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Yield performance of radiation induced rapeseed mutants at M_8 generation

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ABSTRACT

Rapeseed is the most potential oil seed crops of Indian sub-continent. So higher seed yield potential variety is central choice of rapeseed grower. To verify the yield performances of rapeseed mutants an experiment was conducted at various locations of Bangladesh. Four true breeding (homozygous) mutants obtain from three different radiation doses (600, 800 and 900 Gy) along with the mother variety BARI Sarisha-15 and check variety BARI Sarisha-17 were used for each condition. The experiment was laid out in a randomized complete block design with three replications. Interaction between genotype and location showed significant variations for all the agronomic traits, whereas only non-significant variations were provided from branch plant^{-1} and siliquae length for location. Mutant RM-20 produces the highest plant height (101.1cm) and matures earlier than all other mutants' parent and check. At Magura and Ishurdi all the mutants produce significantly higher number of siliquae plant^{-1} then parent BARI Sarisha-15 and check BARI Sarisha-17. RM-18 and RM-20 produce maximum seeds siliquae^{-1} (30) whereas the mutant RM-07 produced lowest number of seeds siliquae^{-1} (22). Combined means over locations showed that mutants namely RM-18 and RM-20 produced significantly higher seed yield (1551.1 and 1385 kg/ha, respectively). This suggests that gamma ray's irradiation can be fruitfully applied to develop mutants with higher seed yield and other agronomic traits in rapeseed.

Keywords: Rapeseed, mutants and yield.

INTRODUCTION: Oils and fats supply calories that help our body to absorb fat-soluble vitamins. The sources of fats and oils are vegetable oils, palm oils, industrial oils and animal oils. Vegetable oils are a group of fats that are derived from some cereal grains, and fruits. The major world sources of vegetable oils are soybeans, sunflowers, rapeseed, cotton, and peanuts. Rapeseed represents an economically significant oilseed crop belongs to genus Brassica. There are 37 species in the genus Brassica cultivated in different region of the world. The oil producing B. rapa and B, napus are commonly known as rapeseed, while *B. juncea* species is familiar as mustard. Rape seed and mustard ranks first among all oil crops grown in Bangladesh. About 78% of the total oil seed crops cultivated in Bangladesh is mustard. In Bangladesh, the average yield of rapeseed is 463.243kg/acre whereas world average is 836.36 kg/acre. Therefore, genetic improvement of yield potential is foremost breeding objective for fill up this gap. The primary gene pool of oil seed has a low genetic diversity (Bus *et al.*, 2011). Therefore, new genetic sources and approaches are needed to diversify the genetic basis of rapeseed germplasm, which will make the current breeding programs more effective (Delourme *et al.*, 2013). Mutation is the ultimate source of genetic variation, and it also creates a new DNA sequence for a particular gene, creating a new allele. It is an effective and simple method for obtaining valuable starting material that can further be used in crop improvement programs. Mutations can be induced by physical or chemical mutagens. Among physical mutagens, gamma rays are the most frequently used, accounting for 64% of the radiation-induced mutant varieties (Maluszynski *et al.*, 2000; Kim *et al.*, 2004; Jankowicz-Cieslak and Till, 2015). Induced mutation has been successfully used for the improvement of many crops including oilseed. More variability of rapeseed germplasms can be created via mutagenesis (Majidi *et al.*, 2015; Malek *et al.*, 2016; Amosova *et al.*, 2019).

OBJECTIVES: Seed yield is the most important character for considering as a promising variety of a particular crop. Yield is a complex quantitative character governed by large number of genes and is greatly affected by environmental fluctuations. Soil heterogeneity as well as meteorological factor of the specific region is the main catalyzed yield variation. Henceforth an attempt was made to estimates the yield performance of rapeseed mutant's (M_8) at various locations to find out the best one for large scale cultivation

