Original research paper

Development of low erucic acid content rapeseed mutant variety BINA Sarisha12

Abstract

Any plant breeding program must have genetic variability, and mutagenesis is a proven method of creating new variability. Gamma irradiation was used to create novel genetic variability in rapeseed at different doses. Recently released new rapeseed (*Brassica napus*) mutant variety, BINA sarisha12 developed from popular variety Binasarisha-9 by gamma irradiation. Though Binasarisha-9 is a high yielding variety but duration is around 90 days and erucic acid content is 39.14%. For developing early maturing and low erucic acid content new variety, initially the seeds of Binasarisha-9 were exposed to different doses of gamma rays (550, 650, 750, 800 and 900 Gy) and M_1 was grown in 2013-14. Irradiated populations were evaluated in M_2, M_3 and M_4 generations during 2014-15, 2015-16 and 2016-17, respectively. Selected mutants carried out of various types of yield trial in 2017-18, 2018-19 and 2019-20 in experimental farms and in the farmers' fields also. Performance of selected three mutants, derived from 650 and 850 Gy of gamma rays (one from 650 and two from 850 Gy), were found to be superior to other mutant lines and mother variety Binasarisha-9. The mutant RM-005 grown in various places around the country following researcher and farmer's management practices during 2020-21 and 2021-22. Comparative assessment done in respect of seed yield, maturity period, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1} etc. Reactions to major disease (*Alternaria* blight), insect-pest (aphid) infestation and analyzing fatty acid profile also studied. Based on the superior performance of RM-005, like as, tolerant to *Alternaria* blight, showed the lower incidence of aphid infestation and low erucic acid content than the check

variety, National Seed Board of Bangladesh registered this mutant as an improved rapeseed variety named BINA sarisha12.

Keywords: Rapeseed, Gamma irradiation, Mutation breeding, Mutants, low erucic acid

Introduction

Estimation of variation in a crop species can assist in the evaluation of genetic transformation that can changes the gene pools to improve the performance of genotypes using mutation breeding. Selecting a breeding material with existing varieties or accessions and assessing the level of improvement within these genotypes is very important for plant breeders. Mutation breeding is one of the best choices of parent selection for specific trait related variety development. Mutation is one of the popular methods to create genetic variation (Acquaah, 2012; Malek et al., 2014; 2016; 2020; 2022, Khatun et al., 2024). Mutation is the ultimate source of genetic variation, and it also creates a new DNA sequence for a particular gene, creating a new allele. 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). Furthermore, to improve the germplasm, cultivar and varieties agronomically important traits, mutation breeding is priority needs. Rapeseed (*Brassica rapa var. toria; Brassica campestris; Brassica napus* and *Brassica juncea*) is the first of the six annual oilseed crops cultivated in Bangladesh, accounting for roughly highest oilseed production.

