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Testing efficacy of different SAR compounds against late blight pathogen on various germplasm lines of potato

Astha and P. S. Sekhon
Department of Plant Pathology, Punjab Agricultural University, Ludhiana– 141 004, Punjab, India
Corresponding author Email: astha-asr@pau.edu
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ABSTRACT

Twenty potato cultivars/germplasm lines having variable degree of susceptibility to *Phytophthora Infestans* (Mont.) De By. pathogen were screened during 2015, 2016 and 2017 cropping seasons for reaction to late blight. Attempts were made to induce systemic acquired resistance (SAR) against the pathogen through application of SAR elicitors Jasmonic acid (JA), Salicylic acid (SA) and Benzothiadiazole (BTH) @ 500µM and Beta Amino butyric acid (BABA) @ 50 mM. The SAR elicitors were sprayed on three-week-old sprouts and their effect on defence related proteins and disease severity was studied. Leaf samples were collected up to 7 days post treatment and used for estimation of total proteins. Sporangial solution (4.0 x 104 sporangia per mL) was sprayed after one week of elicitors spray. Per cent disease severity was recorded at 14 days post inoculation. SA , JA, BTH and BABA increased total soluble proteins in sprayed as well newly emerged unsprayed leaves indicating systemic induction of defense. Mean maximum protein content i.e. 7.1 mg/g FW was highest in both SA treated; MS/6 1947 and Kufri Khayati followed by 6.9 mg/g FW in Garima and 6.8 mg/g FW in Kufri Jyoti. Maximum disease control of 82.09 % was observed in SA treated foliage of MS/6 -39 followed by MS/6 1947 with disease control of 81.28 %. SA treatment gave per cent disease control of 75.43, 77.07, and 77.29 in Kufri Badshah, Kufri Jyoti and Kufri Pukhraj, respectively. Minimum per cent disease control of 50.15 was observed in BTH treated variety Garima after 14 days of inoculation. Foliar application of SA was most effective followed by JA, BABA and BTH. The response to elicitors was higher in moderately resistant variety but susceptible variety also showed decrease in disease severity after elicitor spray. Integration of disease tolerance and elicitor spray thus proved effective against *P. infestans* in potato.

Keywords: *Phytophthora infestans*, foliar spray, salicylic acid (SA), jasmonic acid (JA), benzothiadiazole (BTH), and Beta amino butyric acid (BABA), PR- proteins, disease severity.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is fourth most important food crop of the world after wheat, rice and corn. Late blight of potato caused by an oomycetous fungus, *Phytophthora infestans* (Mont.) De By., is the major decimator of potato cultivation costing over 12 billion USD losses worldwide (Haverkort *et al*., 2008). Late blight completely blightens the plants within three weeks of the first visible infections, if no control measures are taken (Lacy and Hammerschmidt, 1995). Late blight has tremendous potential to cause up to 80% reduction in the yield in susceptible varieties of potato. All the commercial varieties of potato cultivated in Punjab state of India are moderate to highly susceptible to late blight. Moreover, host resistance to *P. infestans* is not generally stable due to development of new multigene races of the pathogen. Therefore, fungicides play an important role in disease management. In India, Metalaxyl resistant strains of *P. infestans* were also reported (Arora *et al*., 1992; Thind *et al*., 2001; Kaur *et al*., 2010). To date, Mancozeb and Ridomil gold, fungicides are commonly used to control potato late blight in India. However, concerns have been raised about their long-term use related to impacts on human health and the environment. New approach of disease control like the application of signalling molecules, i.e. Jasmonic acid, Salicylic acid and Beta Amino butyric acid, *etc* is a new promising way of disease management. These are found to induce systemic acquired resistance (SAR) against various pathogens in many crops by activating various genes coding for PR-proteins e.g. β -1,3-glucanase (PR-2), chitinase (PR-3), thaumatin like and osmotin-like proteins (PR-5), peroxidase (PR-9) and a number of other proteins in stress conditions (Enkerli *et al*., 1993). According to Durrant and Dong (2004) SAR is a mechanism of induced defense that vest in long lasting protection against broad spectrum of pathogens. SAR can be stimulated upon contact with pathogens itself, pathogen associated molecular patterns (PAMPs) (Wurms *et al*., 1999) and with application of natural or synthetic elicitors (via foliar, root or seed treatments) like Salicylic acid (SA), Jasmonic acid (JA), Benzothiadiazole, Beta Amino Butyric Acid, Hydrogen peroxide, Oligosaccharides (Chitosan) (Garcia *et al*., 2013). Therefore, along with preformed barriers and constitutively expressed antimicrobials, plant's own defence mechanism can be exploited by means of systemic acquired resistance for control of diseases (Ryals *et al*., 1996). Exogenous application of SA, or of its functional analogues 2, 6-dichloroisonicotinic acid (INA) and acibenzolar-S-methyl (ASM), can activate PR gene expression and resistance in plants without pathogen inoculation (Edreva, 2005; Van Loon *et al*., 2006).

