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Short Communications

Integrated management of bacterial wilt of tomato caused by *Ralstonia solanacearum*

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Ralstonia solanacearum is a causal agent of bacterial wilt of solanaceous crop plants. It infects plants at any stage but flowering stage is most vulnerable. Disease incidences of 15 to 95 % were reported in Taiwan, in tomato crop (Asian Vegetable Development Centre). The plant mortality and loss in yield ranged from 10 to 100 and 10.83 to 92.62% at different stages of incidence (Singh *et al.* 2010, Dharmatti *et al.* 2006, 2009). The disease was effectively managed by breeding resistant cultivars (Mohamed *et al.* 2004, Sharma *et al.* 2006), good cultural practices (Momol *et al.* 2004), some chemicals fumigation (Sharma and Kumar 2000.), crop rotation (Sharma and Kumar 2004), soil amendment and microbes (Tajul *et al.* 2004a,b, Sharma and Kumar 2009a, b) Some new tactics, viz. plastic mulching play an important role in the management of tomato wilt (Kolalis-Burelle *et al.* 2002, Momol *et al.* 2004). Integrated disease management used most of the effective components in keeping plant disease below the economic threshold level. Integrated management of bacterial wilt in tomato has been reported (Anith *et al.* 2004, Cardoso *et al.* 2006) little information is known on integrated management on commonly cultivated and result are reported.

An experiment was conducted in bacterial wilt sick plots having race 1 biovar III strain of *Ralstonia solanacearum* by randomized block design with three replications on two cultivars of tomato, i.e. resistant check cv. Swarna Lalima (Gazette no 1422 of 2006) and susceptible check cv. Pusa Ruby. The trial was conducted with 11 different treatments for four years (2006-07 to 2009-10) as per guideline of ACRIP in plot size 2.7 × 1.8 m^2 with recommended dose (100:60:40 N: P_2O_5: K_2O) of fertilizers. The treatments details were T_1: Farmyard manure (FYM @ 30 q/ha, cost of ₹ 1 200), T_2: Green manure @ 120 kg /ha (seed of *Sesbania* sp. were sown, cost @ ₹ 34.5/kg), T_3 : PGPR (*Pseudomonas fluorescens*, soil application @ 5 kg/ha ,cost @ ₹ 220.00/kg), T_4: PGPR (*P. fluorescens* containing 9×10^8 colony forming units (CFU)/ml) root dip @ 1.0 % suspension, T5: PGPR (*P. fluorescens*, soil application @5 kg/ha + root dipping 1.0% suspension), T_6: Liming ($CaCO_3$ used as agricultural lime @ 25q/ha, cost @ ₹ 3.99/kg, T_7: Karanj (*Pongamia*) cake@ 10q/ha (cost@ ₹ 8.49/kg) ,T_8: Spent mushroom substrate (*Pleurotus* spp.) @10q/ha (15-20 % moisture level) (Free), T_9: Commination of all treatment, i.e. $T_1+T_2+T_4+T_5+T_6+T_7+T_8$,$T_{10}$: two checks resistant and susceptible cultivars and T_{11}: Surface drainage.

FYM (a well rotten cow dung manure at approx. 15% moisture level) was applied in the plot by broadcasting methods before one month of transplanting. For green manuring, seed of *Sesbania* spp. was sown one month before transplanting in the plots which was produced 50.0 kg fresh wt. per plot green biomass. Green biomass at full growth stage was incorporated by spade in soil thoroughly. Twelve months old spent mushroom compost (SMC) of *Pleurotus* spp. normally contains 1.9: 0.4:2.4 ratio of N: P: K (Gupta *et al.* 2004, Sagar *et al.* 2009) on dry basis before weathering was used by broadcasting. Karanj cake was applied in the field 15 days before transplanting. Five gram *Pseudomonas fluorescence* used as Plant Growth Promoting Rhizobacteria (PGPR) which was commercially available in the market was furrow applied before transplanting. In combination of all treatment, i.e. FYM, Karanj cake, spent mushroom compost, PGPR soil application and lime was incorporated during green manuring and PGPR root dip (0.1%) was done during transplanting. Twenty one day old seedlings were transplanted in respective plot with treatment. Soil samples were collected from the rhizospheric region of tomato of both the cultivars (Swarna Lalima and Pusa Ruby) before imposing treatments at 0 (Initial) and then 30, 60 and 90 days after transplanting from each plot. The wilt incidence was also recorded at 30, 60 and 90 day after transplanting and crop yield was recorded. The *R. solanacearum* population in the rhizospheric soil was determined by serial dilution method on the TTC medium (Kelman 1954). The year wise mean population of *R.*

