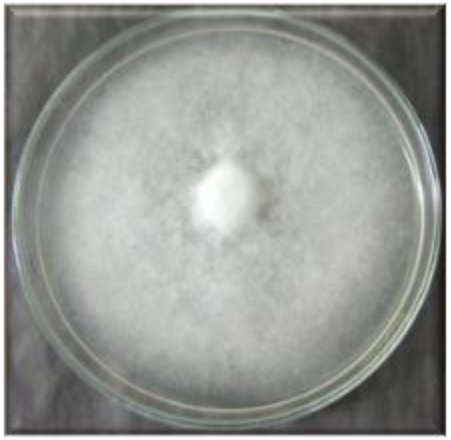
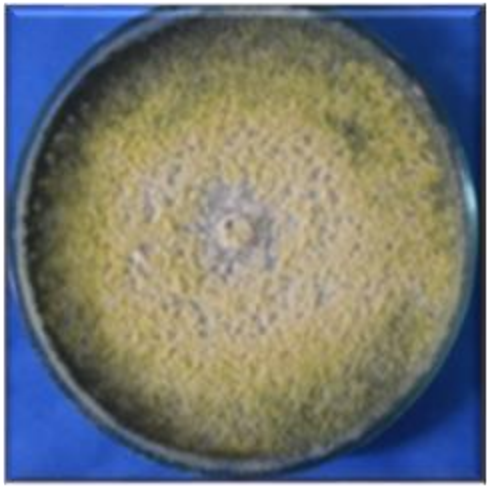
WELCOME





Bio-fungicides and Updates on PLB in Bangladesh

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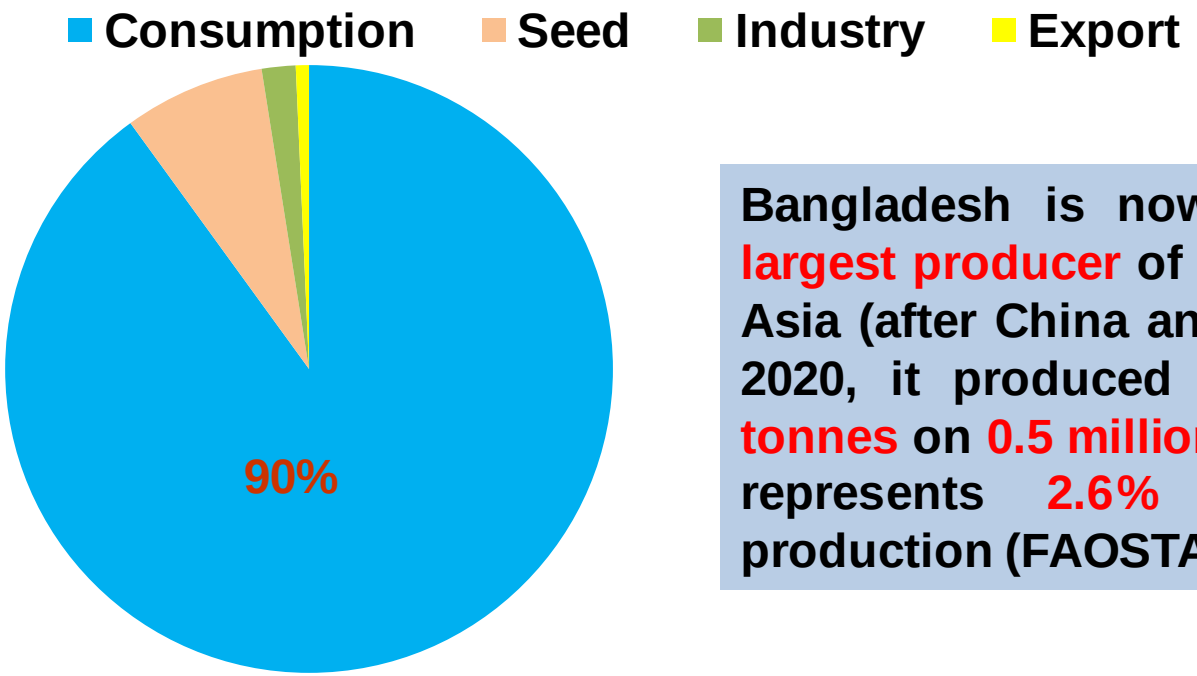
Importance of potato in Bangladesh

- Consumption as vegetable (around 9 million tons)
- As seed (0.75 million tons)
- As industrial raw materials (Chips and French Fries)
- Earning foreign currency by exporting ($13 million)

In 2016: 70000 tons (0.07 million tons)
By 2021: 500000 tons (0.5 million tons)



Bangladesh is now the third largest producer of potatoes in Asia (after China and India); in 2020, it produced 9.6 million tonnes on 0.5 million ha, which represents 2.6% of world production (FAOSTAT 2022).

Annual losses due to unsold potato and post-harvest losses

The Daily Star

WEDNESDAY, September 21, 2022 | Journalism Without Fear or Favour

News Opinion Coronavirus Sports Business Entertainment Life & Living Youth Tech & Startu

Agriculture

Potato farmers lose Tk 2,500cr a year: FAO

Unsold surplus, post-harvest losses to blame

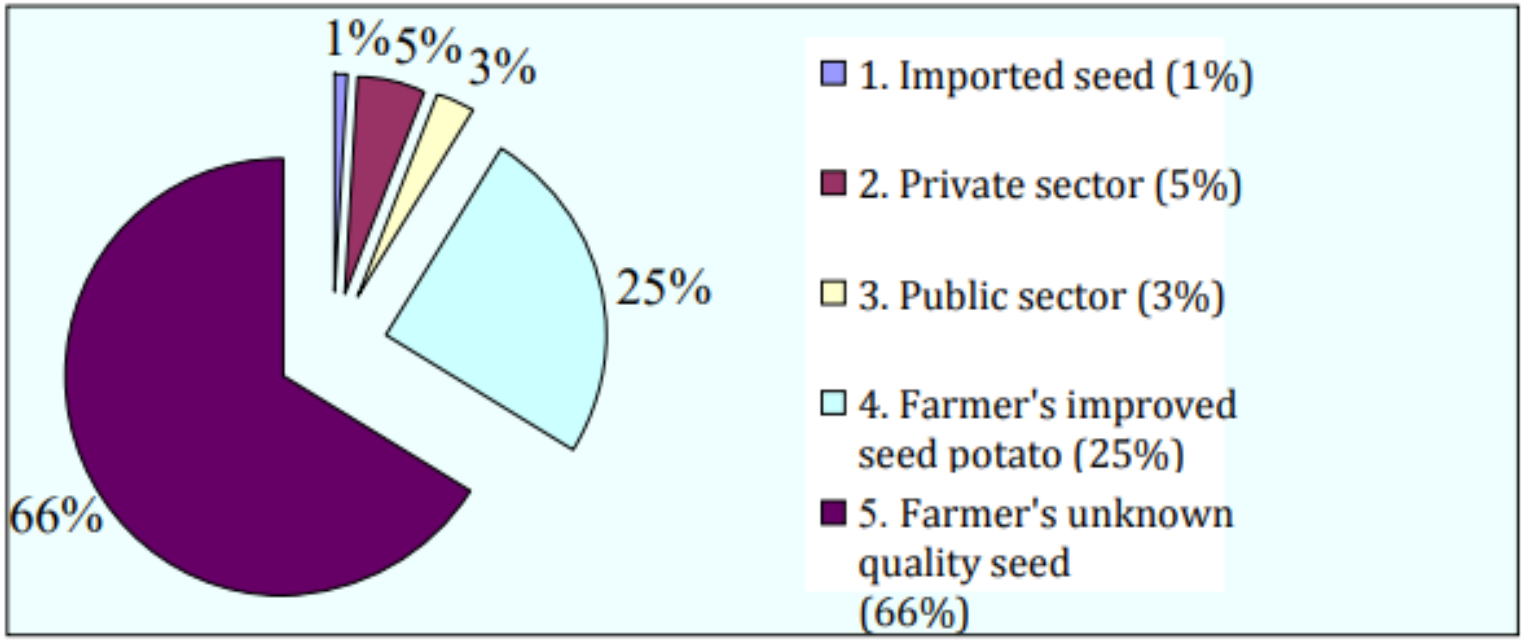
Star Business Report

Mon Mar 21, 2022 12:00 AM Last update on: Mon Mar 21, 2022 03:10 AM

Surplus production: 4-5 million tonnes
Losses: $290 to $400 million

Estimation of seed potato supply in Bangladesh

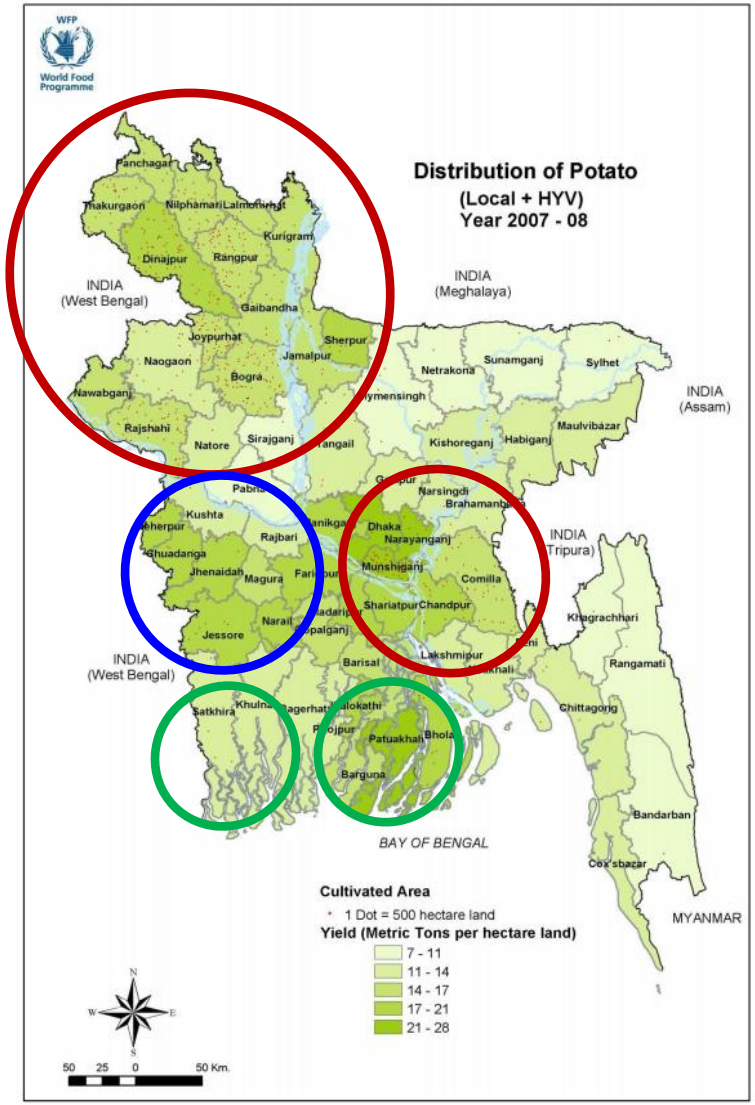
Total requirement of seed potato: 0.75 million tones



Certified and disease free seed would be a potential solution.

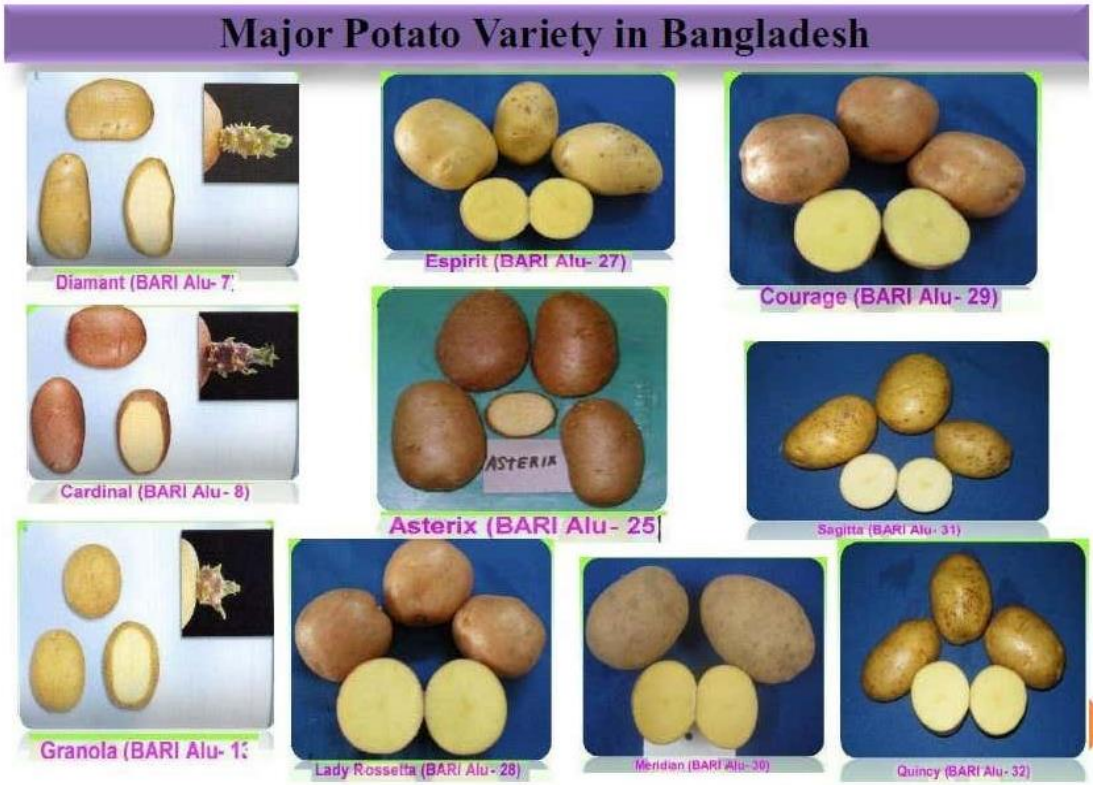
Siddque et al. 2015

Potato growing areas of Bangladesh



Variety wise land utilization

Variety	% Land utilization
Diamant	40
Asterix	30
Cardinal	15
Granola	5
Others	10



Status of Bangladesh in terms of potato production

Top Potato Producing Countries Asia

Source: FAOSTAT (Retrieval Date: January 5, 2019)

Rank	Country	Potato Production 2017 in tonnes
1	China	99,205,600
2	India	48,605,000
3	Bangladesh	10,216,000
4	Iran	5,102,340
5	Turkey	4,800,000
6	Pakistan	4,142,400
7	Kazakhstan	3,551,110
8	Uzbekistan	2,793,690
9	Nepal	2,691,040
10	Japan	2,150,920

Top 25 Potato Producing Countries

Source: FAOSTAT (Retrieval Date: January 5, 2019; Sweet potatoes are NOT included).

Rank	Country	Potato Production in 2017 in tonnes
1	China	99,205,600
2	India	48,605,000
3	Russian Federation	29,590,000
4	Ukraine	22,208,200
5	United States	20,017,400
6	Germany	11,720,000
7	Bangladesh	10,216,000
8	Poland	9,171,730
9	Netherlands	7,391,880
10	France	7,342,200
11	Belarus	6,414,760
12	United Kingdom	6,218,000
13	Iran	5,102,340
14	Turkey	4,800,000
15	Peru	4,776,290
16	Algeria	4,606,400
17	Belgium	4,416,660
18	Canada	4,410,830
19	Egypt	4,325,480
20	Pakistan	4,142,400
21	Brazil	3,656,850
22	Kazakhstan	3,551,110
23	Romania	3,116,910
24	Colombia	2,819,030
25	Uzbekistan	2,793,690

https://www.potatopro.com/bangladesh/potato-statistics

Constraints of potato cultivation in Bangladesh

- Lack of good quality certified seed at Farmer's level
- Lack of high-yielding varieties at Farmer's level
- Lack of indigenous improved varieties
- High post-harvest spoilage
- High incidence of diseases: Late blight

High price of fertilizers

- Lack of irrigation facilities and high cost
- Lack of credit facilities
- Insect pest problem
- Labour crisis
- Lack of storage facilities
- Marketing problem

Source: Farmers' Field Survey, 2009

Why potato late blight is a devastating disease in Bangladesh?