Therefore, the present study was conducted to screen various germplasm lines of potato to assess their level of resistance for late blight and study the effect of SAR inducers like Salicylic acid (SA), Jasmonic acid (JA), Benzothiadiazole (BTH), and Beta Amino Butyric Acid (BABA), on defense related proteins and disease severity.

MATERIALS AND METHODS

Twenty potato cultivars/germplasm lines having variable degree of susceptibility to *P. infestans* pathogen were selected for conduct of experiments; which were obtained from the Department of Vegetables, Punjab Agricultural University, Ludhiana. All these lines were screened for disease development and evaluated for resistance induced by elicitors used.

Sowing of crop and testing of different doses of elicitors: The selected varieties of potato were raised in rows and replicated thrice using standard package of practices in the month of October with plot size of 2 X 3m. Different

concentrations of elicitors used as spray (Prepared in double distilled water) are Jasmonic acid (JA), Salicylic acid (SA) and Benzothiadiazole (BTH) @500µM and Beta Amino butyric acid (BABA) @ 50 mM. These doses were sprayed on three-week-old sprouts using an atomizer. Water sprayed plants of corresponding genotypes were kept as control. All the chemicals and solvents used in present investigation were of analytical grade (Sigma Aldrich).

Collection of plant tissue samples: Periodical potato leaf sampling was done after 24, 48, 72, 96, 120, 144 hrs and at weekly intervals after elicitors spray. Samples were brought to the laboratory under refrigerated conditions and were stored at -80°C in deep freezer to prevent denaturation of proteins. Fresh newly emerged leaves were sampled after one week of spray to study systemic induction of resistance.

Estimation of total soluble proteins (Lowry *et al.*, 1951): Leaf tissue (0.5 g) was weighed and was homogenized in 25 mM Tris HCl buffer (pH 8.0) in a precooled pestle and mortar on the ice bath and centrifuged at 10,000 rpm for 25 minutes at 40C. Supernatant was used for protein estimation. To 0.1 mL of the protein extract added 0.9 mL of distilled water. Then 5 mL of reagent (2% Sodium carbonate in 0.1N Sodium hydroxide and 5% Copper sulphate in 1% Sodium potassium tartarate, mixed in ratio of 50:1) was added and properly mixed. After 10 min, 0.5 mL of Folin Ciocalteau reagent was added, mixed and kept for 30 min at room temperature. The intensity of blue color developed was then read at 520 nm against a reagent blank. Bovine serum albumin (BSA) standards (20-100 mg) were also run along with the test samples and the concentration of protein was calculated from the standard curve of BSA. Tissue was sampled from at least three leaves.

Multiplication of *P. infestans*: The inoculum of *P. infestans* was multiplied by detached leaf technique (Thind *et al.*, 1989). Detached leaves of potato were thoroughly washed with tap water, then were air dried and placed in plastic trays measuring 45 X 50 cm lined with moist blotting paper. The leaves were inoculated with optimum level of sporangial suspension, i.e. 4.0 x 104 sporangia per mL. Hand atomizer was used to spray the leaves kept in tray and were incubated in growth chamber at 20-220° C, photoperiod 12 hr with fluorescent tubes generating light intensity of 2000 Lux. Profuse growth of whitish mycelium with sporangia and sporangiophores was visible after 10 days of incubation.

Preparation of sporangial suspension: Fresh sporulations of *P. infestans*; sporangial solution at approximate concentration of approx. 4.0 x 104 sporangia per mL were prepared by dislodging sporangia from sporulating leaves in double distilled water and used for inoculations in experiments.

Determination of disease severity: After one week of elicitor spray sporangial solution of *P. infestans* was prepared by detached leaf technique (Thind *et al.*, 1989) and this solution at conc. of 4.0 x 104 sporangia per mL was sprayed on all varieties and germplasm lines using an atomizer to create disease. High relative humidity was maintained for next 72 hrs by spraying water. Observations on disease severity were recorded after 7 and 14 days and induction of proteins was biochemically correlated.

