Current Journal of Applied Science and Technology

40(14): 76-86, 2021; Article no.CJAST.61844
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Field Efficacy of Thiophanate Methyl 44.8% + Kasugamycin 2.6% Sc against Major Foliar Diseases of Tomato

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Authors' contributions

This work was conducted in collaboration among all authors. Author HN designed work and performed the statistical analysis. Author BP managed the analyses of the study and conducted field experiment. Author P collected the literature wrote entire draft of manuscript and all authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i1431405
Editor(s):
(1) Dr. Teresa De Pilli, University of Foggia, Italy.
Reviewers:
(1) Igbokwe, Gabriel Ejike, Nnamdi Azikiwe University, Nigeria.
(2) Alfi Inayati, Indonesian Legume and Tuber Crop Research Institute (ILETRI), Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61844

Original Research Article

Received 25 August 2020
Accepted 31 October 2020
Published 26 June 2021

ABSTRACT

Tomato (*Solanum lycopersicum* L.) is the important edible solanaceous plant originated from western South and Central America. Despite botanically being a fruit, it's generally eaten and preferred like a vegetable. Tomatoes are the major dietary source of the antioxidant lycopene, which has been linked to many health benefits, including reduced risk of heart disease and cancer. Early blight caused by *Alternaria solani* and powdery mildew caused by *Erysiphe orontii* and bacterial leaf spot caused by *Xanthomonas campestris* has become a serious problem for successful cultivation of tomato. Therefore, a field experiment was carried out to know the efficacy of Thiophanate methyl 44.8% + Kasugamycin 2.6% Sc on tomato diseases during 2017-18 and 2018-19, at College of Agriculture, Shivamogga. Experimental results revealed that all the treatments significantly reduced the early blight, bacterial leaf spot and powdery mildew disease severity over untreated control. Among all the treatments Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha recorded significantly less Per cent Disease Index (PDI) of Early blight (*Alternaria solani*) (7.78 % and 10.19 %), Bacterial leaf spot (*Xanthomonas*

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campestris) (3.96 and 1.39 %) and Powdery mildew (*Erysiphe orontii*) (1.67 and 2.50 %) with yield of 340.33 and 333.33 q/ha followed by Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml/ha.

Keywords: Tomato; early blight; bacterial leaf spot; Powdery mildew and Thiophanate methyl 44.8% + Kasugamycin 2.6%.

1. INTRODUCTION

The Tomato (*Lycoperiscum esculantum* L.) is a diploid species with 2n=24 chromosomes and belongs to the family Solanaceae. It is the world's largest vegetable crop after potato [1]. Tomato is one of the most popular warm season fruit vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is mostly considered as "Protective food" based on its nutritive value, antioxidant molecules such as carotenoids, particularly lycopene, ascorbic acid, vitamin E and phenol compounds, particularly flavonoids [2]. Lycopene has important dietetic properties since it reduces the risk of several types of cancers and heart attacks [3]. Tomato crop is vulnerable to infect by bacterial, viral, nematode and fungal diseases. Among the fungal diseases, Alternaria leaf blight of tomato caused by *Alternaria solani*, is a soil inhabiting air-borne pathogen responsible for leaf blight, collar and fruit rot of tomato disseminated by fungal spores [4]. It is an important disease of tropical and sub-tropical areas. Distinctive bulls-eye pattern of leaf spots with concentric rings of spores surrounded by a halo of chlorotic leaf area are common. Leaves turn yellow and dry up when only a few spots are present [5]. The pathogen causes infection on leaves, stem, petiole, twig and fruits as well as leads to the defoliation, drying of twigs and premature fruit drop which ultimately reduce the yield 30 to 65% in various states [6,4,7,8]. The disease, if favoured by high temperature and humidity (crowded plantation, high rainfall and extended period of leaf wetness from dew) and plants are more susceptible to the blight infection during fruiting period [9]. Symptoms of powdery mildew caused by *Leveillula taurica* include white lesion on the adaxial leaves surface and on all the other aerial plant parts except on fruits. The fruits are not directly affected but impaired photosynthesis and premature senescence reduces fruit size and nutritional quality leading to diminished yield [10]. In severe out breaks, the lesions coalesce and the disease is debilitating resulting in the death of leaves.

