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EFFECT OF SOWING TIME AND PLANTING DENSITY ON RADIATION USE EFFICIENCY OF INDIAN BRASSICA

RAJ SINGH, V.U.M. RAO and DIWAN SINGH
Department of Agricultural Meteorology, CCS HAU, Hisar - 125 004, India.

Radiation use efficiency (RUE) was worked out for four Indian brassica cultivars raised in field experiments comprising of three dates of sowing and two spacing. The RUE values declined as the sowing time was delayed. The early sown crop was more efficient in converting the photosynthetically active radiation (PAR) into dry matter and hence early sowing need to be preferred. The planting density variation failed to influence the RUE significantly. The lowest values of RUE were observed in brown sarson in both the years due to its shorter reproductive phase. The extinction coefficient (k) continued to increase till the crop attained maximum leaf area index (LAI) and declined thereafter successively till the crop maturity. The highest values (0.99 and 0.96) of 'k' were observed in earliest sown crop at 60 days after sowing (DAS) both in 2003-04 and 2004-05, respectively. The values of k showed no significant trend with change of planting density.

Keywords : Brassica; Brown sarson; Dry matter; Extinction coefficient; Radiation use efficiency.

Introduction

Plants depend for growth and development on their genetic constraints and the environmental conditions. One of the most important aspects of crop development affecting dry matter production and economic yield concerns with the development of leaf canopy and its effect on the efficiency of radiation interception, particularly the photosynthetically active radiation (PAR). Much of the observed seasonal and intra-seasonal variations in agricultural output are frequently attributed to the influence of weather conditions on plant growth. One of the important factors of crop production is solar radiation that provides the source of energy for the process of photosynthesis, plant growth and dry matter (DM) accumulation. However, the requirement for solar radiation differs from one crop to another and one phase to another. The accumulation of biomass is essentially a linear function of the amount of accumulated intercepted photosynthetically active radiation (APAR) by the crop canopy, which is the function of leaf area index[1]. The efficiency of PAR interception is directly related to LAI, extinction coefficient (k) and architecture of the canopy. Plant stand can also influence the canopy structure and thereby influencing the efficiency of PAR interception and subsequently dry matter production. Radiation use efficiency (RUE) provides an estimate on the crop conversion efficiency of APAR into biomass. These values are useful in screening cultivars for their potential productivity. Hence, in order to evaluate the influence of sowing time, spacing on the RUE of Indian Brassica cultivars, a field study was conducted during the winter seasons of 2003-04 and 2004-05.

Materials and Methods

The data used in the present study were collected from field experiment conducted during winter seasons of 2003-04 and 2004-05 at the Research Farm of Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar (29°10'N 75°46'E and 215.2m a.m.s.l.). The experiment was laid out in split-plot design with three replications. The treatment combinations comprising of three sowing dates (D_1 - Oct 5, D_2 - Oct 19 and D_3 - Nov 5), two plant densities (S_1 - 30 cm x 15 cm and S_2 - 40cm x 20 cm) were kept in main plots and the four varieties {V_1 – Varuna, V_2 – Rh-30, V_3 – Laxmi (all three *Brassica juncea*) and V_4 - BSH 1 (*Brassica campestris*)} in sub-plots. The soil of the site was sandy loam, slightly alkaline with poor nitrogen content, medium in phosphorus and rich in potash. Photosynthetically active radiation (incident, transmitted and reflected) over the crop canopy and bare soil were measured at 7 day intervals with line quantum sensor of 1m length. The absorbed photosynthetically radiation (APAR) was worked out as per the formula of Asrar *et al.*[2]. The dry matter produced by the different genotypes was also recorded on the same day when photosynthetically active radiation was measured. The biomass produced per unit amount of APAR expressed as grams of biomass produced per unit of APAR and the same is represented as:

$$\text{Radiation use efficiency (RUE)} = \frac{\text{Biomass (g m}^{-2}\text{) accumulated during the phenophase}}{\text{APAR (MJ m}^{-2}\text{) accumulated during the phenophase}}$$

Table 1. Effect of sowing dates and plant densities on radiation use efficiency of Brassicas at various phenophases (2003-04).