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Table 1 Effect of integrated approaches on *R. solanacearum* population on different days in resistant and susceptible cultivars of tomato

Treatments (A)	(*a*) Mean *R.solanacearum* population (× 10^4cfu/g of soil) in days							
	Swarna Lalima				Pusa Ruby			
	0	30	60	90	0	30	60	90
T1= FYM	106.3(2.02)	43.9.64)	67.9(1.82)	41.7(1.62)	139.0(2.14)	76.2(1.85)	89.2(1.91)	110.5(2.01)
T2=Green manuring	84.9(1.93)	53.6(1.73)	58.7(1.76)	42.1(1.62)	129.5(2.11)	66.0(1.91)	59.7(1.77)	89.3(2.01)
T3= PGPR soil application	80.1(1.90)	48.5(1.67)	56.2(1.75)	41.5(1.61)	174.3(2.24)	100.0(1.98)	48.5(1.66)	117.7(2.02)
T4=PGPR (root dipping)	89.8(1.95)	67.7(1.83)	63.4(1.80)	51.4(1.71)	163.2(2.21)	57.0(1.72)	95.5(1.95)	81.7(1.89)
T5=PGPR(soil + drenching)	82.8(1.92)	67.0(1.81)	61.2(1.78)	53.1(1.72)	164.0(2.21)	67.2(1.72)	101.7(1.98)	58.5(1.72)
T6=Liming	78.7(1.89)	42.6 (1.62)	63.5(1.79)	54.1 (1.73)	144.8(2.16)	50.8(1.70)	81.8(1.90)	60.8(1.78)
T7=Karanj cake	96.4(1.98)	73.0(1.86)	68.6(1.82)	39.3(1.58)	188.5(2.26)	55.0(1.72)	95.5(1.87)	98.0(1.87)
T8=Spent mushroom compost	99.3(1.99)	88.2(1.95)	88.7(1.94)	53.2(1.72)	157.0(2.19)	54.7(1.69)	51.5(1.71)	64.3(1.80)
T9=Combination of all	79.4(1.90)	81.1(1.90)	69.9(1.81)	52.0(1.71)	161.0(2.17)	57.3(1.75)	113.5(2.05)	75.8(1.87)
T10=Check cultivars	86.5(1.93)	72.8(1.85)	64.4(1.78)	59.5(1.77)	164.5(2.20)	65.2(1.81)	81.0(1.90)	74.2(1.86)
T11=Drainage	78.5(1.89)	60.8(1.78)	67.9(1.82)	54.2(1.73)	152.2(2.17)	57.5(1.74)	37.8(1.58)	77.7(1.88)

(b) *Interaction between treatment (A) × variety (B)*

Mean R. solanacearum *(cfu × 10^4/g soil) population in cultivars*

	Swarna Lalima		*Pusa Ruby*		*Mean (A)*
	No.of colony	*% Reduction*	*No. of colony*	*% Reduction*	*No. of colony*
T1= FYM	64.8 (1.77)	20.1	103.7(1.99)	6.1	84.3(1.88)
T2=Green manuring	59.8(1.76)	15.8	86.1(1.99)	11.1	73.0(1.88)
T3= PGPR soil application	56.5(1.73)	15.3	110.1(1.97)	9.8	83.3(1.85)
T4=PGPR (root dipping)	68.1(1.82)	12.3	99.3(1.94)	14.2	83.7(1.88)
T5=PGPR(soil + drenching)	66.0(1.81)	10.0	97.8(1.91)	22.1	81.9(1.86)
T6=Liming	59.7(1.76)	8.2	84.6(1.88)	17.3	72.1(1.82)
T7=Karanj cake	69.3(1.81)	20.2	109.3(1.96)	12.7	89.3(1.88)
T8=Spent mushroom compost	82.3(1.90)	13.6	81.9(1.85)	17.7	82.1(1.87)
T9=Combination of all	70.6(1.85)	9.9	103.9(1.96)	13.8	87.2(1.91)
T10= Check cultivars	70.8(1.83)	8.2	94.3(1.94)	15.4	82.5(1.89)
T11=Drainage	65.3(1.81)	8.4	81.3(1.84)	12.9	73.3(1.83)
Variety (B)	66.7(1.80)	12.9	95.7(1.93)	13.9	

