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Integrated management of bacterial wilt of brinjal incited by *Ralstonia solanacearum*

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Abstract
An experiment was conducted to find out the effective treatments for integrated management of bacterial wilt incited by *Ralstonia solanacearum* infecting brinjal CV. Mattigulla during *Kharif*-2016. Among the treatments combination of Neem cake+*P. fluorescens*+ *T. harzianum*+streptocycline+copper-oxychloride (T_{11}) showed less per cent wilt incidence at 60 DAT (25.70%) and 90 DAT (26.26%). Further per cent disease reduction over control was significantly highest was observed (29.24%) and yield obtained in treated plot was highest and significant yield of 19.27 kg/plot was recorded.The average plant height and number of flowers was recorded more in *P. fluorescens* treatment (58.5 cm and 8.4) was recorded.

Keywords: *R. solanacearum*, Mattigulla, Management

Introduction
The brinjal (*Solanum melongena* L.) belongs to the family solanaceae, is a common and popular warm weather vegetable crop. It is being grown extensively in India and is a major source of income for the small and marginal farmers as well. In Karnataka brinjal is grown in an area of 15.8 thousand ha with production of 402.5 metric tons with the productivity of about 25.4 MT/ha (Anon., 2016) [1]. Mattigulla is an important brinjal variety which has got geographical indication tag and it is severely infected by bacterial wilt incited by *R. solanacearum* (Yabuchi, 1995) [7] causes yield loss up to 60 per cent and it taken as a susceptible variety for integrated disease management. The destructiveness of the pathogen is attributed to its wide spread occurrence, the existence of different strains, its exceptional ability to survive in soil and its broad host range. The characteristic symptoms include wilting of the foliage, followed by collapse of the entire plant. The bacterium can survive in soil or infected plant debris for prolonged periods (Grey *et al*., 2001) [3]. The disease is more severe during heavy monsoon when the fields become very frequently water-logged (Das and Chattopadhyay, 1955) [2]. Not much effort has been directed towards the production of plant bactericides and as a result, very few effective ones are available today for managing plant bacterial diseases. At present single control measure for soil borne pathogens is not effective so need to adopt integrated disease management for effective control. Considering all these factors, the integrated disease management of *R. Solanacearum* would be ideal and which is very effective, economical, eco-friendly and highly specific in the context of the bacterial diseases such as bacterial wilt.

Materials and methods
Integrated disease management experiment was conducted in Agricultural and Horticultural Research Station, Bavikere with a susceptible var. Mattigulla during *Kharif*-2016. Bacterial culture was multiplied in the nutrient broth for artificial inoculation ($1x10^8$cfu/ml) of pathogen and it was carried out by soil application after transplanting of seedlings into the main field.
A set of one botanical (Neem cake), two bio agents (*Trichoderma harzianum* and *Pseudomonas fluorescens*) and one chemical (Streptocycline+ copper-oxy chloride) in single as well as in combination of three were used in integrated disease management of bacterial wilt of brinjal in an experimental plot at AHRS, Bhavikere. The field trial was laid out in Randomized Complete Block Design (RCBD) with twelve treatments inclusive of control replicated thrice. The plots measuring 3m x 3m were marked and randomly selected five plants in each plot were selected and labelled. The required quantities of the chemicals were weighed and suitably dissolved in a requisite quantity of water to get desired concentrations. Treatments were imposed at the 20 days after transplanting; initially soil application of neem cake was to be taken at the rate of 20 g/plant.

Whereas, bioagents were applied as seedling dip as well as soil drenching method was followed. Soil application of chemical was carried out at the fruiting stage and regular observations were taken at 60 days after transplanting and 90 days after transplanting.Observations for Wilt symptoms and the number of wilted plants for each treatment were drawn to calculate the per cent disease incidence on randomly selected five plants before and after soil application was recorded and graded on a 0-5 scale as per Winstead and Kelman (1952) [6] and Zakir Hussain *et al.* (2005) [8] with some modifications. The modified rating scale is given below:

Rating	Disease reaction	Per cent infection
0	Highly resistant (HR)	No wilt symptom
1	Resistant (R)	1 - 10% plants wilted
2	Moderately resistant (MR)	11 -20% plants wilted
3	Moderately susceptible (MS)	21-30%) plants wilted
4	Susceptible (S)	31-40% plants wilted
5	Highly susceptible (HS)	> 40%) plants wilted

Per cent disease incidence assessment

Disease incidence (DI) was calculated with the following formula (Guo *et al*., 2004):

$$PDI = \frac{\text{Number of wilted plants per plot}}{\text{Total number of plants per plot}} \times 100$$

Results and discussion

A field experiment was conducted during *Kharif*-2016 on integrated management of bacterial wilt of brinjal with special reference to *R. solanacearum* with eleven treated and one untreated control. The soil was artificially inoculated with pathogen culture ($1x10^8$ cfu/ml) after transplanting of seedlings and treatments were per cent disease reduction over control and yield (kg/plot) worked out and obtained results are presented in Table 1.

At sixty days after transplanting among the twelve treatments T_{11} (Neem cake+ *P. fluorescens* + *T. harzianum* + streptocycline+copper-oxy chloride) showed less per cent wilt incidence (25.70) followed by T_3 (*P. fluorescens*) with per cent wilt incidence of 26.67 and next best treatments were T_2 (*T. harzianum*) T_6 (Neem cake+ *P. fluorescens*) and T_{10} (*P. fluorescens*+ Streptocycline+ copper oxychloride) which were showed per cent disease incidence of 29.00, 29.11, 29.33 respectively, which were remain on par with each other. Among treated ones T_4 (Streptocycline+ copper oxychloride) showed highest disease incidence of 35.17 because spraying was carried out during 60 days after transplanting whereas highest per cent wilt incidence was observed in control.

Observations on per cent wilt incidence at ninety days after transplanting was recorded among the 12 treatments T_{11} showed less incidence (26.26%) and it reduces the spread of the disease followed by T_{10} (30.72%) and next best treatment was T_3 (*P. fluorescens*) showed 32.77 per cent against control which showed 55.5 per cent wilt incidence.

Further per cent disease reduction over control was calculated, significantly highest reduction was observed in T_{11} (29.24%) followed by T_{10} (24.78%) and next best treatments were T_9 (22.16%) and T_3 (22.73%) which were remain on par with each other. Whereas T_4 (Streptocycline+ copper oxychloride) showed less disease reduction over control (19.40%).

Yield obtained in treated plot indicated that, highest and significant yield of 19.27 kg/plot was recorded in T_{11} followed by T_3 and T_4 with yield of 18.80 kg/plot and 18.40 kg/plot respectively, which were remain on par with each other. Whereas, control plot recorded the less yield which is about 4.70 kg/plot.

Effect on growth parameters

The effect of all the treatments imposed for management of *R. solanacearum* and their influence on plant growth parameters *viz.*, plant height, number of branches and number of flowers in brinjal var. mattigulla was recorded and results are presented in Table 2.

The average plant height and number of flowers was recorded more in *P. fluorescens* treatment (58.5 cm and 8.4) followed by neem cake+ *T. harzianum* treatment (56.5cm and 8.5)and neem cake+ *T. harzianum*+ *P. fluorescens*+ Streptocycline+ copper oxychloride (56.8cm and 7.8)which are remain on par with each other. Whereas number of branches were observed more in NC+ *T. harzianum*+ *P. fluorescens*+ Streptocycline+ copper oxychloride (7.2) followed by *T. harzianum* + *P. fluorescens* (6.4). Among 12 treatments neem cake+ *T. harzianum*+ *P. fluorescens*+ Streptocycline+ copper oxychloride was found effective in all three parameters observed as well as yield (kg/plot). Thus, from the perusal of the results obtained on integrated management of *R. solanacearum* infecting brinjal, revealed that all the treatments imposed were found effective in improving growth as well as managing the disease.

Table 1: Integrated management of bacterial wilt of brinjal caused by *R. solanacearum* during *Kharif*, 2016-17.