Treatments	First flower open DM	IPAR	RUE	50% flowering DM	IPAR	RUE	Start of seed filling DM	IPAR	RUE	End of seed filling DM	IPAR	RUE	Maturity DM	IPAR	RUE
	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}
Sowing Dates															
D_1	136.1	200.5	0.68	233.4	160.9	0.89	467.4	350.2	1.33	1440.5	626.4	2.30	1428.9	721.5	1.98
D_2	119.9	209.8	0.57	190.7	246.5	0.77	385.2	328.7	1.17	1242.5	603.4	2.06	1234.5	696.3	1.77
D_3	69.7	211.4	0.33	130.6	256.9	0.51	286.7	332.1	0.86	773.3	589.6	1.31	774.1	652.8	1.19
Plant Densities															
S_1	109.5	228.6	0.48	186.6	280.6	0.67	383.9	369.9	1.04	1154.6	611.7	1.89	1148.9	689.3	1.67
S_2	107.7	228.4	0.47	183.2	280.3	0.65	375.5	374.2	1.00	1149.6	605.7	1.90	1144.7	690.0	1.66
Varieties															
V_1	113.6	228.0	0.50	189.3	285.3	0.66	388.7	374.0	1.04	1173.3	632.1	1.86	1163.8	713.2	1.63
V_2	116.8	233.2	0.50	194.6	295.4	0.66	396.2	373.7	1.06	1203.5	616.3	1.95	1199.3	694.7	1.73
V_3	117.6	245.1	0.48	197.7	295.9	0.67	404.9	389.2	1.04	1235.5	644.9	1.92	1222.8	724.4	1.69
V_4	86.7	206.2	0.42	158.9	257.3	0.62	328.9	345.6	0.95	996.2	647.0	1.82	1001.2	623.9	1.60

Table 2. Effect of sowing dates and plant densities on radiation use efficiency of Brassicas at various phenophases (2004-05).

Treatments	First flower open DM	IPAR	RUE	50% flowering DM	IPAR	RUE	Start of seed filling DM	IPAR	RUE	End of seed filling DM	IPAR	RUE	Maturity DM	IPAR	RUE
	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}	g	MJ	g MJ^{-1}
Sowing Dates															
D_1	127.1	219.1	0.58	202.6	270.1	0.75	383.8	333.7	1.15	1182.5	619.1	1.91	1234.4	697.4	1.77
D_2	108.6	231.1	0.47	143.5	239.2	0.60	290.9	312.8	0.93	1042.9	592.6	1.76	1097.1	652.8	1.65
D_3	70.9	221.6	0.32	115.0	261.2	0.44	213.8	296.9	0.72	705.7	573.7	1.23	698.4	632.7	1.07
Plant Densities															
S_1	97.0	215.6	0.45	171.5	268.0	0.64	297.5	294.6	1.01	1012.5	592.1	1.71	1023.2	639.5	1.60
S_2	99.2	215.6	0.46	173.7	263.2	0.66	296.2	290.4	1.02	1011.7	584.8	1.73	1019.3	633.1	1.61
Varieties															
V_1	96.4	214.2	0.45	174.2	268.0	0.65	288.7	294.6	0.98	1039.4	564.9	1.84	1086.1	638.9	1.70
V_2	98.5	218.8	0.45	175.8	274.7	0.64	290.9	306.3	0.95	1058.5	584.8	1.81	1114.7	667.5	1.67
V_3	102.9	228.7	0.45	183.2	281.8	0.65	296.8	312.4	0.95	1107.0	615.0	1.80	1172.0	693.5	1.69
V_4	88.6	192.5	0.46	157.6	225.1	0.70	247.3	277.9	0.89	925.6	525.9	1.76	1015.7	619.3	1.64

Table 3. Effect of different treatments on extinction coefficients (k) over Brassicas at various growth intervals.

