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Quantification of microclimate and its effect on yield of field crops under Agri-horti system in Western plain zone of Uttar Pradesh

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Abstract
Result revealed that diurnal dynamics of temperature was continuously increasing from morning to noon hrs (07:30 hrs to 13:30 hrs) and highest temperature was recorded at 13:30 hrs (afternoon) due to highest light intensity. Thereafter, temperature was decreased and reaching to the lowest at 17:30 hrs irrespective of crops and height from the earth surface. Highest relative humidity was observed at 07.30 hrs morning and lowest relative humidity was recorded in 13:30 hrs to 15:30 hrs. Thereafter, it again increased from evening 17:30 hrs to morning 07:30 hrs. As per study maximum CO_2 concentration was found at 07:30 hrs morning and decreased at 15:30 hrs. This decreasing trend of CO_2 concentration after afternoon may be due to enhancement in consumption of CO_2 for the process of carbohydrate assimilation through photosynthesis which reached to maximum at 15:30 hrs.

Keywords: Temperature, relative humidity, CO_2

1. Introduction

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) [15]. It is the local climatic condition near the ground or area around the plants (up to about 2m height) resulting from the general climatic conditions (Maliwal, 2011) [10]. It also refers to the climate of small region 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) [4]. Growth development of plants mainly depends on their genetic constitution and environmental conditions. Climatic elements in the immediate vicinity of the plants are very important as they regulate and determine the physiological reactions such as optimal climatic elements leading to disturbance in plant physiological and energy exchange process resulting in undesired decrease in crop productivity. Microclimate of the crop varies from top to bottom of the canopy. 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 interception and rate of water loss etc.(Kingra & Kaur, 2017) [8].

2. Material Method

The present investigation on ‘‘Quantification of Microclimate and its effect on yield of field crops under Agri - horti system in Western Plain Zone of Uttar Pradesh” has been conducted during rabi season, 2019-20 at present farm of ICAR-IIFSR meerut. The details of materials used and techniques adopted during the course of investigation have been described in this chapter under following heads.

The field observation during was taken the rabi season 2019-20 at ICAR-IIFSR Modipuram, Meerut. Research area situated in sub-tropical at latitude 29.06° N, longitude 77.71° E and altitude of 237 meters above mean sea level.

Meerut comes under the sub-tropical climate. The average rainfall of this place is 845 mm which is received mostly from the south-west monsoon, commencing from around last of June and continues till the middle of September.

Maximum rainfall around 80% of annual rainfall is received during south- west monsoon period and rest amount is received in the month of October & November. Maximum temperature is observed during April and May which ranges between 36.3 ºC to 39.1 ºC. The lowest minimum temperature is observed during December and January which varies from 8 ºC to 7.2 ºC.

The weather data i.e. maximum temperature, minimum temperature and sunshine hours have been collected from agro-meteorology observatory in the field of ICAR-IIFSR, Modipuram, Meerut for the year 2019-20.

Micro-meteorological observations were recorded in experimental field throughout the day time at the interval of 2.0 hrs starting at 07.30 hrs to 17.30 hrs at 15th day’s intervals. CO_2 probes like GMP343, (Diffusion aspiration) were used to collect data of CO_2 concentration and HPM75 probe were used to take the observations of temperature and relative humidity at different heights i.e. 0.5m, 1m, 2m and 3m in field crops like Mustard, chickpea and wheat. In short statured crop like chickpea and wheat observations were taken at on only two heights i.e., 0.5m and 1m.

3. Results and Discussion

Diurnal profile of temperature, RH and CO_2 at different height in different field crops.

3.1 Temperature profile at different height in different field crops

During the month of November (27/11/2019), highest temperature 26.3 ºC was found at 13:30 hrs in mustard crop (emergence) at height of 1m from the ground. However, highest temperature 26.5 ºC was recorded at same time in chickpea crop (emergence). The lowest temperature 12.7 ºC was observed in mustard at 1m height and 14.3 oC was recorded in chickpea at 0.5m height during the day period at 17:30 hrs. Temperature ranges between 12.9 ºC to 26.1 ºC, 12.7 oC to 26.3 oC, 13.2 oC to 26.1 oC and 13.9 ºC to 25.7 ºC at 0.5m, 1m, 2m and 3m, respectively in mustard crop. However, temperature ranges between 14.3 ºC to 26.3 ºC and 14.6 ºC to 26.5 ºC at 0.5m and 1m, respectively in chickpea crop.(Fig 1.1)

In mustard (emergence), highest temperature was found 22.6 ºC at 1m height on 13:30 hrs followed by 22.4 ºC at 2m height while lowest temperature was recorded 8.8 ºC at same height on 07:30 hrs and 8.8 ºC at 0.5m height in December month (11/12/2019). In chick pea (emergence), highest temperature was found 24.1 ºC at 1m height and lowest 10.2 ºC was observed in 07:30 hrs at 0.5m height (Fig 1.2).

