Bangladesh J. Nuclear Agric. 33 & 34: 47-54 (December, 2020) *ISSN 0258-7130*

IMPACT OF MORPHO-PHYSIOLOGICAL TRAITS ON SEED YIELD IN RAPESEED

M. M. A. Mondal[1]* and M. A. Malek[2]

Abstract

The field experiment was conducted at the experimental farm of the Bangladesh Institute of Nuclear Agriculture, Mymensingh, during the period from November 2014 to February 2015 to investigate morpho-physiological characters, yield attributes and seed yield in three mustard mutants *viz.*, MM 05, MM 25 and MM 98 along with a check variety, Binasarisa-4. Leaf area (LA), leaf area index (LAI) and AGR increased till 65 days after sowing followed by a decline due to leaf shedding at later growth stages. The mutant MM 05 showed superiority in respect of branch number, TDM, LA, and growth parameters like LAI and AGR at most of the growth stages and also produced the highest seed yield whilst Binasarisa-4 and MM 98, the low yielding genotypes, showed the inferiority in case of plant height, branch number, LA, LAI and AGR. Moreover, high yielding genotypes showed superiority in chlorophyll content, photosynthesis, total sugar content and nitrate reductase activity in leaves. The highest seed yield both plant^{-1} (2.88 g) and hectare^{-1} (2218 kg) was observed in MM 05 because of production of higher number of siliquae plant^{-1}, seeds siliqua^{-1} and had capacity to superior dry matter partitioning to economic yield. In contrast, the lowest seed yield both plant^{-1} and hectare^{-1} was observed in MM 98 and BINAsarisa-4 due to inferiority in growth and yield contributing characters.

Key words: Rapeseed, Morpho-physiological traits, Seed yield

Introduction

Mustard (*Brassica* spp.) is one of the most important oil crops of global economic importance. About ten oil crops are grown in Bangladesh. Among these, Brassica oil crop is the most important group of the species that supplies major edible oil in Bangladesh. It covers about 80% of the total oilseed acreage and about 71% of the total production (BBS, 2016). Mustard 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.

At present, the oil seed production is about 0.35 million tons, which covers only 28% of the domestic need (BBS, 2016). More than 70% of requirement of oil has been imported every year by spending huge amount of foreign currency involving over Tk. 4100 Crore (BBS, 2016). In Bangladesh, the seed yield of mustard/rapeseed is about 960 kg ha^{-1} which is very low in comparison to other developed countries (2400 kg ha^{-1}) (FAO, 2016). The low yield is due to lack of high yielding varieties and improper agronomic practices. That is why,

[1]Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh
[2]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh
*Corresponding author: mmamondal@gmail.com.

improvement of existing oilseed crops and introduction of a new oilseed crop species as well as proper cultural management practices need urgent attention to meet increasing demand of edible oils for the fast growing population of Bangladesh. To keep pace with the present population growth and oil seed production, the modern variety with mustard area need to be expanded by replacing the local low yielding cultivars under cultivation, and the seed yield per unit area is needed to be increased. There is very little scope for horizontal expansion of mustard area. However, there remains a potential scope where more than 60% of the area is cultivated by the low yielding local cultivars (mainly Tori-7), which should be replaced by the modern varieties developed at different Institutes. Furthermore, the wide gap between achievable (2.4 t ha^{-1}) and average yield (0.96 t ha^{-1}) should be reduced.

The main constraint of mustard production is its low yield potential. From 30 to 50% of mustard flowers do not develop into mature pods (Mondal and Malek, 2017) indicating that potential fruit or seed number is usually much larger than the number actually produced by the plant community. The number of fruits with developing seeds increases after growth stage R1 (Fruit setting stage) and reaches to a maximum after growth stage R5 (maximum seed growth stages) (Mondal *et al*, 2012; Mondal *et al*, 2013) but during this period the plant is still growing vegetatively. 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 (Malek *et al*., 2012; Mondal *et al*, 2013). A plant with optimum LAI and NAR may produce higher biological yield. The capability of efficient partitioning between the vegetative and reproductive parts may produce high economic yield (Mondal *et al*., 2014). For optimum yield in mustard, the LAI should be ranged from 3.5 to 4.5 (Bhat *et al*., 2006). Any reduction of leaf area or the amount/intensity of light may have an adverse effect on yield (Mondal *et al*., 2011). The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time (Mondal *et al*., 2014).

