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BINAMORICH-1: A HIGH YIELDING MUTANT VARIETY OF CHILI USE AS SPICES, SALAD AND VEGETABLES

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Abstract

With a view to develop a high yielding mutant variety of chili, 1000 seeds of the local landrace of china with low yield but highly to most of the pest and disease were irradiated with (75 Gy, 150 Gy and 300 Gy) gamma rays in 2012 at seibersdorf laboratory, Vienna, Austria. At maturity, all M_1 plants were harvested and seeds were kept separately. During M_2 and M_3 generations, selection was conducted following high mean and high/low variances compared to the check. In M_4 and M_5 generations, comparative yield assessment was done in several locationsviz; Mymensingh, Ishwardi, Magura,Rangpur, Bogura, Khagrachari, Cumilla and farmer's field in rabi season.Five true breeding lines were selected in a preliminary yield trial at M_5 generation, based on plant height, number of fruits, fruit length, fruit diameter, average single fruit weight and fruit yield. Based on the same criteria, in an advance yield trial, these mutant lines were further evaluated. Of these five mutant lines, chili$D_{75}P_1$ produced the highest average yield with higher fruit length and diameter than the parent line and check variety, found in both, farmer's field and on-station trials. This chili$D_{75}P_1$ has been registered as high yielding variety of chili (Binamorich-1) for commercial cultivation by National Seed Board of Bangladesh (NSB) in 2017.

Keywords: chili, gamma irradiation, mutant variety, yield

Introduction

Chili is a valuable spice and also one of the most important cash crops grown in Bangladesh. It is available and used in the form of green, dried and powdered. It has become an essential ingredient in Bangladeshi meals. Most of our households always keep a stack of fresh hot green chilies at hand, and use them to flavor most curries and dry dishes. It is typically lightly fried with oil in the initial stages of preparation of the dish. It has diversified uses like meat, fish, vegetables, pulses etc. for its typical color, taste and flavor. Red chilies contain large amounts of vitamin-C and small amounts of carotene (pro-vitamin A). Green chilies (unripe fruit) contain a considerably lower amount of both substances. In addition, peppers are a good source of most vitamin-B and vitamin-B6 in particular. They are very high in potassium, magnesium and iron.

Mutagenesis has been widely applied in the development of new breeding materials with novel characteristics as well as in studies of functional genomics in important crops(Roychowdhury and Tah, 2013).It is one of the important techniques to mainstream plant breeding. With this technique, 15-20% yield improvement and correction of the defects

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to a top cultivar are very easy and straight forward (Gaul, 1961). Gamma radiation, a type of electromagnetic radiation produced by the decay of radioisotopes such as cobalt-60 and cesium-137, has been the most commonly used mutagen among ionizing radiation for at last the past forty years owing to its wide availability and versatility in application (Oladosu*et al.,* 2015).Pleotropic effects are very common and help fix the breeding lines even in M1 generation (Azad *et al.,* 2013a). Genetic improvement of any yield attribute either qualitative or quantitative in nature has been successful with this technique (Azad *et al.,* 2012 and Azad *et al.,* 2013b). So far, 3,246 crop varieties worldwide have been released through this technique that also includes some varieties of chilies (IAEA, 2017).

Various strategies to increase chili genetic variability can be pursued by such as seed introduction, hybridization, and mutation. Mutation seems more preferable than the other two since seed introduction sometimes may function as a media of transferring seed borne diseases, while hybridization will not be effective if there is no resistant gene available. Furthermore, conventional breeding by hybridization usually takes longer, yet sometimes also carries unexpected traits. This may result in an output that is not as good as expected as a commercial variety. Mutation is one of possible alternatives to conventional breeding for crop improvement program (Soeranto, 2011). Mutation is a sudden heritable change in an organism and generally induces structural and composition changes in genome, chromosome, gene, or DNA (Soeranto*et al.,* 2001; Dhanavel*et al.,* 2012). Exposing plant genetic material (seed, pollen, rhizome, callus, etc.) to mutagens enhances the chance for isolating unique genetic material. Induced mutation can rapidly create the variability of inherited traits in crops, both quantitatively and qualitatively (Muduli and Misra, 2007). Post inducedmutation has been effectively utilized in developing new and valuable alternation in plant characteristics that have contributed to increase yield potential or disease resistance. One of physical mutagens in mutation breeding is gamma rays. Gamma rays irradiation is an efficient tool to produce mutants in crop breeding. In breeding program, this approach has not only contributed several crop varieties to national agriculture, but also generated hundreds of promising mutant lines that are ready for further multi-location trials. However, it is noted that no work on desired, high yielding, pest resistant chili mutant development has been carried out yet. In order to improve yield and yield related characteristics induced mutation breeding programmes through gamma rays of chili were undertaken for creation of variability and selection for improved mutant lines.

