ISSN 0258-7122
Bangladesh J. Agril. Res. 38(4): 637-646, December 2013

POTATO (*Solanum tuberosum* L.) VARIETY DEVELOPMENT THROUGH HYBRIDIZATION: A NEW ERA IN BANGLADESH

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Abstract

Systematic research on potato variety development has been in practice in Bangladesh since 1960, but until 2012, not a single variety was developed in this country through conventional breeding method, mainly due to the short day climatic factors which are not congenial for potato plants to flower. Due to the diversified efforts, TCRC scientists were able to make a breakthrough to overcome the climatic barriers. Flowering was induced in HYV potatoes and produce berries in the year 2000. After hybridization and continuous selection, five hybrid clones were placed in a RYT in 2010-11 from a batch of 502 kg F_1 seedling tubers produced from 45 gram hybrid seeds of 2001-02. Based on the performances of SYT, AYT, RYT and on-farm trials, three varieties were released by the NSB in 2012 as BARI Alu-35, BARI Alu-36, and BARI Alu-37. Their genotype numbers are 4.5W, 4.26R, and 4.40, their mean yields were 38.36, 33.82, and 34.88 t/ha in AYT, 44.01, 41.84, and 40.58 t/ha in RYT, and 38.87, 38.52, and 37.53 t/ha in on-farm trials, respectively.

Keywords: Potato, hybridization, Bangladesh.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most promising crops in Bangladesh due to its high productivity, short duration, and wide adaptability. Although research and development of HYV potato was started regularly in 1960, its varietal improvement has only been limited to introduction and selection until the year 2000 (Rashid *et al.*, 1987) due to the adverse climatic factors of Bangladesh. Potato plants do not flower under the short day conditions of Bangladesh. In the recent years, hybridization has been made possible at the TCRC after continuous efforts on variety selection under extended photoperiod and use of flower induction techniques (Rashid *et al.*, 1990; Rashid *et al.*, 1993; Rasul *et al.*, 1994). Several treatments like extension of photoperiod, brick planting, stem girdling, grafting on tomato, and use of hormones, alone or in combination, have been found effective in inducing flowers and berry setting in potato (Clarke and Lombard, 1939; Patterson, 1953; Thijn, 1954; Zafar, 1955; Rashid *et al.*, 1990; Rashid *et al.*, 1993; Rasul *et al.*, 1994).

Systematic hybridization was initiated in 1999-2000 (Rashid & Hoque, 2009) and hybrid seeds are being produced and clones are being evaluated every year

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following systematic evaluation procedure (TCRC, 2001 to 2010; Rashid, 2004). The first batch of clonal hybrids were evaluated by the Technical Committee in 1911-12 and three varieties were released in 2012 (TCRC, 2012; Kundu and Kabir, 2012). These are the first potato varieties of Bangladesh. Through this procedure, new varieties will be coming up with desired qualities, and thus the dependency on imported varieties will reduce. The major objective of the hybridization process is to develop new varieties with high yield, good marketability, disease and insect tolerance/resistance, good keeping quality, and wider adaptability.

Materials and Method

Potato breeding following hybridization is a complex and lengthy procedure developed through trials and errors of 1980s and 1990s (Rashid, 1993). Even after several treatment combinations, maximum varieties, especially long day adapted European ones could not be induced flower under Bangladesh condition. To overcome all the problems, breeding facilities were developed both at Joydebpur and Debigonj. Hybridization was done in open field under extended photoperiod up to 11 pm every day with the help of High Pressure Sodium lights maintaining a minimum of 500 Lux at plant level starting from the emergence to senescence of plants. After flowering, hybridization is made in possible combinations. Seeds are sown in specially prepared beds after breaking dormancy of the true seeds. Following procedure is generally followed to develop a variety after hybridization:

Procedure of variety development of potato through hybridization

Seeds are sown at 10x10cm spacing on the seed beds under net house. Plants are harvested at 110 days. One tuber is selected per seedling. Only tubers of desired shape, size and color are selected.	1st year, $F_1C_{O.}$
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Tubers are planted at wide spacing (70x40cm) under net house. Check varieties are planted in between two progenies. 5-10% hills are selected based on yield, tuber size, shape and color. Each hill is bagged separately (8 to 10 tubers/bag).	2^{nd} year, F_1C_1 (1st clonal gen.), single tuber bed.
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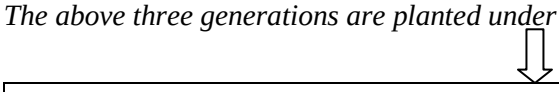
Each bag (7 tubers) are planted in one row at 70 x 40 cm spacing under net house. Rows with desirable plants are marked at 60 DAP. At 90	3^{rd} year, F_1C_2 (2^{nd} clonal gen.), Plant (single) row bed.

