



## The Potency of Unassociated *Trichoderma spp* and the Fungicides Antagonistic of the Late Blight of Potato by *Phytophthora infestans* (Mont.) De-Bary

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### Authors' contributions

This work was carried out in collaboration among all authors. Author AB performed the study and wrote the first draft of the manuscript. Author SKB designed the study and wrote protocol. Author DB performed the statistical analysis and managed the analyses of the study. Author DB managed the literature researches. All the authors read and approved the final manuscript.

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### ABSTRACT

The potato (*Solanum tuberosum*) is one of the most important vegetable crops in the world, belonging to the family Solanaceae and is an important starchy food crop in both sub-tropical and temperate regions. Potato plants are subjected to attack by numerous diseases wherever the crop is grown. Among them, late blight of potato caused by *Phytophthora infestans* (Mont.) de-Bary is of major cause of concern in potato production at present. An experiment was conducted in the Department of Plant Pathology, College of Agriculture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The antifungal activity of different fungicides was evaluated *in-vitro* through the food poison technique. The experimental finding showed that radial growth of mycelium of *Phytophthora infestans* was inhibited by fungicides over control. At 100 ppm, the minimum radial growth of mycelium was found in Equation Pro treatment as 5.3, 8.2, 11.4, 14.2, 16.2, 18.4 and 22.6 mm over control against 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 mm at 1, 2, 3, 4, 5, 6 and 7 days after inoculation respectively. Similarly, at 500 and 1000 ppm the minimum radial growth of mycelium was found in Equation Pro treatment. Efficacy of bio-control agents on

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the radial growth of *Phytophthora infestans* was evaluated using Dual Culture Methods. Among the different concentrations, 1000 ppm was found most effective than 100 and 500 ppm. Among the different bio-agents, *Trichoderma harzianum* able to reduced maximum radial mycelial growth of fungus showing 4.6, 8.8, 10.1, 13.2, 15.6, 19.3 and 23.5 mm against 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 mm at 1, 2, 3, 4, 5, 6 and 7 days after inoculation, respectively.

**Keywords:** *Trichoderma spp*; fungicides; potato; *Phytophthora infestans* and growth of mycelium.

## 1. INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family *Solanaceae*, considered as "King of vegetables". It is an important tuberous crop cultivated for vegetable, food and several other processed products. It can be grown in wider range of altitude, latitude and climatic conditions. The English word "Potato" comes from Spanish word "patata" (the name used in Spain). Food and Agriculture Organization of UN has declared potato as 'Food for future' [1]. The origins of the potato can be traced back to South American natives in 5000 B.C. in the highlands of the Peruvian Andes Mountains. Around 1570, the potato reached Europe with the returning Spanish explorers. There are more than 160 wild potato species and most of them contain high levels of alkaloids. The first edible potato is considered to have been cultivated 4000 years ago in Peru [2]. Potato represents valuable sources of nutrient in a balance diet. The average nutritional value of 200g potato is about Calories: 200, Protein: 4.6g, Carbohydrate: 51g, Fat: 0.2g, Cholesterol free and good source of dietary fiber with 4-8g, Niacin: 16mg, Vitamin B6: 7mg, Vitamin C: 26mg Iron: 2.75mg, Magnesium: 55mg, Thiamine: 22mg and Pantothenic acid: 1.12 [3].

Now a days potato is also gained considerable importance as an export crop to European markets and other parts of the world which is considered an important source for national income [4,5]. India also exports potato to Nepal (32.1%), Sri Lanka (30.4%), Russia (18.6%), Malaysia (5.8%), Mauritius (4.9%) and many other countries of the world. It is the world's fourth important food crop after wheat, rice and maize because of its higher yield potential and high nutritive value. Recently, potato is grown in about 150 countries of the world and the total area under potato production during 2011 was about 19.33 million hectares with a total production of about 19.33 million tons which is consumed by over a billion of peoples across the globe, of which half are in the developing countries [6]. The five major potato-producing

