

Effect of different chemical inducers of systemic acquired resistance(SAR) for the management of late blight disease of potato

### **Abstract:**

Late blight of potato is one of the most devastating diseases with great economic importance. Among several disease management strategies, ISR(Induced systemic resistance) plays an important role in checking the disease spread. So, in the present study, nine different SAR chemical inducers viz. Phosphoric acid, Salicylic acid, Naphthalene acetic acid(NAA), Benzoic acid, Benzothiadiazole, Dichloro-iso nicotinic acid(INA),and Kinetin evaluated at 0.05%(C1),0.10%(C2) and 0.15%(C3) concentrations, whereas Calcium chloride and Ascorbic Acid at 3.5% (C1), 5.0% (C2), 6.5 % (C3) and 1.5 % (C1), 2.0% (C2), 2.5% (C3) respectively at three different concentrations each, along with positive and negative checks of standard fungicide metalaxyl 8+ mancozeb 64 WP @0.25% and control(water) respectively by spraying them at 2-3 compound leaf stage of plants which were challenged by *P. infestans* inoculations five days later in pots to assess disease incidence and intensity which were recorded at weekly intervals of four stages(stage I-IV). It was found that the foliar spray with benzothiadiazole (BTH) @ 0.10 to 0.15% was best in delaying the appearance of first symptoms of the disease by 11 days followed by salicylic acid@ 0.10 to 0.15% and ascorbic acid @2.5%ascorbic acid (2.5%) which delayed the symptom appearance by 9 days, whereas the standard fungicidal spray of metalaxyl 8 + mancozeb 64 WP at the recommended concentration of 0.25% delayed the symptom appearance by only 8 days when compared to water sprayed check. It was also found that on an average BTH sprays completely arrested the late blight development (0% intensity); salicylic acid, INA, and ascorbic acid sprays were the next best SAR inducers exhibiting 0.46-0.74% mean blight intensity compared to 2.00 and 6.28 per cent intensity recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants after a week of pathogen inoculation(stage I). The highest concentrations of all the test chemicals, in general, yielded lesser blight intensity compared to their lower concentrations.

Keywords: late blight of potato, *Phytophthora infestans*, SAR inducers, disease incidence and intensity

## **Introduction:**

Potato (*Solanum tuberosum* L.) is one of the most important food crops worldwide which represents a valuable source of nutrients in a balanced diet. In terms of human consumption, the potato is the third most important food crop in the world, following only rice and wheat. Potato is also one of the important food crops in India.

Late blight of potato is one of the deadly diseases causing devastation to the crop. Yield loss due to late blight in India varies from year to year and range from 20-75 %. The pathogen produces water soaked lesions with chlorotic borders that are small at first expand rapidly under humid conditions, blighting the entire plant in only a few days with subsequent rotting of the developing tubers resulting in heavy yield losses under favourable conditions (Peerzada *et al.*, 2020).

For more than a decade, controlling late blight has become increasingly demanding because of the emergence of new strains of the pathogen, some new strains are known to be more aggressive and resistant to the novel fungicides. Moreover, indiscriminate use of fungicides poses great threat to the environment and it was reported that consumption of these accumulated fungicidal toxic residues which are carcinogenic in nature when entered into the food chain leads to a number of severe health complications. So the present study was focussed upon the use of different SAR inducers in order to elicit a systemic immunity response in plant and thereby protecting the plant against the pathogen attack, which is one of the environmentally safer alternatives among the available management practices.

## **Material and methods:**

### **Isolation of pathogen and production of inoculum**

Blighted samples were brought to the laboratory and the isolation of pure culture was made on V-8 agar medium using standard plant pathological technique. A pure culture of *P. infestans* was transferred onto V8 medium amended with rose Bengal in 90 mm diameter Petri dishes and incubated for about 14 days at 18°C in darkness for sporangia production. The inoculum was harvested from 10 to 14 days old cultures by adding 10 ml sterile distilled water to each plate and scraping the surface lightly with the edge of a glass rod to dislodge the sporangia. These sporangial suspensions were filtered through a double layer of cheese cloth to remove mycelia fragments, and diluted to appropriate concentration with the aid of Haemocytometer. The sporangia were chilled at 4°C for 2 hours to induce zoospore liberation.

### **Use of SAR activators**

Evaluation of systemic acquired resistance (SAR) inducers viz., Phosphoric acid, Salicylic acid, Naphthalene acetic acid, Benzoic acid, Benzothiadiazole, Dichloro-iso nicotinic acid, and Kinetin at 0.05% (C1), 0.10% (C2) and 0.15% (C3) concentrations, whereas Calcium chloride, Ascorbic Acid at 3.5% (C1), 5.0% (C2), 6.5% (C3) and 1.5% (C1),

2.0% (C2), 2.5% (C3) respectively, and metalaxyl 8+ macrozeb 64 WP @0.25% and water sprayed (control) were carried out in pots (30 cm dia,) arranged in completely randomized design in a pot house at experimental Farm of Division of Plant Pathology of the University. Each pot (30 cm dia), filled with pre-sterilized sandy loam field soil (autoclaved at 1.05 kg cm<sup>-2</sup> atmospheric pressure for two hours) and planted with three equidistantly placed healthy whole seed tubers of potato cv. Kufri jyoti, represented a treatment and replicated thrice. Each SAR inducer was applied separately at three different concentrations at 2-3 compound leaf stage maintaining metalaxyl 8+ macrozeb 64 WP (0.25%) and water applied as checks. Spore/sporangia suspension of the pathogen *P. infestans* (2 x 10<sup>4</sup> spores/sporangia per ml) prepared from one week old culture actively growing on V-8 agar medium, was sprayed at the rate of 10 ml suspension per pot after 5 days of application of SAR inducers. All other practices for raising the crop were as per the recommended package. Observations on late blight incidence and intensity were recorded at weekly intervals after first appearance of the disease in control pots.

