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Compensatory Behavior of Different Varieties of Mustard (*Brassica* sp.) for Lower Branch Removal

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Abstract

Plants have natural tendency to compensate for loss of leaves and branches by producing more leaves and branches. To exploit this behabior of mustard, an experiment was conducted at sandy clay loam soils under semi-arid climate for two years i.e. 2004-05 and 2005-06. Two cultivars of mustard namely Pusa Jaikisan and BIO-169-96 were shown on 15 October and 30 October. Lower three to four branches were removed on 40 days after sowing and two debranching treatments were given at 50 days after sowing in addition to control where no branches were removed. Plants compensated considerably well for loss of leaf area except late debranching and late sown crop. Number of primary branches counted at the time of harvesting was statistically at par in each of debranching treatments in both the cultivars that were in range of 4.2 to 6.8. Both the cultivars were found to have compensating tendency for loss of leaves and primary branches for early debranching and by producing more secondary branch per primary branches for late debranching. No linear relation between number of pods per plant and seed yield could be established. Bio-169-96 showed positive or no effect of debranching in terms of yield, hence compensated better while Pusa Jaikisan showed various response. Branch removal in well managed irrigated crop at 5 branch stage coincides between 40 to 60 days depending on weather condition may be manipulated to get extra green biomass that can be used as vegetables and fodder and in tern may increase farmers income.
Key words : Compensatory behavior, Mustard, Branch removal.

Total *kharif* production of nine oilseeds estimated for 2009-10 is 15.23 million ton i.e. 15% less than the production of 2008-09 (1). Total production of oilseed during 2008-09 was 28.1 million tonnes with an area of 27.5 M ha (1). There was increasing trend of area under oilseed production till 2005-06 and thereafter stagnation or slight decline has been observed. This stagnation may be attributed to competitive crop enterprises that are more remunerative than cultivating oilseeds. The then record production of oilseed during 2004-05 (26.1 million tonnes) was achieved with 32% contribution of rapeseed and mustard, but the requirement is far more and the share of vegetable oil is about 69% of total agricultural import (2) which amounts to US $ 1,237.3 million during 2004-05 (3). Mustard is grown in more than 50 countries worldwide in sub-tropical and temperate climates. In India, rapeseed and mustard are among those few crops which are closely associated with farming community probably because of their multiple uses like, seed for edible oil, cake for fodder, green leaves/branches as vegetable or fodder and straw as good quality fuel in rural areas (4). India, with a contribution of 15% of the total world's *Brassica* production, ranks third in world (5). There has been a phenomenal increase in production and productivity from 2.68 million tonnes and 650 kg/ha in 1985-86 to 6.96 million tonnes and 1022 kg/ha in 1996-97, respectively (2) against world average of 1,500 kg/ha (6). To meet the minimal nutritional requirement of fat and oil (12 kg/capita per year) and for other uses, nearly 24 million tonnes of rapeseed and mustard would be required by 2050AD (7). To achieve the desired level of production, it is necessary to popularize rapeseed and mustard cultivation on a war footing to the farmer which is possible by increasing the returns from its cultivation. Low

