International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(3): 170-174
www.biochemjournal.com
Received: 21-01-2024
Accepted: 27-02-2024

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Development of integrated management strategies to control the early blight caused by *Alternaria solani* for tomato crops

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DOI: https://doi.org/10.33545/26174693.2024.v8.i3b.717

Abstract

An integrated control will have to be considered with bio-agents, botanicals as well as chemicals for the management of airborne pathogens. Integrated disease management is a good strategy for the control of the early blight disease in tomato. Therefore, keeping in view of above facts present experiments were conduct on “Development of integrated management strategies for the control of Early Blight in tomato”. Results indicate that the most effective treatment was found T5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) which exhibited minimum diseases intensity, AUDPC and maximum number of fruits and fruit yield followed by T_6 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS)). While, treatment T_7 = Propineb @ 3 g /kg (ST) + NSKE @ 5% (FS) + *Pseudomonas florescence* @ 1x 10^9) was observed less effective against early blight. Highest return was obtained from treatment T_5 followed by T_6. However, highest C: B ratio (1:67.24) was obtained in the treatment T_2 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) followed by T_5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) (1:60.36). While, lowest C: B ratio was obtained (1:20.13) in treatment T_1 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS).

Keywords: *Alternaria solani*, biological control, *Bioagents*, botanicals, chemicals, early blight of tomato, integrated management

1. Introduction

Tomato is highly sensitive to biotic and abiotic stresses. Tomatoes are suffered during whole crop period from emergence to harvest with large number of biotic stresses including insect pests and diseases. In majority of the country’s tomatoes are suffered with diseases cited by fungi, bacteria, viruses, nematodes etc. (Mark *et al*., 2006) [12]. More than 200 diseases have been reported time to time to infect tomato in the world (Atherton and Rudich, 1986) [1]. Among the diseases, large number of fungal diseases such as early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), Septoria leaf blight (*Septoria lycopersici*), Powdery mildew (*Oidiopsis taurica*), Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersici*), collar rot (*Sclerotium rolfsii*), and damping off (*Pythium sp*.) are causes severe losses in tomato.

Early blight caused by *Alternaria solani* is one of the most important and frequent occurring disease of the crop throughout World including India (Jones *et al*., 1991) [9]. Causal organism of early blight of tomato has ability to survive for a long time on the infected plant deberies in soil in the absence of main host (Moore and Thomas, 1942 and Basu, 1971) [15, 2]. Rotem (1998) [19] has been reported the *Alternaria solani* can be survive more than ten years in the soil on plant debris and seeds at normal temperatures. *Alternaria solani* also infect other solanaceous cultivated crops such as potato, pepper, egg plant and solanaceous weed host. The early blight is a most severe disease-causing loss in field and post-harvest stages ranging from 50 to 86 percent (Mathur and Shekhawat, 1986) [13]. It has been reported that every one percent increase in disease intensity can reduce yield the 1.36 per cent yield losses. Crop failure to produce yield when the disease occurs in most severe form. Saha and Das (2012) [20] reported losses in yield 0.75 to 0.77 tons ha^{-1} with 1per cent increase in disease severity.