- Night temperature: 10 to 15ºC
- Day temperature: 15 to 21ºC
- Relative humidity: 90%
- Foggy weather and winter rains

Out break

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	11	13	17	21	24	25	26	26	25	23	18	13
Max (°C)	23	26	31	33	32	32	32	32	31	31	29	25
Min (°F)	52	55	63	70	75	77	79	79	77	73	64	55
Max (°F)	73	79	88	91	90	90	90	90	88	88	84	77

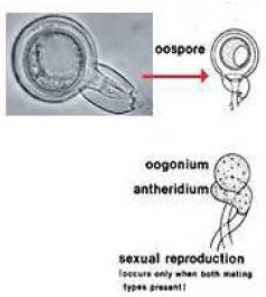
Impact of potato late blight

- Irish potato famine in the 1840s
- Global loss: 3 million hectares of potato crops (16%)
- Economic losses : $6.7 billion [Haverkort et al. 2008]

- Economic losses: ????
- Amount of pesticides sprayed: 36,500 tones per year
- Fungicides sprayed to control late blight of potato:100 tones/year
- Farmers spend to control late blight: About $10 million

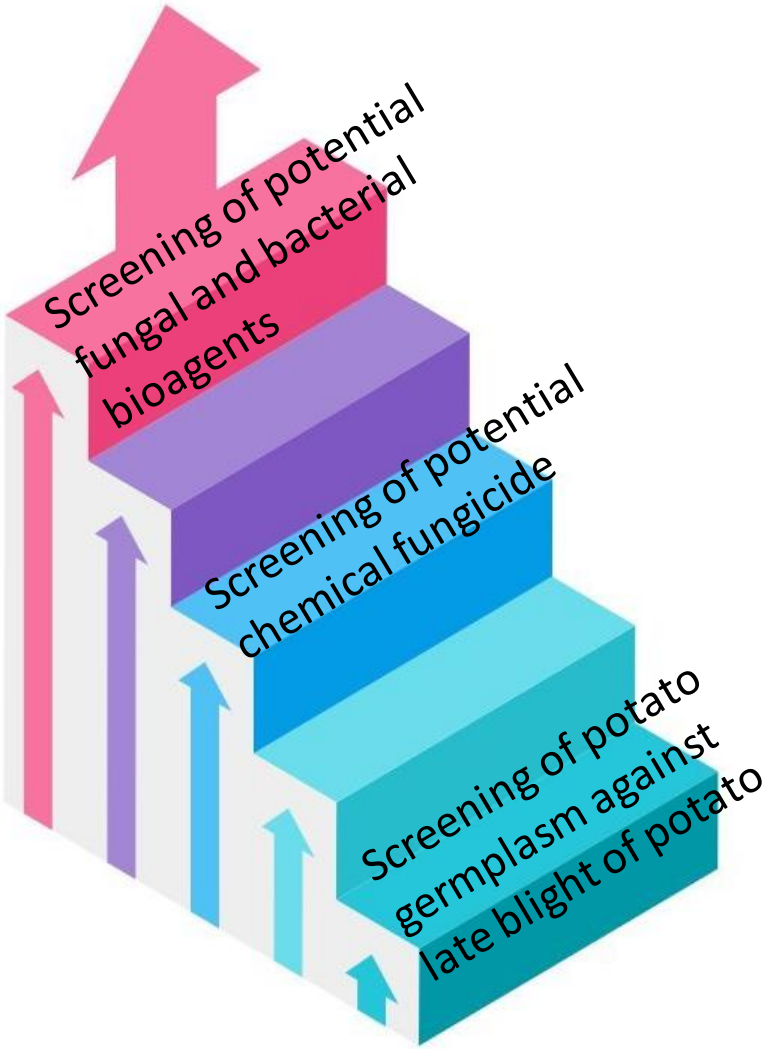
https://acibiolife.net/late-blight-resistant-gm-ge-potato-in-bangladesh-now-a-reality/

- Management issues
  - Primary inoculum source?
  - Decision support system (DSS) effectiveness?
  - Host resistance stability?
  - Fungicide efficacy?



Courtesy: http://www.apsnet.org

Common late blight management practice in Bangladesh



Status of evaluation of chemical fungicides

Int. J. Sustain. Crop Prod. 3(2):10-15 (February 2008)

CONTROL OF LATE BLIGHT DISEASE OF POTATO BY USING NEW FUNGICIDES

M. M. RAHMAN[1], T. K. DEY[2], M. A. ALI[3], K. M. KHALEQUZZAMAN[4] AND M. A. HUSSAIN[5]

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Accepted for publication: November 20, 2007

ABSTRACT

Rahman M. M., Dey T. K., Ali M. A., Khalequzzaman K. M. and Hussain M. A. 2008. *Control of Late Blight Disease of Potato by Using New Fungicides.* **Int. J. Sustain. Crop Prod. 3(2):10-15**

An investigation was carried at Tuber Crops Research Sub-Centre (TCRSC), Bogra during 2002 and 2003 crop season to find out suitable fungicide(s) to combat the late blight disease of potato. Altogether 13 fungicides viz. Amcozeb, Coromil Mz-72, Dithane M-45, Filthane M-45, Mancozeb, Metaril, Melody Duo, Oxivit, Ridomil gold, Secure, Unilax, Vitamyl Mz-72 and Zhemetalax were tested against the disease in two consecutive seasons. All the fungicides significantly reduced the late blight incidence of potato over control. Among the fungicides, Filthane M-45, Secure, Melody Duo, Ridomil gold and Metaril are highly effective to minimize late blight and to increase yield of potato.

Key words: Late blight, fungicide. Potato

- Amcozeb
- Coromil Mz-72
- Dithane M-45
- Mancozeb
- Oxivit
- Unilax
- Vitamyl
- Mz-72
- Zhemetalax
- Filthane M-45
- Secure
- Melody Duo
- Ridomil gold
- Metaril

significantly reduced the late blight incidence of potato over control

Genotypes of *P. infestans* in Bangladesh

Phenotypic and Genotypic Analysis of the Population of Phytophthora infestans in Bangladesh Between 2014 and 2019

Authors
Islam, M.H.
Shanta, S.S.
Hossain, M.A.
Rahaman, E.H.M.S.
Al Mahmud, A.
Akhond, M.A.Y.
Sullivan, L.
Cooke, D.E.L.
Kessel, G.J.T.
Cooke, L.R.
Islam, M.R.

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2022-09

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Islam, M. H.; Shanta, S. S.; Hossain, M. I.; Hossain, M. A.; Hossain, M. M.; Rahaman, E. H. M. S.; al Mahmud, A.; Akhond, M. A. Y.; Sullivan, L.; Cooke, D. E. L.; Kessel, G. J. T.; Cooke, L. R.; Islam, M. R. (2022). Phenotypic and Genotypic Analysis of the Population of Phytophthora infestans in Bangladesh Between 2014 and 2019. Potato Research. ISSN 0014-3065. 19 p.

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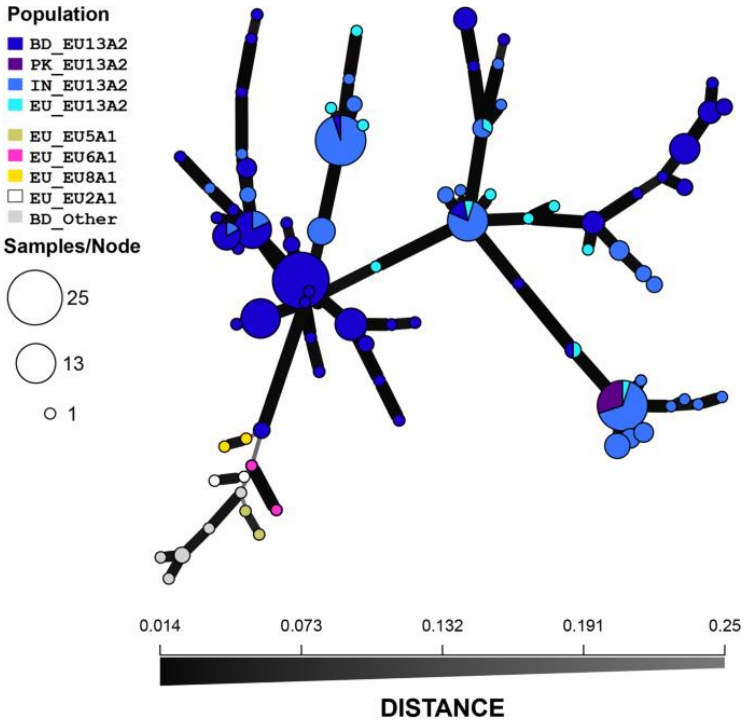
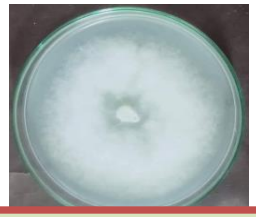
DOI: https://doi.org/10.1007/s11540-022-09581-w

Abstract/Description
In Bangladesh, the third largest producer of potatoes in Asia, late blight, caused by Phytophthora infestans, is the major constraint to production. Nevertheless, there is a lack of published information on the pathogen population. A collection of 69 isolates obtained from samples of infected potato foliage collected in 2018–2019 varied significantly in their aggressiveness to detached potato leaflets and tuber slices of cv. Diamant. On leaflets, most isolates were highly aggressive, colonizing more than half the surface in 7 days. On tuber slices, while some isolates were highly aggressive, those collected in 2019 were less so. There was a significant effect of the locations from which the isolates were obtained on aggressiveness to both leaflets and tuber slices, but aggressiveness to leaflets and to tuber slices was not significantly correlated. All isolates were A2 mating type and either intermediate (38%) or resistant (62%) in sensitivity to the fungicide metalaxyl. A subset of 24 isolates all had mitochondrial DNA haplotype Ia. Samples of P. infestans DNA (124) from infected potato foliage obtained from Bangladesh (2014–2019) were genotyped by 12-plex SSR. The vast majority (95%) were assigned to EU_13_A2, which was present in every year in which samples were collected. Numerous EU_13_A2 variants were identified, many specific to Bangladesh. Six samples (from 2017 to 2019) had genotypes distinct from EU_13_A2 and with no close match to known European lineages. It is concluded that the current P. infestans population of Bangladesh is dominated by the aggressive lineage EU_13_A2, also dominant in India and Pakistan. The implications of this for control of late blight are discussed.



Assessment of metalaxyl resistance/sensitivity assay of *P. infestans* isolates on pea agar medium

Control



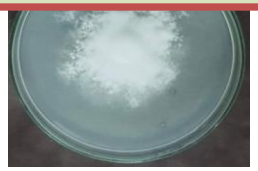
$$\text{Growth \% of non amended control plate} = \frac{R2}{R1} \times 100$$

Where,

R1 = Radial growth of the respective *P. infestans* isolate in control plate

R2 = Radial growth of the respective *P. infestans* isolate in metalaxyl amended plate

Intermediate



Representative photograph of Metalaxyl resistance/sensitivity assay of *P. infestans* isolates on pea agar medium. After autoclaving, pea agar medium was amended with Metataf (25% Metalaxyl) @ 100 µg/ml and 5 µg/ml concentration of metalaxyl.

Sensitive: Isolates exhibited growth less than 40% of nonamended control on both 5 µg/ml and 100 µg/ml metalaxyl.

Intermediate: Isolates exhibited growth greater than 40% of nonamended control media at 5 µg/ml metalaxyl, but less than 40% of the nonamended control media at 100 µg/ml metalaxyl .

Resistant : Isolates exhibited growth 40% or more of nonamended control media with metalaxyl at 100 µg/ml.

Daggett *et al.* 1993

Assessment of metalaxyl resistance/sensitivity assay of *P. infestans* isolates on pea agar medium

Isolate ID	Location	Radial mycelial growth (mm) in treated plates		Radial mycelial growth in non-amended control plates	Growth (% of control)		Resistant/Intermediate/ Sensitive
		Metalaxyl concentration (µg/ml)			Metalaxyl concentration (µg/ml)		
		100	5		100	5	
Pi01_2018	Panchagarh	33.17	36.75	84.33	39.32	43.57	I
Pi02_2018	Panchagarh	32.67	37.5	86.33	37.83	43.43	I
Pi03_2018	Panchagarh	33.83	39.75	86	39.34	46.22	I
Pi04_2018	Thakurgoan	26.83	53	89	30.14	59.55	I
Pi05_2018	Thakurgoan	26.83	50	88.67	30.26	56.39	I
Pi06_2018	Thakurgoan	26.5	51	88.67	29.88	57.51	I
Pi07_2018	Dinajpur	26.16	35	80.33	32.57	43.56	I
Pi08_2018	Dinajpur	26.83	52	89	30.14	58.42	I
Pi09_2018	Dinajpur	25.67	42.5	85.33	30.07	49.80	I
Pi10_2018	Nilphamari	40.83	45	87	46.93	51.72	R
Pi11_2018	Nilphamari	32	37.75	81	40.00	46.60	R
Pi12_2018	Nilphamari	33.33	52.33	87.67	38.02	59.69	I
Pi13_2018	Nilphamari	36	51.33	88	40.90	58.33	R
Pi14_2018	Rangpur	30.33	36	81	37.44	44.44	I
Pi15_2018	Rangpur	40.33	41.75	84.67	47.63	49.31	R
Pi16_2018	Rangpur	25	35	80	31.25	43.75	I
Pi17_2018	Kurigram	35	37.75	84.33	41.50	44.76	R
Pi18_2018	Kurigram	35	37.75	85	41.17	44.41	R
Pi19_2018	Kurigram	34	36	84.67	40.15	42.51	R
Pi20_2018	Kurigram	35	38	85.33	41.01	44.53	R
Pi21_2018	Bogura	22.5	49.25	85.67	26.26	57.49	I
Pi22_2018	Bogura	34.83	50	88.67	39.28	56.39	I
Pi23_2018	Bogura	36.83	50.33	88.67	41.54	56.76	R

Sensitive: Isolates exhibited growth less than 40% of nonamended control on both 5 µg/ml and 100 µg/ml metalaxyl.
Intermediate: Isolates exhibited growth greater than 40% of nonamended control media at 5 µg/ml metalaxyl, but less than 40% of the nonamended control media at 100 µg/ml metalaxyl .
Resistant : Isolates exhibited growth 40% or more of nonamended control media with metalaxyl at 100 µg/ml.

