



Response of *Brassica* to microenvironment modification under semi-arid agroecosystem

TARUN ADAK¹, BHASKAR NARJARY² and N V K CHAKRAVARTY³

Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

Field experiments were conducted during winter (*rabi*) season of 2005–06 and 2006–07 on a Typic Ustocrepts soils at research farm of Indian Agricultural Research Institute (IARI), New Delhi representing a semi-arid environmental condition, to evaluate the response of *Brassica juncea* under modified microenvironments. It was revealed that the possibility of increasing the seed yield in mustard cultivars, viz Pusa Jaikisan and BIO169–96 (developed at National Research Centre Plant Biotechnology IARI, New Delhi) was possible. Modification of microenvironment through debranching, i.e. removal of lower branches at the flowering and pod-filling stages so as to increase the photosynthate flow to the economic parts is found to be promising yet cheaper way. This modified microenvironment has a positive impact on growth and yield in both the years of study. Removal of lower branches at the flowering stage was found to be an alternate practice of microenvironment modification in attaining statistically higher yield.

Key words: *Brassica juncea*, Debranching, Modified microenvironment, Yield components and yield

There are several ways and means to improve the economic yield of oilseed crops of which, improved breeding and biotechnological applications are on the fore front now-a-days. Chakravarty *et al.* (2008) observed that yields could be also improved apart from reducing the incidence and spreading of white rust disease (which eventually helped in increasing the seed yields), could be due to modification of microenvironment in the crop through debranching of lower branches at the flowering and pod-filling stages in *Brassica* crop. The low productivity of lower branches may be attributed to the poor radiation penetration at the lower levels. Plants in the de-branched perform better probably because of (i) higher radiation penetration to lower parts of the plant canopy resulting in higher PAR interception, and (ii) improved translocation of photosynthates to the remaining branches, which became more productive. The present study was conducted keeping in view to generate quantitative information on debranching relating the mustard crop's performance under differential thermal environment along with modified microenvironment under semi-arid conditions of northern India.

¹Scientist (e mail: tarunadak@gmail.com), Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow;

²Research Scholar (e mail: bhaskar.narjary@gmail.com),

³Principal Scientist and Head (Retd.) (e mail: nvkchak@gmail.com), Division of Agricultural Physics

MATERIALS AND METHODS

The experiment was laid out in the experimental farm of Indian Agricultural Research Institute (IARI), New Delhi a semi-arid station (28°35' N latitude, longitude of 77°12' E and at an altitude of 228.7 m above sea level). The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium. The soil texture is sandy clay loam and belongs to Holambi Series. Two cultivars of *Brassica juncea*, viz Pusa Jaikisan (a popular variety) and BIO169-96 (developed at National Research Centre on Plant Biotechnology IARI, New Delhi) were sown during winter (*rabi*) seasons of 2005–06 and 2006–07 following RBD with three replicates of 5×5 m² each plot size. The micro-environment modification was created by removing 3 to 4 lower branches at 40 days after sowing (DAS) (D₁: at flowering stage) and 50 DAS (D₂: at pod filling stage) on 15 October sowing (early sowing), while in case of 30 October sowing (delayed/late sown), debranching was done at 50 and 60 DAS due to restricted plant growth. One control plot (D₀) was also maintained without removing branches.

Ammonium sulphate @ 40 kg N/ha was applied as basal dose and urea @ 40 kg N/ha was applied as top dressing after first irrigation. single super phosphate @ 40 kg P₂O₅/ha and Muriate of potash @ 40 kg K₂O/ha were also applied as basal dose as per recommendation during disking at the time of seedbed preparation. Sowings were done with hand

drill, maintaining a row-to-row spacing of 45 cm and seed rate of 6 kg/ha was maintained. Thinning was done manually between 20 and 25 days after sowing to maintain plant-to-plant distance of 15 cm. Occurrence of various phenological events was visually noted. Three randomly selected plant samples (above ground) were taken and the leaf area was measured using leaf area meter and the same plant samples were used to determine the biomass. Oil content (per cent) of the seeds was measured using low resolution pulsed H1 NMR (model no. PC20 Bruker made, frequency- 20 MHz). Accumulated heat units were calculated considering 5°C as base temperature. Statistical analysis was done using Excel and SPSS packages (Version 12.0).