Once early blight is established in the crop, it is very difficult to be controlled (Smith and Kotcon, 2002) [23]. Fungicide treatments are generally the most effective control measures, but are not economically feasible in all areas of the world and may not be effective under weather conditions favourable for disease epidemics. Beside this *Alternaria solani* has low sensitive with fungicides because of its production of dark brown to black pigment called melanin which enhanced survival and competitive abilities of the pathogen under certain environmental conditions (Bell and Wheeler, 1986) [3]. However, in the recent years, huge use of fungicides in agriculture has been the subject of growing concern for both environmentalist and public health authorities. Now days various botanical and bio-control agents available which can reduce populations of foliar pathogens but their effect are very slow. Plant extracts have shown the antimicrobial activity against fungal pathogens under *in vitro* and *in vivo* conditions (Kagale *et al*., 2004) [10]. Bio-control agents are used for the control of soil borne, foliar and post-harvest diseases in various crops in the field, in commercial green house and storage depots (Jegathambigai *et al*., 2010) [8]. Root colonizing bacteria, especially *Pseudomonas* spp., can efficiently control diseases caused by soil borne pathogens (Maurehofer *et al*., 1994) [14]. Any one of the above control measures is alone unable to suppress disease in sustainable crop production. An integrated control will have to be considered with bio-control agents, botanicals as well as chemicals for the management of disease. Thereby, novel approach requires low amount of chemicals to reduce pollution hazards as well as the cost of management. So, the possibilities of controlling plant disease by the integration of several methods have been the subject of extensive research. An integrated control will have to be considered with bio-agents, botanicals as well as chemicals for the management of airborne pathogens. Integrated disease management is a good strategy for the control of the early blight disease in tomato. Therefore, keeping in view of above facts present experiments were conduct on "Development of integrated management strategies for the control of Early Blight in tomato".

2. Materials and Methods

Experiments were conducted at Research Farm, Sant Kabir College of Agriculture and Research Station, Kawardha (Kabirdham), C.G. having clay soil in nature (Vertisols) locally known as Kanhar. The soil was slightly acidic with a pH of 6.5. Field preparation was done with the help of cultivator. Prior to ploughing well decomposed FYM @ 10t ha^{-1} was incorporated uniformly in the soil. Recommended dose of fertilizers *viz.* 150:60:60 NPK were given through urea, single super phosphate and murate of potash, respectively. Nursery beds of 10 x 1 m^2 were prepared in well ploughed and levelled field as per treatment. A well rotten FYM @ 5kg per nursery bed was added to soil and mixed properly. Seed of variety Pusa Ruby were treated with Propineb @ 3 g Kg^{-1} was sown in lines. For control it was sown without treatment. The beds were covered with paddy straw (mulch). The beds were irrigated by hand sprinkler in morning and in the evening. Field Experiments were conducted under Randomized Block Design (RBD) with Eight Treatments viz., T_1 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS), T_2 = Propineb @ 3 g /kg (ST) + (Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05%) (FS), T_3 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS) + *Pseudomonas florescence* @ 1x 10^9 (FS), T_4 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + *Pseudomonas florescence* @ 1x 10^9 (FS), T_5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + NSKE @ 5% (FS), T_6 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS), T_7 = Propineb @ 3 g /kg (ST) + NSKE @ 5% (FS) + *Pseudomonas florescence* @ 1x 10^9, T_8 = Control (water only) and three replications. Seedlings were transplanted in plots of 4.8 x 3.6 M with row to row spacing 60 cm and plant to plant 45 cm. After the transplanting foliar spray (FS) of fungicide/*P. fluorescens*/plant extracts were applied as per treatment details. First spray of respective fungicides was given after 30 days of transplanting in all the treatments except in treatment T_7 where sprayed NSKE @ 5% instead of fungicide. In case of treatment T_3, T_4 and T_7, *Pseudomonas fluorescens* was sprayed as a second spray after 7 days of first spray, whereas in treatments T5 and T_6 NSKE @ 5% was sprayed as a second spray. In control plot plants were sprayed with water as first and second spray. Observation recorded on severity of the disease on the foliage was recorded at 15, 30, 45, 60, 75 and 90 days after first spray using 0-5 disease rating scale (Pandey *et al*., 2003). Percent Disease Index (PDI) and area under disease progress curve (AUDPC) was calculated using following formulas:

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{Total No. of plant examined X Maximum No. of disease rating}} \text{X } 100$$

Area under the disease progress curve (AUDPC) was calculated by using following formula:

$$\text{AUDPC} = \sum_{i-1}^{n} [0.5(x_{i+1} + x_i)[t_{i+1} + t_i]]$$

Whereas,

x_i = Cumulative disease severity expressed as a proportion at the i$^{\text{th}}$ observation t_i

