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Integrated disease management in tomato

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Abstract
Tomato is one of the most important vegetable crop grown in Telangana in kharif, rabi and summer seasons. It is affected by early blight, late blight, leaf curl virus, collar rot and fusarium wilt diseases which play a key role on yield parameters. An experiment was conducted with six treatments and four replications to test the effective module for the management of these diseases. Among the tested modules, Integrated module which includes nursery treatment with seed pro: seed priming @ 4g/kg ,ii) soil application @10g/Kg of soil while potting and iii) soil drenching @ 5% after seed germination. Main field treatment: seedling dip with 0.1% (carbendazium 12% + Mancozeb 63% WP) +spray with Acephate 75% WP @ 1.5 g/l on 10 day after transplanting +spray with fipronil 5%SC @ 1.5 ml/l on 20 DAT+ spray with copper hydroxide 77% WP (2.0g/l) on 20 DAT +spray with imidacloprid 70% WG @ 2g/15 1 on 40 DAT + spray with fenamidone 10% +Mancozeb 50WDG (0.25%) two to three time from 45 DAT at 10 days intervals was effective in the management of diseases (Damping off, Fusarium wilt, Collar rot, Early blight, Late blight, Bacterial leaf spot and Tomato leaf curl) in tomato and recorded highest yield with no residues and highest benefit cost ratio.

Keywords: Disease, tomato, leaf curl virus

Introduction
Tomato, ranks first in the world for vegetables, accounts for 14% of world vegetable production (FAO, 2010). It is a popular vegetable crop grown in India and second leading producer followed by China. Though India is at second place, production is very less compared to the China due to several biotic and abiotic factors limiting the production. Among the biotic factors diseases are major concern, and nearly 200 diseases caused by fungi, bacteria and virus have been reported to affect the tomato plants in the world.

Among those fungal diseases early blight *(Alternaria solani*) (Chaerani *et al.*, 2007)[2] and late blight (*Phytophthora infestans*) causes (Nowicki *et al.*, 2013) [11] causing high yield losses and Tomato leaf curl virus (ToLCV) also becoming a major problem in Tomato production in India particularly during summer crop (Sadashiva *et al.*, 2002) [13], *Sclerotium rolfsii*, fusarial wilt (*Fusarium oxysporum*) (Ramyabharathi *et al.*, 2012) [12] are major diseases causes economic losses and prevalent in tomato in Telangana state in India. Damping off causes more than 60 per cent loss in seedlings at nursery and main field (Manoranjitham *et al.*, 2000) [7], early blight causes upto 79 percent yield loss (Datur and Mayee,1981) [3], Late blight causes 20–70% yield losse (Nowicki *et al*, 2013) [11], collar rot affects the tomato crop productivity up to 35% (Thiribhuvanamala *et al.*, 1999) [16], *Fusarium* wilt causes 45% yield losses (Ramyabharathi *et al*. 2012) [12], Bacterial leaf spot causes 10 to 80% losses (Sharma and Sharma 2005), and also Tomato leaf curl causes 52.5-100% yield losses in winter-planted crops (Muniyappa, 1991) [10].

The use of chemical pesticides is the most common practice to control various diseases but it causes several problems like toxicity to non-target organisms, development of resistance among the population of pathogens and environmental pollution, so to develop strategies for plant disease management involve biological and integrated control by applying antagonistic microorganisms alone or in combination and/or alternating with fungicides or natural botanicals or bio agents (Bhagat *et al.*, 2015) [1]. Therefore, present investigation was taken up to develop integrated disease management module for the management of important tomato diseases.

Materials and Methods

An experiment was conducted during rabi season over three two consecutive years (2015-16 to 2016-17) under All India Coordinated Research Projects on Vegetable Crops at the Vegetable Research Station of Sri Konda Laxman Telangana State Horticultural University, India to evaluate the efficacy of different modules for integrated disease management in tomato under randomized block design with four replications and six treatments with plot size 10.8 square meters and the spacing adopted was 60x40 cm on popular variety Arka vikas. Disease intensity was recorded for Damping off, Fusarium wilt, Collar rot, Early Blight, Late Blight, Bacterial leaf spot, Tospo virus and yield were recorded.

