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Research Paper

Microclimatic study under wheat, mustard and chickpea crops in western plain zone of Uttar Pradesh

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ABSTRACT

The present study to quantify the variations in microclimate under wheat, mustard and chickpea crops was conducted at ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut (U.P.), India. Air temperature, relative humidity and CO_2 concentration below and above the canopies of wheat, mustard and chickpea were recorded at hourly interval from 07:30 to 17:30 hours at different heights (0.5 m, 1.0 m and 2.0 m) from the ground. CO_2 probes like GMP-343, (Diffusion aspiration) was used to record data of CO_2 concentration and HPM-75 probes was used to capture the observation of air temperature and relative humidity. Results revealed that diurnal air temperature was continuously increasing from morning to afternoon hrs and highest air temperature was recorded at 13:30 hrs (afternoon). Thereafter, air temperature decreased and reached to the lowest at 17:30 hrs irrespective of crops and height from the ground. Analysis of diurnal air temperature variations at different height clearly showed that tall statured crop such as wheat and mustard reached higher air temperature regime early (13.30 hrs) compared to short statured crop like chickpea at 15.30 hrs. Highest relative humidity was observed at 07.30 hrs and lowest relative humidity was recorded either at 13:30 hrs or at 15:30 hrs. As per study maximum CO_2 concentration was found at 07:30 hrs morning and minimum at 15:30 hrs. The lowest concentration of CO_2 (624 ppm) was recorded from the chickpea field and highest from the mustard field (630 ppm) at the same point of observation during vegetative phase of crops.

***Keywords**:* Diurnal variation, Canopy, Temperature profile, Humidity profile, CO_2 concentration, Phenophases

Microclimate refers to climatic conditions in a smaller area i.e., a few meters above or below the earth surface or within the crop canopy (Yoshino, 1974). It is the local climatic condition near the ground or area around the plants (up to about 2 m height) resulting from the general climatic conditions (Maliwal, 2011). It is influenced by the effects of the relief, topography, and the lower surface features, which create disparity between soil and air temperature, humidity, and wind speed (Bishnoi, 2010). No doubt, growth and development of plants mainly depends on their genetic constitution and environmental conditions. However, the lack of favourable climatic elements in the immediate vicinity of the plants are very important as they regulate and determine the physiological reactions and energy exchange process resulting in undesired decrease in crop productivity (Kingra and Kaur, 2017). All the crop management practices namely sowing time, planting method, row spacing, inter cropping, tillage practices, mulch application, shelter belts and irrigation managements etc. affect the microclimate due to their effect on canopy temperature, wind speed, soil moisture, high light interception, and rate of water loss (Kingra and Kaur, 2017; Reddy *et al*., 2022; Kaur *et al*., 2023). The growth and development of crop depends upon the quantitative effect of temperature or thermal time. The solar energy in plant canopy influences the temperature which controls the rate of biochemical and physiological processes depending upon photosynthetically active radiation. Temperature has capacity to change extremely in the first few tens of millimetres from the surface into soil or into the

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air. Shamim *et al*., (2008) reported that vertical profiles of ambient temperature in soybean + pearlmillet intercropping was inverse throughout the day in comparison to the bare field.

As per Srivastava (2023), western plain zone of Uttar Pradesh has the highest land productivity in the state. About 70% land is under agriculture and 5% is under forest cover with 76% of the net sown area as irrigated. Tube wells are the pre-dominant source of irrigation. The climate of zone is dry sub humid to semi-arid and the soil is loam to sandy loam. Under this agroecosystem, besides manageable production factors such as soil productivity, availability of irrigation water, improved seeds etc., natural production elements like air temperature, relative humidity and CO_2 concentration in the field condition need to be studied. This study can be helpful in the simulation for projected various climate change scenarios. Keeping this point in view, the present study had been undertaken with the objectives to study the variations in diurnal as well as vertical air temperature, relative humidity, and CO_2 concentration under at different phenophases of crops like wheat, mustard and chickpea.

