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A study on bio-efficacy of *Bacillus subtilis* based bio-fungicide on early blight, yield and yield attributes of potato (*Solanum tuberosum* L.) *cv.* Kufri Jyoti

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Abstract
The present investigation was carried out at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, B.H.U., Varanasi, India during *rabi* season 2014-15. The study was carried out to judge the performance of *Bacillus subtilis* based bio-fungicide 'Taegro' on early blight diseases of potato with yield and yield traits. Potato cultivar *Kufri Jyoti* was used for investigation because it is one of the leading potato cultivar grown in eastern U.P. conditions. The experiment was laid out in randomized block design with three replications. Sowing was done on 13th and 14th November, 2014. Treatments were consisting of fungicide *viz*., Dithane M-45, Revus, Taegro and *Trichoderma*. They were used in different concentration and combination with control.
The bio-fungicide Taegro (*Bacillus subtilis* var. *Amyloliquefaciens* Strain FZB24**)** exhibited significant potential in reducing the Early Blight disease incidence and their severity in potato as compared to untreated control whereas combined used of Taegro with standard chemical Dithane M-45 (Mancozeb 75% WP) and Revus [Mandipropamid (MPD)] gave better result than Taegro (*Bacillus subtilis* var. *Amyloliquefaciens* Strain FZB24**)** alone, as a consequences, this may be used as part of an integrated disease management approach thereby to reduce the use of standard chemical fungicides at higher doses to which the fungus may develop resistance.

Keywords: triclosan, TCS, determination, detection, sensor

Introduction
Vegetables are important constituents of Indian agriculture and nutritional security due to their short duration, high yield, nutritional richness, economic viability and ability to generate on-farm and off-farm employment. Our country is blessed with diverse agro-climates with distinct seasons, making it possible to grow wide array of vegetables. India produces 14 % (146.55 million tonnes) of world's vegetables on 15 % (8.5 million hectares) of world area under vegetables. Productivity of vegetables in India (17.3t/ha) is less than the world average productivity (18.8t/ha). Potato (28.9%), tomato (11.3%), onion (10.3%) and brinjal (8.1%) are the 4 major vegetables contributing 58.6% of total vegetable production in our country.
India is the one of leading potato producing country. Potato is grown almost throughout the country. In India, Potato is cultivated in almost all states under diverse agro-climate conditions. About 85 per cent of Potatoes are cultivated in Indo-gangetic plains of North India. The states of Uttar Pradesh, West Bengal, Punjab, Bihar and Gujarat accounted for more than 80 per cent share in total production. It has also large area and production in Assam, Madhya Pradesh, Orissa, Karnataka, Punjab, Himachal Pradesh, Meghalaya, Gujrat and Maharashtra.
Early blight caused by *Alternaria solani* (E. & M.) Jones and Grout (Hyphomycetes, Hyphales), is a very common disease of potato and is found in most potato growing areas. Although it occurs annually to some degree in most production areas, the timing of its appearance and rate of its progress determine the impact on the potato crop. The disease occurs over a wide range of climatic conditions and depends in a large part on the frequency of foliage wetting from rainfall, fog, dew or irrigation, on the nutritional status of foliage, and on cultivar susceptibility. Though losses rarely exceed 20%, if left uncontrolled, losses can be higher and impact stored potatoes. In general fungicide treatment helps contain losses.
Thus the study was designed to find out the Bio-efficacy of *Bacillus subtilis* based bio-fungicide on early blight**,** yield and yield attributes of potato.

Material and Methods
Study was conducted during *rabi* season 2014-2015 at Vegetable Research Farm, Department

of Horticulture, Institute of Agricultural Sciences, bhu, Varanasi. The experimental farm was located at an altitude of 75.7 m above MSL with coordinates of 25º 18' N latitude and 83 º 03' E longitudes almost in the centre of Indo-Gangetic belt.

The soil is of sandy loam with good drainage and moderate water holding capacity. Soil samples were collected before planting of the potato tuber from 5 randomly selected spots at a depth of 30 cm from the experimental plot. The soil was air-dried and ground to pass through 20 mm sieve before analysis. The composite soil samples were analyzed for its physico-chemical properties and are presented below.