Disease severity: Calculated by using following formula

$$\text{Disease severity} = \frac{\text{Sum of numerical rating}}{\text{Total no of samples x Maximum of rating scale}} \text{ X } 100$$

Disease rating system for late blight of potato was done using scale given by Mohan and Thind (1998)

Rating/ disease score	Score description in terms of foliage infected (%)	Reaction
0	No visible symptoms	
1	1-10	Resistant (R)
2	10.1-25	Moderately Resistant (MR)
3	25.1-50	Moderately Susceptible (MS)
4	50.1-75	Susceptible (S)
5	>75	Highly susceptible (HS)

The data were analysed with CRD factorial ANOVA for lab data and RBD factorial ANOVA for field data using CPCS version 1.0. Dendrograms and biplot was made using Stat graphia and Past 3 softwares.

RESULTS AND DISCUSSIONS

Potato varieties/ germplasm lines screened against *P. Infestans*: During 2015, 2016 and 2017 cropping seasons, 20 lines/varieties of potato were screened against late blight. Out of 20 varieties/germplasm lines, seven lines showed susceptible reaction with per cent disease severity more than 50%. Eight varieties were moderately susceptible with per cent disease severity in range of 25 to 50%, whereas five varieties showed moderately resistant reaction with per cent disease severity in range of 10-25% , respectively. MS/6 1947 line gave maximum yield than all twenty varieties followed by Kufri Khayati and MS/6 -39. MS/5 1543 and Kufri Chipsona varieties were also good performer in terms of yield followed by Kufri Badshah and Kufri Jyoti (**Table 1 a & b**)

Table 1: Screening of potato varieties / hybrid against late blight of potato under artificial epiphytotic conditions

Sr. No.	Variety	Disease severity (%)			Mean	Yield of potato tubers per plot (2x3m) in kg	Reaction
		2015	2016	2017			
1	MS/6 1947	24.5	23.2	25.3	24.33	27.8	MR
2	Kufri Pukhraj	61.2	51.5	52.33	55.01	17.9	S
3	Kufri Pushkar	57.8	58.4	51.1	55.77	16.6	S
4	Kufri Jyoti	24.1	20.5	22.3	22.30	19.3	MR
5	MS/6 -39	36	35	38.6	36.53	23.6	MS
6	Kufri Chipsona	32.2	30.4	28.5	30.37	22.1	MS
7	Kufri Badshah	32.2	27.0	30.45	29.88	21.6	MR
8	K-3	52.33	55.32	50.1	52.58	16.3	S
9	Garima	24.5	25.3	24.3	24.70	23.3	MR
10	Chipsona 4	42.13	39.15	37.5	39.59	23.3	MS
11	Kufri Khayati	24.11	26.32	22.13	24.19	24.2	MR
12	Altantic	54.69	52.11	55.2	54.00	11.3	S
13	CR	66.23	62.11	63.2	63.85	9.3	S
14	MS/5 1543	36.56	31.87	35.6	34.68	22.8	MS
15	Kufri Frysona	31.12	32.15	36.5	33.26	17.7	MS
16	Kufri Himsona	42.23	36.82	42.1	40.38	16.30	MS
17	Chipsona 2	43.12	39.56	45.5	42.73	15.3	MS
18	Kufri Lauvkar	56.12	50.27	59.8	55.40	12.3	S
19	FC-3	61.57	54.15	56.6	57.44	11.3	S
20	MS/6-8/9	33.25	31.95	35.2	33.47	21.3	MS

Induction of defense related proteins: The data pertaining to changes in mean maximum protein (mg/g FW) recorded at

Table 2: Testing efficacy of selected elicitors in various potato genotypes for induction of defence protein in sprayed leaves and new leaves.

