GROWTH AND DEVELOPMENT OF INDIAN MUSTARD (*BRASSICA JUNCEA*) UNDER DIFFERENT LEVELS OF IRRIGATION AND DATES OF SOWING

B.B. PANDA, Y.S. SHIVAY* AND S.K. BANDYOPADHYAY

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

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SUMMARY

A field experiment was conducted during the winter season (*rabi*) of 1997-98 to study the influence of irrigation levels and dates of sowing on crop physiological and yield parameters of Indian mustard varieties. Successive increase in irrigation levels had significant positive effect on leaf area index (LAI) at 72 and 102 days after sowing (DAS), total dry matter (TDM) accumulation at 72, 102 DAS and at harvest, crop growth rate (CGR) at 42-72 and 72-102 DAS, net assimilation rate (NAR) at 42-72 and 72-102 DAS, days taken to maturity, biological yields, seed yield and harvest index. Each date of delayed sowing after October 16 progressively and significantly decreased the LAI, TDM accumulation, CGR, NAR, days taken to 50% flowering and maturity, biological yield, seed yield and harvest index. Significant genotypic variation was also noticed for these parameters. Pusa bold showed its superiority over newly released SEJ 2 variety in terms of crop physiological characters and yield.

***Key words*: Biological yield, crop growth rate, harvest index, leaf area index, net assimilation rate, seed yield.**

INTRODUCTION

Indian mustard [*Brassica juncea* (L.) Czernj, & Casson] is the second most important oilseed crop in India, ranking next to groundnut (*Arachis hypogaea* L.), accounts for 21.4% of the total oilseed production of the country (Damodaran and Hedge 1999). It is cultivated in a wide range of agro-climatic zones. The productivity of this crop is low (968 kg ha^{-1}) which is even less than one third of its potential (3000 kg ha^{-1}). Since it is normally grown on marginal and sub-marginal lands with limited irrigation. About 80% of the cropped area are characterized by erratic rains in the semi-arid zone. Even if irrigation potential is increased, Indian mustard will remain as rainfed crop because farmers prefer food crops particularly cereals under irrigated conditions. Thus, the only option left is to increase the productivity through better management of the limited and costly input like; irrigation and non-monetary inputs like; sowing time and selection of suitable cultivar. The leaf area index (LAI), crop duration and phenology determines the total dry matter (TDM) production, yield and yield components under dry environment (Silim and Saxena 1993, Mathur and Wattal 1996). Therefore, the present investigation was under taken to find out the effect of irrigation levels, dates of sowing and varieties on the pattern of growth, development and productivity of Indian mustard.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Indian Agricultural Research Institute, New Delhi during *rabi* season of 1997-98. The experimental soil was sandy-loam, low in organic carbon (0.41%), available N (151.2 kg ha^{-1}), P (12.4 kg ha^{-1}) and K (217 kg ha^{-1}) with pH 7.3. Field capacity, permanent wilting point and bulk

* Corresponding author, E-mail: ysshivay@hotmail.com

density recorded were 17.7% (w/w), 7.6% (w/w) and 1.53 g cm^{-3}, respectively in 0-15 cm soil depth.

The treatment combinations comprising of 3 irrigation levels, viz. I_0, no irrigation; I_1, irrigation at flowering; and I_2, 1 irrigation at flowering + 1 at pod development stage as main plots, and 3 dates of sowing viz. October 16; October 31; and November 15 as sub-plots and 2 varieties, viz. synthetic early *juncea* 2 (SEJ 2) and Pusa bold as sub-sub-plot treatments, replicated 3 times in split-split plot design were carried out. Total P, K and half of N were broadcasted before sowing and rest N was top dressed during flowering stage. Indian mustard varieties were sown at a row spacing of 30 cm using the seed rate of 5 kg ha^{-1}. Thinning was done 20 days after sowing to maintain plant to plant distance of 20 cm. The plot size was 3 m x 3 m having 10 rows each. Other recommended cultural practices were followed to establish a good crop. The leaf area was measured by automatic leaf area meter model LI 3100 Li-cor Inc., Nebraska (USA) at 27, 42, 72 and 102 days after sowing (DAS) using five randomly selected plants. The same plant samples were used for recording dry matter accumulation after drying samples at 80°C for 48 hours. From the above physiological observations, leaf area index (LAI), total dry matter (TDM) accumulation, crop growth rate (CGR) and net assimilation rate (NAR) were calculated using the formulae given by Watson (1952) and Radford (1967). Observation on days to 50% flowering and maturity were also recorded in each plot. TDM yield and seed yield were determined at maturity from each plot. The sun-dried plants from each plot were threshed, winnowed and cleaned manually.

