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Effect of shelterbelt on the microclimate of the gram (*Cicer arietinum*) crop

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सार — विभिन्न सघन खेती प्रणालियों में चने की फसल में वायुरोधी पट्टी के सूक्ष्म जलवायु पर प्रभाव का परिमाप निर्धारित करने के लिए चार उपचार, नामतः, शुद्ध चना, 1 : 1, 2 : 1 और 4 : 1 चना तथा रया सम्मिलित किए गए। विभिन्न उपचारों में धवलता में 14.8 से 22.6 प्रतिशत तक भिन्नता रही और उपचार में शुद्ध चने में अधिकतम मान 18.3 प्रतिशत रहा, जबकि 2 : 1 चने के उपचार (76 प्रतिशत) में प्रकाश संश्लेषण की दृष्टि से सक्रिय विकिरण अवशोषण अधिकतम रहा। शुद्ध चने के खेत की तुलना में 1 : 1 चने की सघन खेती प्रणाली में 4 एच० दूरी में वायुरोधी पट्टी के सिरे से पवन गति में अधिकतम कमी (69.2 प्रतिशत) प्रेक्षित की गई। शुद्ध चने की तुलना में वायुरोधी पट्टी के नीचे के चने में सापेक्ष आर्द्रता 8 से 15 प्रतिशत कम थी, जबकि शुद्ध चने की तुलना में वायुरोधी पट्टी के नीचे की फसल में औसत हवा तापमान में 1 से 2 डिग्री सेल्सियस की वृद्धि हुई। यह वृद्धि वायुरोधी पट्टी के किनारे से 4 एच० दूरी में 9.9 से 12.2 प्रतिशत तक थी। जनवरी तथा फरवरी के महीनों में शुद्ध चने की तुलना में 2 : 1 चने के उपचार में सबसे न्यूनतम तापमान में 0.7 डिग्री सेल्सियस तक वृद्धि हुई।

ABSTRACT. The shelterbelt influence on the microclimate of gram crop in different intercropping systems, comprising of four treatments, *viz.*, pure gram, 1 : 1, 2 : 1 and 4 : 1 gram and raya, was quantified. Albedo varied from 14.8 to 22.6 per cent in various treatments with highest value of 18.3 per cent in pure gram treatment, whereas, photosynthetically active radiation absorption was highest in 2 : 1 gram treatment (76%). Maximum reduction (69.2 per cent) in wind speed was observed in 1 : 1 intercropping system at 4h distance from the edge of the shelterbelt in comparison to pure gram field. Relative humidity was 8 to 15 per cent less in the sheltered gram as compare to the pure gram, whereas, the average air temperature increased by 1 to 2°C in the sheltered crop over that of the pure gram and this increase was in the range of 9.9 to 12.2 per cent at 4h distance from the edge of shelterbelt. The grass minimum temperature was higher by 0.7°C in 2 : 1 treatment over that of pure gram during the months of January and February.

Key words — Albedo, Treatment, Shelterbelt, Photosynthetically active radiation (PAR), Microclimate, Air temperature, Relative humidity.

1. Introduction

Gram is an important crop of semi-arid tropics. In India gram covers about 35 per cent of the cultivated area and accounts for about 45 per cent of the pulse production. It is a winter season crop. Severe cold and frosts prove injurious to it. Haryana state experiences the influence of moderate to severe cold wave conditions due to northwesterly cold winds from the last week of December to mid-February and the earth surface temperature often falls below 0°C resulting in heavy damage to gram crop. The leaf temperatures are generally 4 to 5°C below the air temperature in winter and there are fair chances of occurrence of frost at ground surface. Therefore, to improve the performance of crop, the crop microclimate needs to be modified by cultural methods. At critical stages, small change of microclimate causes significant differences in the growth attributes and fruit setting. The use of the shelterbelt has been reported to be an effective and economical method for modification of crop microclimate (Brown and Rosenberg 1970). Various tall crops have been successfully used as temporary wind barriers, such as, corn for protecting sugarbeet and soyabean, sorghum for groundnut, sunflower for wheat and soyabean and oats for tomato (Radke and Hangstorm 1970, Brown and Rosenberg 1971 and Aase and Siddaway 1974). Keeping the importance of shelterbelts in view the present study was undertaken to quantify the effect of shelterbelt of raya on the microclimate of gram crop.

