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Quantification of microclimatic conditions under different planting systems in raya

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सार — विभिन्न रोपण विधियों जैसे समतल क्यारियों में सामान्य बुआई (S_1), समतल क्यारियों में युगल कतार की बुआई (S_2), प्रत्येक खूड में एक पंक्ति सहित मेंड खूड बुआई (S_3), प्रत्येक खूड में दो पंक्तियों सहित मेंड खूड बुआई (S_4), चौथी पंक्ति बीच-बीच में छोड़कर समतल क्यारियों में सामान्य बुआई (S_5) और छठी पंक्ति बीच-बीच मे छोड़कर समतल क्यारियों में सामान्य बुआई (S_6), के अन्तर्गत राया फसल के सूक्ष्म-जलवायु अध्ययन के लिए यादृच्छिक ब्लाक अभिकल्प का अध्ययन करने के लिए एक प्रयोग किया गया। प्रकाश संश्लेषण रूप में सक्रिय विकिरण का अवशोषण सार्थकरूप से S_4 में अधिकतम 79.6 प्रतिशत और S_3 में निम्नतम (68.0 प्रतिशत) था। S_1 संप्रयोग से संबंधित वायु तापमान सापेक्ष, आर्द्रता के विचलन और पवनगति प्रोफाइलस की उपज में योगदान देन वाले प्राचलों की व्याख्या करने हेतु सूक्ष्म-जलवायु परिवर्तनों के लिए परिमात्रित किया गया।

ABSTRACT. An experiment was conducted in a randomized block design to study the microclimate of raya crop under various planting systems, *viz.*, normal sowing in flat beds (S_1), paired row sowing in flat beds (S_2), ridge-furrow sowing with one row in each furrow (S_3), ridge-furrow sowing with two rows in each furrow (S_4), normal sowing in flat beds with 4th row skipping off (S_5) and normal sowing in flat beds with 6th row skipping off (S_6). Absorption of photosynthetically active radiation was significantly highest in S_4 (79.6 per cent) and lowest in S_3 (68.0 per cent). Deviation of air temperature, relative humidity with respect to S_1 treatment and wind speed profiles were quantified for microclimatic changes to explain the yield contributing parameters.

1. Introduction

Rapeseed and mustard are the important oil seed crops of the winter season and occupy an area of 4403.2 thousand hectares in India and produce 3030.20 thousand tonnes of seeds (*Agricultural situation in India*, 1985).

The potential productivity of a region is influenced by climatic factors, but the responses of plant are also influenced by the immediate meteorological factors such as photosynthetically active radiation (PAR) absorption, temperature of air and leaf, relative humidity, prevailing wind speed, CO_2 concentration and soil moisture availability. Meteorological variables are continuously changing from the top of the crop canopy up to the lowest layers of roots influencing the growth, development and yield. Therefore, the study of crop micrometeorological conditions is very essential to understand the plant responses to various weather paramertes.

Brown and Covey (1966), Johnson *et al.* (1976) and Baldocchi *et al.* (1983) studies revealed that the crop microclimate, influencing the growth and development is different from the open observatory microclimate. Therefore, it is essential to quantify the crop microclimate to improve the yield potential. An attempt has been made here to quantify the crop microclimate in raya crop under different planting systems as compared to open observatory data and its relation with the yield contributing parameters.

2. Material and methods

An experiment was conducted in a randomized block design at the experimental farm of Department of Agricultural Meteorology, Haryana Agricultural University, Hisar (Lat. 29°10′N, Long. 75°46′E) during the rabi, 1985-86. Six planting systems were studied, *viz.*, normal sowing in flat beds (S_1, row to row spacing 45 cm), paired row sowing in flat beds (S_2, row to row spacing 30 cm and pair to pair 60 cm), ridge-furrow sowing with one row in each furrow (S_3, furrow to furrow distance 90 cm), ridge-furrow sowing with two rows in each furrow (S_4, furrow to furrow distance 90 cm), normal sowing in flat beds with 4th row skipping off (S_5, row to row spacing 45 cm), normal sowing in flat beds with 6th row skipping off (S_6, row to row spacing 45 cm). All the basic inputs were supplied