### Disease incidence

Total number of diseased and healthy plants were recorded at weekly intervals. Mathematically, incidence was calculated as

$$\text{Late blight incidence (\%)} = \frac{n}{N} \times 100$$

Where n is the number of plants showing blight symptoms and N the total number of plants examined.

### Disease intensity

The observation on the extent of the foliage blighted was recorded at weekly intervals using the disease rating scale given by Mohan and Thind (1999)

Table 1: Disease Rating Scale

Disease Score	Score description in terms of foliage infected (%)
0	No visible symptoms
1	1-10
2	11-25
3	26-50
4	51-75
5	>75

The disease intensity was calculated by using the following formula

$$\text{Late blight intensity (\%)} = \frac{\text{Summation of numerical rating}}{\text{No. of plants Examined} \times \text{Maximum disease score}} \times 100$$

## Results and discussion:

### Use of SAR inducers

Various SAR inducers were sprayed at different concentrations on potato cv. Kufri Jyoti at 2-3 compound leaf stage and challenged by *P. infestans* inoculations five days later to assess the usefulness of these inducers in checking late blight development.

### Effect on disease development

#### Disease incidence

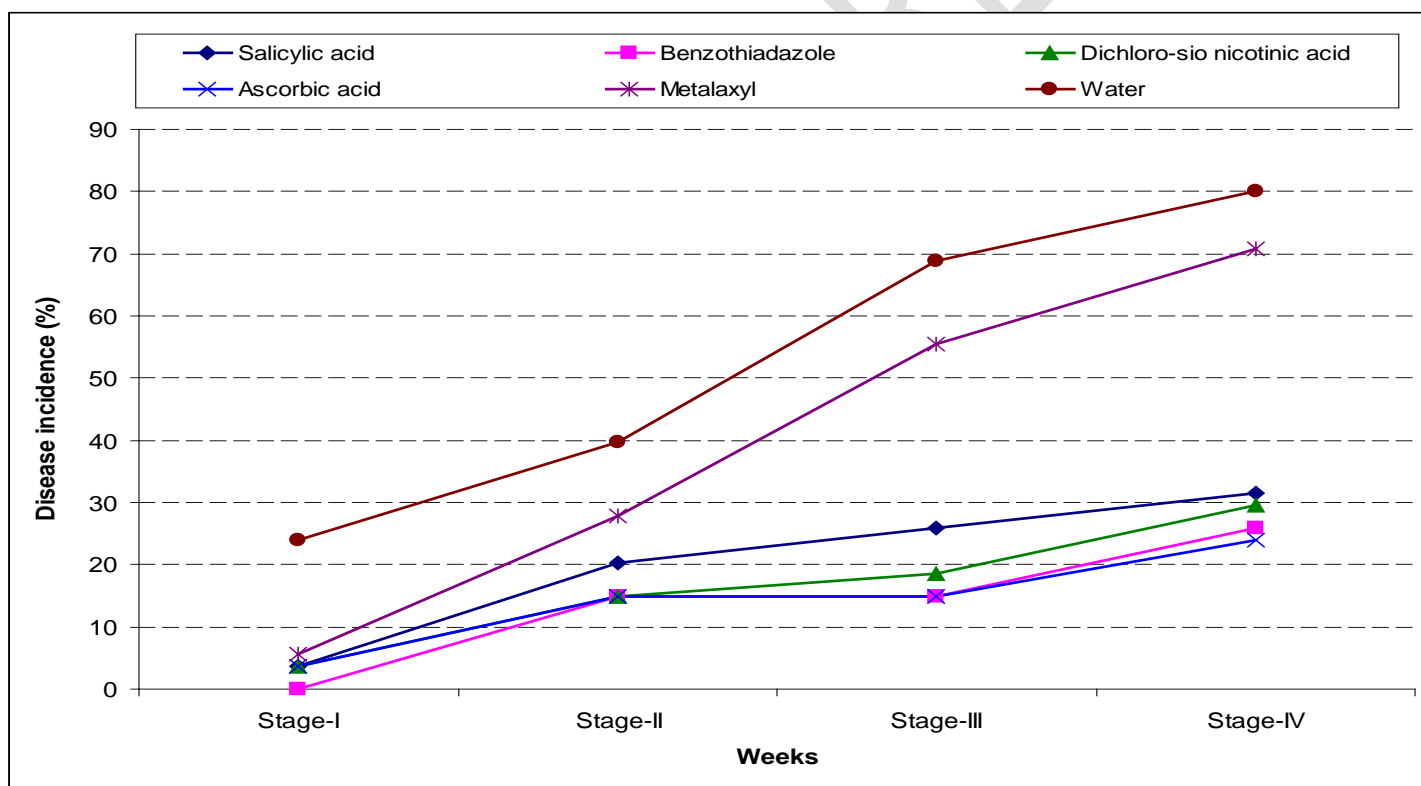
The results (Table-1) revealed that foliar spray with benzothiadiazole (BTH) @ 0.10 to 0.15% was the best treatment in delaying the appearance of first symptoms of the disease by 11 days followed by salicylic acid @ 0.10 to 0.15% and ascorbic acid @ 2.5% which delayed the symptom appearance by about 9 days, whereas the standard fungicidal spray of metalaxyl 8 + mancozeb 64 WP at the recommended concentration of 0.25% delayed the symptom appearance by only 8 days compared to water sprayed check. The observation on late blight incidence recorded seven days after the initial symptom appearance in check pots (stage I) revealed a significant decrease in disease incidence compared to check by the application of SAR inducer. On an average, BTH sprays completely arrested the late blight development (0% incidence); salicylic acid, INA, and ascorbic acid sprays were the next best SAR inducers exhibiting 3.7% mean blight incidence compared to 5.55 and 24.06 per cent incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants. The highest concentration of all the test chemicals, in general, yielded lesser blight incidence compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight incidence also existed.