In 25th December 2019, temperature ranges between 16.2 ºC to 8.6 ºC, 17.1 ºC to 8.5, 17.5 ºC to 8.7 ºC and 16.1 oC to 8.6 ºC at 0.5m, 1m, 2m and 3m, respectively in mustard crop (emergence). Highest temperature 17.5 ºC was found at 2m height on 13:30 hrs and lowest temperature 8.5 ºC was recorded on 07:30 hrs at 1m height. However, highest temperature 15.9 ºC was recorded on 15:30 hrs at 1m height from earth surface and lowest 8.7 oC was found on 07:30 hrs at 0.5m height in chickpea (branching stage). Similarly pattern was observed in wheat crop at (emergence), highest temperature 16.1 ºC was observed in 15:30 hrs at 1m height while lowest temperature 8.5 ºC was found on 07:30 hrs at 1m height (Fig 1.3).

The fig. 1.4 depicted that the highest temperature in mustard crop (vegetative stage) was found 20.5 ºC at 0.5m height on 13:30 hrs followed by 20.0 ºC at 3m height while lowest temperature was recorded 7.2 ºC at 1m height on 07:30 hrs followed by 7.3 ºC at 0.5m height in January month (08/01/2020). Whereas chick pea (branching stage) shows highest temperature 19.7 ºC at 1m height and lowest 7.4 ºC on 07:30 hrs at 1m height. Similarly, highest temperature 20.2 ºC was observed in wheat crop 13:30 hrs at 0.5m height while lowest temperature 7.1 ºC was found on 07:30 hrs at 1m height in wheat crop (CRI stage).

Fig. 1.5 shows that in the month of January (22/01/2020), highest temperature 19.8 ºC was found at 15:30 hrs in mustard crop (flowering stage) at height of 1m from the ground. However, highest temperature 19.1 ºC was recorded on same time at 0.5m height in chickpea crop (flowering stage) and highest temperature 19.4 oC was observed at same time in wheat crop (tillering stage). The lowest temperature 9.5 ºC was observed in mustard at 0.5m height and 10.0 ºC was recorded in chickpea at same height and 9.4 ºC was recorded in wheat crop at 0.5m height during the day period at 07:30 hrs. Temperature ranges between 9.5 ºC to 19.4 ºC, 9.6 ºC to 19.8 ºC, 9.6 ºC to 19.6 ºC and 9.7 ºC to 19.0 ºC at 0.5m, 1m, 2m and 3m respectively in mustard crop. In wheat crop, temperature ranges between 10.0 ºC to 19.1 ºC and 10.1 ºC to 19.0 ºC at 0.5m and 1m respectively in chickpea crop. However temperature ranges between 9.4 ºC to 19.4 ºC and 9.6 ºC to 18.9 ºC at 0.5m and 1m, respectively.

Temperature is of the key factors that affect the seed germination, physical development, flower formation and yield. However, physiological processes and their integration speed up under higher temperature with both positive and negative effects. High temperature promotes faster growth and greater fruit production of plants, especially in cereals but they also remove functional components from leaves through high transpiration rates.

Diurnal dynamics of temperature showed that the temperature was continuously increasing 07:30 hrs to 13:30 hrs. Highest temperature was recorded at 13:30 hrs (afternoon) due to highest light intensity thereafter temperature decreased and reaching to the lowest at 17:30 hrs irrespective of crops and height from the earth surface.

Baldocchi *et al.*, 1983 [3] reported that air temperature is one of the very important factors which are affecting crop production. It affects growth and development of crop or plant in terms of development of phenology of crops. Air temperature profile was affected by leaf orientation and leaf pubescence with phenophitic canopy in soybean. Air temperature decreased with depth to a maximum in mid canopy and decreased with further depth into lower canopy. Within the electrophite canopies, the air temperature profile either lapse or isothermal and they concluded that air temperature was height in the canopy with dense leaf pubescence.

Sharma *et al.*, 2018 [13] revealed that the diurnal temperatures were higher in east-west cotton hybrids as compared to north-south hybrids. The diurnal spread of temperature profiles was higher in first sown cotton hybrids as compared to late sown hybrids. The diurnal spread of temperature profiles was nearly same in all the cotton hybrids**.**

Khichar and Niwas (2006) [7] also reported the temperature profile in wheat crop under different sowing environments. Similar results on temperature profiles were found by Singh *et al.*, (2005) [14] in cotton crop and Bose (2008) [5] in pearl millet. Kingra *et al*. (2013) [9] also observed lower canopy temperature under higher irrigation application in wheat crop.

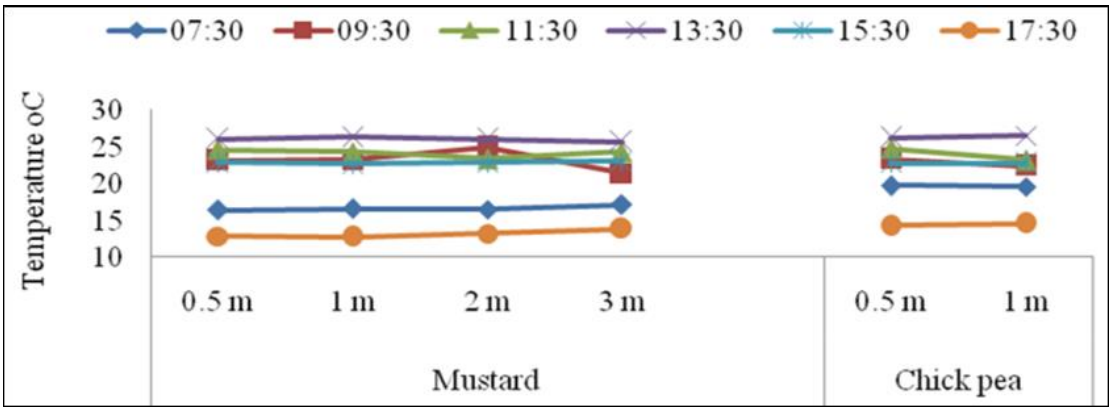

Fig 1.1: Diurnal variation in Temperature on 27/11/2019 in different height from the ground under the canopy of field crops