Materials and Methods

The chili seeds were irradiated with 75 Gy, 150 Gy and 300Gy doses of gamma rays from a ^{60}Co source and sprouted seeds were sown dose wise at Seibersdorf Laboratory glasshouse, IAEA, Vienna in 2012. Seedlings were transplanted in a tray bed of 3 m×1 m at a distance of 40 cm within rows of 50 cm apart. At maturity, the plants that produced fertile seeds were harvested and kept separately plant and dose-wise. Seeds of M_2 populations and the parent variety were sprouted and sown. The seedlings were transplanted after 35 days at a distance of 40 cm within rows of 50 cm apart following non replicated plant-progeny-rows. Fertilizers were applied at the rate of N 110 kg, K 70 kg, P 50 kg, S 20 kg, Zn 1.0 kg and B

1.0 kg/ha in the form of Urea, Muriate of Potash (MoP), Triple Super Phosphate (TSP), Zypsum, Zinc Oxide and Boric Acid together with 10 tons/ha of farm yard manure (FYM). At maturity, seeds were harvested population wise and kept separately. Seeds of M_3 population were sown Seibersdorf Laboratory glass house, IAEA, Vienna and the seedlings were transplanted in 2014 after 35 days following non replicated plant-progeny-rows. Fertilizers and FYM were applied as applied in M_2 generation. At maturity, M_4seeds were harvested population wise and kept separately.In M_4 the 28 mutants were evaluated for high yield potential, crop duration and other agronomic characters and five plants per mutant were evaluated. A total of 12 superior mutants for high yield with good features were selected and advanced to M_5 for further trial during rabi season 2015-16 at BINA HQs farm at Mymensingh. In $M_{5,}$ some of the mutants exhibiting morphological variation and poor performing compared to parent were rejected and ended up with five mutants. These five mutants along with the parent (check) were further evaluated for high yield and other agronomic and quality traits to advance preliminary yield trial and advanced yield trial.

Preliminary yield trial

This experiment was carried out with five M_5 mutant lineswith a check variety of BARI morich-1 at BINA HQs Farm,Mymensingh Sutiakhali farm, BINA sub-stationCumilla, Khagrachari and Magura experimental field during 2015-2016, following Randomized Completely Block design with three replications with spacing 50cm × 40cm. A unit plot size was 3m × 1m. Fertilizers were applied following the Fertilizer Recommendation Guide (BARC, 2005) during final land preparation. Recommended production packages with cultural and intercultural operations were followed to ensure normal plant growth and development. Data on various characters, such as plant height, fruit length, fruit diameter, number of fruit, fruit yield and average fruit weight were taken from each mutants.

Advanced yield trial

This experiment was carried out with five M_6 mutant lines with a check variety of BARI morich-1 at BINA HQ Farm and farmers' field Mymensingh, Cumilla, Khagrachari and Magura during 2016-2017. Randomized Complete Block design with three replications was followed. A unit plot size was 3m × 1m. In all following yield trials, spacing, fertilizer doses, cultural and intercultural operations, and data collection methods were the same. Finally, all the recorded data underwent proper statistical analysis following Gomez and Gomez (1984) and are presented in Table 1 and Table 2.

