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Management of early blight (*Alternaria solani*) in tomato by bio-agent, plant extract and fungicides

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Abstract
The effectiveness of bio agent (*Trichoderma harzianum* @ 5g/kg seed), plant extract (Leaf extract of Datura @15%), fungicides (Contaf Plus @0.1%, Indofil M-45 @0.25%, Saaf @0.25) alone and their different combinations were assessed in the field during *Rabi*, 2020-21 and *Rabi*, 2021-22 for the management of early blight of tomato caused by *Alternaria solani*. The pooled data reveal that the lowest percent disease intensity (13.94%) and highest fruit yield (17.31 t/ha) was recorded when *Trichoderma harzianum* @5g/kg seed used as seed treatment + one foliar spray with Datura leaf extract @15% + two foliar sprays with Indofil M-45 @ 0.25 % followed by three foliar sprays of Contaf Plus @ 0.1% and *T. harzianum* @ 5g /kg seed used as seed treatment + one foliar spray with Datura leaf extract @15% + two foliar sprays with Saaf@ 0.25% recorded 16.46, 17.81 percent disease intensity and fruit yield 16.84, 16.63 t/ha respectively.

Keywords: *Alternaria solani*, bio agent, fungicides, plant extract, tomato

Introduction
Tomato (*Lycopersicon esculentum* Mill) is one of the most significant vegetable crops in the world which is a member of the Solanaceae family. Tomato is referred to as the "poor man's apple." Tomato ranks first worldwide among crops used for processing. Products made from tomato are an important part of the human diet. It is a plentiful source of minerals, carbohydrates, vitamins, and amino acids (A, C & K). Increased tomato production is needed to meet the rising demand for both fresh market and processed tomato varieties (Adhikari *et al*., 2017 [1]. Successful tomato cultivation and marketing depend on several of biotic and abiotic factors, with biotic factors playing a significant impact. As a result of biotic factors, tomato plants in many countries are affected by a variety of diseases brought on by fungi, bacteria, viruses, nematodes, etc. (Mark *et al*., 2006) [11]. There have been reports of more than 200 diseases that affect tomatoes worldwide (Atherton and Rudich, 1986) [2]. Early blight, one of the most significant and common fungal diseases worldwide caused by *Alternaria solani* (Ellis and Martin) Jones and Grout. It was first reported in New Jersey, USA, in 1882. (Bose and Som, 1986) [3]. Brown spots on older leaves are the first sign of early blight. Under favourable climatic conditions, these spots increase in diameter and develop into concentric rings encircled by a yellow halo. *A. solani* causes disease (leaf blight, stem rot, fruit lesions) at all stages of plant development and causes significant loss across the country (Foolad *et al*., 2002) [5]. Early blight is the most devastating disease, causing losses both before and after harvest and a 35–78% reduction in production (Jones *et al*., 1993) [10]. When sustained favourable weather conditions exist for early blight, fruit yield losses may reach 80-86 percent (Pandey and Pandey, 2003) [13].

In addition to having enzymes like cellulases that break down the host's cell wall, *Alternaria solani* also has pectin methyl galacturonase, which promotes host colonisation (Shahbazi *et al*., 2011) [18]. Plantation overcrowding, heavy rainfall, and an extended period of leaf wetness are variables that contribute to the development of disease (Gondal *et al*., 2012) [8].

Different techniques have been employed to manage early blight, including cultural practices, the use of resistant varieties, biological control, chemical control, and disease-free planting materials (Sarfraz *et al*., 2018) [1]. Fungicides are thought to be the most effective method for preventing early blight (Ghazanfar *et al*., 2016) [7]. Natural products are regarded as the ideal substitute for synthetic chemicals since they provide minimal risks to the environment and human health (Raza *et al*., 2016) [16]. Usage of two or more measures in combination is generally used in long-term successful management methods for disease control (Ticha *et al*., 2017) [20].

However, the aim of the present study was to assess the efficacy of selected plant extract, bio agent and fungicides (which were screened *in-vitro*) both individually and in combination against early blight disease of tomato under field conditions.