The six treatments are as follows.

T_1 Treatment with biological control: Nursery treatment with seed pro: seed priming @ 4g/kg, ii) Soil application @ 10 g/Kg of soil while potting, and iii) soil drenching @ 5% after seed germination Main field treatment with seed Pro: seedling dip (5%) and three sprays with seed Pro (1.0%) at 10 days interval.

T_2 Treatment with fungicides: Nursery treatment: Seed treatment with Captan 50% WP (2g/kg) +drenching with Fosetyl A1 80% WP @ 0.1% immediately after germination + Spray with Copper hydroxide 77% WP (2.0 g/l) at 3-5 leaf stage. Main field treatment: Seedling Dip with 0.1% (Carbendazim 12% + Mancozeb 63% WP) + Spray with Copper hydroxide 77% WP (2.0 g/l) on 25 DAT + spray with Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals.

T_3 Treatment with Insecticides: Main field treatment: Spray with Acephate 75% WP @ 1.5 g/l on 10 days after transplanting + Spray with Fipronil 5% SC @ 1.5 ml/l on 20 DAT + Spray with imidacloprid 70% WG @ 2g/ 15 l on 40 DAT.

T_4 Treatment with fungicides and insecticides: Nursery treatment: seed treatment with Captan 50% WP (2g/kg) + drenching with Fosetyl A1 80% WP @ 0.1% immediately after germination + spray with Copper hydroxide 77% WP (2.0 g/l) at 3-5 leaf stage. Main field treatment: Seedling Dip with 0.1% (Carbendazim 12% + Mancozeb 63% WP) + Spray with Acephate 75% WP @ 1.5 g/l on 10 days after transplanting + Spray with Fipronil 5% SC @ 1.5 ml/l on 20 DAT +spray with Copper hydroxide 77% WP (2.0 g/l) on 25 DAT + Spray with WDG (0.25%) t-wo to three times from 45 DAT at 10 days intervals

T_5 Integrated Management : Nursery treatment with Seed Pro: Seed priming @ 4g/kg, ii) Soil application @ 10 g/kg of soil while potting, and iii) Soil drenching @ 5% after seed germination Main filed treatment: seedling Dip with 0.1% (Carbendazim 12% + Mancozeb 63% WP) spray with Acephate 75% WP @ 1.5g/L on 10 days after transplanting + spray with Fipronil 5% SC @ 1.5 ml/l on 20 DAT + spray with Copper hydroxide 77% WP (2.0 g/l) on 25 DAT with imidacloprid 70% WG @ 2g/ 15 L on 40 DAT + Spray with Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 intervals.

T_6 Control

Disease intensity was recorded for Damping off, Fusarium wilt, Collar rot, Early Blight, Late Blight, Bacterial leaf spot, TOLCV and finally yield was recorded. The severity of different diseases (Damping off, Fusarium wilt, Collar rot, Early Blight, Late Blight, Bacterial leaf spot and TOLCV) was recorded from all the respective plots by visual observation and based on different disease grading scales. Ten plants were selected for each treatment damping off disease intensity was recorded by 0-5 scale (Mudyiwa *et al.,* 2016) [9] early blight by using 0-5 scale (Mayee and Datar, 1986) [8], tomato late blight by 0-5 scale(Sokhi *et al.,* 1993) [15], Fusarium wilt disease severity by Lebeda and Bucakowski (1986) [5], collar rot by 0-5 scale(Latunde-Dada, 1993) [4] and tomato leaf curl by using 0-4 scale (Muniyappa *et al.,* 1991) [10].

Percent disease index (PDI) was calculated by using the following formula. (Wheeler, 1969)

$$PDI\ (\%) = \frac{\text{Sum of individual ratings X 100}}{\text{Total number of plants evaluated X disease scale}}$$

Results and Discussion

From the results it can be inferred that all the diseases viz. damping off, fusarium wilt, collar rot, early blight, late blight, bacterial leaf spot and% ToLCV were maximum in control plot when compared to other treatments. However significantly minimum incidence of diseases was recorded in T_5 in which integrated disease management practice was imposed.