Recently, BINA has developed three promising mustard mutants (MM 05, MM 25 and MM 98) of high yield potentials. These mutants need to be assessed for their physiological growth and morphological maneuvering that takes place compared to the existing mustard cultivars. Hence, the present research work has been designed to study morpho-physiological parameters, biochemical, reproductive characters and other yield attributes responsible for higher seed yield. Thus, the research work was undertaken to evaluate the growth and development of three elite mustard mutants compared to the existing variety, Binasarisa-4; and to select better genotype in respect to growth, biochemical, reproductive, yield and yield components in mustard.

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. Three advanced mutants (MM 05, MM 25 and MM 98) and one variety (Binasarisa-4) of mustard 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 × 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 mustard were hand sown in rows on 10 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 stages (30 and 45 DAS) to control aphid.

To study ontogenetic growth characteristics, a total of six 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 35 DAS and continued at an interval of 10 days up to 90 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 0C 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 (1978). 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*. (1976). Total sugar was determined following the method of Dubois *et al*. (1956). NRase was estimated following the procedure of Stewart and Orebanjo (1979). Reproductive efficiency was calculated by dividing total reproductive unit to siliqua number of plant multiplying with 100 and expressed in percentage.

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 (2.50 m × 3.0 m) 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^{-1} ÷ biological yield plot^{-1}) × 100. The collected data were analyzed statistically by using computer package program, MSTAT-C.

Results and Discussion

Morphological and biochemical parameters

The effect of mutants/variety on days to maturity, morphological characters such as plant height and number of branches plant^{-1}, biochemical parameters such as total sugar, nitrate reductase and photosynthesis was significant except chlorophyll content in leaves (Table 1). The two mutants, MM 05 and MM 25 took 96 days for maturity and Binasarisa-4 took the longest days (100 days) to maturity while MM 98 matured the earliest (93.1 days). The mutant MM 25 was the tallest plant (83.3 cm) followed by MM 05 (81.3 cm) with same statistical rank. The shortest plant height was recorded in MM-98 (75.8 cm) which was statistically similar Binasarisa-4 (76.6 cm). The highest number of branches plant^{-1} was recorded in MM 05 and the lowest was recorded in Binasarisa-4. These results are in agreement with the result of Mondal *et al*., (2003) and Malek *et al*. (2014) who stated that days to maturity, plant height and number of branches plant^{-1} differed significantly among the studied genotypes in mustard.

Table 1. Variation in days to maturity, some morphological and biochemical parameters of 3 rapeseed mutants along with check variety

Mutants/ variety	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Chloro-phyll (mg g^{-1}fwD)	Photo-synthesis (µmol CO_2 s^{-1} dm^{-2})	Nitrate reductase (µmol NO_2- g^{-1} fw)	Total sugar (mgg^{-1}fw)
MM 05	96.0 b	81.3 a	2.80 a	2.03	14.22 a	6.66 a	63.50 a
MM 25	96.0 b	83.3 a	2.25 b	1.98	13.85 a	5.42 b	58.21 a
MM 98	93.1 c	75.8 b	2.51 ab	2.13	11.11 c	5.12 b	50.11 b
Binasarisa-4	100.0 a	76.6 b	2.45 b	2.10	12.00 b	5.60 b	48.60 b
F-test.	**	**	*	NS	**	**	**
CV (%)	2.49	5.41	11.56	4.09	3.50	4.14	6.71

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

High yielding mutants showed higher chlorophyll, phosynthates, total sugar content in leaf, nitrate reductase activity than low yielding ones. It means photosynthesis, NR activity are positively correlated with yield. The highest photosynthesis (14.22 µmol CO_2 s^{-1} dm^{-2}), nitrate reductase and total sugar was observed in MM 05, the high yielding mutant and the lowest/lower was recorded in MM 98, the low yielding mutant.

