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Screening of potato genotypes against *Phytophthora infestans* causing late blight of potato under subtropical plains of India

Mehi Lal*, S.K. Luthra, V.K. Gupta and Manoj Kumar

ICAR-Central Potato Research Institute, Regional Station, Modipuram 250 110, Uttar Pradesh

ABSTRACT

The late blight disease caused by *Phytophthora infestans*, is a serious concern to potato cultivation in the world. The varietal resistance is cheapest and environment- friendly option to manage this disease. A total of twenty eight (11 exotic and 17 indigenous) advanced potato hybrids along with nine control varieties namely Kufri Bahar, Kufri Badshah, Kufri Girdhari, Kufri Jyoti, Kufri Pukhraj (white skin) Kufri Arun, Kufri Lalima, Kufri Lalit, Kufri Sindhuri (red skin) were evaluated during two consecutive crop seasons (2015-16 & 2016-17) for resistance against late blight disease. Based on field evaluation (AUDPC values) exotic advanced hybrids CP4401 (11.62), CP4386 (32.49) and CP4403 (55.84) were graded highly resistant. Two indigenous advanced hybrids i.e. MCIP/12-185 and MS/12-935 were resistant and six advanced hybrids were moderately resistant, while remaining 17 advanced hybrids (AUDPC>375) were susceptible against cv. Kufri Bahar (AUDPC-1002.26). The mean rAUDPC values of evaluated advanced stage hybrids, ranged from 0.01 to 0.35 as against highly susceptible cv. Kufri Bahar (0.48). In laboratory detached leaf test, advanced hybrid CP4386 was highly resistant, whereas two advanced hybrids i.e. CP4403 & MCIP/12-185 were resistant and eight were moderately resistant remaining 17 were susceptible for foliar blight while fifteen advanced hybrids were moderately resistant and remaining were susceptible as ascertained through tuber slice method. Foliage resistance, tested under laboratory condition using detached leaf test and field condition did not establish close relationship. The expression of late blight in foliage and tuber were not closely related.

Key words: *Solanum tuberosum*, resistance, foliage, tuber.

INTRODUCTION

The late blight caused by notorious oomycete pathogen *Phytophthora infestans* (Mont.) de Bary, is an important disease of potato and tomato crops. It is one of the most destructive diseases of potato and results in yield losses up to 95% on susceptible varieties in epidemic conditions. In India, the late blight causes up to 10-15% yield loss of potato on over all basis (Lal *et al*., 5). The potato yield loss caused by late blight disease can be minimized using different management strategies i.e. cultural, biological, chemical control and varietal resistance. Chemical control is more common for management of late blight, due to frequent and indiscriminate application of systemic fungicides over the years, create resistance to the pathogen and subsequently emergence of new highly virulent races. Moreover, at elevated temperature fungicides may degrade and their effectiveness could be reduced against late blight of potato (Yadav *et al*., 17). Varietal resistance had always been a better option than the fungicides application, because it is environmental friendly. The high tuber yield, desirable tuber attributes, good keeping quality and moderate level of resistance to late blight (*P. infestans*) are the selection criteria for varietal improvement (Luthra *et al*., 7). For sustainable management late blight of potato, the demand of late blight resistant varieties are always high by the farmers due to it is cheaper than other management strategies. At an estimated 5% infected leaf area per field, the potato haulm has to be destroyed to prevent spread to neighbouring fields, under Dutch government policy for regulation of maximum late blight thresh hold (PA, 9). The annual crop losses along with money spent on fungicides for management of late blight of potato is exceeds more than one trillion US dollar (Majeed *et al*., 8). To progress towards cultivation of organic potato and awareness of environmentalist and consumers, it will be better to minimize the use chemicals or no use of chemicals as a long term strategies. So that we can produce potatoes with a recommended limit of the fungicides residues or fungicides free. At beginning of the twentieth century, breeding for resistant cultivars had been initiated; when the first resistant genes (R-genes) were discovered in the closely related species *Solanum demissum*.