= Time (days after planting) at the i$^{\text{th}}$ observation

n = Total number of observations

Picking of fruits was done at the time of ripening. Total ten picking in management trial were done. Total weight of tomato fruit harvested per plant, per plot from all the pickings was calculated. Finally, the yield tons per hectare was work out. The per cent avoidable number of fruits, fruit yield losses were calculated in all the treatments as follows:

$$\text{Avoidable loss (\%)} = \frac{\text{T} - \text{C}}{\text{T}} X\ 100$$

Whereas,

T = No. of fruits/fruit yields in treatment.

C = No. of fruits/fruit yields in control.

Cost benefit ratio of different treatments were worked out as per the rates of input applied for the disease management and wages prevailing during the course of the study. Present experimental data was analyzed statistically by techniques of analysis of variance applicable RBD. The significance of treatments was tested by F-test value. Critical Value at 5% level of significance was worked out for comparison and statistical interpretation of significant treatment means. The standard error of difference was given in each case for significant treatment effect, critical difference of different treatment combinations per interaction at 5% level of probability was calculated, wherever F-test was significant.

3. Results and Discussion

3.1 Severity of early blight disease

Integrated effect of fungicides, *P. fluorescens* and NSKE was studied against early blight disease severity on Pusa Ruby variety of tomato and results are presented in table 1. The data on PDI of early blight was recorded periodically intervals of 15 days after spray. After 15 days of spray minimum disease intensity (2.0%) was recorded in treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) which was at par with T$_3$, T$_4$ and T$_6$ and significantly lower over T$_1$, T$_2$, T$_7$ and T$_8$ = Control. Whereas, 30 days after spray minimum disease intensity (4.00%) was recorded in T $_5$ which was at par with T$_4$ and T$_6$ and significantly lower over rest of the treatments. After 45 days of spray, minimum disease intensity (8%) was noticed in treatment T$_{5.}$ It was at par with treatment T $_6$ which exhibited 10.67 percent disease intensity. Same trend was found 60 days after spray. Whereas, 75 days after spray treatment T$_5$ was found significantly superior over rest of the treatments which exhibited minimum disease intensity of 33.33 percent. In case of 90 days of spray, minimum disease intensity (43.33%) was recorded in treatment T$_5$ which was at par with T$_6$ and significantly lowers over rest of treatments. While, maximum disease intensity of 83.33 percent was recorded in control plot.

On the other hand, maximum reduction in disease intensity of 81.26, 76.00, 79.31, 73.08, 54.55 and 48.00 was recorded after 15, 30, 45, 60, 75 and 90 days of spray, respectively in treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) followed by T$_6$ = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) and T$_4$ = Pr opineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + *Pseudomonas fluorescens* @ 1x 109 (FS) (Fig. 1).

3.2 AUDPC of early blight disease

Data pertaining to AUDPC in different treatments have been illustrated in figure 2 indicated that the minimum AUDPC (1275) was recorded with the application of treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) followed by T$_6$ = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) (1680), T$_4$ = Pr opineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + *Pseudomonas fluorescens* @ 1x 109 (FS) (1905), T$_3$ = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS) + *Pseudomonas fluorescens* @ 1x 109 (FS) (2140), T$_2$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + Tebuconazole 50% WG @ 0. 05% (FS) (2535), T$_1$ = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS) (2780) and T$_7$ = Propineb @ 3 g /kg (ST) + NSKE @ 5% (FS) + *Pseudomonas fluorescens* @ 1x 10_9, whereas maximum AUDPC (3655) was recorded in control plot.

