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Effect of inorganic chemicals as inducer on the growth parameters of potato (*Solanum tuberosum* L.) against common scab disease caused by *Streptomyces scabies* (Thaxter) Waksman & Henrichi

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Abstract
Common scab caused by *Streptomyces scabies* (Thaxter) Waksman & Henrici is an important disease worldwide, and can cause significant reduction in the economic value of potato. The management of the disease can be done through conventional methods, biological chemical and cultivation of resistant variety. However, resistance against pathogen is not a permanent solution and fungicidal is not ecofriendly and economical. But new search, induce resistance has taken great attention for plant disease management in near future. Therefore, inquest for induce defense by certain inorganic chemicals like Salicylic acid (10mM), Calcium chloride (10 mM), Hydrogen peroxide (10 ppm), Boric acid (0.1%), Di-potassium hydrogen orthophosphate (0.2 %), Ferric chloride (5mM), Indole acetic acid (1 %), and Copper chloride (10 mM) as inducer were assessed during the course of present investigation. Tuber treatment with inducing agent provide good protection against common scab disease caused by *S. scabies* and also stimulate the germination of seed. Growth promoting effects of the inducers were also perceived salicylic acid treated plant showing maximum plant height of 5.20, 16.35, 29.10, 37.85 and 44.75 cm during 2017-18 and 5.35, 16.67, 30.28, 38.43 and 46.15 during 2018-19 at 10, 20, 30, 40 and 50 days age of seedling, respectively against 2.26, 11.90, 19.35, 26.15 and 29.35 cm and 2.47, 12.15, 20.91, 28.33 and 30.67 cm, respectively in case of control. Similarly all the growth parameters like covered area in cm, number of leaves per plant, number of branches per plant, stem diameter in cm *etc*. also found maximum in Foliar spray with the salicylic acid as inducers before pathogen inoculation, protected the plant against infection resulting reduce disease index.

Keywords: inorganic chemicals, growth parameters, *Solanum tuberosum* L., *Streptomyces scabies*

Introduction
Potato (*Solanum tuberosum* L.) is the most important and leading vegetable crop of the world with immense yield potential giving remunerative income to the farmers and having excellent nutritional values. It is one of the most productive and widely grown food crops in the world and produces approximately twice as many calories per hectare as rice and wheat (Poehlman and Slepper, 1995) [28]. It is also used as, stock feed and in industries for manufacturing starch, alcoholic beverages and other processed products (El-Sirafy *et al.* 2008; El-Mougy, 2009) [19, 7]. In India, it is the fourth major important food crop after wheat, rice and maize because of its higher yield potential and high nutritive value. The major potato producing country in the world are China (99.06 mMT), India (43.77 mMT), Russia (31.10 mMT), Ukraine (21.75 mMT) and US (19.99 mMT). The total area under potato cultivation in the world is 20.32 million hectares with a production of 480.96 million tons during 2015-16. India produced 51.310 million metric tonne (mMT) of potato from an area of 21.42 lakh hectares of land during 2017-18 (Anonymous, 2018) [1]. The leading potato producing states in India are Uttar Pradesh, 15323 tonnes with sharing (30.53%), followed by West Bengal, 11000 tonnes with sharing (21.92%), Bihar, 8154 tonnes with sharing (16.25 %) and Gujarat, 3707 tonnes with sharing (7.39 %) which constitute about 76.10 % of the total domestic potato production (Anonymous, 2018-19) [2]. The production and productivity of potato in India are quite impressive. However, in the background of increasing population, there is a need to produce more crop from same piece of land. The main reasons of low productivity are potato suffers from a number of diseases caused like, early blight, late blight, common scab, leaf spot, dry rot, charcoal rot, black scurf, soft rot, leaf roll etc. Among them, common scab *Streptomyces scabies* (Thaxter) Waksman & Henrici was found as major tuber / soil borne diseases that affect both quality and quantity of tubers (Rauf *et al*., 2007).