(c) *Interaction between Treatment (A) × Day (C)*

	0 Day	*30 Day*	*60 day*	*90 day*
T1= FYM	122.7 (2.08)	60.0 (1.75)	78.3 (1.86)	76.1 (1.81)
T2=Green manuring	107.2 (2.02)	59.8 (1.76)	59.2 (1.77)	65.7 (1.82)
T3= PGPR soil application	127.2 (2.07)	74.2 (1.82)	52.3 (1.70)	79.6 (1.82)
T4=PGPR (root dipping)	126.5 (2.08)	62.4 (1.77)	79.5 (1.88)	66.6 (1.80)
T5=PGPR(soil + drenching)	123.4 (2.06)	67.1 (1.77)	81.5 (1.88)	55.8 (1.72)
T6=Liming	111.8 (2.02)	46.7 (1.66)	72.7 (1.84)	57.5 (1.76)
T7=Karanj cake	142.2 (2.12)	71.6 (1.79)	82.1 (1.84)	68.7 (1.78)
T8=Spent mushroom compost	128.1 (2.09)	71.5 (1.82)	70.1 (1.83)	58.7 (1.76)
T9=Combination of all	120.2 (2.03)	69.2 (1.83)	91.7 (1.93)	63.9 (1.79)
T10= Check cultivars	125.5 (2.07)	69.0 (1.83)	72.7 (1.84)	66.8 (1.82)
T11=Drainage	115.3 (2.03)	59.2 (1.76)	52.8 (1.70)	65.9 (1.81)

Contd.

Table 1 (*Concluded*)

	0 Day	30 Day	60 day	90 day
Cultivars	*(d) Interaction between cultivars (B) × Day (D)*			
SwarnaLalima	87.5 (1.94)	63.5 (1.78)	66.3 (1.81)	49.3 (1.68)
Pusa Ruby	158.0 (2.19)	64.3 (1.77)	77.8 (1.84)	82.6 (1.87)
Mean C	122.8 (2.06)	63.9 (1.79)	72.1 (1.83)	65.9 (1.78)
	(e) *Analysis of Variance*			
Source of Variation	*DF*	*MSS*		
		Number×10⁴ (cfu/g)	*Log value*	*CD* (P=0.05) *for log value*
Treatment (A)	10	1582.3	0.017*	(0.05)
Cultivars(B)	1	110947.7	1.061**	(0.02)
Interaction A × B	10	2299.9	0.045*	(0.08)
Day(C)	3	103087.4	1.155*	(0.03)
Interaction A × C	30	906.8	0.015	(0.11)
Interaction B × C	3	31331.6	0.25*	(0.05)
Interaction A × B × C	30	1581.9	0.028	(0.15)
Error	176	608.3	0.018	
Total	263			

Figures in parenthesis are log value of colonies (CFU). *, ** Significant at P (0.05 and 0.01 respectively).

Table 2 Per cent bacterial wilt under different IDM approaches on different days in resistant and susceptible cultivars of tomato