Total protein content (mg /g FW)											
Sr. No.	Variety	DDW		SA		JA		BABA		BTH	
		SL	USL	SL	USL	SL	USL	SL	USL	SL	USL
1	MS/6 1947	3.2	3.3	7.1	6.4	6.1	6.2	5.2	4.1	4.9	4.3
2	K Pukhraj	3.1	3.1	4.5	4.7	4.3	4.1	4.3	3.9	3.8	3.4
3	K Pushkar	2.9	3.1	4.2	3.7	3.8	3.8	4.2	3.9	3.6	3.3
4	K Jyoti	3.3	3.3	6.8	6.5	6.6	6.3	5.6	4.2	5.2	4.7
5	MS/6 -39	3.2	3.2	6.7	6.4	6.2	6.2	5.4	4.2	5.2	4.1
6	K Chipsona	1.9	2.0	5.2	4.5	4.7	4.6	4.4	3.9	3.8	3.5
7	K Badshah	3.1	3.1	6.4	6.3	5.9	5.8	5.3	4.1	4.7	4.4
8	K-3	2.9	3.0	4.6	4.7	4.4	4.2	4.2	3.5	3.3	3.3
9	Garima	3.3	3.4	6.9	6.7	6.2	5.2	5.4	4.3	5.0	4.5
10	Chipsona4	2.9	3.0	5.1	5.2	4.9	4.6	4.4	3.5	4.1	3.6
11	K Khayati	3.1	3.2	7.1	6.2	6.3	6.2	4.7	3.7	5.1	3.8
12	Altantic	3.3	3.3	6.3	6.1	6.1	5.9	4.8	4.0	4.6	4.0
13	CR	2.5	2.7	5.4	5.2	4.9	4.8	4.5	3.8	3.8	3.6
14	MS/5 1543	3.3	3.4	6.3	6.0	5.8	5.5	5.6	4.1	4.6	4.7
15	K Frysona	2.9	2.9	5.2	4.9	4.5	4.5	4.3	3.9	3.8	3.5
16	K Himsona	3.1	3.2	6.1	5.8	5.7	5.6	5.0	4.4	4.6	4.2
17	Chipsona2	2.8	2.9	5.1	4.5	4.8	4.5	5.1	4.0	4.0	4.2
18	K Lauvkar	2.7	2.8	4.6	4.1	4.5	4.2	4.4	3.8	4.1	3.5
19	FC-3	2.4	2.5	4.2	3.8	3.4	3.9	3.9	3.8	4.1	3.8
20	MS/6-8/9	3.1	3.1	5.6	4.6	4.4	4.1	4.3	3.9	4.5	4.1
CD (5%)	Elicitor (A) - 0.030; Variety (B) -0.061; Sprays (C) -NS ; AB - 0.13; AC -0.087; BC - 0.034; ABC- 0.19										
K- Kufri, SL- Sprayed leaves, USL- Unsprayed leaves/new leaves											

7 days interval in response to selected doses of JA, SA and BTH, i.e. at 500 µM and BABA at 50 mM, revealed statistically significant differences among the four elicitors applied on twenty different varieties of potato (**Table 2**). Mean maximum protein content, i.e. 7.1 mg/g FW was highest in SA treated; MS/6 1947 and Kufri Khayati followed by 6.9 mg/g FW in Garima and 6.8 mg/g FW in Kufri Jyoti. Both SA treated MS/6 1947 and Kufri Khayati showed 121 % increase in protein content as compared to control. Garima and Kufri Jyoti gave 109% increase in protein content. Systemic induction of protein in new leaves which were not sprayed directly was also observed. Systemic induction of mean maximum protein content in new leaves of potato variety Garima was observed at 6.7 mg/g FW followed by 6.5 and 6.4 mg/g FW in Kufri Jyoti and MS/6 1947. Systemic induction of proteins in Garima was 97 % higher than control and 96 % higher in case of Kufri Jyoti than control. Best protein induction was observed in case of SA treated plants followed by JA, BABA and BTH. Similar is the case with systemic induction of proteins in untreated, newly emerged leaves. Non-significant difference was observed between protein content of sprayed and unsprayed new emerged leaves; which indicates systemic induction of defence related protein in new leaves in all the elicitors used.

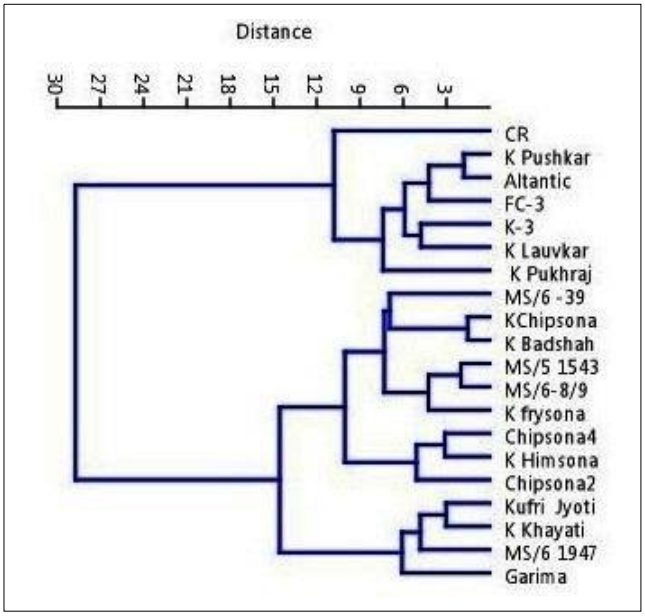

Fig 1: Dendrogram of potato varieties showing different clusters formed on basis of disease reaction and PR-protein induction.

