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Effect of row orientations, row spacings and weed-control methods on light interception, canopy temperature and productivity of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 1988–89 and 1989–90 to study the effect of row orientations, row spacings and weed-control methods on light interception, canopy temperature and productivity of wheat (*Triticum aestivum* L. emend. Fiori & Paol.). It was laid out in split-plot design with 3 replications by keeping the combinations of 3 row orientations (N–S, E–W and bi-directional) and 2 row specings (15 and 20 cm) + broadcast sowing in main plots and 4 weed-control treatments (unweeded check, isoproturon 0.75 kg/ha, isoproturon 1.50 kg/ha and hand-weeding twice) in sub-plots. Bi-directional row orientation resulted in increased light interception which increased the crop yields because of higher photosynthetic activity. Between spacings, 15 cm spacing was found superior to 20 cm spacing in intercepting light, decreasing canopy temperature and increasing the grain yield of wheat. Control of weeds with chemical and physical methods increased the canopy temperature than unweeded check at bottom of canopy, but reverse was the trend at top of canopy. The canopy temperature below middle of canopy was higher by 4.43–5.40°C over the air temperature in effective weed-control treatments. The canopy temperature in bidirectional row orientation was higher at top and middle and was lower at the bottom the crop canopy in comparison to the unidirectional row orientations. The total light interception and light interception below middle of canopy was higher in unweeded than other weed-control treatments.

The solar radiation that falls between crop rows remains unutilized and within rows over-crowded plants suffer from mutual shading. To get the maximum photosynthetic efficiency from all the leaves of a plant a uniform distribution and proper orientation of plants over a cropped area is needed for greater light interception throughout the crop profile. The orientation and spacing of rows also affect photosynthetic efficiency and canopy temperature through increased interception of solar radiation within the crop canopy. Proper orientation of rows increases yield of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) substantially (Dhillon and Kler, 1981). Weed-control methods may further modify the micro-climate by reducing the weed-crop competition under different row orientations and spacings, and may influence the productivity of crop. In the present study, therefore, the effect of different row orientations and spacings under different weed-control methods was studied to evaluate the light interception, canopy temperature and productivity of wheat.

MATERIALS AND METHODS

A field experiment was conducted during

Table 1. Effect of treatments on average light interception (%) and canopy temperature (°C) at maximum tillering stage of wheat

Treatment	Light interception (%) 9.30 AM						Canopy temperature °C at 2.30 PM (1988–89)		
	Total		Above Middle		Below middle		Top	Middle	Bottom
	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90			
Row orientation									
N–S	61.07	62.00	22.72	22.75	39.35	38.26	18.06 (–1.79)	18.74 (+ 0.30)	23.90 (+ 3.39)
E–W	53.15	53.28	19.70	19.92	33.35	33.36	17.99 (–1.26)	18.02 (–1.82)	24.32 (+ 4.89)
Bidirectional	64.95	66.52	26.74	27.25	39.21	39.27	18.95 (–0.68)	18.54 (–1.12)	21.63 (+ 1.68)
CD (P = 0.05)	1.41	1.66	2.76	2.48	2.79	3.40			
Row spacing									
15 cm	62.19	63.09	25.16	25.37	37.02	37.72	18.31 (–1.31)	18.38 (–1.00)	21.91 (– 1.07)
20 cm	57.26	58.11	20.94	21.24	36.37	36.87	18.35 (–1.17)	18.49 (–0.75)	24.65 (+ 5.57)
CD (P = 0.05)	1.12	1.35	2.33	2.03	NS	NS			
Weed-control method									
Unweeded	68.27	69.89	17.62	17.63	50.64	52.26	18.20 (–0.93)	18. 51 (–0.64)	19.39 (+ 1.41)
I soproturon 0.75 kg/ha	57.91	58.80	23.43	23.53	34.57	35.27	19.11 (–0.36)	18.69 (–0.90)	24.47 (+ 4.43)
Isoproturon 1.50 kg/ha	58.44	58.99	29.90	30.07	28.56	28.92	17.74 (–1.56)	17.93 (–1.33)	23.23 (+ 4.54)
Hand-weeding twice	53.40	53.56	21.70	22.03	31.70	31.53	17.86 (–2.04)	18.23 (–0.71)	25.67 (+ 5.30)
CD (P = 0.05)	2.38	2.19	2.06	1.99	2.49	2.45			
Broadcast vs others									
Broadcast	58.18	58.58	23.82	23.39	34.38	35.19	17.63 (–1.58)	17.80 (–1.03)	22.65 (– 3.08)
Others	59.72	60.60	23.05	23.30	36.70	37.30	18.33 (–1.24)	18.43 (–0.88)	23.28 (+ 3.32)
CD (P = 0.05)	NS	NS	NS	NS	NS	NS			