ATERIALS AND METHODS: : Seeds of rapeseed variety BARI Sarisha-15 were irradiated with 600, 700, 800 and 900 Gy doses of gamma rays using Co^{60} gamma radiation to create genetic variations. Irradiated seeds were sown to grow M_1 generation at BINA, Mymensingh in 2013 for selecting desirable mutants in subsequent generations. Selection was made in each of M_2, M_3 and M_4 generation based on desired agronomic traits. From M_5 generation, two mutants namely RM-07 and RM-10 from 600 Gy, RM-18 from 800 Gy and another one mutant RM-20 from 900 Gy were selected for further evaluation. These four true breeding (homozygous) mutants along with the mother variety BARI Sarisha-15 were evaluated on preliminary yield trial and regional yield trial. Considering their agronomic performance four M_8 rapeseed mutants were put into this trial to assess their performance through on-station and on-farm trial. For on station trial the experiment was conducted at the experimental farms of BINA HQs farm, Mymensingh and BINA sub-station farms at Nalitabari, Ishurdi, Chapainowabgonj, Rangpur & Magura and also for on farm trials the experiment was conducted at farmer's field Mymenshing, Jamalpur, Rangpur, Nalitabari, Manikganj, & Magura. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown on 28th October 2019 to 3th November 2019. Unit plot size was $20m^2$ (5m X 4m) with 25cm line to line spacing and 6-8cm from plant to plant within line was maintained. Recommended production packages i.e., application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data were taken on morphological yield contributing characters such as plant height (avg. of 10 randomly selected representative plants), branches/plant (avg. of 10 randomly selected representative plants) and yield attributes like siliqua length (avg. of 10 randomly selected siliqua of 10 representative plants), siliqua/plant (avg. of 10 randomly selected representative plants) and seeds/siliqua (avg. of 10 randomly selected siliqua of 10 representative plants) and 1000 seed weight (from each experimental plot 1000 seed counted and weighted). All the data were collected from each plot at maturity. Maturity period was counted when approximately 70% siliqua of each plot turned into yellowish brown color. Plot seed yield was taken after proper drying of seeds. Seed yield was taken from all the experimental plots and converted into ton ha^{-1}.

The data were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done following the experimental design with the help of the computer package Statistix 10. 5% level of significance was used to compare mean differences among the treatments (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION: Analysis of variance indicated highly significant variations ($p \leq 0.01$) among the mutants and check for most of the studied characters in individual locations and combined over locations indicating the presence of sufficient amount of genetic variability (table1). The presence of variability is the prerequisite for any breeding program.

Souece of Variation	Df	MS (mean squares)						
		Days to maturity	Plant height (cm)	Branches Plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliquae Length (cm)	Seeds siliquae^{-1} (no.)	Seed yield (kg ha^{-1})
Genotype	5	106.2**	538.8**	1.3*	1263.9**	0.2*	376.7*	1280.6**
Location	11	349.8**	392.7**	21.0^{NS}	8859.4**	13.1^{NS}	800.0^{NS}	2762.8**
Genotype* Location	55	84.7**	44.6**	2.0*	394.7**	0.2*	57.6**	2367.6**

Table 1. Analysis of variance (mean squares) for M_8 generation of rapeseed mutants with genotype, environment and genotype X environments. *, ** Significant at 5% and 1% levels, respectively.

Mean squares for location were not significant for all the traits like branches plant^{-1}(no.), siliquae length (cm) and seeds siliquae^{-1}(no.). Mean must be significant when any one of the mean of component is significant. Seed yields, days to maturity, plant height and siliquae plant^{-1} provide significant variation for genotype, location and genotype and location interaction. Significant mean square of genotype indicates the influence of gene to the expression of the characters. There is no way to avoid the effect of location or environments on gene expression. Yield is the most important characters that controlled by many gene. Interaction of multiple gene as well as environment and agronomic practices directly influenced the yield. Significant mean square of yields is expectable for all case that indicates the presence of variation on treated materials. In rapeseed genotypes significant variations for yield have been reported by Mahmud *et al.* (2008) and Mondal *et al.* (2018).