Most of the new generation fungicides are highly specific and single site in mode of action. Thus, a novel fungicide with novel mode of action with combination of bactericide needs to be identified and evaluated under field conditions for the management of disease. Our objective was to determine the efficacy of different doses of combination of fungicidal and bactericidal formulation of Thiophanate methyl 44.8% + Kasugamycin 2.6% to develop a management module for early blight, bacterial leaf spot and powdery mildew of tomato.

2. MATERIALS AND METHODS

The field experiment on bio efficacy and phytotoxicity of Thiophanate methyl 44.8% + Kasugamycin 2.6% against foliar diseases of tomato was carried out during 2017-18 and 2018-19 at College of Agriculture, Shivamogga, UAHS, Shivamogga. The spray schedule was initiated soon after the disease appearance. The experiments consisted of eight treatments. The experiment was laid out with randomized block design (RBD). The treatment fungicides were sprayed to the tomato plot at the beginning of the disease appearance. Spray schedule was repeated at 10 days interval. The observation of *Alternaria solani* (early blight), *X. campestris* (bacterial leaf spot) and *Erysiphe orontii* (powdery mildew) were recorded using 0-5 scale at before and after each spray. Observations are taken at 0, 10 and 20 days after each application. Average of all spray has been given in this and the data was statistically analyzed after suitable transformations. The recorded grade values were converted into Percent Disease Index (PDI) by using following formula proposed by Wheeler [11]. Pandey & Pandey [12] and Mayee and Dattar [13] reported that rating scale for scoring disease intensity early blight of tomato.

Ten plants in each treatment were selected and tagged for recording disease incidence. Plants were rated as per following scale based on the per cent of plant tissue infected with early blight and bacterial leaf spot.

Percent Disease Index (PDI) of the diseases was calculated using the following formula.

$$\text{PDI}\ (\%) = \frac{\text{Total sum of numerical ratings}}{\text{Maximum disease rating x no.of observations}} \text{ x } 100$$

Plants were rated as per following scale based on the per cent of plant tissue infected with Powdery mildew. Percent Disease Index (PDI) of the diseases was calculated using the following formula and disease scale.

$$\text{PDI}\ (\%) = \frac{\text{Total sum of numerical ratings}}{\text{Maximum disease rating x no.of observations}} \text{ x } 100$$

2.1 Phytotoxicity

The phytotoxicity effect of the Thiophanate methyl 44.8% + Kasugamycin 2.6% SC was also tested @ higher dose of 1005.2 g a.i./ha for Epinasty, Hyponasty, Chlorosis, Necrosis, Vein clearing and stunting etc., after 0,1,3,5,7,10 and 15 days after 1st and 2nd sprays in standing crop. Observations on above mentioned phytotoxic parameters were made in each treatment on the 1-10 grading scale as shown below:

2.2 Statistical Analysis

The experimental data collected were analyzed statistically for its significance of difference by the normal statistical procedure adopted for randomized block design. Data from the percent disease index and yield were analyzed by ANOVA. Percent data were transformed arcsine where necessary. Differences within the means were compared by using Fisher's LSD (Least Significant Difference) test [14]. The level of significance used in 'F' and 'T' test was P = 0.05 and P = 0.01. Critical differences were calculated wherever 'F' test was significant. The values percent disease index was subjected to angular transformation according to the table given by Sundarraj et al. [15].

Table A. Treatment details

Sl. No.	Treatment	Dose	
		g. a.i./ha	formulation (g or ml/ha)
1.	Thiophanate methyl 44.8% + Kasugamycin 2.6% SC	301.6	750
2.	Thiophanate methyl 44.8% + Kasugamycin 2.6% SC	402.1	1000
3.	Thiophanate methyl 44.8% + Kasugamycin 2.6% SC	502.6	1250
4.	Thiophanate methyl 70% WP	500	715
5.	Kasugamycin 3% SL	37.5	1250
6.	Azoxystrobin 23% SC	125	500
7.	Flusilazole 40% EC	60	150
8.	Untreated Control	----	----

Table B. Disease rating Scale (0-5) [13]

Grade	Per cent of plant tissue infected
0	No symptoms on the leaf
1	0-5% leaf area affected and covered by spot, no spot-on petiole and branches
2	6-20% leaf area infected and covered by spots on petiole
3	21-40% leaf area infected and covered by spot. Spots also seen on petiole and branches
4	41-70% leaf area infected and covered by spot. spots also seen on petiole, branches and stem
5	>71% leaf area affected and covered by spots. Spots also seen as petiole, branches, stem and fruits

