Adaptability of Exotic Potato Germplasm in North-Western Hills of India

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Late blight resistance and high tuber yield are the two major requirements of potato crop in North-western hills of India. Adaptability of 176 exotic germplasm accessions from 18 countries was studied under these conditions for 2-4 years against Kufri Jyoti, the most popular variety of the region. Most of the accessions were inferior or at par with Kufri Jyoti for one or the other character. There was no relationship between resistance to late blight and performance for tuber yield and its components. Ten accessions were resistant to late blight, 41 moderately resistant and the remaining were found susceptible. Eight accessions were identified as promising being resistant or moderately resistant to late blight and having high tuber yield with acceptable tuber size, shape, eye depth. Strategies for exploiting the various accessions in potato breeding programmes are discussed.

Key Words: Adaptability, Exotic Germplasm, Late Blight, Potato, *Solanum tuberosum*

Potato (*Solanum tuberosum* L.) is believed to have been introduced in India from Europe towards the beginning of the 17th Century (Pushkarnath, 1964). A systematic research on potato in India was started in 1949 with the establishment of Central Potato Research Institute (CPRI), Patna (headquarters shifted to Shimla in 1956). Development of improved potato varieties for different agro-climatic regions of India, has been the major mandate of CPRI since its establishment. To achieve this objective, acquisition of exotic potato germplasm from different countries has been a continuing activity of CPRI. Germplasm accessions so obtained are evaluated for various biotic and abiotic factors to identify parents suitable for use in potato breeding programmes of the country. In North-western hills of India, potato is grown under temperate long-day conditions of summer (April/ May to August/September). Late blight caused by the oomycete *Phytophthora infestans* is a serious problem in this region, and under epiphytotic conditions yield loss can be as high as 90%. In fact this is the most destructive disease of potatoes worldwide. Resistance to late blight and high tuber yield are thus the major requirements of potato crop in North-Western hills of India. The present paper reports adaptability of 176 exotic germplasm accessions received from 28 countries, under these conditions.

Materials and Methods

One hundred and seventy six accessions available in the germplasm repository of CPRI, were divided into three sets (Tables 3-5) depending upon the number of tubers available in various accessions. These were evaluated at the Central Potato Research Station, Kufri (37° N, 77° E, 2500 m above sea level) in two types of trials *i.e.* non-replicated row trial in which an accession was represented by 1-2 rows of 10 tubers each; and replicated randomized complete block design trials with 2-3 replications and a plot size of 3 rows of 10 tubers each.

Set 1: In this 20 accessions were evaluated for four years, in row trials for initial two years and in replicated trials for the remaining two years.

Set 2: In this 56 accessions were evaluated for three years, in row trials for initial two years and in a replicated trial in the final year.

Set 3: In this 100 accessions were evaluated for two years in row trials.

Kufri Jyoti the most popular variety of the region, was used as check in all the trials. This variety being susceptible to late blight also acted as spreader of the disease and for this it was planted after every 10-15 rows (Dowley *et al.*, 1999). Seed tubers of all accessions and check variety were produced at Kufri (a seed production site) and had received the same post-harvest and storage treatments. Genotypes were randomized in each year. All trials were planted at intra-and inter-row spacing of 50 and 20 cm respectively. Normal cultural schedules were followed. However, no fungicide was applied for late blight control in order to screen the accessions against this disease (Dowley *et al.*, 1999). No artificial inoculation was done for this disease as in this region potato is severely attacked by the late blight every year and the objective was to assess the accessions for adaptability under natural conditions.

Data on late blight incidence were recorded in all the trials when the crop was 90 days old and the check variety Kufri Jyoti had been completely killed by this disease. Accessions were grouped into three classes based on data averaged over the years: Resistant (foliage damage < 20%), Moderately Resistant (foliage damage 20-50%) and Susceptible (Foliage damage > 50%). Haulms were cut when the crop was 100 days old (the maximum acceptable crop duration of this region) and at harvest, data were recorded on plot basis for tuber yield (g/plant), tuber number/plant and average tuber weight (g). Kufri Jyoti was planted as check variety after every 10-15 rows and its mean performance was used in the analysis.