country in the world are China (96.01 MT), India (45.9 MT), Russia (30.9 MT), Ukraine (23.0 MT) and USA (19.9 MT) during 2013-14 (FAOSTAT 2016). The production and productivity of potato is quite impressive. During 2004, global potato production was recorded as 336 MT which significantly increased to 374 MT, with more than 80% production recorded in Europe and Asia (Axel et al., 2012; FAOSTAT 2016). India produced 41.565 MT of potato from an area of 18.87 lakh hectares of land during 2011-12 [7]. In India, the leading potato producing states are Uttar Pradesh 33% followed by West Bengal 22%, Bihar 16%, Madhya Pradesh 6%, Gujarat 5%, Punjab 5%, Assam 2%, Haryana 2%, Karnataka 1%, Jharkhand 1%, others 7% which constitute about 100% of the total domestic potato production (Indian Horticulture Database - 2014, NHB). From the last few years, potato production in Uttar Pradesh has caught the attention of many prospective food processing entrepreneurs and even the Netherlands ambassador Alphonsus Stoelinga, during his recent visit to Lucknow, had said that his country was looking for setting up potato processing centre in Uttar Pradesh [7].

Potato suffers from several diseases, such as early blight, late blight, leaf spot, dry rot, charcoal rot, black scurf, common scab, soft rot, leaf roll. Among them, late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important and most destructive disease of potato causes "Irish Famine in 1845". The disease is distributed all over the world like North & South America, Europe, Asian continents [8,9]. In last few years, late blight has become a significant epidemic problem in North Africa and Morocco [10,11], Tunisia [12,13] and Algeria [14]. The annual economic losses caused by the disease worldwide have been about 170 billion US dollars [15,16]. In India, the losses caused by the disease are 10-20% in Uttar Pradesh, 10-15% in West Bengal and Punjab, 10-15% in Karnataka and Uttrakhand also have been reported during 2013-14 [17] but the losses depend on the variety and plant protection measures adopted (Rakesh, et al., 2018).

## 2. MATERIALS AND METHODS

### 2.1 Collection of Infected Plant Samples

Late blight infected leaves were collected from the potato field at Vegetable Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Infected leaves with sporulation lesions were taken from the field and washed in sterilized water and stored in Biological Oxygen Demand for further study.

### 2.2 Preparation of Culture Media

The *Phytophthora infestans* which causes late blight of potato belongs to Class Oomycetes and generally not grown on Potato Dextrose Agar Media. Tomato juice media was used, and the details are as follow:

Tomato juice	-	250 ml
Calcium carbonate	-	0.04 gm
Agar powder	-	20 gm
Dextrose	-	20 gm
Distilled water	-	1000 ml

The tomato dextrose agar medium prepared was sterilized at 121.6°C, 15 psi. for 15 minutes in an autoclave.

### 2.3 Procedure

Fresh and healthy tomato were collected from market(s) during Dec 2017 and washed thoroughly in running tap water and then distilled water to remove dust and foreign matter from the surface. 250 gm tomato was taken and cut into the small pieces and grinding with electric mixer or Oster food blender. The obtained slurry was passed through a sieve with a pore size of 1.5×1.5 mm to remove large pieces of tissues. The filtrate was measured in a measuring cylinder and final volume made up to 1 litre by adding more distilled water. It was again poured in sauce pan and heated. 20 gm agar powder was added slowly in heating juice. The solution was boiled for some time till it tends to solidify on cooling. The prepared media was then poured in four conical flask of about 200 ml. 10 ml of media was poured in 10 culture tubes. Both conical flask and culture tubes were plugged with non-absorbent cotton and mouth was wrapped with butter paper and rubber band. The culture tubes were placed vertically in wire baskets. The media in flask and culture tubes were then auto claved at 15 lb/inch<sup>2</sup> pressure (15 psi) for 20 minutes at 121.6°C.

### 2.4 Isolations of Pathogen

A small piece of infected leaf from border of sporulating lesion along with some healthy green tissue was cut and dipped in mercuric chloride solution (0.1%) for 30 seconds followed by rinse in sterilized distilled water thrice and dried off with sterilized filter paper. The small pieces were then placed on tomato extract based media which was previously pour in sterilized in Petri plates. The plates were then incubated at 18± 1<sup>0</sup> C. The Petri plates were observed daily to find out the presence of mycelium around the leave bits. As soon as the mycelia growth is notices around the bits, the pathogen was purified by hyphal tip culture method.

