Bangladesh J. Pl. Breed. Genet., 30(1): 39-47, 2017

BULB AND SEED YIELD POTENTIALS OF SUMMER ONION VARIETY DEVELOPED THROUGH INDUCED MUTATION

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Abstract

With a view to improve bulb and seed yield potentials of summer onion, seeds of BARI Piaz-2 were irradiated with 75 Gy, 100 Gy and 125 Gy doses of gamma rays from a ^{60}Co source in 2006.Fifty four days old seedlings were transplanted on 20 January 2007.Thirteen, 12 and 9 M_1 plants, respectively, from 75 Gy, 100 Gy and 125 Gy dosesproduced fertile seeds which were kept separately dose wise. In M_2 generation, seedlings of 13 progenies from 75 Gy, 10 from 100 Gy and 7 from 125 Gy were transplanted on 15 December 2008 in plant- progeny- rows and 11, 7 and 6, respectively, were selected based on higher percentage of seed producing plants compare to parent BARI Piaz-2.In $M_3$and M4 generations, 13 progenies, 6 each from 75 Gy and 100 Gy and the other from 125 Gy were further selected based on higher seed yield than the parent. Additionally, in M_3 generation, observation trial with the above 13 mutant lines for bulb yield potential in Kharif-I seasonin 2011 revealed the mutant lines BP_2/75/5 and BP_2/100/2 had significantly higher fresh and dry bulb yield than BARI Piaz-2 and that of BP_2/75/2 had not differed significantly. Shelf life expressed here as rate of weight loss on storage for 2.0 months under ambient condition exhibited all the 13 mutants had longer shelf life than the parent and the check variety. The mutant BP2/100/2 had the longest shelf life followed by BP2/125/1 and BP2/100/12 and BP2/75/13. Preliminary yield trial for seed yield potential in M4 generation in winter season of 2011-2012 showed all the 13 mutant lines could produce seed from seed in the same season but the parent BARI Piaz-2 failed. In advance yield trial for bulb yield potential in Kharif-II season of 2012, the mutants BP_2/75/2, BP_2/75/5 and BP_2/100/2 produced significantly higher bulb yields atIshurdi and Magura than the check variety BARI Piaz-3.Unlike Kharif-I season the shelf life of the bulbs of mutants and the check variety did not differ significantly in Kharif-II although yield was almost double. Advance yield trial for seed yield potentialsin 2012-13 of five selected mutants showed all the mutant lines produced sufficient seeds from seed in the same season like preliminary yield trial. Seed production of the mutants ranged from 798-1193 kg/ha with the highest being in BP_2/75/3 followed by BP2/75/2 while the parent BARI Piaz-2 produced the lowest seed yield of all.

Keywords: Summer onion; mutation; shelf life; seed yield.

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important and major spices crop here in Bangladesh. It is used in all food preparations of our daily diet. The crop is also appreciated as condiments for flavouring foods. It contains high medicinal properties with adequate vitamin B, Vitamin C, iron and calcium (Vohora *et al.*, 1974) and reduces the blood sugar by 25% (Mossa, 1985; Yawalkar, 1985). In Bangladesh, among the spices, onion ranks first in respect of area and production (BBS, 2016). The average yield here is very low (3.94 t/ha) compared to the world average (12.27 t/ha) (FAO, 2002).Total production of onion in Bangladesh is only 1.7million tons from an area of 0.17 million hectares (BBS, 2016) as against the estimated demand of 2.2million tons. Of the total production 0.4-0.5 million tons become spoiled due to short storage ability of the existing varieties. This means to meet the demand we have to produce 0.5-0.6million tons or more onion. This could be possible in two ways, by increasing per unit yield or by bringing more area under onion cultivation. Bringing more area under onion cultivation in winter is difficult although there is scope in the summer season. The existing summer varieties in Bangladesh have low bulb and seed yield potentials and shelf life as well. Moreover, presently, onion seed is produced from bulb by planting in the month of October, which requires nearly 1.5 to 2.0 tons of bulbs to plant a hectare of land. This big amount of bulb is sufficient to meet the annual requirement of 42-56 families of Bangladesh. Additionally, it is very difficult to store such large amount of bulb for a long period from harvesting till planting in the next season. In contrast, production of seed from seed will require only 8-10 kg of seed for the same area of land.