Breeding for *B. juncea* and *B. napus* cultivars that are more suitable and resistant to these stresses is therefore imperative. Brassica oilseed quality determined by the oil's enhanced fatty acid profile and the seed meal cake's low level of total glucosinolates (Pushpa et al. 2016). Brassica oil is widely used for cooking and its meal cake is a wealthy source of proteins and minerals as well as balanced amino acid and vitamin E for poultry and animal feed. In Bangladesh, majority of the farmer's cultivation practices of rapeseed-mustard is *B. rapa var. toria*, which exposes this species is various types of biotic and abiotic challenges and results in significant losses for the farmers. Pyramiding the responsive genes/QTLs individually or in combination created a good number of single and double zero genotypes, which were then used for developing high yielding varieties with low erucic acid and/or low glucosinolates (Singh et al. 2015). The European Food Safety Authority (EFSA) established a tolerable daily intake (TDI) for Erucic Acid of 7 mg/kg body weight in 2016. On this basis, the maximum Erucic Acid levels for vegetable oils allowed in the European Union have been reduced shortly from 50 to 20 g/kg, and for infant formula from 10 to 4 g/kg (Russo M et al. 2021). Current breeding practices largely based on field selection and that is ineffective. It would be more appropriate to use mutation-breeding technique to speed up the selection and creation of new, enhanced rapeseed-mustard genotypes. Monounsaturated fatty acids (oleic and erucic acid) and polyunsaturated fatty acids (linolenic and linoleic) form almost all of mustard oil. In general, 17–25% of proteins, 8–10% fibers, 6–10% moisture, and 10–12% extractable compounds are available in rapeseed–mustard seeds (Chaudhary et al. 2016).The development of a new variety with higher seed yield and quality oil content has an important role to fill the gap between oilseed production and population. Furthermore, plant's developmental stage and environmental conditions have an impact on the above said parameters. Actually, it is not only influenced by environmental influences or the stage for plant developing; the mutation breeding strategy appears to be more appropriate for accelerating the selection and development of new, improved varieties. There is various types of reports where found in this approach. Mutagenic treatments significantly influenced every attribute, and a wide range of variability with more pods per plant in comparison to control plants. Another finding in gamma-irradiated rapeseed produced the highest 1000-seed weight (Channaoui et al., 2019). For rapeseed, breeding program the present study obtained desirable traits improvement through mutation breeding.

Materials and methods

Initially the seeds of the variety were exposed to different doses of gamma rays (550, 650, 750, 800 and 900 Gy) using Co^{60} gamma source in mutation breeding laboratory at BINA, Mymensingh and M_1 was grown in 2013-14. During evaluation of the irradiated population in M_2 generation during 2014-15, a large number of variants were observed. Twenty-eight mutant lines were primarily selected in M_3 generation considering their better field performance including seed yield per plant and other important agronomic characters as compared to the mother variety in 2015-16. These mutant materials were grown in M_4 generations to study their breeding behaviour in respect of seed yield and yield contributing characters, and to select elite mutant lines during 2016-17.

Preliminary yield trial (PYT) was carried out with five selected mutant lines in the farm of BINA sub-stations at Ishurdi during 2017-18 and 2018-19. This study showed that performance of three mutants, derived from 650 and 850 Gy of gamma rays (one from 650 and two from 850 Gy), were found to be superior to other mutant lines and Binasarisha-9. Considering the superior performance of these mutants from these trials then Regional yield trials (RYT) were conducted with three selected mutants in the rapeseed growing areas of the country during 2019-20 in the BINA experimental farms and also in the farmers' fields following two management practices (research and farmers' managements).

On station and on farm yield trial were then conducted with selected mutant RM-005 in the rapeseed growing areas of the country during 2020-21 and 2021-22 in the BINA experimental farms and also in the farmers' fields following two management practices (research and farmers' managements). Mother variety, Binasarisha-9 was included in all the trials as check for comparative assessment in respect of seed yield, maturity period, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1} etc. Reactions to major disease (*Alternaria* blight) and insect-pest (aphid) infestation were also studied. The mutant line, RM-005 was found to be tolerant to *Alternaria* blight and also showed the lower incidence of aphid infestation than the check variety.

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

Results and Discussion

Gamma ray induced mutation techniques for varietal improvement of rapeseed-mustard (Malek et al., 2016; Malek et al., 2020, Bhuiyan et al., 2021) and other oilseed crops like soybean (Malek et al., 2022), sesame (Bhuiyan et al., 2019; Malek, 2020) is still underutilized in Bangladesh and many other countries in the world.

Observation trial during 2017-18

Thirteen true breeding M_5 mutant variants were put into observation trial (non-replicated) at BINA Hqs. farm, Mymensingh during 2017-18. Unit plot size was 8 m^2 (4 m × 2 m). Spacing between two rows was 25 cm and 6-8 cm between plants in a row. Seeds were sown on first week of November 2017. Recommended production practices were followed to ensure normal plant growth and development. Data on various characters, such as plant height, number of primary branches per plant, siliqua per plant and seeds per siliqua were taken from 10 randomly selected plants from each plot.

