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Altering Microclimate of Broccoli Crop by Adjusting Transplanting Date, Mulching, and Irrigation Application in Mid Hill Zone of Himachal Pradesh

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Abstract: Field experiments were conducted during the *rabi* seasons of 2021-22 to evaluate the microclimate of broccoli crops under three dates of transplanting, two mulching, and two irrigation levels at Nauni, Solan the mid-hill-sub humid agroclimatic region of Himachal Pradesh. Soil temperature was maximum during the transplanting stage in timely sown (28th October) crop and decreased during the heading and harvested stage. Photosynthetically active radiation, relative humidity, soil moisture, and leaf area index from transplanting onwards was recorded higher in the timely sown crop and lower in the late sown crop while in the case of irrigation and mulching levels was higher under optimal irrigation and mulching application. At the heading stage, PAR interception was observed to be statistically highest (5.10) due to a higher leaf area index in the timely sown crop followed by the mid-sowing (4.19) and was lowest (3.03) in the late sown crop. Better crop growth and hence, leaf area index resulted in a higher PAR interception on timely sown with optimal irrigation and mulching level. Similarly, dry matter accumulation had a positive relation with chlorophyll content (R^2= 0.55). The higher the dry matter accumulation higher will be the chlorophyll content.

Keywords: Broccoli, Date of transplanting, Irrigation, Microclimate, Mulching and yield

Broccoli is native to the Mediterranean and East Asian regions. It is widely grown in China, India, the USA, Spain, Mexico, Italy, and other parts of the world. In India, it is generally grown in hilly areas of Nilgiri Hills, Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir, and the Northern plains. In India, broccoli occupies nearly 4.5 lakh ha of the area with a production of 8.8 metric tons and productivity of 1.9 kg ha^{-1}. Broccoli grows best when exposed to an average daily temperature between 17-23°C. It requires about 12-16°C, 18-23°C, and 12-18°C temperature for seed germination, vegetative growth, and head development. Temperature below the optimum range delays maturity and led to small sprouts. Moreover, it cannot tolerate high temperatures as it produces poor-quality sprouts. Gouri et al (2005) reported that the growth of the crop largely depends upon the microclimate environment of the crop, which varies from the top of the canopy to the soil surface and affects the growth and yield of the crop. The broccoli plant growth and yield increase when dark mulch is used rather than light colour mulches which maintains the optimum soil temperature, hence dark mulch may be an option for broccoli production in areas with cool conditions. Singh et al (2021) showed that black mulch produced the highest yield of broccoli. The planting date plays an important role to enhance the yield and biomass of the crop. The extremely high temperature at the head development stage cause bolting and affects crop production. The late transplanting of the crop exposes high temperatures at the head development stage of the crop which influences the yield of the crop. Plants from delayed sowing failed to produce viable seeds under the agro-climatic condition of Assam (Gogoi et al 2016) as sowing timely produced the highest head yield. Broccoli planted on 1st October produced a significantly higher diameter, as well as the perimeter of the flowering head compared to other planting dates (Obaid et al 2019). For irrigation scheduling and effective water management, an accurate estimation of evapotranspiration is required. However, factors that affect evapotranspiration are humidity, solar radiation, and crop growth stages. Evapotranspiration can be seen as an integrated response to all these factors and a major contributor to irrigation requirements. The commercial production of broccoli is an emerging challenge in the changing environmental conditions that makes it difficult for farmers to cultivate broccoli appropriately due to the lack of information to overcome these challenges. Therefore, the study was conducted by altering the microclimate of broccoli crop by adjusting transplanting dates, mulching and irrigation application in mid hill zone of Himachal Pradesh

MATERIAL AND METHODS

The field experiment was carried out at UHF, Nauni situated at 30.86 N latitude and 77.17 E longitude and an altitude of 1275 m above sea level. The crop nursery was sown on three different sowing dates 12^{th} September, 2^{nd} October and 23^{rd} October. The crop was transplanted at three different transplanted dates (8^{th} October, 28^{th} October, and 18^{th} November) with two mulching and irrigation levels during the *rabi* seasons of 2021-22. No fertilizers and pesticides were used in the present study. The UV-resistant black plastic mulch sheet 30-micron covered about 4.05 m^2 area was laid in the plots. The phenological stages of the crop were recorded by visual observations.