Mutation breeding technique is one of the important accessories to mainstream plant breeding. With this technique, 15-20% yield improvement and correction of the defects to a top cultivar are very easy and straight forward (Gaul, 1961). Pleotropic effects are very common and help fix the breeding lines even in M_1 generation (Azad *et al.*, 2013a). Genetic improvement of any yield attribute either qualitative or quantitative in nature have been successful with this technique (Azad *et al.*, 2012; Azad *et al.*, 2013b; Azad *et al.*, 2010; Hamid *et al.*, 2006; Azad and Hamid, 2000; Chowdhury *et al.*, 2000; Shamsuzzaman *et al.*, 2005; Shamsuzzaman *et al.*, 2004; Shamsuzzaman *et al.*, 2000; Azad *et al.*, 1999; Shamsuzzaman *et al.*, 1998). So far, 3,246 crop varieties worldwide have been released through this technique that also includes some varieties of onion (IAEA, 2017; Maluszynski *et al.*, 2000; Kataria and Singh 1989). Therefore, the objectives of this study were to develop high bulb and seed yielding summer onion mutant(s) which can produce seed from seed in the same year and longer shelf life through induced mutation.

MATERIALS AND METHODS

Irradiation of seeds and growing of M_1 generation

The seeds of BARI Piaz-2 were irradiated with 75 Gy, 100 Gy and 125 Gy doses of gamma rays from a ^{60}Co source and sprouted seeds were sown dose wise at BINA Head Quarter's farm at Mymensingh on 28 November, 2007. Seedlings were transplanted on 20 January 2008 dose wise in a raised bed of 3 m×1 m at a distance of 20 cm within rows of 30 cm apart. At maturity, the plants that produced fertile seeds were harvested in April-May and kept separately plant and dose-wise.

M_2. Seeds of 31M_2populations and the parent variety were sprouted and sown on 23 October, 2008. The seedlings were transplanted after 54 days on 15 December at a distance of 20 cm within rows of 30 cm apart in a raised bed at BINA Sub-station farm, Ishurdi following non replicated plant-progeny-rows. Fertilizers were applied for seed production at the rate of N 115 kg, K 75 kg, P 55 kg, S 20 kg, Zn 1.0 kg and B 0.85kg/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.

M_3. Seeds of 24 M_3 populations were sown at BINA Head Quarter's farm, Mymensingh and the seedlings were transplantedon7 December 2009 after 55 days at BINA Sub-station farm, Ishurdi following non replicated plant-progeny-rows at a distance of 20 cm within the rows of 30 cm apart. Fertilizers and FYM were applied as applied in M_2 generation. At maturity, seeds were harvested population wise and kept separately.

M_4. For M_4 seed production, seeds of 13 M_3 mutants were sown on 7 Ocotober 2010 at BINA, HQ farm Mymensingh and the seedlings were transplanted on 24 November at the same location with unit plot sizes ranged 2 to 12 rows of 1.5 m length. At maturity, seeds were harvested mutant wise and kept separately.

Preliminary yield trial for bulb yield potential in Kharif-I season

Preliminary yield trial in Kharif-I seasonwas also performed with the above mentioned 13 M_4 mutant lines to assess bulb yield potential in Karif-I season.Seeds were sown on 6 January 2011 at BINA Head Quarter's farm, Mymensingh. Seedlings were transplanted on 7 March 2011 at BINA sub-station farm, Ishurdi following RCB Design.The parent BARI Piaz-2 and a check variety BARI Piaz-3 were included in this experiment. A unit plot size was 2.4 m × 0.6 m. Plants were spaced at 15 cm within rows of 20 cm apart. Fertilizers were applied for bulb production at the rate of N 69 kg, K 87 kg, P 40 kg, S 20 kg and Zn 1.0 kg/ha in the form of Urea, MoP, TSP, Zypsum, Zinc Oxide and Boric Acid together with 10 tons/ha of FYM. Data on individual weight of fresh and dry bulbs were recorded during harvest from randomly selected 10 competitive plants. Fresh and dry weights of bulb were also recorded plot basis at harvest and after two months of storage under ambient condition.

