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Effect of sowing time and in-season growth manipulations on energy balance and radiation use efficiency of Indian mustard

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ABSTRACT

Field studies were conducted at Research Farm, CCS Haryana Agricultural University during two consecutive winter (*rabi*) seasons of 2002-03 and 2003-04 to study the effect of sowing time and in-season growth manipulations on energy balance and radiation use efficiency in Indian mustard. The latent heat of evaporation (LE) varied over crop growth stages owing to differential leaf area index. Sensible heat flux (A) kept on increasing till maturity of crop and was positive. The diurnal variations in soil heat flux were quite small. The diurnal measurements indicated that the net radiation (Rn), LE and A were highest during noon hours. The radiation use efficiency (RUE) was highest in early sown crop (S_1) followed by later sown crops (S_2 and S_3); however, among growth manipulation treatments, RUE was the highest in L_1 (control involving no growth manipulation). The seed yield was linearly correlated with leaf area index indicating the dependence of RUE on canopy development.

Key words **:** Indian mustard, sowing dates, growth manipulations, energy balance, radiation use efficiency

Rapeseed and mustard after groundnut, is second important crop among the oilseed crops, grown in India. The crop growing environmental conditions can be manipulated by opting different sowing dates resulting in different sets of environmental conditions for the crop, which are likely to be encountered during crop growth. There are other possible options by which the micrometeorological conditions can be modified. Altering canopy architecture by physical means involving in-season plant cut-off and leaf defoliation could be adopted to modify the crop architecture which ultimately leads to changes in the radiation interception and utilization efficiency of intercepted light. Assimilation of photosynthates in source and their translocation towards sink is affected because of interference of source and sink relationships through growth manipulations. The crop growth parameters *viz*., biomass accumulation, leaf area index (LAI) and yield are greatly influenced by the seasonal weather conditions. Over the last three decades, there has been increasing research interest in measurement of solar radiation in crop canopies and its use in assessment weather parameters. Positive correlations with temperature range signify that the diurnal variation in temperature should be larger for higher seed yield. Fig. 4 and 5 clearly suggested that for higher yield maximum temperature should be between 30 to 32°C and minimum temperature should be less than 11 to 14°C during flowering and pod development phases of the crop

Regression equation

Based on significant association between weather parameters and seed yield of mustard regression analysis was carried out for development of yield prediction equation (Table 3). It may be seen that BSS, maximum and minimum temperatures, and temperature range explained about 69 % variation in the seed yield of mustard. These equations can be used to predict the seed yield of mustard. However, among all the models, the model developed with temperature range during P2 phase can be preferred for our region as it explained highest (92 %) variation in the seed yield.

CONCLUSION

Thus, it can be concluded that three irrigations had significant influence on seed yield of mustard. However, higher irrigation reduced the seed yield. Further, variety GM-2 recorded higher oil content and lower protein content over varuna. Flowering and pod development phases of the mustard were found to be most sensitive to weather parameters. Temperature range during flowering stages alone accounted for 92 % variation in seed yield of mustard.

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of productivity of important crops. Further, efforts have also been made to quantify the weather relationships in several crops in past. However information on these aspects for mustard crop is scanty. Hence, the present study was undertaken to study the aspects outlined above.

MATERIALS AND METHODS

The study was conducted at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar (Lat. 29°10'N, Long. 75°46'E and altitude of 215.2 m a.s.l.) during winter season of 2002-03 and 2003-04. The experiment was conducted in split-plot design with four replications and comprised of three sowing dates *viz.*, October 5 (S_1), October 20 (S_2), November 5 (S_3) as main plot treatments and seven in-season growth manipulations *viz.*, Control or no manipulation (L_1), main shoot cut-off at 15 cm on 40 DAS (L_2), Main shoot cut-off at 15 cm on 50 DAS (L_3), 1st primary branch cut-off on 55 DAS (L_4), 2nd primary branch cut-off on 60 DAS (L_5), plant defoliated to 50 cm above ground on 60 DAS (L_6) and plant defoliated to 50 cm above ground on 75 DAS (L_7) as sub-plot treatments. Urea @ 80 kg ha^{-1} and single superphosphate @ 40 kg ha^{-1} was applied as per recommended agronomic practices. The seed was drilled in rows of 30 cm apart @ 5 kg ha^{-1} and plants within a row were thinned to 15 cm.

The energy balance components were measured on certain days (mentioned in Tables) at seed development, most seed brown and physiological maturity stages. Net radiometer and soil heat flux plates (Medoes & Co., Australia) were used for measurement of net radiation (Rn) and Soil heat flux (G), respectively. Meteorological parameters recorded at Agromet Observatory located adjoining the experimental site were used. Leaf area index and dry matter accumulation (g m^{-2}) were worked out at different growth stages on the basis of measurements with leaf area meter (LICOR, LI-3000) and dry matter of five randomly selected plants in each plot.