MATERIALS AND METHODS

Field experiment was conducted at ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut (U.P.), India (29.04' N latitude, 77.05' E longitude, and 230 m AMSL) during 2019-20. The sub-tropical semi-arid climate of Modipuram is characterized by scorching summers, cold winters with about 854.26 mm of average annual rainfall, and nearly 1600 mm of potential evapotranspiration. The soil was Typic Ustochrept, deep sandy loam, and slightly saline (pH 8.3). During *rabi* season of 2019-20, wheat + mustard (9:1) with row spacing of 22.5 cm were sown on 25th October 2019, mustard crop with inter row spacing of 15 cm between two rows of kinnow and chickpea as sole crop with row spacing of 30 cm were sown on 16th November 2019. Cultivars like HD-3086, RH-749 and Ganguar (GNG-1581) and were taken for wheat, mustard, and chickpea respectively. The plots sizes were 625 m^2 for each crop, i.e. intercrop of wheat + mustard (9:1), mustard sole and chickpea sole. To make observations on crop phenology and yield, plot size of 10 m x 10 m was marked in each treatment at 3 different spots randomly.

The seed rates for wheat and mustard were 100 kg ha^{-1} and 1 kg ha^{-1} respectively, applied for wheat + mustard (9:1) while 80 kg ha^{-1} for chickpea and 10 kg ha^{-1} for mustard sole were applied. All the crops were sown in lines in lines. Recommended dose of nitrogen, phosphorous and potash @ 150 kg ha^{-1}, 60 kg ha^{-1} and 40 kg ha^{-1} in case of wheat, @ 80 kg ha^{-1}, 40 kg ha^{-1} and 40 kg ha^{-1} in case of mustard and 20 kg ha^{-1}, 40 kg ha^{-1} and 20 kg ha^{-1} in case of chickpea was applied. Other agronomical management practices such as irrigation, weeding, plant protection for each crop was applied as per recommendation of package of practices.

Replicated (3 times) micro-meteorological observations such as air temperature and relative humidity were recorded in experimental field at the interval of 2.0 hrs starting at 07.30 hrs to 17.30 hrs at weekly intervals and averaged to 15 days intervals from crop emergence to physiological maturity. The in-situ CO_2 concentration was measured during crop vegetative to physiological maturity of mustard and chickpea while up to dough stage in the case of wheat using CO_2 probes like GMP 343, (Diffusion aspiration) whereas HPM75 probe was used to take the in-situ observations of air temperature and relative humidity at different heights i.e., 0.5 m, 1.0 m and 2.0 m in different crops like wheat, mustard and chickpea during vegetative to physiological maturity. In short statured crop like chickpea and wheat, observations were taken at only two heights i.e., 0.5 m and 1.0 m. The presentation of these micrometeorological observation was made on phenology basis matching with the observations date with the occurrence of a particular event in the wheat, mustard, and chickpea crops.

RESULTS AND DISCUSSIONS

Profile and diurnal air temperature, relative humidity, and CO_2 concentration in wheat

At vegetative phase of crops, highest air temperature of 18.0°C was recorded and at panicle stage it was 18.3°C at 13:30 hrs at 0.5 m height. However. The lowest air temperature of 9.4°C was found at 07:30 hrs at 1.0 m height at vegetative phase and 7.8°C at the same point of time but at 0.5 m at panicle initiation phase. The highest temperatures of 24.8°C, 27.7°C and 29.4°C were recorded at 0.5 m and 1.0 m and 1.0 m at 13.30 hrs during milking, dough, and physiological maturity stage respectively. However, an opposite trend, both in time and vertical height was found in terms of lowest temperatures which were recorded at 07.30 hrs at 1.0 m, 0.5 m and 0.5 m with the values of 13.3°C, 18.0°C and 19.3°C during the similar phenophases (Fig. 1a). The crop was exposed to the environment having 7.8°C to 29.4°C during the complete life cycle. Diurnal study showed that air temperature attended the peak at 13.30 hrs, but it remained above the 25.34°C even after 17.30 hrs at physiological maturity.