Among the treatments tested T_5 (Nursery treatment with Seed Pro: Seed priming @ 4g/kg, ii) Soil application @ 10 g/kg of soil while potting, and iii) Soil drenching @ 5% after seed germination Main field treatment: seedling Dip with 0.1% (Carbendazim 12% + Mancozeb 63% WP) spray with Acephate 75% WP @ 1.5g/L on 10 days after transplanting + spray with Fipronil 5% SC @ 1.5 ml/l on 20 DAT + spray with Copper hydroxide 77% WP (2.0 g/l) on 25 DAT with imidacloprid 70% WG @ 2g/ 15 L on 40 DAT + Spray with Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 intervals.) was found to be effective in the management of damping off recording 1.43% disease incidence compared to untreated control (10.42%) followed by T_2 (treatment with fungicides) and T_4 (Treatment with insecticides and fungicides). Fusarium wilt disease was recorded lowest (2.08%) in integrated treatment (T_5) and it was on a par with T4 (4.09%) and T2 (5.00%). With regard to collar rot minimum incidence was recorded in T_5 (1.30%) and on par with T_2(1.35%) compared to untreated control (3.25%). Among the treatments minimum fusarium wilt was observed in T_5 (2.08%), however on par with T_4(4.09%)and T_2(5.00%) compared to untreated control (13.07%). similar trend was recorded for collar rot and early blight diseases by recording minimum incidence in T_5 (1.30%) and (10.28%) respectively (Table 1&2).

Early blight incidence was also minimum in T_5 (10.28%) compared to untreated control (26.16) on par with T_4 (11.74%). Similar trend was observed for late blight disease also and it was minimum in T_5 (7.66) followed by T2 (9.53) compared to other treatments. Whereas Bacterial blight was minimum in T_5 (4.68%) and T_4 (5.78). (Table:2) However, like fungal diseases minimum Leaf curl disease incidence (3.62) and higher yield (23.88 t/ha) was recorded in T_5 with B: C ratio of 1:1.75. (Table: 3). The tomato samples of T_5 integrated treatment were sent to Food Safety Referral

Laboratory, IIHR, Bengaluru for residue analysis. The results showed that there were no residues in the produce (Table-4).

Similarly Mandal *et al.,* 2017 also reported that adopting the technologies involving seed priming with Seed Pro @4g/ kg of seed followed by soil application of Seed Pro @10g/kg of soil while filling of plug trays and soil drenching of Seed Pro @5% after seed germination followed by covering with 50-mesh nylon net of nursery bed supplemented with border row planting (2 rows) of maize at least 30 days before transplanting of seedlings in the main field followed by seedling dip with 0.1% (Carbendazim 12%+Mancozeb 63% WP) at the time of transplanting and sequential spraying with Acephate 75% WP @1.5g/l on 10 DAT, Fipronil 5% SC @1.5ml/l on 20 DAT, Copper hydroxide 77% WP (2.0g/l) on 25 DAT, imidacloprid 70% WG @2g/15l on 40 DAT, Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals for better management of tomato diseases. Bhagath *et al.,* 2015 reported that IDM module (integration of cultural practices, biocontrol agents and need based application of chemical fungicides at half of recommended dose) was effective in management of tomato diseases.

Table 1: Evaluation of different fungicide modules for the management diseases in Tomato (Damping off, Fusarium Wilt, Collar rot (2014-2017)

