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An experiment was conducted to evaluate the induced resistance in potato against Late blight caused by *Phytophthora infestans*. Tuber treatments with Calcium chloride ($CaCl_2$) stimulate the tuber germination and increased plant height of potato which was maximum in T_8 (tuber treated with 2g $CaCl_2$/100g tuber for 12 h + spraying with $CaCl_2$) treatment with the value of 16.74 cm against 10.94 cm in case of control at 30 days age of plant. The maximum yield with 400.01 g was also obtained from T_8 treatment which was followed by T_7 treatment at 386.67 g. The disease severity was found minimum in T_8 treatment, showing 22.65% followed by T_7 (23.35%) against control (57.00%).

Key words: Potato, calcium chloride, inducer, growth, yield, disease severity

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important and most widely distributed food crop in the world. No other crop can match the potato in its production of food energy and food value per unit area. It is the world's fourth-largest food crop, following maize, wheat and rice. Potatoes are rich source of carbohydrates, vitamins and minerals and are used as staple food in many countries, especially in England. In India with limited resources, where the nutrition level of the population has to be maintained under inhospitable situations, the potato has a special value as a food. In India, Uttar Pradesh is the highest potato producing state with a production of 1389.94 tonnes which contribute 31.01% in total potato production of the country.

Though it ranked first in potato production in India but at per concerned on productivity, the state is far behind than other countries of the world. The main reasons of low productivity are some abiotic and biotic factors. Among the biotic factors, Late blight caused by *Phytophthora infestans* (Mont.) de Bary is most destructive disease which was responsible for Irish Famine during 1840-1845.

The fungus, *Phytophthora infestans* is basically a pathogen of cold climatic areas but has tremendous capacity to adopt to temperate as well as subtropical areas, which support potato production. It affects leaves, stems and tubers and can destroy a potato field within a few days if weather conditions are favourable.

The management of this disease depends mainly on fungicidal applications. However fungicides are hazardous to human health and the environment. Alternatives of these fungicides are needed in the present scenario for management of diseases and increasing yield. Inorganic chemicals like Calcium chloride, Copper sulphate, Potassium bicarbonate, Sodium bicarbonate, Salicylic acid, Copper oxychloride, Maganse sulphate etc. have been used as alternative strategies for management of plant diseases in several crops under sustainable agriculture (Biswas *et al.* 2012). Smilanick *et al*. (2006) found that baking soda [sodium bicarbonate,

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($NaHCO_3$)] and potassium bicarbonate ($KHCO_3$) are effective for control of various fungal diseases in plants. Spraying of baking soda provided good protection of plants against several diseases was reported by several workers (Janisiewicz and Peterson, 2005). Abd-El-Kareem (2007) reported that potassium bicarbonates combined with Nerol significantly reduce the Early blight and increased the tuber yield of potato under field conditions. Citral as one fractions of citrus essential oil caused complete inhibition of the linear growth of *Giotrichum candidum*, *Penicillium digitatum* and *P. italicum* as causal agents of citrus diseases. Considering the above point on view, the study was undertaken on the present investigation.

MATERIALS AND METHODS

Collection of infected plant sample

Potato plants with typical blight symptoms were first identified and then collected from Vegetable Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kalyanpur (Kanpur). Infected leaf with sporulating lesions were taken from the field and washed in sterilized water. The sample was then placed in between two fold of sterilized blotter paper and preserved at 4 – 6^0C in refrigerator. The samples were later used for isolation and purification of pathogen.

Isolation of pathogen

A small piece of infected leaf from border of sporulating lesion along with some green tissue was cut and dipped in mercuric chloride solution (0.1%) for 30 seconds, followed by rinsed in sterilized distilled water thrice and dried off with sterilized filter paper. The tissue pieces were placed on the top of the selective medium in Petri plates. It was then incubated at 18± 1^0C. The Petri plates were observed daily to notice the presence of mycelium around the leaves bites. As soon as the mycelial growth is noticed around the bits, the pathogen was purified by hyphal tip culture method and characterised based on cultural and morphological data.

Collection of seed tuber

Truly labelled potato seed tubers of variety Kufri Lalima were obtained from Vegetable Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur to conduct the experiment.