DAP, all plants are harvested, data are recorded from five good plants. Good rows are selected based on size, shape, color and yield of tubers, and foliage type. Selected five hills are bulked for seed.

The above three generations are planted under net house



In this generation ten tubers from each bag is planted under the net house for seed multiplication, the rest seeds are planted in one bed at 60 X 40 cm spacing under open field (usually three rows of ten tubers each). First selection is based on the plant type and disease tolerance/resistance at 60 DAP, and final selection is done on yield and tuber qualities. All tubers of each clone are bulked except poor yielding plants. Two checks BARI Alu-7(Diamant) and BARI Alu-8 (Cardinal) are always maintained at same spacing..	4^{th} year, F_1C_3 (3^{rd} clonal gen.) Single bed
In this generation similar methods are followed. Selected clones are planted for seed increase to conduct replicated yield trial in the next generation. Undesirable clones are rejected.	5^{th} year, F_1C_4 (4^{rd} clonal gen.) Single bed
3 rows of 10 tubers each are planted in 3 replicated plots at two locations at 60 × 25 cm spacing in open field. Two checks are used. Clones are selected based on foliage type, tuber yield and tuber qualities. Harvested seeds are bulked for seed.	6^{th} year, F_1C_5 (5th clonal gen.) PYT
3 rows of 10 tubers each are planted in 3 replicated plots at six locations at 60x25 cm spacing in open field. Two checks are used. Clones are selected based on selection criteria (score sheet). Harvested seeds are bulked for seed.	7th year, F_1C_6 (6th clonal gen.) SYT
5 rows of 12 tubers each are planted in 3-4 replicated plots at six locations at 60x25 cm spacing. Two checks are used. Clones are selected based on selection criteria (score	8th year, F_1C_7 (7th clonal gen.) AYT

sheet) and regional choice. Harvested seeds are bulked for seed. Early variety, late planting, processing, storability, disease pressure, agronomic trials and participatory variety trials (PVS), etc. are done separately in this generation. Selection is based on all of the trials. A review meeting is done for selection of varieties to be placed in the RYT in the next season. PVS trial results, yield stability, farmers' preference, storability, etc. are considered during selection.	
Regional yield trial (RYT) is done at 8^{th} or 9^{th} clonal generation.The trials are set up as per NSB requirement in each major agro-ecological region. At least six location means are required presently. One set of trial is conducted at BADC seed farm for their understanding. Net house materials are used. A variety is released by National Seed Board (NSB) on recommendation of the Technical Committee based on the results of the RYT and On-farm trial. Six rows of 12 tubers each are planted in 3-4 replicated plots at least at six locations at 60 × 25 cm spacing. Two checks are used. Two rows are harvested at 65 DAP and others are harvested at 90 DAP in presence of Regional Technical Committee of NSB.	9th year, F_1C_8 (8th clonal gen.) RYT
On farm/participatory trial: With the same varieties at least two trials are set up at each of the six locations in farmers fields. The farmers grow the materials according to their own management but with the monitoring and supervision of the DAE officials and TCRC researchers. Data are recorded in presence of the Technical Committee at crop maturity.	

Results and Discussion

The released three new varieties were selected out of 2001-02 crossed 45g true seeds in 20 combinations which produced 502 kg seedling tubers in 2002-03. Selected plants were grown in plant-rows out of which 400 lines were selected in 2003-04. In the next generation, 42 genotypes (single plots) were selected. In 2005-06, 32 genotypes were planted in replicated yield trial (PYT). In SYT, 18 clones were evaluated at two locations (2008-09). All of the generations' results

were encouraging (TCRC, 2001 to 2010). Advanced yield trial was conducted with 11 clones at six locations in 2009-2010. The results are presented in Table 1.

Table 1. Performances of F_1C_6 clonal hybrids in AYT over six locations.