### 2.5 Purification of *Phytophthora infestans*

The white mycelial bits of *P. infestans* was removed from the margin of fungal colony and then transferred to another Petri-plate which was previously poured with sterilized tomato extract based medium. After purification, the pure culture of *P. infestans* was transferred on slant medium and incubated at 15-18<sup>0</sup>C in darkness till full growth. The culture was then transferred into the incubator at 10-12<sup>0</sup>C for further use.

### 2.6 Identifications of *Phytophthora infestans*

The isolated pathogen was identified on the basis of its morphological, cultural characters and pathogenic behaviour towards the host. *P. infestans* belong to the class Oomycetes. The vegetation is mycelium characterized by the absence of cross walls, along with both asexual and sexual reproduction occurs. The sporangiophores and sporangia emerge at asexual reproduction phase. The sporangia are lemon shape, measurement of 21- 38µm× 12-23µm. Sporangia develop at the end of these sporangiophores. The pathogen was found to produce the characteristics leaf blight symptoms on the affected plants. The isolation pathogen was identified on the basis of its morphological and cultural characters and pathogenic behaviour towards the host.

### 2.7 Maintenance of the Culture

After confirmation of isolated pathogen as *P. infestans*, the pure culture was transferred on media slant and maintain in the BOD at 10 - 12°C for further study.

## 2.8 Pathogenicity Test

The pathogenicity test of isolated fungus was conducted on healthy potato plants in order to establish the pathogenic nature of the fungus. The pathogenicity was tested according to Koch's postulates (1882).

The earthen pots of 30cm diameter were taken to conduct the present experiment. Initially the pots were filled with sterilized soil and water was added to bring the soil under good tilt condition. The healthy tubers of potato variety *Kufri Bahar* (3797) were placed in these pots and were allowed to grow for one month. The homogenized spore suspension was prepared in sterilized water from 7 days old culture of *P. infestans*. The suspension was sprayed on one month old potato plants @ 2 ml/plant. The inoculated plants were placed on the bench of glass house. After 2-3 days, the plants began to show the symptoms of blight. The inoculated plants showed pale to dark green spots occur at the leaf tips and margins that change into brown or black lesions later. These lesions are not delimited in size and enlarged rapidly in a favourable weather. On the lower side of leaves, a white mildew appears on the surface of lesions where the pale and purplish tissues join. These symptoms confirmed that the blighting was caused by *P. infestans*.

## 2.9 Comparative Evaluation of Fungicides against *Phytophthora infestans* (*in-vitro*)

Seven fungicides belonging to different groups *viz* were screened against the pathogen under laboratory conditions to find out their relative efficacy in inhibiting the growth of the pathogen in culture by the "Poison Food Technique" [18]. Required quantity of each fungicide was incorporated in already prepared two per cent tomato extract medium prior to solidification and thoroughly mixed them by shaking prior to pouring in sterilized Petri plates. The medium was allowed to solidify and then 5 mm bits of fungal culture from seven days old culture were placed at the centre of Petri plates. The fungal disc was reversed so that the pathogen could come in direct contact with the medium. Three replications were kept for each treatment. The Petri plates were incubated at 18±1°C. One set of control was maintained in which the medium was not mixed with any fungicide but simply inoculated with the pathogen. The data on radial

growth of fungal colony was measured in mm after every 24 hours till the control Petri plates were not filled up. The per cent inhibition over control was calculated by the following formula as given by Bliss [19].

$$I = \frac{c-T}{c} \times 100$$

whereas,

I = Percent inhibition in mycelia growth  
C = Growth of pathogen in control plates.  
T = Growth of pathogen in treated plates.