Growth parameters

The development of leaf area (LA) and leaf area index (LAI) over time in mustard mutants/variety is presented in Fig. 1. Result revealed that LA and LAI increased till 65 DAS followed by a sharp 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 (65 DAS), the mutant MM 05 showed the highest LA (587.4 cm^2 plant^{-1})

and LAI (3.6) followed by MM 25 (500.0 cm^2 $plant^{-1}$). The lowest LA and LAI were recorded in Binasarisa-4 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 results obtained from the present study are

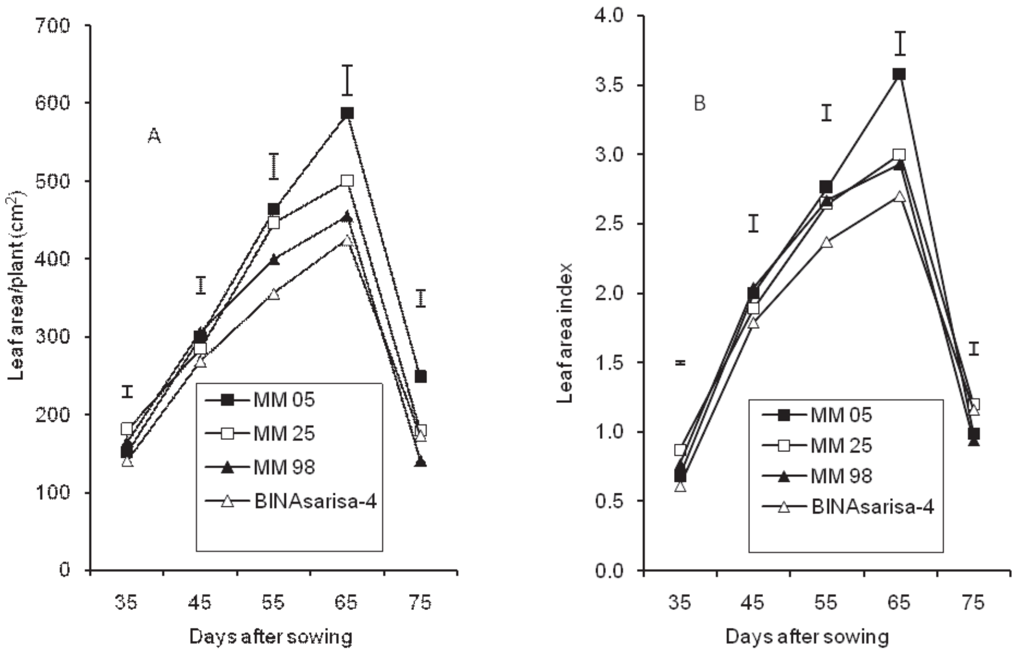

Fig. 1. Variation in (A) leaf area $plant^{-1}$ and (B) leaf area index in four rapeseed mutants/variety at different growth stages. Vartical bars represent LSD (0.05)

consistent with the result of Mondal *et al*. (2014) 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.

Result revealed that TDM production increased with time up to near maturity (Fig. 2). The mutant MM 05 maintained the highest TDM at all growth stages and the lowest TDM was recorded in Binasarisa-4 at most of the growth stages. Increased TDM in MM 05 was possibly due to greater LAI (Fig. 1) and AGR (Fig. 2). 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.* (2015) who reported that TDM increased with increasing plant age up to physiological maturity.