Among the mutant variants, 5 mutant lines were primarily selected to put them into preliminary yield trial on the basis of their maturity period, higher seed yield and desirable yield contributing characters.

Preliminary yield trial (PYT) with M_6 mustard mutants in 2018-19

Five M_6 rapeseed mutant lines along with mother variety Binasarisha-9 as check variety were put into PYT. The trial was conducted at the BINA sub-station farm at Ishurdi. The experiment was laid out in a randomized complete block design with three replicates. Seeds were sown on 05 November 2018. Unit plot size was 12 m^2 (4 m × 3 m) with 30 cm row to row spacing and 6-8 cm from plant to plant within rows. 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 on plant height, branches per plant, siliquae per plant and seeds per siliqua were taken from 10 randomly selected plants from each plot. Maturity period was measured when 70% siliquae were matured i. e., turned light brownish colour. Seed yield of each plot was recoded after harvest and finally, it was converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Result obtained from the trial for all the characters has been presented in **Table 1**. Significant variations were observed among the mutant lines and check variety for all the characters. Days to maturity varied from 82 days in MM-64 to 91 days in MM-93 and Binasarisha-4 required 89 days. MM-2 produced he tallest plant of 121 cm followed by MM-45 (105 cm), and MM-81 had the shortest plant height of 86 cm. Two mutants, RM-005 and RM-19 produced the highest number statistically similar number of Siliquae plant^{-1} (87 and 83, respectively) and seed yield (1817 and 1790 kg ha^{-1}). Mother variety Binasarisha-9 produced seed yield of 1708 kg ha^{-1} and 75 siliquae plant^{-1}.

Table 1. Means of promising M_6 mutants lines and check variety of rapeseed for different characters in preliminary yield trial

Mutants/ varieties	Plant height (cm)	Branches Plant^{-1} (no.)	Siliquae plant^{-1}	Seeds Siliqua^{-1} (no.)	Days to maturity	Seed yield (kg ha^{-1})
RM-02	102 a	5.0a	73d	27 NS	87a	1344f
RM-005	**95c**	**2.6b**	**87a**	**26**	**82c**	**1817a**
RM-14	91e	2.3c	71de	27	85b	1467e
RM-16	93d	2.3c	78c	24	87a	1543d
RM-19	**92de**	**2.3c**	**83b**	**26**	**85b**	**1790b**
Binasarisha-9	97b	1.9d	75cd	26	87a	1708c

Same letter(s) in a column do not differ significantly at 5% level.

Regional yield trial (RYT) with M_7 rapeseed mutants 2019-2020

Three rapeseed mutants along with mother variety Binasarisha-9 and check variety BARI Sarisha-14were evaluated to assess their overall performance for earliness and yield attributes. The trial was conducted at BINA HQ farm, Mymensingh and BINA sub-station farms at Ishurdi, Magura, Rangpur and Nalitabari. This experiment was laid out in a randomized complete block design with three replications. Seeds were sown within 5 to 15 November 2019. Unit plot size was 16m^2 (4m × 4m) and line to line spacing was 25cm. Recommended production packages i.e., application of fertilizers, weeding, thinning, etc. were followed to ensure normal plant growth and development. Data on plant height, branches plant^{-1}, siliquae plant^{-1} and seeds siliqua^{-1}were taken from 10 randomly selected plants from each plot. Maturity period was counted when 90% siliquae were matured in a plot. Seed yield of each plot was converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Results obtained from the trial of individual location and combined over locations for all the characters are presentedin Table 2. Significant variations were observed among the lines and check varieties for most of the characters in both of individual location and combined over locations. On an average, maturity period ranged from 85 to 91 days. All the mutants matured earlier than the mother variety Binasarisha-9. Mutant RM16 and Binasarisha-9 produced the tallest plant (109cm) followed by RM26 (108cm) which had statistically equal plant height. Among the mutants RM-005 was comparatively dwarf having 97 cm plant heights and produced the highest number of branches plant^{-1}(4) similar with Binasarisha-9 and BARI Sarisha-14. Among the mutants and checks, Binasarisha-9 produced the highest number of siliquae plant^{-1} (87) followed by RM-005 (83) and BARI sarisha-14 (82). Mutant RM-005 produced the highest seed yield (1822 kg ha^{-1}) compared among the mutants and its mother Binasarisha-9 (1632 kg ha^{-}