Standard statistical procedure was followed by analyzing data of replicated trials. Pooled analysis over the years was done using non-replicated and replicated data (mean over replications) to partition the observed variation into year, genotype and residual components. Since accessions were grouped into three qualitative grades for late blight reaction, no analysis was conducted for this character.

Results

Set 1: Analyses of variance showed that tuber yield as well as its components were affected by year (Table 1a) whereas replication effect within a year was non-significant for all characters (Table 2a). Average performance over four years showed that all accessions were at par with the check variety Kufri Jyoti for tuber yield and average tuber weight. Two accessions (CP 2370 and CP 2380) had more number of tubers than Kufri Jyoti. Three accessions namely CP 2370, CP2384 and CP 2385 were resistant to late blight, seven were moderately resistant and remaining were found susceptible (Table 3).

Set 2 : Like set 1, replication effect was non-significant in this set also (Table 2b). Year effect was significant only for tuber number (Table 1b). Average performance over three years showed that accessions CP Nos. 1690, 2415, 3098, 3127 and 3157 yielded higher than the check. These genotypes performed better than Kufri Jyoti in the replicated trial also. Eight accessions had more tubers and three had higher average tuber weight than Kufri Jyoti. In this set, only one accession CP 3147 was resistant to late blight, 10 were moderately resistant and remaining susceptible (Table 4).

Set 3: In this set, year effect was significant for tuber yield but non-significant for yield components (Table 1c). Average performance pooled over two years showed that only four accessions CP Nos. 1673, 2110, 2378 and 3250 yielded higher than Kufri Jyoti, whereas 7 accessions had more tubers than Kufri Jyoti. Only three accessions (CP 2332, CP2940 and CP3250) had higher average tuber weight than Kufri Jyoti. Six accessions were resistant to late blight, 25 were moderately resistant and remaining were susceptible (Table 5).

Table 1. Analysis of variance for performance of accessions for tuber yield and its components over years

a. Set 1

Source	df	Mean squares		
		Tuber yield	Tuber number	Av. Tuber weight
Year	3	124233**	94.72**	2410.91**
Accession	20	7035	9.63**	377.35
Residual	60	8173	3.99	244.59

b. Set 2

Source	df	Mean Squares		
		Tuber yield	Tuber number	Av. Tuber weight
Year	2	2076	17.08*	24.20
Accession	56	31808**	15.93**	1025.53**
Residual	112	7075	5.13	154.07

c. Set 3

Source	df	Mean Squares		
		Tuber yield	Tuber number	Av. Tuber weight
Year	1	46264*	7.45	500.61
Accession	100	27176**	15.83**	618.52**
Residual	100	8307	7.34	204.95

* Significant at 5%; ** Significant at 1%

Table 2. Analysis of variance for performance of accessions for tuber yield and its components in a year

a. Set 1

Source	df	Mean squares					
		Ist Year			2nd Year		
		Tuber Yield	Tuber number	Av. Tuber weight	Tuber yield	Tuber number	Av. Tuber weight
Replication	2	6247	1.19	3.08	159	1.39	69.89
Accession	20	27204**	12.13**	535.44**	8439**	5.67**	296.20**
Residual	40	2960	1.70	72.72	1076	0.60	59.65

b. Set 2

Source	df	Mean Squares		
		Tuber yield	Tuber number	Av. Tuber weight
Replication	1	358	0.52	140.98
Accession	56	41828**	15.84**	1203.74**
Error	56	1405	3.35	109.05