Relative humidity in the range of 38% (at physiological maturity) to 100% (at panicle initiation) was recorded as a component of microclimate under the vicinity of wheat. At vegetative stage highest relative humidity was recorded at 7.30 hrs at both heights (0.5 m and 1.0 m). However, lowest relative humidity (52%) was recorded at 1.0 m height. Crop was exposed to 100% relative humidity at morning hours (7.30 hrs to 9.30 hrs) only during panicle initiation at both the heights (0.5 m and 1.0 m). The lowest relative humidity (38% to 78%) at every point of observation were recorded at physiological maturity except dough stage (44%) at the height of 1.0 m at 15.30 hrs (Fig. 1b).

Wheat crop showed maximum CO_2 concentration of 649 ppm at 0.5 m height at 09:30 hrs while lowest (626 ppm) at 15:30 hrs at 0.5 m height during vegetative phase and it was highest (659 ppm) at 1.0 m height on 07:30 hrs while lowest (625 ppm) was recorded at 13:30 hrs at 0.5 m height during panicle initiation stage. During the entire crop season, both extremes of higher (666 ppm) and lower (582 ppm) concentration of CO_2 were recorded in the milking stage of the crop. The higher concentration was recorded during morning time (07.30 hrs) and lower concentration was recorded during afternoon (13.30 hrs). A wide gap was observed in concentrations of CO_2 shown in the line graphs of milking and dough stages at 1.30 hrs. However, these lines overlap to each other 15.30 hrs and thereafter (Fig. 1c).