^{1}). Considering with seed yield and agronomic performances RM-005, RM16 and RM19 were selected as promising mutants for further trial.

Table 2. Mean performance of mutants and checks for different character

Locations	Mutants/ varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliquae^{-1} (no.)	1000 seed wt (gm)	Seed yield (kg ha^{-1})
BINA HQ, Mymensingh	RM-005	86b	102d	5.0a	73d	27c	4.50a	1844a
	RM16	89b	134a	3.0c	82c	21d	4.50a	1425c
	RM19	89b	116bc	4.0b	75d	30b	4.20b	1349d
	BNS-9	91a	122 b	4.0b	122a	28bc	4.40ab	1566b
	BRS-14	88b	115 c	3.0**c**	110b	33a	4.30ab	1526b
BINA sub-station, Ishurdi	RM-005	85c	102 d	3.0a	84a	22ab	2.87d	2186a
	RM16	86c	109 b	2.0b	55d	20b	4.40a	1553e
	RM19	86c	111 a	2.0b	65 b	21ab	3.17c	1623d
	BNS-9	91a	105 c	2.0b	54 d	27a	3.33bc	1970b
	BRS-14	88b	87 d	3.0a	58 c	22ab	3.60b	1739c
BINA sub-station,	RM-005	84c	103b	5.0a	105b	28a	2.97c	1900a

Magura								
	RM16	86b	109a	5.0a	76d	26b	3.60a	1300d
	RM19	86b	108a	4.0b	113a	20c	2.71d	1560c
	BNS-9	89a	108a	5.0a	95c	26b	2.57e	1700b
	BRS-14	84c	87c	4.0b	74d	25bc	3.53b	1570c
BINA sub-station, Rangpur	RM-005	84c	90c	4.0a	78b	26b	2.67c	1850a
	RM16	86b	98bc	3.0b	80 ab	25bc	4.43a	1527d
	RM19	86b	105 a	4.0a	66 d	25bc	2.79c	1563d
	BNS-9	92a	101 b	4.0a	71c	22c	3.32b	1770b
	BRS-14	86b	88 d	3.0b	83a	30a	3.37b	1613c
BINA sub-station, Nalitabari	RM-005	84b	88d	2.0c	76d	23b	3.60NS	1331a
	RM16	86b	96c	3.0b	96a	18d	3.41	1056c
	RM19	86b	101b	4.0a	66e	20c	3.89	1068c
	BNS-9	90a	108a	4.0a	91b	21bc	3.39	1156b
	BRS-14	86b	84d	3.0b	87c	26a	3.20	1092c
Combined means over locations	RM-005	85c	97b	4.0a	83b	25b	3.31c	1822a
	RM16	87b	109a	3.0b	78c	22c	4.07b	1372e

	RM19	87b	108a	3.0b	77c	23bc	3.35c	1433d
	BNS-9	91a	109a	4.0a	87a	24bc	3.41c	1632b
	BRS-14	86b	92c	4.0a	82b	27a	5.60a	1508c
Location means								
BINA HQ, Mymensingh		88a	118a	4.0a	93 a	27a	4.38 a	1542 d
BINA sub-station, Ishurdi		87b	103 b	2.0c	63 d	22c	3.47 b	1814 a
BINA sub-station, Magura		86c	103b	4.0a	93 a	25b	3.08 d	1606 c
BINA sub-station, Rangpur		87b	96 c	4.0a	75 c	25b	3.30 c	1665 b
BINA sub-station, Nalitabari		86c	95 c	3.0b	83 b	21cd	3.50 b	1141 e

N. B.: In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level. BNS-9 means Binasarisha-9 & BRS-14 means BARI Sarisha-14.