Cluster Analysis which seeks to build a hierarchy of clusters was done and dendrogram was made where all observations start in one cluster, and splits are performed recursively as one moves down the hierarchy. As some varieties are close to one another according to one distance and farther away according to another (**Fig.1**). On top of hierarchy, CR, Kufri Pushkar, K-3 varieties which showed susceptible disease reaction along with bit lower protein induction can be observed. On lower side of hierarchy varieties like Kufri Khayati, Garima, MS/6 1947, Kufri Jyoti which revealed moderately resistant reaction as well as high protein content induction on elicitation with SAR inducers are present. Kufri Badshah joined separate cluster based on induced protein content.

Similarly, biplot graph was attempted for disease reaction of various germplasm lines as generalization of the simple two-variable scatter plot. Whose n rows are the varieties and whose p columns are the variables, i.e. disease severity during three consecutive years from 2015-2017, respectively (**Fig. 2**). All potato germplasm lines showed almost same reaction in three years. Varieties on left hand side gave moderately resistant reaction and moving towards right hand side reaction changes into susceptible response, where variety CR presents on extreme end.

Effect on disease severity: Twenty germplasm lines of potato were sown in three replications and after 21 days of sowing selected doses elicitors, i.e. JA, SA and BTH, *i.e.*, at 500 µM and BABA at 50 mM, were sprayed. After one week of elicitor treatment; plants were inoculated at optimum level of sporangial suspension, i.e. 4.0 x 104 sporangia per mL to create late blight disease and high relative humidity was maintained for next 72 hrs by spraying water. Per cent disease severity was worked out after 14 days of challenge inoculations (**Table 3**). Maximum Per cent disease control of 82.09% was observed in SA treated foliage of MS/6 -39 followed by MS/6 1947 with per cent disease control of 81.28 %. SA treatment gave per cent disease control of 75.43%, 77.07%, and 77.29% in Kufri Badshah, Kufri Jyoti and Kufri Pukhraj. Minimum per cent disease control of 50.15 was observed in BTH treated Garima cultivar. SA gave maximum per cent disease control followed by JA, BABA and BTH. Therefore, single spray of elicitors gave 50 to 82 % disease control of late blight disease. The response of moderately resistant variety was higher on treatment with SAR elicitors but susceptible variety also showed better response as is evident by decreased disease severity