Property	Quantity	Method of analysis
Soil fractions %		International pipette method (Piper, 1966) [5].
Sand	50.96	
Silt	29.81	
Clay	19.23	
Chemical composition		
Soil Ph	7.3	Digital pH meter (DI-707) (Jackson, 1967) [2]
Electrical Conductivity (dS per m)	0.37	Conductivity bridge (Jackson,1967) [2]
Organic Carbon (%)	0.58	Wet digestion procedure (Walkley and Black, 1934) [7]
Available N (kg per ha)	87	Alkaline permanganate method (Subbaiah and Asija, 1956) [6]
Available P (kg per ha)	32	Olsen's method (Olsen *et al.,* 1954) [3]
Available K (kg per ha)	142	Flame photometer method (Mehr *et al.,* 1965)

Experimental Details

Cultivar

Potato cultivar *Kufri Jyoti* was used for studies. It is a leading variety of the state. It has a yield potential of 20 t/ha in Hills and 30 t/ha in Plains during *Rabi* season with duration of Hills medium-early (110-130 days); Plains medium (90-100 days). It is moderately resistant to late and early blight, Resistant to wart. Slow rate of degeneration. The experiment was laid out in randomized block design with three replications. The layout plan of the experiment is as depicted:

Experimental design: Randomized Block design
Replication: 3
Total Number of plots: 54 (27 Early Blight + 27 Late Blight)
Spacing: 60 X 15 cm
Plot size: 4 X 3 m^2
Number of rows per treatment: 06
Number of plants in each row: 20
Number of plants in each plot: 120
Total number of plants in experiment: 6480
Time of sowing: 13th & 14th November 2014

Fungicides used in the experimental studies

Trade name and constituents of Different fungicides used in field studies are as follow-

Trade name	Constituents
Dithane M-45	Mancozeb 75% WP
Revus	Mandipropamid (MPD)
Taegro	*Bacillus subtilis* var. *amyloliquefaciens* Strain FZB24
Bio-fungicide	*Trichoderma viride*

Treatments

The details of experimental plan employed in present investigation were as follows-

Total No. of treatments: 9

T_1: Untreated Control (UTC)
T_2: Standard Chemical Control, Dithane M-45 @ 2g/l (8 sprays at weekly intervals)
T_3: Standard Biological Control, *Trichoderma viride* @2 g/l (8 sprays at weekly intervals)
T_4: Taegro foliar spray @ 185g/ha (8 sprays at weekly intervals)
T_5: Taegro foliar spray @ 370g/ha (8 sprays at weekly intervals)
T_6: Tank mix foliar sprays of Standard Chemical Dithane M-45 @ 1g/l + Taegro foliar spray @ 370g/ha (8 sprays at weekly intervals)
T_7: Standard Chemical Control, Dithane M-45 @ 1g/l (8 sprays at weekly intervals)
T_8: Standard Chemical Control, Dithane M-45 @ 2g/l alternated with Taegro foliar spray @ 370g/ha (8 sprays at weekly intervals *i.e.* 1st, 3rd, 5th, 7th sprays of Standard Chemical and 2nd, 4th, 6th, 8th Sprays of Taegro)
T_9: Standard Chemical Control, Dithane M-45 @ 2g/l (4 Sprays coinciding with 1st, 3rd, 5th, & 7th Foliar Sprays)

Note: 1st foliar sprays started at disease appearance.

Plot size

The gross and net plot sizes of the treatments were 4.2 m x 3.6 m (15.12 m^2) and 4 m x 3 m (12 m^2) respectively. Two main irrigation channel of 1 m width each and three sub-irrigation channels of 75 cm each were prepared in the experimental field to meet out the irrigation requirement, Three meter area is left around the field for border line of the same crop.

Spacing

A Spacing of 60 cm between rows and 15 cm within the rows was adopted for all treatments.