Treatments	Rate of application	Per cent wilt incidence (%)		Per cent disease reduction over control	Yield (kg/plot)	Yield (q/ha)
		60 DAT	90 DAT			
T_1- Neem cake	20g/plant	30.00 (33.23)*	34.37 (35.90)	21.13	15.00	138.89
T_2- *Trichoderma harzianum*	10g/l	29.00 (32.75)	35.52 (36.60)	19.98	14.50	134.26
T_3-*Puedomonas fluorescens*	10g/l	26.67 (32.74)	32.77 (34.93)	22.73	18.80	174.07
T_4- Streptocycline+ copper oxychloride	0.3g/l+3g/l	35.17 (36.39)	36.10 (37.75)	19.40	18.40	170.37
T_5- Neem cake+ *T. harzianum*	20g/plant+10g/l	33.56 (35.42)	35.22 (36.42)	20.28	11.83	109.57
T_6- Neem cake + *P. fluorescens*	20g/plant+10g/l	29.11 (32.67)	34.60 (36.05)	20.90	12.03	111.42
T_7-Neem cake + Streptocycline + copper oxychloride	20g/plant+0.3g/l+3g/l	34.60 (36.04)	35.53 (36.61)	19.97	10.97	101.54
T_8- *T. harzianum* + *P. fluorescens*	10g/l+10g/l	30.63 (33.61)	34.72 (36.12)	20.78	13.20	122.22
T_9- *T. harzianum*+ Streptocycline + copper oxychloride	10g/l+0.3g/l+ 3g/l	30.37 (33.45)	33.34 (35.29)	22.16	11.80	109.26
T_{10}- *P. fluorescens*+ Streptocycline + copper	10g/l+0.3g/l+ 3g/l	29.33 (32.81)	30.72 (33.68)	24.78	15.00	138.89

oxychloride						
T_{11}- Neem cake + *T. harzianum*+*P. fluorescens*+ Streptocycline + copper oxychloride	20g/plant+10g/l+0.3g/l+ 3g/l	25.70 (30.47)	26.26 (30.84)	29.24	19.27	178.39
T_{12}- Control		36.83 (37.38)	55.50 (48.19)	0.00	4.70	43.51
SEm ±		0.42	0.86		1.50	
CD (5%)		1.25	2.05		0.51	

* Figures within parentheses indicate angular transformed values, DAT: days after transplanting

Table 2: Effect of various treatments on plant growth parameters.

Treatments	Plant height (cm)*	Number of branches	Number of flowers
T_1- Neem cake	47.2	4.2	4.2
T_2- *Trichoderma harzianum*	41.8	4.8	5.8
T_3-*Puedomonas fluorescens*	58.5	5.8	8.4
T_4- Streptocycline+ COC	55.0	5.6	6.4
T_5- NC+ *T. harzianum*	56.5	6.2	8.0
T_6- NC+ *P. fluorescens*	53.2	5.8	6.0
T_7-NC+ Streptocycline+COC	55.6	6.0	6.2
T_8- *T. harzianum* + *P. fluorescens*	55.0	6.4	7.0
T_9- *T. harzianum*+ Streptocycline+ COC	53.2	5.4	6.0
T_{10}- *P. fluorescens*+ Streptocycline+ COC	50.8	4.4	5.4
T_{11}- NC+ *T. harzianum*+ *P. fluorescens*+ Streptocycline + COC	56.8	7.2	7.8
T_{12}- Control	38.6	4.0	5.0
SEm±	0.59	0.47	0.59
CD (5%)	1.72	1.37	1.74

*-Mean of three replications. NC-neem cake, COC-Copper oxychloride.

Among the twelve treatments T_{11} (Neem cake + *P. fluorescence*+*T. harzianum* + streptocycline + copper oxychloride) was found to be more effective compare to other treatments with respect to less incidence of disease. Because neem cake, *P. fluorescens* and *T. harzianum* applied at the time of transplanting and they acts as protects against *R. solanacearum* though it is a soil borne pathogen. Bioagents exhibits competition, antibiosis and induce systemic resistance as well as significantly improved plant growthby producing the growth hormones and other growth promoting substances, *viz*., auxins, indole-3-acetic acid, and gibberellins (Ramamoorthy & Samiyappan, 2001) [4]. Chemical *i.e* Streptocycline + copper oxychloride was drenched at 60 days after transplanting results in reduce the further spread of disease the finding was also supported by Singh *et al*. (2012) [5].

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