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Management of bacterial wilt of brinjal incited by *Ralstonia solanacearum*

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Abstract
Bacterial wilt of brinjal caused by *Ralstonia solanacearum* is responsible for severe yield losses (10-90%) in farmer's field. A field experiment was conducted for the evaluation of different bio-agents, chemicals and plant extracts against bacterial wilt of brinjal at botany farm, DBSKKV, Dapoli during the *Rabi*, 2016-17 and 2017-18. The study revealed that all the treatments were significantly effective in controlling the disease. Seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting was the most effective against the disease as it was recorded 50.63 percent disease reduction as compared to untreated and was followed by spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation which recorded 48.10 percent disease reduction. Seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting recorded 45.57 percent disease reduction as compared to untreated and it was at par with *P. fluorescens* treatment.

Keywords: Bacterial wilt, *Pseudomonas*, streptocycline, bleaching powder

Introduction
The Brinjal, Aubergine or Eggplant (*Solanum melongena* L.), of the family solanaceae, is grown in the subtropical and tropical regions of the world. It is one of the most common, highly productive and popular vegetable crops grown in India. It is quite popular as the poor man's crop. The unripe fruit of eggplant is primarily used as a cooking vegetable for the various dishes in India and China. The brinjal is also reported to possess medicinal properties. Various plant parts are used for curing ailments such as diabetes, cholera, bronchitis, dysuria, dysentery, otitis, toothache, skin infections, asthenia and haemorrhoids. The major constraint, however, in the production of brinjal is the bacterial wilt disease.

India is the second largest country in the world producing brinjal followed by China. In India, the total area under brinjal was 669 thousand hectares with production of 12,400 thousand MT and with productivity of 18.9 MT/ha during 2016-17. In Maharashtra, area under brinjal was 22.14 thousand hectares with annual production of about 433.28 thousand MT and with a productivity of 19.57 MT/ha. during 2016-17 (Anonymous, 2017) [2]. In Maharashtra, Pune is the leading brinjal growing district with 3.59 thousand hectares area and production of 71.80 thousand MT. Total area under brinjal in Konkan region of Maharashtra was 1.21 thousand ha. with production of 20.02 thousand MT and productivity of 16.54 MT/ha. during the year 2016-17 (Anonymous, 2018) [3].

The bacterial wilt disease caused by *Ralstonia solanacearum* is primarily a soil borne disease of wide distribution in the tropics, subtropics and warm temperate regions of the world. Bacterial wilt is said to be causing 10 to 90% crop losses around the world (Rao, 1976) [12]. In India, the disease is highly devastating and causes losses up to 80-90% (Kishun, 1985 and Kataky *et al.*, 2017) [8]. Sick soil and surface water, including irrigation water, are the primary sources of inoculum. The pathogen infects roots of susceptible plants usually through wounds (Pradhanang *et al.*, 2005) [11]. Bacterial colonization in xylem tissues of infected plants hinders upward movement of water. Initially there is drooping of leaves which subsequently results in wilting of whole plants within 2-3 days and finally death of the whole plant.

Ralstonia solanacearum is a soil borne, rod shaped, Gram negative bacterium that causes bacterial wilt disease in more than 200 plant species including many economically important crops (Aliye *et al.* 2008) [1]. Due to its wide geographic distribution and unusually broad host range (over 50 plant families) the pathogen is responsible for severe crops losses worldwide.

The disease is difficult to control. Although various control measures have been documented, bacterial wilt is still a major threat to brinjal production, because of wide host range of the pathogen and better survival of the pathogen in soil, especially in deeper layers. Thus, it is essential to acquire more knowledge for the effective control of this disease. The present investigation was designed to determine the appropriate control management of bacterial wilt by using different spot application treatment in soil as well as seedling dip root treatment with bio-control agents, chemicals, antibiotics and plant extracts under field conditions.

Material and Methods

The present investigation was carried out during *Rabi* 2016-17 and 2017-18 in wilt sick plot at Botany Farm, College of Agriculture, Dapoli, Dist. Ratnagiri. Wilt susceptible variety 'Kali Rawai' of brinjal was used in this experiment. The experimental was set up by transplanting 30 days old seedlings in bacterial wilt sick plot using Randomized Block Design (RBD) of three replicates to compare 11 treatments (including control). Transplanting was made in 2.40 x 3 m plots with 60 x 60 cm spacing. All the recommended package of practices was followed during whole cropping season. The number of plants wilted per plot was recorded starting from 60 days after transplanting and then at 15 days intervals. Bacterial ooze test was performed for the wilted plants to confirm the disease. Details of the treatments are as follows;

Treatment details

Treat. No.	Treatment Details
T_1	Seedling root dip in 0.1% Asafoetida powder solution for 2 hrs. before transplanting.
T_2	Seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%.
T_3	Spot drenching of *P. fluorescens* suspension 0.3% at the time of field preparation.
T_4	Seedling root dip in 10% soapnut extract for 2 hrs. before transplanting.
T_5	Spot application of fish manure 100 g per plant at the time of transplanting.
T_6	Spot application of lime 50 g per hill at the time of transplanting.
T_7	Seedling root dip in *Azotobacter chroococcum* (0.1%) for 2 hrs. before transplanting and spot application 0.1% at the time of field preparation.
T_8	Seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting.
T_9	Seedling root dip in chloramphenicol @ 0.1% for 2 hrs. before transplanting.
T_{10}	Seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs. before transplanting
T_{11}	Control