Results of mean values of 12 individual locations and combined over locations for all the characters have been presented in table 2. Maturity period is the most important and frequent character which can be modified in oilseed using induced mutation. Significant differences were observed for days to maturity in different locations. In combined over locations, days to maturity varied from 86 to 90 days. Parent BARI Sarisha-15 and check variety BARI Sarisha-17 required shortest maturity period (86 days) having non-significant difference with each other's. Among the mutants RM-10 and RM-20 required the shortest period of 88 days to mature. While without BINA Headquarters' Farm Mymensingh, BINA sub-station Ishurdi and Chapainawabganj, the mother variety BARI Sarisha-15 took the highest maturity period. Mutant RM-20 required shortest maturity period of 78 days at Jamalpur substation and longest maturity period of 103 days at Ishurdi substation. Moreover RM-07 required the longest maturity period having significant difference with other mutants and check at all locations. At Ishurdi sub-station, BARI Sarisha-17 required the longest duration of 99 days to mature. So, in all locations mutants have significantly different maturity period than the mother and check variety. The high yielding ability of a variety depends upon some important plant characteristics; short stature is one of them. For plant height semi dwarf plant type is desire because they show somewhat resistance against not only lodging but also other yield increasing characters (Bhuiyan *et al.*, 2017).

Plant height may vary due to the genetic effects present among the genotypes as well as the proper agronomic management. A significant variation was observed in plant height. In combined over locations, plant height ranged from 92.1 cm to 101.1 cm. Mutation has strong effect on plant height. Mutant induced taller as well as shorter type plants. Mutant RM-20 produced highest plant height (101.1 cm) significantly higher than parent BARI Sarisha-15, whereas mutant RM-10 and RM-07 produced significantly shortest one. Plant height of BARI Sarisha-17, RM-07 and RM-10 was statistically similar and dwarf than other mutants and parent BARI Sarisha -15. Except BINA farm mutant RM-20 was tallest, while at farmer's field at Rangpur, both of RM-20 and BARI Sarisha-15 have statistically similar plant height. Mutant RM-10 showed tallest plant at farmer's field Rangpur. At farmer's field Rangpur, BARI Saridha-17 showed the shortest plant (96.3cm) followed by RM-10 and RM-07, whereas RM-07 showed shortest. In combined over locations, it was sharply reflecting that mutant RM-07 produced the shortest plant height than all other mutants and check variety. Influence of mutation on plant height also obtains by Mondal *et al.* (2018) and Channaoui *et al.* (2019).

Table 1: Mean performance of M_8 rapeseed mutants grown at different locations.