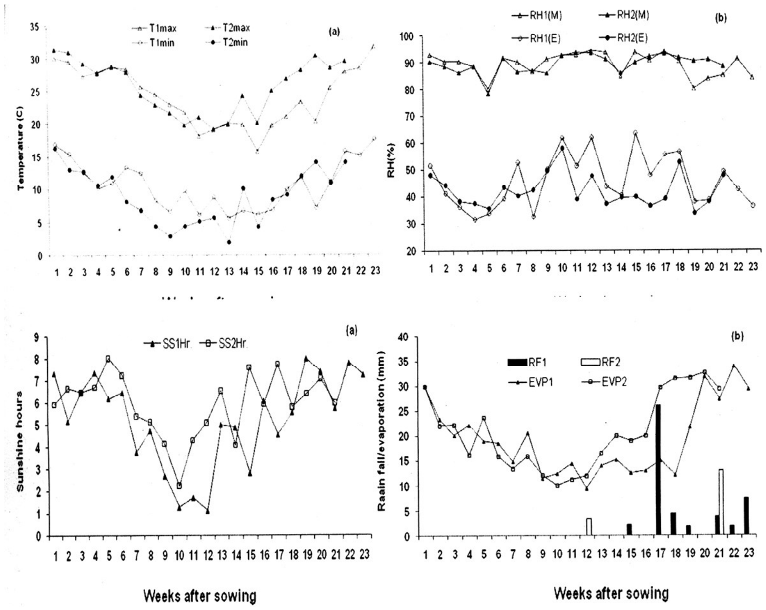

Figure 1. Mean weekly (a) maximum and minimum temperature (b) morning and evening relative humidity (c) mean weekly sunshine hours and (d) weekly rainfall and evaporation during two crop season. 1 : 2004-2005, 2 : 2005-06, max : maximum, min : minimum, M : morning and E : evening. SS : Sunshine hours. RF : rainfall, EVP : evaporation.

productivity of mustard in India may be attributed to several biotic and abiotic stresses. Even in well-managed crops there are intra-plant competition for nutrients, water, radiation and photosynthates among different parts of plants. The loss of flower and pod during flowering stage is mainly due to limitations of assimilate supply (8). In mustard, flowering starts from main shoots followed by upper branches but, when it comes to the lower matured branches, the seed set starts late thus shortening the seed filling period on lower branches and hence lower branches remain less productive. Shortening of seed filling period on lower branches as compared to main stem was reported by Singh et al. (5). Iganga et al. (9) attributed the low productivity of lower branches to the poor radiation penetration. Ancha and Morgan (10) observed that the removal of lower branches during anthesis and a week after anthesis in spring rape cultivar Maris Haplona under green house conditions resulted in higher seed yield. The study was conducted to assess whether branch removal can be recommended as a practice to generate additional income through selling the biomass thus removed and also to increase the seed yield, if so, the time of branch removal, extent of branch removal, response of different cultivars to debranching in terms of yield and the mode of compensation.

Methods

Experiments were laid out on a sandy clay loam soil of IARI research farm during *rabi* seasons of 2004-05 and 2005-06. Pusa Jaikisan, and Bio-169-96, a promising pipeline variety, with two dates of sowing i.e. 15 October and 30 October (hereafter refers as early and late sowing respectively) were subjected to removal of lower three to four branches on 40 days after sowing (DAS) (early debranching) and 50 DAS (late debranching) in addition to control where no branches were removed. During second season early and late debranching for late sown crop was done at 50 and 60 DAS because the plants were too short to remove branches at 40 DAS. The experiment was laid out in a randomized block design with three replications following the standard agronomic practices.

Leaf area index (LAI) was obtained from the weekly measured leaf area of three randomly selected plants removed from each treatment. Number of pri-

Table 1. Growth and yield parameters of two cultivars Pusa Jaikisan and BIO-169-96 sown on 15 October during 2004-05 and 2005-06 under different debranching treatments. Values in parentheses are for year 2005-06.

	Date of sowing 15 October									
	Pusa Jaikisan					BIO-169-96				
Parameters	D0	D1	D2	SE	CD	D0	D1	D2	SE	CD
P	5.2	5	4.6	0.38	1.1	6.8	6.2	5.8	0.36	1.04
	(5.2)	(5.6)	(4.8)	(0.45)	(1.3)	(5.5)	(5)	(4.9)	(0.36)	(1.02)
S/P	2.04	2.67	3.26	0.14	0.4	2.12	2.48	2.72	0.12	0.34
	(2.10)	(2.18)	(2.65)	(0.15)	(0.44)	(2.20)	(2.51)	(2.76)	(0.09)	(0.25)
Pods/plant	290	321	320	17.6	50.3	341	374	384	27.1	77.5
	(267)	(287)	(354)	(22.2)	(63.5)	(360)	(364)	(345)	(16.9)	(48.3)
Yield (q/ha)	32.6	31.9	28.1	0.59	1.7	34.6	34.1	34.3	0.45	1.3
	(21.4)	(23.1)	(25.5)	(0.49)	(1.4)	(24.7)	(26.6)	(24.7)	(0.56)	(1.6)
Harvest index	0.26	0.26	0.24			0.23	0.23	0.23		
(HI)	(0.20)	(0.21)	(0.21)			(0.20)	(0.22)	(0.21)		

mary branches, number of secondary branches per primary branch, seed contribution by each primary branch was determined on five randomly selected plants from each treatment at the time of harvest. Final above ground biomass, and seed yield were determined taking three samples of 1 m^2 area from each plots. Statistical analysis were done for comparing different treatments but compensatory behavior of mustard only one treatment i.e. branch removal, at a time was considered, viz. comparison between early and late branch removal of same variety sown on same date. Weather parameters for crop duration were obtained from nearby agrometerological observatory (Fig. 1).