Elicitors have induced defense related PR-proteins in potato

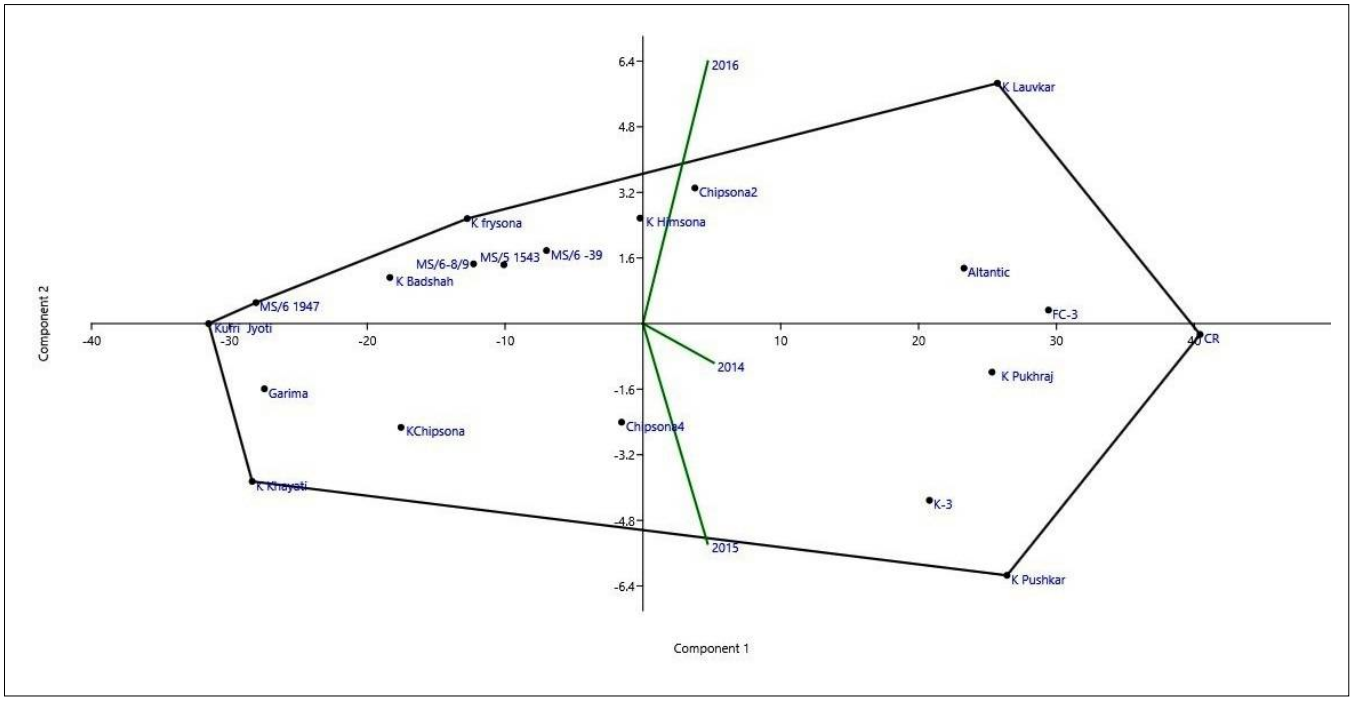

Fig 2: Biplot figure showing all potato varieties indicate that CR variety as most susceptible one and Garima, Kufri Jyoti and Ms/6 1947 on resistant side.

plants. The present study depicted that elicitation could be a promising strategy to control late blight of potato by priming plant own defense system with SAR inducers. The results obtained in present study are corroborated with findings of Gao and Zhang (2013) who, demonstrated that SA treatment showed the best effect on disease control in pear fruit against rot as it significantly induced activities of the enzymes β-1, 3-glucanase, PAL, PPO, and POD, which are type of PR proteins. An important common feature of most PR proteins (chitinase and glucanase) is their antifungal effect, with some also exhibiting antibacterial, insecticidal, nematicidal, and antiviral action (Van Loon *et al.*, 2006). Thaler *et al.* (2012) studied the influence of SA and JA against late blight of potato and studied the evolution of jasmonate and salicylate signal crosstalk. Complete control of late blight in tomato was

Table 3: Efficacy of selected elicitors in controlling late blight of potato after 14 days challenge inoculation of *P. infestans*

		% Disease severity								
Sr. No.	**Variety / Germplasm line**	**DDW**	**SA**	**% Disease control**	**JA**	**% Disease control**	**BABA**	**% Disease control**	**BTH**	**% Disease control**
1	MS/6 1947	24.36	4.56	81.28	5.79	76.23	6.02	75.28	6.55	73.12
2	K Pukhraj	55.04	12.50	77.29	13.73	75.06	16.00	70.93	16.53	69.97
3	K Pushkar	55.80	15.40	72.40	16.63	70.20	18.43	66.97	18.96	66.02
4	Kufri Jyoti	22.33	5.12	77.07	8.78	60.69	8.13	63.58	8.66	61.22
5	MS/6 -39	36.56	6.55	82.09	7.78	78.72	10.56	71.11	11.09	69.67
6	K Chipsona	30.40	8.46	72.17	9.69	68.13	9.70	68.08	10.23	66.35
7	K Badshah	31.86	7.83	75.43	8.48	73.39	9.25	70.97	10.15	68.13
8	K-3	52.61	13.50	74.34	14.73	72.00	21.77	58.62	22.30	57.62
9	Garima	24.73	6.32	74.45	7.55	69.47	11.80	52.28	12.33	50.15
10	Chipsona4	39.62	9.45	76.15	10.68	73.05	13.62	65.62	14.15	64.29
11	K Khayati	23.98	6.87	71.34	8.08	66.31	8.74	63.56	10.25	57.28
12	Altantic	54.57	14.70	73.06	15.93	70.81	19.03	65.12	19.56	64.16
13	CR	63.88	17.23	73.03	18.46	71.10	16.03	74.90	16.56	74.08
14	MS/5 1543	34.71	9.32	73.15	10.55	69.61	13.97	59.75	14.50	58.23
15	K frysona	33.29	10.33	68.97	11.56	65.28	11.77	64.64	12.30	63.06
16	K Himsona	40.41	11.42	71.74	12.65	68.70	14.41	64.34	14.94	63.03
17	Chipsona2	42.76	9.75	77.20	10.98	74.32	16.76	60.80	17.29	59.57
18	K Lauvkar	55.43	16.23	70.72	17.46	68.50	21.78	60.70	22.31	59.75
19	FC-3	57.47	17.45	69.64	18.68	67.50	18.03	68.62	18.56	67.71
20	MS/6-8/9	33.50	9.54	71.53	10.77	67.85	15.07	55.01	15.60	53.44
CD (5%)	Varieties (A)- 0.34 ; Elicitors (B)- 0.17; Interaction AB: 0.76									