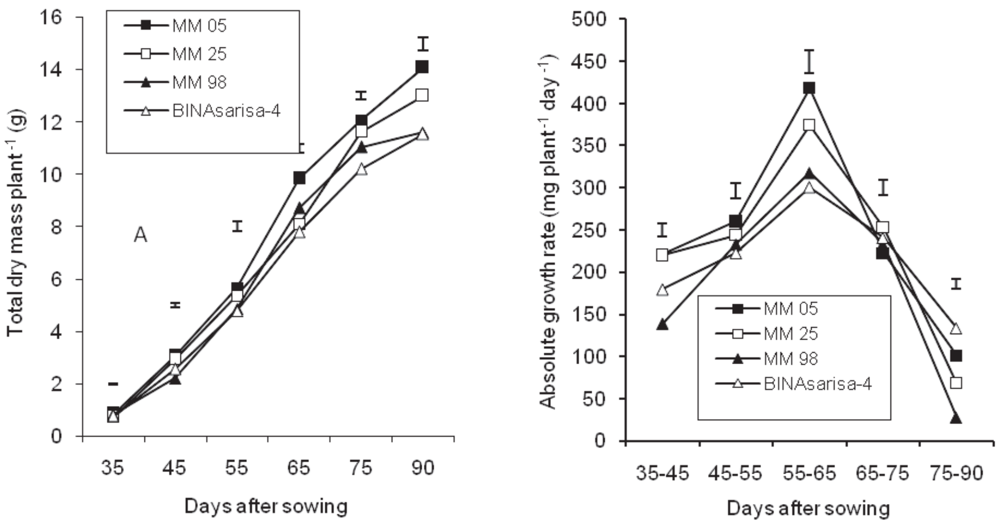

Fig. 2. Pattern of (A) total dry matter production and (B) absolute growth rate in four rapeseed mutants/variety during their growth period. Vartical bars represent LSD (0.05)

The AGR was increased till 65 DAS in all mutants/variety followed by a decline till physiological maturity (Fig. 2). The mutant MM 05 maintained the highest AGR value at 35-65 DAS. In contrast, Binasarisa-4 maintained the lower AGR at peak growth stages. The AGR was higher in MM 05 might be due to 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.* (1978). At 55-65 DAS, the AGR value was found to be maximum which mean that plants expanded it's 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*. (2012).

Reproductive characters

The effect of mutants/variety on reproductive characters such as number of aborted flowers plant^{-1}, number of siliquae plant^{-1} and reproductive efficiency (RE) was significant (Table 2). The highest number of aborted flowers plant^{-1} was observed in Binasarisa-4 (24.60) followed by MM 25 (24.43) and MM 98 (22.87) with same statistical rank. In contrast, MM 05 showed the lowest number of aborted flowers plant^{-1} (20.43). Results revealed that there was a relation between RE and seed yield in mustard. MM 05, the high yielding mutants showed the highest RE (76.4%) followed by MM 25 (70.5%), the second highest yielder mutant. In contrast, MM 98, the lowest yielder mutant, showed the lowest RE (68.7%). Genotypic variation in RE was also observed by Mondal and Malek (2018) in mustard that supported the present experimental result. The highest number of siliquae plant^{-1} was recorded in MM 05 (66.0) and this mutant also produced the highest seed yield plant^{-1} (2.88 g) (Table 2). The second highest siliquae plant^{-1} was recorded in MM 25 (58.4) that also produced the second highest seed yield (2.27 g plant^{-1}). This result indicates that siliqua production is the most yields attributes for getting higher seed yield. The mutant MM 98 produced the lowest number of siliquae plant^{-1} (50.2). Mondal *et al.* (2003) studied 20 mutants/varieties based on

Table 2. Variations in reproductive characters, yield attributes and seed yield in four rapeseed mutants along with check variety

Mutants/ variety	Aborted flowers plant^{-1} (no.)	RE (%)	Siliquae plant^{-1} (no.)	Siliquae length (cm)	Seeds siliquae^{-1} (no.)	1000-seed weight (g)	Seed weight. plant^{-1} (g)	Seed yield (kg ha^{-1})	Harvest index (%)
MM 05	20.4 b	76.4 a	66.0 a	6.27 a	23.1 a	3.78 a	2.88 a	2218 a	20.45 a
MM 25	24.4 a	70.5 b	58.4 b	6.13 a	22.4 ab	3.47 b	2.27 b	2067 ab	17.46 b
MM 98	22.9 ab	68.7 b	50.2 c	6.07 a	20.9 bc	3.28 b	1.72 d	1835 c	14.82 c
Binasarisa-4	24.6 a	69.4 b	55.8 bc	5.80 b	20.4 c	3.58 b	1.99 c	1911 bc	17.23 b
F-test	*	*	**	**	*	*	**	**	**
CV (%)	6.20	4.19	5.21	1.69	5.19	3.81	5.30	5.37	4.54

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; RE = Reproductive efficiency

yield attributes and yield and reported that high yielding mutants produced higher number of siliquae plant^{-1} that also supported the present experimental result.