Solution preparation

Sixteen gram $CaCl_2$ were mixed in a beaker along with 800ml of distilled water to prepare 2% concentration solution of $CaCl_2$. The solution was filtered with muslin cloth and pure solution was prepared for spraying on plant.

Tuber treatment

Seed tubers were treated with Calcium chloride @ 2g/100g of seed. Treated tubers were sown in earthen pots under glasshouse condition. As the seedling began to emerge from the soil, germination percentage was calculated by recording the number of emerged seedlings from number of potato tuber sown.

Inoculation of the crop

After 48 hrs., plants were inoculated with spore suspension of *P. infestans.* The concentration of spore was maintained at 10^6 spore/ ml. The spore suspension was prepared from seven days old culture of the pathogen. The homogenized, spore suspension were inoculated on the foliage of each plant. The inoculated plants were then kept on the bench of wire house. After 2, 6 and 10 days, observations were taken on disease severity.

Effect of $CaCl_2$ on germination, growth parameters and development of disease

At 45 days age, the plants were sprayed first with solution of calcium chloride @ 2% separately, followed by inoculation with spore suspension of *P. infestans.*

The experiment was conducted in the glass house complex, Department of Plant Pathology, C.S.A. University of Agriculture and Technology, Kanpur. The seed tuber of potato variety Kufri Lalima was treated with Calcium chloride and spraying on plants with the same was given at 45 days age of plant. The details of treatment are given below -

T_1= Seed tuber treatment with 2g $CaCl_2$/100gm seed for ½ hour + spraying with $CaCl_2$.
T_2= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 1 hour + spraying with $CaCl_2$.

T_3= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 2 hour + spraying with $CaCl_2$.
T_4= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 4 hour + spraying with $CaCl_2$.
T_5= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 6 hour + spraying with $CaCl_2$.
T_6= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 8 hour + spraying with $CaCl_2$.
T_7= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 10 hour + spraying with $CaCl_2$.
T_8= Seed tuber treatment with 2g $CaCl_2$/100gm seed for 12 hour + spraying with $CaCl_2$.
T_9= No seed tuber treatment (Control).

The treated tubers were then sown in 30cm earthen pots, which were previously filled with a mixture of sterilized sandy loam soil and farm yard manure in the ratio of 2:1. In each pot 1 seed tuber was sown and watered as per need base. The experiment design was laid out in simple CRD. Three replications per treatment and three pots were sown with untreated seed tubers served as control. The observations pertaining to the effect of different treatments were taken on the following parameters -

Observation recorded

- Germination test.
- Plant height (cm) at 12 days after sowing up to 30 days.
- Disease severity (%) at 50, 55, and 60 days after sowing.
- Yield of crop.

Germination

Seed tuber was treated with Calcium chloride might be responsible for early breaking of seed tuber dormancy there by increasing the germination percentage of seed tuber. The observation on pattern of germination of tuber was taken at every 24 hrs up to 10 days. The data were recorded on date of first germination and numbers of sprouting branches.

Plant height

For this purpose, three plants were selected randomly from tagged plots. The shoot height was measured (in cm) at every 24 hrs up to 30 days age of plant from the soil surface at basal portion to flag leaf with the help of meter scale. Three replications were kept for each treatment. The average of three plants height was considered as plant height, represented in cm.

Tuber size and yield

To explore the possible effect of the Calcium chloride on tuber yield was observed and data were taken on the weight of the total tubers per treatment and grading of tuber as number of large, medium and small tubers.

Measurement of disease severity

Observations for measuring the disease severity were taken after 5 days of pathogen inoculation. The disease severity was recorded on 0-9 scale. The disease severity of individual plants was calculated by following formula:

$$\text{Disease severity (PDI)} = \frac{\text{Sum of numerical rating}}{\text{Total number of leaves examined x maximum rating}} \times 100$$

RESULTS AND DISCUSSION

Effect of tuber treatment with calcium chloride as inducers on tuber germination and growth of plant