The result of present findings is partially to agreement with the results obtained by Ganie *et al*. (2013) they reported that the seed treatment with mancozeb 75WP (0.3%) + foliar spray with hexaconazole 5 EC (0.1%) + foliar spray with Dhatura (5.0%) + foliar spray with *Trichoderma harzianum* (1×10^7 spore/ml) was highly effective in controlling the disease severity of early blight of tomato. Similar type result also was obtained by Horsfield *et al*. (2010) [7] and Kavyashree *et al*. (2016) [11]. Sallam (2011) [21] studied the effect of six plant extracts and some fungicides against *Alternaria solani in vivo*. The greatest reduction of disease severity was achieved by Redomil Plus 74.2% followed by *A. sativum* @ 5% and the smallest reduction was obtained when tomato plant was treated with *O. basilicum* @ 1 and 5% (46.1 and 45.2%, respectively). Fungicide, *D. stramonium* and *A. sativum* at 5% increase in fruit yield 85.7, 76.2 and 66.7% compared to infected control. Soni *et al*. (2015) [24] evaluated bionanoformulation (Cu-chitosan) in integration with fungicide and botanicals to develop effective management strategies against early blight of tomato caused by *Alternaria solani*. Under pot study the integration of three component; Cu- chitosan 0.1% as seed treatment with spray of Mancozeb 0.25% and neem oil 2% was found best that gave maximum efficacy of disease control (43.01 and 50.81%) with minimum PDI mean (27.50 and 30.38%), respectively, at first and second spray of the treatment as compare to inoculated control. Rani *et al*. (2017) [18] developed integrated disease management module for early blight of tomato fungicides, plant extracts and bio agents were integrated in different treatments and applied in field with varying spray schedules consecutively for two seasons. It was observed that treatment comprising of Mancozeb (0.25%), Datura (50%) and *T. harzianum* S.T (1x107 spores ml^{-1}) reduced disease intensity up to 84.00% followed by treatment comprising of Mancozeb (0.25%) and *T. harzianum* S.T (1x107 spores ml^{-1}) which reduced disease intensity to 82.33%.

3.3 Number of fruits

Highest number of fruits (45.93 plant^{-1}) was recorded in the treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + NSKE @ 5% (FS)) which was at par with T$_6$ = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) (41.53 plant^{-1}) and T4 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + *Pseudomonas fluorescens* @ 1x 10^9 (FS) (40.00 plant^{-1}) and significantly higher over rest of treatments. In control plot it was recorded lowest (22.27 plant^{-1}) (Table 4.25). In case of avoidable losses in number of fruit, highest losses in number of fruit can be avoided (51.51%) with the application of treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS)) followed by T$_6$ (46.38%), T$_4$ (44.33%), T$_3$ (38.48%), T$_2$ (33.06%), T$_1$ (26.26%) and T$_7$ (11.63%) (Table 2).

3.4 Fruit yield

Data pertaining to fruit yield plant^{-1} have been presented in table 4.25 reveal that maximum fruit yield (1.301 Kg plant^{-1}) was recorded in treatment T$_5$ = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05%

(FS) + NSKE @ 5% (FS) followed by T_6 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) (1.198 Kg plant^{-1}) and T_4 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + *Pseudomonas fluorescens* @ 1x 10^9 (FS) (1.147 Kg plant^{-1}). While, least fruit yield per plant was recorded in control plot (0.716 Kg plant^{-1}). On the other hand, maximum losses in fruit yield per plant can be avoided (44.97%) with the application of treatment T_5 followed by T_6 (40.23%) and T_4 (37.58%) (Table 2).

Maximum fruit yield per plot (84.574 Kg) was recorded in treatment T_5 = Propineb @ 3 g/kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + NSKE @ 5% (FS) which was at par with T_6 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) (75.934 Kg) and significantly higher over rest all the treatments. While, least Fruit yield per plot was recorded in control plot (49.171 Kg) (Table 2).

Total fruit yield was significant higher in all the treatments over control. However, maximum fruit yield (487.5 qha^{-1}) was obtained in Treatment T_5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0.05% (FS) + NSKE @ 5% (FS). It was significantly higher over rest of the treatments. While, least fruit yield (283.85 qha^{-1}) was recorded in control plot (Table 4.25).