RESULTS AND DISCUSSION

LAI of mustard increased progressively upto 72 DAS and declined at 102 DAS in both varieties at all dates of sowing and irrigation levels (Table 1). This might be due to drying and withering of older leaves at 102 DAS. At 27 DAS, LAI of Pusa bold was significantly higher than that of SEJ 2. Delayed in sowing from October 16 to November 15 decreased the LAI significantly and it was due to decrease in mean temperature at later dates of sowing which reduced the leaf expansion and growth of the crop. At this stage there was no significant difference in LAI due to different irrigation levels, as the irrigation treatment

Table 1. Effect of irrigation levels, dates of sowing and varieties on leaf area index (LAI) of mustard

Treatment	DAS			
	27	42	72	102
Irrigation levels				
I_0	0.17	1.20	1.76	1.26
I_1	0.18	1.42	2.08	1.53
I_2	0.17	1.40	2.15	1.55
CD (P=0.05)	NS	NS	0.18	0.08
Dates of sowing				
October 16	0.25	2.04	2.58	1.87
October 31	0.18	1.06	1.85	1.36
November 15	0.09	0.92	1.55	1.11
CD (P=0.05)	0.01	0.17	0.04	0.03
Varieties				
SEJ 2	0.16	1.24	1.97	1.28
Pusa bold	0.18	1.44	2.04	1.61
CD (P=0.05)	0.01	0.15	0.04	0.04

DAS = Days after sowing; I_0 = No irrigation; I_1 = 1 irrigation at flowering; I_2 = 1 irrigation at flowering + 1 irrigation at pod development stage

was not imposed. At 42 DAS, the LAI data followed the same trend as that LAI at 27 DAS. At 72 DAS Pusa bold produced significantly higher LAI (2.04) over SEJ 2. The mean LAI of October 16 sown crop was recorded highest (2.58) and it was 66% more than the crop sown on November 15. Irrigation application at flowering stages increased LAI of the crop significantly over that of unirrigated crop. Similar findings had been reported by Khan and Aggarwal (1988). At 102 DAS, mean LAI of both the varieties was reduced to 72.5% of the mean LAI at 72 DAS. Even at this stage LAI of Pusa bold was more than that of SEJ 2. This indicated that active LAI and leaf area duration (LAD) was more in Pusa bold compared to SEJ 2.

The results on TDM accumulation at different growth stages are given in Table 2. Both varieties viz. SEJ 2 and Pusa bold showed an increasing trend of TDM accumulation upto the final maturity of the crop. TDM accumulation of Pusa bold was significantly higher than SEJ 2 throughout the growth period. At maturity TDM accumulation of Pusa bold was 778.4 g m^{-2} which was significantly higher than that of SEJ 2 (724.2 g m^{-2}). TDM accumulation decreased progressively and significantly at 12, 27, 42, 72, 102 DAS and at final harvest in both the cultivars with delay in sowing from October 16 to November 15. At harvest, mustard produced the highest dry matter (952.4 g m^{-2}) when sown on October 16 and the least (498.6 g m^{-2}) in November 15 sowing. This data indicated that one day delay in sowing of mustard after October 16 reduced TDM accumulation of the crop by 99 kg ha^{-1} up to October 31, while further one day delay in sowing reduced the yield of the crop by 200 kg ha^{-1} upto November 15. The influence of irrigation on dry matter accumulation was significant at 72 DAS. Mustard irrigated twice at flowering + pod development stages (I_2) produced significantly higher dry matter than one irrigation given at flowering (I_1) and unirrigated (I_0). At the time of harvesting, the dry matter accumulation of I_2 treatment was 854.5 g m^{-2} as compared to 797.8 g m^{-2} and 601.6 g m^{-2} in I_1 and I_0 treatments, respectively.