RESULTS AND DISCUSSION

Weather

It was observed that the maximum temperature remained almost same in the early vegetative growth during both the seasons, The maximum temperature was lower by 0.7 to 7.4°C during 16th to 22nd week after sowing in the second season. In contrast, the minimum temperature in the second season was higher at the initial crop growth stages (from 1st to 12th week after sowing) by about 0.3°C to 7°C facilitating rapid crop growth. The number of bright sunshine hours in the second season was relatively lower during the entire crop growth period. The morning relative humidity in second season was lower by 8 to 12% from 5th to 8th week after sowing (WAS) and thereafter the values were more or less similar with that of first season. The afternoon relative humidity in second season was lower by about 5 to 13% from 3rd to 14th WAS. The total rainfall received during first crop season was 26.0 mm while in the second season it was marginally lower (18.4 mm). The total evaporation in the second season (80.9 mm) was higher by 7.6 mm than first season. The wind speed more or less remained near normal value in both the seasons. On the whole, it can be inferred that the second season was much drier than the first season as the evaporation rates were considerably higher and relative humidity was lower.

Phenological stages

The cultivar BIO169-96 took more number of days to

reach different phenological stages than that of Pusa Jaikisan (Table1). The duration of crop maturity was also higher by eight days in early sowing and seven days in late sowing in BIO 169-96 than that in Pusa Jaikisan. Further, it was observed that both the cultivars took more number of days to attain different phenological stages in late sowing than in early sowing in both the seasons of crop production. In the second season the prevailing high day-time temperatures during first four weeks resulted in early flowering of early sown crop in both the cultivars. In late sowing the duration for first few phenol-phases were comparable in both the seasons and was also in accordance with temperature variation. The continuous lower temperature during seed-filling stage in second season accelerated the process of growth and probably led to lengthening of maturity period by 2 and 5 days in Pusa Jaikisan and 3 and 7 days in BIO169-96 in early and late sowing respectively as compared to the first season crop. Similarly, minimum temperatures in second season were found to be lower during early phenological developmental stages and higher during seed-filling stages facilitating rapid growth of the crop. The number of days taken to flowering in *Brassica* spp was found to be strongly influenced by date of sowing and more number of days was required for first flowering with delay in sowing (Bhargava 1988). Later, Rawson (1993) observed that high temperature retarded phenological development only in conditions of low light intensity when *rabi* crops remain source limited. It was observed that both pre-and-post floral growth have tremendous dependence on prevailing temperatures. Changes in sowing dates lead to change in thermal environment of the crop with respect to different growth and development stages.

Rapid growth of plants proceeds only when optimum temperature conditions exists surrounding it. Nevertheless, the concept of optimum temperature for plant growth and development is a dynamic one. It changes with the duration of exposure, age of the plant, the stage of plant development and the particular growth criterion used to evaluate the performance. Changes in sowing dates led to change in thermal environment of the crop with respect to different growth and development stages.

Table 1 Number of days taken to reach different phenological stages

Phenological stage	Pusa Jaikisan				BIO169-96			
	15 October		30 October		15 October		30 October	
	I	II	I	II	I	II	I	II
Emergence	5	4	6	5	6	5	6	5
First flowering	33	34	42	46	36	39	46	51
50% flowering	38	40	52	53	42	45	57	60
Pod initiation	41	42	54	56	45	48	60	63
Maturity	134	136	128	133	142	145	135	140

I, 2005-06; II, 2006-07

Leaf area and biomass partitioning

The maximum leaf area index (LAI) was higher in the second season as compared to the first season crop and delayed sowing (by 15 days) significantly reduced leaf area development. On the whole, higher LAI was found in de-branched treatments as compared to control (non-debranching). Maximum LAI was observed at 95 DAS in case of early sowing during first season while in the next season it was advanced by 6 days (at 89 DAS). Another important finding was that the LAI was higher in BIO169-96 as compared to Pusa Jaikisan in almost all the treatments across sowing dates and seasons. Higher temperature during initial period probably led to early flowering and there after sudden decrease in minimum temperatures (including frost) during leaf expansion and vegetative stage, might have caused reduction in LAI at early sowing of first season. Again, the higher sunshine hours during the crop growth period in the first crop season as compared to the second season, the

higher temperatures, evaporation rates as well as heavy frost coupled with low temperature spell probably reduced LAI in first crop season as compared to that in second crop season. In case of late-sown crops, initial crop growth stages were exposed to relatively low temperatures, which might have caused reduction in leaf area.