**Table-2: Effect of foliar spray of SAR chemicals at different concentrations on incidence of late blight of potato cv. Kufri Jyoti planted in pots**

Chemical	Days to symptoms appearance	Late blight incidence (%)															
		Stage I				Stage II				Stage III			Stage IV				
		C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
Phosphoric acid	5-8	11.11 (16.06)	11.11 (16.06)	5.55 (8.03)	<b>9.25</b> <b>(13.38)</b>	33.33 (35.26)	22.21 (27.81)	16.66 (19.78)	<b>24.07</b> <b>(27.62)</b>	49.99 (44.99)	38.88 (38.50)	38.88 (38.50)	<b>42.59</b> <b>(40.67)</b>	55.55 (48.24)	44.44 (41.75)	38.88 (38.50)	<b>46.29</b> <b>(42.83)</b>
Salicylic acid	5-7	11.11 (16.06)	0.00 (0.00)	0.00 (-0.00)	<b>3.70</b> <b>(5.35)</b>	22.22 (27.81)	22.22 (27.81)	16.66 (19.78)	<b>20.36</b> <b>(25.13)</b>	33.33 (34.78)	22.22 (27.81)	22.22 (27.81)	<b>25.92</b> <b>(30.13)</b>	38.88 (38.50)	27.77 (31.53)	27.77 (31.53)	<b>31.47</b> <b>(33.86)</b>
Naphthalene Acetic acid (NAA)	5-6	11.11 (16.06)	11.11 (16.06)	11.11 (16.06)	<b>11.11</b> <b>(16.06)</b>	33.33 (34.78)	22.22 (27.81)	22.22 (23.50)	<b>25.92</b> <b>(28.70)</b>	38.88 (38.50)	38.88 (38.50)	38.88 (38.50)	<b>38.88</b> <b>(38.50)</b>	44.44 (41.75)	50.00 (45.00)	38.88 (38.50)	<b>44.44</b> <b>(41.75)</b>
Benzoic acid	7-8	16.66 (19.61)	11.11 (16.06)	11.11 (16.06)	<b>12.88</b> <b>(17.24)</b>	27.77 (31.35)	22.22 (27.81)	22.22 (27.81)	<b>24.06</b> <b>(29.05)</b>	38.88 (38.50)	38.88 (38.50)	38.88 (38.50)	<b>38.88</b> <b>(38.50)</b>	50.00 (45.00)	44.44 (41.75)	38.88 (38.50)	<b>44.44</b> <b>(41.75)</b>
Benzothiadiazol	8-11	0.00	0.00	0.00	<b>0.00 (-)</b>	22.22	11.11	11.11	<b>14.81</b>	22.22	11.11	11.11	<b>14.81</b>	27.77	27.77	22.22	<b>24.06</b>