Results and Discussion

Chili varieties/genotypes showed a good response to radiation with gamma rays. In M_1gamma rays influenced germination, seedling height, survival of plants and pollen fertility/sterility, producing deleterious effects on these characters. Moreover, studies on quantitative characters including total yield revealed the induction of mutants in both positive and negative directions for such traits which made a good scope of selection of desirable mutants in M_2 generation. Mutants selected in M_2 were raised in M_3 in plant to progeny rows and further selection was made. Compared to the M_2 generation, the range of family means became narrower in M_3 which indicated the effectiveness of selection in the M_2. True breeding lines isolated in M_3 generation have given potentially higher yield and yield attributing characters in a preliminary yield trial in M_5 compared to parents. Five promising mutant lines were evaluated in M_5 and M_6 generations for yield and other agronomic parameters at various locations of Bangladesh under variable environments. Mutants ChiliD$_{75}$P$_1$ have produced significantly the highest yield at all locations with other yield parameters.

Performances of the selected mutants and check variety on yieldand yield attributingcharacters revealed significant variations for most of the characters in preliminary yield trial (Table 1). Among the mutants and control variety, performance of ChiliD$_{75}$P$_1$ was found to be promising regarding yield and yield attributing characters. Results of preliminary yield trial during rabi 2015-16 showed that ChiliD$_{75}$P$_1$ produced the highest fruit length, average fruit^{-1}, yield plant^{-1} and total yield (t ha^{-1}).

Table 1. Yield and yield contributing characters of M_5 mutants of Chili during Rabi, 2015-16 at HQs Farm, Sutiakhali, Mymensingh, Sub-station Farm, Cumilla, Khagrachari and Magura

Mutant/Variety	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average weight (g fruit^{-1})	Fruit yield (g plant^{-1})	Fruit yield (t ha^{-1})
BINA HQs Farm, Mymensingh							
ChiliD$_{75}$P$_1$	54.5	63.5	14.55	5.58	13.29	725.7	34.74
ChiliD$_{75}$P$_2$	53.7	45.1	11.80	5.13	11.08	682.0	27.28
ChiliD$_{150}$P$_5$	46.6	41.8	11.60	4.63	11.02	583.8	26.84
ChiliD$_{150}$P$_8$	44.5	36.5	12.17	4.91	10.87	511.7	23.23
ChiliD$_{300}$P$_9$	37.7	30.9	12.57	5.14	9.30	484.0	21.87
BARI Morich-1	51.5	114.3	6.50	2.82	1.60	178.0	12.00
LSD$_{0.05}$	2.26	1.53	0.54	0.10	0.59	12.91	0.83
CV	2.78	3.16	2.54	1.18	3.19	0.77	1.84
Sutiakhali, Mymensingh							
ChiliD$_{75}$P$_1$	53.2	60.3	13.94	5.49	13.14	678.90	33.95
ChiliD$_{75}$P$_2$	51.3	44.3	11.34	5.12	11.02	632.04	26.17
ChiliD$_{150}$P$_5$	46.5	39.5	11.42	4.82	10.94	570.08	25.02
ChiliD$_{150}$P$_8$	43.1	35.8	12.33	4.78	13.04	494.36	23.04
ChiliD$_{300}$P$_9$	38.6	30.4	12.64	5.04	10.95	471.15	22.10
BARI Morich-1	48.2	106.7	6.35	2.94	1.65	182.25	11.90
LSD$_{0.05}$	2.13	1.64	0.48	0.08	0.54	2.80	0.76
CV	3.14	3.54	2.79	1.31	3.35	1.02	2.04
BINA sub-station,Cumilla							
ChiliD$_{75}$P$_1$	51.5	62.8	14.06	5.55	14.20	705.46	33.26
ChiliD$_{75}$P$_2$	48.4	45.3	12.00	5.17	12.31	661.58	26.00
ChiliD$_{150}$P$_5$	51.3	42.6	11.66	5.02	11.89	602.55	24.92
ChiliD$_{150}$P$_8$	42.2	38.2	12.47	4.85	12.68	524.67	23.45
ChiliD$_{300}$P$_9$	41.7	32.7	12.65	5.08	11.12	468.54	22.04
BARI Morich-1	50.2	110.5	6.51	3.03	1.73	188.55	11.28
LSD$_{0.05}$	3.05	1.57	0.43	0.12	0.62	2.71	0.64
CV	3.48	3.76	2.94	1.92	3.87	1.48	2.48