The causal agent of common scab was first described by Thaxter (1891) [14] as *Oöspora scabies*, a melanin-producing actinomycete bearing grey spores in spiral spore chains. The name was later changed to *Actinomyces scabies* by Güssow (1914) [8], followed by *S. scabies* (Waksman & Henrici) in 1948. The pathogen producing a phytotoxin, known as thaxtomin is a pathogenicity determinant involved in symptom development of common scab pathogens (King *et al.*, 1989) [11]. *Streptomyces scabies* is the most common species and has been reported worldwide (Loria *et al*., 1997; Miyajima *et al*., 1998) [23, 12]. The management of the disease can be done through cultural, biological, chemical and use of resistant variety and there is no doubt that the chemical are the best method for management of the disease. Presently, bactericide is the mainstay in the control of common scab given the fact there has not been any complete resistant variety in the market for farmers to use (Kemmitt, 2002) [21]. However, continuous use of synthetic chemical are not economical and eco- friendly. A control practice that has shown promise for plant disease management is the use of systemically induced plant resistance. The plant possesses a range of defences that can be activated to protect it from diseases. This defence response, termed systemic acquired resistance, can be localized at the site of application of an inducer and can also be transmitted systemically to other plant tissues of the same plant (Kessmann *et al.,* 1994) [9]. Hence, the topic entitled "Induced systemic resistance in potato against common scab (*Streptomyces scabies* (Thaxter) Waksman & Henrici) through Inorganic chemicals as inducers" has been undertaken in the present investigation.

Materials and Methods

Effect of tuber treatment with inorganic chemicals as inducers on germination and growth parameters of potato plants

Truly labeled potato seed tubers of variety '*Kufri Badshah*' were collected from Vegetable Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur to conduct the experiment. Six seed tubers were placed in each jar containing inorganic chemicals solution of each inducer for 4-5 hours. It was then removes from the jar and shaded dry and used for sowing in pots. The treated tubers seeds were planted in 30 cm pots which were previously filled up with a mixture of sterilized sandy loam soil and Mushroom compost in the ratio of 2:1. Two treated tubers were placed in each pot and watered as per need based. Three replications were kept for each treatment. In one experiment, untreated tubers were sown served as control.

Observations Recorded

Germination test

Seed tuber treated with different inorganic chemicals as inducers may responsible for early breaking of seed tuber dormancy thereby increasing the germination percentage of seed tuber. The observation on germination of tuber was taken at 15 days after sowing. Germination percentage was calculated by (Abdul Baki and Anderson, 1971) use of following formula:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seed tubers}}{\text{Number of total seeds sown}} \times 100$$

Growth Parameters

Plant height (cm)

Plants were selected randomly from each replication and tagged. The height at 10, 20, 30, 40 and 50 DAS was measured in cm with the help of meter scale from the base of the plant to top and mean value was computed as cm on height.

Plant covered area (in diameter)

Plants randomly selected plants were taken from each replication and tagged. Plant covered area were measured at 50 DAS. Total area covered by plant was measured and means value was computed and recorded as plant covered area.

Number of leaves per plant

Plants randomly selected plants were taken from each replication and tagged. Number of leaves per plant were counted at 50 DAS. Total number of leaves was counted and means value was computed and recorded as number of leaves plant^{-1}.

Number of stem per bunch

The above ground parts of three randomly selected plants were taken from sample at 50 DAS. Total number of stem per bunch was counted separately and means value was computed and recorded as number of stem per bunch.

Stem diameter (cm)

The above ground parts of three randomly selected plants were taken from sample at 50 DAS. Total stem diameter was measured separately and means value was computed and recorded as stem diameter in cm.

Fresh weight of shoot

The above ground parts of three randomly selected plants were taken from sample at 50 DAS. The sample was cleaned to water and allow for after that constant weight. Sample was weight with the help of electronic balances and recorded values as gram (g).

Dry weight shoot

The above ground parts of three randomly selected plants were taken from sample at 50 DAS. The sample was sundried and then dried in oven at 70 ^{0}C for 24 hours till constant weight. The dry weight was recorded and means values was computed to express dry matter accumulation in gram (g) plant^{-1}

Results and Discussion

Potato tubers treated with inorganic chemicals as inducer were sown in earthen pots under wire house 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. The result showed that two inorganic chemicals as inducers *i.e.* salicylic acid and calcium chloride were good in stimulating germination of potato tuber representing, 100% germination during both the years 2017-18 and 2018-19 against untreated tuber as control was found least effective in germination of potato tuber, representing the value 65.00 % during both years 2017-18 and 2018-19. The effects of tuber treatment with various inorganic chemicals as inducers on plant height of potato were also studied under Wire House Complex in pots culture experiment. The observations of plant height were taken at 10, 20, 30, 40 and 50 days after sowing. The maximum plant height was found in Salicylic acid treated seed tubers, representing 5.20, 16.35, 29.10, 37.85 and 44.75 cm during 2017-18 and 5.35, 16.67, 30.28, 38.43 and 46.15