Preliminary yield trial for M_5seed yield potential in winter season

Seeds of 13 M_5 mutants together with the parent BARI Piaz-2 were sown on 26 October 2011 at BINA Head Quarter's farm, Mymensingh and seedlings were transplanted on 19 December 2011 at BINA sub-station farm, Ishurdi following non-replicated design. Unit plot sizes ranged 2 to 34 rows of 1.5 m length. Plants were spaced at 15 cm within rows of 20 cm apart. Fertilizers and FYM were applied as applied in M_3 generation. Number of plants, flowering plants, seed yield/ plant was recorded during and after harvest. Seed yield/plot was later converted to seed yield/ha.

Advance yield trial for bulb yield potential in Kharif-II season

Seeds of five mutants were sown on 5 July 2012 at BINA Head Quarter's farm, Mymensingh. Seedlings were transplanted on 25 August 2012 at Ishurdi and 26 August at Magura sub-station farms, BINA. A unit plot size was 1.8 m× 0.6 m for both locations. Plants were spaced at 15 cm within rows of 20 cm apart. Fertilizers were applied as applied in preliminary yield trial for bulb yield potential in Kharif-I season. Data on number of leaves at vegetative stage and bulb diameter were recorded from randomly selected ten competitive plants. Fresh and dry bulb weight was recorded at harvest. Dry bulb weight was recorded after 1.5-2.0 months of harvest.

Advanced yield trial for M_6 seed yield potential in winter season (Production of M_6 seeds)

Seeds of five mutants along with their parent were sown on 26 October at Ishurdi sub-station farm, BINA following non- replicated design and transplanted on 22 December 2012. A unit plot size was 2.0 m × 1.8 m. Fertilizers and FYM were applied as in above experiments for seed production. Data on seed yield/plot were recorded and total number of plant, number of plant with seed, umbel/plant, fruits/umbel, umbel diameter, seeds/fruit, seeds/umbel seed yield/plot were recorded during and after harvest. Seed yield/plot was later converted to seed yield/ha. Finally, all the recorded data in all experiments were subjected to proper statistical analysis following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

In M_1 generation 13 plants from 75 Gy, 10 plants from 100 Gy and 8 plants from 125 Gy irradiated seeds produced fertile seeds. Among these 31 M1 plants had considerably higher percentage of flowering plants than the parent BARI Piaz-2 in M_2 generation. In M_3 and M_4 generations, similar results were observed. It is generally and widely accepted that onion produces bulb in the first year and these bulb when planted in the second year produces seed. Moreover, for seed production, onion plants need verbalization at low temperature (8-10 ºC) for one month or more (Khokhar, 2014). But in this study, the mutated M_1 plants, $M_2$and other populations of the onward generations produced seed from seed directly in the same season. On the other hand the parent variety BARI Piaz-2 could not produce any seed or negligible amount of seeds (Fig.1). This might be due to the predicted segmental homology of the chromosomes of mutants due to duplication by irradiation which might ensure regular meiosis and regular seed production (Chakraborty, 2011 and Hoque, 2011) observed longer chromosome length of the mutants than the parent BARI Piaz-2 apart from increased DNA contents by 1.5 to 3.0 fold.