Results and Discussion

Leaf Area Index

LAI followed inverted parabolic relationship with maximum value during pod development stage (Fig. 2) in both the cultivars and in the two dates of sowing. For Pusa Jaikisan cultivar, during the first crop season (*rabi*, 2004-05), the maximum leaf area indices were 5.88, 5.50 and 5.00 for control, early debranching and late debranching respectively for early sown crop while in late sown crop the values were 4.35, 4.12 and 3.61 respectively that is considerably less than early sown crop.

During second crop season (*rabi*, 2005-06), the maximum LAI values were 4.5, 4.3 and 4.3 for control, early debranching and late debranching in early sown crop while for late sown crop the corresponding value were 4.2, 3.8 and 3.8 which were slightly lower (Fig. 2).

In both the seasons, the highest leaf area index was recorded in the early sown plants with slightly higher values during first season. The trend of LAI for early debranching followed same pattern as control with a small dip point corresponding branch removal while late debranching witnessed significantly lower LAI for considerable period including peak value. Similar trend was observed for branch removal in late sown crop.

After debranching, there was a clear dip in LAI, which was more prominent in case of late debranching (Fig. 2). Marginal or no effect on peak LAI under early debranching shows good compensatory behavior of mustard for loss of leaves and branches. Effect of debranching was less prominent in late sown crop during second crop season probably because of shift in timing of branch removal.

For BIO-169-96 cultivar for the first crop season (2004-05), the peak LAI were 7.56, 7.52 and 7.12 for early sown crop and 5.84, 5.42 and 5.35 for late sown crop for control, early debranching and late debranching, respectively. There was minimal effect of early debranching except a dip in LAI line near debranching (Fig. 2). LAI followed same trend under different branch removal treatment in late sown crop with lower peak value. The LAI for early sown crop was significantly higher than late sown crop with no appreciable effect of debranching and that shows good compensatory behavior of early sown crop.