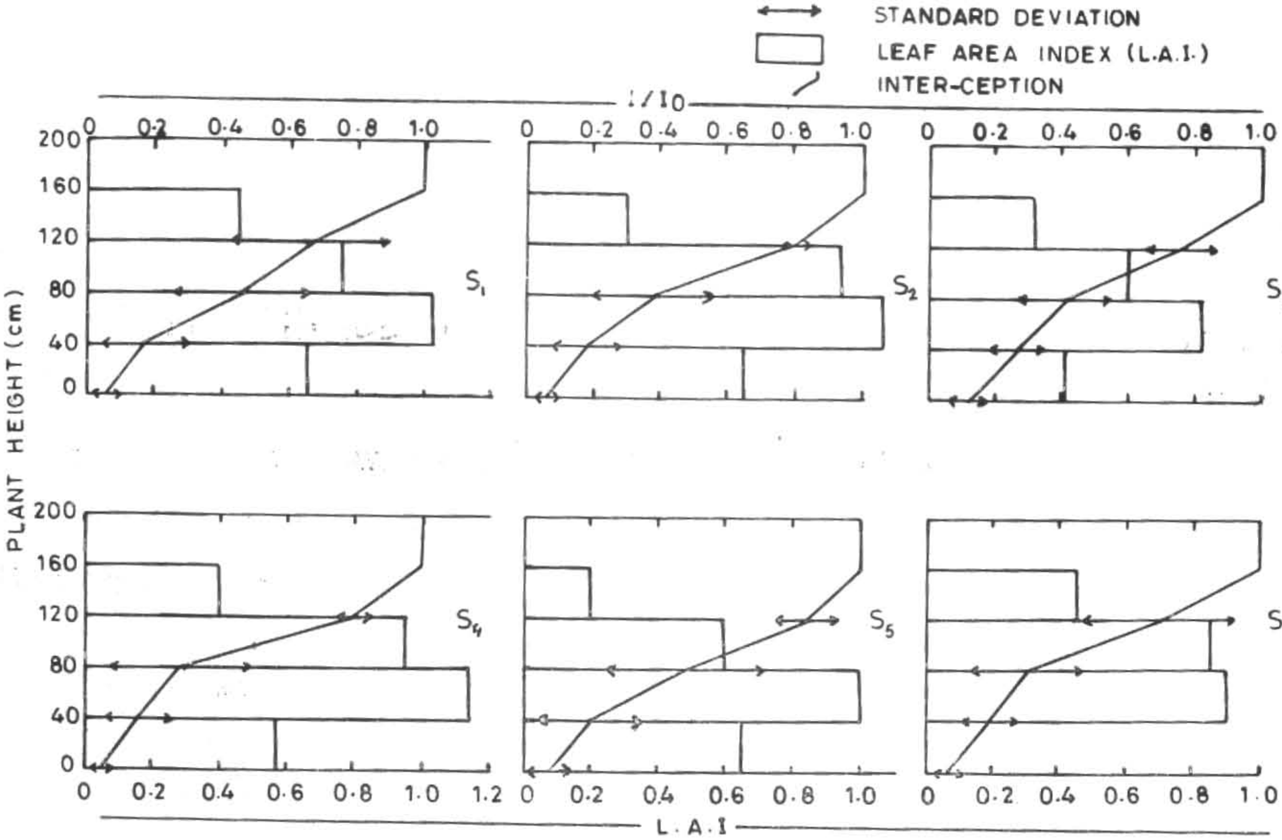

Fig. 1. Light interception under different planting systems in raya at maximum LAI stage, 1 Jan 1986

as per package of practices of the crop. The profiles of the dry and wet bulb temperatures with the help of psychrometer and wind speed with portable anemometer were recorded in the crop under different planting systems at 40, 80, 150, 200 cm height above the ground surface at 0800, 0900, 1100, 1300, 1400, 1500 and 1700 IST at flowering, pod formation and maturity stages. PAR was measured by lux meter at ground level, 40, 80, 120, 160, 200 cm above the surface. Leaf area was measured with the help of leaf area meter.