during 2018-19 at 10, 20, 30, 40 and 50 days age of seedling, respectively against 2.26, 11.90, 19.35, 26.15 and 29.35 cm and 2.47, 12.15, 20.91, 28.33 and 30.67 cm respectively control-1 during 2017-18 and 2018-19 (Fig.1-2). Some chemical inducers are act as endogenous single molecules, which influence a range of diverse metabolic processes in plants, including seed germination (Abdel-Monaim 2010) [17], ion uptake and transport, membrane permeability (Babcock *et al.*, 1993) [18], photosynthetic and growth rate (Khan, *et al.* 2003 and El-Mohamedy, *et al.* 2014) [10, 5], plant defense (Arzoo *et al.* 2012, Biswas *et al.* 2012, Girdhari *et al.* 2008 Kishan *et al.*, 2019) [4, 6, 20, 22] were used some chemical as inducers *viz.* Ethephon, hydrogen peroxide (H_2O_2), mannitol, salicylic acid (SA) at three different concentrations (50,100, 200 ppm) to treat potato tuber by dipping in solution and they found that all these chemicals minimize early blight incidence as well as influence of these chemicals on growth, quantity and quality parameters of potato plants under greenhouse conditions. Mohammed, *et al.*, (2017) [26] reported that the germination increased by 72.9 and 100% in Neveske and Arosa varieties respectively, when treated with ($CaCl_2$ 0.1 kg/t, 4 kg/ ha; chitosan 0.05 kg/t, 0.4 kg/ha). Also, for plant height and branches number, treatment with ($CaCl_2$ 0.1 kg/t, 4 kg/ ha; chitosan 0.05 kg/t, 0.4 kg/ha) was more significant in comparison to the control.

Growth is important parameters for good crop healthy and minimized crop disease. In the present study also, the maximum plant covered area cm in diameter was found in Salicylic acid treated seed tubers, representing 58.75 cm and 59.53 cm in diameter, respectively during 2017-18 and 2018-19 at 50 days age of seedling, followed by calcium chloride treated plant showing 56.89 cm and 58.45 cm in diameter during 2017-18 and 2018-19 at 50 days age of plants, respectively representing second highest among the treatments. The control plant were showing 43.15 cm and 42.84 cm in diameters respectively control during 2017-18 and 2018-19. Kishan, *et al.*, (2019) [22] reported that the Salicylic acid was increased significantly in shoot number, leaf number, leaf area and root length. They also found that it has also significantly increased total soluble protein (16.78 mg/gm) in shoots, chlorophyll content of the shoot leaves and means of microtuber weight and number (1.094), (7.125). Agami *et al.* (2013) [16] reported that seed germination rate was affected by *Trichoderma* application but shoot height, shoot diameter, fresh and dry weight of shoot in tomato seedlings were increased significantly. Roy *et al.* (1994) [32] also reported enhanced the growth of shoot length of swamp cabbage (*Impoeaaquatica*) and okra (*Hibiscus esculentus*) by aquous extract of *Terminalia belirica* whereas the aqueous extract of horitoki significantly reduced and delayed germination, growth of shoot length of swamp cabbage seeds compared with control. Devesh *et al.*, (2016) noted in case of *Lantana camara*treated plant showing 86.34% and 20.2 cm against 71.0 % and 10.4 cm respectively in case of control.