e (BTH)		(-0.00)	(-0.00)	(-0.00)	<b>0.00</b>	(27.81)	(16.06)	(16.06)	<b>(19.97)</b>	(27.81)	(16.06)	(16.06)	<b>(19.97)</b>	(31.53)	(31.53)	(27.81)	<b>(30.29)</b>
Calcium chloride	5-7	27.77	22.22	22.22	<b>24.07</b>	38.33	33.33	27.77	<b>33.33</b>	44.33	38.88	38.88	<b>40.73</b>	55.55	50.00	38.88	<b>48.14</b>
		(31.53)	(27.81)	(23.50)	<b>(27.62)</b>	(38.50)	(35.26)	(31.53)	<b>(35.10)</b>	(41.75)	(38.50)	(38.50)	<b>(39.59)</b>	(48.24)	(45.00)	(38.50)	<b>(43.91)</b>
Dichloro-iso nicotinic acid (INA)	5-8	11.11	0.00	0.00	<b>3.70</b>	22.22	11.11	11.11	<b>14.81</b>	33.33	11.11	11.11	<b>18.51</b>	44.44	22.22	22.22	<b>29.62</b>
		(11.75)	(-0.00)	(-0.00)	<b>(3.91)</b>	(27.81)	(16.06)	(11.75)	<b>(18.54)</b>	(34.77)	(16.06)	(16.06)	<b>(22.29)</b>	(41.75)	(27.81)	(27.81)	<b>(32.46)</b>
Ascorbic acid	6-9	5.55	5.55	0.00	<b>3.70</b>	22.22	11.11	11.11	<b>14.81</b>	22.22	11.11	11.11	<b>14.81</b>	33.33	22.20	16.66	<b>24.06</b>
		(8.03)	(8.03)	(-0.00)	<b>(5.35)</b>	(23.50)	(16.06)	(16.06)	<b>(18.54)</b>	(27.81)	(16.06)	(16.06)	<b>(19.97)</b>	(34.78)	(27.80)	(24.09)	<b>(28.89)</b>
Kinetin	6-8	22.22	16.66	16.66	<b>18.51</b>	38.88	27.77	27.77	<b>31.47</b>	44.44	38.88	38.88	<b>40.73</b>	55.55	49.99	38.88	<b>48.14</b>
		(27.81)	(24.09)	(19.78)	<b>(23.89)</b>	(38.50)	(31.53)	(31.53)	<b>(33.86)</b>	(41.75)	(38.50)	(38.50)	<b>(39.59)</b>	(48.24)	(44.99)	(38.50)	<b>(43.91)</b>
Metalaxyl 8 + mancozeb 64 WP	5-7	5.55	5.55	5.55	<b>5.55</b>	27.77	27.77	27.77	<b>27.77</b>	55.55	55.55	55.55	<b>55.55</b>	79.99	68.88	63.33	<b>70.73</b>
		(8.03)	(8.03)	(8.03)	<b>(8.03)</b>	(31.53)	(31.53)	(31.53)	<b>(31.53)</b>	(48.24)	(48.24)	(48.24)	<b>(48.24)</b>	(67.88)	(56.12)	(52.88)	<b>(58.96)</b>
Water	4-5	22.22	27.77	22.22	<b>24.06</b>	38.88	38.88	41.11	<b>39.62</b>	66.66	68.88	71.11	<b>68.88</b>	77.77	82.22	79.99	<b>79.99</b>
		(27.81)	(31.53)	(27.81)	<b>(29.05)</b>	(38.05)	(38.05)	(39.83)	<b>(38.94)</b>	(54.73)	(56.12)	(57.51)	<b>(56.12)</b>	(66.48)	(69.27)	(67.88)	<b>(67.88)</b>
<b>Mean</b>		<b>13.10</b>	<b>10.09</b>	<b>8.58</b>		<b>29.79</b>	<b>22.72</b>	<b>21.41</b>		<b>40.90</b>	<b>34.03</b>	<b>34.23</b>		<b>51.21</b>	<b>44.54</b>	<b>38.78</b>	
		<b>(16.61)</b>	<b>(13.42)</b>	<b>(10.84)</b>		<b>(32.32)</b>	<b>(26.93)</b>	<b>(24.47)</b>		<b>(39.42)</b>	<b>(33.90)</b>	<b>(34.02)</b>		<b>(46.58)</b>	<b>(42.05)</b>	<b>(38.59)</b>	
		<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>		
SAR		0.26	0.73			0.22	0.81			0.20	0.81			0.28	0.80		
Concentration		0.33	1.05			0.28	1.22			0.31	1.02			0.42	1.32		
F x C		0.54	1.84			0.49	1.83			0.46	1.67			0.55	1.88		

Observations recorded seven days after initial symptom appearance in check (stage I), followed by three more observations (stage II to stage IV) at intervals of seven days; Phosphoric acid, Salicylic acid, Naphthalene acetic acid, Benzoic acid, Benzothiadiazole, Dichloro-iso nicotinic acid, and Kinetin evaluated at 0.05(C1), 0.10(C2) and 0.15(C3) concentration, Calcium chloride, Ascorbic Acid at 3.5 (C1), 5.0 (C2), 6.5 (C3) and 1.5 (C1), 2.0 (C2), 2.5 (C3) respectively, and metalaxyl 8+ mancozeb 64 WP @0.25%. Figures in parenthesis are arc sine transformed values and mean of three replications.



**Fig. 1: Effect of foliar spray with SAR inducers on incidence of late blight of potato cv. Kufri Jyoti planted in pots**