Method of recording observations

Observations regarding wilt disease were recorded at fortnight interval 60 days after transplanting up to the 105 DAT, by counting the number of plants affected by the disease. Percent disease incidence was calculated using the following formula.

$$\text{Percent disease incidence (PDI)} = \frac{\text{Total number of plants infected in the plot}}{\text{Total number of plants in the plot}} \times 100$$

Percent disease control was computed by formula (PDC): X

$$\text{Percent disease control as compared to control (PDC)} \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \times 100$$

Results and Discussion

Percent disease intensity

During *Rabi* 2016-17, results (Table 1) revealed that the terminal percent disease intensity was ranged between 33.33 to 68.33 percent. The lowest percent disease intensity was recorded in the treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting) 33.33% and was statistically at par with treatments T_3 (spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation) which recorded PDI to the tune of 35.00%, Further, the treatment T_3 was statistically at par with T_2 (seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%) with 36.67% PDI. Rest of the treatments were also statistically significant over control.

Percent disease control compared to untreated

During *Rabi*, 2016-17 (Table 1) reduction in wilt disease intensity due to different treatments was ranged between 12.20 to 51.22 percent. The highest percentage disease control over control by 51.22% was observed in treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs before transplanting) and 48.78% in treatment T_3 (spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation) was followed by T_2 (48.78%), T_9 (39.02%) and T_4 (31.71%). Moderate reduction in disease over control was recorded in T_6 (24.39%), T_5 (19.51%) and T_1 (12.20%). Least PDC was recorded in T_7 (seedling root dip in *Azotobacter chroococcum* for 2 hrs. before transplanting and application during field preparation @ 0.1%) and T_{10} (seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs. before transplanting) with 7.32 and 4.88 percent disease control over control, respectively.

Percent disease intensity

In the *Rabi* season of 2017-18 (Table 1) the overall percent disease intensity in wilt sick plot ranged between 31.67 to 63.33 percent. The maximum disease intensity was 5 percent lower than the previous year. The treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting) recorded 31.67 percent disease intensity and was numerically superior to rest of the treatments but statistically at par with T_3 (spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation) with 33.33 percent. The treatment T_3 was at par with T_2 (seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%) 35.00 percent. The treatment T_7 (seedling root dip in

Azotobacter chroococcum for 2 hrs before transplanting and spot application 0.1% at the time of field preparation) was at par with T_{10} (seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs. before transplanting).

Percent disease control compared to untreated

During *Rabi*, 2017-18 (Table 1) reduction in wilt disease intensity due to various different treatments was ranged between 7.89 to 50.00 percent. The highest percentage of disease control over control by 50.00% was observed in treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting) and was followed by T_3 (47.37%), T_2 (44.74%). Medium reduction in disease over control was recorded in T_9 (36.84%), T_4 (28.95%), T_6 (23.68%). These were followed by T_5 (18.42%) and T_1 (13.16%). Least PDC was recorded in T_7 and T_{10} with (7.89%) and (5.26%) percent disease control over control, respectively.

Percent disease intensity (Pooled)

The pooled analysis (Table 1) on percent disease intensity revealed that all the bio-agents, chemicals and plant extracts evaluated were found significantly effective against bacterial wilt of brinjal under wilt sick conditions in the field. Among all the treatments, antibiotic (streptocycline) were found most effective against the disease and were followed by bio-agents (*P. fluorescens*). Least percent disease intensity was observed in treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting) which showed 32.50 percent disease intensity as compared to control (65.83%). This was followed by T_3 (spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation) and T_2 (seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%) with 34.17 and 35.83 percent disease intensity, respectively and which were at par with each other. Treatment T_9 (seedling root dip in chloramphenicol @ 0.1% for 2 hrs before transplanting), T_4 (seedling root dip in 10% soapnut extract for 2 hrs before transplanting), T_6 (spot application of lime 50g per hill at the time of transplanting) and T_5 (spot application of fish manure 100 g per plant at the time of transplanting) recorded 40.83, 45.83, 50.00 and 53.33 percent disease intensity as against control. In the treatment T_1 (seedling root dip in 0.1% asafoetida powder solution for 2 hrs before transplanting) and T_7 (seedling root dip in *Azotobacter chroococcum* for 2 hrs. before transplanting and spot application 0.1% at the time of field preparation) recorded 57.50 and 60.83 percent disease intensity. Least percent disease intensity was observed in treatment T_{10} (seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs before transplanting) 62.50% as compared to control (65.83%).