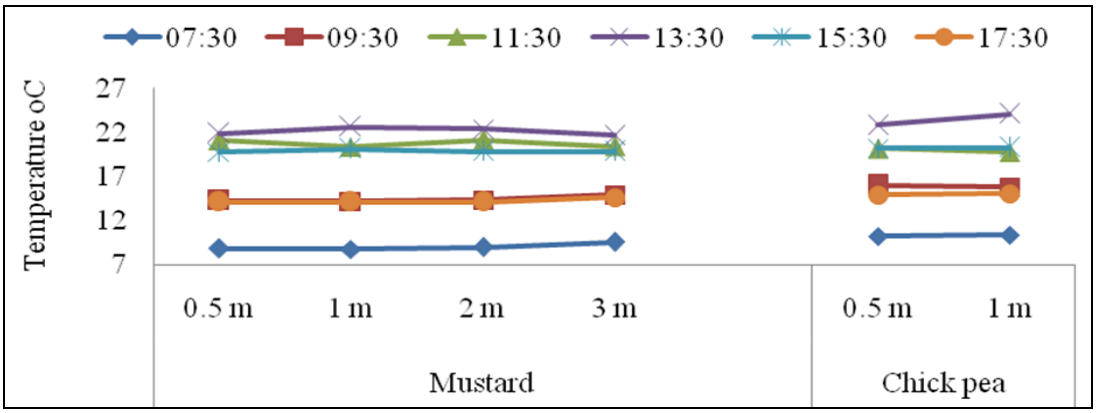

Fig 1.2: Diurnal variation in Temperature on 11/12/2019 in different height from the ground under the canopy of field crops

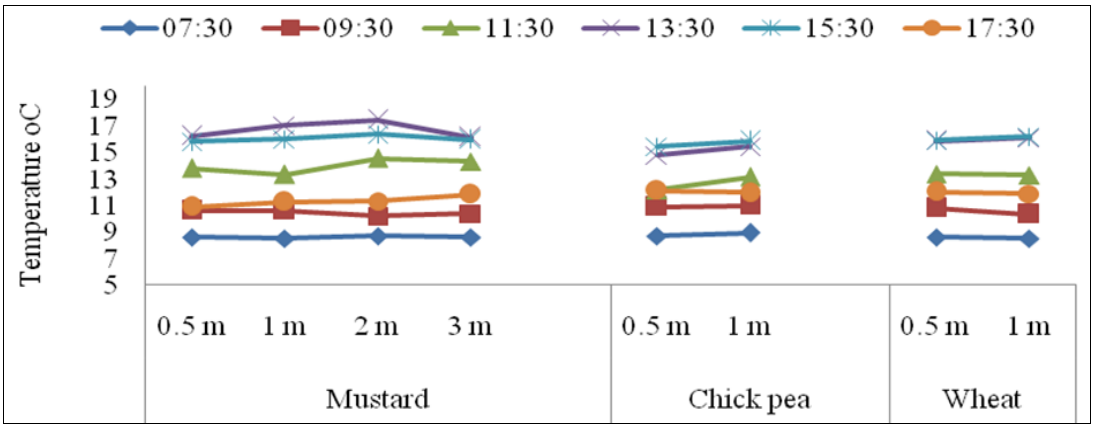

Fig 1.3: Diurnal variation in Temperature on 25/12/2019 in different height from the ground under the canopy of field crops

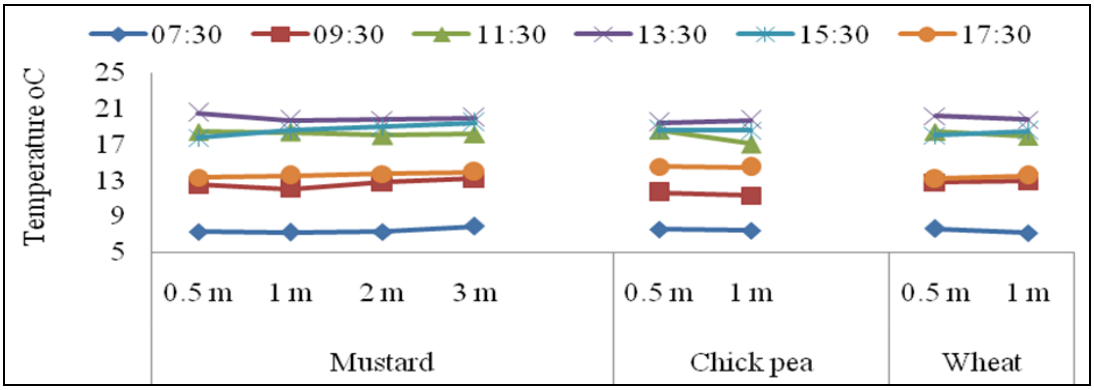

Fig 1.4: Diurnal variation in Temperature on 08/01/2020 in different height from the ground under the canopy of field crops