**Fig.2: Evaluation of different treatments of SAR chemical inducers in pots**

No blight incidence was recorded in treatments sprayed with either BTH (C1-C2 concentration), salicylic acid or INA (both at C2-C3 concentrations and metalaxyl 8 + mancozeb 64 WP at 0.25% concentration were the next best treatments showing blight incidence of 5.55% compared to 22.22 -27.77% incidence recorded on water sprayed plants. The observation on late blight incidence recorded seven days after (stage I) revealed again significant decrease in disease incidence compared to check by the application of SAR inducers. BTH, INA and Ascorbic acid depicted 14.81% incidence followed by those of salicylic acid, NA A, and Benzoic acid sprays exhibiting 20.36-25.92% mean blight incidence compared to 27.77 and 39.62 per cent incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants. The highest concentration of all the test chemicals, in general, yielded lesser blight incidence compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight incidence also existed. Lesser blight incidence of 11.11 per cent was recorded at C2-C3 concentration in treatments sprayed with BTH, INA or ascorbic acid. Salicylic acid or phosphoric acid at C3 concentrations were the next best treatment showing blight incidence of 16.66 compared to 27.77 and 41.11% incidence recorded on water sprayed plants. Similar trend was recorded seven days after stage II which again revealed significant decrease in disease incidence compared to check by the application of SAR inducers, BTH, and ascorbic acid showed 14.81% incidence followed by those of salicylic acid and INA sprays exhibiting 18.51-25.92% mean blight incidence compared to 55.55 and 68.88 per cent incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants. The highest concentration of all the test chemicals, in general yielded lesser blight incidence compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight incidence also existed. Lesser blight incidence of 11.11 per cent was recorded at (C3 concentration) in treatments sprayed with BTH. INA and ascorbic acid. Salicylic acid at C3 and

BTH and INA at C2 concentrations were the next best treatments showing blight incidence of 22.22% compared to 55.55 and 66.66-68.88% incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water sprayed plants. Same trend was recorded seven days after stage III which revealed significant decrease in disease incidence compared to check by the application of SAR inducers, BTH and ascorbic acid showed 24.06% incidence followed by those of salicylic acid and INA sprays exhibiting 29.62-31-47% mean blight incidence compared to 70.73 and 79.99 per cent incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants. The highest concentration of all the test chemicals, in general, yielded lesser blight incidence compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight incidence also existed. Lesser blight incidence of 16.66 per cent was recorded at C3 concentration in treatments sprayed with BTH and ascorbic acid. Salicylic acid, ascorbic acid and INA at C2 and C3 concentrations were the next best treatment showing blight incidence of 22.22% compared to 63.33- 68.88 and 79.99-82.22% incidence recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water sprayed plants. On overall basis it was observed that foliar sprays with BTH showed least disease incidence of 13.88% followed by ascorbic acid with 14.34%. Incidence as compared to 39.90 and 53.14 recorded on metalaxyl 8 + mancozeb 64 WP and water sprayed plants.

**Table-3: Effect of foliar spray of SAR chemicals at different concentrations on intensity of late blight of potato cv. Kufri Jyoti planted in pots**

