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Evaluation and selection of true potato (*Solanum tuberosum*) seed families in North-Central plains of India

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ABSTRACT

Segregating progenies from 19 crosses of potato (*Solanum tuberosum* L.) developed at the International Potato Center (CIP), Peru were tested during 2008-2013 for adaptation and yield attributes in the sub-tropical plains of India i.e. Modipuram, Uttar Pradesh. The progenitors of the crosses showed early foliage maturity, tolerance to biotic stresses and processing attributes. In initial clonal generations, selection was based on desirable tuber attributes and tuber yield components. Clones showing viral symptoms, producing long stolons, irregular tuber shape, russetting, cracking or deep eyes were eliminated. From the initial population of 17,300 true seeds, 13 advanced clones of five crosses were subjected to evaluation in replicated trials and nine better performing clones were selected. Critical evaluation of these nine clones resulted in the identification of five promising clones (305069.701, 305111.701, 305138.702, 397186.703 and 397186.704) with high tuber yield (43 to 50 t/ha) and desirable tuber attributes. These advanced clones hold promise of becoming new potato cultivars and may be used in breeding programmes aiming at high productivity in the region for improving the livelihood of farmers.

Key words: Adaptation, Bi-parental crosses, Clonal selection, Segregating population, Tuber yield components

To develop a variety in potato (*Solanum tuberosum* L.), screening is usually carried out at large scale. Neele *et al.* (1988) reported that on average approximately 180 000 seedlings need to be evaluated to develop a potato variety in the Netherlands, however, Wenzel *et al.* (1983) estimated this value as high as 500 000 to 200 0000. Therefore, number of seedlings required to develop a potato variety depends on the number and range of attributes desired, the conditions of the region for which the variety is to be bred and the progress made so far in breeding for the targeted attributes and region. Breeders presently face multiple challenges to develop new varieties which need to be better suited for a particular region in terms of yield, biotic and abiotic stresses, processing attributes and also perform well under anticipated threats of climate change and its associated repercussions.

The International Potato Center (CIP) Peru, holds an ISO-accredited collection of potato germplasm which offers desirable traits to protect crops from biotic and abiotic stresses. Selected agro-ecologically-oriented elite clones and improved populations are tested in different regions of the world to identify adapted genotypes for sustainable potato production and improving the livelihoods of the poor. The CIP's advanced germplasm combine different sets of productivity, protection and utilization traits required to meet farming, household and market opportunities in tropical, subtropical and temperate regions of the developing world. The development of potato varieties fit for any region generally requires around 10-12 years with climate change further challenging the process. To reduce this time span and orient its improved populations to target environments, the CIP evaluates progenies and promising clones of potato in multi-environment trials across the diverse ecologies and growing seasons of Peru. Results of intentional exposure to biotic and abiotic stresses and information on the performance of progenies and clones in distant, representative test environments is compiled to further support decisions in the breeding programme.

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We selected 19 CIP-bred progenies possessing high yield potential and tolerance to biotic and abiotic stresses for evaluation in the north central Indo-gangetic plains of India, to identify promising clones for the release of varieties for cultivation in north Indian plains.