Evapotranspiration estimation (mm): Evapotranspiration was estimated using the formula given by the Papadakis method:

$$\mathrm{ET} = 0.5262 \times (\mathrm{Emax} - \mathrm{Emin} - 2) \times \left(\frac{10}{30}\right)$$

Whereas, Emax, Emin-2: Saturation vapour pressure corresponding to average maximum temperature and average dew point temperature.

Tmax , Tmin: Maximum and minimum temperature

Soil temperature (°C): Soil temperature was recorded at 15cm depth by using a soil thermometer. The soil temperature was recorded at different phenological stages.

Relative humidity under the canopy of the crop (%): Hygrometer was used to record relative humidity at different phenological stages. Morning and evening relative humidity was recorded under the canopy of the crop.

Soil moisture (%): Soil sample was collected in a moisture can and the wet weight of the sample was recorded. The soil sample was dried in a hot air oven at 105°C until a constant weight was obtained and the dry weight of the sample was recorded (Kelly 2004).

$$\text{Moisture content (on weight basis)} = \frac{\text{Fresh weight - Dry weight}}{\text{Dry weight}} \times 100$$

Leaf area index (LAI): The leaf area index was calculated by dividing the leaf area per plant by land area occupied by the plant. The leaf area index was calculated at the time of the different phenological stages.

$$\mathrm{LAI} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Dry matter accumulation: Each treatment received a portion of the complete plant from six selected plants per plot. Chopping was carried out after taking a new weight. The samples were dried in an oven at 60°C until they reached a consistent weight. The dry matter content of oven-dried samples was measured and expressed as a percentage.

$$\text{Dry matter content (\%)} = \frac{\text{Dried weight of sample}}{\text{Fresh weight of sample}} \times 100$$

Chlorophyll content: The chlorophyll content was estimated by using the method given by Hiscox and Israeistam, 1979. The fresh leaves were chopped to fine pieces under subdued light, 100 mg of chopped leaf samples were placed in vials containing 7 ml of Dimethyl sulphoxide, the vials were incubated at 65°C for half an hour, and the extract was then transferred to the graduated test tube and the final volume was made to 10 ml with Dimethyl sulphoxide. The optical density of the above extract was recorded on Spectrophotometer (Model: Spectronic-20) at 645 and 663 nm wavelength against Dimethyl sulphoxide blank.

The total chlorophyll content was calculated by using formula:

$$\text{Total chlorophyll} = \frac{20.2\mathrm{A}645 + 8.02\mathrm{A}663}{\mathrm{ax}1000\mathrm{xw}} \times \mathrm{V}$$

Where; V = volume of extract made, a = length of light path in cell, w = weight of the sample taken A645 is absorbance at 645nm, A663 is absorbance at 663nm.

RESULTS AND DISCUSSION

Relative humidity: Significantly higher relative humidity (RH) was at the mid-sowing date (T_2) followed by the first sowing date (T_1) and lowest in the late sowing date (T_3) (Table 1). Among different phenophases, RH was highest at the vegetative stage (62%) followed by the heading, and was lowest at the harvesting stage. In the case of mulching levels, relative humidity was maximum in M_1 (61%) as compared to M_2 (54%) at the vegetative stage might be due to more vegetative growth. The relative humidity was higher under optimum irrigation I_1 (64%), due to higher soil moisture and lower soil temperature at the vegetative stage and hence, more availability of moisture under optimum irrigation level. Verma *et al.* (2018) also reported that soil moisture and relative humidity play important role in the growth and development of the crop.