The energy balance components are represented by the following equation:

$$Rn = LE + A + G$$

Where, Rn = net radiation, mW cm^{-2}, LE = latent heat flux, mW cm^{-2}, G=ground heat flux, mW cm^{-2}, A=sensible heat flux, mW cm^{-2}

The energy used for evapotranspiration is expressed as (Suomi and Tanner, 1958; Denmead and Mclory, 1970):

$$LE = (Rn - G) / 1 + \beta$$

Where,

Bowen Ratio (β) = 0.66 × dt/de

Where, dt = temperature gradient between two heights, and de = vapour pressure gradient between two heights

The radiation use efficiency (RUE) was calculated by using the following formula:

$$RUE = \frac{\text{Biomass (g m}^{-2}\text{)}}{\text{APAR (MJ m}^{-2}\text{)}}$$

RESULTS AND DISCUSSION

The daytime energy balance recorded at seed development and physiological maturity stages of mustard crop during two crop seasons is shown in Table 1 and 2, respectively. The results indicated that on an average around 55% of Rs (incoming solar radiation) was utilized as Rn, irrespective of the growth stage or treatment. The values for different energy balance components varied from morning to evening with maxima occurring around noon. In general, a major portion of Rn was utilized in LE followed by A and G. The share of LE, A and G values recorded on 14th February, 2003 at seed development stage during 2002-2003 crop season varied from 62 to 70%, 24 to 33% and 4 to 6% of Rn over different treatments, respectively. During the 2003-04 season these varied from 56-68%, 27-39% and 4-8%, respectively. The observations recorded at physiological maturity during March in two crop seasons showed that the LE and A values remained between 65 to 70% and 58 to 65%; 26 to 31% and 31 to 34% of Rn, respectively. Similarly, the G values were around 4% and between 3-4% during two seasons, respectively. Similar results were reported by Rao *et al.* (1998). In bare field, the soil heat flux values were always higher over those observed in the crop field due to obvious reasons. Higher LE values over cropped field were due to cooling of crop by transpiration process and thus a large fraction of Rn was utilized in LE (Rao *et. al.*, 1998).

The radiation use efficiency (RUE) values were calculated (Table 3) for different treatments based on above ground biomass at physiological maturity. The RUE was highest in S_1 followed by S_2 and S_3 during 2002-03 and 2003-04 crop seasons, respectively. This can be expected since more dry matter accumulation occurred in S_1 than both S_2 and S_3as also observed earlier by Kar (1996) and Singh *et al.* (1999) in mustard. The RUE was higher during 2002-03 than that of 2003-04 owing to better growth and yield parameters realization. Among growth manipulation treatments, RUE was highest in L_1 and lowest in L_3. The higher RUE in L_1 might be due to uninhibited dry matter accumulation with no in-season manipulation. However in L_3 treatment the lowest RUE was result of plant cut-off at 50 DAS which led to considerable loss of biomass and a temporary set-back in growth and development which could not be compensated by the later growth till crop maturity (Table 3). The other treatments involving in-season growth manipulation *viz.*, L_2, L_2 and L_3 had lower RUE in comparison to L_1 irrespective of sowing date during both the years.

The regression equations for seed yield and leaf area index at different growth intervals are depicted in Fig. 1. The trend curve showed that the seed yield was highly dependent on leaf area index at all growth intervals and explained variability of seed yield in the range of 64 to 77 per cent.

Table 1: Energy balance components (mW cm^{-2}) in mustard at seed development

Sowing date	Treatment	Rs	Rn	G	A	LE
Observation day: 14-02-03						
5 Oct. 2002	L_1	532.7	296.7	13.5	90.7	192.2
			(55.7)*	(4.6)@	(30.6)@	(64.8)@
	L_2	532.7	305.3	13.0	81.3	211.0
			(57.3)	(4.3)	(26.6)	(69.1)
20 Oct. 2002	L_1	508.3	284.8	14.9	80.7	189.4
			(56.0)	(5.2)	(28.3)	(66.5)
	L_2	510.3	284.7	15.6	92.6	176.6
			(55.8)	(5.5)	(32.5)	(62.0)
5 Nov. 2002	L_1	509.6	279.8	14.8	67.9	197.0
			(54.9)	(5.3)	(24.3)	(70.4)
	L_2	521.8	274.0	15.9	69.3	188.8
			(52.5)	(5.8)	(25.3)	(68.9)
	Bare soil	480.8	267.9	39.9	62.4	165.6
			(55.7)	(14.9)	(23.3)	(61.8)
Observation day: 05-02-2004						
5 Oct. 2003	L_1	538.5	291.4	14.9	77.1	199.4
			(54.1)	(5.1)	(26.5)	(68.4)
	L_2	522.4	279.4	21.2	94.2	164.1
			(53.5)	(7.6)	(33.7)	(58.7)
20 Oct. 2003	L_1	517.9	276.0	13.5	75.8	186.6
			(53.3)	(4.9)	(27.5)	(67.6)
	L_2	521.2	272.2	13.5	107.3	151.5
			(52.2)	(4.9)	(39.4)	(55.7)
5 Nov. 2003	L_1	513.5	272.6	11.5	78.7	182.3
			(53.1)	(4.2)	(28.9)	(66.9)
	L_2	539.1	283.8	14.4	106.1	163.3
			(52.6)	(5.1)	(37.4)	(57.5)
	Bare soil	537.8	278.2	37.5	82.7	158.0
			(51.7)	(13.5)	(29.7)	(56.8)