2. Material and methods

The present investigation was carried out on the sandy loam soils at Experimental Farm area of

Fig. 1. Reflectivity of shortwave radiation at peak vegetative growth stage of gram

Haryana Agricultural University, Hisar (29° 10′ N, 75° 46′ E, 215.2 m asl) during rabi 1987-88. The experiment was laid out in a randomized block design with five replications. The treatments comprised of 4 sowing methods, *viz.*, sowing of pure gram (T1), intercropping of gram and mustard in row combination of 1 : 1 (T2), 2 : 1 (T3) and 4 : 1 (T4). The row-to-row spacing was 30 cm and plant-to-plant was 15 cm for both crops in all treatments. Crops were raised by adopting the recommended package of practices for the region.

Diurnal observations on the meteorological parameters were made on hourly intervals from 0800 to 1700 hours on clear sky days at important growth stages of the sheltered crop. The incident solar radiation over the top of the crop canopy was measured with a pyranometer. The net radiation was measured by holding net radiometer at one meter above the crop canopy. The soil heat flux was measured with soil heat flux plates kept in the cropped area at 5 cm soil depth. Photosynthetically active radiation (PAR) was measured with luxmeter. Air temperature and humidity were recorded with Assmann psychrometer. The grass minimum temperatures were recorded from thermometers installed in T1 and T3 as in the observatory. The microclimatic data in sheltered and unsheltered treatments were analysed and results are presented in the following section.

3. Results and discussion

Photosynthetically Active Radiation (PAR)

(a) Albedo

The albedo or reflectivity of PAR depends on the leaf characteristics of the crops, *viz.*, colour of the leaves, leaf orientation, chlorophyll content, internal moisture status of plants in addition to the solar elevation. The albedo values were more in T1 over the other treatments at peak vegetative, flowering and pod formation stages of gram. At pod formation in gram (maturity of raya) these were higher in T4 treatment and lowest in T3 (Table 1). The diurnal values of albedo in sheltered and exposed plots at peak vegetative stage are shown in Fig. 1. The albedo values were higher in the morning and evening hours irrespective of treatments due to higher reflectivity at lower solar elevation. Similar variation has been reported by Davies and Bettimor (1969) for crop surface and Nkedmirim (1973) for ground surface. The average albedo values in T2, T3 and T4 were lower by 7.90, 7.36, 2.10 per cent as compared to the pure gram (T1).

The decrease in albedo may be attributed to the differential growth of gram crop in the sheltered and exposed teatments, and also because of more turgid cells in sheltered plants. Turgidity increased the absorption of PAR, whereby reducing the albedo (Rosenberg 1966 and Nimani 1981). The higher albedo at peak vegetative growth and flowering stages of gram in all the treatments was due to higher leaf area prevalent during these growth stages. The albedo of pure gram was more than sheltered crops at peak vegetative growth, flowering and pod setting stages due to better cover of ground because of greater leaf area. However, at pod formation in gram, sheltered treatments had more albedo than unsheltered crop due to exposed bare soil after the harvest of raya (crop harvested on 1 March, 1988). The results are in agreement with earlier reports of Mayer (1981).

(b) Absorption and transmission

PAR absorption varied from 71.9 per cent to 76.2 per cent at peak vegetative growth stage. However, at flowering stage, when raya has reached pod setting, the PAR absorption decreased by 2-4 per cent and a slight increase in transmitted PAR was observed at

TABLE 1

Optical characteristics of PAR (%)

S. No.	Phenological stage of gram	PAR	T1	T2	T3	T4
1.	Peak vegetative in gram & flowering in raya	Albedo	18.3	14.0	14.4	13.0
		Absorption	73.0	71.9	76.0	76.2
		Transmission	8.7	14.1	9.6	10.8
2.	Flowering stage in gram & podding in raya	Albedo	15.4	12.5	11.4	13.8
		Absorption	72.6	71.0	75.9	72.3
		Transmission	12.0	16.5	12.7	13.9
3.	Pod formation in gram & maturity in raya	Albedo	9.8	9.2	8.4	8.6
		Absorption	73.6	70.9	76.8	74.9
		Transmission	16.6	19.9	14.8	16.5

TABLE 2(a)

Average relative humidity (%) on leeward side at different distances from the edge of shelterbelt