It is clear that both the varieties have a tendency to compensate for losses of leaves and branches as higher LAI was observed in early and late de-branched plots. Further, BIO169-96 may have higher proliferating character than Pusa Jaikisan as higher LAI development was found in spite of debranching. The variety probably may have some stimulating effect of debranching to generate more leaves and branches in upper parts which may be the reason for fast compensation. The results of the present study are in conformity with those reported by Nanda *et al.* (1995) that leaf area expansion rate was highest at the higher mean temperature (20°C) than lower mean temperature (13°C) in

Table 2 Biomass partitioning (%) in leaf and stem + pod during *rabi* season of 2005-06

DAS	15 October sowing											
	Leaf						Stem					
	Pusa Jaikisan			BIO169-96			Pusa Jaikisan			BIO169-96		
	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂
46	44.9	22.9	96.6	43.5	31.8	64.8	55.1	77.1	71.1	0	0	0
53	45.7	42.1	28.8	61.4	39.3	43	54.3	57.9	97.4	0	0	0
60	34.5	42.7	28.7	39.2	35.6	28.4	54.6	86.8	91.4	60	67.7	56.6
67	33.7	39.9	23.6	31.6	24	21.1	66.3	94	76.4	78.7	38.6	71.5
74	30.3	29.4	19.3	29.7	22	17.8	96	70.6	97.6	69.6	49.8	48.7
81	25	23.4	18.3	23	19.5	21.1	75	81.5	99.4	38.9	78.2	76
88	18.3	20.5	13.9	21.3	21	16.2	95.5	91	87.4	92.6	62.4	97.4
95	15.3	17	13.9	17.7	18.8	16.8	67.7	71.3	75	73.9	74.9	67.7
102	13.9	16.9	14.8	16.4	15.5	12	86.1	60.9	85.2	72.4	64.3	85.9
111	10.2	16.7	11.9	14.5	14	12	56.7	95.5	88.7	93.6	82.1	86.4
123	7.9	8.2	9.4	12.4	12.1	10.8	77.8	84.8	90.6	61.9	63.7	95
130	5.8	6.4	3.7	4.5	9.6	9.2	84.5	105.1	84.2	79.7	82.1	77.6
DAS	30 October sowing											
	Leaf						Stem					
	Pusa Jaikisan			BIO169-96			Pusa Jaikisan			BIO169-96		
	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂
38	100	100	100	100	100	63.2	53.4	36.6	48.6	0	0	0
45	60.3	46.4	78.5	123.7	51.3	52.2	62.4	33.6	41.3	60	49	49.4
52	30.3	87.4	68.8	50.4	67.2	31.3	26.5	25.9	59	57.7	56	68.7
59	55.1	44.6	65.8	45.3	48.1	49.3	60.5	48	59.4	45.9	51.9	50.7
66	40.9	26.7	26.1	34.7	21.7	28.6	47	40	70.6	65.3	49.4	95.5
73	35.8	36.4	32.1	38	29.1	28.9	59	66.2	84.5	83.2	62.4	71.1
80	30.6	28.9	17.7	26.4	25.9	28.1	77.8	48.7	57.6	73.6	63.9	87.7
87	25.4	24	23.5	26.6	26.2	23.3	44.6	45.9	75.4	85.7	73.8	76.7
94	20.8	17.7	23	11.1	9.5	19.2	57.6	65	57.7	62.9	71	91.4
108	12	13.2	13.3	12.7	15.2	12.4	60.5	49.8	89.8	87.3	92.3	76.4
115	8	8.6	10.2	21.5	10	15.4	58.8	95	92	91.3	60	92.6
122	6.1	4.2	9.9	7.5	9.4	4.8	68	66.6	93.6	99.4	76.3	91.3

field grown *Brassica spp.* Kar and Chakravarty (2000) reported that LAI was lower in a season with higher temperatures (2–3°C more) during vegetative and grain-filling stages as compared to the season with relatively lower temperatures in the same period. Further, differential thermal accumulation due to delay in sowing also cause reduced LAI as reported by Roy *et al.* (2005) that delay in fortnight sowing from 1 October to 1 November reduced LAI by 8.3 and 52.8% in different varieties.