Locations	Mutants/ varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliquae length (cm)	Seeds siliquae^{-1} (no.)
BINA HQs Farm, Mymensingh	RM-07	91.0ab	92.0d	3.0b	104.0b	6.3ab	18.0c
	RM-10	91.0ab	99.6bc	3.0b	106.0a	6.5a	19.0bc
	RM-18	92.0a	96.4c	3.0b	93.0d	6.0b	26.0a
	RM-20	92.0a	99.2bc	4.0a	103.0b	6.0b	25.0ab
	BARI Sarisha-15 (P)	85.0b	101.6b	4.0a	94.0d	5.9b	19.0bc
	BARI Sarisha-17(CV)	84.0b	104.3a	3.0b	98.0c	6.0b	20.0b
Farner's Field Mymensingh	RM-07	92.0b	85.0e	3.0b	95.0b	5.6b	16.0c
	RM-10	80.0e	94.6ab	4.0a	85.0d	5.2d	17.0abc
	RM-18	94.0a	92.6c	3.0b	97.0a	5.8a	17.0bc
	RM-20	81.0de	97.3a	3.0b	89.0c	5.6b	18.0b
	BARI Sarisha-15 (P)	82.0d	92.2c	4.0a	94.0b	5.3cd	23.0ab
	BARI Sarisha-17(CV)	84.0c	89.4d	3.0b	84.0d	5.4c	24.0a
Farner's Field Manikganj	RM-07	95.0a	90.0d	2.0b	103.0ab	5.8b	18.0c
	RM-10	83.0e	99.6ab	3.0a	93.0b	5.4c	19.0abc
	RM-18	93.0b	97.6b	2.0b	105.0a	6.0a	19.0bc
	RM-20	84.0de	102.3a	2.0b	97.0c	5.5c	20.59d
	BARI Sarisha-15 (P)	85.0d	97.2b	3.0a	102.0b	5.5c	25.0ab
	BARI Sarisha-17(CV)	87.0c	94.4c	2.0b	92.0d	5.5c	26.0a
Ishurdi Sub-Station	RM-07	94.0c	94.6ab	7.0a	45.0c	4.0a	25.0a
	RM-10	91.0d	91.3b	4.0b	46.0c	4.0a	24.0b
	RM-18	91.0d	91.0b	6.0ab	81.0a	4.0a	22.0c
	RM-20	103.0a	103.3a	4.0b	60.0b	4.0a	28.0a
	BARI Sarisha-15 (P)	101.0ab	101.0ab	5.0ab	44.0c	4.0a	21.0c
	BARI Sarisha-17(CV)	99.0b	99.3ab	6.0ab	40.0c	4.0a	27.0a
Magura Sub-station	RM-07	81.0c	100.0b	3.0b	72.0b	4.0a	22.0c
	RM-10	90.0a	90.6d	3.0b	84.0a	4.0a	22.0b
	RM-18	82.0c	102.0ab	3.0b	74.0b	4.0a	44.0a
	RM-20	82.0c	105.0a	4.0a	72.0b	4.0a	42.0a
	BARI Sarisha-15 (P)	88.0b	95.0c	4.0a	55.0c	4.0a	26.0bc
	BARI Sarisha-17(CV)	88.0b	100.0b	4.0a	55.0c	4.0a	31.0b
Farmer's Filed Magura	RM-07	83.0c	97.0ab	3.0c	87.0bc	4.0a	40.0c
	RM-10	92.0a	90.6c	4.0b	96.0bc	4.0a	40.0c
	RM-18	84.0c	99.0a	5.0a	111.0ab	4.0a	51.0a
	RM-20	89.0bc	102.0a	4.0b	108.0b	4.0a	40.0c
	BARI Sarisha-15 (P)	91.0b	92.0bc	4.0b	121.0a	4.0a	44.0b
	BARI Sarisha-17(CV)	90.0b	97.0ab	3.0c	80.0c	4.0a	40.0c
Rangpur Sub-station	RM-07	85.0a	95.3bc	3.0c	82.0cd	3.0b	21.0c
	RM-10	83.0b	94.0bc	4.0b	91.0c	3.0b	30.0b
	RM-18	83.0a	103.0ab	4.0b	103.0b	3.0b	31.0b
	RM-20	83.0b	107.0a	5.0a	106.0b	4.0a	32.0ab
	BARI Sarisha-15 (P)	84.0ab	102.0abc	4.0b	116.0a	3.0b	21.0c
	BARI Sarisha-17(CV)	79.0c	93.0c	3.0c	75.0d	3.0b	35.0a
Farmer's Field Rangpur	RM-07	90.0a	98.0bc	3.0c	87.0cd	3.0b	22.0c
	RM-10	89.0ab	97.0bc	4.0b	96.0c	3.0b	31.0b
	RM-18	87.0b	110.0a	5.0a	111.0ab	4.0a	33.0ab
	RM-20	87.0b	106.6ab	4.0b	108.0b	4.0a	32.0ab
	BARI Sarisha-15 (P)	88.0ab	105.0abc	4.0b	121.0a	3.0b	22.0c
	BARI Sarisha-17(CV)	88.0ab	96.3c	3.0c	80.0d	3.0b	36.0a
Jamalpur Sub-statuio	RM-07	81.0a	84.5bc	2.0b	53.0a	7.0a	22.0c
	RM-10	80.0ab	86.3b	3.0ab	54.0a	6.0ab	22.0b
	RM-18	78.0b	91.2a	3.0ab	39.0bc	5.0c	44.0a
	RM-20	78.0b	92.2a	4.0a	46.0b	5.0c	42.0a
	BARI Sarisha-15 (P)	78.0b	84.87bc	4.0a	41.0bc	6.0ab	26.0bc
	BARI Sarisha-17(CV)	79.0ab	80.8c	3.0ab	33.0c	5.0c	31.0b
Chapai-nawabganj Sub-Station	RM-07	91.0ab	98.3bc	3.0c	87.0bc	3.0b	22.0d
	RM-10	91.0ab	97.0bc	4.0b	96.0bc	3.0b	31.0c
	RM-18	92.0a	106.6ab	5.0a	111.0ab	4.0a	33.0b