MATERIALS AND METHODS

Nineteen true seed (TS) families (17 300 seeds) involving 16 female and five male parents (Table 1), developed at the CIP, Peru, were received under a collaborative programme supported by the Indian Council of Agricultural Research (ICAR) for evaluation and clonal selection in the Indian sub-tropical plains. The progenies of crosses involved parents possessing early foliage maturity, high tuber yield, processing attributes and tolerance to biotic and abiotic stresses. The progenies were evaluated during 2008-2013 at Central Potato Research Institute (CPRI) Campus, Modipuram, Meerut (29º 4' N, 77º 46' E, 237 m above sea level) and subjected to four cycles of clonal selection, to identify promising clones and assess the prospective of the progenitors for the subtropical zone. The progenies were evaluated in single hills at the seedling stage (2008-09), in single-row plots of five tubers at F_1C_1 (2009-10), double-row plots of 30 tubers at F_1C_2 (2010-11) and replicated trials with three replications at the F_1C_3 (2011-12) and F_1C_4 stages (2012-13). Clonal evaluations were conducted during the winter season (October-January) when temperature ranges from 4 to 31ºC favouring optimum crop growth and expression of tuber attributes. Recommended cultivation practices of the region were followed, including spacing of 60 cm × 20 cm at seedling stage and in subsequent generations. The clones were evaluated at 90 days in the seedling, F_1C_1 and F_1C_2 stages. For the replicated yield trials, the screening was carried out at 80 days (F_1C_3) and 75 and 90 days crop duration (F_1C_4) to assess bulking behaviour. The selection procedure of Luthra *et al.* (2006) for north Indian plains was followed. The selection was based on desirable tuber attributes; and the clones showing viral symptoms, producing irregular tuber shape or deep eyes were eliminated. Data were recorded on plant vigour at 60 days (1 to 5 scale; 1, least vigorous and 5, highly vigorous), foliage maturity at 75 days (1 to 5 scale; 1, very green or very late and 5, totally dry or very early), marketable (> 20 g) and total tuber number, marketable (> 20 g) and total tuber yield, general impression (1 to 5 scale; 1, very poor and 5, very good) and dry matter content (%) of tubers. General impression included overall appearance of the tuber on the basis of tuber colour, tuber shape, eye depth etc. For tuber dry matter evaluation, half portions of five randomly drawn tubers of each genotype were chopped in small pieces, and 50 g chopped samples with three replications were dried in an oven at 80ºC for 72 hr (Luthra *et al*. 2003, 2013). The

Table 1 True seed families distributed to the Central Potato Research Institute, Shimla (India) by the International Potato Center, Lima (Peru)

Family CIP number	Pedigree		Female attributes	Male attributes	True potato seeds
	Female	Male			
305069	LR00.025	92.187	PVY, PVX	PVY, PVX, PLRV, GCA for PLRV	500
305086	LR00.044	C93.154	PVY, PVX	PVY, PLRV, GCA for PLRV	800
305094	Alpha	I-1039	Earliness	LB, PVY	500
305099	Brda	LR93.050	PLRV, GCA for PLRV	PVY, PVX, PLRV, GCA for PLRV	500
305105	C91.628	I-1039	PVY, PVX, GCA for yield	LB, PVY	800
305106	C91.640	Titia	PVY, PVX, PLRV, GCA for yield and PLRV	Earliness	1000
305108	C93.154	I-1039	PVY, PLRV, GCA for PLRV	LB, PVY	1800
305110	C99.551	I-1039	PVY, PVX	LB, PVY	1000
305111	Goldrush	92.187	Earliness	PVY, PVX, PLRV, GCA for PLRV	2000
305112	Goldrush	LR93.050	Earliness	PVY, PVX, PLRV, GCA for PLRV	1000
305118	LR93.050	I-1039	PVY, PVX, PLRV, GCA for PLRV	LB, PVY	1000
305126	Monalisa	92.187	PVY, Earliness	PVY, PVX, PLRV, GCA for PLRV	500
305127	Monalisa	I-1039	PVY, Earliness	LB, PVY	500
305128	Onaway	LR93.050	Earliness	PVY, PVX, PLRV, GCA for PLRV	500
305133	Ranger Russet	I-1039	Processing, Earliness	LB, PVY	500
305138	Shepody	92.187	Processing, Earliness	PVY, PVX, PLRV, GCA for PLRV	800
305146	Umatilla Russet	I-1039	Processing, Earliness	LB, PVY	2000
305147	Umatilla Russet	LR93.050	Processing, Earliness	PVY, PVX, PLRV, GCA for PLRV	800
397186	C91.612	Titia	PVY, PVX, GCA for yield	Earliness	800

PVY, Potato virus Y; PVS, potato virus; PVX, potato virus X; PLRV, potato leaf roll virus; GCA, general combining ability; LB, late blight

final reading was noted when the weight of sample reached at constant level.