Treatment	Damping off PDI				Mean	Fusarium wilt PDI				Mean	Collar rot PDI				Mean
	2014-15	2015-16	2016-17	2017-18		2014-15	2015-16	2016-17	2017-18		2014-15	2015-16	2016-17	2017-18	
T_1	3.30	4.00	8.00	9.50	6.20	8.00	9.00	6.00	4.20	6.80	2.30	1.60	2.67	2.20	2.19
	(10.49)	(11.47)	(16.34)	(17.89)	(14.05)	(16.24)	(17.45)	(14.14)	(11.77)	(14.90)	(8.74)	(7.11)	(9.38)	(8.51)	(8.44)
T_2	2.00	3.00	6.00	7.30	4.58	6.30	7.30	4.33	2.06	5.00	1.30	1.17	1.50	1.43	1.35
	(6.65)	(9.95)	(13.58)	(15.67)	(11.46)	(14.36)	(15.67)	(11.99)	(8.25)	(12.57)	(5.51)	(5.98)	(6.96)	(6.84)	(6.32)
T_3	2.70	3.73	7.00	8.50	5.48	11.90	12.63	10.00	8.23	10.69	4.00	3.00	3.00	2.80	3.20
	(9.60)	(11.11)	(15.24)	(16.94)	(13.22)	(20.11)	(20.81)	(18.37)	(16.67)	(18.99)	(11.28)	(9.95)	(9.95)	(9.56)	(10.19)
T_4	1.70	2.70	6.00	7.43	4.46	4.40	5.40	4.00	2.57	4.09	2.70	2.00	2.37	2.50	2.39
	(6.13)	(9.40)	(14.14)	(15.82)	(11.37)	(11.99)	(13.43)	(11.47)	(9.21)	(11.53)	(9.08)	(7.95)	(8.83)	(8.97)	(8.71)
T_5	0.70	0.80	1.67	2.53	1.43	2.30	3.33	1.67	1.01	2.08	1.70	1.00	1.23	1.25	1.30
	(2.90)	(5.07)	(7.33)	(9.15)	(6.11)	(8.46)	(10.51)	(7.33)	(5.62)	(7.98)	(6.13)	(5.61)	(6.35)	(6.39)	(6.12)
T_6	6.30	7.50	12.00	15.87	10.42	11.30	10.43	19.00	11.53	13.07	3.00	3.50	3.50	3.00	3.25
	(14.50)	(15.88)	(20.22)	(23.46)	(18.52)	(19.36)	(18.83)	(17.44)	(19.84)	(18.87)	(9.88)	(10.77)	(10.76)	(9.95)	(10.34)
CD (5%)	6.28	1.55	4.82	1.79	1.74	5.13	1.14	2.61	1.17	3.07	NS	3.22	1.54	0.98	0.49
CV	21.48	8.11	18.30	11.58	21.32	18.66	3.91	10.66	13.01	29.27	-	22.37	9.77	24.56	14.24

Table 2: Evaluation of different fungicide modules for the management diseases in Tomato (Early blight, Late blight, Bacterial leaf spot (2014-2017)

Treatment	Early blight PDI				Mean	Late blight PDI				Mean	Bacterial leaf spot PDI				Mean
	2014-15	2015-16	2016-17	2017-18		2014-15	2015-16	2016-17	2017-18		2014-15	2015-16	2016-17	2017-18	
T_1	18.23	20.60	15.00	18.00	17.96	15.30	10.47	10.00	12.50	12.07	7.80	10.73	5.00	5.73	7.32
	(25.25)	(26.88)	(22.71)	(25.09)	(24.98)	(23.04)	(18.51)	(18.42)	(20.70)	(20.17)	(16.19)	(19.06)	(12.74)	(13.81)	(15.45)
T_2	18.93	20.97	15.00	16.20	17.78	12.40	8.37	7.33	10.00	9.53	10.50	12.50	6.00	6.83	8.96
	(25.51)	(26.76)	(22.59)	(23.73)	(24.65)	(20.57)	(16.74)	(15.65)	(18.42)	(17.85)	(18.88)	(20.67)	(14.04)	(15.14)	(17.18)
T_3	25.70	26.10	21.33	24.27	24.35	20.10	15.37	13.00	15.57	16.01	11.20	13.43	5.00	5.10	8.68
	(30.42)	(30.64)	(27.50)	(29.49)	(29.51)	(26.60)	(22.90)	(21.06)	(23.23)	(23.45)	(19.45)	(21.42)	(12.74)	(13.04)	(16.66)
T_4	12.90	14.83	8.33	11.00	11.77	14.00	8.63	7.00	10.23	9.97	6.30	8.30	4.00	4.50	5.78
	(20.96)	(22.37)	(16.75)	(19.36)	(19.86)	(21.94)	(17.02)	(15.10)	(18.64)	(18.18)	(14.34)	(16.68)	(11.28)	(12.21)	(13.63)
T_5	14.87	12.43	6.67	7.17	10.28	12.30	6.63	4.67	7.03	7.66	5.70	6.00	3.67	3.33	4.68
	(22.61)	(20.61)	(14.89)	(15.50)	(18.40)	(20.48)	(14.78)	(12.13)	(15.37)	(15.69)	(13.70)	(14.14)	(10.76)	(10.50)	(12.28)
T_6	24.10	28.53	24.67	27.33	26.16	22.50	18.60	14.33	17.00	18.11	12.30	14.50	6.67	8.40	10.47
	(29.38)	(32.23)	(29.77)	(31.52)	30.73	28.28	25.53	22.21	24.32	(25.09)	20.46	22.24	14.89	16.82	18.60
CD(5%)	3.99	7.42	4.15	2.15	2.41	2.66	6.11	4.91	1.79	1.18	3.94	4.29	NS	1.39	1.74
CV	8.53	15.35	10.20	6.81	8.85	6.25	17.47	17.47	8.15	6.40	2.62	12.36	22.04	13.51	15.12