Chemical	Late blight intensity (%)															Mean	
	Stage I				Stage II				Stage III				Stage IV				
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3		Mean
Phosphoric acid	1.80 (6.26)	1.60 (5.87)	1.60 (4.21)	<b>1.60</b> <b>(5.54)</b>	4.27 (11.73)	4.15 (11.57)	4.15 (9.54)	<b>4.19</b> <b>(10.95)</b>	8.64 (17.02)	6.38 (14.51)	6.30 (14.50)	<b>7.10</b> <b>(15.34)</b>	13.82 (21.55)	10.20 (18.36)	10.08 (18.33)	<b>11.36</b> <b>(19.42)</b>	<b>6.08</b> <b>(12.79)</b>
Salicylic acid	1.48 (5.62)	0.00 (-0.00)	0.00 (-0.00)	<b>0.49</b> <b>(1.87)</b>	3.78 (11.11)	3.45 (10.67)	3.61 (8.96)	<b>3.61</b> <b>(10.25)</b>	7.98 (16.35)	5.89 (13.88)	5.78 (13.88)	<b>6.55</b> <b>(14.70)</b>	12.76 (20.85)	9.42 (17.56)	9.24 (17.12)	<b>10.47</b> <b>(18.51)</b>	<b>5.28</b> <b>(11.33)</b>
Naphthalene Acetic acid (NAA)	1.78 (6.22)	1.64 (5.99)	1.64 (6.00)	<b>1.68</b> <b>(6.07)</b>	4.98 (12.77)	4.84 (12.70)	4.64 (12.42)	<b>4.82</b> <b>(12.63)</b>	7.66 (16.03)	6.50 (14.75)	6.37 (14.60)	<b>6.84</b> <b>(15.13)</b>	12.25 (20.09)	10.40 (18.35)	10.17 (18.32)	<b>10.94</b> <b>(18.92)</b>	<b>6.07</b> <b>(13.19)</b>
Benzoic acid	1.82 (6.31)	1.37 (5.40)	1.33 (5.35)	<b>1.50</b> <b>(5.71)</b>	4.82 (12.65)	4.64 (12.43)	2.84 (9.69)	<b>4.10</b> <b>(11.59)</b>	7.83 (16.21)	6.20 (14.33)	6.13 (14.30)	<b>6.72</b> <b>(14.97)</b>	10.19 (17.90)	9.65 (17.83)	9.80 (17.94)	<b>9.88</b> <b>(17.90)</b>	<b>5.55</b> <b>(12.54)</b>
Benothiadiazole (BTH)	0.00 (-0.00)	0.00 (-0.00)	0.00 (-0.00)	<b>0.00</b> <b>(-0.00)</b>	3.44 (10.63)	2.57 (7.54)	2.48 (7.40)	<b>2.83</b> <b>(8.52)</b>	6.18 (14.34)	3.95 (11.42)	3.88 (11.35)	<b>4.67</b> <b>(12.73)</b>	9.86 (17.67)	6.32 (14.37)	6.20 (14.33)	<b>7.46</b> <b>(15.45)</b>	<b>3.74</b> <b>(9.09)</b>
Calcium chloride	1.78 (7.60)	1.66 (7.35)	1.64 (6.01)	<b>1.69</b> <b>(6.99)</b>	5.33 (13.32)	5.24 (13.18)	5.25 (13.22)	<b>5.27</b> <b>(13.24)</b>	9.67 (18.04)	7.48 (15.82)	7.40 (15.73)	<b>8.18</b> <b>(16.53)</b>	15.47 (22.92)	11.95 (20.14)	11.84 (19.80)	<b>13.08</b> <b>(20.95)</b>	<b>7.05</b> <b>(14.34)</b>
Dichloro-iso nicotinic acid (INA)	1.38 (3.91)	0.00 (-0.00)	0.00 (-0.00)	<b>0.46</b> <b>(1.30)</b>	4.12 (11.68)	3.83 (9.18)	3.60 (6.17)	<b>3.77</b> <b>(9.01)</b>	6.01 (14.15)	4.87 (10.42)	4.72 (10.28)	<b>5.20</b> <b>(11.62)</b>	9.61 (17.65)	7.79 (15.02)	7.55 (15.67)	<b>8.31</b> <b>(16.11)</b>	<b>4.43</b> <b>(9.51)</b>
Ascorbic acid	1.21 (3.66)	1.02 (3.35)	0.00 (-0.00)	<b>0.74</b> <b>(2.34)</b>	4.81 (12.65)	3.58 (10.81)	3.51 (8.81)	<b>3.96</b> <b>(10.75)</b>	6.67 (14.93)	4.78 (12.60)	4.70 (10.17)	<b>5.38</b> <b>(12.56)</b>	10.67 (18.73)	7.64 (15.82)	7.52 (15.61)	<b>8.61</b> <b>(16.72)</b>	<b>4.67</b> <b>(10.59)</b>
Kinetin	1.89 (7.89)	1.49 (6.78)	1.53 (5.79)	<b>1.63</b> <b>(6.82)</b>	4.01 (11.48)	4.70 (12.45)	4.70 (12.39)	<b>4.47</b> <b>(12.11)</b>	7.71 (16.05)	5.90 (5.90)	5.87 (13.93)	<b>6.49</b> <b>(14.65)</b>	11.47 (19.61)	9.44 (17.47)	9.29 (17.27)	<b>10.06</b> <b>(18.11)</b>	<b>5.66</b> <b>(12.92)</b>
Metalaxyl 8 + mancozeb 64 WP	2.01 (4.73)	1.90 (4.60)	2.10 (4.84)	<b>2.00</b> <b>(4.72)</b>	8.29 (16.43)	7.98 (16.30)	8.21 (16.62)	<b>8.16</b> <b>(16.45)</b>	16.30 (23.76)	15.48 (23.11)	16.08 (23.55)	<b>15.95</b> <b>(23.47)</b>	26.08 (30.28)	24.76 (29.48)	25.72 (30.18)	<b>25.52</b> <b>(29.98)</b>	<b>12.90</b> <b>(18.66)</b>
Water	6.39 (14.51)	6.12 (14.20)	6.35 (14.55)	<b>6.28</b> <b>(14.42)</b>	14.10 (21.96)	14.72 (22.51)	16.01 (23.47)	<b>14.94</b> <b>(22.65)</b>	26.02 (30.57)	26.02 (30.57)	28.16 (32.00)	<b>26.78</b> <b>(31.09)</b>	56.68 (48.94)	54.83 (47.92)	55.05 (48.05)	<b>55.52</b> <b>(48.30)</b>	<b>25.88</b> <b>(29.11)</b>
<b>Mean</b>	<b>1.95</b> <b>(6.06)</b>	<b>1.52</b> <b>(4.87)</b>	<b>1.47</b> <b>(4.25)</b>	<b>1.65</b> <b>(5.06)</b>	<b>5.63</b> <b>(13.31)</b>	<b>5.42</b> <b>(12.67)</b>	<b>5.34</b> <b>(11.70)</b>	<b>5.46</b> <b>(12.56)</b>	<b>10.74</b> <b>(17.96)</b>	<b>8.49</b> <b>(15.95)</b>	<b>8.67</b> <b>(15.85)</b>	<b>9.08</b> <b>(16.59)</b>	<b>17.16</b> <b>(23.29)</b>	<b>14.76</b> <b>(21.12)</b>	1.08	<b>15.56</b> <b>(21.85)</b>	
	<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>			<b>S.Em±</b>	<b>CD(0.05)</b>			
SAR	0.08	0.47			0.11	0.48			0.15	0.68			0.14	0.44			
Concentration	0.41	1.09			0.23	0.97			0.23	1.27			0.21	1.87			
F x C	0.66	1.97			0.63	1.69			0.70	2.09			0.63	1.91			