The resistance is governed by mono and polygenic inheritance. It will be always better if we could develop a variety with polygenic inheritance that could counteract against many races of *P. infestans*. Host resistance in late blight can be of two types i.e. foliage

*Corresponding author's Email: mehilalonline@ gmail.com

and tuber resistance. Foliage resistance gives better protection in the field and reduced the chances of yield losses under epidemic condition while tuber resistance minimizes infection of the tubers and also reduces the losses under storage condition. The *P. infestans* is enabled to penetrate a healthy tuber periderm, which subsequently affect the yield and quality and decrease storability by facilitating secondary infections. Moreover, an estimated economic losses > 1 to 3 million dollars were reported in past years, due to tuber rot caused by *P. infestans* in storage facilities in the Columbia Basin of Washington and Oregon (Johnson *et al*., 3). *P. infestans* is polycyclic in nature and completes many cycles in a crop season. Thereby, many number spores are present in the crop season. It changes its pathogenic behavior, forms new race complexes and adapts to new environment very soon. Consequently, host resistance of a variety is run down over the years due to appearance of matching virulent races. Therefore, it is essential to evaluate wide range of genotypes against *P. infestans* for both tuber and foliage resistance.

MATERIALS AND METHODS

A total of twenty eight (11 exotic and 17 indigenous) advanced potato hybrids along with nine control (five white colour and four red) varieties namely Kufri Bahar, Kufri Badshah, Kufri Girdhari, Kufri Jyoti, Kufri Pukhraj (white skin) Kufri Arun, Kufri Lalima, Kufri Lalit, Kufri Sindhuri (red skin) were evaluated during two consecutive crop seasons (2015-16 & 2016-17) for late blight resistance at ICAR-Central Potato Research Institute, Regional Station, Modipuram Meerut (29.1° N, 77.92° E, 300 masl). The genotypes were planted in the first week of November every year in the plot size of 3 × 3m^2 keeping 60×20 cm row plant distances using three replications for each genotype. The crop was raised following the standard agronomic practices (180N, 80P, & 100 K kg /ha) of the regions without any application of fungicides. The artificial inoculation of *P. infestans* (zoospore suspension 6 × $10^{4\text{-}1}$ ml) was done in infector rows for initiation and spread of disease. The sprinkler system was installed at field and initially minimum two times' sprinkled the crop in a day for maintaining proper congenial condition of disease development and spread. Disease severity was recorded at regular interval according to Henfling (2), after appearance of the disease on the cv. Kufri Bahar (Highly susceptible) till it was completely killed. The disease severity was converted into area under the disease progress curve (AUDPC) according (Shanner and Finney, 13). The relative AUDPC (rAUDPC) were also calculated (Perez and Forbes, 11).

For evaluation of foliage resistance to late blight in laboratory, fourth leaf from the top of plant was plucked from each genotype and challenge inoculated with *P.infestans* (Mating type A1, Metalaxyl resistant, Race1.2.3.4.5.6.7.8.9.10.11) using filter-paper discs (0.3 cm^2) pre-dipped into the zoospore suspension (6 × 10^4 ml^{-1}). The inoculated leaves with five replications for each genotype were incubated at 18 ± 1°C and 85% RH in growth chamber for five days and lesion area was measured. The genotypes were grouped based on lesion area (cm^2): up to 1.0- Highly resistant (HR); 1.1 to 2.5- Resistant (R); 2.51-5.0- Moderately resistant (MR); and > 5.0 –Susceptible (S) (Singh, 16).