Daggett *et al.* 1993

Table 1. cont'd. Assessment of metalaxyl resistance/sensitivity assay of *P. infestans* isolates on pea agar medium

Isolate ID	Location	Radial mycelial growth (mm) in treated plates		Radial mycelial growth in non-amended control plates	Growth (% of control)		Resistant/Intermediate/ Sensitive
		Metalaxyl concentration (µg/ml)			Metalaxyl concentration (µg/ml)		
		100	5		100	5	
Pi24_2018	Joypurhat	35	52.33	87	40.22	60.15	R
Pi25_2018	Joypurhat	35	42.25	82.33	42.51	51.31	R
Pi26_2018	Joypurhat	33	37	79.67	41.42	46.44	R
Pi27_2018	Naogoan	41.83	51	85.33	49.02	59.76	R
Pi28_2018	Naogoan	34.83	46	80.67	43.18	57.02	R
Pi29_2018	Jamalpur	26.5	49	88	30.11	55.68	I
Pi30_2018	Jamalpur	31.67	50	87.67	36.12	57.03	I
Pi31_2018	Jamalpur	24.5	46.75	85.33	28.71	54.78	I
Pi32_2018	Sherpur	45.33	47	88	51.51	53.40	R
Pi33_2018	Sherpur	48.33	49	84.33	57.31	58.10	R
Pi34_2018	Sherpur	36.5	42	80	45.62	52.5	R
Pi35_2018	Mymensingh	23.5	52	87	27.01	59.77	I
Pi36_2018	Mymensingh	21.5	44.67	85	25.29	52.54	I
Pi37_2018	Cumilla	26.67	32.5	79.67	33.47	40.79	I
Pi38_2018	Cumilla	29.83	51	87	34.29	58.62	I
Pi39_2018	Munshiganj	31.33	39	80	39.16	48.75	I
Pi40_2018	Munshiganj	26.83	35	79.67	33.68	43.93	I
Pi41_2018	Chandpur	35	37.75	86	40.69	43.89	R
Pi42_2018	Chandpur	32	46	87.33	36.64	52.67	I
Pi-45_2019	Dinajpur	43.67	48	88.33	49.43	54.33	R
Pi-46_2019	Dinajpur	42.17	48.75	88	47.91	55.39	R
Pi-47_2019	Dinajpur	42.83	52	88.67	48.30	58.64	R
Pi-48_2019	Rangpur	44	51	85.33	51.56	59.76	R

Sensitive: Isolates exhibited growth less than 40% of nonamended control on both 5 µg/ml and 100 µg/ml metalaxyl.
Intermediate: Isolates exhibited growth greater than 40% of nonamended control media at 5 µg/ml metalaxyl, but less than 40% of the nonamended control media at 100 µg/ml metalaxyl .
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Daggett *et al.* 1993

cont'd. Assessment of metalaxyl resistance/sensitivity assay of *P. infestans* isolates on pea agar medium

Isolate ID	Location	Radial mycelial growth (mm) in treated plates		Radial mycelial growth in non-amended control plates	Growth (% of control)		Resistant/Intermediate/ Sensitive
		Metalaxyl concentration (µg/ml)			Metalaxyl concentration (µg/ml)		
		100	5		100	5	
Pi-49_2019	Rangpur	47	51.33	87.67	53.23	58.55	R
Pi-50_2019	Rangpur	46	50.33	86.67	52.88	58.07	R
Pi-62_2019	Sherpur	49.5	51	84.67	58.46	60.23	R
Pi-63_2019	Munshiganj	48.83	49	85	57.45	57.64	R
Pi-64_2019	Munshiganj	47.33	52	83.33	56.8	62.4	R
Pi-65_2019	Munshiganj	47.5	52	82.33	57.69	63.15	R
Pi-66_2019	Cumilla	40.5	52.33	87	46.55	60.15	R
Pi-67_2019	Cumilla	51.67	50.33	88.33	58.49	56.98	R
Pi-68_2019	Cumilla	50.83	49.33	87	58.42	56.70	R
Pi-69_2019	Chandpur	36	41	81.33	44.26	50.40	R
Pi-70_2019	Chandpur	37.83	46.5	85.33	44.33	54.49	R
Pi-71_2019	Chandpur	36	40.17	83.67	43.02	48.00	R

The results of metalaxyl sensitivity assay revealed that 62% (43 out of 69) isolates were metalaxyl Resistant and 38% (26 out of 69) were Intermediate type

Sensitive: Isolates exhibited growth less than 40% of nonamended control on both 5 µg/ml and 100 µg/ml metalaxyl.

Intermediate: Isolates exhibited growth greater than 40% of nonamended control media at 5 µg/ml metalaxyl, but less than 40% of the nonamended control media at 100 µg/ml metalaxyl .

Resistant : Isolates exhibited growth 40% or more of nonamended control media with metalaxyl at 100 µg/ml.

Daggett *et al.* 1993

Status of evaluation of chemical fungicides

Article

Identification of potential chemical fungicides with diverse groups of active ingredient for controlling late blight of potato in Bangladesh

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Abstract: Potato is the third important food crop in Bangladesh and Bangladesh ranked as third and seventh in Asia and in the world, respectively. But potato production greatly affected by the late blight of potato caused by an oomycete, *Phytophthora infestans* (Mont.) de Bary worldwide. Application of need-based fungicides is the key factor to control this disease and to avoid development of fungicide resistance in *P. infestans*. Experiments were conducted in both *in vitro* and in field condition to evaluate some selected chemical fungicides to identify the best one to control the late blight disease of potato. The results of *in vitro* test revealed that all the fungicides inhibited the growth of *P. infestans* by 94% over control. But the results of field experiment conceded that the lowest late blight severity was found in T_{10} (Curzate M8) (0.49%) followed by T_6 (AcrobateMz) (0.52%), T_8 (Micra) (0.59%), T_7 (Xtramyl) (0.61%), T_3 (Daconyl) (0.84%), T_5 (Secure) (1.28%), T_9 (Sanoxanyl) (1.43%), T_1 (Unilax) (1.83%), T_2 (TemperM) (2.58%) and T_4 (Amiscore) (6.34%) at 71 DAP while the maximum late blight severity (95.33%) was observed in T_0 (water as control). The highest yield was obtained in T_{10} (Curzate M8) (25.94 t/ha) followed by T_6 (AcrobateMz) (25.67 t/ha), T_5 (Secure) (25.22 t/ha), T_7 (Xtramil) (24.61 t/ha), T_8 (Micra) (24.61 t/ha) and T_9 (Sanoxanil) (23.67 t/ha) which were statistically similar and the lowest (8.39 t/ha) yield was observed in T_0 (water as control). The highest Benefit Cost Ratio (BCR) was obtained from when potato plants were sprayed with T_{10} (Curzate M8) (1.02) following by T_7 (Xtramil) (0.99), T_8 (Micra) (0.99), T_6 (AcrobateMz) (0.92), T_9 (Sanoxanil) (0.90), T_5 (Secure) (0.89), T_1 (Unilax) (0.80), T_3 (Daconil) (0.74), T_4 (Amiscore) (0.71) and T_2 (TemperM) (0.44) compared to control T_0 (water as control) (-0.30). The results indicated that application of these fungicides yielded a benefit of Tk. ranged by 0.44 to 1.02 over the investment of Tk. 1.00. Therefore, identification of a number of potential chemical fungicides might be useful in the alternate use of these fungicides against late blight of potato in the field.

***In vitro* test:**

all fungicides inhibited the growth of *P. infestans* by 94% over control.

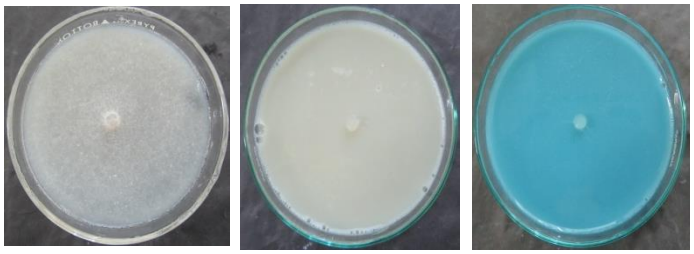
Field experiment

lowest late blight severity was found at 71 DAP

T_{10} (Curzate M8) (0.49%)
T_6 (AcrobateMz) (0.52%)
T_8 (Micra) (0.59%)
T_7 (Xtramyl) (0.61%)
T_3 (Daconyl) (0.84%)
T_5 (Secure) (1.28%)
T_9 (Sanoxanyl) (1.43%)
T_1 (Unilax) (1.83%)
T_2 (TemperM) (2.58%)
T_4 (Amiscore) (6.34%)

Identification of potential fungicide(s) against late blight of potato

A



T_o (Control) T_1 (Unilax) T_2 (Temper M)

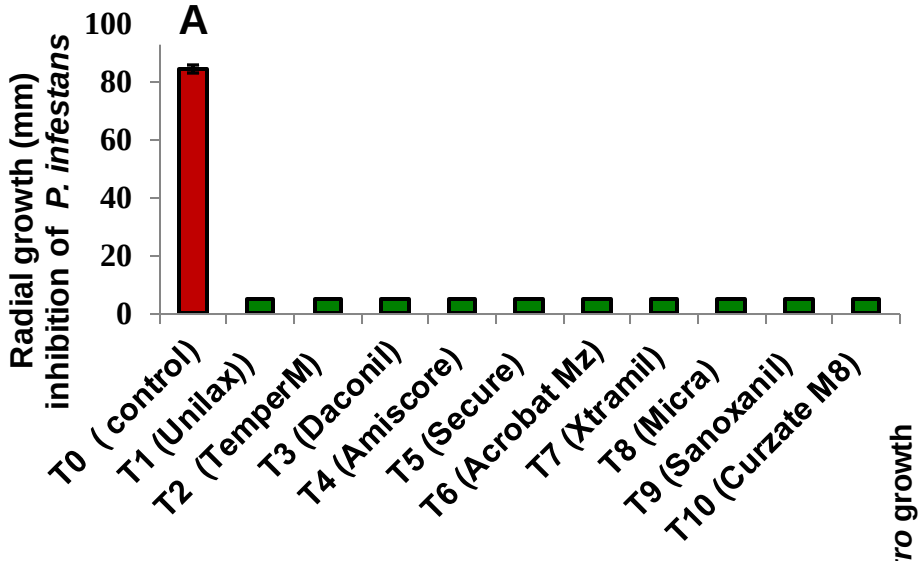
T_3(Daconil) T_4 (Amiscore) T_5 (Secure) T_6 (Acrobat MZ)

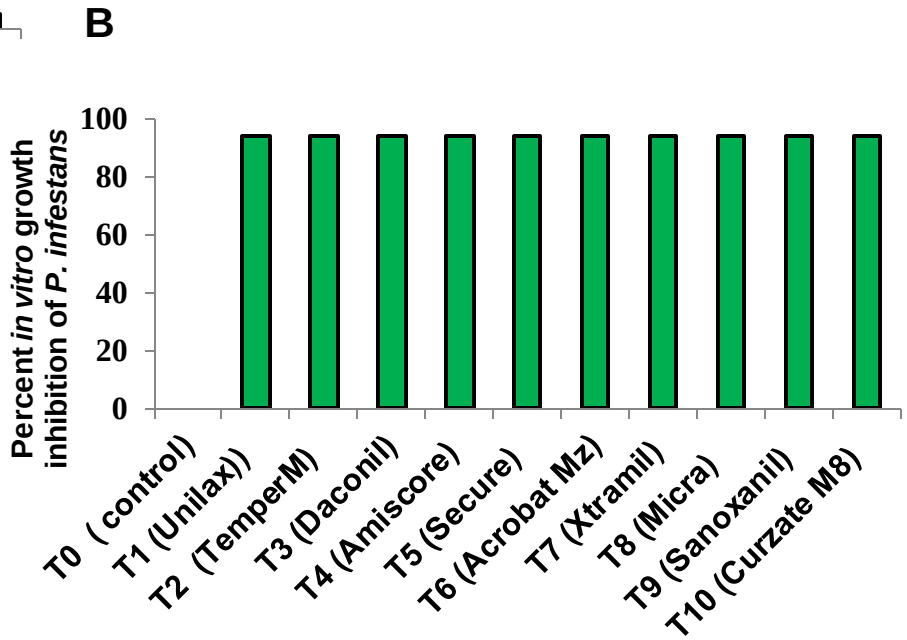
T_7(Xtramil) T_8 (Micra) T_9 (Sanoxanil) T_{10} (Curzate M8)

Name	Active ingredient	Dose
Unilax	Metalaxyl + Mancozeb (8%+64%)	2g/L
Temper M	Propineb + Cymoxanil (70%+6%)	2g/L
Daconil	Chlorothalonil (50%)	1.5 ml/L
Amiscore	Azoxystrobin + Difenoconazole (20%+12.5%)	1 ml/L
Secure	Fenamidone + Mancozeb (8%+64%)	2g/L
Acrobat MZ	Dimethomorph + Mancozeb (9%+60%)	4g/L
Xtramil	Cymoxanil + Mancozeb (8%+64%)	2g/L
Micra	Cymoxanil + Mancozeb (8%+64%)	2g/L
Sanoxanil	Cymoxanil + Mancozeb (8%+64%)	2g/L
Curzate M8	Cymoxanil + Mancozeb (8%+64%)	2g/L

In vitro **growth inhibition of** ***P. infestans*** **by some selected commercially available fungicides on pea agar medium amended with the fungicides.**

In vitro growth inhibition of *P. infestans* by some selected fungicides



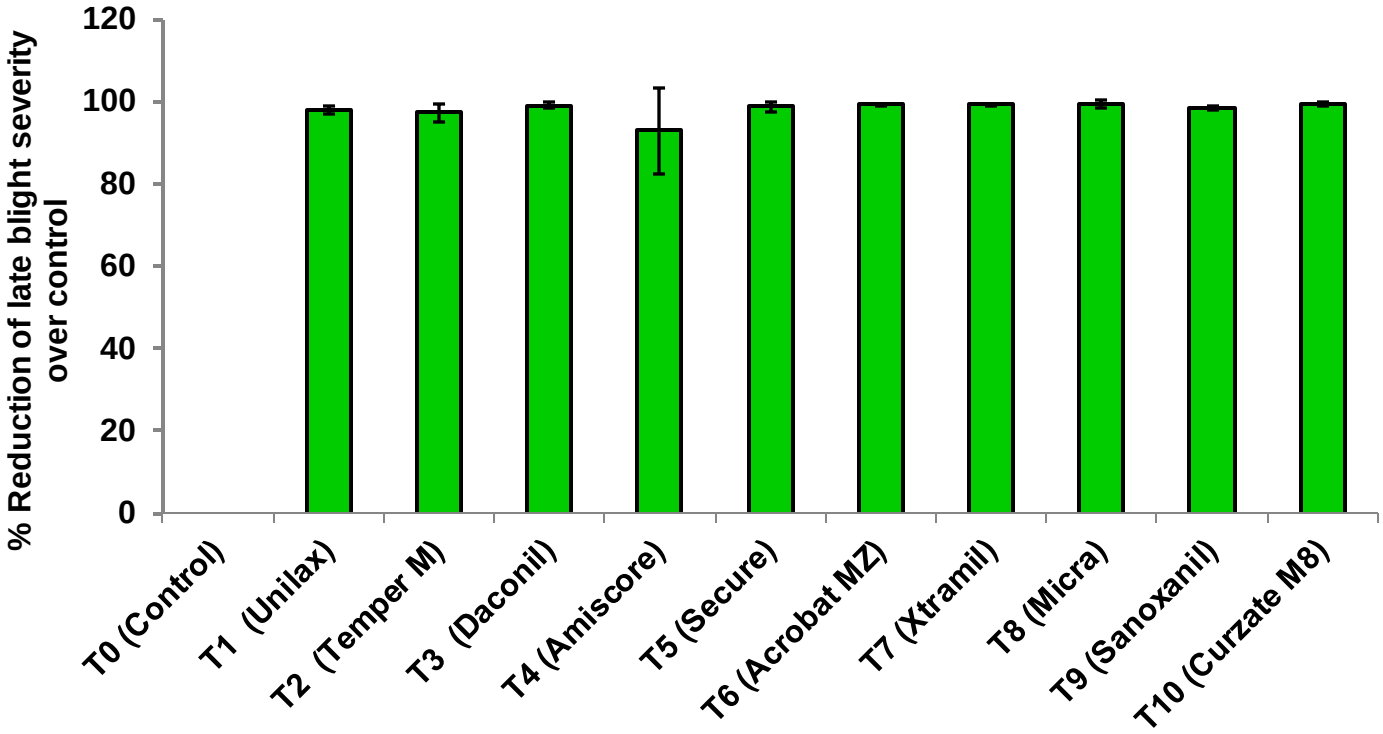


A: Radial growth inhibition (mm) of *P. infestans* by some selected fungicides and
B. Percent *in vitro* growth inhibition of *P. infestans* by some selected fungicides over control.