Materials and Methods

Under field conditions, bio agent, plant extract, fungicides alone and their various combinations were assessed for their effectiveness against tomato early blight. For this, a field experiment using the tomato variety Pusa Ruby was carried out at Central Research Farm (CRF), Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, during *Rabi*, 2020-21 and *Rabi*, 2021-22. There were twelve treatments including control with three replications. The plot size was 3.6 m x 3.15 m each which was separated by 0.5 m wide drains. Seedlings that were 25 days old were transplanted in the main field with 60 cm x 45 cm spacing. Irrigation of the plots was done in accordance with the crop's water needs. Manures and fertilisers were applied in the recommended amounts. Plants were inoculated with *A. solani* spore suspension containing $1x10^6$ spores ml^{-1} of sterilised distilled water, 30 days after transplanting (DAT). In order to provide 12 hrs humid environment for the disease to easily establish itself, the spore suspension was sprayed in the evening. The first spray of plant extract/ fungicides was given five days after spore suspension sprayed (i.e.35DAT). The second spray (50 DAT) was given after 15 days of first spray and third spray (65 DAT) was given 15 days after 2nd spray. Three replications of each treatment were used in the Randomized Block Design (RBD) experiment. The Duncan's Multiple Range Test (DMRT) was used to compare the treatment mean significant differences at p=0.05. The details of treatments were as follow:

T1: Seed treatment (ST) with Trichoderma harzianum @ 5g/kg seed
T2: Three foliar sprays (FS) of Datura leaf extract @15%
T3: Three FS of Indofil M-45 (Mancozeb 75WP) @ 0.25%
T4: Three FS of Saaf (Carbendazim 12 % + Mancozeb 63%) @ 0.25 %
T5: Three FS of Contaf Plus (Hexaconazole 5 EC) @ 0.1%
T6: ST with T. harzianum @5g/kg seed + Three FS of Indofil M-45@ 0.25%
T7: One FS of Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%
T8: ST with T. harzianum @5g/kg seed + One FS of Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%
T9: ST with T. harzianum @5g/kg seed + Three FS of Saaf @ 0.25 %
T10: One FS of Datura leaf extract @15% + Two FS of Saaf @ 0.25 %
T11: ST with T. harzianum @ 5g/kg seed + One FS of Datura leaf extract @15%+ Two FS of Saaf @ 0.25 %
T0: Control

Observations recorded

i. Disease intensity

On the basis of 20 randomly selected leaves from five tagged plants in each plot, observations on disease intensity were made using a 0–5 scale (Mayee and Datar, 1986) [12]. The formula provided by Wheeler (1969) [21] was used to calculate the percent disease intensity (PDI).

$$PDI = \frac{\text{Sum of individual disease ratings X 100}}{\text{Total no. of leaves examined X Maximum no. of disease rating}}$$

The per cent disease control (PDC) over control was calculated as

$$PDC = \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \text{ X } 100$$

ii. Fruit yield

Fruits were picked when they reached ripeness. The total weight of tomato fruit harvested from each plot/replication was calculated. The yield t/ha was finally computed.

Results and Discussion

The impact of bio-agent, plant extract, fungicides alone, and their integration against early blight during the *Rabi*, 2020-21 and *Rabi*, 2021-22 crop seasons was investigated in a field study. Foliar sprays of treatments were applied at an intervals of 15 days. Data on percent disease intensity, percent disease control and yield t/ha was recorded each year and pooled data presented in table 1 and fig i. From the pooled data (*Rabi*, 2020-21 and *Rabi*, 2021-22), all the treatments significantly influenced the early blight disease intensity in tomato as compared to control. The disease intensity ranged from 3.61 to 10.06 percent at the time of the disease's first manifestation (35 DAT), and it was later shown that this intensity increased steadily up to the third spray treatment.

After 1st spray (50 DAT) , the lowest disease intensity (9.62%) was recorded in T_8 (ST with *T. harzianum* @5g/kg seed + One FS of Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%) and this treatment was at par with T_5 (Three FS of Contaf Plus@0.1%) recorded 10.31 percent disease intensity followed by T_{11} (ST with *T. harzianum* @5g/kg seed + One FS of Datura leaf extract @15%+ Two FS of Saaf @ 0.25 %) and T_6 (ST with *T. harzianum* @5g/kg seed + Three FS of Indofil M-45@ 0.25%) recorded 12.31, 13.02 percent disease intensity respectively.

