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Research Article

The Role of Morpho-Physiological Attributes on the Seed Yield of *Brassica juncea*

MMA Mondal[1], MA Malek[2] and MSH Bhuiyan[2]*

[1] *Principal Scientific Officer, Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh*

[2] *Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh*

***Corresponding Author:** MSH Bhuiyan, Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh.

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Abstract

The field experiment was conducted to investigate morphological, growth, biochemical, yield attributes and seed yield in six *Brassica juncea* mutants viz., MM 01, MM 02, MM 04, MM 08, MM 09 and MM 10 along with a cultivar, BARIsarisa-11. Results revealed that high yielding genotypes had higher morphological characters (plant height, branch number and leaf area), growth characters (leaf area index, total dry mass and absolute growth rate), biochemical parameters(total sugar, nitrate reductase and photosynthesis) and yield attributes (siliqua number, siliqua length, number of seeds siliqua-1 and 1000-seed weight) resulting higher seed yield than low yielding ones. High yielding genotypes also showed better assimilate partitioning to economic yield than low yielding ones. The mutants MM 10 and MM 02 showed superiority in respect of growth and biochemical parameters resulting superior yield attributes thereby seed yield (2533 and 2417 kg ha-1, respectively). In contrast, MM 09 showed the inferiority in case of growth, biochemical parameters and siliqua number and also showed lower seed yield (1767 kg ha-1).

Keywords: *Brassica juncea*; BARIsarisa-11; MM 10; MM 02

Introduction

Brassica oil crop has global economic importance. In Bangladesh, *Brassica* oil crop covers about 70% of the total oilseed acreage and about 39% of the total production [1]. *Brassica* oil is used mostly for edible purpose and a part finds industrial applications. Oil cake is used as manure and animal feed. The seeds contain 40 - 45% oil and 20 - 25% protein.

In Bangladesh, the yield of mustard is poor due to the lack of high yielding cultivar coupled with short duration of the winter season. Now, the main strategy for development of mustard in Bangladesh should be to develop lines having high yield potentials with short life span and high levels of resistance to major diseases. To meet increasing demand of edible oils for the fast-growing population of Bangladesh, there need urgent attention to develop high yielding variety under sub-tropical environmental condition. To increase mustard production, there is very little scope for horizontal expansion of mustard area. Furthermore, the wide gap between achievable (2.4 t ha^{-1}) and average yield (0.96 t ha^{-1}) should be reduced.

The low yield potential of mustard is due to 30 to 50% of mustard flowers do not develop into mature pods [3]. It means potential fruit or seed number is usually much larger than the number actually produced by the plant community. During the reproductive stage; the flowering, fruiting and vegetative growth occur simultaneously until physiological maturity [4,5]. Therefore, developing reproductive sinks are competing for assimilates with vegetative sinks. It is evident that seeds per unit area are related to canopy photosynthesis during flowering and pod set. Furthermore, canopy photosynthesis rate determines through leaf area index and crop growth rate.

Important physiological attributes such as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and specific leaf weight (SLW) can address various constraints of a variety for increasing its productivity [4,5]. A plant with optimum LAI and NAR may produce higher biological yield. For optimum yield in mustard, the LAI should be ranged from 3.5 to 4.5 [6]. Any reduction of leaf area or the amount/intensity of light may have an adverse effect on yield [7]. The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time [8]. Not only TDM production, the capacity of efficient partitioning between the vegetative and reproductive parts may produce high economic yield [7]. Probably a better understanding of crop growth and yield parameters and the partitioning of assimilates into seed formation would help to expedite yield improvement of this crop. Keeping all those above in mind, the current research was undertaken to investigate variations in some growth, biochemical parameters and yield attributes for selection of important sources and sinks in 7 elite mutants/variety of *Brassica juncea*.