Table 3: Evaluation of different fungicide modules for the management diseases in Tomato (leaf curl virus and Yield (2014-2017)

Treatment	% ToLCV				Mean	Yield (t/ha)				Mean	B:C ratio
	2014-15	2015-16	2016-17	2017-18		2014-15	2015-16	2016-17	2017-18		
T_1	7.90	9.00	11.00	13.00	10.23	17.70	18.50	21.00	17.50	18.64	1:1.65
	(16.28)	(17.45)	(18.88)	(21.09)	(18.43)						
T_2	4.90	5.50	7.00	9.00	6.60	16.30	16.50	18.00	21.37	18.04	1:1.01
	(12.62)	(13.52)	(15.10)	(17.44)	(14.67)						
T_3	2.30	3.50	5.67	7.33	4.70	18.60	18.00	20.00	23.03	19.91	1:1.57
	(8.56)	(10.77)	(13.72)	(15.70)	(12.19)						
T_4	2.20	3.23	4.00	5.67	3.77	20.30	21.00	23.33	26.23	22.72	1:1.72
	(8.45)	(10.35)	(11.47)	(13.76)	(11.01)						
T_5	1.50	2.00	5.00	6.00	3.63	21.50	22.67	24.00	27.33	23.88	1:1.75
	(6.20)	(7.95)	(12.87)	(14.14)	(10.29)						
T_6	8.40	9.17	13.00	14.33	11.23	12.54	13.00	12.67	12.10	12.57	
	(16.64)	(17.61)	(21.09)	(22.21)	(19.39)						
CD (5%)	3.57	2.20	5.90	2.39	0.87	3.37	1.98	3.94	6.18	1.05	
CV	17.12	9.30	20.90	14.23	8.58	2.18	5.83	10.57	14.51	3.28	

Table 4: Results of residue analysis for integrated module

	Results in ppm	LOD(ppm)	Specification/MRL(ppm)	Techniques used
Acephate	ND	0.005	1.0	LC-MS/MS
Acetamiprid	ND	0.005	NA	LC
Atrazine	ND	0.005	NA	LC
Azoxystrobin	ND	0.005	NA	LC
Benalxyl	ND	0.005	0.2	LC
Bifenazate	ND	0.005	0.5	LC
Bitertanol	ND	0.005	3	LC

Conclusion

Evaluation of different IDM packages revealed that T5 (Integrated Management) Nursery treatment with seed pro: seed priming @ 4g/kg, ii) soil application @10g/Kg of soil while potting and iii) soil drenching @ 5% after seed germination. Main filed treatment: seedling Dip with .1% (carbendazium 12% + Mancozeb 63% WP) +spray with Acephate 75% WP @ 1.5 g/l on 10 day after transplanting +spray with fipronil 5%SC @ 1.5 ml/l on 20 DAT+ spray with copper hydroxide 77% WP (2.0g/l) on 20 DAT +spray with imidacloprid 70% WG @ 2g/15 1 on 40 DAT + spray with fenamidone 10% +Mancozeb 50WDG (0.25%) two to three time from 45DAT at 10 days intervals was effective in the management of diseases (Damping off, Fusarium wilt, Collar rot, Early blight, Late blight, Bacterial leaf spot and Tomato leaf curl) in tomato and recorded highest yield and benefit cost ratio.

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