Treatment	Vegetative stage	Flowering stage	Pod setting stage	Mean	% of control
T1	79	68	66	71	100.0
T2 1h	67	60	59	62	87.3
2h	63	57	57	59	83.0
3h	63	55	55	57	81.2
4h	62	51	51	54	77.0
T3 1h	68	59	61	63	88.3
2h	64	60	56	60	84.5
3h	63	58	53	58	81.7
4h	63	58	54	57	80.8
T4 1h	69	62	55	62	87.3
2h	66	59	56	60	84.9
3h	62	51	54	58	82.2
4h	61	59	54	58	81.7

Peak vegetative stage in gram. Transmission component decreased as the number of rows of gram increased. The variation in absorption component is very little among phenological stages in T1, T2 and T3 compared to T4, where the value was maximum at peak vegetative stage and minimum at flowering stage. The results are in agreement with the observations of Shiv Dev (1986). The absorption component was less in T2 treatment due to lesser leaf area index resulting in poor absorption and greater transmission of PAR through the crop canopy.

(c) *Air temperature and relative humidity on the leeward of shelterbelts*

The average relative humidity and air temperature recorded at various distances from shelterbelt on leeward side at different growth stages of gram are presented in the Tables 2 (a) and (b). Table 2 (a) shows that the relative humidity at various growth stages in exposed treatment is lower than pure gram treatment. Relative humidity in 1h, 2h, 3h and 4h distances from edge was less by 12.5, 16.0, 18.0 and 20.0 per cent respectively over the exposed T1 treatment when averagd over the crop season. No appreciable differences were observed in relative humidity among the three sheltered treatments. The low relative humidity in sheltered treatments was due to the prevalent higher air temperature as the two are negatively correlated.

TABLE 2(b)

Average air temperature (°C) on leeward side at different distances from the edge of shelterbelt

Treatment	Vegetative stage	Flowering stage	Pod setting stage	Mean	% of control
T1	14.8	16.1	19.8	16.9	100.0
T2 1h	16.3	17.3	20.1	17.9	105.9
2h	16.6	17.0	21.0	18.2	107.1
3h	16.8	17.5	21.5	18.6	110.1
4h	17.1	17.9	21.9	18.9	112.2
T3 1h	15.9	17.3	20.8	18.0	106.5
2h	16.2	17.2	20.8	18.1	106.9
3h	16.8	17.6	21.1	18.5	109.5
4h	17.0	18.0	21.4	18.8	111.2
T4 1h	15.8	16.9	20.3	17.6	104.5
2h	16.0	17.2	20.7	17.9	106.3
3h	15.8	17.4	21.1	18.1	107.1
4h	16.7	17.6	21.4	18.6	109.9

TABLE 3

Wind speed (cm/sec) on leeward side at different distances from the edge of shelterbelt

Treatment	Vegetative stage	Flowering stage	Pod setting stage	Mean	% of control
T1	0.60	0.58	0.56	0.60	100.0
T2 1h	0.34	0.32	0.32	0.34	55.8
2h	0.26	0.24	0.24	0.25	42.1
3h	0.21	0.20	0.22	0.22	36.3
4h	0.19	0.17	0.18	0.19	30.8
T3 1h	0.39	0.36	0.37	0.39	65.0
2h	0.30	0.28	0.29	0.30	50.0
3h	0.24	0.23	0.23	0.24	40.0
4h	0.23	0.20	0.20	0.21	35.0
T4 1h	0.42	0.40	0.39	0.42	69.2
2h	0.33	0.29	0.33	0.32	53.8
3h	0.27	0.25	0.26	0.26	43.8
4h	0.25	0.22	0.22	0.32	38.8

The average air temperature increased with the increase of distance away from the shelterbelt (Table 2 b). The values, when considered for whole crop season, exceeded by 4.4 to 6.5, 6.3 to 7.1, 7.1 to 10.0 and 9.9 to 12.2 per cent at 1h, 2h, 3h and 4h respectively in sheltered treatments to those recorded in exposed field (T1). Similar trends were reported earlier by Skidmore and Hagan (1970) and Brown and Rosenberg (1972).