Table 1. Bulb yield and related traits of 13 mutant lines of summer onion during summer season of 2011 at Ishurdi

Mutant lines/ varieties	Individual fresh bulb weight (g)	Individual dry bulb weight (g)	Rate of weight loss (%)	Fresh bulb weight of (kg/ha)	Dry bulb weight (kg/ha)
BP_2/75/2	12.23	10.85	11.28	2468.12	2193.68
BP_2/75/3	10.00	9.20	8.00	1616.88	1479.79
BP_2/75/5	10.79	10.00	7.32	2622.78	2435.90
BP_2/75/6	10.19	9.13	10.40	2163.12	1931.53
BP_2/75/7	10.08	9.25	8.23	1931.88	1781.73
BP_2/75/13	9.67	9.02	6.72	1259.09	1171.18
BP_2/100/1	9.52	8.64	9.24	1719.79	1561.46
BP_2/100/2	12.26	11.54	5.87	2878.75	2705.14
BP_2/100/5	7.37	6.79	7.87	1090.07	1007.15
BP_2/100/6	14.19	12.63	10.99	2219.93	1976.88
BP_2/100/7	9.15	8.535	6.72	1852.08	1729.38
BP_2/100/12	8.25	7.62	7.64	1459.86	1344.31
BP_2/125/1	8.42	7.91	6.06	1550.28	1429.93
BARI Piaz-2	13.92	12.34	11.35	2420.35	2177.64
BARI Piaz-3	6.64	5.76	13.25	816.74	693.33
LSD $_{(0.05)}$	1.56	1.41	-	162.29	142.50

Preliminary yield trial with M_4 mutant lines of summer onion for bulb yield potential in Kharif-I season, 2011

All mutant lines had significantly larger fresh and dry bulb sizes, expressed here as individual fresh and dry bulb weight, than BARI Piaz-3 except BP_2/100/5 (Table1). Bulb size of BP_2/100/5 did not differ significantly with BARI Piaz-3. When compared with the parent BARI Piaz-2 all the mutants had significantly smaller fresh and dry bulb sizes except the mutant BP_2/100/6.

Table 2. Seed yield and yield attributes of 13 mutant lines of summer onion along with the parent BARI Piaz-2 during winter season, 2011-12 at Ishurdi

Mutant lines	Total plant (no.)	Flowering plant (%)	Seed yield/ plant (g)	Seed yield/ ha(kg)
BP_2/75/2	252	60.32	0.24	79.37
BP_2/75/3	401	79.05	0.24	78.97
BP_2/75/5	224	87.50	0.22	74.40
BP_2/75/6	283	68.55	0.08	25.91
BP_2/75/7	239	77.41	0.06	20.92
BP_2/100/7	44	90.91	0.20	68.18
BP_2/100/12	192	81.25	0.08	26.04
BP_2/100/1	162	83.95	0.43	144.03
BP_2/100/2	443	73.59	0.16	52.67
BP_2/100/5	291	56.70	0.12	38.95
BP_2/75/13	230	71.30	0.07	23.19
BP_2/125/1	340	77.94	0.04	11.76
BP_2/75/11	84	76.19	1.07	357.14
BARIPiaz-2	21	9.52	0	0.0
SE	31	2.73	0.08	25.40

Table 3. Bulb yield and some related traits of five promising summer onion mutants during Kharif season, 2012

Mutant/check variety	Leaves/ plant (no.)	Individual bulb diameter (cm)	Individual bulb weight (g)	Fresh bulb weight (kg/ ha)	Dry bulb weight (kg/ha)	Rate of weight loss (%)
Magura						
BP_2/75/2	6.15	16.34	69.44	6389	4599	27.96
BP_2/75/5	6.99	15.60	50.12	5062	3580	29.16
BP_2/75/11	5.37	13.40	44.59	3025	2160	28.35
BP_2/75/3	6.20	15.05	55.60	6543	4182	36.18
BP_2/100/2	5.78	13.49	46.71	3611	2500	29.28
BARI Piaz-3	5.40	15.23	27.77	2176	1512	29.83
LSD (0.05)	0.32	0.31	0.19	843	599	NS
Ishurdi						
BP_2/75/2	9.64	15.19	51.85	6743.83	5046	24.84
BP_2/75/5	8.46	15.31	52.18	8734.57	6574	24.29
BP_2/75/11	7.26	14.60	52.35	8379.63	6235	24.29
BP_2/75/3	7.69	15.56	55.87	6512.35	4753	27.02
BP_2/100/2	6.78	15.56	55.96	9969.14	7469	24.82
BARI Piaz-3	5.45	15.54	55.08	5756.17	4336	24.91
LSD (0.05)	0.21	0.53	0.42	2267	1299	NS
Means over locations						
BP_2/75/2	7.90	15.77	60.65	6566.36	4822.48	26.40
BP_2/75/5	7.73	15.46	51.15	6898.15	5077.16	26.72
BP_2/75/11	6.32	14.00	48.47	5702.16	4197.53	26.32
BP_2/75/3	6.95	15.30	55.74	6527.78	4467.59	31.60
BP_2/100/2	6.28	14.53	51.34	6790.12	4984.57	27.05
BARI Piaz-3	5.43	15.39	41.43	3966.05	2924.38	27.37
LSD (0.05)	0.23	0.42	0.29	1467.38	888.11	NS