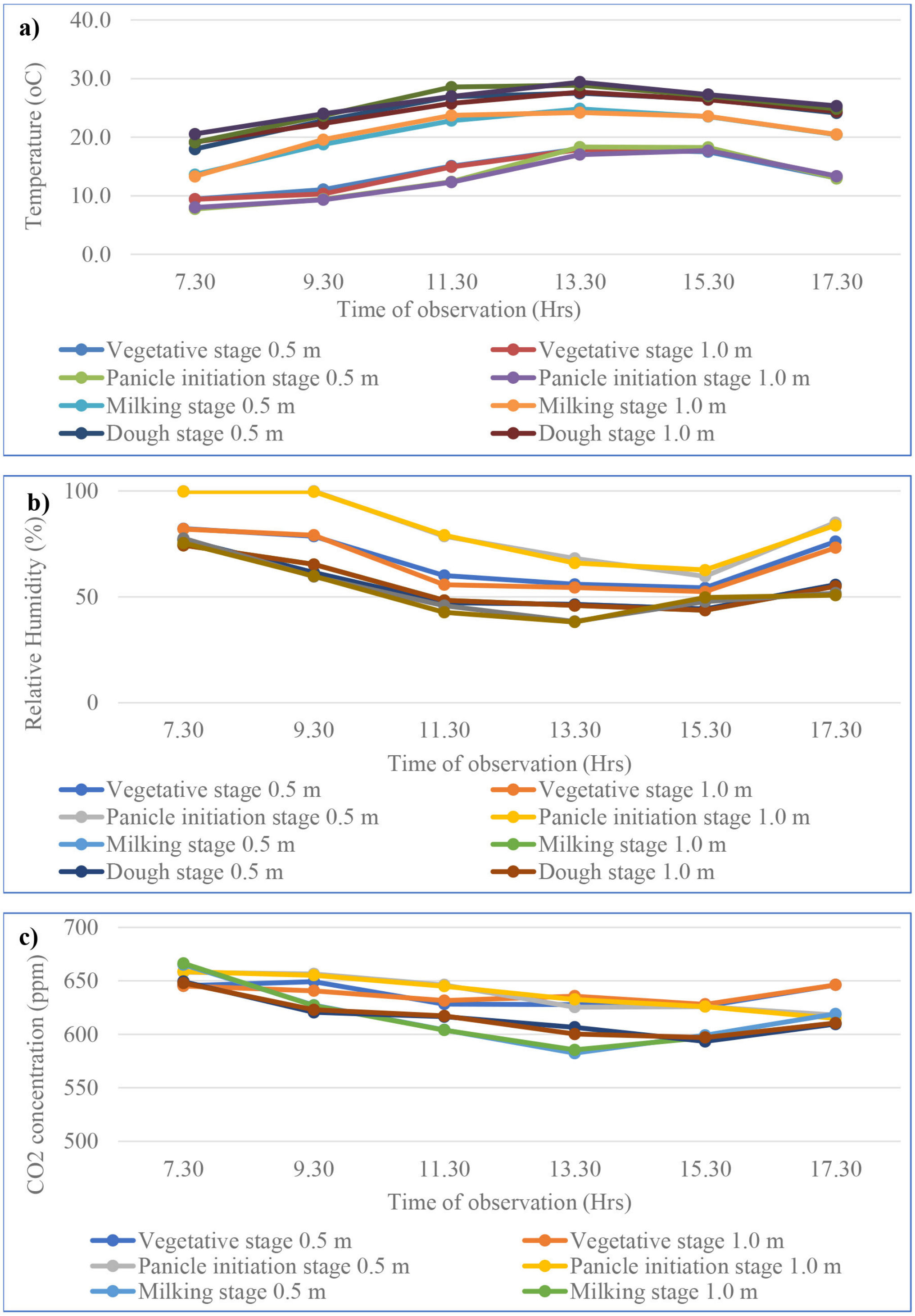

Fig. 1: Diurnal and vertical variation in a) air temperature, b) relative humidity and c) CO_2 concentration at various stages of wheat at 0.5 m and 1.0 m height from the ground.

Profile and diurnal air temperature, relative humidity, and CO_2 concentration in mustard

At vegetative phase, highest air temperature of 19.2°C was recorded at 0.5 m height at 13:30 hrs and lowest air temperature of 9.3°C was recorded at 07:30 hrs at 1.0 m height from the surface in mustard. At the flowering stage of mustard, the highest air temperature of 19.2 °C was recorded at the height of 0.5 m at 13:30 hrs and lowest air temperature was recorded at 07.30 hrs at the vertical height of 2.0 m. Diurnal variation of 13.1°C to 27.6°C was recorded at siliqua formation stage of mustard. At physiological maturity, highest temperature 28.4°C was found at 2.0 m height on 11:30 hrs and lowest temperature 17.7°C was recorded on 07:30 hrs at 0.5 m height (Fig. 2a).