Values given in the parentheses are the deviations from ambient temperature.

the winter (*rabi*) season of 1988–89 and 1989–90 at HPKV, Palampur in split-plot design with 3 replications by keeping combinations of 3-row orientations (N–S, E–W and bidirectional) and 2 row spacings (15 and 20 cm) + broadcast sowing in main plots and 4 weed-control treatments (unweeded check, isoproturon 0.75 kg/ha, isoproturon 1.50 kg/ha and hand-weeding twice at 30 and 60 days after sowing) in sub-plots. The soil of the experimental filed was silty-clay loam in texture and acidic in reaction. The fertility of the soil was low in available N, medium in available P and high in available K.

'S 308' wheat was sown on 11 November and 15 November 1988 and 1989 by using 120 kg seed/ha. Fertilizer, irrigation and other cultural practices were applied in accordance with the recommended practices. For bidirectional sowing the seed and fertilizer were divided into 2 halves and was sown in equal quantity in both directions. The isoproturon was sprayed in 600 litres water/ha at 35 days after sowing by using knapsack sprayer. The light intensity was recorded at top, middle and bottom of crop canopy with the help of Photometer Model Luxomet 300. The data collected were utilized to calculate light interception (%) as per the formulae given by Walia and Cheema (1986).

The canopy temperature was recorded at top, middle and bottom of crop canopy with the help of infra-red thermometer AG 42. The difference between canopy temperature and ambient temperature was calculated in different layers of crop canopy. The species-wise weed population was recorded at maximum weed population stage (90 days after sowing) and data were analysed after square-root transformation.

RESULTS AND DISCUSSION

Weed count

The major weed species associated with the crop were *Phalaris minor* Retz., *Lolium temulentum* L., *Avena fatua* L. and *Vicia sativa* L. Uniform distribution of plants in bidirectional sowing reduced the weed count of all weed species except *Vicia sativa* (Table 3.) and thereby helped penetration of more light up to middle of crop canopy. Similarly closer row spacing (15 cm) reduced the population of all weed species except *Vicia sativa* and thus resulted in more light interception up to middle of canopy. All the weed-control methods reduced the population of all weed species over unweeded check and thus increased the light interception by the crop up to middle of crop canopy.

Light interception (%)

In both the years, bidirectional row orientation resulted in significantly highest total and above the middle of the crop canopy light interception (%) followed by N–S row orientation (Table 1). Walia and Cheema (1986) also reported similar results. The light interception below middle of the canopy was significantly higher in bidirectional and N–S row orientations. Bidirectional row orientation resulted in more uniform distribution of the plants per unit area, better establishment of seedlings and more attenuation of solar radiation by the canopy (Dhingra *et al.*, 1986). The lesser light interception in unidirectional row orientations could be ascribed to the poor plant development due to competition and mutual shading of plants in rows. These results confirm those of Grewal (1987).

Total light interception, and light interception above middle of the canopy was sig-