On-station and on-farm yield trial with one advanced M_8 rapeseed (*B. napus*) mutant 2020-21

One M_8 rapeseed mutant along with two check varieties Binasarisha-9 and BARI Sarisha-17 were evaluated through this trial. For on-station, the trial was conducted at BINA HQ farm, Mymensingh and BINA sub-station farms at Rangpur, Ishurdi, Magura, Gopalganj and Jamalpur. For on-farm trial, the same experiment was conducted at the farmer’s field at Tangail, Manikgonj, Ishurdi, Gopalgonj and Nalitabari. The experiment was laid out in a RCB design with three replications. Seeds were sown within 1 to 15 November 2020. Unit plot size was $20m^2$

(5m × 4m) and line to line was 25cm. Recommended production packages i.e., application of fertilizers, weeding, thinning etc. were followed to ensure normal plant growth and development. Data on plant height, branches plant^{-1}, siliquae plant^{-1}, and seeds siliqua^{-1}were taken from 10 randomly selected plants from each plot. Maturity period was counted when 90% siliquae were matured in a plot. Seed yield of each plot was recorded after harvest and converted into kg ha^{-1}. Results obtained from the trials of individual location and combined over locations for all the characters are presented in **table 3**. Significant variations were observed among the mutant and check varieties for most of the characters in both of individual location and combined over eleven locations. RM-005 required 86 days to mature whereas the check variety BARI Sarisha-17 was 85 days and Binasarisha-9 took 92 days to mature. Binasarisha-9 produced the highest plant height of 107cm followed by RM-005 (104cm) and check BARI Sarisha-17 produced the shortest plant height of 99cm. Number of branches plant^{-1} varied from location to location due to environmental effects. RM-005 produced the highest number of siliquae plant^{-1} (86) followed by Binasarisha-9 (80), and BARI Sarisha-17 produced the lowest number of siliquae plant^{-1} (75). Furthermore, parental check variety Binasarisha-9 produced the highest number of 28 seeds siliquea^{-1}. Mutant RM-005 produced the highest seed yield of 1788 kg ha^{-1} and check variety BARI Sarisha-17 produced only 1602 kg ha^{-1} seed yield, whereas the parental check variety Binasarisha-9 produced 1703 kg ha^{-1}. Among the locations, yield performance was better at Magura and Ishurdi (2144 kg ha^{-1} and 2017 kg ha^{-1}, respectively).

Table 3. On-station & on-farm trial with advanced M_8 rapeseed mutants

Locations	Mutant & check varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliquae^{-1} (no.)	1000 seed wt (gm)	Seed yield (kg ha^{-1})
BINA HQ, Mymensingh	RM-005	84b	103b	4.0b	92c	33a	3.40b	1674a
	BNS-9	87a	119a	4.0b	122a	27b	3.65a	1526b
	BRS-17	81c	98c	5.0a	96b	26b	2.94c	1477c
Farmer's field, Tangail	RM-005	87ab	100b	4.0a	55a	29b	4.20 ^{NS}	1883a
	BNS-9	89a	108a	4.0a	42c	37a	4.40	1800b
	BRS-17	86b	93c	3.0b	49b	26c	4.30	1792c
Farmer's field, Manikganj	RM-005	83c	96b	3.0b	72a	25c	3.82a	1823a
	BNS-9	96a	86c	4.0a	48b	28b	3.73b	1721b
	BRS-17	86b	106a	4.0a	41c	34a	3.67c	1714b
BINA sub-station, Magura	RM-005	91b	116b	4.0b	80b	29 ^{NS}	2.83b	2251a
	BNS-9	94a	120a	5.0a	62c	29	2.99a	2133b
	BRS-17	85c	94c	4.0b	92a	28	2.52c	2051c
BINA sub-	RM-	88b	103a	4.0a	73a	27a	3.21c	2105a