Table 1. Continued

Mutant/Variety	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average weight (g fruit^{-1})	Fruit yield (g plant^{-1})	Fruit yield (t ha^{-1})
BINA Sub-station,Khagrachari							
ChiliD$_{75}$P$_1$	49.9	60.4	13.96	5.42	14.27	695.75	32.55
ChiliD$_{75}$P$_2$	47.2	48.2	12.07	5.06	12.26	645.07	25.92
ChiliD$_{150}$P$_5$	46.6	44.7	11.52	4.89	11.83	597.80	24.24
ChiliD$_{150}$P$_8$	46.9	37.4	12.86	4.74	12.22	512.73	22.56
ChiliD$_{300}$P$_9$	42.3	33.6	13.05	5.02	11.39	451.00	21.58
BARI Morich-1	48.0	108.8	6.39	3.12	1.68	175.00	11.07
LSD$_{0.05}$	2.83	1.52	0.39	0.08	0.57	2.57	0.53
CV	3.79	3.81	3.10	2.07	3.95	1.93	2.71
BINA Sub-station,Magura							
ChiliD$_{75}$P$_1$	52.8	65.3	14.03	5.89	13.04	702.29	33.32
ChiliD$_{75}$P$_2$	47.5	49.8	12.38	5.56	12.12	662.38	26.96
ChiliD$_{150}$P$_5$	52.3	42.1	11.32	5.23	11.31	593.46	25.02
ChiliD$_{150}$P$_8$	52.8	38.6	12.81	5.56	11.08	518.25	24.42
ChiliD$_{300}$P$_9$	47.9	32.3	12.92	5.64	12.08	466.78	22.02
BARI Morich-1	48.3	105.7	6.23	3.14	1.62	181.12	12.42
LSD$_{0.05}$	2.79	1.47	0.33	0.12	0.52	2.48	0.48
CV	3.92	4.04	3.29	2.32	4.07	2.02	2.92

Maximum plant height was scored from ChiliD$_{75}$P$_1$ (54.5 cm) and minimum from ChiliD$_{300}$P$_9$ (37.7 cm) at HQs Farm, Mymensingh. At Magura sub-station, the highest plant height was recorded from ChiliD$_{75}$P$_1$ (52.5 cm) whereas the lowest from ChiliD$_{75}$P$_2$ mutantwhich is statistically similar with ChiliD$_{300}$P$_9$ mutant.An increased plant height may increase the branches and leaves number of plant. There was a significant variation in height of Capsicum plants obtained by Hosmani (1982). High phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) were found for plant height obtained by Mini and Khader (2004). The result indicates that the highest number of fruits (114.3 plant^{-1}) was obtained from the check variety BARI Morich-1 and the second highest (63.5) from mutant ChiliD$_{75}$P$_1$while ChiliD$_{300}$P$_9$ (30.9) attained the lowest number of fruits plant^{-1} at BINA HQs Farm. Obidiebube*et al.* (2012) found similar result i.e. significant variation from one mutant to another in number of fruits of chili.

Though mutant ChiliD$_{75}$P$_1$ gave lower number of fruits plant^{-1} compared to check variety but its single fruit weight is higher compared to check, as a result total yield is the highest than the other mutants and check variety. The longest fruit length (14.55 cm) was recorded from ChiliD$_{75}$P$_1$ mutantwhile BARI Morich-1 gave the smallest fruit (6.50) at BINA HQs Farm, Mymensingh. Similar results were observed in all other locations at preliminary yield trial during 2015-16. Fruit diameter of six mutants and check variety were ranged from 5.58 cm to 2.82 cm. The mature fruits of ChiliD$_{75}$P$_1$ mutantshowed maximum fruit diameter (5.58 cm) and minimum (2.82 cm) were recorded fromcheck variety BARI Morich-1 (Table 1). Smitha and Basavaraja (2006) observed significant differences among the chili mutants in respect of fruit length.Significant variations in yield plant^{-1}as well as total yield (t ha^{-1}) were noticed among the mutants in preliminary yield trial. The highest yield plant^{-1} (725.75 g) and total yield (34.74 t ha^{-1}) were recorded fromChiliD$_{75}$P$_{1}$ mutant at BINA HQs Farm while the lowest yield (178.2 g plant^{-1}) and total yield (11.07 t ha^{-1}) were noted from the check variety BARI Morich-1 at BINA substation Khagrachari farm (Table 1). More or less similar results were observed at all the locations.