Treatment Details and Time of Application

T_1: The treatment T_1 is an untreated control therefore no biological or chemical fungicide is applied to the plants.
T_2: The treatment T_2 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance. The plants are sprayed with Dithane M-45 @ 2g/l of water.
T_3: The treatment T_3 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar spray-cum soil drenching. The plants are sprayed with standard biological control in which the *Trichoderma viride* is applied @2 g/l of water.
T_4: The treatment T_4 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar spray. The plants are sprayed with Taegro 185g/ha.
T_5: The treatment T_5 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar spray. The plants are sprayed with Taegro 370g/ha.

T_6: The treatment T_6 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar spray. The plants are Tank mix foliar sprays of Standard Chemical Dithane M-45 @ 1g/l + Taegro foliar spray @ 370g/ha.

T_7: The treatment T_7 consist of 8 applications at 7 days interval which was started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar spray. The plants are sprayed with Standard Chemical *i.e.* Dithane M-45 @ 1g/l.

T_8: The treatment T_8 consists of spraying Taegro and Dithane M-45 alternatively. The potato crop receive 8 applications out of which four foliar spray of Taegro @ 370g/ha and four sprays of Dithane M-45 @ 2g/l of water. The spray started with the day of disease appearance and then after 7, 14, 21, 28, 35, 42 and 49 days after disease appearance as foliar sprays.

T_9: The treatment T_9 consists of 4 applications at 14 days interval which was started with the day of disease appearance and then after 14, 28 and 42 days after disease appearance as foliar sprays. The plants are sprayed with Standard Chemical *i.e.* Dithane M-45 @ 2g/l of water.

Cultivation Details

Preparatory cultivation

The whole experimental plot was brought to fine tilth by repeated ploughings followed by harrowing. Finally it was levelled and divided into plots as per the layout plan.

Seed sowing

Tubers of *Kufri Jyoti* were soaked in solution of Dithane M-45 @ 2g/l and soaked them for 10 minutes before planting and then allowed to dry in shade for 30 minutes prior to planting into the field. Dig a trench to a depth of about 10 cm (4″) and place the seed potatoes into the trench with the rose end facing upwards with a spacing of 60 cm between rows and 15 cm within the row.

Manures and fertilizers

A common dose of farmyard manure 30 tonnes per hectare was applied to experimental land area uniformly in last ploughing and incorporated into the soil. Nitrogen (150 Kg per ha) was applied in two splits doses viz., half dose as a basal dressing at the time of planting and remaining half at the time of earthing-up in each plot. Phosphate (60 kg per ha) and potash (100 kg per ha) fertilizers were applied along with the basal dose of nitrogen in each plot. Nitrogen, Phosphorus and Potash were applied in the form of Urea, Single Super Phosphate and Muriate of Potash respectively. The top dressing of nitrogen was done at 50 days after planting during early vegetative growth period.

Irrigation

The first irrigation was given 4 days after sowing while subsequent irrigations were given as and when required depending upon soil moisture and weather conditions. In all, a total of 6 irrigations were given to the crop of 100 days duration. Irrigation was stopped about two weeks before dehaulming.

Intercultural operations

The experimental area was kept weed free throughout the cropping period by manual weeding.

Plant protection

Necessary plant protection measures were adopted to control the pests and diseases during the crop growth period.

Harvesting

Dehaulming [Cutting of haulms /aerial parts by sickle or killing by chemicals (e.g. Gramoxone) or destroying by machines] when the crop attains 90 days and when the aerial part of the plant turns yellow. The crop was harvested 100 days after sowing. Bruising and skinning of tubers was avoided.

Drying and Curing

After harvesting tubers were dried in storage shed quickly to remove excess moisture from the surface of tubers for improving their keeping quality. Potato tubers were kept in a cool and dry place for curing process at 25 degree centigrade with a 95 per cent relative humidity for optimum suberization. Curing is essential for healing the wounds of tubers resulted from cutting and bruising during harvesting. All the damaged and diseased tubers were removed during sorting.

Sampling procedure

20 plants were selected at random from the net plot of each treatment and tagged for recording biometric observations such as plant length, chlorophyll content, No. of tuber per plant for Early Blight disease incidence observation.

Observations recorded

The observations recorded and the methods followed during the course of investigation are furnished below.

Days to 50 per cent germination

The number of germinated potato tuber was noted daily. Emergence of plumule above the ground was taken as criterion for germination. The number of days taken for 50 per cent potato tuber germinated within the plot was recorded.