Comparative efficacy of different potential fungicides available on the market in Bangladesh against late blight of potato under field conditions in 2017-2018

Treatment	% Plant infection		% Late blight severity	
	Days after planting		Days after planting	
	59	71	59	71
T_0 (Control)	100.00±0.00[a]	100.00	6.27±4.81[a]	95.33±2.68[a]
T_1 (Unilax)	42.20±19.45[b]	100.00	0.04±0.02[b]	1.83±0.55[b]
T_2 (Temper M)	52.87±25.18[b]	100.00	0.05±0.03[b]	2.58±1.12[b]
T_3 (Daconil)	27.41±15.50[b]	97.50	0.027±0.01[b]	0.84±0.37[b]
T_4 (Amiscore)	45.40±17.00[b]	100.00	0.06±0.02[b]	6.34±5.39[b]
T_5 (Secure)	36.99±14.61[b]	100.00	0.053±0.02[b]	1.28±0.67[b]
T_6 (Acrobat MZ)	9.84±1.41[b]	97.54	0.01±0.01[b]	0.52±0.03[b]
T_7 (Xtramil)	33.19±7.58[b]	97.52	0.04±0.01[b]	0.61±0.12[b]
T_8 (Micra)	34.17±13.44[b]	97.59	0.04±0.01[b]	0.59±0.42[b]
T_9 (Sanoxanil)	30.33±13.38[b]	100.00	0.04±0.02[b]	1.43±0.34[b]
T_{10} (Curzate M8)	9.05±2.14[b]	97.44	0.007±0.00[b]	0.49±0.17[b]
Level of significance	*	NS	*	*
CV (%)	66.08	2.32	417.53	28.67

Data are the averages of three replications. Values with same letters in the same column are statistically similar.



Effect of different fungicides in reducing percent reduction of late blight severity of potato under field condition at 71 DAP in 2017-2018

T_o (Control)

T_1 (Unilax)

T_2 (Temper M)

T_3(Daconil)

T_4 (Amiscore)

T_5 (Secure)

T_6 (Acrobat MZ)

T_7(Xtramil)

T_8 (Micra)

T_9 (Sanoxanil)

T_{10} (Curzate M8)

Effect of different fungicides in reducing the late blight severity of potato under field condition. Photographs were taken at 71 DAP.

Comparative efficacy of different potential fungicides available on the market in Bangladesh in increasing growth and yield contributing parameters of potato in 2017- 2018

Treatments	Germination (%)	Plant height (cm) Days after planting (DAP)			No. of plantlets/hill	No. of tubers/ plant	Yield (t/ha)
		34	52	71			
T_0 (Control)	96.03	22.27±0.23^{e}	53.00±0.40^{g}	71.23±0.38^{e}	1.73	4.467	8.39±1.31^{d}
T_1 (Unilax)	95.24	25.03±0.44^{bc}	46.63±0.93^{i}	82.17±0.12^{c}	2.33	6.733	27.44±1.48^{abc}
T_2 (Temper M)	96.83	24.60±1.05^{c}	49.40±0.85^{h}	89.30±0.15^{a}	1.73	5.000	23.11±2.95^{c}
T_3 (Deconil)	97.62	25.03±0.39^{bc}	57.17±0.64^{de}	75.27±0.27^{d}	2.00	5.600	26.72±2.36^{bc}
T_4 (Amiscore)	96.83	26.10±0.29^{b}	59.17±0.15^{bc}	86.13±0.33^{b}	1.87	6.200	26.67±0.48^{bc}
T_5 (Secure)	97.62	26.13±0.66^{b}	60.17±0.07^{ab}	83.37±0.43^{c}	2.20	5.933	31.22±0.62^{ab}
T_6 (Acobat MZ)	96.83	24.17±0.70^{cd}	55.90±0.20^{ef}	83.50±0.87^{c}	2.07	5.867	31.67±0.96^{ab}
T_7 (Xtramil)	97.62	28.00±0.61^{a}	61.40±0.17^{a}	75.70±0.92^{d}	1.73	4.800	31.11±1.11^{ab}
T_8 (Micra)	97.62	23.10±0.58^{de}	54.50±0.06^{f}	76.10±0.92^{d}	2.27	6.067	31.11±2.42^{ab}
T_9 (Sanoxanil)	96.83	25.370.49^{bc}	54.87±0.27^{f}	82.07±0.22^{c}	2.13	5.933	29.67±0.33^{ab}
T_{10} (Curzate M8)	96.03	26.10±0.55^{b}	58.37±0.69^{cd}	82.63±0.27^{c}	2.47	6.133	32.94±1.18^{a}
Level of significance	NS	*	*	*	NS	NS	*
CV(%)	2.35	2.68	1.48	1.17	19.09	22.54	10.58

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Cost-benefit analyses of different fungicides available on the market in Bangladesh used for controlling late blight of potato in 2017-2018

Treatment	Yield (t/ha)	Gross return (Tk./ha)	Production cost (Tk./ha)	Cost of the treatment (Tk/ha)	Total production cost with treatment (Tk/ha)	Net return (Tk./ha)	BCR
T_0 (Control)	8.39	125833.33	192500	0	192500	-62500	-0.35
T_1 (Unilax)	27.44	411666.67	192500	7200	199700	211966.67	1.06
T_2 (Temper M)	23.11	346666.67	192500	8160	200660	146006.67	0.73
T_3 (Deconil)	26.72	400833.33	192500	7376	199876	200957.33	1.01
T_4 (Amiscore)	26.67	400000.00	192500	10560	203060	196940.00	0.97
T_5 (Secure)	31.22	468333.33	192500	20800	213300	255033.33	1.20
T_6 (Acobat MZ)	31.67	475000.00	192500	20960	213460	261540.00	1.23
T_7 (Xtramil)	31.11	466666.67	192500	5360	197860	268806.67	1.36
T_8 (Micra)	31.11	466666.67	192500	5600	198100	268566.67	1.36
T_9 (Sanoxanil)	29.67	445000.00	192500	6720	199220	245780.00	1.23
T_{10} (Curzate M8)	32.94	494166.67	192500	13000	205500	288666.67	1.40

Price: Potato Tk. 15.00/kg, Fungicide Tk. 670-2600/kg & Tk.1230-2640/L, Dose: Fungicide 8-16 kg/ha (on an average) and 4-6 L/ha (on an average).

Status of evaluation of chemical fungicides and potato genotypes

Potato J. 37 (3 - 4): 99-102, 2010

PREVALENCE, EPIDEMIOLOGY AND MANAGEMENT OF POTATO LATE BLIGHT IN BANGLADESH

T.K. Dey, M. Hossain[1], M.S. Kadian[2], S. Hossain[1], M. Bonierbale[3] and A.A. Mahmud[1]

Abstract: Late blight (*Phytophthora infestans*) is the most potential disease threat to the potato production in Bangladesh. Epidemiological studies indicate that the disease appears in the first week of January when the day temperature range 14-19°C and night temperature 9-14°C accompanied with foggy weather and heavy deposition of dew drops. The sporangial production accelerated when temperature gradient ranged 15-20°C and low temperature (10-13°C) supports enormous production of zoospore. Twenty races of *P. infestans* have been identified in the country. Initially simple races were predominant but in last five years complex races have recorded. The complex races are predominant in the northern part of the country where winter sets earlier and continues for longer period. Twelve CIP clones were tested for late blight resistance at three locations in 2006-07 and 2007-08. CIP-393077.159 had moderate resistance to late blight under all three locations. Some of the clones yielded over 40t/ha but were highly susceptible to late blight. The indiscriminate use of metalaxyl containing fungicides throughout the country has developed metalaxyl resistant strain of *P. infestans*. Till now more than 30 fungicides such as mancozeb, phenylamides copper, dimethomorph, chlorothalonil, phenomadone, priopaneb have been registered in the country. The varieties Raja, Dheera and BARI TPS-I having moderate resistance to late blight have also become susceptible. Biocontrol agents like *Trichoderma harzianum*, *T. viride*, *Penicillium* sp., *Chaetomium* sp., collected from Phyllosphare have been tested against late blight. Some of these proved effective against *P. infestans* when applied as prophylactic but were ineffective when applied as curative.

- Potential against *P. infestans*
- Biocontrol agents:

T. harzianum, *T. viride*, *Penicillium* sp. *Chaetomium* sp.

- CIP Clones: Clone CIP 393077.159
- Fungicidal:

chlorothalonil, copper, dimethomorph, mancozeb,phenylamides, phenomadone, propineb

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EVALUATION OF SOME SELECTED POTATO GENOTYPES AGAINST LATE BLIGHT UNDER BANGLADESH CONDITION

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[1]*Scientific Officer, Agricultural Research Station, BARI, Rangpur*

ABSTRACT

Potato is an important source of food and income in the highlands of Bangladesh. Identification and use of superior genotypes resistant to late blight with improved agronomic characteristics will enhance tuber yield and eventually improve livelihoods of farmers. Three promising potato clones (quantitative resistance to late blight) obtained from the International Potato Center (CIP) viz. LB3 (391058.175), LB6 (393280.64) and LB7 (393371.58) were evaluated against late blight disease under Bangladesh conditions. Results revealed that disease infection, yield and yield contributing characters varied significantly among the tested genotypes. Late blight infection ranged 20-90% in the field. Clones LB-7 and LB-3 showed promising results in respect to late blight incidence together with better agronomic characteristics. Considering late blight infection and yield these two clones (LB-3 and LB-7) could be selected in tuber crops research centre project of CIP for regional yield trial before releasing varieties.

Key words: *Late blight, tuber and Potato*

- **Obtained from International Potato Center (CIP):**

LB3 (391058.175), LB6 (393280.64) and LB7 (393371.58)

- **Promising results: LB-3 and LB-7**

Evaluation of potato varieties and germplasms

ISSN-1991-3036 (Online)
Int. J. Sustain. Crop Prod. 13(1):1-4(August 2018)

SCREENING OF POTATO VARIETIES AND GERMPLASM AGAINST LATE BLIGHT DISEASE

M.M.H. TIPU[1*], F.S. SHIKHA[2], M. YASMIN[2], P.R. SARKER[3] AND R. SULTANA[4]

[1]Plant Pathology Division, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh; [2]Soil Science Division, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh; [3]Tuber Crops Research Centre, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh; [4]Horticulture Research Centre, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jamalpur-2000, Bangladesh.

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Accepted for publication on 14 July 2018

ABSTRACT

Tipu MMH, Shikha FS, Yasmin M, Sarker PR, Sultana R (2018) Screening of potato varieties and germplasm against late blight disease. *Int. J. Sustain. Crop Prod.* 13(1), 1-4.

The study was conducted at Regional Agricultural Research Station, Jamalpur during 2014-2015 to find out resistant or tolerant cultivars against late blight of potato caused by *Phytopththora infestans*. Seeds of a total 56 cultivars were sown under natural epiphytotic condition. Out of fifty six germplasm 16 germplasm were found highly susceptible and thirty two germplasm were susceptible against *P. infestans*. Four varieties were moderately resistant. The variety LB-6 was found resistant to late blight. Germplasm Sarpo Mira, Bionica and LB-7 were found highly resistant against *P. infestans* that can be used in breeding programme for the development of late blight resistant potato variety.

Key words: *potato, late blight, phytophthora infestans, resistance*

Home » Acta Horticulturae » Acta Horticulturae 834

RESEARCH EXPERIENCE ON POTATO LATE BLIGHT DISEASE MANAGEMENT IN BANGLADESH

ভাষা বেছে নিন

Authors

M. Hossain, T.K. Dey, M. Iqbal Hossain, S.N. Begum, M.S. Kadian

Abstract

Potato is an important commercial crop in Bangladesh. Unfortunately, potato suffers from many destructive diseases, of which late blight, caused by *Phytophthora infestans* is the most important one. In Bangladesh, late blight causes serious yield loss in potato every year. Late blight was first reported in Bangladesh in 1922. In recent years more than 300 varieties, 2050 germplasm lines and 250 true potato seed (TPS) progenies were evaluated for resistance to major diseases under field conditions. Screening for late blight resistance was carried out under both natural and artificial conditions. So far more than 300 germplasm (exotic and local) and TPS progenies were screened through artificial inoculation. Of these only three lines (CIP-607, CIP-272 and CIP-616) were found to be tolerant to late blight. Some of the field resistant TPS progenies are: TS-6 × TS-9, HPS-7/67, HPS-II/13, TS-5 × TS, LM × 501, 501 × 9, 801000 and 300999. A set of 15 late blight resistant germplasm lines received from CIP, Peru in 2005 was evaluated under natural conditions of which 6-7 were found to be resistant to the disease. Attempts were made to develop late blight resistant transgenic potato varieties by transforming the RB resistance gene into two commercial varieties. Twenty races of *P. infestans* have so far been identified in Bangladesh. The frequency of races differed greatly with maximum occurrence of race 2. Existence of metalaxyl resistant strains of *P. infestans* have been identified which might be due to indiscriminate spraying of metalaxyl (Ridomil) fungicide. Both fungicide management and farmer training with farmer field schools are discussed.

- Moderately resistant:

Four varieties of germplasm

- Resistant to late blight:

LB-6

- Highly resistant:

Sarpo Mira, Bionica and LB-7

- Tolerant to late blight:

CIP-607, CIP-272 and CIP-616

- field resistant TPS progenies:

TS-6 × TS-9, HPS-7/67, HPS-II/13, TS-5 × TS, LM × 501, 501 × 9, 801000 and 300999.

- Existence of metalaxyl-resistant strains of *P. infestans*

The GEOPOTATO project: Control fungal disease in potato in Bangladesh

Develops and implements a decision support service (DSS) for an optimal control strategy of late blight in potatoes.

Continuously measures and forecasts weather and biomass growth of potato crops in relation to the late blight disease cycle.

Provides farmers with timely preventive spray advice

Information based upon satellite data and using various models

Uses geo data to control late blight fungal disease in potatoes in Bangladesh.

Partners: Wageningen Plant Research ICCO – Bangladesh, AIS – Bangladesh, mPower – Bangladesh, Bangladesh Centre for Advanced Studies, Terra Sphere – Netherlands

Bangladesh imports two blight-resistant (GM) potato lines developed at Michigan State University for a field trial

- Late blight-resistant 3R-gene
  - a genetically engineered potato variety
  - The Biotechnology Division of BARI and MSU
- Till now 10 3R-gene lines events have been selected as late blight resistant by MSU
- The best performing GE lines – DIA-MSU-UB #1 and DIA-MSU-UB #2 will be imported to Bangladesh for continued confined field trials.
- Bangladesh apart, the RB potato is being field-tested in Indonesia under the same initiative by the Indonesian Agency for Agricultural Research and Development (IAARD).