** Significant at 1%

Table 3. Mean performance of 20 exotic germplasm accessions over four years

CPRI Accession number	Donor's culture/variety name or number	Source country	Tuber yield (g/plant)	Tuber number per plant	Av. Tuber weight (g)	Reaction to late blight
CP2278	Maris Peer	Bangladesh	234	5.2	45.9	S
CP2292	P-3	Peru	188	3.9	51.6	S
CP2297	P-6	Peru	305	4.0	79.4	MR
CP2333	AA-624	Ethiopia	314	8.2	37.2	MR
CP2334	AL-575	Ethiopia	273	5.4	52.5	MR
CP2335	Ica Sirena	USA	245	5.9	45.8	S
CP2348	Stina	Sweden	205	5.4	38.9	S
CP2358	Islander	USA	292	8.1	39.4	S
CP2370	Muziranzara	Peru	237	8.4	33.1	R
CP2371	LT-8	Peru	261	6.3	43.9	S
CP2380	CFQ69.1	Mexico	319	10.3	36.2	MR
CP2381	CFJ69.1	Mexico	353	7.9	47.6	MR
CP2384	AGG69.1	Mexico	298	7.8	45.9	R
CP2385	AND69.1	Mexico	258	6.2	42.4	R
CP2390	BL1.5	UK	273	6.4	38.3	MR
CP2407	Montsama	Mexico	297	7.7	40.1	MR
CP2420	Mineira	Brazil	242	6.8	35.6	S
CP2421	Serrana Inta	Argentina	268	7.1	42.2	S
CP2427	Pirola	Germany	227	5.6	43.0	S
CP2428	Granola	Germany	323	6.6	51.2	S
Check	K. Jyoti	India	258	5.5	50.1	S
	LSD (5%)		n.s	2.8	n.s.	

R = resistant; MR = moderately resistant; S = susceptible

Table 4. Mean performance of 56 exotic germplasm accessions (set 2) over three years

CP No.	Donor's culture/variety	Source country	Tuber yield (g/plant)	Tuber number per plant	Av. Tuber weight (g)	Reaction to late blight
CP1636	Ackersegen	Germany	117	3.9	40.1	S
CP1690	Irish Cobbler	USA	466	7.5	62.2	MR
CP2125	Up-to-date	UK	266	6.5	39.8	S
CP2181	I-931	India	271	8.9	36.6	MR
CP2277	Dohazari Sada	Bangladesh	62	7.2	9.5	S
CP2280	Lal Pakari	Bangladesh	74	8.5	8.1	S
CP2339	Garana	Madagascar	87	7.0	27.9	S
CP2362	Timate	Netherlands	344	5.2	67.3	S
CP2364	Isna	Bulgaria	197	3.7	61.2	S
CP2413	Piratini	Brazil	306	11.7	29.1	S
CP2415	MEX.750821	Mexico	399	10.5	38.6	MR
CP2417	MEX.750838	Mexico	221	9.5	32.9	MR
CP3079	Bintje	Netherlands	230	5.3	42.6	S
CP3084	Baraka	Netherlands	244	4.4	58.0	S
CP3087	Hertha	Netherlands	229	3.8	69.3	S
CP3088	Obelix	Netherlands	313	4.7	66.3	S
CP3089	Origo	Netherlands	205	4.2	46.8	S
CP3098	27/15	Peru	420	6.5	59.3	MR
CP3099	Lal Shil	Bangladesh	27	5.2	5.10	S
CP3100	Nishiyutaka	Japan	167	3.2	58.6	S
CP3101	Esperanza	Ecuador	105	8.3	11.8	S
CP3111	Huaycha	Peru	69	3.5	19.9	S
CP3124	CIP379676.3	Peru	178	8.0	24.1	S
CP3125	SR-1	Peru	253	7.8	33.1	S
CP3126	Haille	Peru	241	5.7	42.4	S
CP3127	CIP378711.2	Peru	423	7.3	59.2	MR
CP3134	Santa Cecilia	Ecuador	89	12.8	7.7	S
CP3142	Maine-28	USA	267	2.8	100.7	S
CP3144	Desital	Italy	160	3.5	48.3	S
CP3145	Yana	Peru	63	3.0	20.2	MR
CP3147	Muruta	Peru	279	10.4	26.8	R
CP3148	Muru	Peru	66	4.6	14.6	MR
CP3151	CIP379693.153	Peru	236	5.3	43.1	S
CP3152	TM-3	Peru	101	3.3	33.3	S
CP3153	TM-4	Peru	103	3.8	26.1	S
CP3154	P110	Peru	242	7.5	34.6	S
CP3156	Monserrate	Colombia	137	9.4	14.1	MR
CP3157	Dalia	Poland	424	5.8	70.9	S
CP3158	Ruta	Poland	322	8.0	41.2	S
CP3159	Lotos	Poland	334	6.6	45.1	S
CP3160	Janeka	Poland	310	5.6	62.3	S
CP3162	Sowa	Poland	252	5.4	47.6	S
CP3165	Tarpan	Poland	270	5.1	56.9	S
CP3166	Pola	Poland	181	3.9	48.7	S
Cp3167	Perkoz	Poland	170	3.6	48.9	S
CP3171	Bzura	Poland	243	6.6	36.8	MR
CP3172	Frezja	Poland	183	4.1	47.5	S
CP3173	Elba	Poland	339	7.4	46.1	S
CP3174	Fala	Poland	190	5.6	36.3	S
CP3175	Stobrawa	Poland	245	6.9	34.2	S
CP3176	Sokol	Poland	308	5.8	51.1	S
CP3178	Elida	Poland	180	4.7	41.1	S
CP3180	Atoe	Poland	248	6.3	38.4	S
CP3193	BW-4	Peru	167	5.8	31.0	S
CP3200	Dejima	Japan	182	3.7	31.0	S
CP3204	MF-II	Peru	156	2.9	49.7	S
Check	Kufri Jyoti	India	239	4.7	48.1	S
	LSD (5%)		136	3.7	20.1	