Plant Length (cm)

Plant length from the base of the plant to tip of the main stem was measured with the help of a scale. Plant length was measured at 90 DAS and expressed in centimetre.

Number of branches per plant

The number of branches was recorded once the plant had attained its full vegetative growth and prior to harvesting.

Leaf area (cm^2)

Representative leaf sample was fed to LI 3100 leaf area metre (LI-COR ltd., Linclonm, Nebraska, USA) to get the leaf area in cm^2. The readings are taken from leaf samples at 60 DAS.

Leaf Chlorophyll Content

Leaf chlorophyll content of potato was measured with the help of a portable chlorophyll meter (SPAD-502 model, Konica Minolta, Sakai, Osaka, Japan). If SPAD value <35.5 then Nitrogen requirement to the crop.

Disease incidence and severity

They were assessed using a disease severity index. Disease severity classes were determined as:

In case of early blight disease severity is commonly estimated visually on the basis of the proportion (%) of leaf area

affected, At CIP a scale has been developed where the % corresponding to value 1 (no symptoms) to 9 (Plant dead).
Where,

- 1 = 0% leaf area affected
- 2 = <5 % leaf area affected
- 3 = 5 to <15% leaf area affected
- 4 = 15 to <35% leaf area affected
- 5 = 35 to <65% leaf area affected
- 6 = 65 to <85% leaf area affected
- 7 = 85 to <95% leaf area affected
- 8 = 95 to <100% leaf area affected
- 9 = All leaves and stem dead

And then the rating scales were converted into percentage severity index (PSI) for the analysis of disease severity using the following formula-

$$\text{Percentage Severity Index} = \frac{\sum \text{of individual numarical rating}}{\text{Total Number ofAssessed} \times \text{MaximumScore} \in \text{Scale}} \times 100$$

$$\text{Disease Incidence} = \frac{\text{Number of Diseased Plant}}{\text{Total Number of Plant Inspected}} \times 100$$

Statistical analysis

The results obtained from field observations were analysed statistically as per Panse and Sukhatme (1985) [4] for Randomised Block Design. The significance was tested by referring to 'F' tables of Fisher and Yates (1963) [1].
The results from RBD can be arranged in two way table according to the replications (blocks) and treatments; there will be `rk' observations in total.

Results and Discussion

The results of the experiments were statistically analyzed to test their significance and presented under following heads:

Number of days taken to 1st germination

The given table 1 showed that the observed mean values for number of days taken to 1st germination of potato tuber were ranged between T_8 (9.0) to T_1 (10.96), among the treatments, least values were observed for T_8 followed by T_2. The trends of treatments were as follows: $T_8 < T_2 < T_3 < T_6 < T_9 < T_7 < T_5 < T_4 < T_1$.

Table 1: Mean performance of number of days taken to first germination of potato

Treatments	1st germination (DAS)
T_1	10.96
T_2	9.56
T_3	9.66
T_4	10.86
T_5	10.59
T_6	10.25
T_7	10.35
T_8	9.00
T_9	10.33
SE(d)	0.43
SE.m.±	0.30
C.D.	0.90

Number of days taken to 50 per cent germination

The below given table 2 showed that the recorded mean values for number of days taken to 50 per cent germination of potato tuber were ranged between T_8 (14.27) to T_1 (15.93). Among the treatments, the least days taken to 50% germination was observed for T_8 followed by T_6. The trends of treatments were as follows: $T_8 < T_6 < T_7 < T_3 < T_2 < T_9 < T_5 < T_4 < T_1$.

Table 2: Mean performance of number of days taken to 50% germination of potato

Treatments	50 per cent germination(DAS)
T_1	15.93
T_2	14.69
T_3	14.66
T_4	15.83
T_5	15.33
T_6	14.56
T_7	14.62
T_8	14.27
T_9	15.00
SE(d)	0.47
SE.m.±	0.33
C.D.	0.99

Number of haulms per plant

The below given table 3 showed that the recorded mean values for number of haulms per plant were ranged between T_1 (4.07) to T_8 (6.65). Out of nine treatments, the highest haulms/plant was observed for T_8 followed by T_6. The trends of treatments were as follows: $T_1 < T_4 < T_5 < T_9 < T_7 < T_6 < T_2 < T_3 < T_8$.