The aerodynamic parameters, *i.e.*, frictional velocity, turbulent wind force momentum of eddy diffusivity were computed from the wind profile data using the logarithmic expressions. Correlation coefficients were obtained between the crop micrometeorological parameters and biological observations for understanding crop environmental interactions.

3. Results and discussion

3.1. *PAR interception*

Amount of solar radiation (PAR) interception by the crop canopy under different planting systems at maximum leaf area index (LAI=3.06) at different heights has been shown in Fig. 1. It was found (Table 1) that the absorption of PAR was significantly higher in S_4 (79.6 per cent), over S_3 (68.1 per cent), S_5 (76.6 per cent) and S_6 (77.0 per cent) whereas in S_1, S_2, S_5 and S_6, the absorption of PAR was statistically at par*. The absorption of PAR in S_3 was signficantly lower than all other planting systems. PAR albedo was not significantly (statistically) different among the planting systems. Transmission coefficient was significantly higher in S_3 over other planting systems.

TABLE 1

PAR characteristics in raya at maximum LAI stage

Planting systems	Optical characteristics in percentage (1230 IST)		
	Transmitted	Reflected	Absorbed
S_1	6.0	15.9	78.1
S_2	6.0	15.5	78.5
S_3	17.0	14.9	68.1
S_4	5.0	15.4	79.6
S_5	7.6	15.8	76.6
S_6	7.0	16.0	77.0
S Em ±	0.54	0.28	0.60
CD at 5%	1.70	N.S.	1.89

Absorption of PAR which was maximum in S_4 planting system, could be due to significant leaf area index (Table 7) more interception of radiation by the canopy. Similar results were reported in maize crop by Hatefield and Carlson (1979) and Siva Kumar and Virmani (1984). Significance of transmission coefficient corresponding to S_3 planting system could be due to less leaf area index and wider row spacing as compared to other planting systems.

*However, it can be also seen that S_1, S_2 and S_6 are at par with S_4 and these four systems, in turn, are signficant over S_3.

TABLE 2

Deviations of air temperature and relative humidity from S_4 planting system in different treatments at pod formation stage

Ht. above ground	0800 IST S_1	S_2	S_3	S_5	S_6	1300 IST S_1	S_2	S_3	S_5	S_6	1700 IST S_1	S_2	S_3	S_5	S_6
(a) Air temperature deviations (°C)															
Ground	0.4	—0.6	0.9	0.5	0.7	—0.8	—1.8	—1.0	—2.0	—0.4	—1.2	—2.2	—1.7	—2.2	—0.7
40 cm	0.4	—0.6	1.1	0.3	—0.2	2.2	0.6	—0.6	2.2	1.6	—2.6	—2.8	—3.8	—3.8	—2.0
80 cm	0.6	1.2	1.3	0.8	1.0	—1.5	—1.3	—1.5	—3.3	—0.5	—0.8	—0.8	—2.1	—2.1	—0.3
120 cm	1.0	1.3	1.5	0.7	0.5	—1.3	—0.3	0.4	—1.4	—2.3	—1.0	—1.2	—2.5	—2.0	0.0
160 cm	1.1	1.3	1.5	0.7	0.4	1.2	1.0	—1.5	0.8	1.5	0.0	—1.0	—2.0	—1.0	0.0
Avg. dev.	0.70	0.76	1.26	0.60	0.48	0.16	—0.36	—0.84	—0.74	—0.06	-1.12	-1.60	-2.42	-2.22	-0.60
(b) Relative humidity deviations (per cent)															
Ground	2	—1	—1	0	—1	—10	11	—4	—5	—7	1	6	4	6	—8
40 cm	3	—4	—8	—2	0	—7	—14	—7	—3	—13	10	15	20	15	3
80 cm	2	0	—1	—1	—2	—4	—9	—11	—3	—4	—2	—2	7	5	—6
120 cm	—6	—2	—2	—1	—3	5	2	—2	2	11	1	3	12	8	—4
180 cm	0	—2	—2	—9	—1	—2	—7	—10	—7	1	—4	—1	8	—1	—1
Avg. dev.	0.2	-1.8	-2.8	—2.6	-1.4	-3.6	-3.4	-6.8	-3.2	-2.4	1.2	4.2	6.6	6.6	3.2