## 2.10 Statistical Analysis

The data were analyzed by following the procedure of Randomized Block Design (RBD) and Completely Block Design (CRD). Data recorded in percentage were first transformed as

Arc sin value (Fisher and Yates, 1963)  $\sqrt{\sin^{-1}}$  before statistical analysis. Treatments were compared by means of critical difference (CD) at 5 per cent level of significant.

## 3. RESULTS AND DISCUSSION

The preliminary works have been undertaken for comparative evaluation of different, bio-agents and chemicals against *P. infestans*, *in-vitro* through Poison Food Techniques. The data presented in Table 1 showed that the minimum radial growth of mycelium was found in Equation Pro treatment, representing 5.3, 8.2, 11.4, 14.2, 16.2, 18.4 and 22.6 mm at 1, 2, 3, 4, 5, 6 and 7 days after inoculation against as 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 mm in case of control at 100 ppm. Similarly, at 500 and 1000 ppm, the minimum radial was noted from Equation Pro treatments. From the (Tables 2, 3), it is also cleared that among the different concentrations, 1000 ppm is found most effective to reduce the mycelial growth of *P. infestans*. Similar findings were also reported by several workers against several pathogenic fungi [20,21,22]. The bicarbonates salts has been shown to have a profound inhibitory effect on several fungi and cause the collapse of hyphal walls and shrinkage of conidia [22,23]; Abd-El-Kareem [24]; and Montaser Fawzy et al., 2012). Fungicides of different formulations of inorganic and organic materials which have the potentials of growth inhibition, killing of zoospore/zoospores and mycelium of the causative organism [25].

**Table 1. Evaluation of different fungicides against *Phytophthora infestans* at the concentration of 100 ppm (in-vitro)**

Treatments	Radial mycelial growth at different days after inoculation (mm)							Per cent inhibition over control at 7 DAI
	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI	
Krilaxyl	6.8	10.6	15.2	17.4	20.5	22.1	28.1	56.64
Equation Pro	5.3	8.2	11.4	14.2	16.2	18.4	22.6	65.12
Zampro	6.4	9.6	13.1	16.1	19.4	21.3	26.2	59.57
Matco	7.3	10.9	15.9	17.9	21.6	22.8	29.7	54.17
Curzate	5.8	8.6	12.3	15.5	18.3	19.5	24.4	62.34
Combi Plus	8.1	12.5	16.4	19.7	23.8	24.6	31.2	51.85
Indofil M-45	8.5	13.4	18.2	22.7	25.1	27.7	34.5	46.75
Control	12.3	19.1	26.1	35.9	42.5	51.4	64.8	-
SEm±	0.063	0.191	0.268	0.326	0.403	0.278	0.495	-
CD at 5%	0.190	0.577	0.812	0.987	1.218	0.842	1.497	-

**Table 2. Evaluation of different fungicides against *Phytophthora infestans* at the concentration of 500 ppm (in vitro)**

Treatments	Radial mycelial growth at different days after inoculation (mm)							Per cent inhibition over control at 7 DAI
	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI	
Krilaxyl	4.8	8.6	12.5	15.6	18.4	21.2	26.4	59.25
Equation pro	3.1	5.8	8.2	11.3	15.4	17.3	20.5	68.36
Zampro	4.2	9.6	11.1	13.4	17.4	20.7	24.6	62.03
Matco	5.3	9.4	13.9	17.7	19.1	22.4	28.5	56.02
Curzate	3.5	6.4	8.7	12.4	16.3	18.2	22.8	64.81
Combi Plus	6.1	10.5	13.4	18.9	21.2	23.6	31.8	50.92
Indofil M-45	6.5	11.4	15.2	20.7	24.0	26.4	33.6	48.14
Control	12.3	19.1	26.1	35.9	42.5	51.4	64.8	-
SEm±	0.076	0.143	0.221	0.342	0.264	0.374	0.471	-
CD at 5%	0.229	0.433	0.667	1.035	0.797	1.130	1.423	-

**Table 3. Evaluation of different fungicides against *Phytophthora infestans* at the concentration of 1000 ppm (in vitro)**