Table C. Disease rating Scale (0-5)

Grade	Per cent of plant tissue infected
0	No symptoms on the leaf
1	10% leaves with lesions and minimal defoliation
2	25% leaves infected with slight defoliation
3	50% leaves infected with moderate defoliation
4	75% leaves infected with heavy defoliation
5	90 leaves infected with lesions and very high defoliation

Table D. Phytotoxicity estimation

Sl. No	Treatments	Dosage (g a.i./ha)	Formulation (ml/g/Litre)
1	Untreated control	-	-
2	Thiophanate methyl 44.8% + Kasugamycin 2.6% SC	1005.2	2500

Table E. Phytotoxic parameters were made in each treatment on the 1-10 grading scale

Phytotoxicity	Grade
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-80	8
81-90	9
91-100	10

3. RESULTS AND DISCUSSION

3.1 Bio-efficacy against Early Blight (*Alternaria solani*)

During 2017-18early blight did not differ significantly amongst the fungicidal treatments and control (PDI 7.78 to 8.89 %).Ten days after 1st and 2nd spray treatment, Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml/ha & 1250 ml/ha were effective in management of early blight with PDI of 8.15 and 7.78 respectively and 23% SC @ 500 ml/ha recorded significantly less PDI (7.96) in comparison to remaining fungicidal treatments and above three treatments were at par with each other. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha reduced 63.16 % disease intensity over control (Table 1).

During 218-19 early blight did not differ significantly among the fungicidal treatments and control with PDI (9.63 to 11.11%). Ten days after 1st and 2nd spray treatments, Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml/ha & 1250 ml/ha (10.56 and 10.19 PDI) and Azoxystrobin 23% SC @ 500 ml/ha recorded significantly less PDI (10.56) in comparison to remaining fungicidal treatments and above three treatments were at par with each other. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha reduced 58.33 % disease intensity over control (Table 2).

3.2 Bio-efficacy against Bacterial Leaf Blight (*Xanthomonas campestris*)

During 2017-18, pre-treatment PDI (2.96 to 4.07%) of Bacterial leaf blight did not differ significantly amongst the fungicidal treatments and control. Ten days after 1st spray and 2nd spray treatment, Thiophanate 44.8% + Kasugamycin 2.6% SC @ 1000 ml & 1250 ml/ha and Kasugamycin 3% SL @ 1250 ml/ha recorded significantly less PDI 3.96, 4.07 and 4.44 respectively in comparison to remaining fungicidal treatments and control. The above three fungicides were at par with each other. Thiophanate 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha recorded 65.48 % control of disease over control (Table 3).

During 2018-19, bacterial leaf blight PDI (1.48, 1.39 and 1.96%) was found to be significantly less in Thiophanate 44.8% + Kasugamycin 2.6% SC @ 1000 ml & 1250 ml/ha and Kasugamycin 3% SL @ 1250 ml/ha in comparison to remaining fungicidal treatments and control. The above three treatments were at par with each other. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha reduced 68.75 % disease intensity over control (Table 4).

3.3 Bio-efficacy against Powdery Mildew (*Erysiphe orontii*)

During 2017-18, powdery mildew PDI (1.85, 1.67 and 1.85%) was found to be significantly less in Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml & 1250 ml/ha and Flusilazole 40% EC @ 150 ml/ha in comparison to remaining fungicidal treatments and control. Three above treatments were at par with each other. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha recorded 71.88 % reduction in disease control over control (Table 5).

Table 1. Bio-efficacy evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against early blight (*Alternaria solani*) of tomato crop during 2017-18