Source: Dhaka Tribune

Assessment of field performance of some formulated bacterial and fungal bioagents

Experimental location: Farmer's Field, Sutiakhali, Mymensingh

Experimental Design: RCBD

Treatment: Different Formulated bacterial and fungal bioagents

Replication: 3

Application of the treatment:

Tuber treatment: Drenching potato tuber pieces with 0.4% solution of formulated bacterial and fungal bioagents)

Foliar spray: Spray @ 0.4% formulated bioagents for eight times at 34. 41, 48, 53, 59, 63, 69 and 75 DAP

Data collection: Incidence and severity at 48, 59 and 71 DAP, Plant height, No. plantlets/hill, No. of tubers/plant and yield

Selected bacterial and fungal bioagents used in this study

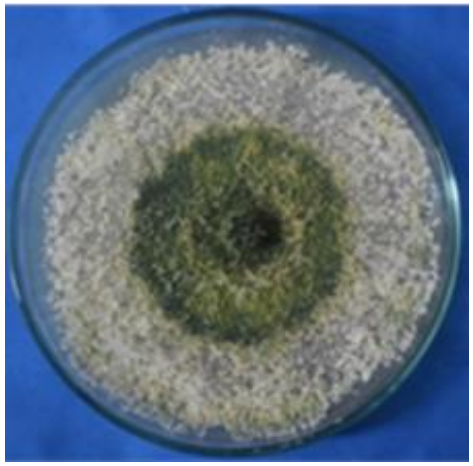
Lab Collection

Pseudomonas putida (BDISO64RanP)

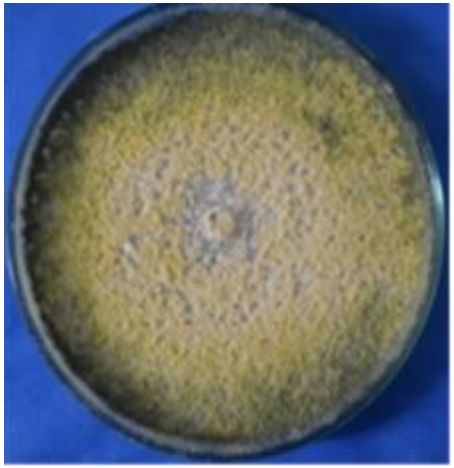
Islam *et al.* 2021

Bacillus subtilis (BDISO36ThaR)

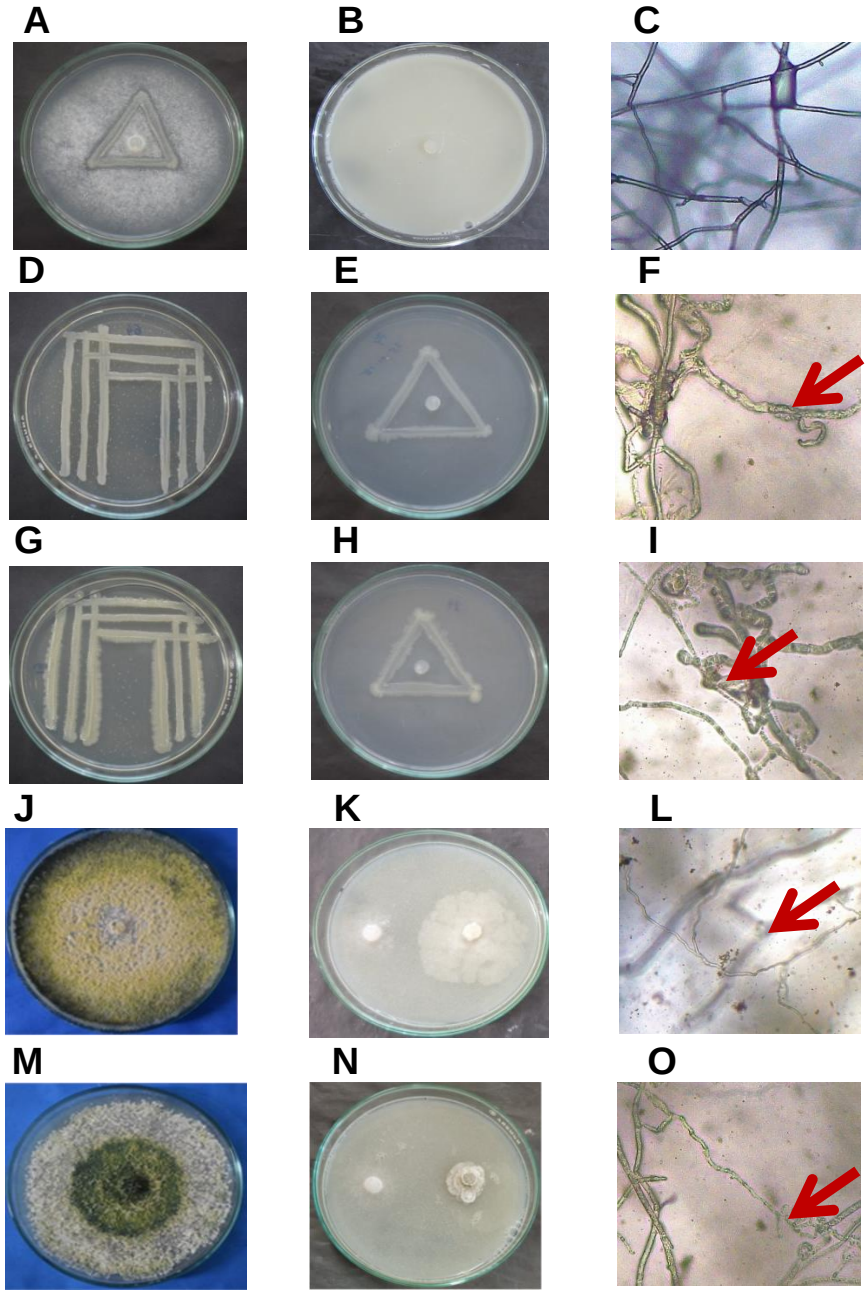
Lab Collection



Trichoderma paraviridescens (BDISOF67R)



T. erinaceum (BDISOF91R)



A. Negative control,

B. Positive control (Curzate M8),

C. Mycelia of *P. infestans*,

D. Pure culture of *P. putida*,

E. Growth inhibition of *P. infestans* by *P. putida*,

F. Deformation of mycelial structure of *P. infestans* by *P. putida* under stereo binocular microscope,

G. Pure culture of *B. subtulis*,

H. Growth inhibition of *P. infestans* by *B. subtulis*,

I. Deformation of mycelial structure of *P. infestans* by *B. subtulis* under stereo binocular microscope,

J. Pure culture of *T. erinacium*,

K. Growth inhibition of *P. infestans* by *T. erinacium*,

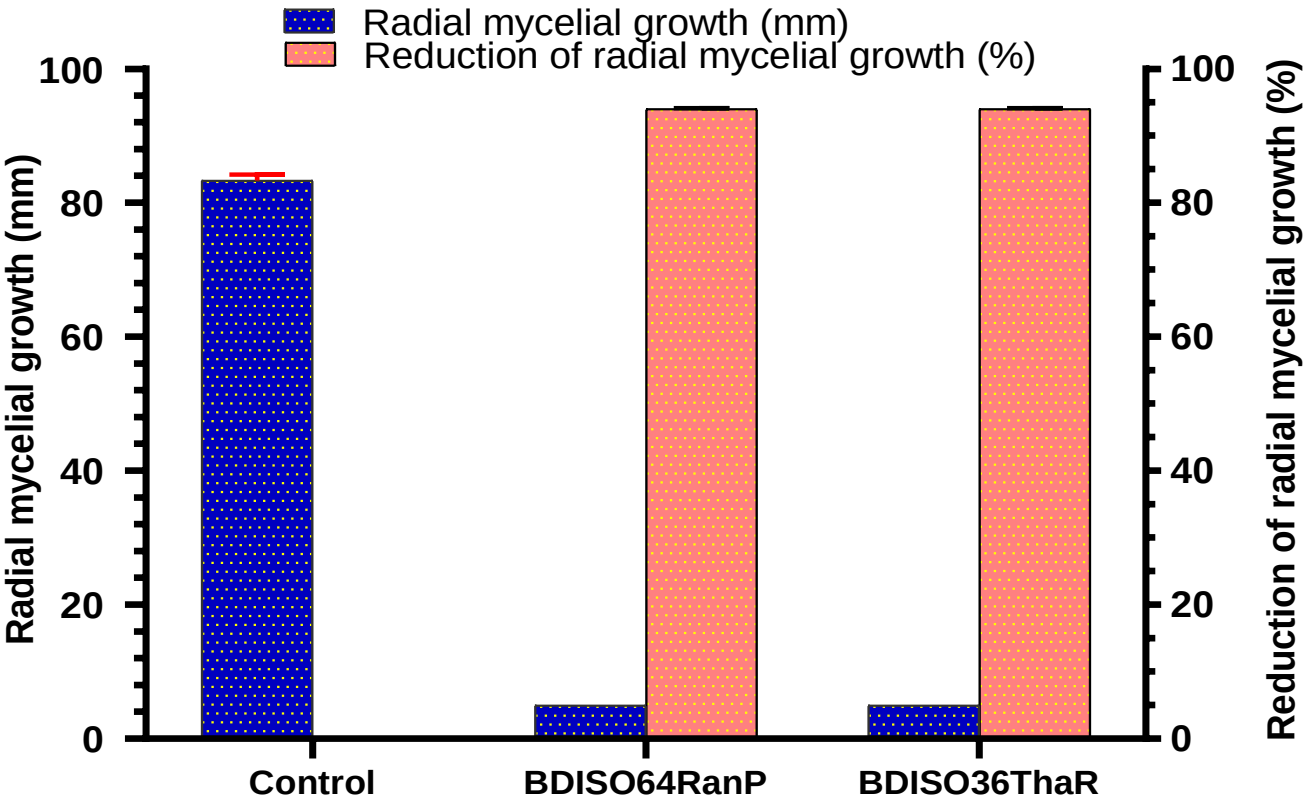
L. Deformation of mycelial structure of *P. infestans* by *T. erinacium* under stereo binocular microscope

M. Pure culture of *T. paraviridescens*,

N. Growth inhibition of *P. infestans* by *T. paraviridescens*,

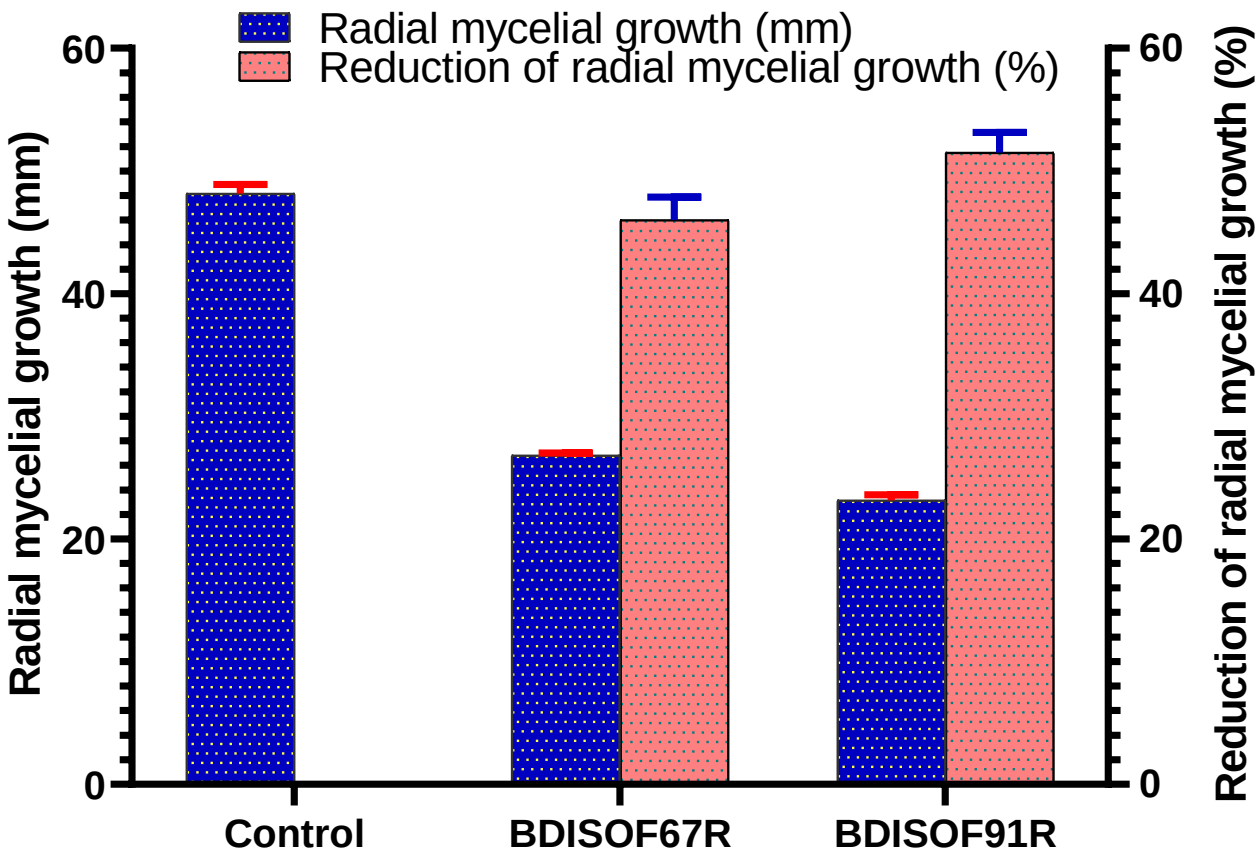
O. Deformation of mycelial structure of *P. infestans* by *T. paraviridescens* under stereo binocular microscope.

Fig. 2: Growth inhibition of *P. infestans* by bioagents with control.



the growth of *P. infestans* was inhibited by 93.99% over control by both the bacterial strains.

Fig. 3: *In vitro* growth inhibition (mm) of *Phytophthora infestans* by antagonistic bacterial isolates (Lab collection): Radial mycelial growth(mm) of *P. infestans* isolates and Percent reduction of radial mycelial growth of *P. infestans*. BDISO64RanP: Isolates no. 64 of Rangpur from potato phyllosphere, BDISO36ThaR: Isolates no. 36 of Thakurgaon from potato rhizosphere.



T. paraviridescens **inhibited the growth of** ***P. infestans*** **by 46.0% and** ***T. erinaceum*** **inhibited the growth of** ***P. infestans*** **by 51.5% over control**

Fig. 4: ***In vitro*** **antagonistic assay between** ***T. paraviridescens*** **(BDISOF67R)/*T. erinaceum* (BDISOF91R) and** ***P. infestans*****: Radial mycelial growth (mm) of** ***P. infestans*** **and Percent reduction of radial mycelial growth of** ***P. infestans*** **isolates. Photographs and data were taken at 7 days after inoculation.**

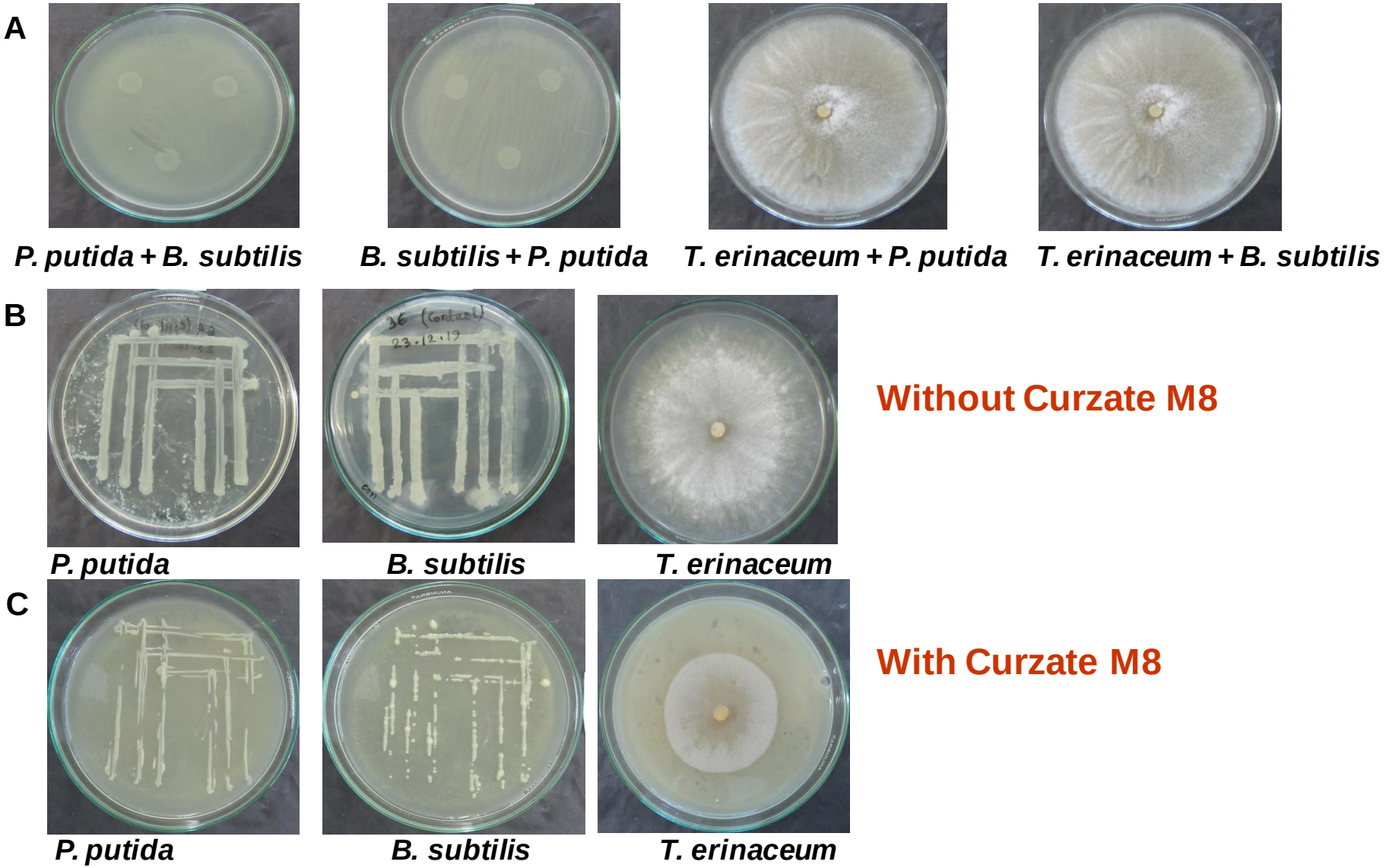


Fig. 8 A: Interactions effect among the bacterial and fungal bioagents, B. Growth of *P. putida*, *B. subtilis* and *T. erinaceum* without Curzate M8 and C. Growth of *P. putida*, *B. subtilis* and *T. erinaceum* with Curzate M8 used for controlling late blight of potato.