	RM-20	92.0a	110.3a	4.0b	108.0b	4.0a	32.0b
	BARI Sarisha-15 (P)	85.0b	105.0bbc	4.0b	121.0a	3.0b	22.0d
	BARI Sarisha-17(CV)	84.0b	96.3bc	3.0c	80.0c	3.0b	36.0a
Nalitabari Sub-Station	RM-07	96.0a	85.0c	4.0b	89.0a	5.0a	16.0c
	RM-10	94.0b	94.6ab	5.0a	79.0cd	5.0a	17.0abc
	RM-18	94.0b	92.6b	4.0b	91.3a	5.0a	17.0bc
	RM-20	90.0d	97.3a	4.0b	83.0c	4.0b	18.0abc
	BARI Sarisha-15 (P)	92.0c	92.2b	5.0a	88.0b	4.0b	23.0ab
	BARI Sarisha-17(CV)	88.0e	89.4bc	4.0b	78.0d	5.0a	24.0a
Farmer's Field Nalitabari	RM-07	95.0ab	85.7b	4.0ab	80.0a	6.0a	17.0c
	RM-10	93.0bc	85.3b	4.0ab	70.0b	5.b	21.0bc
	RM-18	94.0b	90.6a	3.0b	31.0d	4.0c	24.0b
	RM-20	94.0b	91.7a	5.0a	48.0c	5.0b	28.0a
	BARI Sarisha-15 (P)	92.0c	85.4b	4.0ab	39.0cd	5.0b	19.0bc
	BARI Sarisha-17(CV)	96.0a	79.7c	3.0b	31.0d	5.0b	24.0b

P=Parent and CV= Check variety. In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level

The number of branches is one of the important selection criteria for oilseed improvement programs. Higher number of branches enables bearing more siliquae per plant and result in higher seed yield. Lowest number of branches/plants was observed in farmer's field Manikganj and higher in BINA Sub-station Ishurdi. At Manikganj, mutant RM-07 produced the highest number of branches/plant (3.0) similar with BARI Sarisha-15. All other mutants including BARI Sarisha-17 produced the lowest number of branches plant^{-1}. At BINA Sub-station Ishurdi, mutant RM-7 produced the highest number of branches plant^{-1} (7) closely followed by RM-18 and BARI Sarisha-17. On an average number of branches plant^{-1} ranged from 3 to 5. Without RM-7 all other mutants produced similar as well as significantly higher number of branches than mother BARI Sarisha-15. The present results having different number of branch in the rapeseed mutants and other oilseed than the mother confirms the findings of Malek *et al.* (2016) and Bhuiyan *et al.* (2019).

A significant variation was found among the mutants and mother variety on the number of siliquae plant^{-1} in individual location and combination over locations. It is the most important agronomic character link with seed yield. Considering combined over locations, siliquae plant^{-1} ranged from 68 to 87. At BINA Sub-station farm Ishurdi and Magura, all the mutants produced significantly higher number of siliquae plant^{-1} than the parent BARI Sarisha-15 and check BARI Sarisha-17. At Magura, RM-07 produced the highest number of siliquae plant^{-1} (84) and the mother variety produced the lowest number (55). At Ishurdi, RM-18 produced the highest siliquae plant^{-1} (81) followed by RM-20. Significant differences were also observed for siliquae length in different locations. On an average, the mutant RM-07, produced significantly higher siliquae length than others. Mutants RM-10, RM-18 and RM-20 had equal siliquae length and the parent BARI Sarisha-15 was the shortest one. In oilseed Brassica, as a consequence of mutagenesis for siliquae plant^{-1} and siliquae length reported earlier by Malek *et al.* (2016) and Ali *et al.* (2016). Like siliquae plant^{-1} another important yield controlling trait is seeds siliquae^{-1}. Number of seeds siliquae^{-1} differ significantly both in individual locations and combined over locations. Mutant RM-07, RM-10 and BARI Sarisha-15 were formed double chamber whereas mutant RM-18, RM-20 and BARI Sarisha-17 were four chambered type siliquae. Double chambered type siliquae have been produced by the mutants RM-07, RM-10 and BARI Sarisha-15. Mutant RM-10 and BARI Sarisha-15 produced similar number of seeds siliquae^{-1}. Four chambered mutant RM-18 and RM-20 produced the highest number of seeds siliquae^{-1} (figure 1)

