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Management of stem-end rot disease of sweet orange caused by *Colletotrichum gloeosporioides*

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ABSTRACT

Among the most important fruit crops in Maharashtra, sweet orange [*Citrus sinensis* (L) Osbeck] holds a distinctive position. It is third largest crop industry in India after mango and banana. Sweet orange is known to be affected by several fungal diseases. Recently, the pre-harvest fruit drop caused by *Colletotrichum gloeosporioides*, has become severe which affects the marketable fruit yields of sweet orange in Maharashtra state. The purpose of the current study was to evaluate the effectiveness of novel fungicides and bio-agent molecules against stem-end rot of sweet orange. Among three sprays applied at monthly interval, after every spray, all the treatments showed significant reduction in per cent fruit drop over untreated control. The treatment thiophanate methyl @ 0.7 g per litre, resulted in lowest fruit drop (4.33%) as compared to 9.72 per cent in control after third spray. This treatment was at par with treatment carbendazim + mancozeb 75 WP @ 2.5 g per litre during first and second spray. Treatment thiophanate methyl @ 0.7 g per litre also recorded highest fruit yield of 45.44 kg per plant at par with carbendazim + mancozeb 75 WP @ 2.5 g per litre (43.43 kg/plant) and difenoconazole 25 WP @ 0.5 ml per litre (40.20 kg/plant). Maximum net return of Rs 1,77,880 was recorded in treatment thiophanate methyl @ 0.7 g per litre with highest B-C ratio of 1:2.30 among all the treatments.

Keywords: Sweet orange; stem-end rot; fungicides; fruit drop; yield; economics

INTRODUCTION

Citrus fruits, which are members of the genus *Citrus* and family Rutaceae, are historically been known for their nutritional and medicinal benefits. One of India's most important fruit crops, citrus is among the most well-known and widely cultivated tropical and sub-tropical fruits. It contributes significantly to India's income and economy being the country's third-largest fruit industry after mango and banana. The sweet orange is the most important species among those belonging to the *Citrus* genus, representing about 50 per cent of global citrus production (Seminara et al 2023). One of the most significant and well-known states for producing high quality citrus fruits, including sweet oranges, Nagpur mandarins, acid limes etc is the Maharashtra state. The major sweet orange growing districts in Maharashtra are Amravati, Nagpur, Jalna, Aurangabad, Beed and Nanded. In Maharashtra, the total area under sweet orange cultivation was 55.18 thousand hectares with annual production of 684.80 thousand MT in 2017-18 (Anon 2019).

Citrus yield is threatened by pre- and post-harvest fungal diseases, which can cause heavy reductions in production and commercialization worldwide. Among these diseases, citrus anthracnose caused by *Colletotrichum* species, is one of the 10 most important plant pathogenic fungi in the world (Dean et al 2012) which has become an economically important citrus disease and represents a serious threat for orange production at all the growing stages, inducing various types of disease symptoms (Guarnaccia et al 2017).

Pre-harvest fruit falling, as a result of pre-harvest illness, causes Nagpur mandarin fruit losses of over 22 per cent (Sharma et al 2011). Moreover, it lowers the market value and commands little to no price in the market. The main tool for managing plant diseases is the application of fungicides. The issue of citrus pathogen resistance to certain agrochemicals was caused by the prolonged use of certain agro-chemicals (Ladaniya 2008). The need to test new fungicides against *Colletotrichum gloeosporioides* causing stem-end rot has arisen due to the resistance of fungal infections to antifungal chemicals. Hence, efforts were made to investigate the performance of different novel fungicides and bio-agent molecules against the stem-end rot of oranges in the field.

MATERIAL and METHODS

The field trials were conducted for four consecutive crop seasons (2018-19 to 2021-22) to check the efficacy of new molecules of fungicides and bio-agents against stem-end rot of sweet orange (Plates 1 and 2) at AICRP on Fruits, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. About 15 year-old plants having uniform canopy were selected for the present experiment. The experiment was laid out in randomized block design with three replications and nine treatments viz T_1 (Carbendazim + mancozeb 75%WP @ 2.5 g/l), T_2 (Difenoconazole 25 WP @ 0.5 ml/l), T_3 (Chlorothalonil 75 WP @ 2 g/l), T_4 (Tebuconazole 25 EC @ 0.5 ml/l), T_5 (Thiophanate methyl 70 WP @ 0.7 g/l), T_6 (Bordeaux mixture @ 1%), T_7 (*Trichoderma viride* @ 5 g/l), T_8 (*Pseudomonas fluorescence* @ 5 g/l) and T_9 (Unsprayed control). The fungicides and bio-agents were sprayed on the leaves three times at monthly interval from July to September. Two plants per treatment were maintained and recommended agronomical package of practices was followed for getting the quality production of the crop. The observations on fruit drop were recorded after each spray. On each plant, rotten fruits were observed from the first spray to the last harvest. The fruits were picked after they were fully developed and fruit yield per plant was recorded. Statistical analysis was done as per Panse and Sukhatme (1985). The benefit-cost ratio of various treatments was also assessed.