R = resistant, MR = moderately resistant; S = susceptible

Table 5. Mean performance of 100 exotic germplasm accessions (set 3) over two years

CPRI accession number	Donor's culture/variety name/number	Source country	Tuber yield (g/plant)	Tuber number per plant	Av. tuber weight (g)	Reaction to late blight
CP1673	Dr. McIntosh	Ireland	460	9.5	48.0	MR
CP1998	Michoacan	Mexico	84	4.4	20.5	MR
CP2000	I-1062	India	284	8.4	40.5	R
CP2011	CIP676082	Mexico	434	12.5	42.5	R
CP2013	Atzimbe	Mexico	315	7.0	45.5	S
CP2014	CIP720048	Mexico	286	8.5	54.5	R
CP2053	CIP379376	Peru	175	2.6	65.5	S
CP2110	CFK.69.1	Mexico	488	13.3	36.0	MR
CP2161	Pentland Hawk	UK	394	8.9	44.5	S
CP2272	PI458391	USA	118	4.9	24.0	S
CP2282	Iwa	New Zealand	185	6.2	58.0	S
CP2284	Bremer	Australia	162	4.6	48.5	S
CP2289	Magayar Rozsa	Hungary	211	5.9	35.5	S
CP2293	V-2	Peru	188	6.8	30.0	S
CP2298	P-7	Peru	119	4.9	15.5	S
CP2302	Santo Amor	Brazil	205	5.2	28.0	S
CP2304	Aracy	Brazil	158	4.3	32.0	S
CP2305	Primicia Inta	Argentina	90	4.3	21.0	S
CP2329	KTT60.21.19	Netherlands	333	5.6	60.0	S
CP2330	Atlantic	USA	163	4.5	37.5	S
CP2332	AL-204	Ethiopia	300	4.1	96.5	S
CP2336	Seseni	Zaire	205	6.4	38.5	S
CP2340	104-12-43	Peru	216	3.6	50.0	S
CP2346	F6	Peru	201	5.2	40.0	S
CP2347	Gasore	Peru	263	6.1	40.5	S
CP2351	Tobique	Canada	123	3.6	27.5	S
CP2355	Yankee Supreme	USA	195	5.8	24.5	S
CP2360	Palma	Switzerland	229	3.5	23.0	S
CP2363	Rila	Bulgaria	230	4.7	35.5	S
CP2368	TS-2	Peru	196	4.0	36.5	S
CP2374	TM.1	Peru	204	3.9	28.0	S
CP2376	Cruza-27	Mexico	210	7.2	31.5	MR
CP2377	ABZ69.1	UK	264	8.6	32.0	S
CP2378	Poos.16	Netherlands	453	10.0	44.0	R
CP2379	CEW69.1	Mexico	192	6.3	40.0	R
CP2382	CFS69.1	Mexico	45	4.0	10.5	S
CP2383	AGB69.1	Mexico	229	6.7	35.0	S
CP2391	BL-1.10	UK	190	5.9	39.5	S
CP2392	BL-2.9	UK	171	6.3	27.0	S
CP2397	Santanlalla	Peru	30	3.0	9.0	S
CP2403	Chejchi	Bolivia	238	5.3	46.0	S
CP2409	Yungay	Peru	113	5.5	20.5	S
CP2411	ARX 69.1	UK	221	8.5	25.0	MR
CP2416	MEX 750826	Mexico	315	7.2	37.0	MR
CP2418	Chiquita	Brazil	267	8.6	29.5	S
CP2422	Ballenera	Peru	226	4.7	39.5	S
CP2940	TS-3	Peru	250	2.6	96.5	S
CP3029	Clavela	Chile	88	6.5	13.0	S
CP3072	Flor-Blanca	El Salvador	371	9.4	37.0	MR
CP3080	Alpha	Germany	105	3.4	30.0	S
CP3083	Campbell-14	USA	218	3.9	60.5	S
CP3094	Hybrid-14	Nepal	263	7.7	41.0	S
CP3108	69.56.52	Mexico	114	5.9	21.0	S