Materials and Methods

The field experiment was performed at the experimental field of Bangladesh Institute of Nuclear Agriculture, Mymensingh during November 2014 to February 2015. Six advanced mutants (MM 01, MM 02, MM 04, MM 08, MM 09 and MM 10) and one variety (BARI Sarisa-11) of *Brassica juncea* were used as treatment in the experiment. The experiment was laid out in a Randomized Complete Block Design with 3 replications. The size of the unit plot was 4 m x 3 m. Plant to plant distance was 6 cm and row to row distance was 30 cm. Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and borax were used as source of nitrogen, phosphorus, potassium, sulphur and boron, respectively. Total amount of TSP, MP, gypsum, borax and half of urea were applied at basal doses during final land preparation. The rest half of urea were applied as top dress at 21 days after sowing. The doses of fertilizers were: urea 250, TSP 160, MP 80, gypsum 180 and borax 2.0 kg ha-1. The seeds of Brassica juncea were hand sown in rows on 12 November, 2014. Seeds were placed at about 3 - 4 cm depth from the soil surface. Plants were thinned to 5 - 8 cm distance from one another at 20 days after sowing (DAS). Weeding was done once at 20 DAS only. Two irrigations were applied. The first irrigation was applied at 21 DAS and second one at 45 DAS. Insecticide (Malathion 57 EC at 0.025%) was sprayed at flowering and fruiting stage (30 and 45 DAS) to control aphid.

To study ontogenetic growth characteristics, a total of five harvests were made and at final harvest, data were collected on some morpho-physiological parameters, yield attributes and yield. The first crop sampling was done at 40 days after sowing (DAS) and continued at an interval of 10 days up to 80 DAS. From each sampling, five plants were randomly selected from each plot and uprooted for collecting necessary parameters. The plants were separated into leaves, stems and roots and the corresponding dry weight were recorded after oven drying at 80 ± 2^{o}C for 72 hours. The leaf area of each sample was measured by automatic leaf area meter (Model: LICOR 3000). The growth analyses like AGR, RGR and NAR were carried out following the formulae of Hunt [9]. Photosynthesis was measured at flowering and pod development stage by portable photosynthesis meter ((LI- 6400XT, USA). Leaf chlorophyll was determined by following the method of Yoshida., *et al* [10]. Total sugar was determined following the method of Dubois., *et al* [11]. Nitrate reductase (NR) was estimated following the procedure of Stewart and Orebanjo [12].

The yield contributing characters were recorded at harvest from ten competitive plants of each plot. The seed yield was recorded from five rows of each plot (2.50m × 3.0m) and converted into seed yield hectare^{-1} and seed weight plant^{-1} was determined by dividing the plant number. Harvest index was calculated from the collected data using formula: (economic yield/plot ÷ biological yield/plot) × 100. The collected data were analyzed statistically by using computer package program, MSTAT.

Results and Discussion

Morphological and biochemical parameters

The effect of mutants/variety on morphological characters such as plant height and number of branches plant^{-1}, biochemical parameters such as total sugar content, nitrate reductase activity and photosynthesis rate were significant except chlorophyll content in leaves (Table 1). The mutant MM 10 was the tallest plant (147.0 cm) followed by MM 02 (146.0 cm) and BARIsarisa-11 (145.7 cm) with same statistical rank. The shortest plant was recorded in MM 08 (129.2 cm) which was statistically similar MM 04 (132.5 cm). The highest number of branches plant^{-1} was recorded in MM 02 (4.40) followed by BARIsarisa-11 (4.30) and the lowest was recorded in MM 04 (3.40). These results are in agreement with the result of Mondal., *et al.* [13] and Malek., *et al.* [14] who stated that plant height and number of branches plant-1 differed significantly among the studied genotypes in mustard.

Mutants/ variety	Plant height (cm)	Branches plant^{-1} (no)	Chlorophyll (mg g^{-1} fw)	Photo-synthesis (µmol CO_2 dm^{-2} s^{-1})	Total sugar (mg g^{-1} fw)	Nitrate reductase (µmol NO_2^- g^{-1} fw)
MM 01	138.0 ab	3.60 c	2.28	15.85 abc	66.33 c	7.40 c
MM 02	146.0 a	4.40 a	2.39	17.10 a	78.41 a	8.55 ab
MM 04	132.5 b	3.40 c	2.33	15.20 bc	70.61 bc	8.40 b
MM 08	129.2 b	3.90 bc	2.32	14.90 c	69.80 bc	7.18 cd
MM 09	136.8 ab	3.60 c	2.26	13.23 d	64.40 c	6.73 d
MM 10	147.0 a	4.00 b	2.36	16.44 ab	80.10 a	9.11 a
BARIsa-risa-11	145.7 a	4.30 ab	2.36	16.24 abc	75.63 ab	8.67 ab
F-test	**	*	NS	**	**	**
CV (%)	5.04	6.72	3.76	4.54	5.04	4.00

Table 1: Variation in morphological and biochemical parameters of Brassica juncea mutant/variety.
In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively; NS, not significant.