reported with BABA, even when applied post- infection as reported by Cohen (2002). Induction of PR proteins, i.e. P14a and β-1, 3-glucanase was higher in BABA-treated tomato plants as compared with control plots. Kone *et al.* (2009) studied in greenhouse that SA applied as soil drench or foliar spray at 25 or 50µg mL^{-1} significantly reduced severity of disease caused by *Phytothphora capsici*, compared with control. Tian *et al*. (2005) demonstrated that pear fruits treated with various elicitors like SA, oxalic acid, calcium chloride, *etc.* significantly enhanced defence-related proteins activities such as β, 1-3 glucanase and reduced the disease incidence of *Alternaria alternata*. Benhamou and Belanger (1998) studied Benzothiadiazole-mediated induced resistance to *F. oxysporum* f. sp. *radicis-lycopersici* in tomato. They also reported induction of systemic acquired resistance to *Pythium* damping-off in cucumber plants by Benzothiadiazole. Oliviri *et al.* (2009) studied biochemical mechanisms by which BABA increases resistance against *P. infestans*, as well the effect of BABA on the activity of a potential pathogenic factor of *Fusarium solani*. Mostafa and Gado (2007) reported that the application of ethyl salicylic acid (ESA) and JA, reduces the disease severity compared to check against late blight of potato. The study of Aldesuquy (2015) supports our study by demonstrating that in *Vicia faba*, SA application increases the total soluble protein content against *Botryis* spp. Similar, results were observed in case of, tomato plant treated with JA and SA showed higher total soluble protein and free amino acid content compared to infected control plants with *Fusarium* wilt (El-Khallal, 2007). Agamy *et al.* (2013) reported that application of SA in tomato against leaf spot significantly increased total free proline and soluble protein contents than their healthy control. In the present study the response to elicitors was higher in

moderately resistant variety, *i.e.* Kufri Jyoti but susceptible variety like Garima also showed some response which is evident from decreased disease severity. Systemic induction of defense related protein in new unsprayed leaves was also at par with protein content of SA, JA, BABA and BTH sprayed leaves, which is important inference to indicate systemic induction of resistance in potato plants. Understanding how to boost levels of resistance in susceptible plants by pre-treatment with SAR inducing agents could be incorporated in disease management strategies.

CONCLUSION

In conclusion, it may be possible to, in certain cases, replace conventional chemical fungicides with any of the four elicitors especially with SA due to its safety for humans and environment and thus providing both economical and ecological efficacy. Thus, Integration of disease tolerance and elicitors spray proved effective against *P. infestans* in potato.

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Department of Vegetables science, Punjab Agricultural University, Ludhiana.

REFERENCES

Agamy, R., Alamri, S., Moustafa, M.F.M. and Hashem, M. 2013. Management of tomato leaf spot caused by *Alternaria tenuissima* using salicylic acid and Agrileen. *Int. J. Agric. Biol.* **15**: 266-272.

Aldesuquy, H.S. 2015. Shikimic acid and salicylic acid induced protection on growth vigor, seed yield and biochemical aspects of yielded seeds of *Vicia faba* plants infected by *Botrytis fabae*. *J. Pl. Pathol. Microb.* **69**: 65-78.

Arora, R.K., Kamble, S.S. and Gangawane, L.L.. 1992. Resistance to metalayxl in *P. infestans* in nilgiri hills of southern India. *Phytopathols newsletter* **18**: 8-9.

Benhamou, N. and Belanger, R.R. 1998. Induction of systemic resistance to *pythium* damping-off in cucumber plants by benzothiadiazole: ultrastructure and cytochemistry of the host response. *Plant J.* **14**:13–21.

Cohen, Y. 2002. β -Aminobutyric acid-induced resistance against plant pathogens. *Plant Dis.* **86**:448–457.

Durrant, W.E. and Dong ,X. 2004. Systemic acquired resistance. *Annu. Rev. Phytopathol.* **42**: 185-209.

Edreva, A. 2005. Pathogenesis-related proteins: research progress in the last 15 years. *General and Appl. Plant Physiol.* **31**:105-124.