For estimation of tuber resistance, tubers of genotypes were tested after harvesting using tuber slice method. In this method tubers were initially surface sterilized with ethyl alcohol (95%.con) followed by cutting the thick slices (1.0 cm) aseptically after that each genotype were challenge inoculated with *P. infestans* (Mating type A1, Metalaxyl resistance, Race1.2.3.4.5.6.7.8.9.10.11) using filter-paper discs (0.3 cm^2) pre-dipped into the zoospore suspension (6 × 10^4 ml^{-1}). The inoculated tuber slice with three replications for each genotype were incubated at 18 ± 1°C and 85% RH in growth chamber for five days and lesion area was measured. The lesion area (cm^2) was measured and the genotypes were grouped into highly resistant (up to 1.0), resistant (1.1-2.5), moderately resistant (2.51-6.0) and susceptible (>6.0). Co-relation coefficient between AUDPC and rAUDPC, AUDPC and detached leaf, foliar and tuber blight resistance were calculated. The experimental data were analyzed with the help of IRRISTAT software (version 4.4.20030719).

RESULTS AND DISCUSSION

The results revealed that advanced potato hybrids showed different levels of resistance to *P. infestans.* All advanced hybrids showed less AUDPC compared to highly susceptible cv Kufri Bahar. On the basis of mean (2015-2017) AUDPC data, minimum AUDPC was recorded in CP4401 (11.62) and highest was in MS/12-2116 (740.78) as against cv. Kufri Bahar (1002.26), Kufri Pukhraj (749.66), Kufri Jyoti (662.00), Kufri Sindhuri (557.87), Kufri Badshah (470.50), Kufri Lalima (437.04), Kufri Lalit (393.36), Kufri Arun (370.09) and Kufri Girdhari (18.34). Therefore, three exotic advanced hybrids i.e. CP4401 (11.62), CP4386 (32.49), CP4403 (55.84) were graded highly resistant (AUDPC up to 75.00). Two advanced hybrids i.e. MCIP/12-185 and MS/12-935 were resistant (AUDPC 75.10 to 150) and six advanced hybrids including four exotic hybrids viz., CP4395, CP4389, MS/12-636, CP4404, CP4393 and MS/12-1283 (AUDPC 150.10 to 375) were moderately resistant, while remaining 17 advanced hybrids (AUDPC > 375) was susceptible (Table 1). The mean rAUDPC values of evaluated advanced stage hybrids ranged from 0.01 to 0.35 (Table 1) as against highly susceptible cv Kufri

Bahar (0.48) and known late blight resistant varieties i.e. Kufri Girdhari (0.01). It was also observed that among the red skin colour control varieties, lowest AUDPC was in Kufri Arun while in white skin colour in Kufri Girdhari.

Table 1. Screening of advanced stage hybrids against late blight under field conditions during 2015-2017.