After 2nd spray (at 65 DAT), the lowest disease intensity (12.30%) was recorded in T_8 (ST with *T. harzianum* @5g/kg seed + One FS of Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%) followed by T_5 (Three FS of Contaf Plus @ 0.1%) and T_6 ST with *T. harzianum* @5g/kg seed + Three FS of Indofil M-45@ 0.25%) recorded 14.49, 16.44 percent disease intensity respectively.

After 3rd spray (80 DAT) lowest disease intensity (13.94%) was recorded in T_8 (ST with *T. harzianum* @5g/kg seed + One FS of Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%) this treatment was significantly superior over all other treatments followed by T_5 (Three FS of Contaf Plus @ 0.1%) and T_{11} (ST with *T. harzianum* @ 5g /kg seed + One FS of Datura leaf extract @15% + Two FS of Saaf @ 0.25%) recorded 16.46, 17.81 percent diseases intensity respectively. The significant difference of the treatments mean were compared after 3rd spray. Treatments (T_1, T_2,) (T_3, T_4), (T_3, T_{10}), (T_6, T_7, T_9), (T_6, T_{11}), and (T_5, T_{11}) were non-significant among each other.

The percent disease reduction over control (PDC) was recorded after third spray (80 DAT) which was highest in T_8 (65.91%) followed by T_5 (59.76%) and T_{11} (56.44%).

Maximum fruit yield (17.31 t/ha) was recorded in the treatment T_8 (ST with *T. harzianum* @5g/kg seed + One FS of

Datura leaf extract @15% + Two FS of Indofil M-45@ 0.25%) followed by T_5 (Three FS of Contaf Plus@ 0.1%) and T_{11} (ST with *T. harzianum* @5g/kg seed + One FS of Datura leaf extract @15% + Two FS of Saaf@ 0.25%) recorded fruit yield of 16.84, 16.63 t/ha respectively. Treatments (T_8, T_5) (T_5, T_{11}), (T_{11}, T_6), (T_6, T_7, T_9), (T_7, T_9, T_{10}, T_3), (T_9, T_{10}, T_3), (T_{10}, T_3) (T_3, T_4) and (T_2, T_3) were non-significant among each other.

In the present study, the minimum disease intensity of early blight and maximum fruit yield of tomato was observed when *Trichoderma harzianum* @5g/kg seed used as seed treatment along with one foliar spray of Datura leaf extract @15% and two foliar sprays of Indofil M-45 @ 0.25 %. The most likely explanation for this finding is that *Trichoderma harzianum*, Datura leaf extract, and the fungicide Indofil M-45 may have had an impact on the pathogen's spore germination and mycelium development, which may have prevented the plant from becoming infected and increased the plant's resistance. Tomato plants grew more effectively as a whole and were in good health as a result. This might be the cause of the lower disease intensity when compared to other treatments.

Rani, *et al*.(2017) [15] have also observed similar findings that mancozeb (0.25%), Datura (50%) and *T. harzianum* ($1x10^7$ spores ml^{-1}) used as seed treatment were found to reduce disease intensity up to 84.00 percent, they were followed by mancozeb (0.25%) and *T. harzianum* ($1x10^7$ spores ml^{-1}) used as seed treatment, which lowered disease intensity to 82.33 percent. According to Patel *et al*. (2005) [14], need-based plant protection techniques used in the IDM programme were more cost-effective and produced an economic yield with less environmental pollution than the use of only chemicals.

Several workers have reported using mancozeb as an efficient fungicide for the control of early blight and maximising fruit yield (Sobolewski and Robak, 2004; Ilhe *et al*., 2008; Chourasiya *et al*., 2013) [19, 9,4]. According to research by Ganie, *et al*. (2013) [6], seed treatment with mancozeb, foliar sprays of hexaconazole, Datura, and *Trichoderma harzianum*, under field conditions, were highly effective in controlling the early blight disease of potato.