The partitioning of assimilates among different parts of the plant affects both productivity and survival of the plants. For *Brassica spp.* It appears of greater importance because a major portion of dry matter gets accumulated after flowering.

The level of accumulation before and after flowering however is known to vary with species, varieties change and temperature fluctuations. Higher biomass partitioning in leaf was observed in BIO 169-96 and in de-branched microenvironment than in no de-branched environment (Tables 2, 3). The debranching improved in biomass partitioning in pods. It was found that a significant correlation existed between the variation in biomass partitioning and accumulated heat unit, around 70 to 88 % variation in biomass partitioning to leaf (Fig 1) could be explained through thermal heat accumulation while in case of stem and pod (Fig 2), the range is quite larger; 40 to 87% across seasons and cultivars. The variety BIO169-96 produced higher biomass as

Table 3 Biomass partitioning (%) in leaf and stem+pod during *rabi* season of 2006-07

DAS	15 October sowing											
	Leaf						Stem					
	Pusa Jaikisan			BIO169-96			Pusa Jaikisan			BIO169-96		
	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂
41	100	100	100	36.7	59.4	44.1	0	0	0	63.3	40.6	55.9
48	37	41.2	32.7	36.1	48.9	37.3	63	58.8	67.3	63.9	51.1	62.7
54	35.2	35.9	33.4	33	53.1	27.2	64.8	64.1	66.6	67	46.9	72.8
61	28.1	37.7	28.6	25.3	10.1	23.7	71.9	62.3	71.4	74.7	89.9	76.3
68	22.6	27	29.8	23.7	25	29.3	77.4	73	70.2	76.3	75	70.7
75	24.7	22.3	18.1	21.6	23.5	23.5	75.3	77.7	81.9	78.4	76.5	76.5
82	19	18.3	17.2	21.1	20.7	21.8	81	81.7	82.8	78.9	79.3	78.2
89	13.4	14.6	17.5	18.3	19	13.2	86.6	85.4	82.5	81.7	81	86.8
96	16.6	17.2	18.4	14.3	17.5	18.8	83.4	82.8	81.6	85.7	82.5	81.2
104	11.9	9.2	9.8	10.8	10.6	9.3	88.1	90.8	90.2	89.2	89.4	90.7
109	9.9	7.4	7.4	10.6	8	7.1	90.1	92.6	92.6	89.4	92	92.9
115	8.9	6.3	6.1	9.3	6.3	6.8	91.1	93.7	93.9	90.7	93.7	93.2
124	8.6	5.7	8	10.1	7.7	11.3	91.4	94.3	92	89.9	92.3	88.7
130	5.7	4.5	4.8	5.3	5.1	5.3	94.3	95.5	95.2	94.7	94.9	94.7
136	6.1	2.5	5.3	3.4	3.5	3.6	93.9	97.5	94.7	96.6	96.5	96.4
DAS	30 October sowing											
	Leaf						Stem					
	Pusa Jaikisan			BIO169-96			Pusa Jaikisan			BIO169-96		
	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂	D ₀	D ₁	D ₂
41	100	100	100	58.8	66.9	67.7	0	0	0	41.2	33.1	32.3
46	25.3	68.4	56.4	48.1	30.7	21.6	74.7	31.6	103.6	51.9	69.3	78.4
53	28.2	30.6	44.6	34.5	30.1	21.8	61.9	69.4	77.5	65.5	69.9	69.8
60	30.4	21.4	31.3	40.7	33.2	16.9	56.2	78.6	100.9	59.3	66.8	82.9
67	32.2	18.8	25.8	28.6	25.3	15.1	67.8	81.2	90.6	71.4	74.7	84.9
74	22.2	24.3	20.3	23.3	26	13.9	77.8	75.7	79.7	76.7	74	86.2
81	25.7	25.1	21.8	21	19.4	12.4	74.3	74.9	93	79	80.6	87.6
89	19.2	20.3	15	16.5	19.2	10.4	80.8	79.7	85	83.5	80.8	89.6
94	15.1	17.9	17.4	14.9	16.3	9.9	84.9	82.1	82.6	85.1	83.7	90.1
100	10.8	18.6	9.9	12.1	13.9	10	89.2	81.4	90.1	87.9	86.1	90
109	10.5	10.7	7.2	11.6	11.4	12.4	89.5	89.3	92.8	88.4	88.6	87.6
115	7.2	8.5	5.8	9.4	9.1	8.8	92.8	91.5	94.2	90.6	90.9	91.2
121	5.1	4.3	3.1	6.1	6.5	8.3	94.9	95.7	96.9	93.9	93.5	91.7
128	4.1	2.9	2.2	5.5	5.9	5.1	95.9	97.1	97.8	94.5	94.1	94.9