RESULTS and DISCUSSION

Effect of treatments on fruit drop: The pooled mean data of four years (2018-19 to 2021-22) on fruit drop of sweet orange as influenced by different fungicide and bio-agent treatments are presented in Table 1. After first spray, all the treatments showed significant reduction in fruit drop over untreated control. The treatment T_5 (Thiophanate methyl @ 0.7g/l) and T_1 (Carbendazim + mancozeb 75 WP) resulted in lowest fruit drop of 6.67 and 7.22 per cent respectively, which were at par as compared to 10.55 per cent in T_9 (Unsprayed control). After second spray, lowest fruit drop of 5.50 and 5.95 per cent was observed in T_5 and T_1 respectively, which were at par in contrast to 12.00 per cent in T_9. After third spray, lowest fruit drop was observed in T_5 (4.33%) followed by 5.11 and 5.50 per

Table 1. Fruit drop in sweet orange due to the application of fungicides and bio-agents against stem-end rot (pooled mean of 3 years)

Treatment	Fruit drop (%)		
	After 1st spray	After 2nd spray	After 3rd spray
T_1: Carbendazim + mancozeb 75 WP @ 2.5 g/l	7.22 (3.25)	5.95 (2.98)	5.11 (2.88)
T_2: Difenoconazole 25 WP @ 0.5 ml/l	8.00 (3.38)	7.11 (3.30)	5.89 (3.05)
T_3: Chlorothalonil 75 WP @ 2 g/l	7.67 (3.32)	7.00 (3.25)	5.50 (2.95)
T_4: Tebuconazole 25 EC @ 0.5 ml/l	8.00 (3.38)	6.64 (3.23)	6.22 (3.09)
T_5: Thiophanate methyl 70 WP @ 0.7 g/l	6.67 (3.16)	5.50 (2.95)	4.33 (2.70)
T_6: Bordeaux mixture @ 1%	8.22 (3.42)	7.83 (3.39)	6.44 (3.15)
T_7: *Trichoderma viride* @ 5 g/l	8.89 (3.51)	8.72 (3.52)	7.44 (3.31)
T_8: *Pseudomonas fluorescence* @ 5 g/l	8.11 (3.42)	7.72 (3.39)	6.66 (3.19)
T_9: Unsprayed control	10.55 (3.84)	12.00 (4.04)	9.72 (3.69)
SE(±)	0.03	0.04	0.02
$CD_{0.05}$	0.10	0.13	0.08
CV	2.13	2.67	1.86

Figures in parentheses are angular transformed values cent in T_1 and T_3 (Chlorothalonil 75 WP @ 2 g/l) respectively, the latter two being at par, as compared to 9.72 per cent in control. Thus the fruit drop decreased with the increase in number of sprays. Among bio-agents, T_8 (*Pseudomonas fluorescence* @ 5 g/l) and T_7 (*Trichoderma viride* @ 5 g/l) were at par and resulted in 8.11 and 8.89 per cent fruit drop after first spray and 7.72 and 8.72 per cent fruit drop after second spray respectively. After third spray, T_8 proved superior over T_7 with 6.66 and 7.44 per cent fruit drop respectively.

Effect of treatments on fruit yield: The data presented in Table 2 depict that the treatments T_5 (45.44 kg/plant), T_1 (43.43 kg/plant) and T_2 (Difenoconazole 25 WP @ 0.5 ml/l) (40.20 kg/plant) recorded maximum fruit yield, which were at par, in contrast to 27.74 kg per plant in T_9. Bio-agent treatments, T_7 and T_8 proved at par with T_3, T_6 (Bordeaux mixture @ 1%) and T_4 (Tebuconazole 25 EC @ 0.5 ml/l) with 31.55, 33.42, 36.02 and 36.98 kg per plant fruit yield respectively.