In general, the CGR of mustard increased at a faster rate during 42-72 DAS as compared to during 12-27

Table 2. Effect of irrigation levels, dates of sowing and varieties on total dry matter (TDM) accumulation (g m^{-2}) of mustard

Treatment	DAS					
	12	27	42	72	102	At maturity
Irrigation levels						
I_0	0.40	8.42	69.67	291.53	479.98	601.85
I_1	0.42	9.38	79.59	414.76	650.65	797.83
I_2	0.40	9.14	86.22	485.98	716.92	854.53
CD (P=0.05)	NS	NS	NS	39.92	18.26	27.83
Dates of sowing						
October 16	0.50	12.51	98.54	531.64	794.83	952.38
October 31	0.39	9.97	74.73	428.54	660.48	802.95
November 15	0.32	4.46	62.20	232.09	392.24	498.61
CD (P=0.05)	0.02	0.51	6.24	13.51	16.12	20.04
Varieties						
SEJ 2	0.39	9.00	75.75	391.38	599.77	724.18
Pusa bold	0.42	8.96	81.24	403.47	631.92	778.45
CD (P=0.05)	0.01	NS	3.42	10.94	6.98	17.53

DAS = Days after sowing; I_0 = No irrigation; I_1 = 1 irrigation at flowering; I_2 = 1 irrigation at flowering + 1 irrigation at pod development stage

DAS, 27-42 DAS and 72-102 DAS of crop growth. The influence of irrigation on CGR was significant during 42-72 DAS and 72-102 DAS. Irrigation water applied to mustard at flowering and pod development stages increased the CGR by 81.1 % higher as compared to unirrigated crop during 42-72 DAS. Even at 72-102 DAS the CGR value was 22.9% more in I_2 treatment as compared to I_0 treatment. Higher CGR values in irrigated crop plants were due to higher production of dry matter owing to higher LAI. Mondal and Paul (1992) also reported similar results on CGR of mustard. CGR decreased progressively and significantly with delay in sowing through out the growth period (Table 3). The highest values of CGR were observed in crop sown October 16 and the least values were recorded in November 15 sowing at all the growth stages. This result corroborates with the findings of Babu (1985). CGR of Pusa bold did not differ significantly with SEJ 2 during early stages of growth i.e. 12-27 DAS but CGR of Pusa bold was significantly higher than SEJ 2 during later stages except during 42-72 DAS.

NAR is essentially an estimation of canopy photosynthesis per unit leaf area and can be used as a measure of photosynthetic efficiency. Its contribution to yield is not direct (Shivay *et al.* 2002). The influence of irrigation on NAR was significant during 42-72 and 72-102 DAS. Mustard irrigated twice (I_2) each at flowering and pod development stages registered a higher value of NAR than the crop irrigated once or not irrigated. The least NAR was marked in unirrigated crop irrespective of the crop growth stage. Dates of sowing had significant effect on NAR values at all the crop growth stages. During 12-27 DAS, NAR values did not differ significantly in October 16 and October 31 but these were significantly higher than November 15 sowing. During 27-42 DAS, NAR showed higher value (10.8 mg m^{-2} d^{-1}) in November 15 followed by October 31 (8.8 mg m^{-2} d^{-1}) least value with October 16 (6.8 mg m^{-2} d^{-1}). But during 42-72 and 72-102 DAS, second sowing marked highest value of NAR followed by first sowing date and least value is third sowing date (Table 4). NAR of SEJ 2 was significantly

Table 3. Effect of irrigation levels, dates of sowing and varieties on crop growth rate (g $m^{-2}d^{-1}$) of mustard