Table 2. Effect of treatments on grain yield and yield-contributing characters

Treatment	Grain yield (q/ha)		Effective tillers/m^2		Spike length (cm)		Spikelets/ spike		Grains/ spike		1,000-grain weight (g)	
	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90
Row orientation												
N–S	31.81	29.53	402.1	400.1	10.69	10.38	13.59	12.97	28.51	26.71	49.28	48.17
E–W	29.33	26.88	375.1	372.7	10.55	9.83	13.40	12.50	30.23	26.68	48.45	47.04
Bidirectional	36.32	32.95	486.5	480.9	10.74	10.23	13.87	13.05	29.98	27.00	49.20	47.92
CD (P = 0.05)	1.15	2.35	2.0	4.2	NS	0.39	NS	0.41	NS	NS	NS	Ns
Row spacing												
15 cm	33.30	30.74	446.5	438.5	10.66	10.22	13.67	12.87	29.22	26.90	48.94	47.95
20 cm	31.68	28.83	396.0	397.3	10.66	10.07	13.62	12.81	29.93	26.70	49.01	47.47
CD (P = 0.05)	0.94	NS	1.6	3.4	NS	NS	NS	NS	NS	NS	NS	NS
Weed-control method												
Unweeded	22.18	13.73	386.5	357.4	9.81	7.12	12.30	9.51	25.19	17.80	45.61	39.52
Isoproturon 0.75 kg/ha	32.62	30.53	423.4	427.7	10.82	10.88	13.90	13.80	29.48	28.23	49.94	50.00
Isoproturon 1.50 kg/ha	38.40	40.29	431.3	436.5	11.26	11.46	14.29	13.98	30.54	32.85	50.74	50.66
Hand-weeding twice	34.43	31.09	425.6	426.6	10.96	10.87	14.15	13.77	31.58	28.92	49.61	48.98
CD (P = 0.05)	1.15	2.34	2.1	5.3	0.51	0.33	0.54	0.33	2.27	1.05	0.73	0.69
Broadcast vs others												
Broadcast	28.43	23.67	389.6	377.33	11.04	9.69	13.75	12.34	30.44	25.36	48.98	46.79
Others	32.48	29.79	421.2	417.9	10.66	10.15	13.65	12.84	29.57	26.80	48.98	47.71
CD (P = 0.05)	1.76	3.60	3.1	6.4	NS	NS	NS	NS	NS	NS	NS	NS

nificantly higher in 15 cm row spacing. This may be attributed to higher crop plant stand in narrower spacing. Because of higher weed population (Table 3) and restriction of weeds height up to middle of the crop height, the light interception below the middle of the crop canopy was numerically higher in 20 cm spacing over 15 cm spacing.

Due to the maximum weed population (Table 3), the unweeded check resulted in significantly highest total and below the middle of crop canopy light interception, whereas the light interception above the middle of the crop canopy was higher in weed-control methods over unweeded check (Table 1).

The methods of sowing did not influence the light interception significantly but numerically interception was higher in line sowing than broadcast sowing.

Canopy temperature

In general, the canopy temperature at the top and middle of the crop was lower than the ambient temperature, whereas, at the bottom of the canopy, the canopy temperature was higher than the ambient temperature (Table 1). Higher the canopy temperature, more was the difference for the ambient temperature. The absorption of the short-wave radiation at the top and middle of the crop canopy and the transmission of infra-red (IR) radiation to the bottom might be responsible to increase the canopy temperature from top to the bottom of the crop canopy. The canopy temperature in bidirectional row orientation was higher at the top and middle, and was lower at the bottom of the crop canopy compared with the unidirectional row orientations. It may be attributed to more interception of radiation up to middle of the crop canopy and decreased interception thereafter which caused gradient in air temperature from top to the bottom of the crop canopy. Similar results were reported by Grewal (1987).

Row spacings did not cause much variation in canopy temperature at the top and middle of crop canopy. However, the higher population of weeds at 20 cm spacing compared with 15 cm spacing (Table 3) might have helped in increasing the canopy temperature at the bottom by checking the circulation of air within the crop canopy (Table 1). The same reason could be attributed to increase in canopy temperature by 5.57°C over ambient temperature.

There was not much variation in canopy temperature due to weed-control treatments in top and middle of crop canopy. But at the bottom of crop canopy, weed-control methods increased the canopy temperature by 3.84—6.28°C over the unweeded check. Among weed-control methods, hand weeding twice resulted in the highest canopy temperature which was higher by 5.30°C over ambient temperature at the bottom of the crop canopy. This is attributed to the effective control of weeds which helped in greater interception of light by crop canopy than weeds.

The weed suppression and uniform distribution of the crop plants in other methods of sowing increased the light penetration and thus increased the canopy temperature over broadcast method at all the layers of crop canopy.