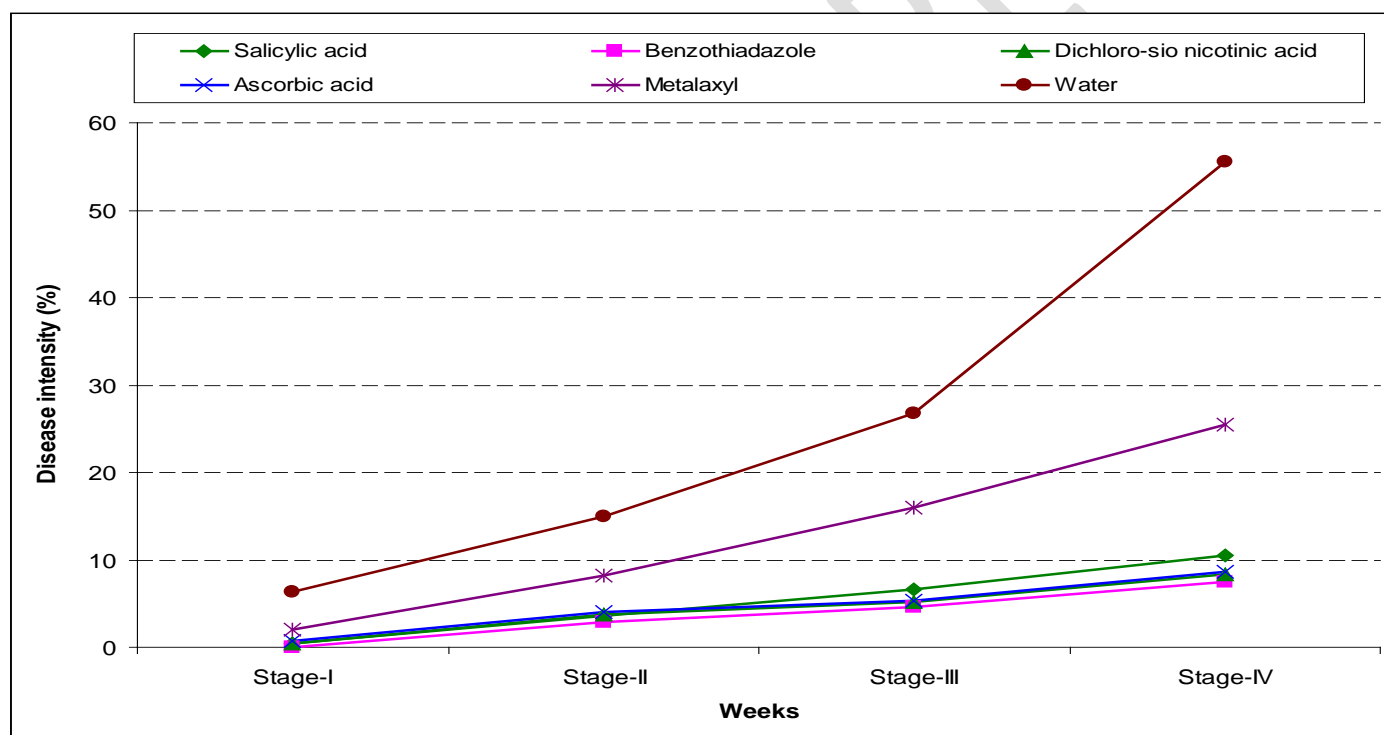


Observations recorded seven days after initial symptom appearance in check (stage I), followed by three more observations (stage II to stage IV) at intervals of seven days; Phosphoric acid, Salicylic acid, Naphthalene acid, Benzoic acid, Benzothiadiazole, Dichloro-iso nicotinic acid, and Kinetin evaluated at 0.05 (C1), 0.10 (C2) and 0.15 (C3) concentration, calcium chloride, ascorbic acid at 3.5 (C1), 5.0 (C2), 6.5 (C3) and 1.5 (C1), 2.0 (C2), 2.5 (C3) respectively, and metalaxyl 8 + mancozeb 64 WP @ 0.25%. Figures in parenthesis are arc sine transformed values and mean of three replications.

An insight into the data (Fig. 1&2) revealed that the leaf blight incidence was not allowed to exceed beyond 20% up to 4<sup>th</sup> stage about a month after spraying with BTH and ascorbic acid compared to standard fungicide metalaxyl 8 + mancozeb 64 WP and water foliar spray which exhibited 71 and 80% disease incidence after the same period.

### Disease intensity

The observation on late blight intensity (Table-2) recorded seven days after the initial symptom appearance in check pots (stage I), revealed a significant decrease in disease intensity compared to check by the application of SAR inducer.



**Fig. 3 : Effect of foliar spray with SAR inducers on intensity of late blight of potato cv. Kufri Jyoti planted in pot**

On an average BTH sprays completely arrested the late blight development (0% intensity); salicylic acid, INA, and ascorbic acid sprays were the next best SAR inducers exhibiting 0.46-0.74% mean blight intensity compared to 2.00 and 6.28 per cent intensity recorded, respectively, on metalaxyl 8 + mancozeb 64 WP and water-sprayed plants. The highest concentrations of all the test chemicals, in general, yielded lesser blight intensity compared to their lower concentrations. A significant interaction

between the SAR inducers and their concentrations in reducing blight intensity also existed. No blight intensity was recorded in treatments sprayed with either BTH (C1-C3 concentration), salicylic acid or INA (both at C2 and C3 concentration) or ascorbic acid (C3 concentration). Benzoic acid, ascorbic acid at C2 concentration and metalaxyl 8 + mancozeb 64 WP at 0.25% concentration were the next best treatments showing blight incidence of 1.02-1.38 and 2.01-2.10 per cent compared to 6.28% disease intensity recorded on water- sprayed plants.