Sl. No.	Hybrid	Foliage resistance in field					
		*AUDPC		Mean	**rAUDPC		Mean
		2015-16	2016-17		2015-16	2016-17	
1	CP4386	9.73	55.25	32.49	0.00	0.03	0.01
2	CP4388	389.03	596.33	492.68	0.19	0.27	0.23
3	CP4389	60.20	528.17	294.19	0.03	0.24	0.14
4	CP4393	238.33	484.95	361.64	0.12	0.22	0.17
5	CP4395	53.57	458.83	256.20	0.03	0.21	0.12
6	CP4397	395.67	596.78	496.23	0.20	0.27	0.24
7	CP4398	544.38	748.67	646.53	0.27	0.34	0.31
8	CP4401	16.07	7.17	11.62	0.01	0.00	0.01
9	CP4403	10.25	101.42	55.84	0.01	0.05	0.03
10	CP4404	160.52	466.00	313.26	0.08	0.21	0.15
11	CP4406	173.43	648.83	411.13	0.09	0.30	0.19
12	MCIP/10-15	443.13	569.92	506.53	0.22	0.26	0.24
13	MCIP/11-118	418.55	576.85	497.70	0.21	0.26	0.24
14	MCIP/11-163	457.08	640.58	548.83	0.23	0.29	0.26
15	MCIP/12-47	454.00	625.75	539.88	0.23	0.28	0.26
16	MCIP/12-185	74.75	116.92	95.84	0.04	0.05	0.05
17	MCIP/12-286	195.80	590.25	393.03	0.10	0.27	0.18
18	MCIP/12-453	337.00	480.00	408.50	0.17	0.22	0.19
19	MS/11-664	357.77	558.75	458.26	0.18	0.25	0.22
20	MS/11-938	568.93	635.58	602.26	0.28	0.29	0.28
21	MS/11-1123	344.58	702.27	523.43	0.17	0.32	0.24
22	MS/12-636	91.83	500.92	296.38	0.05	0.23	0.14
23	MS/12-655	406.00	703.93	554.97	0.20	0.32	0.26
24	MS/12-682	555.03	360.92	457.98	0.28	0.16	0.22
25	MS/12-935	79.33	192.42	135.88	0.04	0.09	0.06
26	MS/12-1283	169.33	573.00	371.17	0.08	0.26	0.17
27	MS/12-2116	659.38	822.17	740.78	0.33	0.37	0.35
28	MS/12-2241	364.82	634.92	499.87	0.18	0.29	0.23
29	Kufri Arun	342.93	397.25	370.09	0.17	0.18	0.18
30	Kufri Badshah	-	470.50	470.50	-	0.21	0.21
31	Kufri Bahar	905.35	1099.17	1002.26	0.45	0.50	0.48
32	Kufri Girdhari	28.15	8.53	18.34	0.01	0.00	0.01
33	Kufri. Jyoti	588.25	735.75	662.00	0.29	0.33	0.31
34	Kufri.Lalima	303.82	570.25	437.04	0.15	0.26	0.20
35	Kufri Lalit	260.97	525.75	393.36	0.13	0.24	0.18
36	Kufri Sindhuri	396.57	719.17	557.87	0.20	0.33	0.26
37	Kufri Pukhraj	572.40	926.92	749.66	0.29	0.42	0.36
$CD_{(0.05)}$		187.09	251.72		0.94	0.11	

*AUDPC: Area Under Disease Progress Curve, **rAUDPC: Relative Area Under Disease Progress Curve-Observation not recorded

The results of detached leaf test showed that the exotic advanced hybrid CP4386 (0.56 cm^2) was highly resistant. Whereas two advanced hybrids i.e. CP4403, MCIP/12-185 were resistant (lesion area between 1.1 to 2.5 cm^2). The eight advanced hybrids viz., CP4393, CP4401, CP4404, MCIP/10-15, MCIP/11-163, MCIP/12-286, MS/11-1123 and MS/12-655 were moderately resistant (lesion area between 2.51 to 5.0 cm^2). The remaining 17 advanced hybrids along with control cv. Kufri Bahar with lesion area more than 5.0 cm^2 were susceptible (S) to late blight (Table 2).

A lower AUDPC value indicates higher level of resistance. Low values of rAUDPC have low infection level during the period of evaluation and therefore correspond to more resistant varieties (Perez and Forbes, 11; Lal *et al*., 6). Foliage resistance tested under laboratory and field conditions did not establish a close relation because in laboratory, ideal temperature and humidity were maintained with a fixed amount of inoculum load, while in field conditions, inoculum load and weather may be variable. Under field condition one year may be extreme humidity due to high rainfall, while in other year may be low humidity due to existing weather conditions. A technique developed for laboratory estimation of field resistance to late blight for screening of resistant genotypes. It was reported that the ranking of the genotypes with almost similar level of resistance in laboratory was not exactly the same as obtained in the field (Singh and Birhman, 15). Similarly, the greenhouse screening is also have limitation that the controlled environment may not adequately mimic the complexities of a field trial. Consequently, level of resistance may not correlate strongly with the greenhouse studies (Simko *et al.,* 14). In present study the resistant advanced hybrids were less under laboratory test than the field condition. Similar observation also observed by Kaushik *et al*. (4) that the numbers of resistant accessions were less in detached leaf test because the most complex race was used in challenge inoculation and inoculum load was also high compared to field conditions. The laboratory and greenhouse assays cannot replace the value of evaluating germplasm for foliar resistance to late blight under field conditions (Dorrance and Iglis, 1). Under field condition, the hybrids are exposed against *P. infestans* in natural environment with all existing climatic factors (temperature, humidity, light and precipitation etc.) and hybrids tries to fend off from pathogen attack while pathogen tries to dominate on the hybrids. Therefore, no substitute is available to replace field evaluation system with laboratory/greenhouse system for evaluation of hybrids against late blight. However, laboratory results may be taken as initial information in the form of resistance to screen initial population of hybrids.