station, Ishurdi	005							
	BNS-9	90a	100b	3.0b	58b	25b	3.79a	2017b
	BRS-17	84c	89c	3.0b	75a	25b	3.33b	1931c
Farmer's field,Ishurdi	RM-005	87b	102c	5.0a	42c	36a	4.99a	1573a
	BNS-9	92a	128a	3.0c	64b	30b	2.90b	1466b
	BRS-17	85c	112b	4.0b	75a	29b	5.00a	1242c
BINA sub-station, Rangpur	RM-005	86b	94a	4.0 NS	95	33a	4.20a	1408a
	BNS-9	94a	91b	4.0	101a	22b	3.37c	1393b
	BRS-17	85b	89c	4.0	86c	24b	3.50b	1380b
BINA sub-station, Gopalganj	RM-005	85b	115a	8.0a	130a	29	3.45a	1671a
	BNS-9	94a	115a	7.0b	128b	29	3.37b	1642a
	BRS-17	84b	103b	8.0a	104c	29NS	3.38b	1554b
Farmer's field, Gopalganj	RM-005	88b	128b	9.0b	124a	30b	3.23c	1768a
	BNS-9	96a	127b	8.0c	105b	43a	3.42a	1696b
	BRS-17	87b	130a	10.0a	79c	29c	3.38b	1487c
BINA sub-station, Jamalpur	RM-005	86c	95b	5.0 NS	45c	30b	4.60a	1575a
	BNS-9	93a	105a	5.0	49b	43a	2.03c	1513a
	BRS-17	88b	93c	5.0	56a	30b	4.39b	1300b

Farmer's field, Nalitabari	RM-005	85c	100a	4.0 NS	143a	23b	4.22c	1937a
	BNS-9	92a	85c	4.0	106b	22b	4.60a	1826b
	BRS-17	87b	89b	4.0	73c	32a	4.55b	1703c
Combined means over locations	RM-005	86a	104b	4.9NS	86a	27ab	3.8a	1788a
	BNS-9	92b	107a	4.6	80b	28a	3.4b	1703b
	BRS-17	85a	99c	4.9	75c	26b	3.7a	1602c
Location means								
BINA HQ, Mymensingh		84e	97d	3.0d	103c	26 d	3.44d	1559f
Farmer's field,Tangail		87d	110c	4.0c	49g	10e	2.78e	1825c
Farmer's field, Manikganj		88c	91e	4.0c	54g	26d	3.68c	1753d
BINA sub-station, Magura		90a	106cd	4.0c	78e	29c	3.33d	2144a
BINA sub-station, Ishurdi		87d	111c	8.0a	69f	29c	3.40d	2017b
Farmer's field, Ishurdi		88c	98d	5.0b	63f	34a	3.67c	1427g
BINA sub-station, Rangpur		88c	114b	4.0c	94d	32b	4.29b	1394h
BINA sub-station, Gopalganj		87d	100c	3.0d	126a	31bc	4.30b	1622e
Farmer's field,Gopalganj		90a	96d	4.0c	115b	29c	3.73c	1650e

BINA sub-station, Jamalpur	89b	129a	8.0a	54g	34a	3.34d	1463g
Farmer’s field, Nalitabari	88c	91e	4.0c	107c	26d	4.5a	1822c

N. B.: In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level. BNS-9 means Binasarisha-9 & BRS-17 means BARI Sarisha-17.