El-Khallal, S.M. 2007. Induction and modulation of resistance in tomato plants against *Fusarium* wilt disease by bioagent fungi arbuscular mycorrhiza. and/ or hormonal elicitors jasmonic acid and salicylic acid.: Changes in growth, some metabolic activities and endogenous hormones related to defense mechanism. *Aust. J. Basic Appl. Sci.* **1**: 691-705.

Enkerli, J.U., Gisi E., and Mosinges. 1993. Systemic acquired resistance to *Phytophora infestans* in tomato and the role of pathogenesis-related proteins. *Physiol. Mol. Plant Pathol.* **43**: 161-171.

Gao, L. and Zhang, Y. 2013. Effect of Salicylic Acid on Pear Leaf Induced Resistance to Pear Ring Rot. *Appl. Sci. J.* **22**: 1534-1539.

Garcia-Mier L.,Guevara-Gonzalez R.G., Mondragon-Olguin V.M., Verduzco-Cuellar D. and Torres-Pacheco B.R. 2013. Agriculture and Bioactives: Achieving Both Crop Yield and Phytochemicals. *Int. J. Mol. Sci.* **14**: 4203–4222.

Haverkort, A.J., Boonekamp, P.M. , Hutten, R. Jacobsen, Lotz ELAP, Kessel G.J.T., Visser, R.G.F. and Van, E.A.G. 2008. Societal costs of late blight in potato and prospects of durable resistance through cisgenic modification. *Potato Res.* **51**: 47-57.

Kaur, R., Thind, T.S. and Goswami, S. 2010. Profiling of *P. infestans* populations for Metalaxyl resistance and its Management with novel action fungicides. *JB. Mycol. Pl.* **401**:14-21.

Kone, A.S., Csinos, K.L. and Jackson, P.J. 2009. Evaluation of systemic acquired resistance in plants and its inducers for control of *Phytophthora capsici* on squash. *Crop Protec.* **28**: 6533-6538.

Lacy, M.L. and Hammerschmidt, R. 1995. Diseases of potato late blight. *Extension bulletin* E-1802.

Lowry, O.H., Rosebrough, N.J., Furr, A.L. and Randal, R.J. 1951. Protein measurement with folin-phenol reagent. *J. Boil. Chem.* **193**: 265-275.

Mostafa, M.H. and Gado, E.A.M. 2007. Inducing resistance in potato plants against Late blight disease in relation to elicitation of Phytoalexins. *Egypt J. Phytopathol.* **35**: 11-22.

Olivieri, F.P., Lobato, M.C., Goozlez, E., Altamiranda, Daleo G.R., Huarte, M., Guevara, M.G. and Andrea, A.B. 2009. BABA effects on the behavior of potato cultivars infected by *P. infestans* and *Fusarium solani*. *Eur. J. PL. Pathol.* **123**:47-56.

Ryals, J.A., Neuenschwander, U.H., Willits, M.G., Molina, A. and Steiner, H.Y. 1996. Systemic acquired resistance. *Plant cell* **8**:439-450.

Thaler, J.S., Humphrey, P.T. and Whiteman, N.K. 2012. Evolution of Jasmonate and Salicylate signal crosstalk. *Trends Pl. Sci.* **17**:260-270.

Thind, T.S. and Mohan, C. 1998. Severity of late blight and assessment of yield losses in potato during 1997-98 epiphytotic in Punjab. *Plant Dis. Res.* **13**: 204-205.

Thind, T.S., Mohan, C., Sokhi, S.S. and Bedi, J.S. 1989. A detached leaf technique for maintenance and multiplication of *P. infestans* and evaluation of fungicides. *Current Sc.* **58**: 388-389.

Thind. T.S., Singh, L., Mohan, C. and Paul, J. 2001.

Monitoring for metalaxly resistance in populations of *P. infestans* and their characteristics in Punjab. *Indian phytopath.* **54**:91-97.

Tian, S., Wang, Y., Qin, G. and Xu, Y. 2005. Induction of defense against *Alternaria* rot by different elicitors in harvested pear fruit. *Appl. Pl. Microbial Biotechnol*. **78**:1-6.

Van Loon, L.C., Rep, M. and Pieterse, C.M. 2006. Significance of inducible defense-related proteins in infected plants. *Annu. Rev. Phytopathol*. **44**: 135-162.

Wurms, K., Labbe, C., Benhamou, N. and Belanger, R.R. 1999. Effects of Milsana and benzothiadiazole on the ultrastructure of powdery mildew haustoria on cucumber. *Phytopathology* **89**:728-36.