The effect of tuber treatment with $CaCl_2$ on growth parameters and tuber germination in glass house conditions shows that $CaCl_2$ were effective in increasing tuber germination and vigour of plants (Table 1). The maximum germination with 100 per cent was found in T_8 (Seed tuber treatment with 2g $CaCl_2$/100 g seed for 12 hrs. + spraying with $CaCl_2$), T_7 (Seed tuber treatment with 2g $CaCl_2$/100 g seed for 8 hrs. + spraying with $CaCl_2$), T_6 (Seed tuber treatment with 2 g $CaCl_2$/100g seed for 8 hrs + spraying with $CaCl_2$) and T_5 (Seed tuber treatment with 2 g $CaCl_2$/100g seed for 6 hrs + spraying with $CaCl_2$) treatments where as in case of control, it was only 60.00%. Indiresh *et al.* (2003) reported that the response of potato *cv. Kufri Jyoti* to individual and combined inoculation of *Azotobacter croococcum, Acetobacter diazotrophicus* and *Pseudomonas striata,* showed significant effect on increasing per cent emergence of tubers, number, tuber weight per plant, total tuber yield and marketable tuber yield.

Table 1 : Effect of calcium chloride as inducer on germination plant growth parameters of potato at different days of interval (ware house condition)

Treatments	Concentration %	Germination (%)	Effect of inducers on plant height of potato (cm)					% Increase of plant height over control at 30 Days
			10 DAS	15 DAS	20 DAS	25 DAS	30 DAS	
T_1	2.0	80.00	1.00	2.63	5.13	8.36	11.33	3.56
T_2	2.0	80.00	1.46	3.73	5.73	9.06	12.36	12.97
T_3	2.0	80.00	1.90	4.30	6.06	9.76	13.86	26.69
T_4	2.0	80.00	1.93	4.60	8.46	10.20	14.56	33.08
T_5	2.0	100.00	2.70	4.70	8.53	11.60	14.90	36.19
T_6	2.0	100.00	2.56	5.70	8.63	11.90	14.96	36.74
T_7	2.0	100.00	2.72	5.80	9.60	12.90	15.06	37.65
T_8	2.0	100.00	3.58	6.46	10.26	13.93	16.74	53.01
T_9	0.0	60.00	.82	1.56	3.90	6.85	10.94	-
SE±			0.097	0.363	1.302	1.618	2.077	-
C.D (0.05%)			0.540	1.043	1.975	2.202	2.495	-

Table 2 : Effect of calcium chloride as inducers on tuber size and yield of potato (ware house condition)

Treatment	Concentration (%)	Size of tuber						Total yield (g/plant/pot)	% increase yield over control
		Large (> 50g)		Medium (25-49.5g)		Small (< 25g)			
		Total number of tuber	Total weight (g)	Total number of tuber	Total weight (g)	Total number of tuber	Total weight (g)		
T_1	2.0	0	0.00	1	33.20	15	271.17	304.37	31.89
T_2	2.0	0	0.00	2	77.52	13	226.96	304.48	32.12
T_3	2.0	1	51.45	2	85.00	10	186.65	323.10	40.01
T_4	2.0	1	58.62	3	125.25	8	156.49	340.36	47.49
T_5	2.0	2	104.50	3	120.00	7	135.73	360.23	56.10
T_6	2.0	2	135.67	4	150.16	4	88.42	374.25	62.18
T_7	2.0	3	168.50	5	185.72	2	32.45	386.67	67.56
T_8	2.0	4	220.78	5	146.86	3	32.46	400.10	73.38
T_9	0.0	0	0.00	1	28.75	16	202.01	230.76	
SE±								1.066	
C.D (0.05%)								1.787	

Effect of tuber treatment with calcium chloride as inducers on tuber size and yield of potato

The effect of tubers treatments and foliar spray with $CaCl_2$ as inducers on tuber size and yield was studied after harvesting. Tubers were graded as large (> 50g), medium (25-49.5g) and small (< 25g) in size. The data represented in Table 2 showed that maximum number of large size tuber was harvested from T_8 treatment, representing 4 tubers with total weight of 220.78 g per plant, followed by T_7 which is 3 tubers having total weight of 168.50 g per plant. The maximum number of medium size tuber was obtained in T_7 and T_8 representing 5 tu-

bers for each treatment with the total weight of 185.72 g and 146.86 g respectively. In case of small sized tubers, the maximum number was found in T_1 followed by T_2 treatment, representing the 15 and 13 tubers, respectively. From the Table 2 it is also cvident that T_1 and T_2 treatment and even control plants (T_9) did not produced any large size tubers. As per yield is concerned, the highest total yield with 400.10 g per plant was recorded from T_8 treatment. T_7 treatment produced 386.67 g of potato per plant representing, second highest among