NS = not significant

Fresh and dry bulb sizes of this mutant were statistically indifferent with the parent variety. Fresh and dry weight of bulb/ha was significantly higher in two mutants like BP_2/100/2 and BP_2/75/5 than the parent variety. But all the mutants including the above two had significantly higher fresh and dry weight of bulb/ha than the check variety, BARI Piaz-3 (Table 1). Shelf life, expressed here as rate of weight loss, was longer in all the mutants than the parent and check variety as well. The mutant BP_2/100/2 had the lowest weight loss on drying followed by BP_2/100/6 and BP_2/100/13.

Preliminary yield trial for M_5seed yield potential in winter season

Almost all the mutants that flowered could produce seed. Seed yield/plant and ha of the mutants ranged 0.04 to 1.07g and 11.76 to 357.14 kg with BP_2/75/11 being the highest while BP_2/125/1 the lowest. BARI Piaz-2 had lower plant population yet it had the lowest percentage of flowering plants and the flowering plants did not produce any seed, finally (Table 2).

Advance yield trial with five promising summer onion mutant lines for bulb yield potential in Kharif-II season

Irrespective of mutants and check variety, leaf number was significantly higher at Ishurdi than Magura (Table 3). Accordingly, individual bulb weight and diameter, and fresh and dry bulb weight were also significantly higher at Ishurdi than Magura. At both Ishurdi and Magura, all the mutans had signficantly higher number of leaves than check variety. At Magura, the mutant BP_2/75/5 had the highest number of leaves followed by BP_2/75/3 and BP_2/75/2. In contrast, at Ishurdi, the mutant BP_2/75/2 had significantly the highest number of leaves followed by BP_2/75/5 and BP_2/75/3. The check variety had significantly the lowest number of leaves at both locations. At Magura, the mutant BP_2/75/2 and BP_2/75/5 had significantly broader diameter than the check variety. In contrast, at Ishurdi, none of the mutants had significantly broader bulb diameter than the check variety but the mutant BP_2/75/11 had significantly narrower bulb diameter.

Table 4. Seed yield and some related traits of some summer onion mutants

Mutant/ variety	Total plant (no.)	Plant with seed (no.)	Umbel /plant (no.)	Fruits/ umbel (no.)	Umbel dia (cm)	Seeds/ fruit (no.)	Seeds/ umbel (no.)	Seed yield/ umbel (g)	Seed yield (kg /ha)
BP_2/75/2	165	154	1.0	166.0	14.6	4.0	395.6	0.96	1159
BP_2/75/3	184	176	1.0	168.4	15.8	4.4	366.0	1.39	1193
BP_2/75/5	144	127	1.1	240.4	18.4	3.8	446.0	1.73	1153
$BP_2$75/11	137	119	1.1	159.4	4.2	4.4	266.0	0.87	907
BP_2/100/2	98	78	1.1	241.6	12.5	3.6	440.8	1.49	798
BARI Piaz-2	110	10	1.0	170.4	16.0	4.4	324.0	1.23	50
SE	13	24	0.02	15.87	2.03	0.14	28.48	0.13	178