	2003-04							2004-05						
Treatments	30	45	60	75	90	105	120	30	45	60	75	90	105	120
Sowing Dates														
D_1	0.54	0.75	0.99	0.89	0.76	0.63	0.59	0.53	0.68	0.96	0.83	0.73	0.65	0.54
D_2	0.51	0.78	0.86	0.97	0.80	0.70	0.59	0.50	0.63	0.84	0.81	0.70	0.63	0.52
D_3	0.50	0.61	0.80	0.84	0.86	0.75	0.55	0.49	0.59	0.78	0.75	0.68	0.62	0.49
Plant Densities														
S_1	0.53	0.73	0.92	0.91	0.81	0.71	0.59	0.48	0.64	0.88	0.85	0.71	0.64	0.52
S_2	0.51	0.69	0.90	0.88	0.79	0.68	0.58	0.47	0.63	0.87	0.86	0.70	0.63	0.51
Varieties														
V_1	0.52	0.74	0.92	0.90	0.80	0.68	0.58	0.48	0.63	0.86	0.85	0.71	0.63	0.52
V_2	0.53	0.71	0.87	0.88	0.81	0.69	0.56	0.49	0.64	0.88	0.86	0.70	0.62	0.51
V_3	0.54	0.70	0.93	0.91	0.81	0.72	0.58	0.50	0.65	0.89	0.86	0.72	0.64	0.53
V_4	0.51	0.70	0.86	0.88	0.78	0.67	0.54	0.50	0.61	0.82	0.78	0.69	0.62	0.49

The light extinction coefficient 'k'of the canopy was calculated using the modified Bouguer-Lambert-Beer's Law[3].

Results and Discussion

Radiation use efficiency: Radiation provides source of energy for plant growth and dry matter production and the ability of different species to provide the latter can be assessed in terms of RUE values obtained over different phenophases in brassica are presented in Table 1 and Table 2. Though, the amount of PAR received above the canopy was almost same in different treatments, but the intercepted PAR differed because of differential crop cover owing to variation in leaf area index (LAI) and varying levels of biomass production in different treatments implying that RUE also differed. Highest RUE of 2.3 and 1.91 g MJ^{-1} were recorded in earliest sown crop of D_1 in 2003-04 and 2004-05, respectively. Among the cultivars, the higher RUE values in the early sown crop are expected since the crop had already attained significant LAI which resulted in better dry matter accumulation. Several studies on sowing time have earlier revealed that the seed yield and dry matter accumulation declined with delayed sowing[4]. Further the studies have indicated that yield decline in late sown crop was associated with early flowering, short reproductive period and poor dry matter accumulation. The lowest RUE was recorded in late sown crop (D_3) sowing date in both years. The continuous increase in biomass till end of seed filling resulted in increased RUE at successive growth stages; however, slight fall in RUE at maturity was because of slower rate of gain in biomass during this period. The results of the present investigation are akin to those reported earlier by Kar[5] in mustard crop. Radiation use efficiency (RUE) varied between 0.33 to 2.30 g MJ^{-1} in 2003-04 and 0.32 to 1.91 g MJ^{-1} in 2004-05. The RUE of the crop was lower during 2004-05 as compared to 2003-04 due to poor crop establishment and inferior growth parameters and also due to low temperature during early establishment and vegetative stage and higher temperature during reproductive stage resulting in poor growth and development resulting in lower RUE. Planting density failed to influence the RUE significantly.

The differences of RUE were quite narrow among the *Brassica juncea* cultivars, however it was highest in RH-30 during both the years. The lowest values of RUE were observed in BSH-I (*Brassica campestris* Var *brown sarson*) in both the years because of its shorter duration of vegetative and reproductive phases.

Light extinction coefficient: The light extinction coefficient (k) is a measure of the attenuation of the radiation when passing through the canopy per unit LAI. The values of k calculated for different treatments are presented in Table 3. Among the sowing dates, the highest values (0.99 and 0.96) of k were observed in D_1 at 60 days after sowing (DAS) in 2003-04 and 2004-05, respectively. The lowest values (0.50 and 0.49) of k were recorded at 30 DAS in 2003-04 and 2004-05 in D_3. In general, the k values were less in 2004-05 as compared to 2003-04 in all three dates of sowing. This was because of the poor crop establishment and lower values of LAI in 2004-05. The extinction coefficient continued to increase till the crop attained maximum LAI and then decreased thereafter successively till the crop maturity. The values of k showed no significant change in trend as plant density varied. Among the cultivars, Laxmi had maximum k values of 0.93 and 0.89 at 60 DAS in 2003-04 and 2004-05, respectively. The values of extinction coefficient varied from 0.51 to

0.93 in 2003-04 and 0.48 to 0.89 in 2004-05 among the cultivars. The lowest k values were observed in BSH 1 throughout the crop period in both the years as compared to other cultivars which was a result of the lower LAI values in this cultivar as compared to the rest. These results are in conformity with earlier reports of Rao[6] for mustard crop.

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