Hybrid clone/ variety	Tuber yield (t/ha) at 90 DAP						
	Joy.	Mun.	Bog.	Jam.	Jes.	Deb.	Mean
3.24	26.10 c	26.3 cde	24.99 a-c	33.50 e	27.78 c	-	27.73
4.11	18.54 d	22.00 e	10.78 d	23.00 f	18.59 d	45.33 b-e	23.04
4.15	25.20 c	36.80 a	24.35 a-c	35.60 cd	30.85 bc	46.63 a-e	33.24
4.26 (W)	33.07 b	24.5 de	22.92 bc	34.60 de	28.14 c	47.31 a-d	31.76
4.26 (R)	22.97 cd	27.9 b-e	21.75 c	41.70 a	34.90 ab	53.70 ab	33.82
4.27	29.65 bc	32.50 abc	28.51 a-c	42.30 a	35.83 ab	55.18 a	37.33
4.32	33.34 b	33.20 abc	23.05 bc	39.50 b-e	39.59 a	54.98 a	37.28
4.40	27.05 bc	29.60 a-d	31.94 ab	42.30 ab	36.30 ab	42.07 c-f	34.88
4.47 (R)	25.64 c	34.30 ab	27.96 a-c	36.60 be	33.24 abc	52.63 ab	35.06
4.5 (W)	41.08 a	33.00 abc	30.00 a-c	42.70 abc	31.30 bc	52.08 ab	38.36
4.5 (R)	27.58 bc	33.00 abc	22.31 c	31.40 de	33.05 abc	50.55 abc	32.98
BARI Alu-7 (Diamant)	27.53 bc	31.10 a-d	32.89 a	41.40 ab	31.39 bc	44.41 b-e	34.79
BARI Alu-8 (Cardinal)	33.00 b	27.90 b-e	32.59 a	29.50 e	34.07 ab	46.18 a-e	33.87
CV (%)	12.70	9.44	19.08	7.45	10.29	12.3	-

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT

AYT results showed that the clones 4.5W, 4.40, and 4.26R performed better in most of the stations. 4.5W produced the highest mean yield (38.36 t/ha), followed by 4.40 (34.88 t/ha). 4.26R produced 33.82 t/ha. This high yield in the 8^{th} generation is highly encouraging.

Similarly, in the RYT at six locations, 4.5 W produced the highest yield (44.01 t/ha), white 4.26 R produced the 2^{nd} highest yield (41.84 t/ha), closely followed by 4.40 (40.58t/ha). All these three were better than the checks (Table 3). Genotype 4.5 W also yielded highest at 65 days of harvesting (27.2 t/ha), 4.40 was the 2^{nd} highest (23.67), while 4.26R produced 20.9 t/ha (Table 2). The check varieties produced 24.34 and 23.13 t/ha. This indicated that these varieties are also early bulkers.

Table 2. Performances of clonal potato hybrids for tuber yield at 65 DAP in RYT at six locations.

Hybrid Clone/Variety	Tuber yield (t/ha) at 65 DAP						
	Joy.	Bog.	Mun.	Jes.	Jam.	Deb.	Mean
4.15	18.43 a	13.67 b	11.50 b	20.56 cd	25.00 c	23.56	18.79
4.26 R	19.58 a	16.33 ab	11.30 b	24.00 bc	28.56 bc	25.65	20.90
4.27	21.13 a	15.33 ab	10.30 b	16.36 d	28.93 bc	23.01	19.18
4.40	21.79 a	16.33 ab	20.60 a	23.03 c	30.72 ab	29.57	23.67
4.5 W	23.98 a	21.33 a	17.77 a	33.00 a	34.82 a	29.31	27.26
BARI Alu-7 (Diamant)	23.98 a	17.67 ab	19.80 a	27.78 b	30.76 ab	26.53	24.34
BARI Alu-8 (Cardinal)	20.96 a	15.00 ab	20.10 a	23.89 bc	31.86 ab	26.94	23.13
CV%	14.35	16.07	0.98	7.63	13.09	12.06	-

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT.

Table 3. Performances of clonal potato hybrids for tuber yield in RYT at six locations.

Hybrid Clone/Variety	Tuber yield (t/ha) at 90 DAP						
	Joy	Bog	Mun	Jes	Jam	Deb	Mean
4.15	30.87 b	32.30 c	32.85 bc	36.48 bc	45.73 ab	35.83	35.68
4.26 R	33.95 ab	40.28 abc	32.93 bc	45.78 a	52.09 a	46.01	41.84
4.27	37.30 a	36.04 bc	37.10 ab	45.26 a	48.17 ab	40.23	40.68
4.40	35.24 ab	43.73 ab	34.99 bc	36.26 bc	48.56 ab	44.69	40.58
4.5 W	34.26 ab	46.41 a	41.37 a	41.80 ab	52.83 a	47.36	44.01
BARI Alu-7 (Diamant)	32.58 ab	38.00 bc	29.43 c	33.70 c	40.65 b	39.81	35.70
BARI Alu-8 (Cardinal)	29.86 ab	33.68 c	31.91 bc	32.52 c	39.97 b	40.46	34.73
CV%	14.05	11.46	8.86	9.21	5.75	7.35	-

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT.

Table 4 represents the size of the tubers in RYT at Joydebpur. Results showed that the tuber grades by number and weight as expressed in percentage were comparable to the check varieties, which indicated that all the three varieties are acceptable in production of marketable tubers.

Table 4. Grading of tubers of the clonal potato hybrids by number and weight of RYT at 90 DAP.