The effect of mutants/variety on yield attributes and seed yield both per plant and per hectare was significant (Table 2). The highest seed yield both plant^{-1} (2.88 g) and hectare^{-1} (2218 kg) was observed in MM 05 because of production of higher number of siliquae plant^{-1}, seeds siliqua^{-1} and bolder seeds. The mutant MM 05 also showed the highest harvest index (20.45%). In contrast, the mutant MM 98 had the lowest HI (14.82%). The mutant MM 98 was a low yielding mutants and also showed lower HI which indicating that dry matter partitioning to economic was poor in MM 98 than the others while reverse trend was observed in MM 05, the high yielding mutant. In contrast, the lowest seed yield both plant^{-1} and hectare^{-1} was observed in MM 98 due to production of lowest number of siliqua plant^{-1} and smaller seed size.

Conclusion

Based on the experimental results, it may be concluded that high yielding mutants have taller plant, having higher number of branches, higher LA as well as LAI, TDM and AGR which resulted higher number of siliquae plant^{-1}, seeds siliqua^{-1} than the low yielding ones in rapeseed.

References

BBS (Bangladesh Bureau of Statistics). 2016. Hand book of Agricultural Statistics, December, 2015. Ministry of Planning, Govt. People's Repub. Bangladesh. p. 84.

Bhat, S. A., Khan, F. A. and Khan, M. I. 2006. Effect of nitrogen and phosphorus on growth, nutrient content, seed yield and quality of mustard. Indian J. Plant Physiol., 11 (3): 281-286.

Dubois, M., Gilles, K. A., Hamilton, J. K., Robers, P. A. and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem., 28: 350-356.

FAO (Food and Agriculture Organization). 2016. Production Year Book of 2015. No. 74. Published by FAO, Rome, Italy. P. 85.

Hunt, R. 1978. Plant growth analysis studies in biology. Edward Arnold Ltd., London. P. 67.

Malek, M. A., Mondal, M. M. A., Ismail, M. R., Rafii, M. Y. and Berahim, Z. 2012. Physiology of yield in soybean: Growth and dry matter production. African J. Biotech., 11: 7643-7649

Malek, M. A., Pramanik, M., Pramanik, M. H. R., Ismail, M. R., Rafii, M. Y., Puteh, A. B., Mondal, M. M. A. and Hasan, M. M. 2014. Evaluation and selection of rapeseed mutants for higher seed yield. J. Food Agric. Environ., 12 (1): 285-288

Mondal, M. M. A. and M. A. Malek. 2018. Role of morphological and reproductive characters on yield in mustard/rapeseed. Bangladesh J. Agril. Res., 43 (2): 361-368.

Mondal, M. M. A., Das, M. L., Malek, M. A. and Khalil, M. I. 2003. Performance of advanced generation rapeseed mutants under high and low input conditions. Bangladesh J. Agric. Sci., 30: 115-118.

Mondal, M. M. A**.,** Fakir, M. S. A., Islam, M. N. and Samad, M. A. 2011. Physiology of seed yield in mungbean: growth and dry matter production. Bangladesh J. Bot., 40 (2): 133-138.

Mondal, M. M. A., Malek, M. A. and Puteh A. B. 2015. Variation in morpho- physiological characters and yield components of summer mungbean varieties. Bangladesh J. Bot., 44 (3): 469-473.

Mondal, M. M. A., Puteh A. B., Kashem M. A., Haque, M. A. and Razzaque A. H. M. 2014. Growth and dry matter partitioning in plant parts of lentil. Legume Res., 37 (4): 434-438.

Mondal, M. M. A., Puteh, A. B, Malek, M. A., Ismail, M. R., Rafii, M. Y. and Latif, M. A. 2012. Seed yield in relation to growth and developmental aspects of mungbean. *The Scientific World Journal*, Vol. 2012: doi:10.1100/2012/425168

Mondal, M. M. A., Puteh, A. B., Malek, M. A., Roy, S. and Rafii, M. Y. 2013. Contribution of morpho-physiological attributes on yield in lentil. Australian J. Crop Sci., 7: 1167-1172.

Prasad, V. V. S., Pandey, R. K. and Saxena, M. C. 1978. Physiological analysis of yield variation in gram genotypes. Indian J. Plant Physiol., 21: 228-234.

Stewart, G, R. and Orebamjo, T. O. 1979. Some unusual characteristics of nitrate reduction in Erythrana senegalensis. New Physiol., 83: 311-319.

Yoshida, S., Forno, D. A., Cock, J. A. and Gomes, K. A. 1976. Laboratory manual for physiological studies of rice. 3rd ed., IRRI, Los Banos, Philippines.