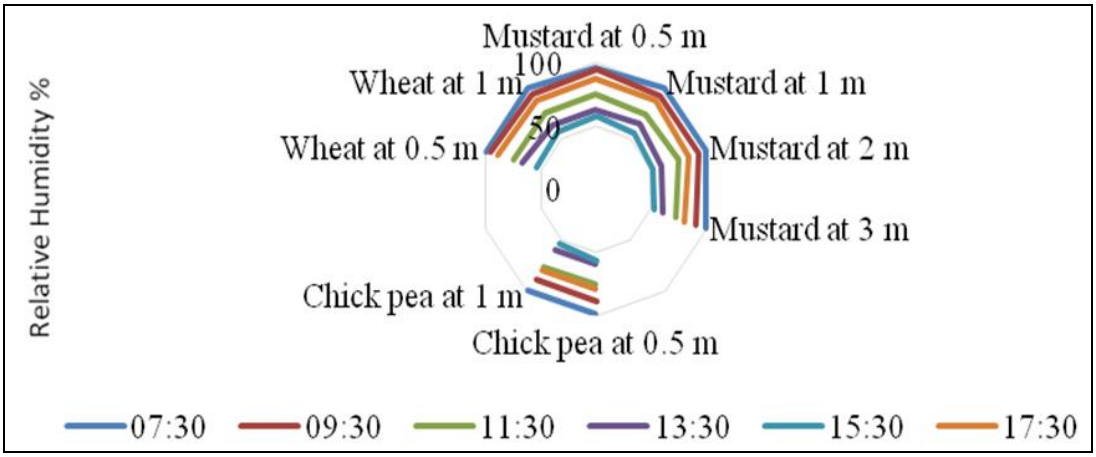

Fig 1.5: Diurnal variation in Relative humidity on 22/01/2020 in different height from the ground under the canopy of field crops

3.2 Relative humidity at different heights in different field crops

Fig 2.1 depicted that the highest relative humidity 88% was found at 17:30 hrs in mustard crop (emergence) at height of 1m from the ground. However highest relative humidity 81% was recorded at same time at 0.5m height in chickpea crop (emergence). The lowest relative humidity 47% was observed in mustard at 2m height and 50% was recorded in chickpea at 0.5m height during November (27/11/2019) at 13:30 hrs. Relative humidity ranges between 55% to 86%, 53% to 88%, 47% to 84% and 51% to 81% at 0.5m, 1m, 2m and 3m, respectively in mustard crop. However, relative humidity ranges between 50% to 81% and 50% to 80% at 0.5m and 1m, respectively in chickpea crop.

A close observation of fig. 2.2 revealed that highest relative humidity in mustard crop (emergence) was found 92% at 0.5m height on 07:30 hrs followed by 92% at 1m height and lowest relative humidity was recorded 36% at 3m height on 13:30 hrs and 37% at 2m height at 13:30 hrs in December month (11/12/2019) while chick pea crop (emergence) showed highest relative humidity 84% at 0.5m height in 07:30 hrs and lowest 33% in 13:30 hrs at 1m height.

In 25th December, relative humidity ranges between 87% to 59%, 86% to 54%, 86% to 52% and 85% to 51% at 0.5m, 1m, 2m and 3m, respectively in mustard crop (emergence). Highest relative humidity 87% was found at 0.5m height on 07:30 hrs and lowest relative humidity 51% was recorded on 13:30 hrs at 3m height. However, highest relative humidity 87% was recorded on 07:30 hrs at 0.5m height from earth surface and lowest 56% was found on 13:30 hrs at 1m height in chickpea crop (branching stage). Similarly pattern was observed in wheat crop (emergence) highest relative humidity 87% was observed in 07:30 hrs at 0.5m height while lowest relative humidity 55% was found on 13:30 hrs at 1m height (Fig 2.3).

The fig. 2.4 showed that the highest relative humidity in mustard crop (vegetative stage) was found 88% at 0.5m height on 07:30 hrs followed by 87% at 1m height on 07:30 hrs and lowest relative humidity was recorded 41% at 3m height on 13:30 hrs followed by 42% at 2m height at 13:30 hrs in January month (08/01/2020). However, chick pea crop (branching stage) showed highest relative humidity 87% at 0.5m height at 07:30 hrs and lowest 43% in 13:30 hrs at 0.5m height and wheat crop (CRI stage) showed highest relative humidity 87% at 0.5m height at 07:30 hrs and lowest 42% in 13:30 hrs at same height.

Fig. 2.5 revealed that the month of January (22/01/2020), highest relative humidity 99% was found at 07:30 hrs in mustard crop (flowering stage) at height of 3m from the ground. However, highest relative humidity 98% was recorded at same time at 0.5m height in chickpea crop (flowering stage) and wheat crop (tillering stage) highest relative humidity 99% was found at same time at 1m height. The lowest relative humidity 51% was observed in mustard at 2m height at 15:30 hrs and 53% was recorded in chickpea at 1m height at same time and wheat crop recorded lowest relative humidity 53% was found at 0.5m during the day period at 15:30 hrs.