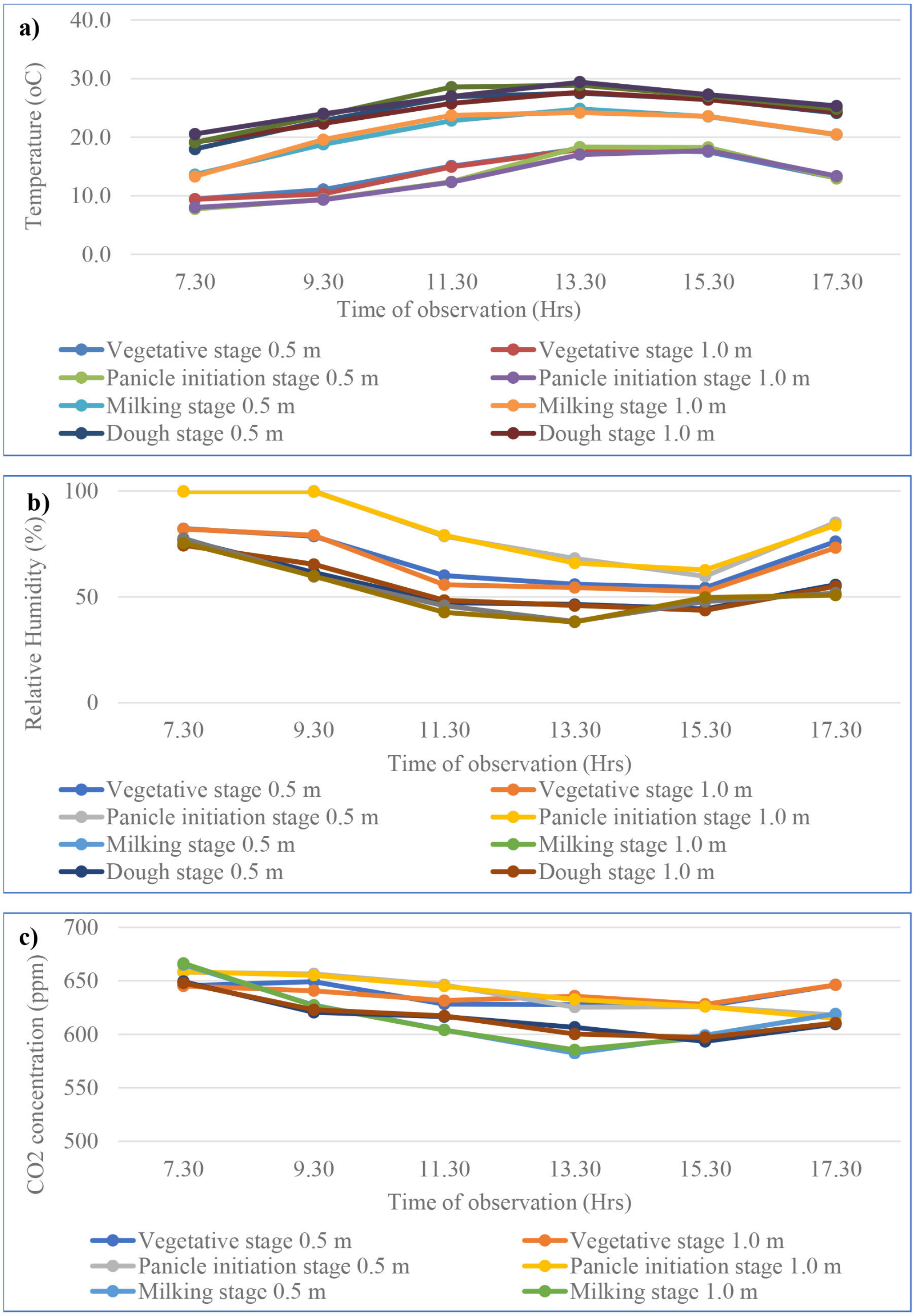

Fig. 2: Diurnal and vertical variation in a) air temperature, b) relative humidity and c) CO_2 concentration at various stages of mustard at 0.5 m, 1.0 m and 2.0 m height from the ground

Relative humidity at vegetative phase ranged between 50% to 99% whereas these were 44% to 99%, 38% to 82% and 36% to 77% for flowering, siliqua formation and physiological maturity respectively. The crop experienced highest magnitude of relative humidity (99%) only at flowering phase during morning hours (07.30 hrs to 09.30 hrs) irrespective of distance from the soil surface. The trends of all the lines of the graphs are almost similar across the day however these were zigzag during mid-day (11.30 hrs to 15.30 hrs) (Fig. 2b).

Prevailing CO_2 concentration in the mustard field was recorded in the range of 626 ppm (at 15.30 hrs at the height of 1.0 m) to 658 ppm (at 07.30 hrs at the height of 2.0 m). However, these data were in the range of 613 ppm to 660 ppm at the

Table 1: Optimum temperature range for lower microclimate CO_2 concentration in the canopy of different crops

Crops	Vegetative phase		Reproductive phase	
	13.00 hrs	15.30 hrs	13.30 hrs	15.30 hrs
Wheat	18.0°C	17.7°C	17.7°C	18.0°C
Mustard	18.5°C	17.2°C	17.7°C	18.0°C
Chickpea	17.4°C	17.9°C	17.8°C	18.6°C

flowering stage. In the entire crop season i.e. from vegetative to physiological maturity, both the extremes of 679 ppm (at 07.30 hrs at the height of 2.0 m) and 574 ppm (at 13.30 hrs at the height of 0.5 m) were recorded at siliqua formation stage of the crop. During the physiological maturity phase these data points were lower than the siliqua formation phase. Fig. 2c showed that all the lines are overlapped with each other during morning hours (at 7.30 hrs and 9.30 hrs) except points of sliliqua formation at the height of 2.0 m, and again it is almost merged during evening hours. But the lines are very staggered during mid-day (11.30 to 15.30 hrs).