The maximum number of stem / plant was found in Salicylic acid treated seed tubers, representing 4.27 and 4.33, respectively during 2017-18 and 2018-19 at 50 days age of seedling, which was followed by calcium chloride treated plant showed 4.12 and 4.21 during 2017-18 against 3.38 and 3.45, respectively in case of control during 2017-18 and 2018-19. Similarly, The maximum stem diameter in cm was found in Salicylic acid treated seed tubers, representing 6.37 cm and 6.41 cm, respectively during 2017-18 and 2018-19 at 50 days age of seedling, which as followed by, calcium chloride treated plant showed 6.22 cm and 6.26 cm during 2017-18 and 2018-19 against 5.25 cm and 5.33 cm, respectively in case of control. The maximum no of leaves / plant was found in Salicylic acid treated seed tubers, representing 49.55 and 49.92 respectively during 2017-18 and 2018-19 at 50 days age of seedling, which was followed by calcium chloride treated plant representing 47.68 and 48.26 during 2017-18 and 2018-19 against 40.95 and 41.25 respectively in case control. Mohammed, *et al.*, (2017) [26] found that the results indicated that combined pre-planting application with 0.1 kg/t CaCl2 and 0.05 kg/t chitosan with 2 h intervals, then, spraying foliar twice with 4 kg/ha CaCl2 and 0.4 kg/ha chitosan with 10 days intervals starting at 40 days after planting was most effective in maintaining the germination, plant height, and branches number. Tilak Chowdary (2019) [29] also recorded that maximum number of branches and flowers/plant were also found in the T7 treatment where soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + first foliar application with Benfil (Carbendazim) + Second foliar application with Matco (Metalaxyl +Mancozeb) showing 13.60 branches/ plant and 90.60 flowers/ plant where in case of control-1 the values are 5.80 and 50.90 and control-2 values are 3.60 and 16.40. Mohammed *et al.*, (2020) [27] reported that the spraying foliar twice with 4 kg/ha CaCl2 and 0.4 kg/ha chitosan with 10 days intervals starting at 40 days after planting was most effective in maintaining the germination, plant height, and branches number.). Agami *et al.* (2013) [16] reported that seed germination rate was affected by *Trichoderma* application but shoot height, shoot diameter, fresh and dry weight of shoot in tomato seedlings were increased significantly. They also found that soil amended by *Trichoderma* sp. had marked increase in leaf number and area of leaf. The maximum fresh weight in g was found in Salicylic acid treated seed tubers, representing 305.10 g and 309.23 g respectively during 2017-18 and 2018-19 at 50 days age of seedling, against 219.05 g and 224.10 g respectively in case of control. The calcium chloride treated plant showed 297.90 g and 301.35 g during 2017-18 and 2018-19 at 50 days age of plants, respectively representing second highest among the treatments. It has found that the maximum dry weight of shoot in g was found in Salicylic acid treated seed tubers, representing 32.28 g and 33.41 g respectively during 2017-18 and 2018-19 at 50 days age of seedling, followed by calcium chloride treated plant as 31.72 g and 32.95 g during 2017-18 and 2018-19 at 50 days age of plants, respectively representing second highest among the treatments against 22.61 g and 22.26 g respectively control-1. Similarly, dry shoot weight was also found increase in all the treatments but maximum with 7.27gm was recorded in treatment T8where treatment was given as soil application of FYM + seedling deep in *T. harzianum* formulation +spray of Mancozeb. On the other hands, the minimum with 3.60gm by Walke, *et al.* (2014) [30]. Agami *et al.*, (2013) [16] reported that seed germination rate was affected by *Trichoderma* application but shoot height, shoot diameter, fresh and dry weight of shoot in tomato seedlings were increased significantly. They also found that soil amended by *Trichoderma* sp. had marked increase in leaf number and area of leaf. Mansoor *et al.* (2001) [24] also observed that the *Azotobacter* improved plant height and shoot dry weight significantly. Yogesh, *et al.*, (2016) reported that the fresh and dry shoot and root weight was also found maximum with 25.3 g & 7.27gm and 22.00gm & 4.25gm respectively in treatment T8where treatment was given as soil application of FYM + seedling deep in *T. harzianum* formulation + spray with mancozeb.

Table 1: Effect of inorganic chemicals as inducer on plant growth parameters of potato at different days of interval under Wire house condition) during 2017-18

Name of inorganic chemicals	Concentration of inorganic chemicals	Germination (%)	Effect of inducers on plant height of potato (cm) at different days during 2017-18					% Increased of plant height over control at 50 Days
			10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	
SA	10mM	100.00	5.20	16.35	29.10	37.85	44.75	52.37
$CaCl_2$	10 mM	100.00	5.08	15.42	28.25	36.50	43.00	46.51
H_2O_2	10ppm	90.00	4.36	14.75	27.08	35.28	41.39	41.02
Boric acid	0.1 %	90.00	4.73	15.00	27.56	36.05	42.60	45.14
DPHP	0.2 %	80.00	3.82	13.85	25.67	32.30	37.08	26.34
$FeCl_3$	5mM	85.00	3.97	14.05	25.95	33.45	37.92	29.20
IAA	1 %	85.00	4.11	14.52	26.80	34.12	38.50	31.18
$CuCl_2$	10mM	80.00	3.73	13.10	24.25	30.65	36.85	25.55
Control	-	65.00	2.26	11.90	19.35	26.15	29.35	-
SEm±	-	1.05	0.04	0.19	0.41	0.43	0.56	
CD at 5 %	-	3.13	0.12	0.58	1.22	1.27	1.66	

