for different dates of sowing. Crops sown at 75 cm x 20 cm spacing (S2), soil temperature varies from 22.4°C at knee height stage to 33.5°C at physiological maturity stage. Trends of variation across different phenological stages was similar as S1 spacing. It was observed that soil temperature varied from 20.9°C at knee height stage to 32°C at physiological maturity stage for crops sown at 45 cm x 20 cm spacing. When averaged, it was observed that in S2 (75 cm x 20 cm) sown crops, soil temperature was recorded to be the highest (28.4°C) among all spacings, while the lowest was associated with S3 (45 cm x 20 cm) spaced crops.

Interaction between different dates of sowing and spacings revealed that the crops sown on 10 December having spacing of 75 cm x 20 cm (D5S2) had the highest mean soil temperature (30.5°C) among all treatments and crops sown on 10 November with spacing 45 cm x 20 cm (D2S3) gave rise to the lowest (24.4°C) mean soil temperature among all other treatments. It was noted here that mean soil temperature never exceeded 30°C up to knee height stage in different treatment combinations.

The variations in soil temperature at different spacing for D1, D2, D3, D4 and D5 are presented in Fig. 3. Soil temperature was found to be slightly lower for the crops sown on 2nd date of sowing (D2) and the highest for crops sown on fifth date of sowing (D5). Considering spacing factor, the soil temperature was recorded to be the lowest for S3 spacing and the highest for S2 spacing.

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