Variety	Grading by Number (%)			Grading by Weight (%)		
	<28mm	28-55mm	<28mm	<28mm	28-55mm	>55mm
4.15	12.79 a	87.02 a	0.19 b	2.08 a	97.16 a	0.77 b
4.26 R	17.80 a	82.05 a	0.15 b	2.80 a	96.29 a	0.91 b
4.27	12.08 a	86.68 a	1.23 a	1.57 a	93.72 a	4.71 a
4.40	14.40 a	85.10 a	0.50 b	2.07 a	96.02 a	1.91 b
4.5W	11.44 a	88.21 a	0.35 b	1.86 a	96.69 a	1.45 b
BARI Alu-7 (Diamant)	16.03 a	83.20 a	0.77 ab	3.32 a	93.11 a	3.57 ab
BARI Alu-8 (Cardinal)	13.34 a	89.69 a	0.31 b	2.81 a	95.87 a	1.33 b
CV%	32.12	4.60	42.12	43.11	2.43	70.62

Table 5. Yield performances of the clonal hybrids in participatory/on-farm variety trials over locations.

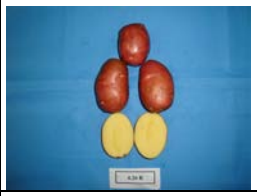
Hybrid Clone/Variety	Tuber Yield (t/ha) at 90 DAP					
	Mun	Bog	Jess	Jam	Deb	Mean
4.15	34.7	34.89	34.85	33.4	33.09	34.19
4.26R	33.9	40.22	36.23	36.9	45.37	38.52
4.27	32.0	27.33	33.70	35.1	36.70	32.97
4.40	32.7	38.77	36.08	37.4	42.69	37.53
4.5W	31.9	38.66	39.16	39.5	45.12	38.87
BARI Alu-7 (Diamant)	35.3	31.99	31.96	35.6	36.81	34.33
BARI Alu-8 (Cardinal)	33.8	27.55	32.94	30.7	40.28	33.05

On-farm performance trials showed very good results. All of the three genotypes were top yielders in most of the locations. The average yields were also higher than the other varieties including checks. The mean yields of 4.5W, 4.26R, and 4.40 were 38.87, 38.52, and 37.53 t/ha, respectively, compared to 33.05 and 34.33 t/ha in checks BARI Alu-8 (Cardinal) and BARI Alu-7 (Diamant), respectively (Table 5).

Table 6. The identifying characters of three clonal potato hybrids developed by TCRC.

Sl. no.	Character	BARI Alu-35	BARI Alu-36	BARI Alu-37
01.	Origin	Bangladesh	Bangladesh	Bangladesh
02.	Accession number	4.5W	4.26R	4.40
03.	Parentage	Cardinal X TPS-67	Patrones X TPS-67	934 X TPS-67
04.	Plant and Stem	Medium plant height with intermediate type of stem. Stems are green with weak extension of anthocyanine coloration.	Medium plant height with intermediate type of stem. Stems are green with strong extension of anthocyanine coloration.	Medium plant height with intermediate type of stem. Stems green with no anthocyanine coloration.
05.	Foliage	Medium size of leaf with weak anthocyanine coloration of mid rib. Very weak waviness of margin of the leaflet.	Medium size of leaf with strong anthocyanine coloration of mid rib. Weak waviness of margin of the leaflet.	Medium size of leaf with no anthocyanine coloration of mid rib. Very weak waviness of margin of the leaflet
06.	Growth habit	Erect	Semi-erect.	Erect
07.	Tubers Characters			
	Skin Colour	Yellow	Red	Yellow
	Shape	Oval	Long oval	Oval to long oval
	Depth of eyes	shallow	shallow	shallow
	Size	medium	medium to large	medium
	Flesh colour	Light cream	Light cream	Light yellow
08.	Sprout	Sprout size is medium, broad cylindrical shape, red violet, strong intensity of anthocyanine coloration of base, very strong intensity of pubescence at the base	Small, spherical with pubescence at the base; weak anthocyanin coloration of tip and pubescence of tip is absent.	Large, cylindrical, strong, intensity of anthocyanin coloration and medium to strong pubescence of the base.
09.	Duration of the crop	90 to 95 days	90 to 95 days	90 to 95 days
10.	Yield range	30-45 (t/ha)	32-45 (t/ha)	30-45 (t/ha)

Table 7. Pictorial presentation of some identifying characters of the three clonal potato hybrids developed by TCRC.

Sl. no.	Character	BARI Alu-35 (4.5W)	BARI Alu-36 (4.26R)	BARI Alu-37 (4.40)
01.	Foliage			
02.	Plant and Stem			
03.	Leaves			
04.	Tubers with cross section (Flesh colour)			
05.	Sprout			

These three varieties 4.5W, 4.26R, and 4.40 were released by NSB in 2012 as BARI Alu-35, BARI Alu-36, and BARI Alu-37. The identifying characters of the three varieties are presented in Table 6 and 7.

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