The *P. infestans* is a hemibiotrophic infect both foliage and tubers of potato. Moreover, it perpetuates from one season to another mainly through infected tubers. However, wherever both mating types (A1& A2) are existing, they may be survive in the form of oospores, which is thick walled structure and can initiate infection in the congenial environment. The infected tubers are sole source for spreading of the disease in the new areas where disease has not been reported yet. Wherever, foliar infection occurs in the field during crop season along with rain fall, the risk of tuber infection is very high that could affect the tubers yield. Therefore, late blight resistance in tuber becomes an important attributes for screening of potato genotypes for tuber resistance. Late blight screening based on tuber slice method, results revealed that none of the hybrids was highly resistant and resistant; however, fifteen advanced hybrids including four exotic CP4386, CP4395, CP4397, CP4406, MCIP/10-15, MCIP/11-118, MCIP/11-163, MS/11-664, MS/11-938, MS/12-636, MS/12-655, MS/12-682, MS/12-935, MS/12-1283 and MS/12-2116 along with control cv. Kufri Girdhari with lesion area between 2.51 to 6.0 cm^2 were moderately resistant. Remaining 13 advanced hybrids along with control cv. Kufri Bahar with lesion area above 6.0 cm^2 were found susceptible to late blight in tubers (Table 2).

Co-relation coefficient between AUDPC and rAUDPC was high (1.00). It may be due to rAUDPC is highly correlated with AUDPC. Moreover, rAUDPC is dependent on AUDPC. Co-relation coefficient between AUDPC and detached leaf was low 0.64. Co-relation coefficient between AUDPC and tuber resistance was 0.21. Similarly, no co-relation coefficient between detached leaf and tuber resistance was observed. At present study, foliar resistance (AUDPC & detached leaf) and tuber resistance (tuber slice) was less correlated. Various workers have also reported that the expression of resistance in tubers and leaves is not closely related (Park *et al*., 10). However, Porter *et al*. (12) reported that some of potato clones demonstrating high stable partial tuber resistance to *P. infestans* at Washington and Wisconsin had also demonstrated high foliar to moderate foliar resistance in previous field or greenhouse trials.

In conclusion, the foliage resistance, tested under laboratory condition using detached leaf test and field condition did not establish close relationship. The expression of late blight in foliage and tuber were not closely related. The hybrids namely CP4401, CP4386, CP4403 MCIP/12-185 and MS/12-935 possessed high level of foliar resistance to late blight and fifteen hybrids i.e. CP4386, CP4395, CP4397, CP4406, MCIP/10-15, MCIP/11-118, MCIP/11-163 MS/11-664, MS/11-938, MS/12-636, MS/12-655, MS/12-682, MS/12-935, MS/12-1283 and MS/12-2116 possessed moderate level of resistance to tuber. Advanced hybrids viz., MS/11-664, MS/12-2116, MCIP/12-185

Table 2. Screening of advanced stage hybrids against late blight through detached leaf and tuber slice method under laboratory conditions during 2015-2017.