Yield and yield-attributes

Because of the increased light interception and higher canopy temperature (Table 1), bidirectional row orientation increased the wheat grain yield significantly by a significant increase in yield-contributing characters like effective tillers, spike length and

Table 3. Effect of row orientations, row spacings and weed-control methods on species wise shoot count/m^2 of weeds at 90 DAS

Treatments	*Lolium temulentum*		*Phalaris minor*		*Avena fatua*		*Vicia sativa*	
	1989	1990	1989	1990	1989	1990	1989	1990
Row orientation								
N–S	8.23 (77.5)	7.45 (62.6)	8.51 (82.9)	8.31 (77.5)	2.90 (11.3)	7.00 (56.1)	4.37 (21.2)	5.67 (33.0)
E–W	9.50 (100.4)	8.88 (87.0)	9.15 (92.9)	9.00 (87.5)	2.98 (11.6)	8.56 (81.0)	4.27 (20.9)	6.07 (37.8)
Bidirectional	7.37 (60.9)	6.97 (54.7)	6.74 (50.3)	6.79 (51.3)	1.94 (4.5)	6.73 (51.3)	4.73 (24.6)	6.21 (39.8)
CD (P = 0.05)	0.46	0.37	0.83	0.44	NS	0.20	NS	NS
Row spacing								
15 cm	7.58 (66.5)	7.18 (59.2)	7.92 (71.9)	7.74 (66.4)	2.55 (8.5)	6.88 (54.6)	4.70 (24.4)	6.03 (37.4)
20 cm	9.16 (92.7)	8.35 (77.1)	8.35 (78.7)	8.33 (77.8)	2.67 (9.7)	7.98 (71.0)	4.21 (20.1)	5.94 (36.3)
CD (P = 0.05)	0.37	0.31	NS	0.35	NS	0.15	NS	NS
Weed-control method								
Unweeded	13.14 (174.6)	12.38 (154.6)	12.97 (166.7)	12.21 (151.4)	4.63 (22.5)	12.03 (145.6)	5.21 (29.6)	7.09 (50.5)
Isoproturon 0.75 kg/ha	7.78 (64.6)	6.93 (49.6)	7.26 (55.0)	7.60 (60.2)	2.15 (5.7)	6.64 (45.6)	4.61 (24.9)	6.41 (41.2)
Isoproturon 1.50 kg/ha	6.37 (42.2)	6.17 (39.6)	5.00 (29.7)	5.52 (32.1)	1.73 (2.2)	5.72 (33.6)	4.91 (25.4)	6.19 (38.6)
Hand-weeding twice	6.66 (46.0)	6.40 (43.2)	7.49 (57.4)	7.30 (54.3)	1.57 (3.7)	6.25 (41.2)	3.88 (16.7)	4.76 (23.2)
CD (P = 0.05)	0.49	0.31	0.82	0.52	0.78	0.23	NS	0.25
Broadcast vs others								
Broadcast	9.20 (95.1)	9.19 (93.5)	8.42 (88.2)	8.90 (89.3)	2.33 (7.1)	9.00 (88.9)	5.83 (35.3)	6.87 (47.7)
Others	8.37 (79.6)	7.77 (68.1)	8.14 (75.3)	8.03 (72.1)	2.61 (9.1)	7.43 (62.8)	4.46 (22.2)	5.98 (36.8)
CD (P = 0.05)	0.70	0.59	NS	0.68	NS	0.28	1.16	0.37

Values given in the parentheses are the means of the original values number of spikelets/spike followed by N—S row orientation (Table 2). However, the row orientations did not influence the grain number per spike and 1000-grain weight significantly. The N—S row orientation resulted in 8.5 and 9.9% higher grain yield than E—W row orientation during 1988—89 and 1989—90 respectively. Bidirectional sowing gave further increase of 14.1 and 11.6% over N—S direction during respective years. Similar results were reported by Walia and Cheema (1986).

The effect of row spacings was significant only during 1988—89 in influencing the grain yield and during both the years in influencing the effective tillers. The closer spacing of 15 cm increased these parameters significantly over 20 cm spacing (Table 2) by increased interception of light (Table 1).

The better physiological performance of the crop in weed-control methods due to effective reduction in weeds and proper distribution of solar radiation throughout the crop canopy, increased the yield and yield attributes of wheat crop significantly over unweeded check (Table 2). Signi-ficantly higher grain yield was recorded with isoproturon 1.50 kg/ha, followed by hand-weeding twice during both the years; however, the later was statistically at par with isoproturon 0.75 kg/ha during second year.

The other methods of sowing increased the grain yield significantly over broadcast sowing due to uniform distribution and higher crop plant stand. These findings corroborate the results of Chatha and Nazir (1985).

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