Soil moisture: Significantly higher soil moisture was found in T_2 followed by T_1 and lowest in T_3 (Table 2). Among different phenophases, soil moisture was highest at the vegetative stage (63.6 %) followed by the heading and was lowest (52.5%) at the harvesting stage. In the mulching levels, soil moisture was maximum in M_1 (59.8 %) as compared to M_2 (52.50 %) at the vegetative stage might be due to more vegetative growth. Soil moisture was higher under optimum irrigation I_1 (63.2 %) at the vegetative stage.

Photosynthetically active radiation: At the transplanting and heading stage, PAR interception (%) was lower than vegetative as it increased with an increase in the leaf area index (Table 3). At the vegetative stage, PAR interception was observed to be statistically highest (522 Wm^{-2}) due to a higher leaf area index in T_2 followed by T_1 and was lowest

Table 1. Variation in relative humidity under different dates of transplanting, mulching and irrigation levels at different phenophases of crop

Treatment	Relative humidity (%)			
Date of transplanting	Transplanting	Vegetative	Heading	Harvesting
T_1	44	56	49	42
T_2	51	62	59	49
T_3	41	54	43	40
CD (p=0.05)	1.68	1.48	0.88	0.76
M_1 (Mulching)	49	61	53	44
M_2 (No Mulching)	42	54	48	43
CD (p=0.05)	1.37	1.21	0.72	0.62
I_1 (Irrigation)	53	64	54	41
I_2 (No Irrigation)	38	51	47	46
CD (p=0.05)	1.37	1.21	0.72	0.62

Table 2. Variation in soil moisture under different dates of transplanting, mulching and irrigation levels at different phenophases of crop

Treatment	Soil moisture (%)			
Date of transplanting	Transplanting	Vegetative	Heading	Harvesting
T_1	50.5	54.5	52.0	43.1
T_2	50.2	63.6	62.3	52.5
T_3	41.9	50.4	47.7	38.0
CD (p=0.05)	1.96	1.65	1.59	1.50
M_1 (Mulching)	52.7	59.8	57.9	48.0
M_2 (No Mulching)	42.4	52.5	50.0	41.0
CD (p=0.05)	1.60	1.35	1.30	1.22
I_1 (Irrigation)	53.4	63.2	61.6	52.0
I_2 (No Irrigation)	41.6	49.0	46.4	37.0
CD (p=0.05)	1.60	1.35	1.30	1.22

Table 3. Photosynthetically active radiation under different dates of transplanting, mulching and irrigation levels at different phenophases of crop

Treatment	Photosynthetically active radiation (Wm^{-2})				
Date of transplanting	Transplanting	Vegetative	Heading	Harvesting	Yield/plot (kg)
T_1	401	464	414	343	8.589
T_2	400	522	444	403	10.440
T_3	292	416	338	288	6.353
CD (p=0.05)	1.98	1.40	0.88	1.46	0.26
M_1 (Mulching)	369	468	402	348	9.714
M_2 (No Mulching)	359	466	397	341	7.207
CD (p=0.05)	1.62	1.15	0.72	1.19	0.21
I_1 (Irrigation)	370	469	402	352	9.166
I_2 (No Irrigation)	358	466	396	337	7.755
CD (p=0.05)	1.62	1.15	0.72	1.19	0.21

(416 Wm^{-2}) in T_3. Among mulching and irrigation levels, crop having mulching application (M_1) and optimal irrigation (I_1) captured more radiation, which might be due to better crop stand and hence higher leaf area index leading to a more PAR interception. At the vegetative stage, PAR interception was 468 Wm^{-2} under the mulching application. Similarly, the higher PAR interception was observed under I_1 (469Wm^{-2}) than under I_2 (466Wm^{-2}). Mehta and Dhaliwal (2022) also reported that normal sowing resulted in higher biomass production with a higher leaf area index, thus intercepting more of the available radiation within the canopy in different crops.