Treatments(A)	Wilt incidence (%)* in Cultivars (B)					
	Swarna Lalima			Pusa Ruby		
	30 day	60 day	90 day	30 day	60 day	90 day
T1= FYM	4.4 (11.77)	6.3 (13.81)	6.7 (14.12)	17.8 (24.79)	32.8 (34.77)	54.4 (48.09)
T2=Green manuring	1.1 (3.50)	2.2 (4.99)	2.2 (4.99)	18.9 (24.19)	26.7 (28.97)	57.2 (49.15)
T3= PGPR soil application	1.7 (5.98)	6.711.90)	6.7 (11.90)	13.9 (20.16)	23.3 (26.84)	28.9 (30.04)
T4=PGPR (root dipping)	7.2 (15.27)	9.4 (16.31)	9.4 (16.31)	12.8 (20.83)	28.9 (32.42)	59.4 (50.50)
T5=PGPR(soil + drenching)	2.2 (4.99)	3.3 (8.06)	3.3 (8.06)	15.0 (22.64)	26.7 (30.62)	63.9 (53.22)
T6=Liming	1.7 (5.98)	3.3 (10.28)	3.3 (10.28)	14.4 (21.82)	26.1 (29.48)	45.6 (42.02)
T7=Karanj cake	0.6 (2.47)	3.3 (8.49)	3.3 (8.49)	17.8 (24.25)	29.4 (31.72)	63.9 (53.80)
T8=Spent mushroom compost	1.7 (4.31)	3.9 (8.62)	3.9 (8.62)	12.8 (20.61)	23.9 (28.33)	61.1 (51.85)
T9=Combination of all	1.1 (4.95)	1.1 (4.95)	1.1 (4.95)	10.0 (18.00)	23.3 (27.73)	45.0 (42.10)
T10= Check cultivars	4.4 (9.97)	6.1 (11.64)	2.5 (5.30)	15.6 (23.02)	26.7 (30.30)	62.8 (52.51)
T11=Drainage	5.0 (10.58)	7.8 (15.95)	4.2 (9.60)	15.6 (21.98)	25.6 (28.34)	48.3 (44.02)
	Wilt incidence (%) in Treatment (A) × Day(C)*					
	30 day	*60 day*	*90 day*	*Mean*		
T1: FYM	11.1 (18.28)	19.6 (24.29)	30.6 (31.11)	20.4 (24.56)		
T2: Green manuring	10.0 (13.85)	14.4 (16.98)	29.7 (27.07)	18.1 (19.30)		
T3: PGPR soil application	7.8 (13.07)	15.0 (19.37)	17.8 (20.97)	13.5 (17.80)		
T4: PGPR (root dipping)	10.0 (18.05)	19.2 (24.37)	34.4 (33.41)	21.2 (25.27)		
T5: PGPR (soil + drenching)	8.6 (13.82)	15.0 (19.34)	33.6 (30.64)	19.1 (21.27)		
T6:Liming	8.1 (13.90)	14.7 (19.88)	24.4 (26.15)	15.7 (19.98)		
T7: Karanj cake	9.2 (13.36)	16.4 (20.11)	33.6 (31.14)	19.7 (21.54)		
T8: Spent mushroom compost	7.2 (12.46)	13.9 (18.47)	32.5 (30.23)	17.9 (20.39)		
T9: Combination of all	5.6 (11.48)	12.2 (16.34)	23.1 (23.53)	13.6 (17.11)		
T10: Check cultivars	10.0 (16.50)	16.4 (20.97)	32.6 (28.90)	19.7 (22.12)		
T11: Drainage	10.3 (16.28)	16.7 (22.14)	26.3 (26.81)	17.7 (21.74)		
Cultivars	*Cultivar (B) × Day (C)*					
Swarna Lalima	2.8 (7.25)	4.9 (10.46)	4.2 (9.33)	4.0 (9.01)		
Pusa Ruby	15.0 (22.03)	26.7 (29.96)	53.7 (47.03)	31.8 (33.00)		
Mean	8.9 (14.64)	15.8 (20.21)	29.0 (28.18)			

*Figures in parenthesis are angular transformed value of per cent incidence.

solanacearum, wilt incidence and yield of tomato were subjected to variance analysis. The mean of four years populations of *R. solanacearum* was recorded in different samples at different day in different treatment and varieties were converted to log value and the statistically analyzed in complete randomized block design. The wilt disease incidence and yield were also analyzed (Panse and Shukatme 1984). The benefit: cost (B : C) ratio was also calculated on the basis of rate mentioned in the treatments above in Swarna Lalima resistant variety but in susceptible variety (Pusa Ruby) the yield was very less hence B: C ratio was not determined.

It is revealed from Table 1 and 2 that the significant effect of integrated disease management on *R. solanacearum* population in Swarna Lalima and Pusa Ruby. A significant effect of treatments, cultivar and days of sampling on the population of *R. solanacearum*, wilt incidence and crop yield was observed (Table 2 and 3). The interaction due to treatment × cultivars (Table 1b) revealed that (66.7×10^4cfu/g of soil) than Pusa Ruby (95.7×10^4cfu/g of soil) in the soil. The differences in population of *R. solanacearum* in the soil was affected by the cultivars and dates of sampling (Table 1c) and at initial stage, the population was 122.8×10^4 cfu/g of soil), whereas it was reduced at 90 days (65.9×10^4 cfu/g of soil). The minimum wilt incidence was found in cv. Swarna Lalima (4.00%) followed by Pusa Ruby (31.8 %) after 90 days (Table 2), Swarna Lalima cultivar resulted mean yield (251.6 q/ha, Table 3), whereas Pusa Ruby yielded (23.2 q/ha) which is low.