Efficacy of some selected bacterial and fungal bioagents in reducing late blight severity of potato under growth chamber in 2018-2019

Treatment	% Severity (0.1-100) Days after planting (DAP)		% Reduction of Late blight severity over control at 65 DAP
	61	65	
T_0	41.67±8.33[a]	73.33±13.02[a]	0.00
T_1	18.33±6.67[ab]	33.33±8.33[bc]	52.34
T_2	11.67±6.67[ab]	18.33±6.67[bc]	70.47
T_3	11.67±6.67[ab]	26.67±13.02[bc]	60.78
T_4	26.67±13.02[ab]	33.33±8.33[bc]	52.34
T_5	33.67±16.33[ab]	41.67±8.33[b]	43.57
T_6	25.33±14.15[ab]	33.33±8.33[bc]	54.68
T_7	18.33±6.67[ab]	33.33±8.33[bc]	46.78
T_8	11.67±6.67[ab]	25.00±0.00[bc]	63.45
T_9	14.67±2.91[ab]	17.83±3.93[bc]	72.44
T_{10}	10.33±7.42[ab]	17.00±8.00[bc]	71.87
T_{11}	3.67±1.33[b]	5.00±0.00[c]	92.69
Level of significance	*	*	-
CV (%)	85.15	49.40	-

T_0 = Water (Negative control)

T_1 = Tuber treatment + Foliar spray of formulated *T. paraviridescens*

T_2 = Tuber treatment + Foliar spray of formulated *T. erinaceum*

T_3 = Tuber treatment + Foliar spray of formulated *Pseudomonas putida*,

T_4 = Tuber treatment + Foliar spray of formulated *Bacillus subtilis*

T_5 = Tuber treatment + Foliar spray of formulated *T. paraviridescens* and *P. putida*

T_6 = Tuber treatment + Foliar spray of formulated *T. erinaceum* and *P. putida*

T_7 = Tuber treatment + Foliar spray of formulated *T. paraviridescens* and *Bacillus subtilis*

T_8 = Tuber treatment + Foliar spray of formulated *T. erinaceum* and *Bacillus subtilis*

T_9 = Tuber treatment + Foliar spray of formulated *T. paraviridescens*, *T. erinaceum* *P. Putida* and *Bacillus subtilis*

T_{10} = Tuber treatment + Foliar spray of Curzate M8 (Cymoxonil + Mancozeb) and

T_{11} = Tuber treatment + Foliar spray of formulated *T. paraviridescens*, *T. erinaceum*, *P. putida* and *B. subtilis* with T_{10}.

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Efficacy of some selected bacterial and fungal bioagents in reducing late blight infection and severity of potato under field condition in 2018-2019

Treatment	% Plant infection Days after planting			% Late blight severity Days after planting			% Reduction of Late blight severity over control at 71 DAP
	48	59	71	48	59	71	
T_0	66.67±5.34^{ab}	100±0.0^{a}	100	1.50±0.38^{abc}	69.33±2.92^{a}	95.50±2.08^{a}	0.00
T_1	70.09±9.86^{ab}	100±0.0^{a}	100	2.14±0.67^{ab}	50.83±5.92^{b}	90.50±1.80^{ab}	5.05
T_2	58.12±9.86^{ab}	100±0.0^{a}	100	1.34±0.38^{abc}	47.50±3.69^{b}	79.50±3.75^{bc}	16.71
T_3	67.52±9.40^{ab}	100±0.0^{a}	100	1.46±0.68^{abc}	59.50±6.43^{ab}	91.00±3.21^{ab}	4.74
T_4	71.12±7.31^{ab}	100±0.0^{a}	100	1.60±0.38^{ab}	53.50±4.25^{a}	85.00±1.04^{ab}	10.93
[illegible]	69.86±7.40^{ab}	100±0.0^{a}	100	2.84±0.12^{a}	60.17±5.83^{ab}	83.33±3.18^{ab}	12.75
T_{10}	1.71±1.71^{c}	64.96±13.27^{b}	100	0.00±0.00^{c}	3.37±1.07^{c}	21.30±6.33^{d}	77.50
T_{11}	0.00±0.00^{c}	29.91±2.26^{c}	100	0.00±0.00^{c}	2.43±0.62^{c}	10.33±3.53^{d}	89.16
Level of significance	*	*	NS	*	*	*	-
CV (%)	21.57	7.53	0.00	56.06	17.08	9.07	-

Combined use of Bacterial and fungal bioagents along with Curzate M8 reduced late blight severity by 89% which was 12% higher than single use of Curzate M8.

Efficacy of some selected bacterial and fungal bioagents in reducing late blight severity of potato under field condition at 71 DAP in 2018- 2019.

Efficacy of some selected bacterial and fungal bioagents in increasing growth and yield contributing parameters of potato under field condition in 2018-2019

Treatments	Germination (%)	Plant height (cm) Days after planting (DAP)			No. of plantlets/hill	No. of tubers/plant	Yield (t/ha)
		34	52	71			
T_0	92.86	31.48	42.30	58.53±1.22^{ab}	3.27	6.07±0.66^{abc}	7.22±0.72^{bc}
T_1	92.86	35.68	46.17	61.90±2.25^{ab}	3.00	5.47±0.18^{bc}	6.44±0.45^{c}
T_2	92.86	32.29	43.33	59.90±1.13^{ab}	2.67	4.20±0.46^{c}	6.56±0.39^{c}
T_3	92.86	33.99	43.63	58.10±2.07^{ab}	3.53	6.60±0.81^{ab}	6.28±0.20^{c}
T_4	95.24	34.48	44.30	59.03±3.31^{ab}	3.20	6.00±0.20^{abc}	6.67±1.00^{c}
T_5	94.44	33.94	42.77	56.00±0.13^{b}	2.87	5.47±0.48^{bc}	7.22b±0.64^{c}
T_6	94.44	33.96	45.00	61.57±1.18^{ab}	2.73	4.40±1.00^{c}	6.33±0.42^{c}
T_7	92.86	34.09	44.73	60.70±2.77^{ab}	3.27	6.73±0.29^{ab}	6.89±0.15^{c}
T_8	92.86	34.76	44.93	60.20±2.33^{ab}	2.53	5.07±0.33^{bc}	6.89±0.40^{c}
T_9	92.86	34.11	44.36	62.73±1.67^{a}	3.40	6.93±0.07^{ab}	10.06±1.20^{b}
T_{10}	92.86	33.76	45.87	60.53±1.89^{ab}	3.20	7.53±1.17^{a}	18.67±2.60^{a}
T_{11}	92.86	34.68	46.23	63.57±1.49^{a}	3.47	7.60±0.12^{a}	20.11±0.11^{a}
Level of significance	NS	NS	NS	*	NS	*	*
CV(%)	1.67	8.23	7.29	5.38	18.76	17.64	18.48

T_0 = Water (Negative control)
T_1 = Tuber treatment + Foliar spray of formulated *T. paraviridescens*
T_2 = Tuber treatment + Foliar spray of formulated *T. erinaceum*
T_3 = Tuber treatment + Foliar spray of formulated *P. putida*,
T_4 = Tuber treatment + Foliar spray of formulated *B. subtilis*
T_5 = Tuber treatment + Foliar spray of formulated *T. paraviridescens* and *P. putida*
T_6 = Tuber treatment + Foliar spray of formulated *T. erinaceum* and *P. putida*
T_7 = Tuber treatment + Foliar spray of formulated *T. paraviridescens* and *B. subtilis*
T_8 = Tuber treatment + Foliar spray of formulated *T. erinaceum* and *B. subtilis*
T_9 = Tuber treatment + Foliar spray of formulated *T. paraviridescens*, *T. erinaceum* *P. Putida* and *B. subtilis*
T_{10} = Tuber treatment + Foliar spray of CurzateM8 (Cymoxonil + Mancozeb) and
T_{11} = Tuber treatment + Foliar spray of formulated *T. paraviridescens*, *T. erinaceum*, *P. putida* and *B. subtilis* with T_{10}.

Data are the averages of three replications. Values with same letters in the same column are statistically similar. NS = Non-significant and * indicates the means were significant at 5% level of probability

Cost-benefit analyses of some selected bacterial and fungal bioagents used for controlling late blight of potato under field condition in 2018-2019

Treatment	Yield (t/ha)	Gross return (Tk./ha)	Production cost (Tk./ha)	Total cost of the treatment (Tk/ha)	Total cost with treatment (Tk/ha)	Net return (Tk./ha)	BCR
T_0	7.22	115555.56	192500	0	192500	-76944.44	-0.40
T_1	6.44	103111.11	192500	9600	202100	-98988.89	-0.49
T_2	6.55	104888.89	192500	9600	202100	-97211.11	-0.48
T_3	6.28	100444.44	192500	9600	202100	-101655.56	-0.50
T_4	6.67	106666.67	192500	9600	202100	-95433.33	-0.47
T_5	7.22	115555.56	192500	9600	202100	-86544.44	-0.43
T_6	6.33	101333.33	192500	9600	202100	-100766.67	-0.50
T_7	6.89	110222.22	192500	9600	202100	-91877.78	-0.45
T_8	6.89	110222.22	192500	9600	202100	-91877.78	-0.45
T_9	10.06	160888.89	192500	9600	202100	-41211.11	-0.20
T_{10}	18.67	280000.00	192500	13000	205500	74500.00	0.36
T_{11}	20.11	301666.67	192500	22600	215100	86566.67	0.40

Price: Potato Tk. 16.00/kg (Organic), Tk. 15.00/kg (Inorganic), Fungicide Tk. 1625/kg, Bioagents Tk. 600/kg, Fungicide 8 kg/ha, Biaoents 16 kg/ha

Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight of potato under artificial inoculation in growth chamber in 2019-2020

Treatment	% Severity (0.1-100)		% Reduction of Late blight severity over control	
	Days after planting (DAP)		Days after planting (DAP)	
	61	65	61	65
T_0	81.67±6.67[a]	100.00±0.00[a]	0.00	0.00
T_1	2.33±1.33[e]	10.33±7.42[f]	97.36	89.67
T_2	58.33±8.33[b]	66.67±8.33[b]	26.90	33.33
T_3	6.67±1.67[e]	33.33±8.33[de]	92.05	66.67
T_4	5.33±2.60[e]	18.33±6.67[ef]	93.82	81.67
T_5	5.33±2.60[e]	15.00±5.00[ef]	93.36	85.00
T_6	5.00±0.00[e]	12.67±3.71[f]	93.80	87.33
T_7	46.67±3.33[c]	58.33±8.33[bc]	42.46	41.67
T_8	30.00±5.00[d]	53.33±3.33[bcd]	62.34	46.67
T_9	2.03±1.51[e]	20.00±2.89[ef]	97.76	80.00
T_{10}	1.73±1.63[e]	17.00±8.00[ef]	98.16	83.00
T_{11}	1.70±1.65[e]	15.00±2.89[ef]	98.20	85.00
T_{12}	23.33±1.67[d]	41.67±8.33[cd]	71.23	58.33
T_{13}	5.03±2.86[e]	33.33±8.33[de]	94.22	66.67
T_{14}	2.03±1.51[e]	10.33±7.42[f]	97.38	89.67
T_{15}	0.70±0.30[e]	10.33±7.42[f]	99.16	89.67
T_{16}	0.40±0.30[e]	10.00±5.00[f]	99.56	90.00
Level of significance	**	**	-	-
CV (%)	32.70	33.79	-	-

T_0 = Water (Negative control)
T_1 = Tuber treatment + Eight sprays of Curzate M8 (Positive control)
T_2 = Tuber treatment + Eight sprays of formulated *Pseudomonas putida* + *Bacillus subtilis*
T_3 = T_2 + one spray of Curzate M8
T_4 = T_2 + two sprays of Curzate M8
T_5 = T_2 + three sprays of Curzate M8
T_6 = T_2 + four sprays of Curzate M8
T_7 = Tuber treatment + Eight sprays of formulated *Trichoderma erinaceum*
T_8 = T_7 + one spray of Curzate M8
T_9 = T_7+ two sprays of Curzate M8
T_{10} = T_7+ three sprays of Curzate M8
T_{11} = T_7 + four sprays of Curzate M8
T_{12} = Tuber treatment + Eight sprays of formulated of *P. putida*, *B. subtilis* and *T. erinaceum*
T_{13} = T_{12}+ one spray of Curzate M8
T_{14} = T_{12}+ two sprays of Curzate M8 and
T_{15} = T_{12}+ three sprays of Curzate M8 and
T_{16} = T_{12}+ four sprays of Curzate M8

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

T_0 = Water (Negative control)
T_1 = Tuber treatment + Eight sprays of Curzate M8 (Positive control)
T_2 = Tuber treatment + Eight sprays of formulated of *P. putida* + *B. subtilis*
T_3 = T_2 + one spray of Curzate M8
T_4 = T_2 + two sprays of Curzate M8
T_5 = T_2 + three sprays of Curzate M8
T_6 = T_2 + four sprays of Curzate M8
T_7 = Tuber treatment + Eight sprays of formulated *T. erinaceum*
T_8 = T_7 + one spray of Curzate M8
T_9 = T_7+ two sprays of Curzate M8
T_{10} = T_7+ three sprays of Curzate M8
T_{11} = T_7 + four sprays of Curzate M8
T_{12} = Tuber treatment + Eight sprays of formulated *P. putida*, *B. subtilis* and *T. erinaceum*
T_{13} = T_{12}+ one spray of Curzate M8
T_{14} = T_{12}+ two sprays of Curzate M8 and
T_{15} = T_{12}+ three sprays of Curzate M8 and
T_{16} = T_{12}+ four sprays of Curzate M8