Results of advanced yield trial during 2016-17 showed that one mutant line performed better regarding fruit length, diameter as well as yield attributes than the control variety with the similarities of previous year result. ChiliD$_{75}$P$_{1}$ mutant produced the highest yield (34.86 t ha^{-1}) followed by ChiliD$_{75}$P$_{2}$ mutant (27.89 t ha^{-1}) and ChiliD$_{75}$P$_{5}$ mutant (26.04 t ha^{-1}) at BINA HQ farm, Mymensingh. It was also observed that all the high yielding mutants performed better above average for most of the morphological characters and yield attributes. Results of advanced yield trial at farmers fields of different areas of Bangladesh showed that ChiliD$_{75}$P$_{1}$ mutantproduced better plant height (55.7 cm), acceptable number of fruits plant^{-1} (64.2), the longest fruit (14.67 cm), the highest fruit diameter (5.65 cm), the highest single fruit weight (15.56 g), the highest yield plant^{-1} (770.56 g) as well as total yield (34.86 t ha^{-1}) than the other mutants and check variety (Table 2). Differences found in different plant parameters among the mutant population and control variety attributed to the effect of mutagenic radiations that can directly cause DNA double-strand breaks, and then prevent plant growth or make it slow. The reduction of growth rate with increase in dose of irradiation may interrupt cell division as a result of DNA mutation that DNA synthesizes at the interphase. A little variation was observed in yield and yield attributing characteristics among the mutant lines and control variety within locations, and also in years, and this phenomenon is attributed to the prevailing environmental factors. The incidence of anthracnose, wilting and mosaic diseases, and insect (thrips and aphid) infestation were also studied in different locations under field conditions (data not presented). ChiliD$_{75}$P$_{1}$ mutant was found to be tolerant to anthracnose, wilting and mosaic diseases and also showed lower infestation by insects. Overall infestation caused by leaf feeder insects like aphid and thrips were lower in ChiliD$_{75}$P$_{1}$ mutant compared to the check variety.

Main distinguishing characteristics of ChiliD$_{75}$P$_{1}$ mutant (new variety Binamorich-1) which makes the variety different from other varieties:

- High yielding, yield is two folds higher compared to traditional varieties
- Used as a spice, salad and also vegetables
- Low pungency but very much succulent and scented
- Fruit length and diameter is high (10-14 cm and 3-5 cm, respectively)
- Profusely branched and bushy type plant
- Yield plant^{-1} (650-730 g) and yield (30-34 t ha^{-1})

Table 2. Advanced yield trial of M_6 mutants of Chili during Rabi, 2016-17 at HQ Farm, Mymensingh, farmers field of Mymensingh, Cumilla, Khagrachari and Magura