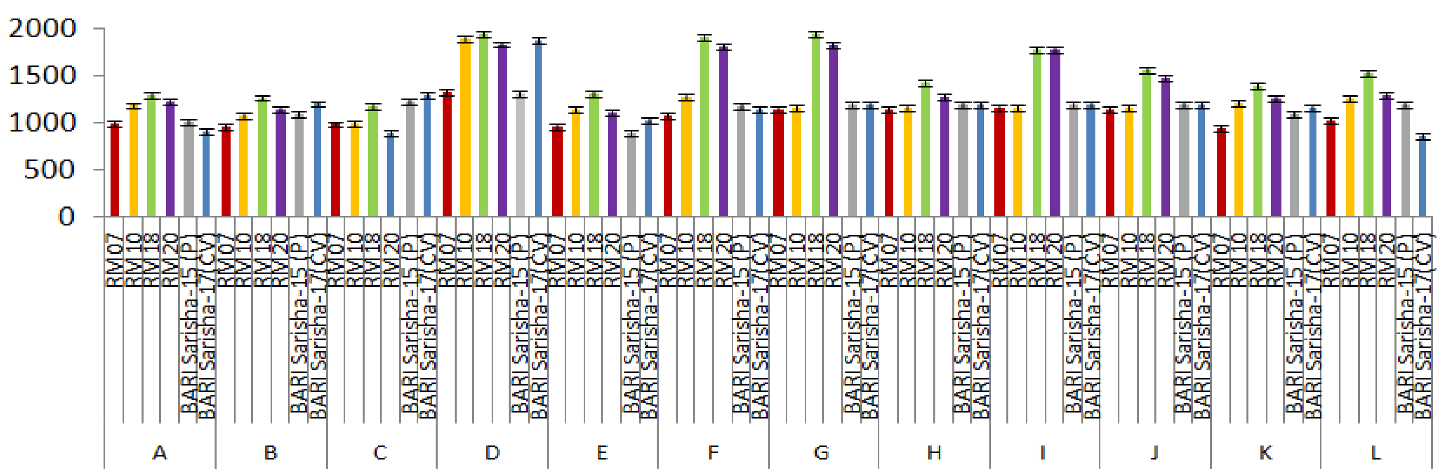

Figure 1: Yield performance of M_8 rapeseed mutants and varieties grown at different locations.
A=BINA Hqs farm, Mymensingh, B= Farmer's field Mymensingh, C= Manikganj, D= BINA sub-station Ishurdi, E= BINA sub-station Magura, F= Farmer's field Magura, G= BINA sub-station Rangpur, H = Farmer's field Rangpur, I= BINA sub-station Jamalpur, J = BINA sub-station Chapainowabgonj, K= BINA sub-station Nalitabari and L= Farmer's field Nalitabari.

Seed yield is the most important character for considering as a promising variety of a particular crop. The mutants RM-18 produced the highest seed yield of 1950 kg ha^{-1} at BINA Sub-station farm Rangpur, while RM-18 gave the lowest seed yield of 1175.0 kg/ha at Manikganj. Combined means over twelve locations (figure 2) showed that three mutants namely RM-10, RM-18 and RM-20 produced significantly higher seed yield (1224.5, 1551.1 and 1385 kg ha^{-1}, respectively) than mother variety BARI Sarisha-15 (1144.2 kg/ha). In location wise performance of yields, Magura showed the best performance followed by Chapainawabganj and Rangpur may be due to the environmental and soil characteristics of a particular location. Maximum seed yield of 1916.7 kg ha^{-1} was obtained from farmer's field at Magura (figure 3).