On-station and on-farm yield trial with one advanced M_9 rapeseed (*B. napus*) mutant 2021-22

One M_9 rapeseed mutants along with two check varieties Binasarisha-9 and BARI Sarisha-14 were evaluated through this trial. For on-station, the trial was conducted at BINA HQ farm, Mymensingh and BINA sub-station farms at Rangpur, Gopalganj and Magura. For on-farm trial, the same experiment was conducted at the farmers’ field at Mymenshingh, Ishurdi, Magura and Manikgonj. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown within 1 to 15 November 2021. Unit plot size was $20m^2$ (5m × 4m) and line to line was 25cm. Recommended production packages i.e., application of fertilizers, irrigation and pesticide, weeding, thinning etc. were followed to ensure normal plant growth and development. Data on plant height, branches plant^{-1}, siliquae plant^{-1}, siliqua length and seeds siliqua^{-1}were taken from 10 randomly selected plants from each plot. Maturity period was counted when 90% siliquae were matured in a plot. Seed yield of each plot was recorded after harvest and converted into kg ha^{-1}. Appropriate statistical analysis was performed for comparison of means of each character.

Results obtained from the trial of individual location and combined over locations for all the characters are presented in **table 4**. Significant variations were observed among the mutant and check varieties for most of the characters in both of individual location and combined over eight locations. On an average, mutant RM-005 matured earlier than both check varieties. RM-005 required 84 days to mature which is statistically similar with BARI Sarisha-17 (85 days) and Binasarisha-9 took 92 days to mature. Binasarisha-9 produced the highest plant height of 111cm followed by BARI Sarisha-17 (102cm) and mutant RM-005 produced the shortest plant height of 87cm. Mutation has strong effect on plant height. Mutant induced taller as well as shorter type plants. Influence of mutation on plant height also obtains by Mondal et al. (2018) and Channaoui et al. (2019). Number of branch plant^{-1} varied from location to location due to environmental effects. RM-005 produced the highest number of siliquae plant^{-1} (145.0) followed by Binasarisha-9 (113) and BARI Sarisha-17 produced the lowest number of 87. 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).

Table 4: Mean of M_9 rapeseed mutants and check variety for different characters

Locations	Mutant/ checks	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliqua length (cm)	Seeds siliquae^{-1} (no.)	Seed yield (kg ha^{-1})
BINA HQ, Mymensingh	RM-005	81c	77c	5.0a	137.0a	6.6a	28.0c	2400a
	BNS-9	87a	110a	4.0b	83.0b	7.0a	26.0b	2204b
	BRS-17	84b	89b	4.0b	69.0c	4.2b	33.0a	1665c
Farner's field Mymensingh	RM-005	86b	82c	5.0a	145.0a	6.6b	33.0b	2650a
	BNS-9	89a	115a	4.0b	91.0b	7.1a	31.0c	2454b

	BRS-17	87b	94b	4.0b	77.0c	4.2c	38.0a	1915c
Farner's field Manikganj	RM-005	83c	92c	5.0a	130.0a	6.6b	35.0b	2850a
	BNS-9	96a	125a	4.0b	96.0b	7.1a	33.0c	2654b
	BRS-17	86b	104b	4.0b	82.0c	4.3c	38.0a	2115c
Magura sub-station	RM-005	85c	89c	5.0b	155.0a	6.4a	40.0a	1883a
	BNS-9	94a	113a	4.0b	152.0a	5.9b	34.0c	1717b
	BRS-17	91b	102b	8.0a	121.0b	3.5c	36.0b	1683c
Farmer's field Magura	RM-005	85b	88c	4.0b	167.0a	4.9a	43.0a	2650a
	BNS-9	89a	116a	4.0b	144.0b	4.7b	33.0b	2550b
	BRS-17	83c	110b	7.0a	119.0c	6.8a	30.0b	2634b
Rangpur sub-station	RM-005	86b	87c	4.0b	143.0a	6.3a	32.0b	2830a
	BNS-9	94a	93b	5.0a	89.0b	4.1c	32.0b	1150c
	BRS-17	85b	120a	3.0c	75.0c	3.9b	37.0a	2193c
Farmer's field Rangpur	RM-005	88b	87c	4.0b	143.0a	6.3b	32.0b	2230a
	BNS-9	96a	120a	5.0a	89.0b	6.8a	30.0c	1834b
	BRS-17	87b	105b	3.0c	87.0b	4.9c	36.0a	1481c
Gopalganj sub-station	RM-005	85b	89b	5.0a	155.0a	6.4a	40.0a	2830a