During second crop season (*rabi*, 2005-06) the

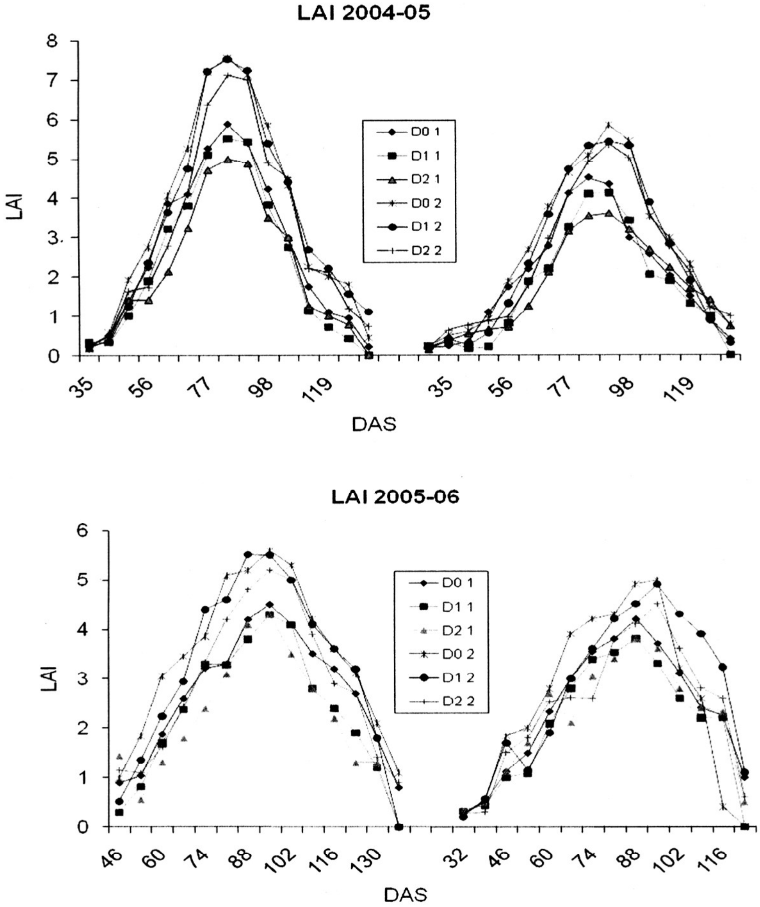

Figure 2. Leaf area index for the crop sown on 15 Oct and 30 Oct (a) 2004-05 (b) 2005-06. D0 1, D1 1 and D1 2 : control, early debranching and late debranching in Pusa Jaikisan ; D0 2, D1 2 and D2 2 : control, early debranching and late debranching in BIO-169-96.

highest LAI of 5.61 was recorded in early sown crop in case of control and decreased with delay and debranching as evidenced by lower peak in case of early (5.52) and late (5.21) debranching. The peak LAI was recorded at 95 DAS as against at 89 DAS in first season, for all three debranching treatments, which coincides with pod development stage.

In late sowing, the peak LAI observed in control (5.0) and early debranching (4.9) were almost same but late debranching showed slightly lower value (4.5). The LAI in late debranching plot was lower for considerable period (60 to 94 DAS).

LAI was higher in BIO-169-96 than Pusa Jaikisan irrespective of seasons and sowing dates. Higher temperature during initial period probably led to early flowering and there after sudden decrease in minimum temperature including frost (Fig. 1a) during leaf expansion might have caused reduction in LAI during second season for early sown crop. Initial crop growth stages of late sown crop were exposed to relatively low temperatures (Fig. 1a), which might have caused reduction in leaf area.

Both the variety show tendency to compensate for loss of leaves and branches. BIO-169-96 has more proliferating character than Pusa Jaikisan. High growth rate at the time of early debranching and probably some stimulating effect of debranching to generate more leaves and branch in upper part may be

Table 2. Growth and yield parameters of two cultivars, Pusa Jaikisan and BIO-169-96 sown on 30 October during 2004-05 and 2005-06 under different debranching treatments. Values in parentheses are for year 2005-06.

	Date of sowing 30 October									
	Pusa Jaikisan					BIO-169-96				
Parameters	D0	D1	D2	SE	CD	D0	D1	D2	SE	CD
P	4.8	4.8	5	0.42	1.21	4.8	4.6	4.4	0.45	1.3
	(4.6)	(5.1)	(5.1)	(0.43)	(1.24)	(5)	(5.3)	(4.2)	(0.42)	(1.2)
S/P	1.92	3.23	3.04	0.21	0.61	2.38	2.48	2.50	0.14	0.39
	(2.34)	(2.87)	(3.2)	(0.18)	(0.51)	(2.13)	(2.24)	(2.56)	(0.14)	(0.41)
Pods/plant	335	324	410	23.5	67	289	309	327	15.6	45
	(234)	(313)	(302)	(18.7)	(54)	(352)	(313)	(289)	(16.1)	(46)
Yield (q/ha)	25.7	21.9	22.5	0.73	2.1	25.0	24.9	26.7	0.49	1.4
	(23.9)	(23.0)	(26.5)	(0.70)	(2.0)	(23.0)	(26.6)	(23.1)	(0.52)	(1.5)
Harvest index (HI)	0.23	0.23	0.23	–	–	0.24	0.24	0.26	–	–
	(0.20)	(0.20)	(0.22)			(0.20)	(0.24)	(0.21)		

the reason for fast compensation. Late debranching may not have compensatory effect of same magnitude in terms of leaves but may be some other terms like branches or pods.

LAI was within the range reported by Kar (11). The results are in partial conformity with earlier findings of Khader (12) who observed that under Delhi conditions in mustard cultivar Pusa Bold, maximum LAI occurred between 70—85 DAS depending on the date of sowing and peak value of LAI (6.2) was observed for early October sown crop. Lower LAI under lower temperature was corroborated with observation of Nanda et al. (13).