Table 2: Effect of inorganic chemicals as inducer on germination (%) and plant height of potato at different days of interval under Wire house condition during 2018-19

Name of inorganic chemicals	Concentration of inorganic chemicals	Germination (%)	Effect of inducers on plant height of potato (cm) at different days during 2018-19					% Increased of plant height over control at 50 Days
			10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	
SA	10mM	100.00	5.35	16.67	30.28	38.43	46.15	50.47
$CaCl_2$	10 mM	100.00	5.16	16.22	29.55	37.25	44.78	46.00
H_2O_2	10ppm	90.00	4.83	15.60	27.48	36.82	41.83	36.38
Boric acid	0.1 %	90.00	5.03	15.84	28.67	37.01	43.46	41.70
DPHP	0.2 %	80.00	3.98	14.19	25.44	33.94	38.74	26.31
$FeCl_3$	5mM	85.00	4.27	14.71	26.32	34.67	39.23	27.91
IAA	1 %	85.00	4.51	15.05	26.77	35.52	40.35	31.56
$CuCl_2$	10mM	80.00	3.76	13.90	24.21	32.75	37.59	22.56
Control	-	65.00	2.47	12.15	20.91	28.33	30.67	-
SEm±	-	0.88	0.05	0.25	0.34	0.55	0.64	
CD at 5 %	-	2.62	0.15	0.74	1.01	1.65	1.89	

Table 3: Effect of inorganic chemicals as inducer on plant growth parameters of potato at different days of interval under Wire house condition during 2017-18

Name of inorganic chemicals	Concentration of inorganic chemicals	Plant spread (cm)	No. of leaves/ plant	No. of stem per plant	Stem diameter (cm)	Fresh weight of shoot / plant (g)	Dry weight of shoot / plant (g)
SA	10mM	58.75	49.55	4.27	6.37	305.10	32.28
$CaCl_2$	10 mM	56.89	47.68	4.12	6.22	297.90	31.72
H_2O_2	10ppm	53.36	45.74	3.96	6.03	279.45	30.04
Boric acid	0.1 %	55.15	46.27	4.05	6.18	286.50	30.83
DPHP	0.2 %	48.23	43.75	3.79	5.67	258.15	27.16
$FeCl_3$	5mM	49.06	44.16	3.84	5.78	265.20	28.45
IAA	1 %	50.57	44.94	3.95	5.89	272.35	29.33
$CuCl_2$	10mM	46.40	42.30	3.71	5.46	243.60	26.58
Control-I	-	42.84	40.95	3.38	5.25	219.05	22.61
SEm±	-	0.68	0.82	0.06	0.12	3.37	0.35
CD at 5 %	-	2.02	2.42	0.18	0.34	10.02	1.04

Table 4: Effect of inorganic chemicals as inducer on plant growth parameters of potato at different days of interval under Wire house condition during 2018-19

Name of inorganic chemicals	Concentration of inorganic chemicals	Plant spread (cm)	No. of leaves/ plant	No. of stem per plant	Stem diameter (cm)	Fresh weight of shoot / plant (g)	Dry weight of shoot / plant (g)
SA	10mM	59.53	49.92	4.33	6.41	309.23	33.41
$CaCl_2$	10 mM	58.45	48.26	4.21	6.26	301.35	32.95
H_2O_2	10ppm	55.73	46.83	4.02	6.05	287.16	30.79
Boric acid	0.1 %	56.30	47.55	4.11	6.18	294.40	31.67
DPHP	0.2 %	50.18	44.17	3.87	5.76	270.95	28.13
$FeCl_3$	5mM	51.84	44.79	3.92	5.84	277.33	28.92
IAA	1 %	53.42	45.32	3.98	5.95	281.55	29.84
$CuCl_2$	10mM	48.65	43.48	3.81	5.59	259.48	27.37
Control-1	-	43.15	41.25	3.45	5.33	224.10	23.26
Control-2	-	40.24	39.52	3.36	4.99	214.75	21.64
SEm±	-	0.71	0.80	0.07	0.08	4.22	0.40
CD at 5 %	-	2.11	2.39	0.20	0.24	12.55	1.18

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