Profile and diurnal air temperature, relative humidity, and CO_2 concentration in chickpea

Chickpea experienced temperature range of 8.1°C to 28.8°C during the vegetative to physiological maturity phase. At branching stage, highest air temperature of 18.4°C was recorded at 15:30 hrs at 1.0 m height from the ground and lowest of 9.5°C was observed at 07:30 hrs at 0.5 m height. During flowering phase of the crop, the temperature range was 8.1°C to 18.8 °C while it was 12.5°C to 24.2°C during pod setting stage. The temperature range (17.3°C to 28.8°C) was found to be increased during physiological maturity phase. The pattern of diurnal air temperature variations was found to be similar from vegetative to flowering phase in reaching to highest temperature at 15.30 hrs while it was similar in pod setting to physiological maturity in attaining the highest air temperature at 13.30 hrs. Vertical temperature profile i.e. magnitude of air temperature was increased with height, was similar from vegetative to pod setting stage and it was reversed at physiological maturity i.e. decreased with height at all points of time except 07.30 hrs (Fig. 3a).

The crop exposed to the relative humidity in the range of 34% (at 13.30 hrs at the height of 1.0 m) to 100% (at 7.30 hrs at the height of 0.5 m). During vegetative phase, 51% to 83% relative humidity were recorded above and below the canopy across the day. However, it was highest (100%) during flowering stage of the crop. In the post flowering stage both temporal and profile wise variations in the relative humidity was observed to be least. The pattern of distributions of lines are almost like the diurnal patterns of lines shown in Fig. 1b and 2b of the case of wheat and mustard.

Chickpea modified the atmospheric CO_2 concentrations to 595 ppm (at 13.30 hrs at the height of 0.5 m) to 670 ppm (at 07.30 hrs at the height of 0.5 m) during the entire cropping season. Phenophase wise trends of CO_2 concentrations showed that chickpea was able to reduce the atmospheric CO_2 concentrations up to maximum extent during pod setting stage and least by flowering stage. Fig. 3c showed clearly that lines of diurnal CO_2 concentrations at vegetative and flowering stage are overlapped with each other at 13.30 hrs irrespective of heights from the surface and almost similar in case of pod setting and physiological maturity stage of the crop.

Temperature profile study indicated that erected architect of the crop allowed to penetrate solar radiation to the vicinity of soil surface (0.5 m) resulted into higher air temperature in comparison to upper layer of the canopy at 1.0 m. However, spreading architect of crop like chickpea did not allow the solar radiation hence air temperature remained lower in the vicinity of soil surface. Diurnal dynamics of relative humidity revealed that highest relative humidity was observed at 07.30 hrs mornings, and it decreased with increasing intensity of solar light. Lowest relative humidity recorded in 13:30 hrs to 15:30 hrs irrespective of crop and height. Relative humidity was higher at the ground level in all the days of observation irrespective of crop. It was observed the relative humidity varied within the plant canopy and was minimum at the top of the crop. Higher relative humidity under canopy indicates that the canopy influences the microclimate of the environment. It was not able to affect the microclimate inside the canopies and immediately above them. This might be due to evapotranspiration within the canopy which resulted in more exchange of water vapour with upper air layer over the canopy. Higher humidity within canopy might be due to active transpiration by dense foliage at the height and more turbulence at top surface during noon hours as compared to under canopy.

The CO_2 concentration influences the photosynthesis rate, metabolism and physiological and chemical nature of plants. As an essential substrate of the photosynthesis process, CO_2 is directly absorbed by plants. CO_2 also influences the transpiration process of plants. Irrespective of type of crops (Oil seeds, legumes, and cereals), maximum CO_2 concentration under the canopy and just above it, was found during morning hours (07:30 to 09.30 hrs) and decreased after it and least concentration of CO2 was observed at 15:30 hrs. This decreasing trend of CO_2 concentration during afternoon may be due to enhancement in consumption of CO_2 for the process of carbohydrate assimilation through photosynthesis.