	BNS-9	94a	93a	5.0a	143.0b	6.3a	32.0b	1717b
	BRS-17	84b	89b	4.0b	69.0c	4.2b	33.0b	1665c
Combined means over locations	RM-005	84c	87c	5.0a	145.0a	6.1a	33.0b	2541a
	BNS-9	92a	111a	4.0b	113.0b	6.5a	32.0b	2221b
	BRS-17	85b	102b	5.0a	87.0c	4.1b	35.0a	1733c
Location means								
BINA HQ farm, Mymensingh		84c	92c	4.0b	96.0c	5.9ab	29.0c	2090c
Farmer’s field Mymensingh		87b	97bc	4.0b	104.0bc	5.9ab	34.0ab	2340b
Farmer’s field Manikganj		88ab	107a	4.0b	102.0c	6.0a	35.0ab	2540a
Magura sub-station		90a	101b	5.0a	142.0c	5.2bc	36.0a	1761d
Farmer’s field Magura		85bc	105ab	5.0a	143.0c	4.5c	36.0a	2117bc
Rangpur sub-station		88ab	100b	4.0b	109.0bc	5.6b	33.0ab	2553a
Farmer’s field Rangpur		90a	104ab	4.0b	106.0bc	6.0a	32.0b	1849cd
Gopalganj sub-station		87b	90c	4.0b	122.0b	5.6b	35.0ab	2071c

N. B.: In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level. BNS-9 means Binasarisha-9 and BRS-17 means BARI Sarisha-17

Length of siliquae ranged from 4.1 to 6.5cm. Check variety BARI Sarisha-17 produced the highest number of 35 seeds siliquea^{-1} whereas the mutant and parental check Binasarisha-9 produce statistically similar number of seeds siliquae^{-1} (32 and 33, respectively). Finally, RM-005 produced the highest seed yield of 2541 kg ha^{-1} and check variety BARI Sarisha-17 produced only 1733 kg ha^{-1} seed yield, which was statistically and significantly lower than (2221 kg ha^{-1}). Positively increase in seed yield of rapeseed-mustard due to the effect of gamma-rays induction was also reported earlier by many researchers likes Malek et al., 2012; Begum & Dasgupta, 2015; Malek, 2020. Mutant RM-005 matured earlier than both check varieties. Considering seed yield and maturity period RM-005 can be considered for registration as a new variety. Among the locations, yield performance was better at Rangpur and Manikgonj districts (2553 and 2540 kg ha^{-1}, respectively). Moreover, the development of mutant variety BINA sarisha12 indicated the potentiality of having higher seed yielding variant with low erucic acid content through induce mutation.

Conclusion

The newly release mutant variety "BINA sarisha12" has been developed from Binasarisha-9. The erucic acid content of Binasarisha-9 is 39.14% but the erucic acid content of BINA sarisha12 is 26%. This result revealed that induced mutations can be extensively and successfully used for the improvement of rapeseed-mustard in respect of seed yield and fatty acid content like erucic acid. The mutant also showed lower incidence of insect-pests infestation. This can be considered as a milestone achievement in mutation breeding. There is an opportunity to increase cultivable land under rapeseed-mustard cultivation which can mitigate the challenges of increasing demand of edible oil in Bangladesh. This can be considered as a milestone achievement in mutation breeding.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript. ACKNOWLEDGEMENT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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