The size of the bulb expressed here as individual bulb weight was significantly higher in all the mutants than the check variety at Magura. In contrast, at Ishurdi, the check variety had significantly bigger bulbs than BP_2/75/2, BP_2/75/5 and BP_2/75/11. At Magura, fresh and dry bulb weights of all the mutants were significantly higher than the check variety with BP_2/75/3 being the highest for fresh weight and BP_2/75/2 being the highest for dry weight. Similarly, at Ishurdi, fresh and dry bulb weight of all the mutants was significantly higher than that of check variety. The mutant BP_2/100/2 had significantly the highest fresh and dry bulb weights followed by BP_2/75/5 and BP_2/75/11. Weight loss on storage of the mutants and check variety did not differ significantly at any location despite differed between the locations. Means over all locations exhibited significantly higher number of leaves, individual bulb weight, and fresh and dry bulb weights in all the mutants than check variety, BARI Piaz-3. Here it is important to note that the same onion mutants, parent and the check variety had much lower weight loss in Kharif-I season (Table1) compare to Kharif-II season (Table 3). This is because better storing of onion requires minimum temperature, low relative humidity and lesser rainfall (Chuku *et al*., 2008). In Kharif-II season, higher temperature associated with higher rainfall and humidity induce higher fungal infections which speeds up the spoilage of the bulb onions and nutritional qualities as well.

Advanced yield trial for seed yield potential in winter season (Production of M_6 seeds)

Population differed significantly among the mutants/variety with BP_2/75/5 being the highest followed by BP_2/75/2 while the mutant BP_2/100/2 had significantly the lowest population followed by BARI Piaz-2 (Table 4). Number of plants that produced seed also differed significantly among the mutants/variety. The mutant BP_2/75/3 had the highest number of plants that produced seed followed by BP_2/75/2. The mutants/variety mostly produced one umbel/plant but number of fruits/umbel differed significantly. The mutant BP_2/100/2 had the highest number of fruits/umbel although its umbel diameter and seed/fruit were lower. The mutant BP_2/75/5 had the highest number of seeds/umbel followed by BP_2/100/2. The mutant BP_2/100/3 produced significantly the highest seed yield followed by BP_2/75/2, BP_2/75/ 5 and BP_2/75/11.

CONCLUSIONS

The effective mutations for higher bulb and seed yields along with longer shelf life could be induced in summer onion by gamma irradiation dose range of 75Gy-125 Gy. The most spectacular result of this study is almost all the induced mutant lines, in M_1 to M_6 generations, produced seed from seed in the same season while the parent variety produced very negligible or no seed. In Kharif-I season, the mutant lines BP_2/75/5 and BP_2/100/2 had significantly higher fresh and dry bulb yield than the parent BARI Piaz-2 and that of BP_2/75/2 had not differed significantly. Additionally, all the mutants had longer shelf life than the parent and the check variety when stored for 2.0 months under ambient condition. The mutant BP2/100/2 had the longest shelf life followed by BP2/125/1 and BP2/100/12 and BP2/75/13. In Kharif-II season, the mutants BP_2/75/2, BP_2/75/5 and BP_2/100/2 produced significantly higher bulb yields at Ishurdi and Magura than the check variety BARI Piaz-3. Unlike Kharif-I season, the shelf life of the bulbs of mutants and the check variety was much lower and did not differ significantly in Kharif-II season although yield was almost double. Seed production of the mutants ranged from 798-1193 kg/ha with the highest being in BP_2/75/3 followed by BP2/75/2 while the parent BARI Piaz-2 produced the lowest seed yield of all. Considering bulb yield, Kharif-II season appeared advantageous but with some penalty in shelf life. On the other hand considering shelf life, Kharif-I season appeared preferable but with some bulb yield penalty. Therefore, there should be a compromise either for bulb yield or for shelf life of bulb based on profitability analysis for choosing the season in summer.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of Bangladesh Academy of Sciences (BAS) through BAS-USDA-PALS-BINA-CR41 and BAS-USDA-PALS-BINA-CR 4 projects for this study.

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