The disease intensity recorded, a week after the stage I observation again revealed a significant decrease in disease intensity compared to check; BTH, and salicylic acid sprays exhibited 2.83-3.61 per cent blight intensity. Ascorbic acid and INA were the next best SAR inducers, exhibiting 3.77 and 3.96% mean blight intensity compared to 8.16 and 14.94 per cent intensity recorded in on metalaxyl 8 + mancozeb 64 WP and water- sprayed plants. The higher concentrations of all the test chemicals, in general, yielded lesser blight intensity compared to their lower concentrations. A significant interaction was observed between the SAR inducers and their concentrations in reducing blight intensity. Blight incidence of 2.48% was recorded in treatments sprayed with either BTH. Salicylic acid, INA or ascorbic acid at C3 concentration exhibited 3.51- 3.61 per cent disease intensity as compared to 7.98- 8.29% and 14.10-16.01% recorded on metalaxyl 8 + mancozeb 64 WP and water- sprayed check plants. Similar trend was recorded seven days after stage II revealed, significant decrease in disease intensity compared to check. BTH sprays exhibited 4.67 per cent blight intensity. INA and ascorbic acid were the next best SAR inducers exhibiting 5.20-5.38 mean blight intensity compared to 15.95 and 26.78 per cent incidence recorded on metalaxyl 8 + mancozeb 64 WP and water sprayed plants. The higher concentrations of all the test chemicals, in general, yielded lesser blight intensity compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight intensity also existed at this stage too. Blight intensity of 3.88- 3.95% was recorded in treatments sprayed with BTH at C2-C3 concentration followed by ascorbic acid at the same concentration as compared to 15.48-16.30% and 26.02-28.16% disease intensity recorded on metalaxyl 8 + mancozeb 64 WP and water- sprayed plants.

The disease intensity recorded a week after the stage III, revealed a significant decrease in disease intensity compared to check. BTH exhibited 7.46 per cent blight intensity. INA and ascorbic acid were the next best SAR inducers exhibiting 8.31 and 8.61 per cent disease intensity. The higher concentrations of all the test chemicals, in general, yielded lesser blight intensity compared to their lower concentrations. A significant interaction between the SAR inducers and their concentrations in reducing blight intensity also existed at this stage too. Blight intensity of 6.20-6.32% was recorded in treatments sprayed with BTH at C2-C3 concentration followed by ascorbic acid and INA 7.51-7.79%

at the same concentration as compared to 24.76-25.72% and 54.83-55.05% disease intensity recorded on metalaxyl 8 + mancozeb 64 WP and water- sprayed plants.

An insight into the data (Fig.3) revealed that the leaf blight intensity was not allowed to exceed beyond 7% about a month after the spraying SAR inducers stage IV compared to standard fungicide metalaxyl 8 + mancozeb 64 WP and water foliar spray which exhibited 13 and 26% disease intensity after the same period.

The use of SAR inducers had been gaining significant importance since a long time ago due to their eco-friendly nature with no adverse effects on human health and ecology. Foliar sprays with SAR inducers in the present study have been found to result in significant decrease in the incidence and intensity of potato late blight. Foliar spray with BTH caused maximum delay (8-11 days) in initial symptom appearance followed by salicylic acid (6-9 days) compared to check. BTH, INA or salicylic acid sprays further exhibited reduced blight intensity compared to check, indicating thereby that a spray or two with these chemicals can be helpful in containing the disease without any deleterious effects on ecology and environment. The use of SAR inducers for controlling many plant diseases has been made by several other workers. Kazemi (2014) studied foliar application with salicylic acid on growth, flowering, yield, fruit quality and resistance against diseases in tomato and demonstrated its positive correlation. The reduction of disease severity in potato and many other crops by SA, BTH and INA application may be attributed to the role of elicitors in induction of local and/or systemic acquired resistance (SAR) in treated plants against invasion of the pathogen. SAR with elicitors has been reported in a number of crops that stimulates the accumulation of signal molecules such as jasmonic acid, SA, hydrogen peroxide, reactive oxygen species and protein kinase, all of which play crucial role in intracellular signalling pathways (Atia *et al.*, 2005). Astha and sekhon, 2017 reported that SAR elicitors, especially SA and BTH, stimulated defense reactions in potato against late blight and in muskmelon against downy mildew disease and thereby decreasing the disease severities in those plants. They reported that this effect might be due to the impact of these substances on enzymatic activity and translocation of the metabolites to potato and muskmelon plants. Our findings are in agreement with those of Astha and sekhon, (2017); Farouk *et al.* (2008); Buonauro *et al.*, (2002); Ghandi (2000); Mur *et al.*, (2000); Cole (1999); Lawton *et al.* (1996), Cohen *et al.* (1994) who also demonstrated that BTH and other SAR inducers controls various Phytophthora diseases of different crops. From our present findings it can be concluded that SAR elicitors play a very important role in defence response against various pathogens apart from their safety to the environment. They can as well be included as one of the several practices of the integrated disease management.

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