The relative humidity of the ambient environment also directly affects plant growth by resisting water and nutrient consumption. During transpiration, the relative humidity level becomes saturated. As a result plant half transpiration and nutrient uptake from the soil at high relative humidity saturation. The photosynthesis rate is proportional to the relative humidity level as a higher rate of relative humidity however water stress in the leaves and increases stomatal conductance.

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 and it again increased from evening 17:30 hrs to morning 07:30 hrs.

Relative humidity was higher at the ground level in all the days of observation. It was observed the relative humidity varied within the plant canopy. It was minimum at the top of the crop plants. Higher relative humidity under canopy indicates that the canopy influences the microclimate of the ambiance. Higher humidity observed at ground level might be due to low temperature and less air measurement compared to upper canopy complete canopy closer, it was not able to affect the microclimate inside the canopies and immediately above them. This might be because of evapotranspiration within the canopy which resulted in more exchange of water vapour with upper air layer over the canopy at 8 oC m. higher humidity at 8 oC m height within canopy might be because of active transpiration by dense foliage at the height. At top surface more turbulence during noon hours as compared to under canopy. (Similar result on relative humidity profiles were found by Bose (2008) [5] in pear millet and Kichar and Ram Niwas (2006) [7] in wheat, Sharma *et al.*, (2018) [13], Singh *et al.*, (2005) [14] in cotton, and Georgi, N. J. and Zafiriadis, K. (2006) [6].

Relative humidity is highest when the temperature is lowest and vice-versa. Relative humidity and temperature are inversely related to one another, so during morning hours higher relative humidity is observed due to low temperature, as temperature starts rising during noon relative humidity percentage decreases with increase in temperature (Mavi *et. al* 1992) [11].

The study revealed that day time relative humidity was low at noon hours within crop canopy. Roy and Triphati (2006) also observed similar results in wheat crop. Similar trend in relative humidity was also observed above crop canopy. Higher relative humidity (up to 6%) was recorded within crop canopy than above crop canopy during both the seasons. Higher relative humidity was recorded within crop canopy at flowering stage than panicle initiation stage. This is in conformity with the findings of Reddy *et al*. (2007) [12].

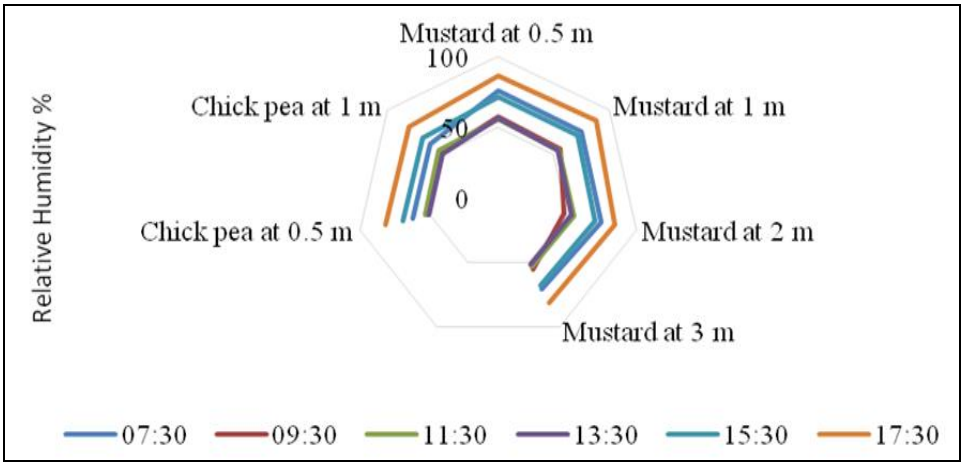

Fig 2.1: Diurnal variation in Relative humidity on 27/11/2019 in different height from the ground under the canopy of field crops

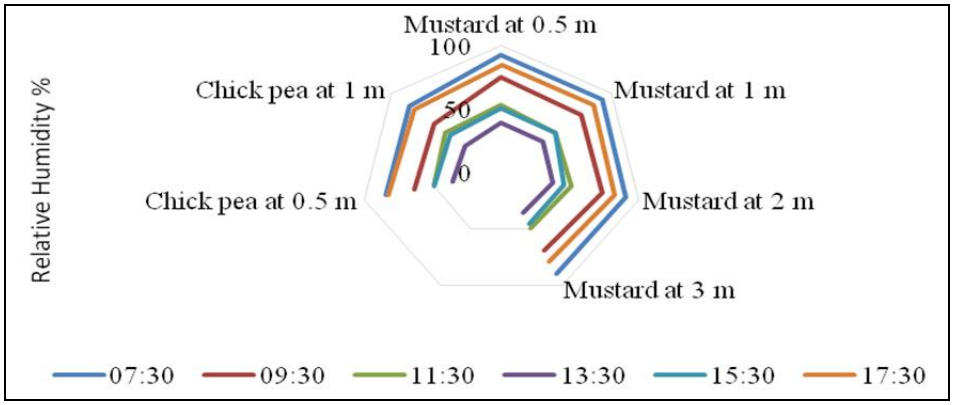

Fig 2.2: Diurnal variation in Relative humidity on 11/12/2019 in different height from the ground under the canopy of field crops