Branch, Pod and Seed Distribution

Number of Primary Branches. Pusa Jaikisan : Number of primary branches per plant, at the time of harvest was 5.2, 5.0 and 4.6 in control, early debranching and late debranching respectively during first season in early sown crop. For late sown crop the primary branches were 4.8, 4.8 and 5.0 for control, early debranching and late debranching respectively (Tables 1 and 2).

In the second season (*rabi*, 2005-06) early sown crop, number of primary branches per plant at the time of harvest were 5.2, 5.6 and 4.8 for control, early debranching and late debranching while for late sown crop these were 4.6, 5.1 and 5.1.

BIO-169-96 : During first season (*rabi*, 2004-05) in early sown crop, primary branches at the time of harvest were 6.8, 6.2 and 5.8 for control, early debranching and late debranching while for late sown crop corresponding values were 4.8, 4.6 and 4.4.

During the second season, the primary branches per plant in control, early debranching and late debranching were 5.6, 5 and 4.9, respectively in early sown crop and 5, 5.3 and 4.2 for second sown crop.

No significant difference between different control and debranching treatments at the time of harvest number indicates a very strong tendency of plants to compensate for the removal of lower branches as it compensated well for removal of three to four branches. Both the cultivars were almost equally responsive to removal of lower branches.

Secondary Branches / Primary Branches (S/P). Pusa Jaikisan : Number of secondary branches per primary branches was significantly higher in late debranching in both the season and date of sowing. During first season, the secondary branches per primary branch were 2.04, 2.67 and 3.26 for control, early debranching and late debranching in early sown crop while the corresponding values were 1.92, 3.23 and 3.04 for late sown crop. In second season (2005-06) the values were 2.10, 2.18 and 2.65 for the early sown crop and for late sown crop these were 2.34, 2.87 and 3.2.

BIO-169-96 : In both the debranching treatments number of secondary branches per primary branches was either significantly higher than or almost equal to control treatment irrespective of date of sowing and cultivar (Tables 1 and 2). In both the cultivars, the number of secondary branches per primary branch was maximum in case of late debranching that em-

Table 3. Fresh biomass obtained through branch removal in two cultivar sown on 15 and 30 October under different debranching treatments.

	DOS 15 Oct			DOS 30 Oct		
	D0	D1	D2	D0	D1	D2
2004-05						
Pusa Jaikisan (q/ha)	0	43.3	59.7	0	17.2	33.1
BIO-169-96 (q/ha)	0	44.7	53.3	0	17.3	39.1
2005-06						
Pusa Jaikisan (q/ha)	0	36.8	44.2	0	33.1	71.3
BIO-169-96 (q/ha)	0	51.7	83.6	0	58.9	80.8

ploys plant compensates more in terms of primary branches for early debranching and for late debranching it compensates more in terms of secondary branches.

Number of Pods and Its Distribution. Pusa Jaikisan : Percent of pods contributed by lower two branches varied from 5 to 13% in control as against 11 to 19% in case of debranched treatments. The number of pods per plants in Pusa Jaikisan varied from 290 (D1 D0) to 410 (D2 D2) during *rabi* 2004-05 and 234 (D2 D0) to 354 (D1 D2) during 2005-06. Number of pods per plant was significantly higher in case of late debranching (Tables 1 and 2).

Though the number of pods contributed by different primary branches reveals that lower branches are less productive but to see it more precisely, weight of seed contributed by different primary branch was also recorded during second crop season. Lower two branches contributed in the range of 5 to 9% to the total seed in case of control while it contributed 11 to 20% in debranching treatment. Here it is evident that lower few branches are less productive as compared to upper branches. There was no one to one relation between number of pods per plant and seed yield.

BIO-169-96 : The lower two branches contributed between 5 to 10% in controlled while debranched treatment contributed between 10 to 19% of pods during *rabi* 2004-05. Further in terms of seed weight, lower two branches contributed 6 to 9% in control as against 11 to 28% in debranched treatments during 2005-06.

In both of the cultivars, lower branches were less productive which may be because of poor rediation penetration and hence less photosynthesis by lower leaves and branches. Even though lower branches appear first on plant but flower and pods appear late on these branches the seed filling duration got reduced due to source limitation (less photosynthesis) and forced maturity (4).