Economics of use of treatments against end-rot disease: Maximum net return of Rs 1,77,880 was recorded in treatment T_5 with highest B-C ratio of 2.30 as compared to rest of the treatments followed by T_1 with net return of Rs 1,62,870 and B-C ratio of 2.18 as compared to minimum net return of Rs 61,185 and B-C ratio 1.47 recorded in T_9 (Unsprayed control) (Table 3).

Beniwal et al (2018) reported that out of six fungicides, spray schedules comprising copper oxychloride (0.3%), carbendazim (0.1%), copper oxychloride (0.3%) and thiophanate methyl (0.1%) proved significantly superior to rest of the fungicide treatments and control in controlling the post-harvest

Table 2. Effect of different fungicides and bio-agents on fruit yield of sweet orange

Treatment	Fruit yield (kg/plant)					Yield (tonnes/ha)
	2018-19	2019-20	2020-21	2021-22	Pooled	
T_1: Carbendazim + mancozeb 75 WP @ 2.5 g/l	49.81	38.45	50.53	34.93	43.43	12.03
T_2: Difenoconazole 25 WP @ 0.5 ml/l	46.03	37.22	46.69	30.88	40.20	11.13
T_3: Chlorothalonil 75 WP @ 2 g/l	42.77	33.75	43.49	32.72	38.18	10.57
T_4: Tebuconazole 25 EC @ 0.5 ml/l	39.76	35.36	40.48	32.32	36.98	10.24
T_5: Thiophanate methyl 70 WP @ 0.7 g/l	50.40	43.71	51.23	36.43	45.44	12.58
T_6: Bordeaux mixture @ 1%	39.52	35.87	40.27	28.43	36.02	9.98
T_7: *Trichoderma viride* @ 5 g/l	33.09	31.23	33.84	28.05	31.55	8.74
T_8: *Pseudomonas fluorescence* @ 5 g/l	35.60	32.25	36.21	29.65	33.42	9.25
T_9: Unsprayed control	30.13	25.31	30.85	24.69	27.74	7.68
SE(±)	2.56	1.85	2.52	1.73	1.12	0.31
$CD_{0.05}$	7.60	5.50	7.59	5.13	3.29	0.91
CV	10.89	9.25	10.69	9.70	6.06	6.00

Table 3. Economics of management of stem-end rot of sweet orange using different fungicides and bio-agents

Treatment	Yield (tonnes/ha)	Gross return (Rs)	Cost of production (Rs)	Net return (Rs)	B-C ratio
T_1: Carbendazim + mancozeb 75%WP @ 2.5 g/l	12.03	3,00,750	1,37,880	1,62,870	2.18
T_2: Difenoconazole 25 WP @ 0.5 ml/l	11.13	2,78,250	1,39,605	1,38,645	1.99
T_3: Chlorothalonil 75 WP @ 2 g/l	10.57	2,64,250	1,41,375	1,22,875	1.87
T_4: Tebuconazole 25 EC @ 0.5 ml/l	10.24	2,56,000	1,37,295	1,18,705	1.86
T_5: Thiophanate methyl 70 WP @ 0.7 g/l	12.58	3,14,500	1,36,620	1,77,880	2.30
T_6: Bordeaux mixture @ 1%	9.98	2,49,500	1,40,415	1,09,085	1.78
T_7: *Trichoderma viride* @ 5 g/l	8.74	2,18,500	1,37,415	81,085	1.59
T_8: *Pseudomonas fluorescence* @ 5 g/l	9.25	2,31,250	1,41,240	90,010	1.64
T_9: Unsprayed control	7.68	1,92,000	1,30,815	61,185	1.47

Plate 1. Fruit drop in sweet orange due to stalk-end rot

Plate 2. Stalk-end rot of sweet orange

fruit decay. The microbial counts were found significantly lowest in copper oxychloride (0.3%) and carbendazim (0.1%) followed by copper oxychloride (0.3%) and mancozeb (0.2%) as compared to control.

Ritenour et al (2004) reported that benomyl and thiophanate-methyl significantly reduced stem-end rot of Florida citrus after storage, with an average of 65 per cent less decay compared to the control. Though benomyl significantly reduced anthracnose (*C gloeosporioides*) in two of four tests with substantial (>20%) infection and phosphorus acid significantly reduced it once; thiophanate-methyl did not significantly reduce the incidence of anthracnose post-harvest. The data suggested that pre-harvest application of thiophanate-methyl might reduce post-harvest stem-end rot and total decay similar to pre-harvest benomyl treatments.