This diurnal trend of CO_2 concentration was due to suboptimal temperature and light intensity during the morning and evening hours which were independent of crop type. The lowest concentration of CO_2 during afternoon (15.30 hrs) evidenced the availability of optimal conditions for photosynthesis which attracted the authors to see the differences in CO_2 concentration among the different crop fields. The lowest concentration (624 ppm) was recorded from the chickpea field and highest from the mustard field (630 ppm) at the same point of observation. This result clearly showed discreate discrepancy in the efficiency of the crops (such as oilseeds, legumes, and cereals) in rate of consumption of CO_2 under optimal environment condition.

By viewing the Fig. 1c, 2c & 3c the diurnal pattern of CO_2 concentration was found to be different at different phenophases such as vegetative and flowering. The lowest CO_2 concentration was recorded at 15.30 hrs at vegetative phase while at reproductive stage, it was lowest at 13.30 hr. This diurnal difference in the CO_2 concentration might be due to achievement of optimum air temperature at 15.30 hrs during vegetative phase and at 13.30

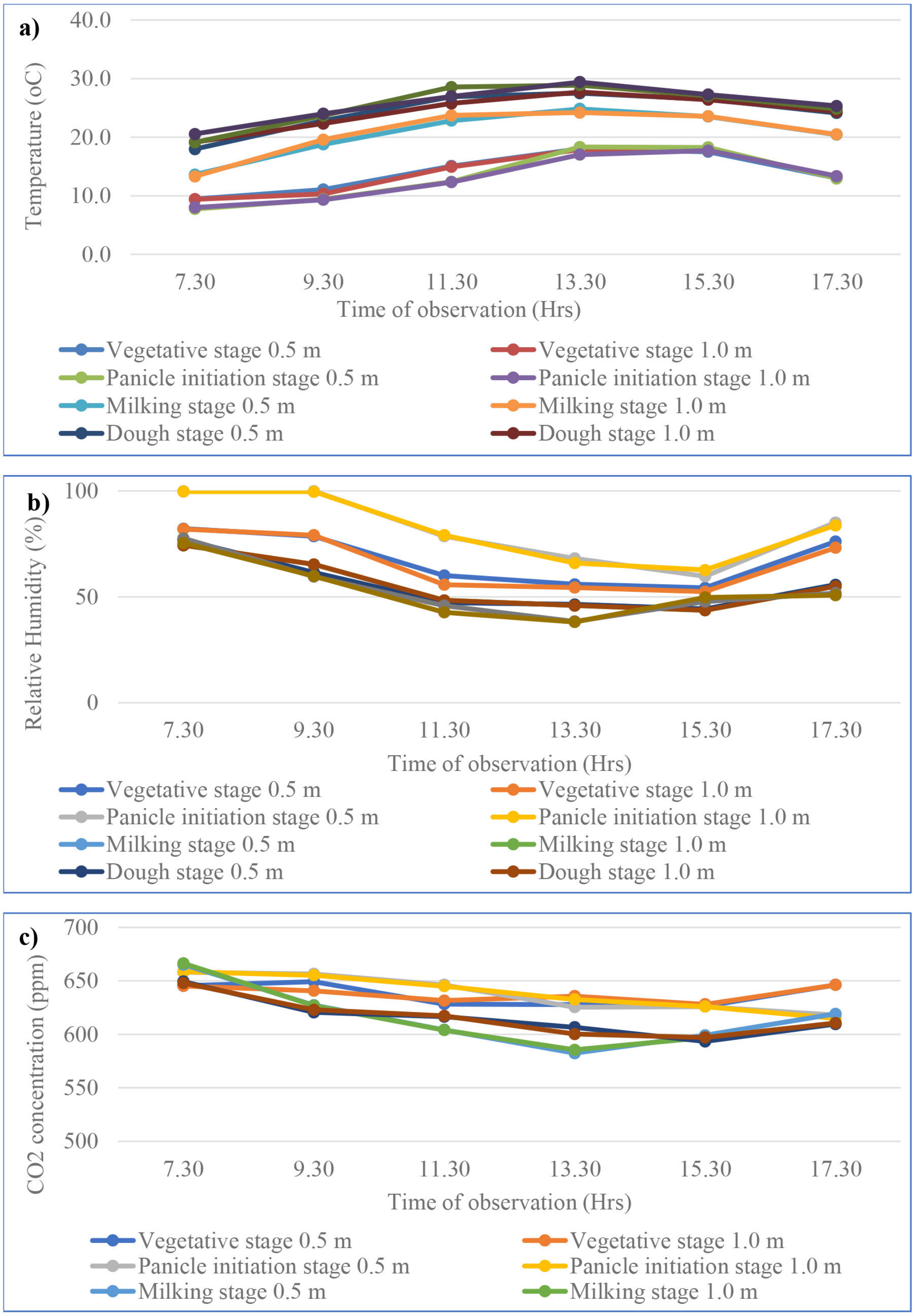

Fig. 3: Diurnal and vertical variation in a) air temperature, b) relative humidity and c) CO_2 concentration at various stages of chickpea at 0.5 m and 1.0 m height from the ground

hrs during reproductive phase of crops. The average optimum air temperature for the mustard, chickpea and wheat were found to be in the range of 17.2°C to 17.7°C, 17.8°C to 17.9°C and 17.7°C respectively (Table 1).

CONCLUSION

Air temperature of crops field was found to be lower during morning hours compared to afternoon hours while relative humidity and CO_2 concentration profile was reverse of it. The optimum temperature for modifying ability of atmospheric CO_2