corded in T_8 treatment at 2, 6 and 10 days after pathogen inoculation, respectively followed by T_7 treatment as16.70%, 21.87% and 23.35% and T_6 treatments 16.95%, 22.68% and 24.08%. The T_5 treatment was showing 17.75%, 23.40% and 25.30% disease severity which are superior to control but inferior to T_8 and T_7 treated plant in respect to severity of disease at 2, 6 and 10 days of pathogen inoculation. From the Fig.1, it is also cleared, that all the inducer treated potato plants were showing comparatively low disease severity over con-

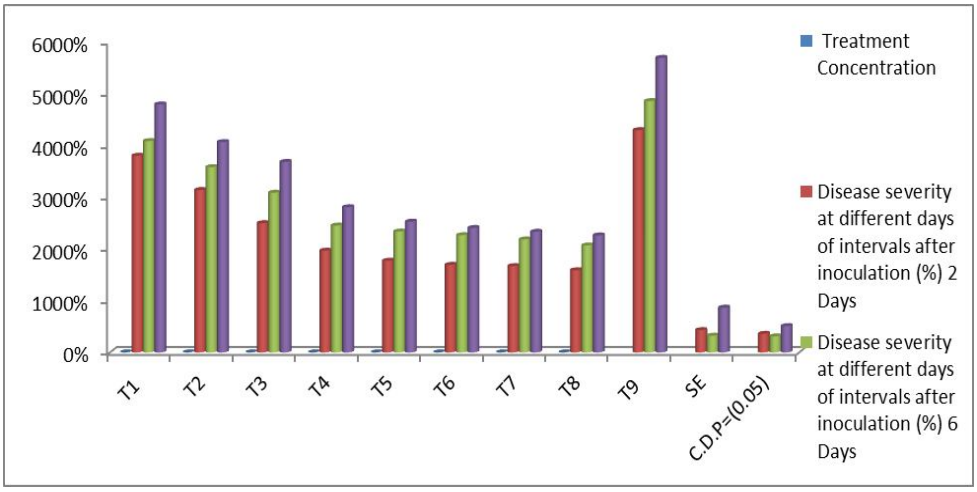

Fig. 1 : Effect of calcium chloride as inducer on disease severity of Late blight of Potato

the treatment which was followed by T_6 (374.25 g) and T_5 (360.23 g) treatment. Among the treatments, the lowest yield was recorded from T_1 treatment, representing only 304.37 g of tuber per plant. The per cent increase of tuber yield ranged from 31.89-73.38%. From the data, it is also cleared that all the treatments were statistically significant in respect of potato yield. Singh and Pathak (2006) found that effect of FYM alone or in combination *Pseudomonas striata* and phosphorus and reported that highest tubers yield was obtained from combined effect of FYM + *Pseudomonas striata* followed by FYM alone.

Effect of calcium chloride as inducer on severity of Late blight of potato

The effect of tuber treatment and foliar spray with calcium chloride as inducers significantly reduced disease severity of Late blight of potato as compared to control under wire house condition.

Among the treatments, the minimum disease severity with 15.90%, 20.70% and 22.65% were recorded in T_8 treatment at 2, 6 and 10 days after pathogen inoculation, respectively followed by T_7 treatment as16.70%, 21.87% and 23.35% and T_6 treatments 16.95%, 22.68% and 24.08%. The T_5 treatment was showing 17.75%, 23.40% and 25.30% disease severity which are superior to control but inferior to T_8 and T_7 treated plant in respect to severity of disease at 2, 6 and 10 days of pathogen inoculation. From the Fig.1, it is also cleared, that all the inducer treated potato plants were showing comparatively low disease severity over control. The decrease in disease severity might be the activity of calcium chloride which stimulates to synthesis of some defense related compounds in potato plant against *P. infestans*. Several workers also reported that application of biotic and abiotic inducers reduce disease severity in rice (Girdhari *et al.* 2008) in tomato against Fusarium wilt (Arzoo *et al.* 2010; Biswas *et al.* 2012), in wheat against Spot blotch (Mishra *et al.* 2011).

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