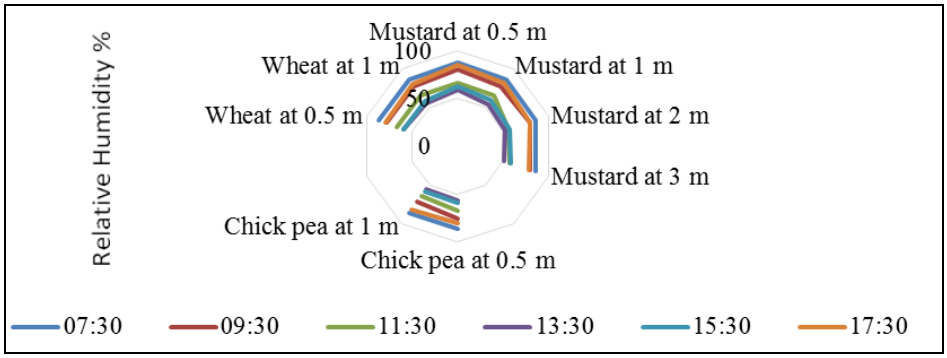

Fig 2.3: Diurnal variation in Relative humidity on 25/12/2019 in different height from the ground under the canopy of field crops

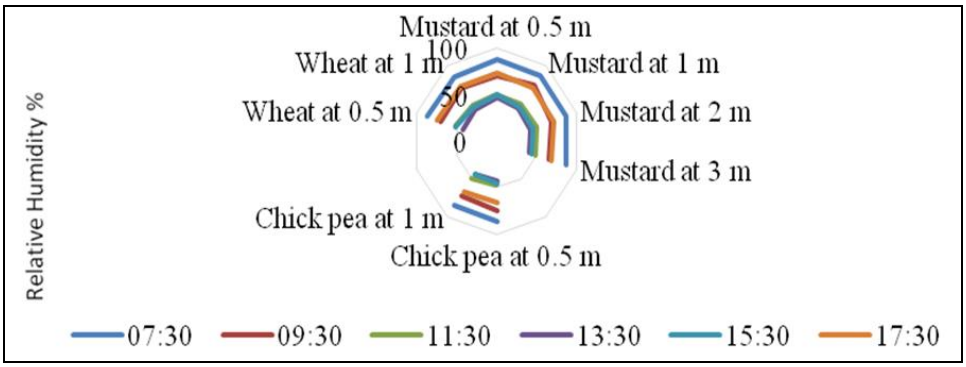

Fig 2.4: Diurnal variation in Relative humidity on 08/01/2020 in different height from the ground under the canopy of field crops

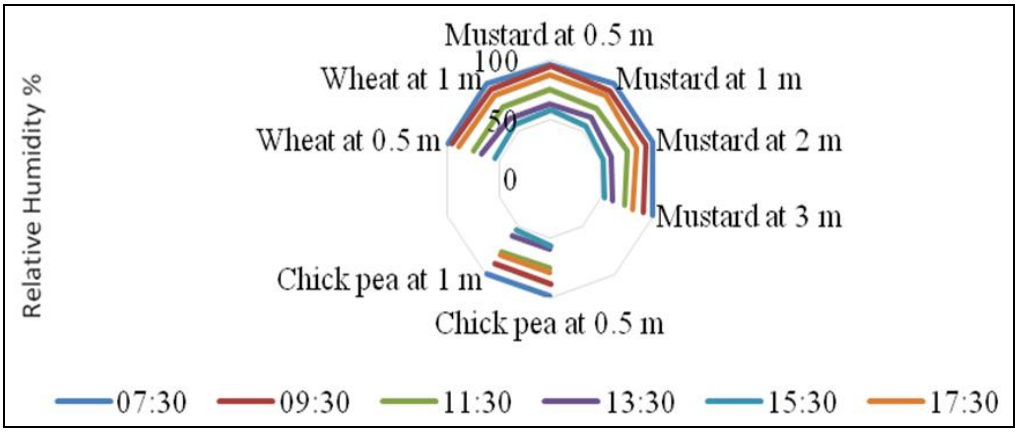

Fig 2.5: Diurnal variation in Relative humidity on 22/01/2020 in different height from the ground under the canopy of field crops

3.3 CO_2 concentration at different height in different field crops

In 27th November, 2019, CO_2 concentration ranged between 679ppm to 632ppm, 671ppm to 627ppm, 667ppm to 627ppm and 668ppm to 628ppm at 0.5m, 1m, 2m and 3m, respectively in mustard crop (emergence). Maximum CO_2 concentration 679ppm was found at 0.5m height on 07:30 hrs and lowest CO_2 concentration 627ppm was recorded on 13:30 hrs at 1m height. However, maximum CO_2 concentration 679ppm was recorded in chickpea on 17:30 hrs at 0.5m height from earth surface and lowest 630ppm was found on 13:30 hrs at 1m height in chickpea crop (emergence). (Fig 3.1)

Fig 3.2 depicted that the, maximum CO_2 concentration in mustard crop (emergence) was found 761ppm at 1m height on 07:30 hrs followed by 756 ppm at 2m height and lowest CO_2 concentration was recorded 626ppm at 0.5m height on 15:30 hrs followed by 626 ppm at 0.5m height on 13:30 hrs in December month (11/12/2019), while chick pea crop (emergence) showed maximum CO_2 concentration was observed 757ppm at 0.5m height on 07:30 hrs and lowest 629ppm was found in 15:30 hrs at 0.5m height.