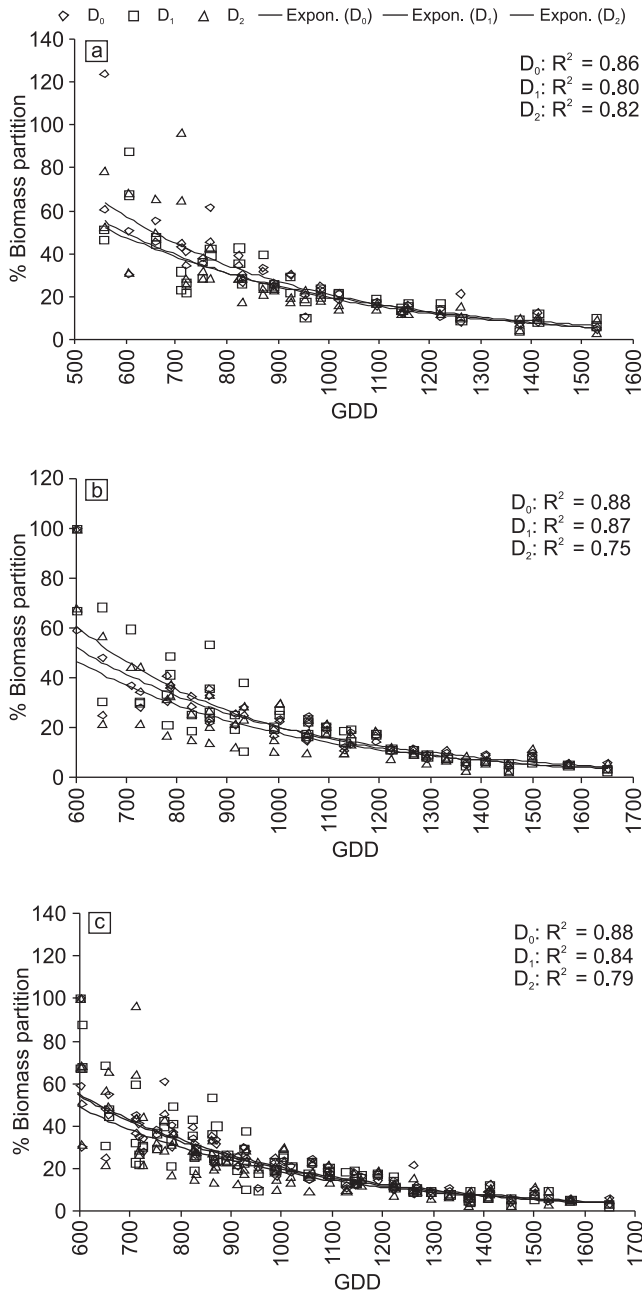


Fig 1 Biomass partition (%) in leaf as a function of accumulated heat unit (1, 2, 3 = first, second season and pooled one)

compared to Pusa Jaikisan, irrespective of sowing dates and crop-growing seasons which might be due to higher leaf area index, leaf area duration and more proliferating characters. Relatively higher biomass was found in the debranched plot (at 50 DAS) than that of in control plots in both the varieties. Delayed sowing by 15 days reduced biomass production in both the cultivars in the first season. Cold spell during initial period for first crop might have restricted growth. One more interesting fact is that debranching at 50 DAS was relatively