TABLE 3

Wind speed (m/sec) at different crop height under various treatments at flowering stage

Date of observation (Dec '85)	Treatments	Crop height (cm) 0800 IST 40	120	200	1100 IST 40	120	200	1400 IST 40	120	200	1700 IST 40	120	200
24	S_1	0	0	78	0	29	160	0	27	180	0	0	44
21	S_2	Calm			0	24	128	0	19	85	0	17	70
9	S_3	0	35	62	34	190	286	27	140	250	0	112	182
10	S_4	Calm			0	29	122	0	30	156	0	12	64
19	S_5	0	73	122	22	126	253	0	160	266	0	71	117
20	S_6	24	39	197	41	64	273	21	52	220	18	36	180

3.2. *Air temperature and relative humidity profiles*

Deviation of air temperatures and relative humidity in treatments S_1, S_2, S_3, S_5 and S_6 from the S_4 treatment (which had significantly highest PAR) at 0800, 1300 and 1700 IST with crop height above the ground level at pod formation stage is presented in Table 2.

At 0800 IST the deviations of air temperature at different levels inside the crop varied from 0.4 to 1.1, —0.6 to 1.3, 0.9 to 1.5, 0.5 to 0.8, —0.2 to 1.0 and at 1300 IST; —0.8 to 2.2, —1.8 to 1.0, —1.5 to 0.4, —3.3 to 2.2, —2.3 to 1.5 in °C under S_1, S_2, S_3, S_5, S_6, planting systems respectively. At 1700 IST these deviations were —2.6 to 0.0, —2.8 to —0.8, —3.8 to —1.7, —3.8 to —1.0, —0.7 to 0.0 in °C under S_1, S_2, S_3, S_5, S_6 planting systems respectively, which reveal a reversal in the sign of the deviation values. This might be due to the fact that the crop canopy contributes energy to sensible heat flux. Rama Krishna *et al.* (1982) reported similar observations in case of pearlmillet crop. The average values of deviation were higher in S_3 as compared to other planting systems irrespective of sign (Table 2). Higher deviation of air temperature was probably due to the lowest leaf area index in S_3 (Table 7) which resulted in lesser solar radiation interception and more energy is utilized as sensible heat in the system.

At 0800 IST the deviation of relative humidity values in different treatments S_1, S_2, S_3, S_5, S_3 from S_4 at different levels inside the canopy ranged from —6 to 3, —4 to 0, —8 to —1, —9 to 0, —3 to 0 per cent and at 1300 IST from —10 to 5, —14 to 11, —11 to —2, —7 to 2, —13 to 11 in per cent under S_1, S_2, S_3, S_5, S_6 respectively. At 1700 IST these deviations were ranging from —4 to 10, —2 to 15, 4 to 20, —1 to 15, —8 to 3 in per cent. The relative