* The values in parenthesis are per cent fraction of Rs

@ The values in parenthesis are per cent fraction of Rn

Table 2: Energy balance components (mW cm^{-2}) in mustard at physiological maturity

Sowing date	Treatment	Rs	Rn	G	A	LE
			Observation day: 06-03-03			
5 Oct 2002	L_1	692.3	363.5	13.5	103.0	247.0
			(52.5)*	(3.7)@	(28.3)@	(68.0)@
	L_7	691.0	370.4	14.9	96.2	259.4
			(53.6)	(4.0)	(26.0)	(70.0)
20 Oct 2002	L_1	680.8	366.6	13.5	104.8	248.3
			(53.9)	(3.7)	(28.6)	(67.7)
	L_7	680.8	366.6	13.5	104.8	248.1
			(53.8)	(3.7)	(28.6)	(67.7)
5 Nov 2002	L_1	703.2	382.8	14.9	100.6	267.3
			(54.4)	(3.9)	(26.3)	(69.8)
	L_7	695.5	382.7	14.9	119.0	248.8
			(55.0)	(3.9)	(31.1)	(65.0)
	Bare soil	703.3	319.7	49.0	89.3	181.5
			(45.5)	(5.3)	(27.9)	(56.8)
			Observation day: 05-03-2004			
5 Oct 2003	L_1	670.5	358.3	15.5	122.2	220.7
			(53.4)	(4.3)	(34.1)	(61.6)
	L_7	665.4	368.1	14.9	114.4	239.0
			(55.3)	(4.0)	(31.1)	(64.9)
20 Oct 2003	L_1	697.4	373.2	14.9	126.6	231.8
			(53.5)	(4.0)	(33.9)	(62.1)
	L_7	666.0	362.4	10.1	121.4	230.9
			(54.4)	(2.8)	(33.5)	(63.7)
5 Nov 2003	L_1	672.4	351.8	15.2	132.9	203.6
			(52.3)	(4.3)	(37.8)	(57.9)
	L_7	693.6	356.3	10.2	117.4	228.8
			(51.4)	(2.9)	(32.9)	(64.2)
	Bare soil	691.1	359.1	52.9	123.8	182.4
			(51.9)	(14.7)	(34.5)	(50.8)

* Values in parenthesis are per cent fraction of Rs

@ Values in parenthesis are per cent fraction of Rn

Table 3: Radiation use efficiency (g MJ^{-1}) at maturity in Indian mustard

Treatments	Growth manipulations				
	L_1	L_2	L_3	L_7	Mean
2002-03					
Sowing dates					
S_1	2.23	2.18	2.09	2.20	2.18
S_2	1.86	1.69	1.58	1.71	1.71
S_3	1.31	1.18	1.15	1.26	1.23
Mean	1.80	1.68	1.67	1.72	
2003-04					
S_1	2.11	2.08	1.97	2.08	2.06
S_2	1.78	1.62	1.47	1.69	1.64
S_3	1.20	1.14	1.04	1.16	1.14
Mean	1.70	1.61	1.49	1.64	

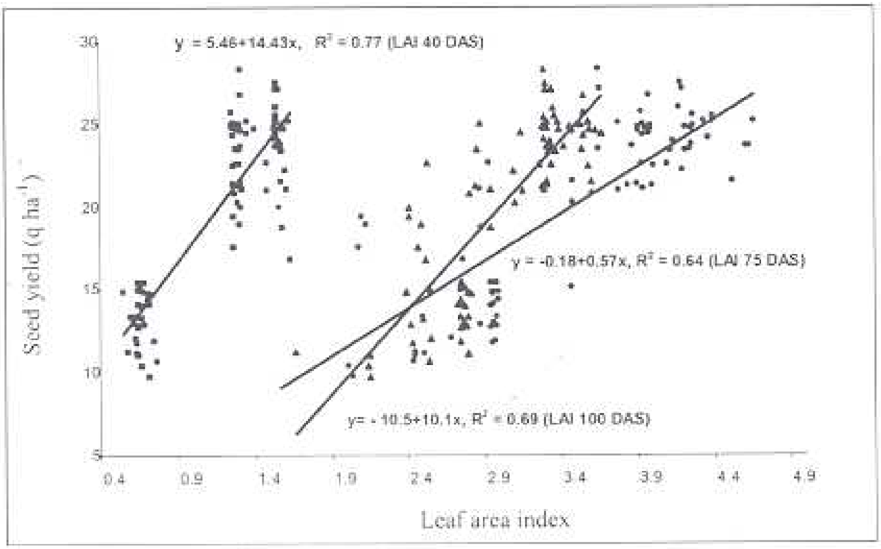

Fig. 1 : Relationship between seed yield and leaf area index at different growth intervals in Indian mustard

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