Treatment	DAS			
	12-27	27-42	42-72	72-102
Irrigation levels				
I_0	0.53	4.15	7.36	6.28
I_1	0.59	4.68	11.17	7.86
I_2	0.58	5.14	13.33	7.72
CD (P=0.05)	NS	NS	1.46	1.00
Dates of sowing				
October 16	0.80	5.73	14.43	8.78
October 31	0.62	4.39	11.77	7.73
November 15	0.27	3.85	5.66	5.36
CD (P=0.05)	0.04	0.46	0.39	0.34
Varieties				
SEJ 2	0.57	4.49	10.50	6.94
Pusa bold	0.56	4.83	10.74	7.64
CD (P=0.05)	NS	0.25	NS	0.46

DAS = Days after sowing; I_0 = No irrigation; I_1 = 1 irrigation at flowering; I_2 = 1 irrigation at flowering + 1 irrigation at pod development stage

Table 4. Effect of irrigation levels, dates of sowing and varieties on net assimilation rate (mg $m^{-2}d^{-1}$) of mustard

Treatment	DAS			
	12-27	27-42	42-72	72-102
Irrigation levels				
I_0	11.24	8.66	4.97	4.75
I_1	11.73	8.43	6.50	6.19
I_2	12.18	9.44	7.59	7.08
CD (P=0.05)	NS	NS	1.03	0.62
Dates of sowing				
October 16	12.25	6.84	6.30	6.43
October 31	12.14	8.82	8.18	7.28
November 15	10.76	10.86	4.63	4.31
CD (P=0.05)	0.64	0.83	0.47	0.24
Varieties				
SEJ 2	12.97	8.99	6.53	6.47
Pusa bold	10.87	8.69	6.21	5.55
CD (P=0.05)	1.11	NS	NS	0.15

DAS = Days after sowing; I_0 = No irrigation; I_1 = 1 irrigation at flowering; I_2 = 1 irrigation at flowering + 1 irrigation at pod development stage

higher than Pusa bold during 12-27 and 27-102 DAS. But they did not differ significantly during 27-42 and 42-72 DAS. However, the highest values of NAR, 12.9 and 10.8 mg m^{-2} d^{-1} were recorded by SEJ 2 and Pusa bold during 12-27 DAS, respectively. At each stage Pusa bold showed a lower value of NAR than SEJ 2.

Irrigation levels failed to produce significant differences in days to 50% flowering of mustard however, number of days taken by the plants to come to 50% flowering was progressively reduced by delay in sowing (Table 5). One-month delay in sowing caused the plants 4 days advancement to reach at 50% flowering when crop was sown on October 16 and October 31. The crop also produced higher dry matter and might have produced better sink number per unit dry matter available with the crop. Both the varieties significantly differed in respect of number of days taken by the plants to reach 50% flowering stage. Pusa bold attained 50% flowering about 58 DAS whereas SEJ 2 reached the same stage 15 days earlier than Pusa bold.

Irrigation levels significantly influenced the days to maturity of the mustard crop (Table 5). Irrigation delayed the maturity as compared to unirrigated. Irrigation might have affected the leaf area by delaying senescence and drying of leaves or by increasing evapo-transpiration of the crop (Turner and Burch 1983). Days to maturity reduced significantly with delay in sowing since October 16. Duration of the crop sown on October 16 was 135 days which was significantly higher over October 31 sowing (129 days) and shortest maturity period was recorded with November 15 sowing (122 days). The reduction in maturity period of delayed sowing was mainly due to higher temperature during grain filling stage. Maturity period was significantly different for the two cultivars. SEJ 2 on an average matured 28 days earlier than Pusa bold.