Treatments	Radial mycelial growth at different days after inoculation (mm)							Per cent inhibition over control at 7 DAI
	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI	
Krilaxyl	2.8	4.6	7.0	11.4	14.2	17.1	21.5	66.82
Equation pro	1.8	2.5	3.7	6.0	10.1	12.4	15.5	76.08
Zampro	2.3	4.3	5.8	9.6	12.2	15.3	19.3	70.21
Matco	3.3	5.5	9.1	13.2	16.1	19.4	23.6	63.58
Curzate	1.9	2.7	5.7	8.4	11.5	14.0	17.2	73.46
Combi Plus	4.1	7.3	10.2	14.6	18.8	22.6	26.8	58.64
Indofil M-45	5.5	9.0	11.5	16.0	19.0	25.0	32.6	49.69
Control	12.3	19.1	26.1	35.9	42.5	51.4	64.8	-
SEm±	0.086	0.171	0.165	0.350	0.293	0.446	0.402	-
CD at 5%	0.260	0.518	0.498	1.057	0.887	1.349	1.215	-

**Table 4. Evaluation of different bio-agents against *Phytophthora infestans* (in-vitro)**

Treatments	Radial mycelial growth at different days after inoculation (mm)							Per cent inhibition over control at 7 DAI
	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI	
<i>T. harzianum</i>	4.6	8.8	10.1	13.2	15.6	19.3	23.5	63.73
<i>T. viride</i>	5.3	9.5	11.3	13.5	16.4	20.4	24.3	62.50
<i>T. koningii</i>	5.7	10.3	13.6	14.7	17.2	22.6	26.9	58.49
<i>T. virens</i>	6.2	10.9	14.8	16.4	18.5	24.5	28.6	55.86
Control	12.3	19.1	26.1	35.9	42.5	51.4	64.8	-
SEm±	0.178	0.251	0.288	0.194	0.537	0.455	0.645	-
CD at 5%	0.567	0.754	0.920	0.620	1.713	1.454	2.060	-

Efficacy of bio-control agents viz *T. harzianum*, *T. viride*, *T. koningii* and *T. virens* on the growth of *P. infestans* was evaluated using Dual Culture Technique. The result presented in the Table 4 showed that the all the treatment significantly reduced the radial growth of mycelial of the pathogens. Among the different bio-agents, *T. harzianum* able to reduced maximum radial mycelial growth of fungus showing 4.6, 8.8, 10.1, 13.2, 15.6, 19.3 and 23.5 mm over control as 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 at 1, 2, 3, 4, 5, 6 and 7 days after inoculation, representing 63.73 % inhibition over control at 7 days of inoculation. Shailbala and Pundhir [26] and Glare et al. [27] found that among the seven potato phyloplane fungi, only three fungi viz., *Fusarium* spp, *Trichoderma* spp, *Aspergillus* spp showed antagonistic potential against *P. infestans*, causal agent of late blight of potato. Many bio-agents i.e. *Trichoderma viride*, *Penicillium viridicatum*, *P. aurantiogriseum*, *Chetomium brasilense* [28], *Acremonium strictum* [29], *Myrothecium varrucaria* and *P. aurantiogriseum* [30] showed antagonistic effect against *P. infestans* in lab studies. The antagonistic activities of *Pseudomonas fluorescens*, *Pseudomonas* sp. *Aspergillus flavus*, *A. niger*, *Penicillium* sp., *T. virens* and *T. harzianum* showed positive inhibition of mycelial growth of *P. infestans*, *Fusarium* spp and *Rhizoctonia solani* under *in-vitro* conditions [31]. *Bacillus* sp. were used for managing late blight disease of potato *in-vitro* [32]. Yuan Hang et al., 2014 [33] also reported that *T. koningiopsis* and *T. asperellum* were effective against *P. infestans* under both laboratory and field conditions.

#### 4. CONCLUSION

The pathogen *Phytophthora infestans* was isolated from potato leaves showing typical late

blight symptoms. The fungus growing on tomato juice media produced white colored mycelium, distinctive sympodial sporangiophores with pear shaped sporangia having distinct papilla. The description of the fungus agreed with the description given by Common wealth Mycological Institute, Kew, Surrey, England, [34]. Thus the pathogen causing late blight of potato has been identified as *P. infestans*. Successful pathogenicity of the fungus on potato was proved following Koch's postulates by inoculating the spore suspension.