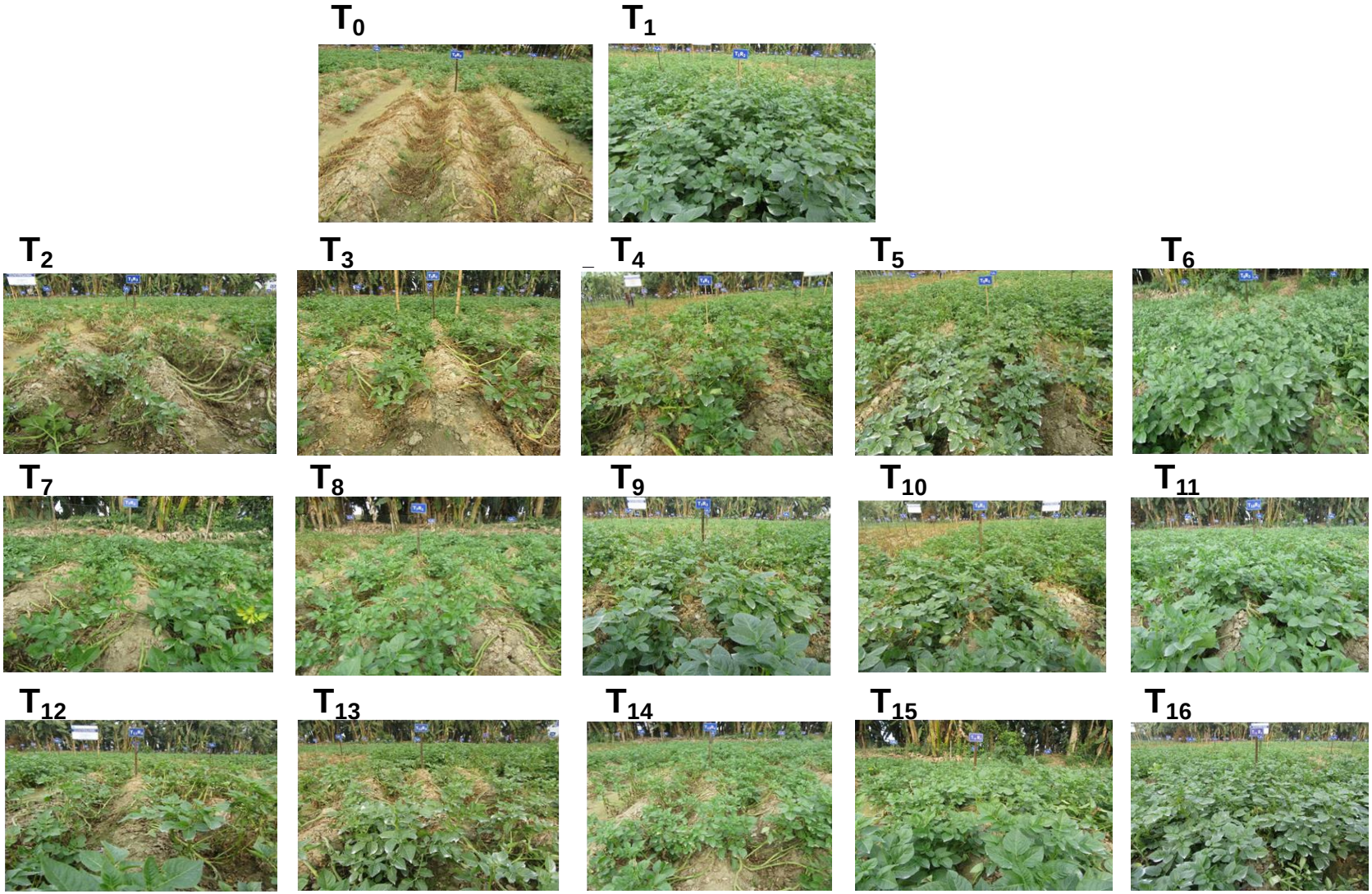
Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicides for controlling late blight severity of potato under artificial inoculation in growth chamber condition in 2019-2020. Photographs were taken at 65 DAP.

Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight severity of potato under field condition in 2019-2020

Treatment	% Severity			% Reduction of Late blight severity over control	
	Days after planting			Days after planting	
	48	59	71	59	71
T_0	0.020±0.01[a]	44.930±21.44[a]	99.16±0.60[a]	0.00	0.00
T_1	0.000±0.00[d]	0.007±0.003[b]	0.45±1.89[f]	99.91	99.54
T_2	0.003±0.003[cd]	4.513±2.89[b]	72.83±6.33[b]	80.29	26.57
T_3	0.010±0.01[b]	0.197±0.07[b]	8.36±0.6[ef]	97.45	91.57
T_4	0.000±0.00[d]	0.147±0.06[b]	8.07±1.50[ef]	97.54	91.85
T_5	0.000±0.00[d]	1.817±1.75[b]	8.07±1.62[ef]	97.01	91.87
T_6	0.000±0.00[d]	0.683±0.36[b]	2.76±1.62[f]	92.56	97.20
T_7	0.011±0.006[b]	1.400±0.29[b]	64.17±4.32[b]	90.01	35.33
T_8	0.010±0.01[b]	1.343±0.19[b]	19.27±7.18[de]	89.28	80.63
T_9	0.000±0.00[d]	1.100±0.10[b]	18.83±0.67[de]	88.24	76.65
T_{10}	0.000±0.00[d]	0.170±0.08[b]	9.00±0.58[ef]	98.31	94.28
T_{11}	0.010±0.006[b]	0.183±0.00[b]	5.26±3.0[ef]	98.20	94.69
T_{12}	0.000± 0.00[d]	0.773±0.36[b]	53.33±0.83[c]	89.38	46.20
T_{13}	0.007±0.007[bc]	0.050±0.01[b]	30.07±9.93[d]	99.34	69.64
T_{14}	0.000±0.00[d]	0.390±0.16[b]	25.17±9.23[d]	98.81	74.72
T_{15}	0.003±0.003[cd]	0.140±0.04[b]	6.07±3.47[ef]	98.29	97.38
T_{16}	0.000±0.00[d]	0.083±0.04[b]	1.86±0.52[f]	99.63	98.13
Level of significance	**	**	**		-
CV (%)	232.72	263.53	34.16		-

T_0 = Water (Negative control)
T_1 = Tuber treatment + Eight sprays of Curzate M8 (Positive control)
T_2 = Tuber treatment + Eight sprays of formulated of *P. putida* + *B. subtilis*
T_3 = T_2 + one spray of Curzate M8
T_4 = T_2 + two sprays of Curzate M8
T_5 = T_2 + three sprays of Curzate M8
T_6 = T_2 + four sprays of Curzate M8
T_7 = Tuber treatment + Eight sprays of formulated *T. erinaceum*
T_8 = T_7 + one spray of Curzate M8
T_9 = T_7+ two sprays of Curzate M8
T_{10} = T_7+ three sprays of Curzate M8
T_{11} = T_7 + four sprays of Curzate M8
T_{12} = Tuber treatment + Eight sprays of formulated *P. putida*, *B. subtilis* and *T. erinaceum*
T_{13} = T_{12}+ one spray of Curzate M8
T_{14} = T_{12}+ two sprays of Curzate M8 and
T_{15} = T_{12}+ three sprays of Curzate M8 and
T_{16} = T_{12} + four sprays of Curzate M8

Data are the averages of three replications. Values with same letters in the same column are statistically similar.



Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicides for controlling late blight severity of potato under field condition in 2019-2020. Photographs were taken at 71 DAP

Efficacy of formulated two bacterial and one fungal bioagents in increasing growth and yield parameters of potato under field condition in 2019-2020

Treatments	Germination (%)	Plant height (cm) Days after planting (DAP) 34	52	71	No. of plantlets/hill	No. of tubers/plant	Yield (t/ha)
T_0	96.83	22.97±0.25^{h}	54.33±0.95^{e}	71.97±0.54^{fg}	2.23±.03^{a}	4.53	6.50±0.33^{e}
T_1	96.03	26.10±0.55^{b-f}	58.37±0.69^{b-d}	76.17±0.74^{d}	2.17±0.23^{a}	6.13	24.01±2.89^{a}
T_2	99.21	25.20±1.22^{d-g}	58.47±0.23^{b-d}	73.23±0.24^{ef}	2.20±0.06^{a}	4.60	8.78±0.98^{de}
T_3	96.83	26.37±0.50^{b-d}	60.87±0.98^{a-c}	72.03±0.64^{fg}	2.30±0.12^{a}	4.33	14.83±0.93^{bc}
T_4	98.41	27.67±0.45^{b}	58.03±0.90^{b-d}	84.30±0.81^{a}	2.43±0.27^{a}	5.93	16.56±1.83^{b}
T_5	96.83	27.50±0.66^{b}	58.63±1.32^{a-d}	73.97±0.63^{e}	2.23±0.12^{a}	6.00	16.50±0.44^{b}
T_6	96.83	25.00±0.61^{d-g}	61.23±0.39^{ab}	71.50±0.44^{g}	2.33±0.20^{a}	4.60	24.72±0.28^{a}
T_7	98.72	24.60±1.10^{fg}	58.50±1.72^{b-d}	77.50±1.91^{d}	2.46±0.02^{a}	6.00	11.39±1.00^{cd}
T_8	99.21	29.53±0.52^{a}	62.37±1.16^{a}	81.90±0.40^{b}	2.43±0.18^{a}	5.73	13.33±1.73^{b-d}
T_9	97.62	23.73±0.66^{gh}	58.27±1.56^{b-d}	76.03±0.68^{d}	2.47±0.15^{a}	5.07	13.72±1.39^{bc}
T_{10}	97.62	26.43±0.57^{b-d}	56.73±2.24^{de}	81.93±0.41^{b}	2.30±0.25^{a}	5.47	17.00±1.84^{b}
T_{11}	98.41	26.97±0.79^{bc}	61.73±0.97^{ab}	78.80±0.38^{c}	2.17±0.17^{a}	6.07	23.83±3.18^{a}
T_{12}	99.21	24.70±0.90^{e-g}	58.10±1.27^{b-d}	77.50±0.76^{cd}	2.50±.06^{a}	4.60	11.11±1.47^{cd}
T_{13}	97.62	24.63±0.94^{fg}	57.20±0.44^{c-e}	71.73±0.63^{fg}	2.30±0.12^{a}	5.33	12.50±1.73^{b-d}
T_{14}	99.21	26.30±1.04^{b-e}	59.27±1.55^{a-d}	78.40±0.47^{c}	2.47±0.12^{a}	5.40	14.67±0.88^{bc}
T_{15}	97.62	25.53±0.52^{c-f}	58.73±1.51^{a-d}	78.43±0.23^{c}	2.20±0.31^{a}	5.80	15.78±1.18^{bc}
T_{16}	97.62	24.97±0.83^{d-g}	56.57±0.58^{de}	82.10±0.40^{b}	2.43±0.03^{a}	6.07	24.78±0.29^{a}
Level of significance	NS	*	*	*	*	NS	*
CV(%)	1.93	3.3	3.37	1.18	12.73	19.3	16.27

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Cost benefit analyses of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight of potato under field condition in 2019-2020

Treatment	Yield (t/ha)	Gross return (Tk./ha)	Production cost (Tk./ha)	Total cost of the treatment (Tk/ha)	Total cost with treatment (Tk/ha)	Net return (Tk./ha)	BCR
T_0	6.50	110500.00	192500	0	192500	-82000.00	-0.43
T_1	24.01	384166.67	192500	13000	205500	178666.67	0.87
T_2	8.78	140444.44	192500	9600	202100	-61655.56	-0.31
T_3	14.83	237333.33	192500	11225	203725	33608.33	0.16
T_4	16.56	264888.89	192500	12850	205350	59538.89	0.30
T_5	16.50	264000.00	192500	14475	206975	57025.00	0.28
T_6	24.72	395555.56	192500	16100	208600	186955.56	0.90
T_7	11.39	182222.22	192500	9600	202100	-19877.78	-0.09
T_8	13.33	213333.33	192500	11225	203725	9608.33	0.05
T_9	13.72	219555.56	192500	12850	205350	14205.56	0.07
T_{10}	17.00	272000.00	192500	14475	206975	65025.00	0.31
T_{11}	23.83	381333.33	192500	16100	208600	172733.33	0.83
T_{12}	11.11	177777.78	192500	9600	202100	-24322.22	-0.12
T_{13}	12.50	200000.00	192500	11225	203725	-3725.00	-0.02
T_{14}	14.67	234666.67	192500	12850	205350	29316.67	0.14
T_{15}	15.78	252444.44	192500	14475	206975	45469.44	0.22
T_{16}	24.78	396444.44	192500	16100	208600	187844.44	0.90

Price: Potato Tk. 16.00/kg (Organic), Tk. 15.00/kg (Inorganic), Fungicide Tk. 1625/kg, Bioagents Tk. 600/kg, Fungicide 8 kg/ha, Bioagents 16 kg/ha. Data are the averages of three replications.

Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight of potato under artificial inoculation in growth chamber in 2020-2021

Treatment	% Severity (0.1-100)		% Reduction of Late blight severity over control at 65 DAP	
	Days after planting (DAP)		Days after planting (DAP)	
	61	65	61	65
T_0	88.33±6.67[a]	100.00±0.00[a]	0.00	0.00
T_1	3.67±1.33[e]	11.67±6.67[f]	96.05	88.33
T_2	66.67±8.33[b]	81.67±6.67[b]	33.92	18.33
T_3	8.33±1.67[e]	41.67±8.33[de]	90.76	58.33
T_4	8.33±1.67[e]	21.67±1.67[ef]	90.76	78.33
T_5	6.67±1.67[e]	20.00±5.00[ef]	92.05	80.00
T_6	6.67±1.67[e]	15.00±5.00[f]	92.51	85.00
T_7	58.33±8.33[c]	66.67±8.33 [bc]	42.69	41.67
T_8	33.33±8.33[d]	58.33±8.33[bcd]	60.23	41.67
T_9	3.67±1.33[e]	23.33±1.67[ef]	96.05	76.67
T_{10}	2.33±1.33[e]	18.33±6.67[ef]	97.45	81.67
T_{11}	2.03±1.51[e]	13.33±1.67[ef]	97.85	86.67
T_{12}	33.33±8.33[d]	40.00±10.00[cd]	62.57	60.00
T_{13}	15.00±5.00[e]	33.33±8.33[de]	83.27	66.67
T_{14}	2.33±1.33[e]	11.67±6.67[f]	97.08	88.33
T_{15}	1.00±0.00[e]	8.33±1.67[f]	98.85	91.67
T_{16}	0.70±0.30[e]	6.67±1.67[f]	99.17	93.33
Level of significance	**	**		-
CV (%)	32.70	33.79		-

T_0 = Water (Negative control)
T_1 = Tuber treatment + Eight sprays of Curzate M8 (Positive control)
T_2 = Tuber treatment + Eight sprays of formulated of *P. putida* + *B. subtilis*
T_3 = T_2 + one spray of Curzate M8
T_4 = T_2 + two sprays of Curzate M8
T_5 = T_2 + three sprays of Curzate M8
T_6 = T_2 + four sprays of Curzate M8
T_7 = Tuber treatment + Eight sprays of formulated *T. erinaceum*
T_8 = T_7 + one spray of Curzate M8
T_9 = T_7+ two sprays of Curzate M8
T_{10} = T_7+ three sprays of Curzate M8
T_{11} = T_7 + four sprays of Curzate M8
T_{12} = Tuber treatment + Eight sprays of formulated *P. putida*, *B. subtilis* and *T. erinaceum*
T_{13} = T_{12}+ one spray of Curzate M8
T_{14} = T_{12}+ two sprays of Curzate M8 and
T_{15} = T_{12}+ three sprays of Curzate M8 and
T_{16} = T_{12} + four sprays of Curzate M8

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Efficacy of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight severity of potato under field condition in 2020-2021