Table 3: Mean performance of number of haulms/plant of potato

Treatments	Number of haulms per plant
T_1	4.07
T_2	6.31
T_3	6.36
T_4	4.31
T_5	4.99
T_6	5.90
T_7	5.35
T_8	6.65
T_9	5.05
SE(d)	0.29
SE.m.±	0.21
C.D.	0.62

Leaf area index (cm^2)

The below given table 4 showed that the observed mean values for potato leaf area index were ranged between treatment T_1 (4.25) to T_8 (7.34). Among the treatments, the highest leaf area index was observed for treatment T_8 followed by T_3. The trends of treatments were as follows: $T_1 < T_4 < T_5 < T_9 < T_6 < T_7 < T_2 < T_3 < T_8$.

Table 4: Mean performance of potato leaf area index (cm^2)

Treatments	Leaf area index (cm^2)
T_1	4.25
T_2	6.94
T_3	6.99
T_4	5.40
T_5	5.45
T_6	6.24
T_7	6.27
T_8	7.34
T_9	6.02
SE(d)	0.26
SE.m.±	0.19
C.D.	0.56

Plant height (cm)

The below given table 5 showed that the exhibited mean value for potato plant height (cm) were ranged between treatment T_4 (68.61) to T_8 (90.35). Out of nine treatments, highest plant height was observed for treatment T_8 followed by T_5. The trends of treatments were as follows: $T_4 < T_1 < T_7 < T_3 < T_6 < T_2 < T_9 < T_5 < T_8$.

Table 5: Mean performance of potato plant height (cm)

Treatments	Plant height (cm)
T_1	70.06
T_2	76.25
T_3	74.98
T_4	68.61
T_5	79.00
T_6	75.16
T_7	70.35
T_8	90.35
T_9	77.33
SE(d)	6.95
SE.m.±	4.91
C.D.	14.73

Leaf chlorophyll content

The given table 6 showed that the noted mean values for chlorophyll content (SPAD value) of potato leaf were ranged between treatment T_1 (31.46) to T_8 (41.22). Among the treatments the highest leaf chlorophyll content was observed for treatment T_8 followed by T_3. The trends of treatments were as follows: $T_1 < T_6 < T_2 < T_9 < T_5 < T_4 < T_7 < T_3 < T_8$.

Table 6: Mean performance of potato leaf chlorophyll content

Treatments	Chlorophyll content (SPAD value)
T_1	31.46
T_2	34.66
T_3	38.51
T_4	37.52
T_5	36.98
T_6	33.98
T_7	37.97
T_8	41.22
T_9	36.62
SE(d)	1.87
SE.m.±	1.32
C.D.	3.96

Tuber yield per plot (kg)

The given table 7 showed that the noticed mean values for potato tuber yield per plot (kg) were varied between treatment T_1 (19.03) to T_8 (25.37). Among the nine treatments, the highest tuber yield / plot was observed for treatment T_8 followed by T_2. The trends of treatments were as follows: $T_1 < T_3 < T_4 < T_5 < T_7 < T_9 < T_6 < T_2 < T_8$.

Table 7: Mean performance of potato tuber yield/plot (kg)

Treatments	Tuber yield per plot (kg)
T_1	19.03
T_2	25.27
T_3	19.77
T_4	20.17
T_5	20.40
T_6	25.00
T_7	22.72
T_8	25.37
T_9	23.46
SE(d)	0.61
SE.m.±	0.43
C.D.	1.30

Average weight of 40 potato tubers at different state (kg)