High yielding mutants showed higher photosynthesis rate, chlorophyll and total sugar content in leaf, nitrate reductase activity in leaves than low yielding ones. It means photosynthesis rate, total sugar content in leaf, NR activity is positively correlated with seed yield. The higher photosynthesis rate, nitrate reductase and total sugar was observed in MM 02 and MM 10, the high yielding mutants and the lowest/lower was recorded in MM 09, the low yielding mutant.

Growth parameters

The development of leaf area (LA) and leaf area index (LAI) over time in Brassica juncea mutants/variety is presented in tables 1 and 2. Result revealed that LA and LAI increased till 70 DAS followed by decline because of leaf shedding. The increment of LA and LAI varied significantly due to mutants/variety at all growth stages. At peak LA and LAI developmental stage (70 DAS), the mutant

MM 10 showed the highest LA (4568 cm2 plant-1) and LAI (5.61) followed by MM 02 (4159 cm2 plant-1; 5.20, respectively). The lowest LA and LAI were recorded in MM 09 at most of the growth stages. The variation in LA and LAI might occur due to the variation in number of leaves and the expansion of leaf. The result obtained from the present study is consistent with result of Mondal., *et al.* [7] who stated that variation in LA could be attributed to the changes in number of leaves. The results obtained from the present study are consistent with the result of Mondal., *et al.* [8] who stated that the variation in LAI could be attributed to the changes in the number of leaves and rate of leaf expansion and abscission.

Mutants/ variety	Leaf area plant^{-1} (cm^2)† at				
	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS
MM 01	729 cd	1826 d	2466 cd	3538 cd	3216 b
MM 02	1048 a	2155 b	3629 ab	4159 ab	3676 a
MM 04	929 b	1371 e	3444 b	3930 bc	3051 bc
MM 08	794 c	1906 cd	2870 c	3200 d	3017 bc
MM 09	714 d	2075 bc	2681 c	3045 d	2642 cd
MM 10	899 b	2510 a	3950 a	4568 a	3762 a
BARIsa-risa-11	884 b	1786 d	2136 d	3120 d	2414 d
F-test	**	**	**	**	**
CV (%)	3.60	5.87	7.36	7.18	7.27

Table 2: Genotypic effect on leaf area development at different growth stages of Brassica juncea.

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; ** indicate significant at 1% levels of probability; †: Leaf was not found at harvest.

Result revealed that TDM production increased with time up until 80 DAS followed by declined due to severe leaves shedding during maturity starting (Table 4). The mutants MM 02 and MM 10 maintained the higher TDM at all growth stages and the lowest TDM was recorded in MM 09 at most of the growth stages. Increased TDM in MM 02 and MM 10 was possibly due to greater LAI (Table 3) and AGR (Table 5). Result further revealed that high yield genotypes produced higher TDM than the low yielding ones. The result is supported by the result of Mondal., *et al*. [14] who reported that TDM increased with increasing plant age up to physiological maturity.

The AGR increased till 60 DAS in all mutants/variety followed by a decline till starting physiological maturity except BARIsarisa-11 (Table 5). The AGR of BARIsarisa-11 declined after 60 DAS and then increased at peak siliqua filling stage (70 - 80 DAS). The AGR was higher in MM 02 and MM 10 at most of the growth stages might be due production of higher TDM plant-1. The lower value of AGR at initial stages of growth was the result of lower LAI. This result is in agreement with the findings of Prasad., *et al* [15]. At 50-60 DAS, the AGR values were found to be maximum which mean that plants expanded its assimilate for the growth of leaf area and feeding of pods. The declining of AGR after reaching the maximum in all genotypes might be the result of abscission of leaves. These results are consistent with the results of Malek., *et al* [16].