As revealed from ANOVA Table 1 that combined treatments (FYM + GM + PGPR + Liming + KC + SMC) reduced the 34.5% in *R. solanacearum* population in Swarna Lalima plot over initial population and the similar trend in reduction of population was also observed in Pusa Ruby plot by 52.9% after 90 days (Table 1a). Bacterial wilt incidence was also reduced significantly in both the cultivars and wilt incidence 1.1% was observed in Swarna Lalima followed by Pusa Ruby (26.1%, Table 3). The maximum yield was obtained (Table 3) 343.8 q/ha in Swarna Lalima which was 47.2% more over without any IDM approach, whereas in Pusa Ruby yield was 38.4 q/ha.

The results of all combination of all (T9) treatment, i.e. FYM, green manure (*Sesbania* sp.), PGPR soil application, PGPR root dip, PGPR soil application + root dip, liming, karanj cake, spent mushroom compost use of resistant cultivar and surface drainage showed significant reduction in *Ralstonia*. Various potential integrated approaches reported by various workers indicated the possibilities to manage of *Ralstonia* by organically means. The present investigation was confirmed with the reports of other workers (Sharma and Kumar 2006, 2009a, b). The present investigation in karanj cake was in conformity with earlier works of authors (Sharma and Kumar 2009a, b). Dutta *et al.* (2009) reported 9.5 fold decreases in *R. solanacearum* population and were observed in the treatment where seedlings were treated with bio-agent community and the soil was amended with lime + bleaching powder + neem cake + vermicompost.

Table 3 Per cent bacterial wilt and yield under different IDM approaches in resistant and susceptible cultivars

Treatment	Wilt incidence (%) *		Yield (q/ha)	
	Swarna Lalima	Pusa Ruby	Swarna Lalima	Pusa Ruby
T1: FYM	5.8 (13.23)	35.0 (35.88)	298.4 (1.38:1)*	18.8
T2: Green manuring	1.9 (4.49)	34.3 (34.10)	258.2 (1.19:1)	25.4
T3: PGPR soil application	5.0 (9.92)	22.0 (25.68)	202.4 (0.94:1)	29.2
T4: PGPR (root dipping)	8.7 (15.96)	33.7 (34.58)	220.4 (1.03:1)	20.0
T5: PGPR (soil + drenching)	3.0 (7.04)	35.2 (35.50)	264.0 (1.23:1)	12.2
T6: Liming	2.8 (8.85)	28.7 (31.11)	221.6 (0.99:1)	19.6
T7: Karanj cake	2.4 (6.49)	37.0 (36.59)	230.2 (1.04:1)	19.4
T8: Spent mushroom compost	(7.18) 3.1	(33.60) 32.6	(1.31:1) 280.8	27.4
T9: Combination of all	1.1 (4.95)	26.1 (29.28)	343.8 (1.49:1)	38.2
T10: Check cultivars	4.4 (8.97)	35.0 (35.28)	233.6 (1.09:1)	14.2
T11: Drainage	5.6 (12.04)	29.8 (31.45)	213.8 (1.0:1.0)	23.2
Cultivar mean	4.0 (9.01)	31.8 (33.00)	251.6	23.2
	CD (P = 0.05)			
Treatment (A)	NS		35.08	NT
Cultivar (B)	(2.54)		14.96	
Treatment × cultivar interaction	(4.4)		49.62	

*Figures in parenthesis are angular transformed value of per cent incidence and in yield, and benefit cost ratio mentioned in parenthesis.

SUMMARY

An integrated management of bacterial wilt of tomato against race 1 biovar III of *Ralstonia solanacearum* was conducted with eleven treatment combinations on resistant (cv Swarna Lalima) and susceptible (cv. Pusa Ruby) of tomato from 2006 to 2009-10 during rainy seasons. The pooled analysis of different treatments × variety × date of sampling were showed significanteffects on *Ralstonia* population, wilt incidence and yield of the crop. This treatment also reduced *R. solanacearum* population and increased the yield 47.2% in cv. Swarna Lalima (343.7 q/ha) with B: C ratio (1.49:1) over resistant check.

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