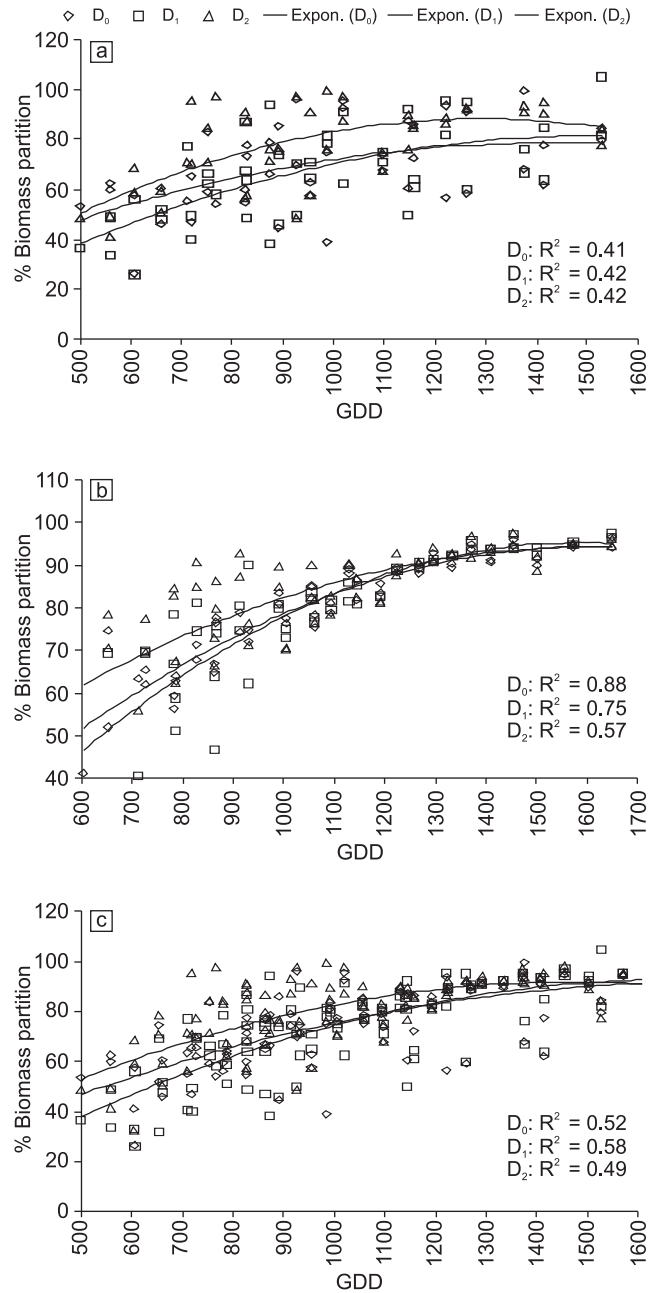


Fig 2 Biomass partition (%) in stem (+ pod) as a function of accumulated heat unit (1, 2, 3 = first, second season and pooled one)

more effective than debranching at 40 DAS which may be either because the environmental conditions were favourable immediately after the debranching, to facilitate faster growth rate or probably the plant have that inherent genetic quality of recouping faster after debranching.

The debranching improved in biomass partitioning in pods. Further, a significant correlation existed between the variation in biomass partitioning and accumulated heat units wherein about 70 to 88% variation in biomass partitioning

to leaf (Fig 1) could be explained through thermal heat accumulation while in case of stem and pod (Fig 2), the range is 40 to 87% across seasons and cultivars. The variety BIO169-96 produced higher biomass as compared to Pusa Jaikisan, irrespective of sowing dates and crop-growing seasons which might be due to higher leaf area index, leaf area duration and more proliferating characters. Relatively higher biomass was found in the debranched plot (at 50 DAS) than that of in control plots in both the varieties. Delayed sowing by 15 days reduced biomass production in both the cultivars in the first season. Cold spell during initial period for first crop might have restricted growth.

One more interesting fact is that debranching at 50 DAS was relatively more effective than debranching at 40 DAS which may be either because the environmental conditions were favourable immediately after the debranching at 50 DAS thus facilitating faster growth rate or probably the plants have that inherent genetic quality of recouping faster after debranching. The biomass production levels obtained in the present study and the reduction of biomass production due to the effects of differential temperature/thermal environment are in conformity with the earlier findings in different agro-ecological regions (Nanda *et al.* 1996).

Seed yield

The seed yield was higher in debranched plots wherein microenvironment was modified (Table 4). In case of Pusa Jaikisan, early and late debranching increased seed yield by about 4.1 and 9.1% in early sowing, while in the late sowing, the corresponding values were 9.7 and 3.0%. In BIO169-96, the corresponding values were marginally lower.