Mutants/ variety	Leaf area index† at				
	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS
MM 01	0.91 d	2.28 cd	3.08 d	4.42 c	4.02 b
MM 02	1.31 a	2.69 b	4.54 b	5.20 b	4.60 a
MM 04	1.16 b	1.71 e	4.31 b	4.91 b	3.81 b
MM 08	0.99 c	2.38 bcd	3.59 c	4.00 d	3.77 b
MM 09	0.89 d	2.59 bc	3.35 cd	3.81 d	3.30 c
MM 10	1.12 b	3.13 a	4.94 a	5.61 a	4.70 a
BARIsa-risa-11	1.10 b	2.23 d	2.67 e	3.90 d	3.02 c
F-test	**	**	**	**	**
CV (%)	4.52	7.48	4.73	4.29	5.46

Table 3: Effect of mutants/variety on leaf area index at different growth stages of Brassica juncea.

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively; †: Leaf was not found at harvest.

Mutants/ variety	Total dry mass plant^{-1} (g) at					
	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	At harvest
MM 01	1.09 b	3.79 bc	8.76 b	11.49 d	13.03 bc	12.26 b
MM 02	1.54 a	4.11 b	9.46 a	14.32 a	16.98 a	13.96 a
MM 04	0.80 c	3.57 c	8.40 bc	12.38 c	14.13 b	12.47 b
MM 08	0.75 c	3.63 c	8.28 bc	10.56 e	12.98 bc	10.13 d
MM 09	0.93 bc	3.92 bc	7.41 d	10.05 e	12.13 c	10.79 cd
MM 10	1.16 b	4.61 a	9.73 a	13.65 b	18.13 a	13.63 a
BARIsarisa-11	0.98 bc	4.14 b	8.07 c	10.04 e	14.36 b	11.51 bc
F-test	**	**	**	**	**	**
CV (%)	12.70	5.57	3.95	2.93	5.47	5.22

Table 4: Total dry mass production at different growth stages in seven Brassica juncea mutants/variety.

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; ** indicate significant at 1% levels of probability.

Mutants/ variety	Absolute growth rate† (mg/plant/day) at			
	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
MM 01	270 cd	497 abc	273 c	154 e
MM 02	257 d	535 a	486 a	266 b
MM 04	277 cd	483 bc	398 b	175 de
MM 08	288 bcd	465 c	228 d	242 bc
MM 09	299 bc	349 e	264 c	208 cd
MM 10	345 a	512 ab	392 b	348 a
BARIsa-risa-11	316 ab	393 d	197 d	332 a
F-test	**	**	**	**
CV (%)	5.69	4.89	5.80	8.69

Table 5: Effect of mutants/variety on absolute growth rate at different growth stages of Brassica juncea.

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; ** indicate significant at 1% levels of probability; †: AGR at 80-100 DAS was negative value.

Mutants/ variety	Relative growth rate† (mg/g/d) at			
	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS
MM 01	124.6 b	83.8 a	27.1 cd	12.6 e
MM 02	98.2 c	83.4 a	41.5 a	17.0 d
MM 04	149.6 a	85.6 a	38.8 a	13.2 e
MM 08	157.5 a	82.5 a	24.3 de	20.6 c
MM 09	144.0 ab	63.7 c	30.5 bc	18.8 cd
MM 10	138.0 ab	74.7 b	33.9 b	28.4 b
BARIsa-risa-11	144.0 ab	66.7 c	21.8 e	35.8 a
F-test	**	**	**	**
CV (%)	8.05	4.46	7.22	7.50

Table 6: Variation in relative growth rate due to mutants/ variety at different growth stages of Brassica juncea.

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; ** indicate significant at 1% levels of probability, respectively; †: RGR at 80-100 DAS was negative value.