The observed mean values for weight of 40 potato tubers at different state (kg) obtained were given in table 8 and it ranged for just after harvesting between treatment T_1 (2.32) to T_8 (3.16), for 60 days after without washing between treatment T_1 (2.11) to T_8 (3.10) and for 60 days after washing between treatment T_1 (1.52) to T_8 (2.99). Among the nine treatments, the highest weight of 40 tubers was observed for treatment T_8 followed by T_7. Potato tuber weight of without washing state was better than washing state regarding the shelf life. The trends of potato tuber weight for all the treatments for EB plot were as follows: Potato weight just after harvesting: $T_1 < T_5 < T_9 < T_3 < T_2 < T_4 < T_6 < T_7 < T_8$, for 60 days after without washing: $T_1 < T_3 < T_5 < T_9 < T_6 < T_4 < T_7 < T_2 < T_8$ and for 60 days after washing: $T_1 < T_2 < T_5 < T_3 < T_6 < T_9 < T_7 < T_4 < T_8$. There was gradual weight loss of tubers found in both state of without washing and after washing storage conditions. Potato tuber weight of without washing state was better than washing state regarding the shelf life.

Table 8: Mean performance of 40 potato tubers weight at different state (kg)

Treatments	Mean performance of 40 potato tubers weight (kg)		
	Just after harvesting	After 60 days of without washed	After 60 days of washed
T_1	2.32	2.11	1.52
T_2	2.76	2.69	1.78
T_3	2.59	2.12	1.98
T_4	2.73	2.50	2.22
T_5	2.45	2.13	1.90
T_6	2.80	2.40	2.12
T_7	2.89	2.68	2.20
T_8	3.16	3.10	2.99
T_9	2.53	2.30	2.12
SE(d)	0.25	0.17	0.04
SE.m.±	0.18	0.12	0.03
C.D.	0.54	0.35	0.09

Polar diameter of potato tubers (mm)

The observed mean values for polar diameter of potato tubers (mm) obtained were depicted in table 9 and it ranged between treatment T_3 (56.95) to T_8 (66.66). Out of nine treatments, the highest polar diameter was observed for treatment T_8 followed by T_2. The trends of treatments were as follows: $T_3 < T_5 < T_1 < T_4 < T_6 < T_9 < T_7 < T_2 < T_8$.

Table 9: Mean performance of polar diameter of potato tubers (mm)

Treatments	Polar diameter (mm)
T_1	57.62
T_2	65.62
T_3	56.95
T_4	58.81
T_5	57.38
T_6	60.35
T_7	64.75
T_8	66.66
T_9	63.82
SE(d)	2.40
SE.m.±	1.70
C.D.	5.08

Radial diameter of potato tubers (mm)

The given table 10 showed that the observed mean values for radial diameter of potato tubers (mm) obtained were varied between treatment T_5 (45.95) to T_8 (50.96). Among the nine treatments, the maximum radial diameter was noted for treatment T_8 followed by T_6. The trends of treatments were as follows: $T_5 < T_7 < T_1 < T_4 < T_3 < T_9 < T_2 < T_6 < T_8$.

Table 10: Mean performance of radial diameter of potato tubers (mm)

Treatments	Radial diameter (mm)
T_1	46.21
T_2	49.34
T_3	46.47
T_4	46.25
T_5	45.95
T_6	49.90
T_7	46.05
T_8	50.96
T_9	49.30
SE(d)	1.90
SE.m.±	1.34
C.D.	4.02

Disease incidence (DI)

The data on disease incidence were taken periodically as influenced by the different treatments which are presented in given table 11. The perusal of the data with respect to early blight disease incidence indicated significant difference among all the nine treatments. The mean value of the disease incidence of all the treatments till 9th spray were ranged for treatment T_1: 8.33 - 93.33%, T_2: 0.0 - 40.0%, T_3: 5.0 -83.33%, T_4: 5.0 - 81.67%, T_5: 5.0 – 83.33%, T_6: 1.67 – 43.33%, T_7: 5 – 36.67%, T_8: 0.0 – 35.0% and T_9: 5.0 – 38.33%, respectively. Among all the treatments, significantly least incidence was noticed with treatment T_8 followed by T_2, while the highest disease incidence was observed with treatment T_1 (control).