(d) Wind speed on the leeward of the shelterbelts

Table 3 shows that the lowest wind speeds were generally recorded at 4h from the edge of the shelterbelt in all the treatments. This may be due the fact that the coming winds were obstructed by shelterbelt. However, due to porosity, some wind passed through these shelterbelts affecting the wind speed at 1h, 2h, 3h and further this wind was

TABLE 4

Number of days with Grass minimum temperature (°C) during January and February, 1988

Temperature (°C)	January			February		
	Bare	T1	T3	Bare	T1	T3
< 0	8	10	9	5	5	5
< −1	6	7	5	3	3	1
< −2	4	4	4	1	2	1
< −3	0	3	0	0	0	0
Lowest temperature recorded	−3.0	−3.3	−2.6	−2.4	−3.0	−2.3

minimized at 4h (Marshall 1967). The wind speed values were considerably higher in T1 treatments over the rest. The wind speed values were 31 to 39 per cent at 4h, 36 to 44 per cent at 3h, 42 to 54 per cent at 2h and 56 to 69 per cent the sheltered treatments of the wind speed recorded in exposed (T1) treatment. Miller *et al.* (1973) also found 40 to 60 per cent reduction of wind speed at 4h by 50 per cent porous shelterbelt and 20 to 30 per cent reduction when the porosity was increased at same distance.

(*e*) *Grass minimum temperature and frost*

The minimum temperature at grass level is more important during rabi season as compared to minimum temperature at screen height because the microclimate of crop is quite different from the open place. Therefore, grass level temperature was taken into consideration. The grass minimum temperature data in Table 4 indicated that January was cooler than February. The lowest value attained in January in T1 treatment was −3.3°C, whereas, in T3 treatment, it was −2.6°C. The January month had 10 days with grass minimum temperature of less than 0°C in T1, 8 days in bare field and 9 days in T3 treatment. This indicated that bare field was warmer than pure gram treatment (T1), where more heat loss took place through vegetation. However, in open environment of bare field, the free mixing of air helped in comparatively less fall of temperature. The possible reasons for which may be the rapid heat loss in form of sensible heat exchange taking place by the numerous thinner and narrower leaves in pure gram (T1) as compared to the sheltered crop in T3, where raya leaves are thicker and broader thus having low heat exchange.

References

Aase, J. K. and Siddoway, F. H., 1974, "Tall wheat grass barriers and winter wheat responses", *Agric. Meteorol.*, **13**, 321-338.

Brown, K. W. and Rosenberg, N. J., 1970, "Effect of wind breaks and soil water potential on stomatal diffusion resistance and photosynthetic rate of sugarbeets", *Agron. J.*, **62**, 4-8.

Brown, K. W. and Rosenberg, N. J., 1971, "Turbulent transport and energy balance as affected by windbreak in an irrigated sugarbeet field", *Agron. J.*, **63** (3), 351-355.

Brown, K.W. and Rosenberg, N. J., 1972, "Shelter effect on microclimate, growth and water use of irrigated sugarbeet in the Great Plains". *Agric. Meteorol.*, **9**, 241-263.

Davies, J. A. and Bettimor, P. H., 1969, "Reflection coefficients and net radiation at Simcoe, Ontario", *Agric. Meteorol.*, **6**, 373-386.

Marshall, J. K., 1967, "The effect of shelter on the productivity of grasslands and field crops", *Field Crop Abstr.*, **20**, 1-14.

Mayer, H., 1981, "Radiation measurements over bare soil, a maize crop and a vinegard", *Agric. Meteorol.*, **2**, 317-330.

Miller, D. R., Bagley, W. T. and Rosenberg, N. J., 1973, "Soyabean water use in the shelter of a slatfence wind break", *Agric. Meteorol.*, **11**, 405-418.

Nimani, R. K., Rao, 1981, "Effect of shelterbelt on the microclimate and yield of ground crop", M.Sc. Thesis, PAU, Ludhiana.

Nkedmirim, L. C., 1973, "Radiative flux measurements over crops", *Agric. Meteorol.*, **11**, 229-242.

Radke, J. K. and Hangstorm, R. T., 1970, "Wind turbulence in soyabean field sheltered by four types of wind barriers", *Agron. J.*, **66**, 273-278.

Rosenberg, N. J., 1966, "Influence of snowfence and corn wind breaks on agriculture in dry regions in ground level climatology", *Amer. Assoc. Adv. Sci.*, 327-349.

Shiv Dev, 1986, "Quantification of crop microclimate in intercropping of gram (Cicer aeritinum) with raya (Brassica juncea)", M.Sc. Thesis, HAU, Hisar.

Skidmore, E. L. and Hagan, L. J., 1970, "Evaporation in sheltered area as influenced by wind break porosity", *Agric. Meteorol.*, **7**, 363-374.