Irrigation levels increased the biomass yield progressively and significantly as the frequency of irrigation was increased (Table 5). The biological yield was increased by 32 and 40% over unirrigated crop when mustard

Table 5. Effect of irrigation levels, dates of sowing and varieties on days to 50 per cent flowering, maturity, biological yield, seed yield and harvest index of Indian mustard

Treatment	Days to		Biological yield (q ha^{-1})	Seed yield (q ha^{-1})	Harvest index (%)
	50% flowering	Maturity			
Irrigation levels					
I_0	50.33	127.92	46.90	10.83	22.93
I_1	51.08	128.50	62.00	15.32	24.50
I_2	51.83	129.67	65.70	17.59	26.12
CD (P=0.05)	NS	0.31	3.14	0.58	2.08
Dates of sowing					
October 16	52.90	134.80	73.50	19.45	26.22
October 31	51.70	129.20	62.30	15.56	24.86
November 15	48.70	122.30	38.90	8.72	22.47
CD (P=0.05)	0.88	0.89	2.08	0.49	1.43
Varieties					
SEJ 2	43.83	114.70	55.20	13.89	24.54
Pusa bold	58.33	142.70	61.30	15.27	24.50
CD (P=0.05)	0.90	0.95	1.54	0.41	NS

I_0 = No irrigation; I_1 = 1 irrigation at flowering; I_2 = 1 irrigation at flowering + 1 irrigation at pod development stage

received one and two irrigations, respectively. This result corroborates with the findings of Reddy and Sinha (1987). The biomass yield of crop was significantly influenced by the date of sowing. The crop sown on October 16 produced the highest biomass (73.5 q ha^{-1}) and it was 18% higher than the crop sown on October 31 but there was drastic reduction in total harvested biomass when crop was sown on November 15. This might be attributed to favorable weather parameters in case of crop sown on October 16 as compared to October 31 and November 15 sowing. Biological yield of Pusa bold was significantly higher than that of SEJ 2. The biomass yield of Pusa bold was 61.3 q ha^{-1} which was 14.3% higher than biomass yield of SEJ 2. Higher LAI of Pusa bold provided more photosynthesis sites that led to increase in total drymatter of plant.

Similarly, irrigation levels progressively and significantly increased the seed yield of mustard (Table 5). The crop irrigated once at flowering and twice at flowering + pod development stage produced seed yield of 17.59 and 15.32 q ha^{-1} which were 67.1 and 41.0 % higher than unirrigated (10.83 q ha^{-1}). Seed yield of mustard sown on October 16 was significantly higher than delayed sowings. There was 20% reduction in yield when sowing was delayed 15 days after October 16 but 55% reduction in yield when crop was sown 30 days after first sowing. This reduction in yield might be due to adverse weather condition in late sowings. Seed yield of Pusa bold was 15.27 q ha^{-1}, which was 10% higher than that of SEJ 2. Increased seed yield of Pusa bold was attributed to higher LAI (Table 1) and CGR (Table 3) compared to SEJ 2. During crop growth period, both capacity factor (LAI) and green LAD of Pusa bold was higher than that of SEJ 2. Thus, higher LAI of Pusa bold variety enabled better utilization of resources like solar radiation and water compared to SEJ 2. The intensity factor i.e. NAR of Pusa bold during growth period was as comparable to SEJ 2 and with higher LAI value finally reflected in higher TDM production and seed yield of the crop.

The highest value of harvest index was recorded when irrigation was applied twice one each at flowering +

pod development stages but it decreased significantly with decrease in frequency. This indicates greater transportation of assimilates to the economic sink as compared to biological sinks (Dudhade *et al.* 1996). Harvest index progressively and significantly decreased with delay in sowing and the crop sown on October 16 was recorded the highest harvest index (26.22%). Harvest index of both the tested varieties did not differ significantly and remained on par to each other.

The present findings indicate that irrigation to mustard at flowering and pod development stages had significant positive effect on crop physiological parameters, yield and days taken to 50% flowering. Each date of delayed sowing after October 16 progressively and significantly decreased the LAI, TDM accumulation, CGR, NAR, yield and also days taken to 50% flowering and maturity. Between the tested varieties, Pusa bold recorded its superiority over newly released SEJ 2 variety in terms of all crop physiological characters and yield. Such information can be used in planning of future strategies for higher productivity of mustard.

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