Among the seven different fungicides tested on mycelial growth of the *P. infestans*, at 100 ppm, the minimum radial growth of mycelium was found in Equation Pro treatment as 5.3, 8.2, 11.4, 14.2, 16.2, 18.4 and 22.6 mm over control against 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 mm. Similarly, 500 and 1000 ppm the minimum radial growth of mycelium was found in Equation Pro treatment. Among the different bio-agents, *T. harzianum* able to reduced maximum radial mycelial growth of fungus showing 4.6, 8.8, 10.1, 13.2, 15.6, 19.3 and 23.5 mm against 12.3, 19.1, 26.1, 35.9, 42.5, 51.4 and 64.8 mm at 1, 2, 3, 4, 5, 6 and 7 days after inoculation, respectively, similarly result was reported by NHB,[34] Montaser, et. al., [35].

#### DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

- Hawkes JG. In the potato evolution, biodiversity and genetic resources. Belhaven Press, London, UK. 1989;58-79.
- Hijmans RJ, Spooner DM. Geographic distribution of wild potato species. *American J. Bot.* 2001;88(11):2101-2112.
- USDA. Nutritional Profiles of potato. United States Department of Agriculture. 2014; 1-61.
- El-Sirafy ZM, Abbady KA, El-Ghamry AM, El-Dissoky RA. Potato yield quality, quantity and profitability as affected by soil and foliar potassium application. *Res. J. Agri. Biol. Sci.* 2008;4(6):912-922.
- El-Mougy NS, Abdel-Kader MM. Salts application for suppressing potato early blight. *J. Plant Protec. Res.* 2009;49(4): 353-361.
- Sumit Kumar, Biswas SK, Prakesh HG. Integrated disease management approaches for control of late blight of potato and enhancing the growth of potato. *J. of Biol. Control.* 2018;32(4):264-269.
- Gracy CP, Jyoti Naik, Nagashree N. Store potato and sell in may. *Agropedia*, Department of Agricultural marketing co-operation and business Management UAS, GKVK, Bangalore. 2013;65.
- Fry WE, Goodwin SB, Dyer AT, Matuszak JM, Drenth A, Tooley PW, et al. Historical and recent migrations of phytophthora infestans: Chronology, pathways, and implications. *Plant Dis.* 1993;77:653-661.
- Chowdappa P, Kumar NBJ, Madhura S, Kumar MSP, Myers KL, Fry WE, et al. Emergence of 13\_A2 blue lineage of phytophthora infestans was responsible for severe outbreaks of late blight on tomato in south west India. *J. Phytopathol.* 2013;161: 49-58.
- Sedegui M, Carroll RB, Morehart AL, Hamlen RA, Power RJ. Comparison of assays for measuring sensitivity of phytophthora infestans isolates to fungicides. *Plant Disease.* 1999;83:1167-1169.
- Andrivon D, Pilet F, Montarry J, Hafidi M, Corbière R, Achbani EH. Adaptation of phytophthora infestans to partial resistance in potato. Evidence from French and Moroccan Populations. *Phytopathol.* 2007; 97:338-343.
- Jmour W, Hamada W. First report of A<sub>2</sub> mating type of phytophthora infestans in Tunisia using molecular markers and some observations on its metalaxyl resistance. *Tunisian J. Plant Protect.* 2006;1:85-91.
- Harbaoui K, Lee T, Vleeshouwers VGAA, Khammassy N, Harrabi M, Hamada W. Characterization of phytophthora infestans isolates collected from potato and tomato crops in Tunisia during 2006–2008. *Potato Research.* 2013;56:11-29.
- Corbière R, Rekad FZ, Galfout A, Andrivon D, Bouznad Z. Phenotypic and genotypic characteristics of algerian isolates of phytophthora infestans. Twelfth Euro Blight workshop. PPO-Special Report no. 2010; 14:133–146.
- Haverkort AJ, Struik PC, Visser RGF, Jacobsen E. Applied biotechnology to combat late blight in potato caused by phytophthora infestans. *Potato Res.* 2009; 52:249-264.
- Wu Y, Jiang J, Gui C. Low genetic diversity of phytophthora infestans population in potato in north China. *African J. Biotech.* 2012;11(90):15636-15642.
- Lal M, Arora RK, Maheshwari U, Rawal S, Yadav S. Impact of late blight occurrence on potato productivity during 2013-14. *Int. J. Agricult. Stat. Sci.* 2016;12(1):187-192.
- Schimtz H. A suggested toxiometric method of food preservation. *Indus Engias Chem. Analyst.* 1930;4:89-104.
- Bliss CI. The method of probits-a correction. *Science.* 1934;79(2053):409-410.
- Kone AS, Csinos KL, Jackson PJ.. Evaluation of systemic acquired resistance inducers for control of *Phytophthora capsici* on squash. *Crop Prot.* 2009;28: 6533-6538.
- Alex K. Comparative studies of different fungicides with neem leaf extract against different pathogens. M.Sc. Thesis, CSAUA & T, Kanpur. 2019;1-80.
- Ziv O, Zitter TA. Effects of bicarbonates and film-forming polymers on cucurbit foliar diseases. *Plant Disease.* 1992;76:513-517.
- Punja ZK, Grogan RG. Effects of inorganic salts, carbonate-bicarbonate anions, ammonia, and the modifying influence of pH on sclerotial germination of *Sclerotium rolfsii*. *Phytopathol.* 1982;72(6):635-639.
- Abd-El-Kareem F, Abd-El-Latif Faten. Using bicarbonates for controlling late