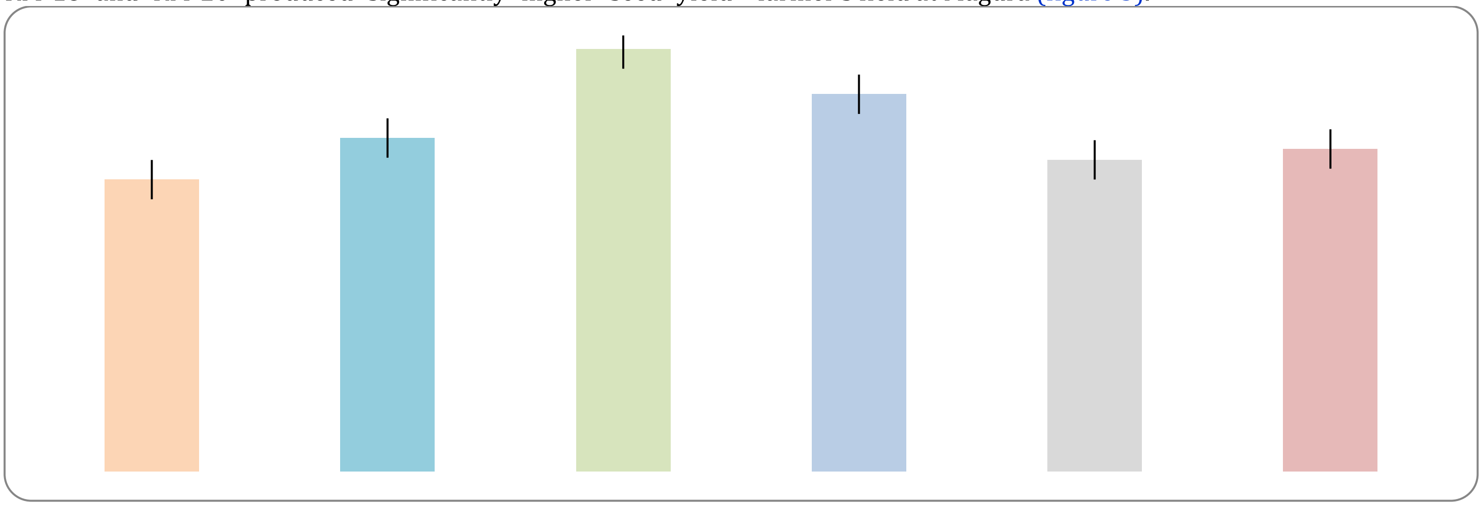

Figure: 2: Yield performance of rapeseed mutants and varieties based on combined means over locations