Treatment	% Severity			% Reduction of Late blight severity over control	
	Days after planting (DAP)			Days after planting (DAP)	
	48	59	71	59	71
T_0	0.030±0.012[a]	53.00±10.77[a]	99.17±0.33[a]	0.00	0.00
T_1	0.000±0.000[d]	0.03±0.003[b]	0.89±0.14[f]	99.93	99.10
T_2	0.010±0.006[cd]	4.24±2.18[b]	80.67±5.47[b]	92.33	18.68
T_3	0.013±0.009[b]	1.22±0.052[b]	32.03±1.02[d]	97.43	67.69
T_4	0.003±0.003[d]	0.97±0.38[b]	17.00±1.16[de]	97.98	82.85
T_5	0.000±0.000[d]	0.58±0.79[b]	14.50±0.76[de]	98.85	85.37
T_6	0.007±0.0007[d]	0.40±0.27[b]	5.27±0.71[ef]	99.14	94.68
T_7	0.013±0.009[b]	2.42±0.210[b]	51.50±2.08[c]	95.07	48.06
T_8	0.000±0.003[d]	1.71±0.283[b]	35.83±0.83[d]	96.41	63.87
T_9	0.000±0.000[d]	0.72±0.090[b]	16.67±1.64[de]	46.59	83.19
T_{10}	0.013±0.009[b]	0.46±0.052[b]	10.87±1.27[ef]	99.03	71.65
T_{11}	0.003±0.003[d]	0.43±0.030[b]	6.07±0.74[ef]	99.08	93.88
T_{12}	0.010±0.006[cd]	0.75±0.038[b]	45.83±0.83[d]	98.82	53.78
T_{13}	0.003±0.003[d]	1.23±0.253[b]	34.33±1.59[d]	97.30	65.38
T_{14}	0.007±0.007[d]	1.04±0.210[b]	15.00±1.16[de]	97.65	84.87
T_{15}	0.000±0.000[d]	0.37±0.049[b]	12.87±1.27[de]	99.27	87.02
T_{16}	0.000±0.000[d]	0.16±0.006[b]	3.80±0.23[f]	99.66	96.17
Level of significance	**	**	**	-	-
CV (%)	232.72	263.53	34.16	-	-

T_0 = Water (Negative control)
T_1 = Tuber treatment + Eight sprays of Curzate M8 (Positive control)
T_2 = Tuber treatment + Eight sprays of formulated of *P. putida* + *B. subtilis*
T_3 = T_2 + one spray of Curzate M8
T_4 = T_2 + two sprays of Curzate M8
T_5 = T_2 + three sprays of Curzate M8
T_6 = T_2 + four sprays of Curzate M8
T_7 = Tuber treatment + Eight sprays of formulated *T. erinaceum*
T_8 = T_7 + one spray of Curzate M8
T_9 = T_7+ two sprays of Curzate M8
T_{10} = T_7+ three sprays of Curzate M8
T_{11} = T_7 + four sprays of Curzate M8
T_{12} = Tuber treatment + Eight sprays of formulated *P. putida*, *B. subtilis* and *T. erinaceum*
T_{13} = T_{12}+ one spray of Curzate M8
T_{14} = T_{12}+ two sprays of Curzate M8 and
T_{15} = T_{12}+ three sprays of Curzate M8 and
T_{16} = T_{12} + four sprays of Curzate M8

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Efficacy of formulated two bacterial and one fungal bioagents in increasing growth and yield parameters of potato under field condition in 2020-2021

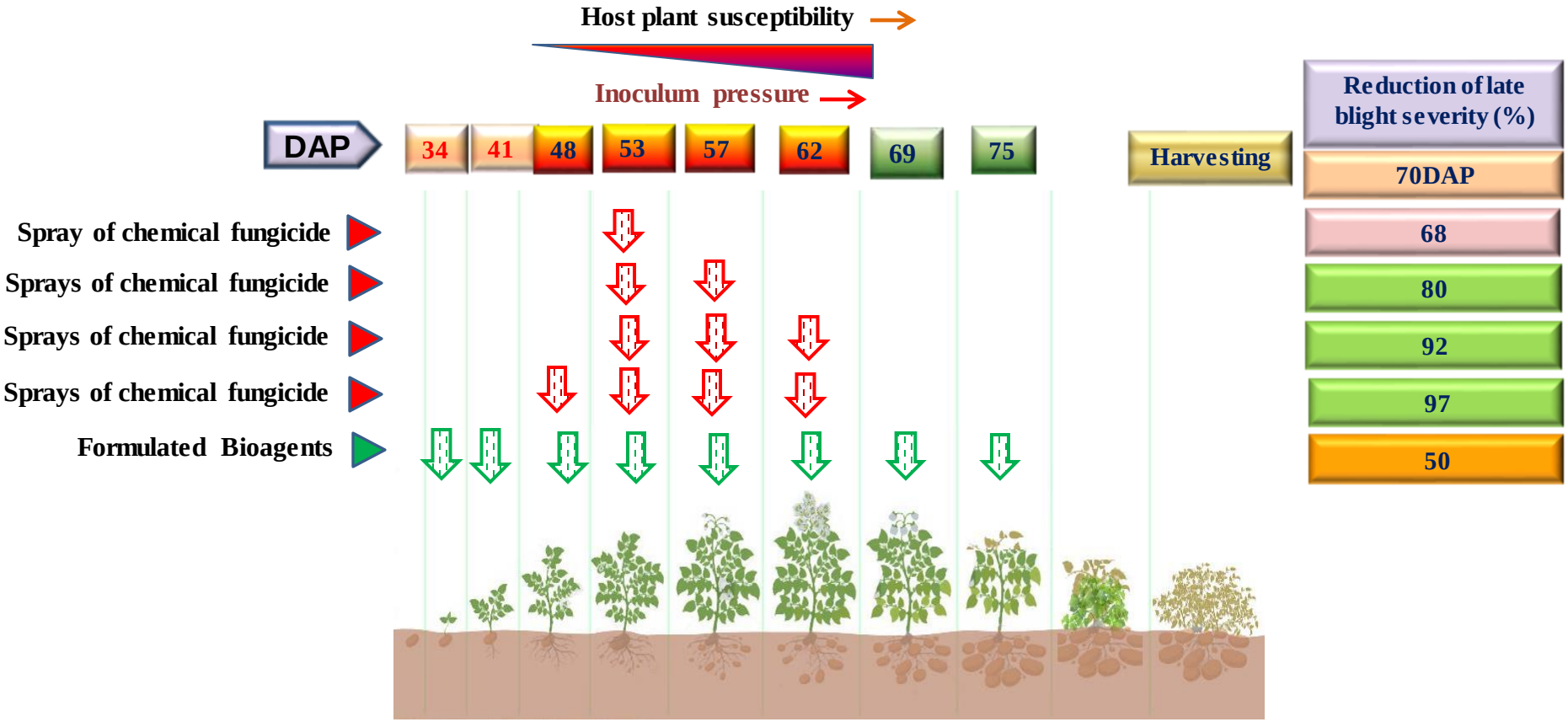
Treatments	Germination (%)	Plant height (cm) Days after planting (DAP) 34	52	71	No. of plantlets/hill	No. of tubers/plant	Yield (t/ha)
T_0	95.24	22.53±0.23^{h}	53.90±1.16^{e}	73.83±0.83^{g}	2.17±0.09^{a}	4.27	6.33±0.10^{e}
T_1	95.24	25.23±0.18^{b-f}	57.90±0.40^{bc}	76.90±0.60^{cd}	2.30±0.15^{a}	5.07	23.39±1.07^{a}
T_2	99.21	24.87±1.11^{d-g}	57.33±0.59^{bc}	75.73±0.50^{e}	2.17±0.03^{a}	4.60	8.44±0.89^{de}
T_3	96.03	25.87±0.03^{b-d}	59.53±0.32^{a}	74.40±0.52^{f}	2.30±0.12^{a}	4.13	14.11±0.78^{bc}
T_4	98.41	26.43±0.54^{b}	57.07±0.94^{c}	80.27±0.41^{a}	2.47±0.13^{a}	5.27	15.67±1.26^{b}
T_5	97.62	26.00±0.60^{b}	57.53±0.72^{bc}	76.60±0.49^{cd}	2.27±0.03^{a}	5.47	15.94±0.58^{b}
T_6	97.62	24.53±0.33^{d-g}	58.87±0.37^{b}	75.93±0.18^{e}	2.40±0.15^{a}	5.80	24.06±0.39^{a}
T_7	99.21	27.73±0.65^{a}	59.77±0.90^{a}	78.53±0.72^{bc}	2.33±0.15^{a}	5.47	11.06±0.81^{cd}
T_8	97.62	22.93±0.56^{h}	57.07±1.07^{c}	76.37±0.39^{cd}	2.43±0.03^{a}	4.87	12.61 ±1.43^{bd}
T_9	96.83	25.20±0.35^{b-f}	56.53±1.36^{cd}	78.97±0.42^{bc}	2.40±0.12^{a}	5.40	13.50±1.42^{bc}
T_{10}	98.41	25.60±0.57^{b-d}	59.73±0.09^{a}	77.73±0.49^{c}	2.37±0.12^{a}	5.47	16.28±1.22^{b}
T_{11}	99.21	24.07±0.43^{fg}	56.40±1.02^{d}	77.50±0.35^{c}	2.50±0.15^{a}	4.40	23.03±3.16^{a}
T_{12}	98.41	23.87±0.52^{gh}	55.70±0.32^{de}	75.37±0.12^{ef}	2.40±0.06^{a}	4.93	11.17±1.23^{cd}
T_{13}	97.62	25.27±0.84^{b-f}	57.07±0.41^{c}	76.87±0.18^{cd}	2.43±0.03^{a}	5.20	12.50±0.96^{bd}
T_{14}	99.21	24.77±0.15^{d-g}	57.53±1.18^{bc}	78.43±0.23^{bc}	2.30±0.15^{a}	5.53	14.56±1.13^{bc}
T_{15}	96.83	24.27±0.87^{fg}	55.93±0.64^{de}	79.33±0.38^{b}	2.40±0.12^{a}	5.73	16.61±0.81^{b}
T_{16}	97.62	25.50±0.80^{b-d}	55.69±0.46^{de}	78.77±0.34^{bc}	2.57±0.09^{a}	5.53	24.61±0.29^{a}
Level of significance	NS	**	**	**	**	NS	**
CV(%)	1.93	3.3	3.38	1.18	12.73	19.3	16.27

Data are the averages of three replications. Values with same letters in the same column are statistically similar.

Cost benefit analyses of formulated two bacterial and one fungal bioagents in reducing the application frequency of chemical fungicide for controlling late blight of potato under field condition in 2020-2021

Treatment	Yield (t/ha)	Gross return (Tk./ha)	Production cost (Tk./ha)	Total cost of the treatment (Tk/ha)	Total cost with treatment (Tk/ha)	Net return (Tk./ha)	BCR
T_0	6.33	10133.33	192500	0	192500	-91166.67	-0.47
T_1	23.39	374240.00	192500	13000	205500	168740.00	0.82
T_2	8.44	135111.11	192500	9600	202100	-66988.89	-0.33
T_3	14.11	225777.78	192500	11225	203725	22052.78	0.11
T_4	15.67	250666.67	192500	12850	205350	45316.67	0.22
T_5	15.94	255111.11	192500	14475	206975	48136.11	0.23
T_6	24.06	384888.89	192500	16100	208600	176288.89	0.85
T_7	11.06	176888.89	192500	9600	202100	-25211.11	-0.12
T_8	12.61	201777.78	192500	11225	203725	-1947.22	-0.01
T_9	13.50	216000.00	192500	12850	205350	10650.00	0.05
T_{10}	16.28	260444.44	192500	14475	206975	53469.44	0.26
T_{11}	23.03	368444.44	192500	16100	208600	159844.44	0.77
T_{12}	11.17	178666.67	192500	9600	202100	-23433.33	-0.12
T_{13}	12.50	200000.00	192500	11225	203725	-4912.00	-0.02
T_{14}	14.56	232888.89	192500	12850	205350	27538.89	0.13
T_{15}	16.61	265777.78	192500	14475	206975	58802.78	0.28
T_{16}	24.61	393777.78	192500	16100	208600	185177.78	0.89

Price: Potato Tk. 16.00/kg (Organic), Tk. 15.00/kg (Inorganic), Fungicide Tk. 1625/kg, Bioagents Tk. 600/kg, Fungicide 8 kg/ha, Bioagents 16 kg/ha. Data are the averages of three replications.



A working model showing the spray schedule of formulated bioagents with chemical fungicide in reducing the late blight of potato through minimizing the use of chemical fungicide. Reduction of late blight sevirity (%) is the average of consecutive two years results

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Article

Potentiality of Formulated Bioagents from Lab to Field: A Sustainable Alternative for Minimizing the Use of Chemical Fungicide in Controlling Potato Late Blight

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Abstract: Late blight of potato caused by an oomycete, *Phytophthora infestans* (Mont.) De Bary limits the production of potato worldwide. Late blight management has been based on chemical fungicide application, and the repeated use of these fungicides introduces new and more aggressive genotypes, which can rapidly overcome host resistance. Therefore, innovative and effective control measures are needed if fungicide use is to be reduced or eliminated. Some potential formulated bacterial bioagents viz. *Pseudomonas putida* (BDISO64RanP) and *Bacillus subtilis* (BDISO36ThaR), and fungal bioagents viz. *Trichoderma paraviridicens* (BDISOF67R) and *T. erinaceum* (BDISOF91R), were evaluated for their performance in controlling late blight of potato under growth chamber and field conditions. Both artificial inoculation and field experiments revealed that eight sprays of these bacterial (*P. putida* and *B. subtilis*) and fungal (*T. erinaceum*) bioagents were found to be most effective at reducing late blight severity by 99% up until 60 days after planting (DAP), whereas these bioagents were found to be partially effective until 70 DAP, reducing late blight severity by 46 to 60% and 58 to 60% in the field and growth chamber conditions, respectively. However, these bioagents can reduce the spray frequencies of Curzate M8 by 50% (four sprays instead of eight) when applied together with this fungicide. Economic analysis revealed that T_6 (eight sprays of formulated *P. putida* + *B. subtilis* + four sprays of Curzate M8) and T_{16} (eight sprays of formulated *P. putida*, *B. subtilis*, and *T. erinaceum* + four sprays of Curzate M8) performed better in consecutive two years, applying less fungicidal spray compared to T_1 (eight sprays of Curzate M8 (Positive control)), which indicated that the return ranged, by Bangladeshi Currency (Taka), from 0.85 to 0.90 over the investment of Bangladeshi Currency (Taka) 1.00 in these treatments, and these results together highlight the possibility of using bioagents in reducing late blight of potato under a proper warning system to reduce the application frequency of chemical fungicide.

- Some potential formulated bacterial bioagents viz. *P. putida* (BDISO64RanP) and *B. subtilis* (BDISO36ThaR), and fungal bioagents viz. *T. paraviridicens* (BDISOF67R) and *T. erinaceum* (BDISOF91R), were evaluated under growth chamber and field conditions.
- Both artificial inoculation and field experiments revealed that eight sprays of these bacterial (*P. putida* and *B. subtilis*) and fungal (*T. erinaceum*) bioagents were found to be most effective at reducing late blight severity by 99% up until 60 days after planting (DAP)
- These bioagents can reduce the spray frequencies of Curzate M8 by 50% (four sprays instead of eight) when applied together with this fungicide.
- Economic analysis revealed that T6 (eight sprays of formulated *P. putida* + *B. subtilis* + four sprays of Curzate M8) and T16 (eight sprays of formulated *P. putida, B. subtilis,* and *T. erinaceum* + four sprays of Curzate M8) performed better in consecutive two years, applying less fungicidal spray compared to T1 (eight sprays of Curzate M8 (Positive control)),
- Indicated that the return ranged, by Bangladeshi Currency (Taka), from 0.85 to 0.90 over the investment of Bangladeshi Currency (Taka) 1.00 in these treatments

Conclusion

- **Possibility of using these native formulated bacterial (*P. putida* and *B. subtilis*) and fungal (*T. erinaceum*) bioagents can be an alternative in controlling late blight severity of potato through minimizing the use of chemical fungicides under the proper warning system.**

- **Therefore, monitoring of population changes should continue to avoid the outbreak of the disease due to evolution and introduction of new genotypes in the country.**

- **Efficacy of these formulated bacterial and fungal bioagents need to be investigated in all potato growing areas of the country using all commercial potato varieties under a suitable warning system.**

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