TABLE 4

Aerodynamic characteristics in raya

Date of obsn (Feb 86)	planting systems	Height (cm) 0800 IST 150	0800 IST 200	1100 IST 150	1100 IST 200	1400 IST 150	1400 IST 200	1700 IST 150	1700 IST 200
		(a) *Frictional velocity (cm/sec)*							
5	S_1	8.5	16.0	76.2	62.4	85.0	75.9	74.8	66.9
8	S_2	5.9	11.6	28.1	28.3	52.7	42.1	7.6	11.4
14	S_3	30.8	31.8	31.8	25.6	41.0	42.2	22.5	23.8
17	S_4	9.3	9.4	9.4	26.7	14.8	16.0	12.6	12.8
6	S_5	6.6	6.0	6.0	34.1	29.0	31.3	15.8	21.1
7	S_6	9.4	12.9	24.0	28.9	20.5	20.3	19.4	19.6
		(b) *Momentum of diffusivity (cm/sec)*							
5	S_1	522.7	1312.0	4686.3	5116.8	5227.5	6223.8	4600.2	5485.8
13	S_2	362.8	951.2	1728.1	52312.4	3241.0	3452.2	467.4	934.8
14	S_3	1894.0	2607.6	1574.4	2115.6	2521.5	3480.0	1383.7	1951.6
17	S_4	571.9	770.8	1648.2	2189.4	910.2	1312.0	774.9	1008.6
6	S_5	405.9	492.0	2097.1	2927.4	1783.5	2568.6	971.0	—
7	S_6	578.8	1057.8	1476.0	269.8	1260.7	1664.6	1205.4	1590.8
		(c) *Turbulent force (dynes/cm²)*							
5	S_1	0.081	0.289	6.561	4.400	8.164	6.500	6.322	6.057
8	S_2	0.039	0.152	0.892	0.898	3.138	2.002	0.065	0.146
14	S_3	1.071	1.142	0.740	0.752	1.89	2.022	0.572	0.640
9	S_4	0.097	0.099	0.811	0.805	0.247	0.289	0.179	0.170
6	S_5	0.049	0.040	1.313	1.440	0.950	1.107	1.282	0.503
7	S_6	0.099	9.188	0.943	0.474	0.465	0.434	0.445	

TABLE 5

Correlation coefficients between plant height and meteorological parameters

Met parameters		Cropping systems S_1	S_2	S_3	S_4	S_5	S_6
Air temp from germination to 50% flowering	Max	—0.95*	—0.95*	—0.95*	—0.94*	—0.95*	—0.95*
	Min	—0.96*	—0.96*	—0.96*	—0.96*	—0.96*	—0.96*
	Mean	—0.98*	—0.98*	—0.98*	—0.98*	—0.98*	—0.98*
Air temp from 50 per cent flowering to maturity	Max	0.57*	0.68*	0.64*	0.69*	0.56*	0.55*
	Min	0.84*	0.90*	0.88*	0.91*	0.82*	0.82*
	Mean	0.70*	0.79*	0.77*	0.80*	0.69*	0.69*
Relative humidity from germination to maturity		0.77*	0.76*	0.77*	0.77*	0.77*	0.77*
Vapour pressure deficit from germination to maturity		—0.81*	—0.82*	—0.82*	—0.82*	—0.82*	—0.76*

*Significant at 5 per cent level of significance

TABLE 6

Correlation coefficients between dry matter accumulation per plant and meteorological parameters

Met parameters		Cropping system					
		S_1	S_2	S_3	S_4	S_5	S_6
Air temp from germination to 50 per cent flowering	Max	—0.98*	—0.99*	—0.99*	—0.99*	—0.99*	—0.98*
	Min	—0.70*	—0.70*	—0.69*	—0.71*	—0.73*	—0.68*
	Mean	—0.94*	—0.95*	—0.91*	—0.95*	—0.96*	—0.93*
Air temp from 50 per cent flowering to maturity	Max	0.79*	0.79*	0.80*	0.80*	0.79*	0.79*
	Min	0.95*	0.95*	0.96*	0.96*	0.95*	0.96*
	Mean	0.88*	0.88*	0.88*	0.88*	0.88*	0.88*
Relative humidity from germination to maturity		0.71*	0.78*	0.78*	0.77*	0.75*	0.75*
Vapour pressure deficit from germination to maturity		—0.81*	—0.82*	—0.82*	—0.87*	—0.82*	—0.76*

*Significant at 5% level of significance

humidity variation shows a reserve trend similar to that of air temperature. Similar results were reported by Shrinivas (1984) obtained in case of rice crop.

The average values of the deviation were highest in S_3 irrespective of the sign due to the lowest leaf area index in this treatment. Similar trend was observed by Rama Krishna *et al.* (1982) in pearlmillet crop.