Leaf area index: The leaf area index was lower during the early stages of crop growth and increased with the growth of crop reaching a maximum at the vegetative and heading stage after sowing and after that, it started decreasing gradually as the crop reached senescence and maturity. At the transplanting stage, the leaf area index was observed to be lower than the vegetative and heading stages (Table 4). At the heading stage, PAR interception was statistically highest due to a higher leaf area index in T_2 (5.10) followed by T_1 (4) and was lowest (3.03) in T_3. Among mulching and irrigation levels, crop having mulching application (M_1) and optimal irrigation (I_1) captured more radiation, which might be due to better crop stand and hence higher leaf area index leading to a more PAR interception. At the vegetative stage, PAR interception was (4.41) under the mulching application. Similarly, the higher PAR interception was under I_1 (4.41) than under I_2 (3.80). Gupta et al (2017) also concluded that the leaf area gets reduced with delayed sowing which may be due to a decline in photosynthetic rate and poor leaf development leading to a lower leaf area index (LAI).

Evapotranspiration: Among different sowing dates, evapotranspiration at the harvesting stage was observed higher in T_3 followed by T_2 and lowest in T_3. The evapotranspiration was higher during the initial growth and harvesting period which decreased with the advancement of crop growth. At the harvesting stage due to an increase in soil temperature, the evapotranspiration in T_3 was 2.50 mm, whereas it was 2.10 mm in T_1 (Table 5). At the harvesting stage, the treatments with no mulching (2.37mm) and no irrigation (2.48mm) application recorded higher evapotranspiration. The higher soil temperature results in higher evapotranspiration and increases the water use availability to crop and affects the growth and yield of the crop.

Soil temperature: Soil temperature at the transplanted stage was observed higher in T_1 followed by T_2 and lowest in T_3. The soil temperature in T_1 was 29.2˚C, whereas in T_3 it was 17.7˚C at 1400 and 0730 hrs as respectively (Fig. 1). Higher soil temperature under earlier sowing might have proved beneficial for better crop establishment and growth. The soil temperature at the vegetative and harvesting stage was observed higher in T_3. At the harvesting stage, the treatments with mulching and no irrigation application recorded higher soil temperatures of 26.6 and 23.6˚C at 1400 and 0730 hrs respectively. The higher soil temperature results in higher evapotranspiration and increases the water use availability to crop and affects the growth and yield of the crop.

Regression relationship between dry matter accumulation and chlorophyll content at the heading stage of broccoli: The model explained 0.55 variations in dry matter accumulation with chlorophyll content under different transplanted dates, mulching and irrigation levels respectively (Fig. 2). The higher the dry matter accumulation and leaf area index increases the chlorophyll content of the crop under different treatments. Gupta et al (2017) also concluded that the leaf area gets reduced with delayed

Table 4. Leaf area index during different phenophase of broccoli

Treatment	Leaf area index			
Date of transplanting	Transplanting	Vegetative	Heading	Harvesting
T_1	0.06	3.44	4.19	0.81
T_2	0.04	4.21	5.10	1.08
T_3	0.05	2.70	3.03	0.62
CD (p=0.05)	0.007	0.047	0.081	0.059
M_1 (Mulching)	0.04	3.83	4.41	0.93
M_2 (No Mulching)	0.05	3.07	3.80	0.74
CD (p=0.05)	NS	0.038	0.066	0.048
I_1 (Irrigation)	0.05	3.71	4.41	0.95
I_2 (No Irrigation)	0.05	3.19	3.80	0.72
CD (p=0.05)	NS	0.038	0.066	0.016

Table 5. Evapotranspiration under different dates of transplanting, mulching and irrigation levels at different phenophases of crop