The trends for all the 9 time sprays were as follows:

Before 1st spray: $T_8 < T_2 < T_6 < T_3 < T_4 < T_5 < T_7 < T_9 < T_1$
Before 2nd spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$
Before 3rd spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$
Before 4th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$
Before 5th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$
Before 6th spray: $T_8 < T_6 < T_2 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$
Before 7th spray: $T_2 < T_8 < T_7 < T_9 < T_6 < T_5 < T_4 < T_3 < T_1$
Before 8th spray: $T_8 < T_7 < T_9 < T_6 < T_2 < T_3 < T_5 < T_4 < T_1$
Before 9th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_4 < T_3 < T_5 < T_1$

Table 11: Effect of bio-fungicides on early blight disease incidence (DI)

Treatments	Before 1st spray	Before 2nd spray	Before 3rd spray	Before 4th spray	Before 5th spray	Before 6th spray	Before 7th spray	Before 8th spray	Before 9th spray
T_1	8.33	21.67	30.00	33.33	31.67	38.33	51.67	48.33	93.33
T_2	3.33	0.00	6.67	3.33	5.00	11.67	33.33	40.00	21.67
T_3	5.00	15.00	26.67	23.33	23.33	25.00	48.33	40.00	83.33
T_4	5.00	13.33	18.33	16.67	15.00	20.00	46.67	45.00	81.67
T_5	5.00	8.33	13.33	13.33	13.33	15.00	45.00	43.33	83.33
T_6	3.33	1.67	8.33	6.67	5.00	10.00	43.33	40.00	23.33
T_7	5.00	6.67	11.67	13.33	10.00	13.33	36.67	33.33	33.33
T_8	0.00	0.00	5.00	3.33	3.33	6.67	35.00	30.00	15.00
T_9	5.00	5.00	10.00	10.00	8.33	11.67	38.33	36.67	30.00

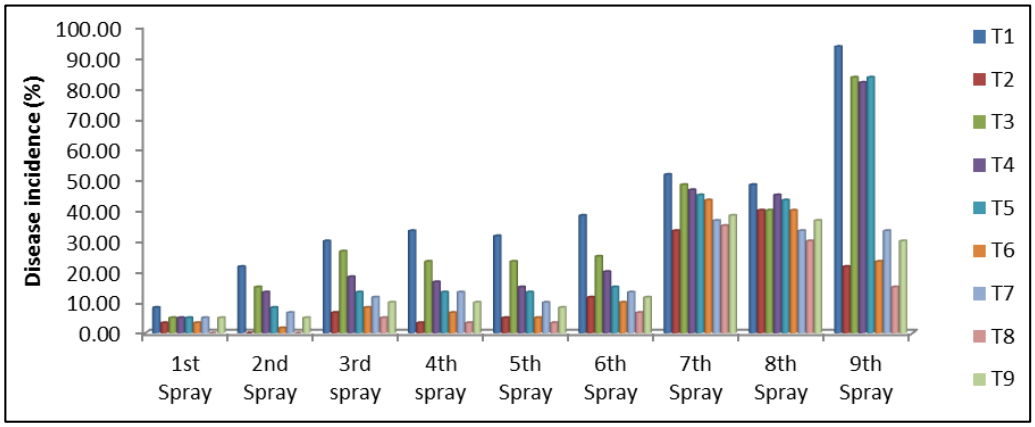

Fig 1: Effect of bio-fungicides on early blight disease incidence (DI)

Early blight disease severity index (DSI)

The data on disease severity of early blight are calculated as influenced by different treatments which are depicted in table 12 from the perusal of the data with respect to early blight disease severity indicated significant difference among all the nine treatments. The mean values of the early blight disease severity index for all the treatments till 9th spray were varied for treatment T_1: 0.83-21.0%, T_2: 0.33-2.83%, T_3: 5.0-

19.33%, T_4: 0.5- 17.67%, T_5: 0.5-14.50%, T_6: 0.33-3.17%, T_7: 0.5-4.0%, T_8: 0.0-2.33% and T_9: 0.5-3.67%, respectively. Among all the treatments, significantly least disease severity index was recorded with treatment T_8 followed by T_2. However, the highest disease severity index was recorded with treatment T_1 (control).