Salvatore and and Ritenour (2007) reported that compared to control (unsprayed) fruit, pre-harvest application of benomyl (Benlate) or thiophanate-methyl (Topsin) most often resulted in significantly more healthy citrus fruits and less decay from stem-end rot after storage, often reducing total decay by about half. Pyraclostrobin (Headline), pyraclostrobin + boscalid (Pristine) and phosphorus acid (Phostrol) only occasionally reduced decay from stem-end rot or anthracnose.

Zhang and Timmer (2007) evaluated five fungicides, benomyl, thiophanate methyl, azoxystrobin, fludioxonil and pyraclostrobin applied 2, 14, 21, and 28 days before harvest for control of post-harvest anthracnose, stem-end rot and green mould on early season Florida Fallglo and Sunburst tangerine hybrids in 2003 and 2004. Most fungicides significantly reduced anthracnose incidence on Fallglo when applied 2 days before harvest in both the years and at 14 and 21 days before harvest in 2003. At other application dates, none of the fungicides was effective. On Fallglo fruit in 2004, the five tested fungicides reduced post-harvest anthracnose by 37.4-62.6 per cent when sprayed 2 days before harvest. In both cultivars and in both years, benomyl and thiophanate methyl consistently and significantly reduced stem-end rot incidence.

Sharma et al (2011) reported that the spray treatment of prochloraz was superior in controlling the pre-harvest stem-end rot of Kinnow fruits which was the same with carbendazim. These spray treatments allowed just 5.41 and 6.61 per cent rot incidence respectively as compared to 18.47 per cent in control. Under these treatments 70.71 and 61.24 per cent reduction in rot incidence was recorded over control. The spray treatment of prochloraz provided maximum fruit yield of 185.55 kg per plant which was statistically at par with the spray treatment of carbendazim (175.65 kg/plant). The spray treatments of carbendazim 12 per cent + mancozeb 63 per cent (Saaf) and thiophanate methyl were next in order of efficacy which rendered at par fruit yield of 164.93 and 158.60 kg per plant respectively. Low to moderate fruit yield of 146.02, 143.10, 121.20, 111.18 and 97.15 kg per plant was obtained accordingly under the spray treatments of mancozeb, copper oxychloride, propineb, captan and calcium nitrate, however, these fruit yields were significantly higher to control (76.02 kg/plant). The study of benefit-cost ratio revealed that spray of carbendazim 12 per cent + mancozeb 63 per cent (Saaf) was the most economically viable for controlling stem-end rot and gave highest B-C ratio of 12.2:1. Fungicides like mancozeb, carbendazim and prochloraz were followed in terms of B-C ratio which rendered 11.9:1, 10.5:1 and 9.1:1 ratio respectively. Lowest B-C ratio was recorded under the treatment of calcium nitrate (1.5:1) and captan (3.0:1).

Sharma and Gaur (2021) found that sprays of copper hydroxide at 0.2 and 0.15 per cent concentration proved significantly superior over rest of the treatments in reducing stem-end rot incidence in fruits. The per cent fruit rot at these spray concentrations (0.2 and 0.15%) was 3.87 and 6.01 per cent respectively as compared to 29.08 per cent under control. Maximum fruit yield was obtained under 0.2 per cent dose of copper hydroxide which was at par with 0.15 per cent dose of it.

Lombardo et al (2023) tested the efficacy of mineral fertilizers-based Kiram and Vitibiosap 458 Plus, citrus essential oil-based Prev-Am Plus and chitosan-based Biorend in open field trials, in naturally infected citrus fruits. In these trials, Biorend was the best alternative product, significantly reducing disease incidence (71% reduction).

CONCLUSION

Based on the outcome of the investigations, it can be concluded that all the treatments showed significant reduction in per cent fruit drop over untreated control. The treatment thiophanate methyl @ 0.7 g per litre, resulted in lowest fruit drop. This treatment also recorded highest fruit yield of 45.44 kg per plant at par with carbendazim + mancozeb 75 WP @ 2.5 g per litre (43.43 kg/plant) and difenoconazole 25 WP @ 0.5 ml per litre (40.20 kg/plant). Maximum net return of Rs 1,77,880 was also recorded in treatment thiophanate methyl @ 0.7 g per litre with highest B-C ratio of 2.30 among all the treatments. Thus this treatment can be recommended for control of stem-end rot disease of sweet orange.

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