Sr. No.	Treatments	Dose		Percent Disease Index (PDI)			Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha	Before spray	10 Days after 1st spray	10 Days after 2nd spray	
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	8.52 (16.95)	9.63 (18.06)	10.37 (18.77)	50.88
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	7.78 (16.16)	7.85 (16.24)	8.15 (16.54)	61.40
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	8.15 (16.57)	8.15 (16.57)	7.78 (16.16)	63.16
4.	Thiophanate methyl 70 % WP	500.0	715	7.78 (16.16)	8.89 (17.34)	10.37 (18.77)	50.88
5.	Kasugamycin 3 % SL	37.5	1250	8.89 (17.31)	10.00 (18.42)	13.33 (21.39)	36.84
6.	Azoxystrobin 23 % SC	125.0	500	8.52 (16.95)	8.70 (17.15)	7.96 (16.37)	62.28
7.	Flusilazole 40 % EC	60.0	150	7.41 (15.75)	10.37 (18.77)	14.81 (22.62)	29.82
8.	Untreated control	-	-	8.15 (16.57)	15.19 (22.92)	21.11 (27.33)	0.00
SEM ±				(0.560)	(0.344)	(0.537)	-
CD at 5 %				(NS)	(1.05)	(1.64)	-

**Average of three replications, Data in parenthesis are angular transformed value*

Table 2. Bio-efficacy Evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against Early blight (*Alternaria solani*) of tomato crop during 2018-19

Sr. No.	Treatments	Dose		Percent Disease Index (PDI)			Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha	Before spray	10 Days after 1st spray	10 Days after 2nd spray	
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	10.37 (18.77)	11.11 (19.46)	11.85 (20.12)	51.52
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	10.00 (18.41)	10.37 (18.77)	10.74 (19.11)	56.06
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	9.63 (18.06)	10.00 (18.42)	10.19 (18.60)	58.33
4.	Thiophanate methyl 70 % WP	500.0	715	10.37 (18.77)	11.48 (19.79)	12.59 (20.77)	48.48
5.	Kasugamycin 3 % SL	37.5	1250	10.74 (19.11)	12.96 (21.08)	14.44 (22.32)	40.91

Sr.	Treatments	Dose		Percent Disease Index (PDI)			Percent disease
		a.i. (g)/ha	Formulation (g or ml)/ha	Before spray	10 Days after 1st spray	10 Days after 2nd spray	
6.	Azoxystrobin 23 % SC	125.0	500	10.00 (18.41)	10.37 (18.77)	10.56 (18.94)	56.82
7.	Flusilazole 40 % EC	60.0	150	11.11 (19.46)	14.07 (22.01)	17.41 (24.64)	28.79
8.	Untreated control	-	-	10.74 (19.11)	16.30 (23.79)	24.44 (29.61)	0.00
SEM ±				(0.43)	(0.26)	(0.25)	-
CD at 5 %				(NS)	(0.79)	(0.76)	-

**Average of three replications, Data in parenthesis is angular transformed value*

Table 3. Bio-efficacy Evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against bacterial leaf blight (*Xanthomonas campestris*) of tomato crop during 2017-18

Sr. No.	Treatments	Dose		Percent Disease Index (PDI)			Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha	Before spray	10 Days after 1st spray	10 Days after 2nd spray	
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	4.07 (11.61)	4.81 (12.65)	5.19 (13.14)	54.84
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	3.33 (10.51)	3.52 (10.79)	4.07 (11.61)	64.52
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	3.70 (11.06)	3.89 (11.34)	3.96 (11.45)	65.48
4.	Thiophanate methyl 70 % WP	500.0	715	3.70 (11.06)	4.89 (12.76)	5.56 (13.63)	51.61
5.	Kasugamycin 3 % SL	37.5	1250	3.89 (11.34)	4.81 (12.65)	4.44 (12.15)	61.29
6.	Azoxystrobin 23 % SC	125.0	500	2.96 (9.86)	6.67 (14.96)	8.89 (17.34)	22.58
7.	Flusilazole 40 % EC	60.0	150	3.33 (10.41)	6.30 (14.51)	9.26 (17.70)	19.35
8.	Untreated control	-	-	3.89 (11.34)	8.52 (16.95)	11.48 (19.79)	0.00
SEM ±				(0.580)	(0.370)	(0.352)	-
CD at 5 %				(NS)	(1.13)	(1.07)	-

**Average of three replications, Data in parenthesis are angular transformed value*

Table 4. Bio-efficacy evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against bacterial leaf blight (*Xanthomonas campestris*) of Tomato crop during 2018-19