Contd.

Table 5. Contd.

CPRI accession number	Donor's culture/variety name/number	Source country	Tuber yield (g/plant)	Tuber number per plant	Av. tuber weight (g)	Reaction to late blight
CP3138	Maria	Euacdor	125	2.8	41.0	S
CP3139	Santa Catalina	Euacdor	42	4.0	9.5	S
CP3163	Irys	Poland	143	5.0	28.5	S
CP3181	G-2	Peru	37	3.7	10.0	S
CP3182	Santaana	Peru	44	2.0	23.0	S
CP3184	Yurac Sinchi	Peru	149	6.9	21.5	S
CP3187	BW-3	Peru	164	4.8	34.5	S
CP3188	Kinga	Peru	212	4.3	49.5	S
CP3189	Sissay	Peru	121	6.2	20.0	S
CP3190	Kinigi	Peru	125	6.3	20.0	S
CP3191	25/40	Peru	140	4.4	25.0	S
CP3197	TS-4	Peru	38	1.9	20.5	S
CP3201	Sanjuan	UK	32	1.7	22.0	S
CP3207	P111	Peru	150	21.3	12.0	MR
CP3208	MF-1	Peru	100	3.6	27.5	S
CP3242	CIP381146.12	Peru	25	4.2	7.0	S
CP3243	CIP381169.16	Peru	291	9.4	29.5	MR
CP3246	CIP381381.13	Peru	275	13.1	21.5	R
CP3248	CIP381376.15	Peru	295	5.1	60.0	MR
CP3250	CIP381379.15	Peru	619	8.9	91.0	MR
CP3250A	Unknown	Peru	200	8.5	24.0	MR
CP3251	CIP381381.20	Peru	364	10.0	36.0	MR
CP3252	CIP381382.34	Peru	175	13.6	43.0	MR
CP3253	CIP381388.34	Peru	53	3.5	15.5	S
CP3254	CIP381403.1	Peru	319	7.9	40.5	S
CP3255	CIP381403.5	Peru	244	6.9	34.5	MR
CP3256	CIP381403.8	Peru	306	7.6	41.0	S
CP3258	CIP382119.17	Peru	44	3.5	10.5	S
CP3259	CIP382119.20A	Peru	275	11.4	24.0	MR
CP3262	CIP382122.23	Peru	125	7.3	17.0	S
CP3263	CIP382138.4	Peru	19	2.3	8.0	S
CP3268	CIP382255.8	Peru	64	6.1	10.0	S
CP3270	CIP383034.8	Peru	88	5.8	14.0	S
CP3272	CIP384298.35	Peru	291	11.2	26.5	S
CP3275	CIP384319.1	Peru	69	3.9	18.0	S
CP3276	CIP384321.3	Peru	238	11.0	20.0	MR
CP3277	CIP384321.9	Peru	253	11.9	19.5	MR
CP3279	CIP384329.21	Peru	48	3.3	11.0	MR
CP3280	CIP384375.3	Peru	370	6.4	22.5	MR
CP3281	CIP381403.22	Peru	342	10.3	33.5	MR
CP3282	CIP382119.27	Peru	15	2.5	5.5	S
CP3283	CIP382150.5	Peru	7	2.5	3.0	S
CP3284	CIP383117.6	Peru	37	2.1	16.5	S
CP3285	CIP384651.14	Peru	125	5.6	20.5	MR
CP3286	CIP385021.12	Peru	148	9.2	16.5	MR
CP3287	CIP386002.4	Peru	200	5.8	34.5	MR
CP3288	CIP384331.10	Peru	172	4.9	23.0	MR
Check	Kufri Jyoti	India	267	6.0	44.0	S
	LSD (5%)		181	5.4	28	