The promising clones were exposed to severe late blight conditions at Kufri (31° 6' 0 N, 77° 15' 0 E, 2289 m above sea level) in 1.2 m^2 plot, replicated thrice. Observations were recorded at weekly intervals and area under disease progress curve (AUDPC) was computed as per Shanner and Finney (1977).

The data from replicated yield trials was analyzed following standard statistical procedures as described by Gomez and Gomez (1984) using the software Windostat 8.5 (Ameerpet, Hyderabad, India).

RESULTS AND DISCUSSION

The results (Tables 2 and 3) of the evaluation of segregating populations in various clonal generations under subtropical plains of India are described here.

Seedling stage

As a clonally propagated crop, the genetic integrity of potato selections is fixed in the first filial generation (F_1), i.e. the seedling stage. Thus each clone identified with desirable attributes holds the promise of becoming a variety if perceived suitable for traits and across locations in later generations of the evaluation scheme. Gopal *et al.* (1992) and Gopal and Khurana (2006) advised that selection for highly heritable traits like tuber skin and flesh colour, tuber shape, cracking and eye depth can be initiated at the seedling stage to reduce the plant population in subsequent generations for more effective selection. A total of 5 067 seedlings of 19 families recovered from 17 300 true seeds sown in nursery beds were transplanted to the field during 2008-09, and 94% seedling survived 20 days after transplanting. The selection procedure suggested by Gopal *et al.* (1994) for early and safe elimination of unproductive genotypes for tuber yield and its components, tuber colour, shape and eye depth was adopted. Tuber yield is not representative in initial clonal generations due to insufficient and non-uniform experimental material/plots size, and thus it was not considered in early clonal generations (Luthra *et al.* 2006). As the crop was raised following the seed plot technique, the clones which showed severe virus infections under these conditions were rejected. At harvesting, 840 (16.6%) promising clones of 19 families were selected from the 5 067 transplanted seedlings. The highest number of clones were selected in the CIP family 305 069 (41%), followed by CIP families 305 108 (26%), 305 111 (23%), 305 138 (22%), 305 086 (20%) and 305 118 (20%). Seed stock of the selected clones was maintained following seed plot technique and the tuber material was cold stored at 2-4°C for subsequent clonal evaluation.

F_1C_1 generation

In total 840 clones of 19 CIP families were evaluated along with controls in single-row plots of five tubers at 90 days crop duration during the winter crop season. Clones showing virus infections and undesirable tuber attributes

Table 2 Performance of F_1C_3 clones at Modipuram during 2011-12

Genotype	Plant vigour	Foliage maturity	Tubers/plant		Tuber yield (t/ha)		General impression	Tuber dry matter (%)
			Marketable	Total	Marketable	Total		
305069.701*	5.00	1.67	5.49	5.81	36.6	38.3	4.00	17.8
305069.702	5.00	1.00	5.05	6.52	35.5	36.5	5.00	17.2
305069.703	5.00	1.33	4.98	10.34	20.2	23.7	4.00	16.7
305105.701*	5.00	1.67	6.07	9.70	30.8	32.7	4.00	19.5
305110.701	5.00	1.00	5.66	7.61	27.1	28.1	4.00	16.0
305111.701*	5.00	2.67	7.66	9.48	37.1	38.8	5.00	16.7
305138.701	5.00	1.00	5.00	9.40	22.5	25.0	4.00	17.4
305138.702*	5.00	2.67	6.21	10.05	34.0	36.6	4.00	15.7
397186.701*	5.00	1.67	5.36	6.73	37.1	37.9	5.00	17.7
397186.702*	5.00	1.67	5.52	8.62	31.0	32.8	5.00	18.5
397186.703*	5.00	1.33	5.00	6.23	34.9	35.9	5.00	17.5
397186.704*	5.00	1.67	6.56	8.12	36.0	37.4	5.00	14.3
397186.705*	5.00	1.00	4.98	7.00	30.4	31.6	5.00	13.9
Atlantic	5.00	2.67	4.26	5.28	27.4	28.1	4.00	20.6
Kufri Bahar	5.00	2.67	4.14	6.19	28.7	30.0	4.00	18.3
Kufri Chipsona-1	5.00	1.67	5.09	7.87	27.5	29.3	4.00	19.5
Kufri Frysona	5.00	1.00	6.67	9.21	27.8	29.9	4.00	19.6
Kufri Sadabahar	5.00	2.00	5.19	6.33	29.9	30.8	5.00	17.3
Kufri Surya	5.00	2.67	6.02	7.36	29.4	30.4	5.00	17.7
CD (P=0.05)		0.80			3.66	3.48		1.24