- blight disease of potato plants under field conditions. Life Sci. J. 2012;9:280-285.
25. Song J, Bradeen JM, Naess SK, Raasch JA, Wielgus SM, Haberlach GT, et al. Gene RB cloned from *Solanum bulbocastanum* confers broad spectrum resistance to potato late blight. Proceedings of the National Academy of Science, U.S.A. 2003;100:9128-9133.
  26. Shailbala, Pundhir VS. Effect of potato mustard inter cropping on late blight severity, yield and economics of potato. Plant Dis. Res. 2007;22(1):67-69.
  27. Glare T, Caradus J, Gelernter W, Jackson T, Keyhani N, Kohl J, et al. Have bio pesticides come of age. Trends Bio-tech. 2012;30:250-258
  28. Gupta H, Singh BP, Jitendra M. Bio-control of late blight of potato. Potato J. 2004;31: 39-42.
  29. CPRI. Annual progress report. Central Potato Research Institute, Shimla, India. 1999;1-86.
  30. Roy S, Singh BP, Bhattacharyya SK. Biocontrol of late blight of potato. Phytophthora Newsl. 1991;17:18.
  31. Lal M, Singh PA, Tomar S, Hussain T, Sharma S, Kaushik SK, Singh BP. Antagonistic effect of bio-agents against three potato fungal diseases and their fungicidal sensitivity. Vegetos. 2013;26: 362-367.
  32. Sunaina V, Ajay S, Dureja P. Bacterial metabolites from *Bacillus cereus* B4 responsible for potato plant growth. Potato J. 2005;32:187-188.
  33. Yuan-Hang QU, Qi W, Yan-Po Y, Zhen-Lin H, Yan L. Antagonistic trichoderma isolates against potato late blight caused by *Phytophthora infestans*. Mycosystema. 2014;33:1231-1241
  34. Ellis MB. Dematiaceous hyphomycetes. C.M.I. Kew, Surrey, English. 1971;608.
  35. Indian Horticulture Database. Department of agriculture & cooperation. NHB. 2014; 1-107.
  36. Montaser F, Abdel-Monaim, Mohsen AW, Abdel-Gaid, Hanaa A, Haliem A. Effect of chemical inducers on root rot and wilt diseases, yield and quality of tomato. Inter. J. Agric. Sci. 2012;2(7):2011-2020.

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