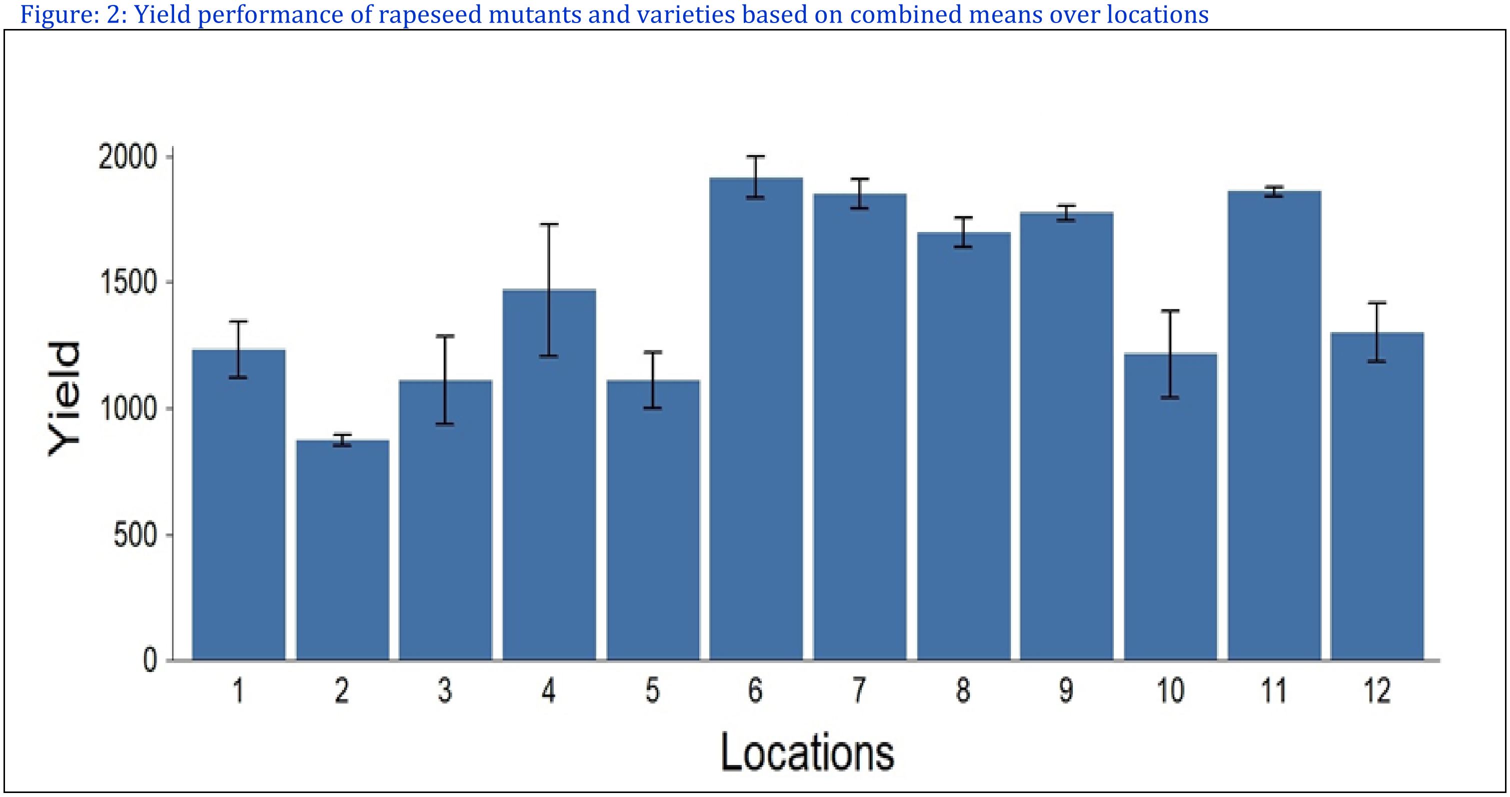

Figure 3: Location wise yield performance of rapeseed mutants and varieties.
1=BINA Hqs farm, Mymensingh, 2= Farmer's field Mymensingh, 3= Manikganj, 4= BINA sub-station Ishurdi, 5= BINA sub-station Magura ,6= Farmer's field Magura, 7= BINA sub-station Rangpur, 8 = Farmer's field Rangpur , 9= BINA sub-station Jamalpur, 10 = BINA sub-station Chapainowabgonj, 11= BINA sub-station Nalitabari and 12= Farmer's field Nalitabari.

Considering promising variety of a particular crop, seed yield is the most important trait. Rapeseed yield varies depending on the variety and favorable ecosyatems with proper agronomic management practices. In rapeseed-mustard and other oilseed mutants having higher seed yield over mother varieties also reported by Zhao *et al.* (2009), Ali *et al.* (2016) and Mondal and Bhuiyan *et al*. (2020).

Based on total planted area and yield, rapeseed and mustard are the most important oilseed crops Bangladesh's. In comparison to other oilseed-growing countries across the world, the current output of rapeseed-mustard (0.95 tha-1) is relatively low. By selecting high producing genotypes, there is a lot of room to increase production. We know that yield attribute characteristics like siliqua per plant and seeds per siliqua might improve seed yield. Various genotypes differ in their yield regulating characteristics which play an essential role in yields of mustard. Yield is a complicated characteristic that is influenced by polygenes and environmental factors. The mutants RM-18 and RM-20 provide maximum siliqua per plant and seeds per siliqua in respect of all location with combination mean of the genotypes. Majidi *et al*. (2015) found the number of siliqua per plant had the highest direct effect on seed yield that's is also reflect on the performance of RM-18 and RM-20.

CONCLUSION: For rapeseed the most important yield attributes responsible for the increased seed yield are the siliquae number and seed number in siliqua. It was observed that among the mutants and mother variety, mutants RM-18 and RM-20 performed better for seed yield and yield contributing characters which can be selected for further trials to be registered as varieties. Moreover, the performance of RM-18 and RM-20 was consistence over the environment and management practices. Location wise yield performance also influenced by the mean performance of RM-18 and RM-20. Due to their desirable performance at diversified environment these mutants could be served as breeding materials for further genetic improvement of different characters of the rapeseed also. Moreover, this finding suggests that gamma ray's irradiation can be fruitfully applied to induce mutants in rapeseed with higher seed yield and other improved agronomic traits.

CONFLICT OF INTEREST: Authors have no conflict of interest

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