R = resistant; MR = moderately resistant; S = susceptible

Discussion

Genotype x environment interaction is known to be important for tuber yield and its components in potato (Yildrim and Caliskan, 1985; Gopal, 1989) suggesting thereby that location-specific evaluations for such characters should be conducted over the years. In the present study, each accession was tested for a minimum of two years. Replication mean squares were non-significant (Table 2) probably due to high within replication (error) variation on account of soil heterogeneity and micro-climatic variations in the terraces in which the accessions of a set were planted. This is an unavoidable situation due to hilly topography of the region. Birhman and Kang (1993) have also reported non-significant replication mean squares for such characters in potato. In such a situation data based on non-replicated trial should serve the same purpose as the one based on replicated trial. As the clones were tested over years and randomized in each year, reliable estimates of the performance could be obtained. Analysis pooled over the years was conducted by including data from replicated (mean over replications) as well as non-replicated trials. Residual mean squares from such an analysis include both year x accession interaction and error components, and hence LSD values were large (Table 3-5). This was used for testing the significance of year and accession mean squares, as the objective was to identify consistently superior performers.

In potato, susceptibility to late blight is known to be affected by age (Umaerus, 1970): initial phase of high susceptibility is succeeded by an intermediate phase of greater resistance coinciding with the period of most rapid growth, which is followed in turn by a final phase of higher susceptibility as flowering and tuberization begin. To be sure of the resistance to late blight in the accessions tested in the present study, data on late blight incidence were recorded in the final phase of higher susceptibility when the disease was in severe form and the susceptible accessions including Kufri Jyoti had been killed by the pathogen. From a practical point of view accessions were grouped into three grades of resistance, but a continuous variation was observed with regard to disease intensity in various accessions. Highly complex (9-10 genes) races of *Phytophthora infestans* occur at Kufri (Singh and Bhattacharyya, 1999) and there was no chance of escape as the disease was severe in the experimental plots. The resistance observed was thus field resistance controlled by minor genes. Canizares and Forbes (1995) made similar conclusions in their study of the reaction of *Solanum phureja* sub-species *phureja* Juz and Buk to *Phytophthora infestans.* This is the preferred type of resistance as many years of practical experience has shown that race-specific, mostly mono-genically inherited resistance which is expressed as a hyper-sensitive reaction is not durable (Umaerus and Umaerus, 1994). Our results, however, do not exclude the possibility of presence of major genes along with minor genes for resistance to late blight in the accessions tested (Swiezynski *et al.*, 1991). It is rather difficult to separate specific and general resistance to *Phytophthora infestans* (Colon and Budding, 1988: Gees and Hohl, 1988; Turkensteen, 1989).

The results presented in Tables 3-5 showed that there was no relationship between resistance to late blight and performance for tuber yield and its components. Many accessions having more resistance than Kufri Jyoti, were inferior to Kufri Jyoti for tuber yield and its components. A similar situation has also been reported by Swiezynski *et al.* (1991). Such accessions though not suitable for commercial exploitation, can be exploited in breeding programmes to produce progenies with resistance to late blight and some segregants among them may yield higher than Kufri Jyoti as gene action for tuber yield is known to be predominantly non-additive (Gopal, 1998a). Accessions having high tuber yield but susceptible to late blight (*e.g.* CP3157) can also be used in potato breeding programmes by crossing them as females with late blight resistant males as high yielding females may result in high yielding progenies (Gopal, 1998b) and males may contribute to late blight resistance of such progenies (Jellis, 1992; Stewart *et al.*, 1994).

Though most of the exotic accessions were either inferior or at par with Kufri Jyoti, a few accessions were better and had all the desired attributes *i.e.* resistance or moderate resistance to late blight, significantly higher yield than Kufri Jyoti and at par or better than Kufri Jyoti for tuber number and average tuber weight. These were CP1673, CP1690, CP2110, CP2378, CP2415, CP3098, CP3127, and CP3250. Except CP2415, which had pink tubers all these accessions had white tubers with acceptable tuber shape, eye depth, and uniformity. These accessions, however, need to be tested in large scale multilocation trials to pick up a few best for commercial cultivation.

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