Therefore, it may be concluded that the late debranching

at 50 DAS in case of early-sown crop and early debranching at 50 DAS in case of late-sown crop produced significantly higher seed yields as compared to control plots. A fortnight delay in sowing from 15 October decreased seed yield to the tune of 25.0 and 20.5% in control and debranched plots (at 50 DAS) in Pusa Jaikisan while in BIO169-96 a 24.3 and 26.2% reduction was observed. It was interesting to see that within the de branched plots, yields were statistically at par. Higher seed yields in the second season could probably be attributed to higher minimum temperature at the early growth stages (which might have enhanced higher crop growth) and optimum maximum temperature (20 to 24°C) during pod-filling stage. The crop in the first season experienced relatively higher day time (maximum) temperatures (above 25°C) during the pod-filling stage which might have forced the maturity while ground frost coupled with prolonged cold spell for 10 days (during the same stage) probably caused lower biomass partitioning resulting in lower seed yield. Higher leaf area index, biomass production as well as proliferating nature of BIO169-96 might have contributed to higher seed yields as compared to Pusa Jaikisan. Higher seed yields in debranched plots as compared to control plots may be due to higher LAI and higher biomass production in the later treatments. Within the debranched plots, higher seed yields in debranching at 50 DAS in both the sowings could be partially due to hastened higher biomass partitioning and biomass production.

Oil content

The oil content was statistically at par within the debranching treatments (Table 5). However, a marginal increase was found in debranched as compared to control plots in early sowing while in delayed sowing it was

Table 4 Seed yield (tonnes/ha) in *Brassica juncea* during rabi, 2005-06 and 2006-07

Varieties	Seasons	15 October sowing			30 October sowing		
		D0	D1	D2	D0	D1	D2
Pusa Jaikisan	2005-06	2.76	2.86	2.83	2.3	2.65	2.39
	2006-07	3.14	3.28	3.41	2.42	2.53	2.46
	Mean	2.95	3.07	3.12	2.36	2.59	2.43
BIO169-96	2005-06	2.94	2.96	3.12	2.45	2.51	2.66
	2006-07	3.20	3.43	3.52	2.48	2.76	2.45
	Mean	3.07	3.19	3.32	2.47	2.63	2.55
		Pusa Jaikisan		BIO169-96			
		SEm ±	CD (P=0.05)	SEm ±	CD (P=0.05)		
Season		0.31	0.61	0.38	0.75		
Treatment		0.38	0.75	0.46	0.92		
Sowing date		0.31	0.61	0.38	0.75		
Interactions							
Season × date		0.43	0.86	0.53	1.1		
Season × treatment		0.53	1.0	0.65	1.3		
Date × treatment		0.53	1.0	0.65	1.3		
Season × date × treatment		0.75	1.4	0.92	1.8		

Table 5 Oil content (%) in *Brassica juncea* during rabi, 2005-06 and 2006-07

Varieties	Seasons	15 October sowing			30 October sowing		
		D ₀	D ₁	D ₂	D ₀	D ₁	D ₂
Pusa Jaikisan	2005-06	32.77	34.77	35.53	33.17	32.33	33.53
	2006-07	33.20	35.23	36.87	33.57	34.57	33.57
	Mean	32.98	35.0	36.2	33.37	33.45	33.55
BIO169-96	2005-06	34.93	37.3	36.13	34.83	35.27	35.23
	2006-07	37.70	39.30	39.07	34.67	33.20	33.23
	Mean	36.13	38.3	37.6	34.75	34.23	34.23

	Pusa Jaikisan		BIO169-96	
	SEm ±	CD (P=0.05)	SEm ±	CD (P=0.05)
Season	0.21	0.44	0.13	0.27
Treatment	0.26	0.54	0.16	0.33
Sowing date	0.21	0.44	0.13	0.27
Interactions				
Season × date	0.30	0.62	0.18	0.38
Season × treatment	0.37	0.76	0.22	0.46
Date × treatment	0.37	0.76	0.22	0.46
Season × date × treatment	0.52	1.10	0.32	0.65

statistically at par. In contrast, the oil content was significantly reduced in delayed sowing.

Thus, the present study concludes that significant yield improvement is possible in *Brassica* under debranching conditions wherein relatively higher LAI, biomass production and seed yield were observed. Even under delayed sowing, debranching is found to be fruitful than non-removal of lower low-light compensated branches. Thus, it is quite likely that the microenvironment modification, if practised at the farmer's field might lead to higher economic yields.

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