The fig 3.3 showed that in the month of December (25/12/2019), maximum CO_2 concentration 648 ppm was found at 17:30 hrs in mustard crop (emergence) at height of 1m height from the ground. However, maximum CO_2 concentration 641ppm was recorded at 07:30 hrs in 0.5m height in chickpea crop (branching stage) and 651 ppm was recorded at 17:30 hrs in 1m height on wheat crop (emergence). The lowest CO_2 concentration 626ppm was observed in mustard at 1m height and 626ppm was recorded in chickpea at same height and 628ppm was recorded in wheat crop at 0.5m height during the day period at 15:30 hrs. CO_2 concentration ranged between 627ppm to 646ppm, 626ppm to 648ppm, 628ppm to 647ppm and 627ppm to 644ppm at 0.5m, 1m, 2m and 3m, respectively in mustard crop. However, CO_2 concentration ranged between 626ppm to 641ppm and 626ppm to 641ppm at 0.5m and 1m, respectively in chickpea crop and 628ppm to 642ppm and 628ppm to 651ppm at 0.5m and 1m, respectively in wheat crop.

On 8th January 2020, CO_2 concentration ranged between 677 ppm to 614 ppm, 681 ppm to 617 ppm, 677 ppm to 618 ppm and 676 ppm to 616 ppm at 0.5m, 1m, 2m and 3m, respectively in mustard crop (vegetative stage stage). Maximum CO_2 concentration 682ppm was found at 1m height on 07:30 hrs and lowest CO_2 concentration 614ppm was recorded on 13:30 hrs at 0.5m height. However, maximum CO_2 concentration 679 ppm was recorded on 07:30 hrs at 1m height while lowest 616 ppm was found on 13:30 hrs at 0.5m height in chickpea crop (branching stage). In wheat crop (CRI stage) maximum CO_2 concentration 677ppm was recorded on 07:30 hrs at 0.5m height while lowest 617ppm was found on 15:30 hrs at 0.5m height (Fig 3.4).

Fig. 3.5 depicted that maximum CO_2 concentration in mustard crop (flowering stage) was found 658 ppm at 2m height on 07:30 hrs followed by 656ppm at 3m height and lowest CO_2 concentration was recorded 613 ppm at 0.5m height on 13:30 hrs followed by 613ppm at 2m height on 13:30 hrs in January month (22/01/2020). While chickpea crop (flowering stage) showed maximum CO_2 concentration 656 ppm at 0.5m height on 07:30 hrs and lowest 617 ppm in 13:30 hrs at 0.5m height and wheat crop (Tillering stage) showed maximum CO_2 concentration 654 ppm at 1m height on 07:30 hrs while lowest 613ppm in 13:30 hrs at 0.5m height.

The CO_2 concentration influences the photosynthesis rate, metabolism and physiological and chemical deters of plants. A leaf of CO_2 would not only result in a lower biomass but the plants would also be of inferior quality and strength. As an essential substrate of the photosynthesis process, CO_2 is directly absorbed by plants. CO_2 also influences the transpiration process of plants.

As per study maximum CO_2 concentration was found at 07:30 hrs morning and decreased 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 which reached to maximum at 15:30 hrs.

Anda and Kocsis, 2008 [2]. found that if the rise of the stomatal resistance might limit the penetrating quantity of CO_2 in the leaf, the higher concentration of the gas caused a more intensive photosynthesis. In case of the first scenario photosynthetic intensity grew by 25.43% on daytime average (8-19 o'clock), but this increase exceeded 30% between 13 and 15 o'clock. Doubling the present CO_2 level model run predicted 51.75% higher photosynthetic intensity for the daytime hours. Beside high sun radiation (10-17 o'clock) the increase exceeded 60% on average. Similar result found by Ainsworth and Rogers 2007 [1].

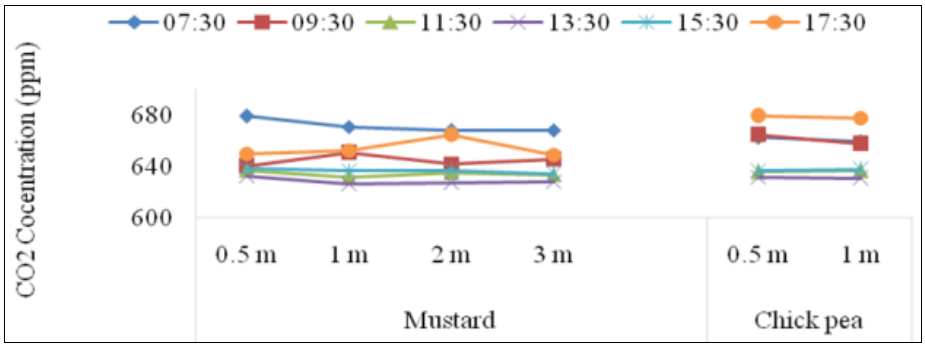

Fig 3.1: Diurnal variation in CO_2 concentration on 27/11/2019 in different height from the ground under the canopy of field crops