Table 1: Effect of bio-agent, plant extract, fungicides alone and their integration on disease intensity of early blight and yield of tomato (Pooled data *Rabi*, 2020-21 and 2021-22)

Treatment	Percent Disease Intensity (PDI)				PDC	Yield (t/ha)
	At 1st appearance	After 1st spray	After 2nd spray	After 3rd spray		
T_1	5.37 (13.28)	19.56 (26.21)	24.23 (29.45)	28.26^{a} (32.09)	30.88	14.35
T_2	9.26 (17.69)	20.18 (26.63)	25.93 (30.59)	26.73^{a} (31.11)	34.62	14.60
T_3	9.63 (18.06)	16.99 (24.89)	20.82 (27.10)	23.36^{bc} (28.87)	42.88	15.53
T_4	9.60 (18.03)	17.96 (24.90)	23.65 (29.06)	24.37^{b} (29.54)	40.41	15.20
T_5	9.07 (17.51)	10.31 (18.61)	14.49 (22.32)	16.46^{f} (23.90)	59.76	16.84
T_6	5.91 (13.95)	13.02 (20.97)	16.44 (23.82)	19.14^{de} (25.81)	53.20	16.3
T_7	9.17 (17.56)	14.06 (21.90)	17.43 (24.59)	20.08^{d} (26.55)	50.89	15.98
T_8	5.25 (13.06)	9.62 (17.94)	12.30 (20.49)	13.94 (21.85)	65.91	17.31
T_9	6.03 (14.18)	13.78 (21.68)	18.54 (25.34)	20.64^{d} (26.99)	49.54	15.86
T_{10}	9.56 (18.00)	15.07 (22.75)	19.71 (26.70)	22.46^{c} (28.25)	45.07	15.63
T_{11}	3.61 (10.91)	12.31 (20.41)	15.34 (22.90)	17.81^{ef} (24.80)	56.44	16.63
T_0	10.06 (18.48)	24.00 (29.27)	33.73 (35.47)	40.89 (39.73)		13.70
S.Em(±)	0.64	0.71	0.65	0.59		0.17
CD (p=0.05)	1.87	2.09	1.91	1.69		0.50

*Average of three replications.

**Figures in parentheses are angular transformed values

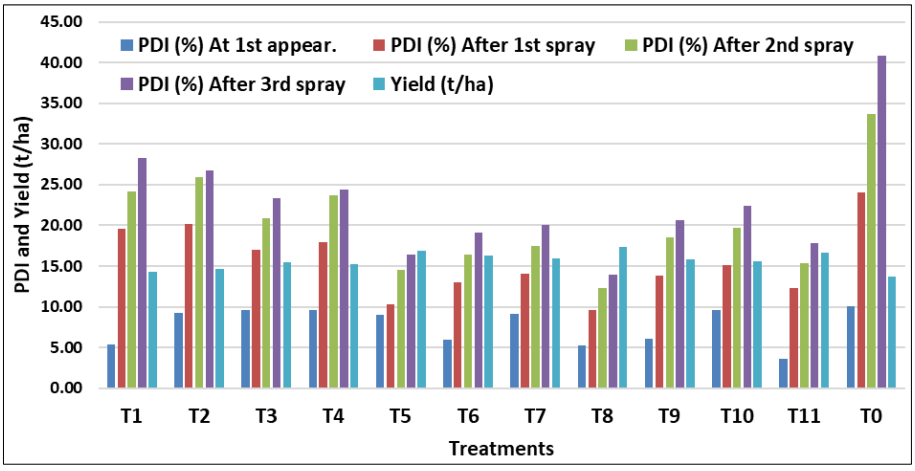

Fig 1: Effect of different treatments on intensity of early blight and yield of tomato

Conclusion

All the evaluated treatments showed significant effect against early blight of tomato under field condition but when *Trichoderma harzianum* @5g/kg seed was used as a seed treatment + one foliar spray of Datura leaf extract @15 percent +two foliar sprays of Indofil M-45 @ 0.25 percent at 15 days intervals started from the appearance of disease symptoms, this combination was the most effective treatment

combination for the management of early blight disease recorded minimum disease intensity(13.94%) and maximum fruit yield (17.31 t/ha) of tomato. The use of plant extract and bio control agent in alternation with the fungicides could be suggested and recommended to be applied especially in order to manage fungicide residues.

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