Sr. No.	Treatments	Dose		Percent Disease Index (PDI) at 10 Days after 2nd spray	Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha		
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	2.11 (8.34)	52.50
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	1.48 (6.88)	66.67
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	1.39 (6.69)	68.75
4.	Thiophanate methyl 70 % WP	500.0	715	2.41 (8.90)	45.83
5.	Kasugamycin 3 % SL	37.5	1250	1.96 (8.01)	55.83
6.	Azoxystrobin 23 % SC	125.0	500	3.89 (11.34)	12.50
7.	Flusilazole 40 % EC	60.0	150	3.70 (11.06)	16.67
8.	Untreated control	-	-	4.44 (12.15)	0.00
SEM ±		-	-	(0.45)	-
CD at 5 %		-	-	(1.40)	-

**Average of three replications, Data in parenthesis is angular transformed value*

Table 5. Bio-efficacy evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against Powdery mildew (*Erysiphe orontii*) of tomato crop during 2017-18

Sr. No.	Treatments	Dose		Percent Disease Index (PDI) at 10 Days after 2nd spray	Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha		
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	2.59 (9.21)	56.25
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	1.85 (7.72)	68.75
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	1.67 (7.42)	71.88
4.	Thiophanate methyl 70 % WP	500.0	715	2.78 (9.55)	53.13
5.	Kasugamycin 3 % SL	37.5	1250	4.44 (12.15)	25.00
6.	Azoxystrobin 23 % SC	125.0	500	2.78 (9.55)	53.13
7.	Flusilazole 40 % EC	60.0	150	1.85 (7.72)	68.75
8.	Untreated control	-	-	5.93 (14.08)	0.00
SEM ±				(0.557)	-
CD at 5 %				(1.70)	-

**Average of three replications, Data in parenthesis are angular transformed value*

Table 6. Bio-efficacy evaluation of Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC against Powdery mildew (*Erysiphe orontii*) of tomato crop during 2018-19

Sr. No.	Treatments	Dose		Percent Disease Index (PDI) at 10 Days after 2nd spray	Percent disease control
		a.i. (g)/ha	Formulation (g or ml)/ha		
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	3.33 (10.51)	52.63
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	2.59 (9.25)	63.16
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	2.50 (9.06)	64.47
4.	Thiophanate methyl 70 % WP	500.0	715	3.24 (10.36)	53.95
5.	Kasugamycin 3 % SL	37.5	1250	5.93 (14.07)	15.79
6.	Azoxystrobin 23 % SC	125.0	500	3.33 (10.51)	52.63
7.	Flusilazole 40 % EC	60.0	150	2.67 (9.39)	62.11
8.	Untreated control	-	-	7.04 (15.37)	0.00
SEM ±		-	-	(0.33)	-
CD at 5 %		-	-	(1.02)	-

**Average of three replications, Data in parenthesis is angular transformed value*

Table 7. Impact of different fungicidal treatments on tomato yield (q/ha) during 2017-18

Sr. No.	Treatments	Dose		Yield (q/ha)	Yield percent increase over control
		a.i. (g)/ha	Formulation (g or ml)/ha		
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	328.00	8.49
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	339.33	12.24
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	340.33	12.57
4.	Thiophanate methyl 70 % WP	500.0	715	319.00	5.51
5.	Kasugamycin 3 % SL	37.5	1250	317.00	4.85
6.	Azoxystrobin 23 % SC	125.0	500	313.33	3.64
7.	Flusilazole 40 % EC	60.0	150	312.33	3.31
8.	Untreated control	-	-	302.33	0.00
SEM ±				1.302	-
CD at 5 %				3.98	-

Table 8. Impact of different fungicidal treatments on tomato yield (q/ha)

Sr. No.	Treatments	Dose		Yield (q/ha)	Yield percent increase over control
		a.i. (g)/ha	Formulation (g or ml)/ha		
1.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	301.6	750	321.33	11.96
2.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	402.1	1000	332.00	15.68
3.	Thiophanate methyl 44.8 % + Kasugamycin 2.6 % SC	502.6	1250	333.33	16.14
4.	Thiophanate methyl 70 % WP	500.0	715	317.00	10.45
5.	Kasugamycin 3 % SL	37.5	1250	315.00	9.76
6.	Azoxystrobin 23 % SC	125.0	500	313.00	9.06
7.	Flusilazole 40 % EC	60.0	150	315.33	9.87
8.	Untreated control	-	-	287.00	0.00
SEM ±				1.13	-
CD at 5 %				3.46	-