Hybrid	Detached leaf lesion area (cm^2)				Tuber slice lesion area (cm^2)			
	2015-16	2016-17	Mean	Grade	2015-16	2016-17	Mean	Grade
CP4386	0.43	0.68	0.56	HR	5.72	3.40	4.56	MR
CP4388	5.51	5.34	5.43	S	11.06	9.16	10.11	S
CP4389	5.82	5.10	5.46	S	6.80	-	6.80	S
CP4393	4.07	4.39	4.23	MR	0.00	8.33	8.33	S
CP4395	6.44	5.23	5.84	S	0.00	3.47	3.47	MR
CP4397	4.28	5.80	5.04	S	4.58	5.89	5.24	MR
CP4398	5.63	5.23	5.43	S	7.22	5.69	6.46	S
CP4401	3.69	3.66	3.68	MR	5.42	8.70	7.06	S
CP4403	1.22	2.09	1.66	R	10.47	8.90	9.69	S
CP4404	1.87	4.71	3.29	MR	9.16	6.08	7.62	S
CP4406	6.47	5.56	6.02	S	4.45	6.54	5.50	MR
MCIP/10-15	5.00	2.48	3.74	MR	0.00	4.32	4.32	MR
MCIP/11-118	6.55	7.07	6.81	S	2.00	3.14	2.57	MR
MCIP/11-163	2.13	6.08	4.11	MR	-	3.14	3.14	MR
MCIP/12-47	6.90	6.28	6.59	S	6.02	10.53	8.28	S
MCIP/12-185	0.49	2.29	1.39	R	6.63	5.63	6.13	S
MCIP/12-286	3.95	4.67	4.31	MR	9.29	11.51	10.40	S
MCIP/12-453	7.42	5.02	6.22	S	1.58	4.19	2.89	MR
MS/11-664	4.19	6.28	5.24	S	1.96	7.65	4.81	MR
MS/11-938	-	-	-	-	6.07	-	6.07	S
MS/11-1123	2.19	4.78	3.49	MR	6.54	6.21	6.38	S
MS/12-636	6.92	5.36	6.14	S	4.97	5.76	5.37	MR
MS/12-655	2.68	5.30	3.99	MR	2.98	8.44	5.71	MR
MS/12-682	5.40	7.39	6.40	S	3.82	6.35	5.09	MR
MS/12-935	6.02	4.57	5.30	S	0.00	3.21	3.21	MR
MS/12-1283	5.50	7.92	6.71	S	6.70	4.58	5.64	MR
MS/12-2116	9.21	5.91	7.56	S	6.80	4.32	5.56	MR
MS/12-2241	3.63	9.62	6.63	S	7.46	-	7.46	S
Kufri Arun	6.97	5.56	6.27	S	0.00	5.76	5.76	MR
Kufri Badshah	-	3.52	3.52	MR	0.00	8.11	8.11	S
Kufri Bahar	8.89	9.42	9.16	S	11.25	9.16	10.21	S
Kufri Girdhari	2.50	1.57	2.04	R	2.86	2.88	2.87	MR
Kufri Jyoti	5.70	9.42	7.56	S	5.30	5.95	5.63	MR
Kufri Lalima	3.56	5.23	4.40	MR	8.70	5.63	7.17	S
Kufri Lalit	6.67	5.63	6.15	S	5.82	-	5.82	MR
Kufri Sindhuri	3.64	4.18	3.91	MR	6.15	7.00	6.58	S
Kufri Pukhraj	4.47	-	4.47	MR	6.51	6.74	6.63	S
$CD_{(0.05)}$	0.51	2.69			3.73	2.85		

Grading for detached leaf method: Lesion area (cm^2) Up to 1.0-Highly resistant (HR); 1.1 to 2.5-Resistant (R); 2.51-5.0-Moderately resistant; (MR) > 5.0–Susceptible (S).

Grading for tuber slice method: Lesion area (cm^2) Up to 1.0-Highly resistant (HR); 1.1 to 2.5-Resistant (R); 2.51-6.0-Moderately resistant (MR) > 6.0–Susceptible (S); -Observation not recorded.

and CP4393 are in multi-location evaluation trials under All India Coordinated Research Project on Potato (AICRP-P). After successful evaluations some of the hybrids may become popular variety in coming years. Moreover, some advanced hybrids with late blight resistance can be used as a parent for further breeding programme for late blight management as well as enhancing the potato production.

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