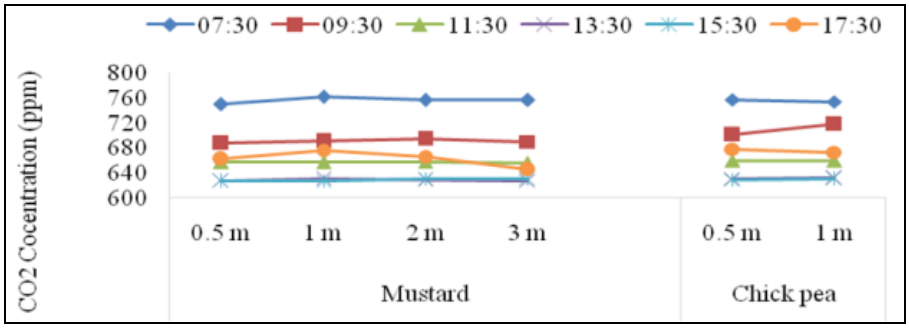

Fig 3.2: Diurnal variation in CO_2 concentration on 11/12/2019 in different height from the ground under the canopy of field crops

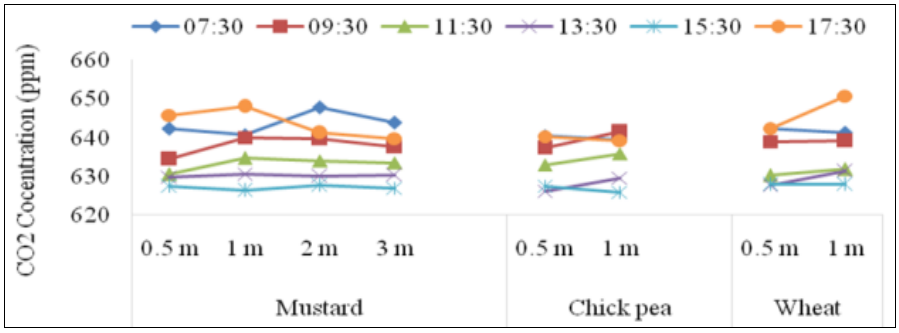

Fig 3.3: Diurnal variation in CO_2 concentration on 25/12/2019 in different height from the ground under the canopy of field crops

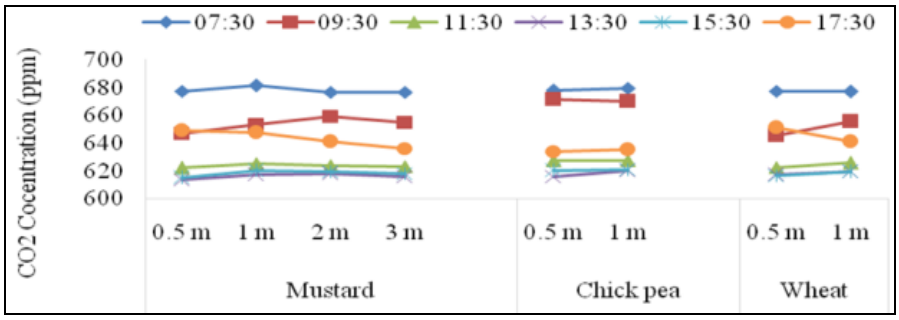

Fig 3.4: Diurnal variation in CO_2 concentration on 08/01/2020 in different height from the ground under the canopy of field crops

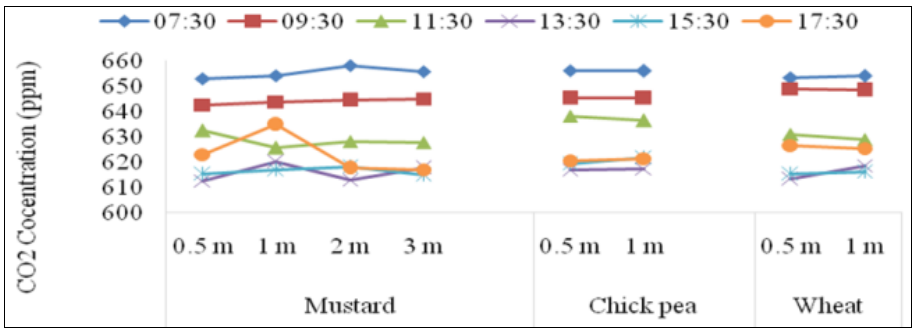

Fig 3.5: Diurnal variation in CO_2 concentration on 22/01/2020 in different height from the ground under the canopy of field crops

Conclusion

In diurnal temperature there was increases during 07:30 hrs to 13:30 hrs thereafter it was decreased till 17:30 hrs, while RH and CO_2 were found highest values at 07:30 hrs and lowest were observed during 13:30 hrs to 17:30 hrs.

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