Table 9. Phytotoxic effect of Thiophanate methyl 44.8% + Kasugamycin 2.6%Sc @ 2500 ml/ha on tomato during 2017-18

Treatments	Dose (g or ml/ha)	Score Values on																																							
		0 DAA						1 DAA						3 DAA						5 DAA						7 DAA						10 DAA						15 DAA					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
T_9	2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Untreated control	----	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

T_9: Thiophanate methyl 44.8% + Kasugamycin 2.6% SC
A: Epinasty; B: Hyponasty; C: Chlorosis; D: Necrosis; E: Leaf vein clearing; F: Stunting
DAA: Days After Application

During 2018-19 powdery mildew PDI (2.59, 2.50 and 2.67 %) was found to be significantly less in Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml & 1250 ml/ha and Flusilazole 40% EC @ 150 ml/ha in comparison to remaining fungicidal treatments and control. The above three treatments were at par with each other. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1250 ml/ha reduced 64.47 % disease intensity over control (Table 6).

3.4 Yield (q/ha)

Thiophanate methyl 44.8% + Kasugamycin 2.6% SC during 2017-18 @ 1000 ml & 1250 ml/ha recorded significantly more fruit yield in comparison to remaining fungicidal treatments and control. Both treatments were at par with each other and recorded 12.24% to 12.57% increase in fruit yield (Table 7).

During the 2nd season (2018-19) experiment, again the three diseases- Early blight (*Alternaria solani*), Bacterial leaf spot (*Xanthomonas campestris*) and Powdery mildew (*Erysiphe orontii*) were encountered. Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 ml and 1250 ml/ha recorded significantly more fruit yield in comparison to remaining fungicidal treatments and control. Both treatments recorded 15.68% to 16.14% increase in fruit yield (Table 8).

3.5 Phytotoxicity

Two sprays of Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 750 ml, 1000 ml, 1250 ml and 2500 ml/ha and other check fungicides were done on the tomato crop during 2017-18 and 2018-19 and no phytotoxic symptoms *viz*., Epinasty, Hyponasty, Chlorosis, Necrosis, Vein clearing and Stunting were observed in any of the treatments (Table 9).Development of resistance is a major concern any time antibiotics are used routinely hence combination of fungicide and bactericide was used. Thiophanate methyl + Kasugamycin was very effective in management of diseases of tomato. Similar results were obtained by Archana and Jamadar [16] where they found that thiophanate methyl was very effective in the management of Alternaria blight of pomegranate followed by propiconazole. Kasugamycin provided a level of bacterial spot control on tomato in field trials. The results were in agreement with earlier work of Vallad et al. [17].Many researchers have reported the usefulness of antibiotics against BLB disease. Singh et al. [18] stated the encouraging effect of antibiotics in suppression of causal pathogen of rice bacterial blight i.e. Agrimycin 500, Brestanol, Agric. Teramycin 17 and mixture of Cytoxan + Agrimycin 100. Likewise, Khan et al. [19] achieved the suppression of *Xanthomonas oryzae* pv *oryzae* colonies during *invitro* studies by using the antibiotics (Kasugamycin, Benzylpenicillin, Ampicillin, Kanamycin, Streptomycin, Chloramphenicol and Sinobionic). Thiophanate methyl + Kasugamycin would give growers an alternative to copper-based bactericides for the management of bacterial spot, especially in areas where copper-tolerant Xanthomonas strains are problematic, and could possibly be alternated with copper + mancozeb as part of an integrated program to manage bacterial spot because aminoglycoside antibiotic Kasugamycin targets the bacterial ribosome and thiophanate methyl is a tubulin inhibitor fungicide falling into the FRAC Group 1 for Benzimidazoles. Its Mode of Action is the inhibition of microtubule assembly. It has protectant, systemic and curative actions, each of these specific to certain crops, fungi and climatic conditions.

4. CONCLUSION

Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 1000 and 1250 ml/ha recorded significantly less Per cent Disease Index (PDI) of Early blight (*Alternaria solani*), Bacterial leaf spot (*Xanthomonas campestris*) and Powdery mildew (*Erysiphe orontii*) and recorded significantly more fruit yield in comparison to remaining fungicidal treatments. No Phytotoxicity of Thiophanate methyl 44.8% + Kasugamycin 2.6% SC @ 2500 ml/ha was observed to tomato crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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