Percent disease control compared to untreated (Pooled)

Data (Table 1) also revealed that all the bio-agents, chemicals and plant extracts were effective in the bacterial wilt disease under field conditions. All the treatments were found significantly superior as compared to control. Highest percent disease control compared to control by 50.63% was recorded in treatment T_8 (seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting). It was followed by T_3 (spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation) and T_2 (seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%) with 48.10% and 45.57% disease control compared to untreated, respectively. Treatment T_9 (seedling root dip in chloramphenicol @ 0.1% for 2 hrs. before transplanting), T_4 (seedling root dip in 10% soapnut extract for 2 hrs. before transplanting), T_6 (spot application of lime 50g per hill at the time of transplanting) and T_5 (spot application of fish manure 100 g per plant at the time of transplanting) which recorded 37.96, 30.38, 24.05 and 18.99 percent disease reduction. In the treatment T_1 (seedling root dip in 0.1% asafoetida powder solution for 2 hrs. before transplanting) and T_7 (seedling root dip in *Azotobacter chroococcum* for 2 hrs. before transplanting and spot application 0.1% at the time of field preparation) recorded 12.66 and 7.59 percent disease reduction. Least percent disease reduction was observed in treatment T_{10} (seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs. before transplanting) 5.06%.

The findings are in close agreement with those of Dhital *et al.* (1997) [7], according to them stable bleaching powder @ 25kg/ha was effective against *R. solanacearum* of potato. Biswas and Singh (2007) [5] reported that soil disinfection with lime one month before transplantation and the use of *P. fluorescens* as bio-control agent were effective to minimize the bacterial wilt incidence in field. Baura and Bora (2008) found that highest reduction of bacterial population in soil was recorded in *P. fluorescens* when applied @ 15 g/kg soil. Similarly, Chakravarty and Kalita (2012) [6] reported that *P. fluorescens* had potential to be used as a biocontrol agent for the management of bacterial wilt of brinjal by application of antagonist suspension to seed+root+soil method and root+soil method. Ghosh *et al.* (2015) [10] reported that application of bleaching powder (20 kg/ha.) followed by lime (500 kg/ha.), one month before transplanting, were most effective.

Conclusion

All the bio-agents, chemicals and plant extracts evaluated were found significantly effective against bacterial wilt of brinjal under wilt sick conditions in the field. Among all the treatments, seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting was the most effective against the disease as it recorded 50.63 percent disease reduction compared to untreated. It was followed by spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation which recorded 48.10 percent disease control. Seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting recorded 45.57 percent control and it was at par with *P. fluorescens* treatment.

Table 1: Management of bacterial wilt of brinjal with use of bio-agents, chemicals and plant extracts

Tr. No.	Treatments	*Rabi*, 2016-17		*Rabi*, 2017-18		Pooled	
		Percent Disease Intensity (PDI)*	Percent disease control compared to untreated	Percent Disease Intensity (PDI)*	Percent disease control compared to untreated	Percent Disease Intensity (PDI)*	Percent disease control compared to untreated
T_1	Seedling root dip in 0.1% asafoetida powder solution for 2 hrs. before transplanting.	60.00 (50.79) **	12.20	55.00 (47.88)	13.16	57.50 (49.33)	12.66
T_2	Seedling root dip in bleaching powder solution (0.1%) for 2 hrs. before transplanting and spot application at the time of field preparation @ 0.3%.	36.67 (37.26)	46.34	35.00 (36.27)	44.74	35.83 (36.76)	45.57
T_3	Spot drenching of *Pseudomonas fluorescens* suspension 0.3% at the time of field preparation.	35.00 (36.27)	48.78	33.33 (35.25)	47.37	34.17 (35.76)	48.10
T_4	Seedling root dip in 10% soapnut extract for 2 hrs. before transplanting.	46.67 (43.09)	31.71	45.00 (42.13)	28.95	45.83 (42.61)	30.38
T_5	Spot application of fish manure 100 g per plant at the time of transplanting.	55.00 (47.87)	19.51	51.67 (45.96)	18.42	53.33 (46.91)	18.99
T_6	Spot application of lime 50g per hill at the time of transplanting.	51.67 (45.96)	24.39	48.33 (44.04)	23.68	50.00 (45.00)	24.05
T_7	Seedling root dip in *Azotobacter chroococcum* (0.1%) for 2 hrs. before transplanting and spot application 0.1% at the time of field preparation.	63.33 (52.74)	7.32	58.33 (49.80)	7.89	60.83 (51.27)	7.59
T_8	Seedling root dip in streptocycline @ 0.1% for 2 hrs. before transplanting.	33.33 (35.25)	51.22	31.67 (34.23)	50.00	32.50 (34.74)	50.63
T_9	Seedling root dip in chloramphenicol @ 0.1% for 2 hrs. before transplanting.	41.67 (40.20)	39.02	40.00 (39.21)	36.84	40.83 (39.70)	37.96
T_{10}	Seedling root dip in *Justicia adhatoda* leaf extract @ 10% for 2 hrs. before transplanting.	65.00 (53.76)	4.88	60.00 (50.77)	5.26	62.50 (52.27)	5.06
T_{11}	Control	68.33 (55.77)	-	63.33 (52.74)	-	65.83 (54.26)	-
	S. Em±	0.97		1.02		0.81	
	C. D at 5%	2.86		3.00		2.38	

*Mean of three replications ** Values in parentheses are arc-sin transformed values

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