* Promising clones selected

Table 3 Performance of F_1C_4 clones at Modipuram during 2012-13

Genotype	Plant vigour	Foliage maturity	Tubers/ plant		Marketable tuber yield (tonnes/ha)		Total tuber yield (tonnes/ha)		General impression	Tuber dry matter (%)	
			Marketable	Total	75 DAP	90 DAP	75 DAP	90 DAP		75 DAP	90 DAP
305069.701*	5	1.67	6.32	8.74	29.3	44.2	31.6	46.2	5.00	16.0	17.3
305105.701	5	2.00	5.51	7.87	21.8	32.1	24.0	34.3	4.17		
305111.701*	5	2.67	7.28	9.85	31.4	40.2	34.9	42.7	4.84	15.0	15.3
305138.702*	5	3.00	5.46	7.71	31.2	48.0	33.3	50.3	4.84	15.6	16.1
397186.701	5	2.67	5.58	6.47	30.9	40.8	31.6	41.9	4.34		
397186.702	5	2.33	5.14	6.88	26.9	40.3	28.5	42.1	4.84		
397186.703*	5	1.67	4.88	6.23	28.0	45.9	29.4	47.0	5.00	15.8	17.1
397186.704*	5	2.00	5.43	6.97	30.2	44.7	31.9	46.2	5.00	15.1	16.9
397186.705	5	2.00	5.79	7.37	30.1	41.1	31.3	43.6	5.00		
Atlantic	5	3.00	4.49	5.46	21.9	29.6	23.1	30.6	4.17	19.6	21.5
Kufri Chipsona 3	5	1.67	5.96	8.92	24.4	40.2	26.8	43.8	4.67	18.9	20.0
Kufri Frysona	5	1.00	6.28	8.43	21.1	35.8	23.4	37.6	4.84		
Kufri Bahar	5	2.33	7.12	10.03	26.8	39.9	30.7	41.7	4.50	15.5	16.1
Kufri Pukhraj	5	3.00	6.09	8.14	34.1	39.4	35.8	41.8	5.00	15.2	15.8
Kufri Sadabahar	5	2.00	3.87	4.76	23.9	35.3	24.8	36.4	4.17	15.9	17.1
Kufri Surya	5	2.00	5.03	6.47	20.8	29.2	22.6	30.4	4.84	17.0	17.5
CD (P=0.05)		0.65	1.19	1.24	2.05	2.09	2.12	2.13	0.51	0.8	0.9

* Promising clones selected; DAP, days after planting

were rejected. The selection was based on desirable tuber attributes and tuber yield. The clones with white, yellow and red skinned tubers were selected keeping in view the preference of regional consumers. At harvesting, 23 promising clones of 9 families were selected. Maximum selection was found in families 397186 (12.3%) and 305105 (11.5%).

F_1C_2 generation

The 23 clones selected in previous generations were evaluated along with control varieties in double- row plots of 30 tubers at 90 days during the winter crop season. Selection at this stage was based on the ability of clones to produce uniform tubers with desirable tuber attributes and high yield. At harvesting, 13 promising clones of five families were selected for further evaluation. The selected clones were assigned accession numbers according to the family they were selected from, to retain the identity of its pedigree in further screenings. The selections within same family were allocated accession numbers as "family number suffixed with .701, .702, .703 and so on".