The trends for all the 9 time sprays were as follows

Before 1st spray: $T_8 < T_2 < T_6 < T_3 < T_4 < T_5 < T_7 < T_9 < T_1$

Before 2nd spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 3rd spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 4th spray: $T_8 < T_2 < T_6 < T_9 < T_5 < T_6 < T_4 < T_3 < T_1$

Before 5th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 6th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 7th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 8th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Before 9th spray: $T_8 < T_2 < T_6 < T_9 < T_7 < T_5 < T_4 < T_3 < T_1$

Table 12: Effect of bio-fungicides on early blight disease severity index (DSI)

Treatments	Before 1st spray	Before 2nd spray	Before 3rd spray	Before 4th spray	Before 5th spray	Before 6th spray	Before 7th spray	Before 8th spray	Before 9th spray
T_1	0.83	2.17	4.67	6.33	6.67	5.17	7.00	7.00	21.00
T_2	0.33	0.00	0.67	0.33	0.50	1.17	2.83	2.83	2.00
T_3	0.50	1.50	3.50	3.17	3.33	3.83	6.33	6.33	19.33
T_4	0.50	1.33	2.00	1.83	1.67	2.67	5.17	5.17	17.67
T_5	0.50	0.83	1.33	1.50	1.67	1.83	4.50	4.50	14.50
T_6	0.33	0.17	0.83	0.67	0.50	1.33	3.17	3.17	2.50
T_7	0.50	0.67	1.17	1.33	1.00	1.67	4.00	4.00	3.17
T_8	0.00	0.00	0.67	0.33	0.33	0.67	2.33	2.33	1.33
T_9	0.50	0.50	0.83	1.00	0.83	1.50	3.67	3.67	3.00

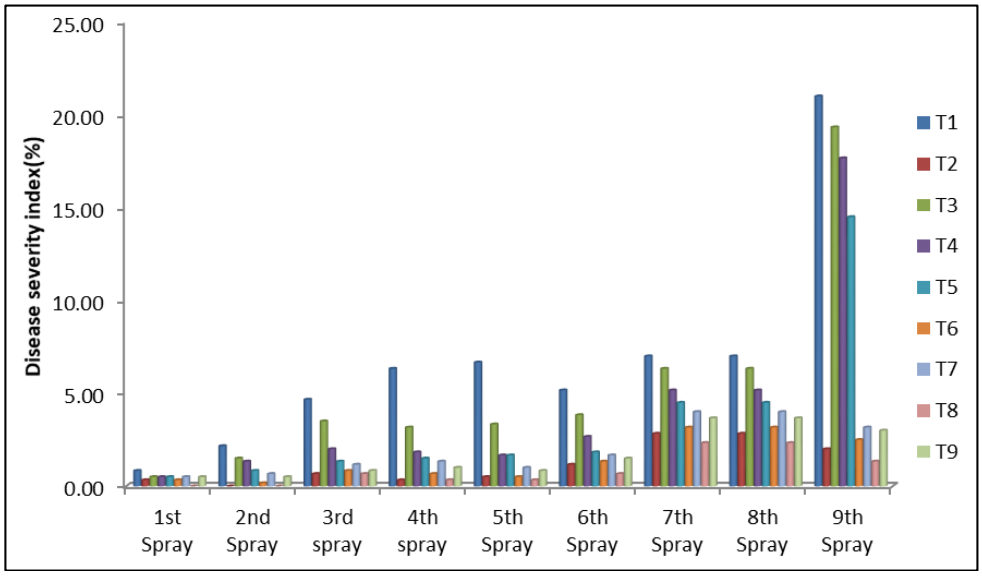

Fig 2: Effect of bio-fungicides on early blight disease severity index (DSI)

Conclusion

The bio-fungicide Taegro (*Bacillus subtilis* var. *Amyloliquefaciens* Strain FZB24) exhibited significant potential in reducing the Early Blight disease incidence, severity, yield and yield attributes in potato as compared to untreated control whereas combined used of Taegro with standard chemical Dithane M-45 (Mancozeb 75% WP) and Revus [Mandipropamid (MPD)] gave better result than Taegro (*Bacillus subtilis* var. *Amyloliquefaciens* Strain FZB24) alone, as a consequences, this may be used as part of an integrated disease management approach thereby to reduce the use of standard chemical fungicides at higher doses to which the fungus may develop resistance.

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