Seed Yield. Pusa Jaikisan : During *rabi* 2004-05, the seed yields of Pusa Jaikisan were 32.9, 31.9 and 28.1 q/ha in early sown crop and 25.7, 21.9 and 22.5 q/ha in late sown crop for control, early debranching and late debranching treatments (Tables 1 and 2). The yield was less by 21.2% in late sown crops as compared to early sown crop in control. In the second season (*rabi* 2005-06), the seed yields were 21.4, 23.9 and 25.5 q/ha in early sown crop and 23.9, 23.0 and 26.5 q/ha in late sown crop for control, early debranching and late debranching plots respectively.

Unlike first season, the highest yield was recorded in late sowing in the second season. Yield differences in three treatments of early sowing were significant with 11.7 and 19.1% increase for early debranching and late debranching respectively. Hence unlike first season there was positive effect of debranching in the second season.

BIO-169-96 : In the first crop season, the seed yield in BIO-169-96 varied from 24.9 q/ha to 34.6 q/ha in two sowing dates under different debranching treatments. In early sown crop there was no significant effect of debranching with 34.6 q/ha, 34.1 q/ha and 34.3 q/ha in case of control, early debranching and late debranching (Tables 1 and 2). Similar is the case with late sown crop but yield was 28% less than early sown crop in control treatment. During second season yields of BIO-169-96 were 24.7, 26.6 and 25.7 q/ha in early sown crop and 23.0, 26.6 and 23.1 q/ha in late sown crop in control, early debranching and late debranching treatments. There was no appreciable effect of debranching in early sowing but in late sown crop early debranching produced higher yield (26.6 q/ha) as compared to control (23 q/ha) and late debranching (23.1 q/ha).

Results infer high yielding capacity of cultivar BIO-169-96 though under adverse conditions (high temperature spell during seed filling and maturity) the yields were at par with Pusa Jaikisan. Lower yields in both cultivars in late sown crop during *rabi* 2004-05 could be attributed to the compound effect of cold temperature spell during initial period and forced maturity due to high temperature during pod maturing stage (Fig. 2). Lower yield in late sown crop was reported by different worker (11, 13, 14). Panda et al. (15) recorded higher seed yield (1945 kg/ha) in case of crop sown on 16 October than the crops sown on 31 October (1,556 kg/ha) is also supporting finding of the present study.

The yield reduction of about 25% in the second season which was relatively cooler at initial stage and significantly warmer at late stage of crop growth period, is in conformity with the earlier findings of Rao (16) who reported a reduction of about 36%.

Lower yield in late debranching of early sown Pusa Jaikisan was due to more severe debranching than desired as evidenced form Table 3, and hence the plant was left with insufficient leaves and branches to compensate for loss. Lower seed yields in the late sown debranched plots of Pusa Jaikisan could be due to poor growth of plants at the time of debranching (due to prevailing low temperature spell) hence less photosynthetic area available after for fast growth and compensation debranching. In the second season, there was positive effect of debranching in terms of yield in early sown crop of Pusa Jaikisan. The reason may be the fact that removal of lower branches might have led to more photosynthates available for upper productive branches as reported by Ancha and Morgan (10). Positive or no effects of debranching in BIO-169-96, in all combination of treatments tested, reveals high proliferating character of the cultivar than was also supported by more LAI.

Conclusion

Removal of lower branches between 40 and 60 days or at suitable period in timely sown crop has either positive or no effects on performance, though the response varies from cultivar to cultivar and season to season. BIO-169-96 was found to be more suitable for removal of lower branches as it compensates faster. Low temperature exposure at leaf expansion stage and high temperature exposure at pod growth and seed filling stage are responsible for reduction in seed yield of late sown crop. Early rise of temperature during crop growth stage could lead to lower yield of mustard. Further, it may be concluded that plant compensates for the loss of leaves and branches first in terms of producing more number of primary branches and leaves and later on by producing more secondary branch per primary branch and number of pods. For early sown crop, debranching between 40 and 50 DAS and for late sown crop between 50 and 60 DAS may be practiced to generate additional biomass in BIO-169-96 in particular. Response of Pusa Jaikisan is subjected to further investigation in form of extent of branch removal as varying response was observed. The conclusion was drawn for two cultivars sown on 15 and 30 October and grown under well managed condition, but for other cultivars, date of sowing and various stresses like water and nutrients shall be borne in mind.

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