Mutant/Variety	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average weight (g fruit^{-1})	Fruit yield (g plant^{-1})	Fruit yield (t ha^{-1})
BINA HQs Farm, Mymensingh							
Chili$D_{75}P_1$	55.7	64.2	14.67	5.65	15.56	770.56	34.86
Chili$D_{75}P_2$	51.2	46.6	11.94	5.21	13.26	697.04	27.89
Chili$D_{150}P_5$	47.6	42.4	12.04	4.82	14.53	622.80	26.04
Chili$D_{150}P_8$	44.4	38.9	12.28	5.02	14.56	532.73	23.54
Chili$D_{300}P_9$	41.2	33.2	12.76	5.19	12.23	481.00	22.53
BARI Morich-1	48.1	118.2	6.58	2.95	1.86	185.00	13.02
$LSD_{0.05}$	2.71	1.31	0.27	0.11	0.47	2.04	0.35
CV	4.12	4.12	3.53	2.65	4.34	2.57	3.41
Farmers field, Sutiakhali, Mymensingh							
Chili$D_{75}P_1$	52.5	60.2	13.76	5.48	14.63	689.52	31.59
Chili$D_{75}P_2$	50.9	46.1	11.63	5.15	13.02	618.23	24.57
Chili$D_{150}P_5$	46.6	40.5	11.74	4.66	13.92	593.46	25.73
Chili$D_{150}P_8$	42.2	38.6	12.12	4.82	14.15	480.65	26.46
Chili$D_{300}P_9$	40.1	31.4	12.23	5.05	12.05	409.98	21.58
BARI Morich-1	49.4	100.5	6.26	2.91	1.86	192.08	10.40
$LSD_{0.05}$	2.50	1.23	0.19	0.09	0.35	1.91	0.28
CV	4.42	4.55	3.80	2.90	4.60	3.78	3.90
Farmers field, Cumilla							
Chili$D_{75}P_1$	50.9	56.9	13.28	5.27	14.46	670.09	32.32
Chili$D_{75}P_2$	48.7	45.8	11.46	5.13	13.12	625.23	25.76
Chili$D_{150}P_5$	44.6	40.6	11.44	4.72	12.56	558.08	24.15
Chili$D_{150}P_8$	42.4	38.7	12.06	4.78	13.77	487.74	24.64
Chili$D_{300}P_9$	40.5	33.2	12.24	4.97	12.16	407.12	22.05
BARI Morich-1	49.3	103.5	6.21	2.90	1.83	195.56	11.39
$LSD_{0.05}$	2.56	1.20	0.16	0.07	0.30	1.82	0.22
CV	4.52	4.80	3.78	3.15	4.52	3.90	4.12
Farmers field, Khagrachari							
Chili$D_{75}P_1$	52.9	53.4	13.89	5.42	14.70	692.04	32.92
Chili$D_{75}P_2$	47.1	48.6	11.45	5.18	13.56	630.16	26.06
Chili$D_{150}P_5$	45.8	42.7	11.63	4.84	13.08	565.52	24.40
Chili$D_{150}P_8$	43.2	38.3	12.45	4.92	13.73	496.65	25.00
Chili$D_{300}P_9$	40.7	32.5	12.64	5.02	12.32	423.12	22.24
BARI Morich-1	48.4	108.1	6.56	3.02	1.92	204.00	12.02
$LSD_{0.05}$	2.40	1.09	0.17	0.13	0.34	1.09	0.18
CV	3.48	5.20	4.24	3.54	4.10	3.45	4.00
Farmers field, Magura							
Chili$D_{75}P_1$	54.1	56.6	14.08	5.54	14.94	701.21	33.40
Chili$D_{75}P_2$	49.3	48.5	11.45	5.15	13.45	628.05	26.13
Chili$D_{150}P_5$	47.2	40.1	11.77	4.83	13.78	536.56	24.62
Chili$D_{150}P_8$	44.9	37.7	12.49	5.00	12.84	503.14	24.97
Chili$D_{300}P_9$	42.5	31.2	12.32	5.15	11.43	442.02	22.41
BARI Morich-1	48.7	110.9	6.74	3.10	1.72	201.52	12.25
$LSD_{0.05}$	2.04	1.00	0.20	0.10	0.30	1.02	0.12
CV	3.12	4.65	4.04	4.16	3.91	3.78	4.18

Conclusion

The effective mutations for higher yield and yield attributing characteristics along with better plant morphology could be induced in winter chili by gamma irradiation dose range of 75Gy-300 Gy. The most spectacular result of this study is almost all the induced mutant lines, in M1 to M6 generations, produced better yield while the parent and check variety produced lower yield. In rabi season, the mutant line Chili$D_{75}P_1$ had significantly higher yield attributes than the parent and check variety BARI Morich-1. Due to higher yield, Chili$D_{75}P_1$ was found suitable for selection and registration. BINA applied to the National Seed Board of Bangladesh (NSB) for registration of Chili$D_{75}P_1$. Consequently, the NSB registered Chili$D_{75}P_1$ in 2017 as a new chili mutant variety, Binamorich-1 for commercial cultivation in Bangladesh.

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