F_1C_3 generation

Thirteen clones of five families were assessed in multiple-row plots (6 rows) at 80 days during the winter crop season. At harvesting, nine promising CIP clones, viz. 305069.701, 305105.701, 305111.701, 305138.702, 397186.701, 397186.702, 397186.703, 397186.704 and 397186.705 were selected on the basis of high tuber yield and desirable tuber attributes. The mean tubers per plant in selected clones varied from 5.81 (305069.701) to 10.05 (305138.702). Among the selected clones, high total tuber yield was obtained in 305111.701 (38.8 tonnes/ha) followed by 305069.701 (38.3 tonnes/ha), 397186.701 (37.9 tonnes/ha), 397186.704 (37.4 tonnes/ha), 305138.702 (36.6 tonnes/ha), 397186.703 (35.9 tonnes/ha), as compared to the best control Kufri Sadabahar (30.8 tonnes/ha) at 80 days crop duration (Table 2).The tuber dry-matter content (%) ranged from 13.9 (397186.705) to 19.5 (305105.701). Selection was done on the basis of foliage maturity, general impression of tubers, tuber yield and tuber dry matter for targeting the clones for wider adaptation. Though Love *et al.* (1997) suggested that selection at this stage should be carried out on individual characters rather than on a combined trait assessment.

F_1C_4 generation

Nine clones were evaluated at 75 and 90 days after planting in replicated yield trials during the winter crop season along with controls. At harvesting, five clones namely 305069.701 (MCIP/9-1), 305111.701 (MCIP/9-6), 305138.702 (MCIP/9-8), 397186.703 (MCIP/9-11) and 397186.704 (MCIP/9-12) were selected (Table 3). Mean tuber number per plant of the selected clones ranged from 6.23 (397186.703) to 9.85 (305111.701). At 75 days, two clones, viz. 305111.701 (34.9 tonnes/ha) and 305138.702 (33.3 tonnes/ha), gave significantly higher yield than Kufri Bahar (30.7 tonnes/ha), the leading variety of the region. However at 90 days, significantly higher total tuber yield was obtained for clones 305138.702 (50.3 tonnes/ha) followed

by 397 186.703 (47.0 tonnes/ha), 397 186.704 (46.2 tonnes/ha), 305 069.701 (46.2 tonnes/ha) than for the best control Kufri Chipsona 3 (43.8 tonnes/ha) and 305 111.701 (42.7 tonnes/ha) remained at par. The selected clones possessed very high plant vigour, early to medium late foliage maturity and very high general impression. Clone 305 138.702 was the earliest maturing and as good as Atlantic and Kufri Pukhraj. Of these selected five clones, four clones (305069.701, 305111.701, 305138.702 and 397 186.703) had white tubers skin colour (preferred in the north Indian plains) and one clone (397186.704) had red skin colour (preferred in eastern India). The selected clones produced attractive, oval/ oblong tubers with shallow to medium eye depth. These selected clones possessed tuber 15.0-16.0% dry matter at 75 days and 15.3-17.3% at 90 days harvest.

Keeping in view the damage caused by late blight (*Phytophthora infestans*) infection in sub-tropical plains, the selected clones were exposed for late blight screening with controls Kufri Girdhari and Kufri Jyoti under natural epiphytotic conditions of Kufri, Himachal Pradesh during 2013. Clone 397186.704 was found moderately resistant to late blight with AUDPC (210) as compared to variety Kufri Jyoti with AUDPC (457).

The identification of five promising advanced hybrids derived from CIP crosses from Peru under subtropical short-day condition of India supports the purpose of dissemination of CIP crosses to similar agro-ecologies. The selected clones possessed high tuber yield and desirable tuber attributes. These clones (305069.701, 305111.701, 305138.702, 397186.703 and 397186.704) hold promise to become a cultivar or can be well utilized in breeding programme targeted for higher yield and tolerance to abiotic or biotic stress in potato. These advanced clones will be further assessed for yield, virus resistance, dry matter, keeping quality and acceptability and based on three years replicated yield data, the one or two elite advanced clones will be introduced in All India Coordinated Research Project on Potato (AICRP-Potato) for evaluation at 12-16 locations in different agro-ecologies. It is pertinent to mention that at least two-year evaluation at AICRP location followed by on-farm evaluation is mandatory for deciding the worth of genotype for release of variety for particular region.

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