Treatment	Evapotranspiration (mm)			
Date of transplanting	Transplanting	Vegetative	Heading	Harvesting
T_1	2.38	1.72	1.74	2.10
T_2	2.48	2.19	1.57	2.36
T_3	2.17	1.60	1.90	2.50
CD (p=0.05)	0.14	0.32	0.13	0.13
M_1 (Mulching)	2.15	1.67	1.66	2.26
M_2 (No Mulching)	2.53	2.00	1.82	2.37
CD (p=0.05)	0.11	0.26	0.11	0.10
I_1 (Irrigation)	2.27	1.46	1.61	2.16
I_2 (No Irrigation)	2.42	2.21	1.87	2.48
CD (p=0.05)	0.11	0.26	0.11	0.10

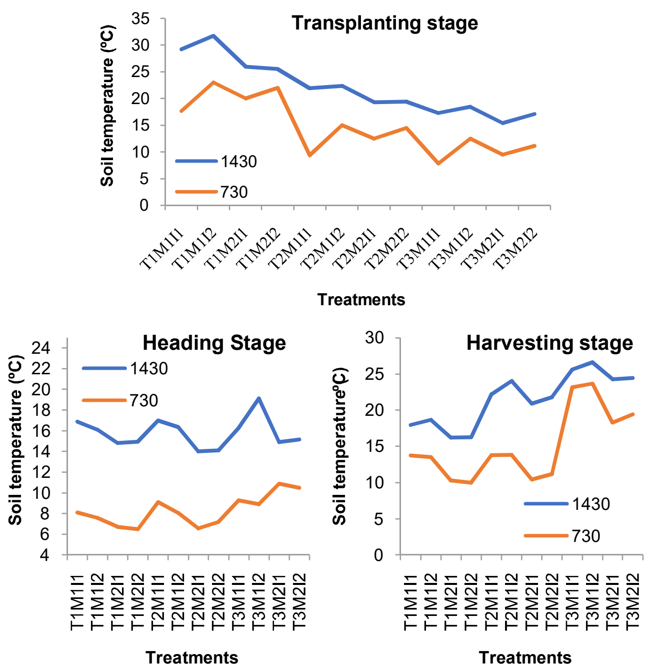

Fig. 1. Soil temperature under different dates of transplanting at 0730 and 1430 hrs during different phenophases of crop

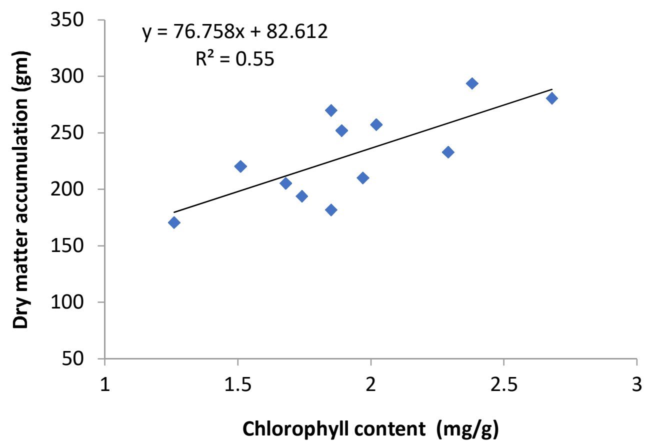

Fig. 2. Relationship between dry matter accumulation and chlorophyll content at the heading stage of broccoli

sowing which may be due to a decline in photosynthetic rate and poor leaf development leading to lower chlorophyll content.

CONCLUSION

The study concluded that under mid-hill sub-humid agroclimatic conditions, warming scenarios might negatively impact broccoli growth and yield. From transplanting onward, higher levels of photosynthetically active radiation, relative humidity, soil moisture, and leaf area index were observed in the timely-sown crop than in the late-sown crop. The study concluded that higher dry matter accumulation and leaf area index will increase PAR and chlorophyll content and improve crop quality. The control of irrigation and mulching, as well as adjustments in the date of planting, can all be used as efficient adaptation measures to reduce field crop sensitivity to extreme weather.

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