Data of avoidable yield losses have been illustrated in figure 3 indicated that the maximum avoidable yield losses (41.77%) was recorded in treatment T5 followed by T_6 (35.38%), T_4 (31.65%), T_3 (29.61%), T_2 (24.10%), T_1 (19.72%) and T_7 (18.45%). Sallam (2011) [21] reported greatest reduction of disease severity by Redomil Plus 74.2% followed by *A. sativum* @ 5% and the smallest reduction was obtained when tomato plant was treated with *O. basilicum* @ 1 and 5% (46.1 and 45.2%, respectively). Fungicide, *D. stramonium* and *A. sativum* at 5% were increased in fruit yield 85.7, 76.2 and 66.7% compared to infected control. Tewari and Vishunavat (2012) [25] evaluated fungicides along and with cultural practices to develop an effective management strategy for early blight of tomato. Cultural practices (inter cropping with marigold, mulching and stacking) when integrated with fungicides reduced the percent disease index and increased the yield.

3.5 Economics of different management practices

Economics of different treatments for the control of early blight of tomato have been presented in Table 3 indicated that the cost of treatment per hectare was Rs. 3468, 1340, 4596, 2468, 3375, 5503 and 3163 of treatment T_1, T_2, T_3, T_4, T_5, T_6 and T_7, respectively. Although higher return (Rs. 203700 ha^{-1}) was recorded in treatment T_5 followed by T_6 (Rs. 155400 ha^{-1}), T_4 (Rs. 131400 ha^{-1}) T_3 (Rs. 119400 ha^{-1}), T_2 (Rs. 90100 ha^{-1}), T_1 (Rs. 69800 ha^{-1}) and T_7 (Rs. 64200 ha^{-1}). However, highest cost benefit ratio (C: B) was obtained (1:67.24) in the treatment T_2 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) followed by T_5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS) (1:60.36), T_4 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) +*Pseudomonas fluorescens* @ 1x 10^9 (FS) (1:53.24) and T_6 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% + NSKE @ 5% (FS) (1:28.24). While, least cost benefit ratio (C: B) was obtained (1:20.13) in treatment T_1 = Propineb @ 3 g /kg (ST) + Azoxystrobin 23% SC @ 0.1% (FS). Ganeshan and Chethana (2009) also previously documented that pyraclostrobin gave higher cost benefit ratio in comparison to other treatments. However, Prasad and Naik (2003) reported that mancozeb gave the highest cost-benefit ratio (1:11.4) in addition to reducing the disease incidence. This clearly indicated that foliar spray of Pristine (1.0 g/litre) was most effective for disease management and it was also a cost-effective treatment and gave higher benefits thus can be recommended for the management early blight of tomato followed by Maccani (3.0 g/litre), and Boscalid (1.0 g/litre). Hence, spraying of Pristine (1.0 g/litre) could be considered as an effective management practice to manage early blight of tomato. Desta and Yesuf (2015) revealed that every week and every two-week spray interval of the fungicide ridomil gold had the highest total variable costs. Sharma *et al*. (2018) reveal that the highest cost benefit ratio was obtained with treatment carbendazim 12% + mancozeb 63% WP (1:3.56) followed by propiconazole 25 EC (1:3.24) and difenconazole 25 EC (1:2.95), however, propineb 70 WP (1:2.60), mancozeb 75 WP (1:2.59), copper-oxy-chlorode 50% WP (1:2.16) and neem leaf extract 20% (1:2.06) were promising in obtaining higher returns over control.

4. Conclusion

Under development of integrated management strategies for the control of Early Blight in tomato, most effective treatment was found T5 = Propineb @ 3 g /kg (ST) + Trifloxystrobin 25% + tebuconazole 50% WG @ 0. 05% (FS) + NSKE @ 5% (FS).

5. Acknowledgement

Authors extend sincere gratitude to Director of Research, Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh - 492012, India financial support.

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