There was an inverse relationship between RGR and plant age (Table 6). Generally, with the advancement of the plant age, the RGR decreased in most of the field crops [17]. The RGR of the mutants/ variety showed the highest value at 40 - 50 DAS and followed a declining trend with being the lowest at 70 - 80 DAS. Mentionable that RGR value at 80 - 100 DAS was negative due to decreased TDM at 100 DAS. At early growth stage (40 - 50 DAS), MM 08 showed the highest RGR (157.5 mg g-1 d-1) and the lowest was recorded in MM 02 (98.2 mg g-1d-1). The results of the present study are in agreement with the results of Bhat., *et al.* [6] in mustard who stated that the maximum RGR was observed during vegetative stage and declined rapidly with the advancement of growth stages.

Seed yield and yield contributing characters

The effect of mutants/variety on days required to maturity, yield contributing characters and seed yield was significant (Table 7). The mutant, MM10 took the longest days (112 days) to maturity while MM 04 matured earliest (109 days). The highest/higher number of siliqua plant^{-1} was recorded in two mutants, MM 02 and MM 10, and these two mutants also produced the highest/higher seed yield plant^{-1} (Table 7). This result indicates that siliqua production is the most important yields attributes for getting higher seed yield. Results indicated that though the mutant MM 08 produced higher number of siliqua plant^{-1} but showed the lowest seed weight plant^{-1} for its smaller size seeds (Table 7). Mondal., *et al.* [18] studied 20 mutants/varieties based on yield attributes and yield and reported that high yielding mutants produced higher number of siliqua plant^{-1} that also supported the present experimental result.

Mutants/ variety	Days to maturity	Filled siliqua/ plant (no.)	Siliqua length (cm)	Seeds/ siliqua (no.)	1000- seed weight (g)	Seed weight /plant (g)	Seed weight (kg/ha)	Harvest index (%)
MM 01	110 ab	113.3 bc	3.51 c	10.80 abc	3.87 c	3.73 d	2100 b	23.33 bc
MM 02	111 ab	128.5 a	3.72 bc	11.07 ab	4.13 b	4.87 b	2417 a	25.86 ab
MM 04	109 b	123.2 ab	3.80 ab	10.67 a-d	3.93 bc	4.17 c	2150 b	25.06 b
MM 08	111 ab	118.0abc	3.63 bc	10.40 cd	2.99 d	2.67 e	2033 b	20.86 c
MM 09	112 ab	107.7 c	3.55 bc	10.60 bcd	4.05 bc	3.62 d	1767 c	25.12 b
MM 10	113 a	130.1 a	4.03 a	11.20 a	4.40 a	5.55 a	2533 a	28.94 a
BARIsa-risa-11	111 ab	112.0 bc	3.73 bc	10.13 d	2.89 d	2.28 f	2050 b	16.53 d
F-test	*	**	**	**	**	**	**	**
CV (%)	1.47	5.41	3.53	2.70	3.07	5.24	6.66	7.69

Table 7: Days to maturity, yield attributes and yield in seven mutants/variety of *Brassica juncea.*

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively.

The highest seed yield both plant^{-1} (5.55g) and hectare^{-1} (2533 kg) was observed in MM 10 because of production of higher number of siliqua plant^{-1}, seeds siliqus^{-1} and bolder seeds. The mutant MM 10 also showed the highest harvest index (28.94%). The mutant MM 08 produced medium seed yield hectare^{-1} (2033 kg) though it showed the lowest seed weight plant^{-1} (2.67g) may be due to narrow canopy with accommodation of increased number of plants per unit area. In contrast, the mutant MM 09 showed the lowest seed yield (1767 kg ha^{-1}) might be due to production the lowest number of siliqua plant-1 (107.7). BARIsarisa-11 showed the lowest HI (16.53%) which indicating that dry matter partitioning to economic was poor in BARIsarisa-11 than the others while reverse trend was observed in MM 02 and MM 10, the high yielding mutants.

Conclusion

Based on the experimental results, it may be concluded that high yielding mutants should have higher number of branches with taller plant, higher LA as well as LAI, TDM and AGR which resulted higher number of siliqua plant^{-1}, seeds siliqua^{-1} than the low yielding ones in *Brassica juncea*. Among the studied mutants/variety, MM-10 performed the best with respect to growth, yield attributes and seed yield. This information may be useful in future plant breeding program.

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