3.3. *Profiles of wind speed*

The wind speed profile observations at flowering are presented in Table 3. At all the heights, the wind speed increased with the advancement of the day up to noon hours, and afterwards the wind speed gradually decreased. The wind speed declined by 34 to 44, 39 to 51, 77 to 80, 62 to 82, 76 to 81 and 82 to 100 per cent at 120 cm height inside the crop canopy under S_3, S_5, S_6, S_2, S_4 and S_1 planting systems as compared to the bare soil surface at the flowering stage, respectively. At 40 cm height, the wind speed reduced by 100 per cent in S_1, S_2 and S_4, while in S_3, S_5, S_6 the reduction was 89 to 100, 92 to 100 and 85 to 90 per cent respectively. The reduction in wind speed was more at 40 cm than at 120 cm height, because more leaves were present in lower layers than upper layers interfering the flow of wind. Similar results were reported by Singh *et al.* (1981) in arhar crop.

3.4. *Frictional velocity*

The raya crop affected the aerodynamic characteristics. The frictional velocity increased with the advancement of the day and it was minimum at morning and evening hours and maximum at noon hours in all the planting systems. The data recorded at the pod formation stage given in Table 4 confirms this behaviour. Van Hylckama (1969) had similar observations in saltcedar.

3.5. *Momentum of diffusivity*

This parameter represent the rate of transfer of turbulent energy in between different layers which is responsible for generation of eddies inside the canopy. Data presented in Table 4, shows that the momentum of diffusivity increased from 0800 to 1400 IST and then decreased up to 1700 IST at pod formation stage. This behaviour is in conformity with the results of Willson *et al.* (1982) observed in corn canopy.

3.6. *Turbulent force*

Table 4 shows that the turbulent force increased from 0800 to 1100 IST and then decreased up to 1700 IST. It was maximum during noon hours and minimum at morning and evening hours at pod formation stage. Similar results were reported by Wright and Lemon (1966) in corn crop.

Correlation coefficients between plant heights and meteorological parameters presented in Table 5 indicate that the plant height in all the planting systems was significantly correlated with the temperature, relative humidity and vapour pressure deficit from germination to maturity. The plant height was positively correlated with maximum, minimum and mean air temperature from 50 per cent flowering to maturity and relative humidity from germination to maturity. There is a negative correlation between plant height and maximum, minimum and mean air temperature from germination to 50 per cent flowering and vapour pressure deficit from germinating to maturity.

Dry matter production and meteorological parameters (Table 6) indicate that the dry matter accumulation per plant in all the treatments was significantly correlated with the temperature, humidity and vapour pressure deficit during the growth cycle of raya. There is positive correlation between dry matter accumulation per plant and air temperature (maximum, minimum, mean) from 50 per cent flowering to maturity, relative humidity from germination to maturity, whereas the air temperature (maximum, minimum & mean) from germination to 50 per cent flowering and vapour pressure deficit from germination to maturity are negatively correlated with dry matter accumulation per plant.

TABLE 7

Effect of various planting systems on leaf area index (LAI), dry matter production, plant height, yield and harvesting index

Treat-ments	Max. LAI	Total dry matter production (q/ha)	Plant (cm)	Yield (q/ha)	Harvest index
S_1	2.90	80.10	164.50	16.22	0.20
S_2	2.95	82.36	171.10	16.63	0.202
S_3	2.20	55.16	162.50	12.16	0.220
S_4	3.06	84.96	173.40	17.99	0.211
S_5	2.45	76.50	168.50	15.20	0.199
S_6	2.65	78.16	167.20	15.81	0.202
S. Em ±	0.119	1.489	1.340	0.51	0.291
C.D. at 5%	0.347	4.660	4.210	1.59	N.S.

Maximum Leaf Area Index (LAI), plant height, dry matter and yield contributing parameters were significantly higher in S_4 planting systems as compared to the other planting systems and lowest in S_3 (Table 7). S_4 planting system provided higher biological contributing parameters due to higher PAR interception and better availability of microclimatic conditions for growth and development.

Harvesting index was not significant among the different planting systems due to small differences in the magnitudes of the biological contributing parameters generated due to microclimatic differences.

4. Conclusions

Ridge-furrow sowing with two rows in each furrow (S_4) produced maximum LAI, which resulted into higher photosynthetically active radiation interception. The increase in yield and dry matter production were resulted due to optimum temperature, humidity conditions available in S_4 system as compared to the other systems.

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