concentrations for different crop was different and was found to be in the range of 17.2°C to 17.7°C, 17.8°C to 17.9°C and 17.7°C for mustard, chickpea, and wheat which may be utilized as input for projecting the yield of studied crops under various scenarios of climate change for understanding the national food status of cereals, legumes and oilseeds.

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Data availability statement: Data sets were generated as a part of M.Sc. thesis by the first author, M.Sc. student of Department of Agrometeorology, IGKVV, Raipur.

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REFERENCES

Bishnoi, O. P. (2010). Applied micrometeorology, applied climatology, Oxford Book Company, Jaipur, India. 70 (1-2): 114-122.

Kaur, Jobanpreet, Navneet Kaur, Sarabjot Kaur Sandhu, and Harmandeep Kaur (2023). Microclimate and thermal indices of garden pea (*Pisum Sativum* L.) under poplar (Populus Deltoides Bartr.) based agroforestry system. *J. Agrometeorol.*, *25*(2): 330–332. https://doi.org/10.54386/jam.v25i2.2054

Kingra PK and Kaur H (2017). Microclimatic Modifications to Manage Extreme Weather Vulnerability and Climatic Risks in Crop Production. *J. Agri. Physics*, 17 (1): 1-15.

Maliwal, P.L. (2011). Agronomy at a glance, pp. 337. S SS Printers, New Delhi

Reddy, D. C., Dheebakaran, G., Thiribhuvanamala, G., Kokilavani, S., and Sathyamoorthy, N. (2022). Seasonal variation of paddy straw mushroom performance under different microclimate environments. *J. Agrometeorol., 24*(4): 367–372. https://doi.org/10.54386/jam.v24i4.1806

Shamim, M., Singh, R., Rao, V. U. M. and Singh, D. (2008). Microclimatic profiles in soybean-pearl millet intercropping system. *J. Agrometeorol.,* 10 (2): 151-157.

Srivastava N.S.L (2023). Long-term Strategies and Programmes for Mechanization of Agriculture in Agro Climatic Zone–V: Upper Gangetic Plains region 06035-04-ACZ5-15052006 (farmech.gov.in)

Yoshino, M. M. (1974). Agricultural Climatology in Japan, In Agricultural Meteorology of Japan, Education Yoshiaki Mihara. University of Tokyo Press: 19-21.