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Efficacy of different fungicides, botanicals, nano-formulations and bio-control agents against *Colletotrichum siamense* causing fruit drop in Kinnow mandarin

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ABSTRACT

Fruit drop (*Colletotrichum siamense*) in Kinnow mandarin is a major problem causing quantitative and qualitative losses, globally to the growers. Keeping in view, an attempt has been made to manage the disease by various systemic and non-systemic fungicides, botanicals, nano-formulations and bio-control agents under *in vitro* conditions. The field evaluation of different treatments was also carried out at Fruit Research farm, Punjab Agricultural University, Ludhiana on Kinnow trees during 2021 and 2022. Among various treatments evaluated for their inhibitory effect on the mycelial growth of *Colletotrichum siamense*, azoxystrobin 18.2% + difenoconazole 11.4% SC and propiconazole 25% EC proved to be the most effective by inhibiting 100 % and 88.33% mycelial growth at 25 ppm concentration, respectively. Among, non-systemic fungicides copper oxychloride 50% WP exhibited 100% mycelial growth inhibition at 1000 ppm concentration. In case of botanicals and bio-control agents, maximum mycelial growth inhibition was shown by neem extract (47.96%) and *T. harzianum* (55.12%), respectively while the nano-formulations were found least effective in inhibiting the growth of the pathogen under *in-vitro* conditions. Under field conditions, the fungicides treatment of azoxystrobin 18.2% + difenoconazole 11.4% SC (63.81%) and propiconazole 25% EC (59.12%) were significantly effective in reducing per cent fruit drop over control while neem extract (33.61%) was at par with *T. harzianum* (33.41%) during the two consecutive years. Thus, these disease management strategies could be further incorporated in the IDM programmes for effective management of fruit drop in Kinnow mandarin.

Key words: Kinnow mandarin, anthracnose, *Colletotrichum siamense*, fungicides, botanicals, bio-control agents, nano-formulations, management

Citrus, a member of family Rutaceae, is a perennial plant that have been cultivated across the world from long period of time mostly in tropical and sub-tropical regions of Southern Asia and Northeastern Australia (Savita *et al.,* 2012). It includes fruits such as mandarins, sweet oranges, limes, grapefruit, lemons, sweet lime, pumelos, tangerines, kumquats etc. In Punjab citrus ranks first on the basis of area and production followed by guava and mango (Anonymous, 2021a). Kinnow is a hybrid developed by crossing two cultivars of mandarin i.e King (*Citrus nobilis)* x Willow leaf (*Citrus deliciosa*) (Hui *et al.,* 2006). Because of the favourable agro-ecological conditions, Punjab is the leading Kinnow producing state in India covering an area of 55,470 hectares with yearly production of 13,12,425 MT (Anonymous, 2021b).

Despite of the high nutritive value, the commercial cultivation of Kinnow mandarin is adversely affected by various biotic and abiotic factors, among which pre-harvest fruit drop is one of the major problems in all the regions of the world like Argentina, Brazil, Mexico and the United States (Kuramae *et al.,* 1997; McMillan and Timmer, 1989; Santos and Garza, 1986; Schwarz *et al.,* 1978) and India as well (Bhullar, 1978) thus leading to enormous quantitative yield losses. Pathological fruit drop, caused by different

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species of *Colletotrichum* is a major bottleneck causing reduction in yield and quality of harvested produce. The fungus belongs to order *Melanconiales,* a facultative parasite. It is widely distributed plant pathogen in the world and is more common in tropical and subtropical regions than temperate regions (CABI, 2005). The pathogen generally stays inactive in dry season, but the disease incidence increases under warm and humid weather conditions. The initial symptoms appear on trees such as drying of twigs from the tip downwards. Further, infection on stalk-end of the fruit appears in the form of circular, small, light-brown lesions. When the infected area expands, a soft pliable dark brown rot occurs which leads to pre-mature fruit drop (Fig. 1).

Fig. 1. Symptoms of fruit drop in Kinnow mandarin

No doubt for management of this disease application of suitable combination of plant growth regulators (El-Otmani, 1992; Monselise and Goren, 1978), macro- and micro- nutrients (Doberman and Fairhurst, 2000; Rodríguez *et al.,* 2005; Saleem *et al.,* 2005) and different fungicides have proved effective (Kumar and Garg, 2012; Patil and Ingle, 2011) but a search for economically viable and eco-friendly strategy for its management is more desirable as mere use of fungicides can adversely affect the environment and human health as well. Keeping in view the devastating potential of the disease, the present study was conducted to manage pathological fruit drop in Kinnow mandarin by using various fungicides, botanicals, nano-formulations and bio-control agents. The research trials were carried out both under *in vitro* and *in vivo* conditions.

MATERIALS AND METHODS

In vitro efficacy of fungicides, botanicals, nano-formulations and bio-control agents against *Colletotrichum siamense*

The fungus isolated from the infected fruit samples of Kinnow mandarin was identified as *Colletotrichum siamense* after molecular confirmation. The ITS, *ACT* and *TUB2* sequences were deposited in GenBank as accession numbers OQ857285, OQ888798, OQ888802, OQ888842, OQ983464, OQ983465, OQ983466, OQ983467 (Kaur, 2023).

Five systemic fungicides treatments *viz*., tebuconazole 50% + trifloxystrobin 25%WG, azoxystrobin 18.2% + difenoconazole 11.4% SC, carbendazim 12% + mancozeb 63%WP, propiconazole 25% EC and zineb 68% + hexaconazole 4% WP (@ 5, 10, 25, 50, 100 and 200 ppm); three non-systemic fungicides *viz*., zineb 75% WP, mancozeb 75% WP and copper oxychloride 50% WP (@50, 100, 200, 500 and 1000 ppm); three botanicals *viz.,* neem extract (leaves, tender branches and fruits), garlic extract (clove) and mustard oil (seeds) @ 5,10 and 15%; two different metal and metal oxide nano-formulations *viz.,* copper and silver @ 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 ppm and lastly two bio-control agents *viz., Trichoderma harzianum* and *Pseudomonas fluorescens* were evaluated under *in vitro* conditions. The bio-control agents, botanicals and nano-formulations were procured from Department of Plant Pathology, School of Organic Farming and Department of Soil Science, PAU, Ludhiana, respectively. *In vitro* evaluation of the chemicals, botanicals and nano-formulations was done using Poisoned food technique (Nene and Thapliyal, 1993), while the bio-control agents were evaluated for their efficacy using dual culture technique (Skidmore and Dickinson, 1976). Each of different concentrations of test chemicals were mixed with 100 ml of double-strength potato dextrose agar (PDA) medium. After the mixing of agar and test chemicals, approximately 15-20 ml of poisoned PDA medium was poured into Petri plates of 90 mm diameter. Circular bits (5 mm) were cut from the periphery of the actively growing fungal culture and were placed aseptically in the centre of each Petri plate. The Petri plates having non-poisoned PDA medium served as control. After inoculation the Petri plates were incubated at 25±2°C and the colony growth of pathogen was recorded until the growth in the control Petri plate was full (90 mm). Per cent growth inhibition in colony was calculated at each concentration by the formula given by Vincent (1947).

$$PDI = \frac{C-T}{C} \times 100$$

Where,

C = Colony radial growth in control (mm)
T = Colony radial growth in test concentration

Field evaluation of fungicides, botanicals and bio-control agents against fruit drop in Kinnow mandarin

Five systemic fungicides *viz.,* tebuconazole (50%) + trifloxystrobin (25%WG), azoxystrobin (18.2%) + difenoconazole (11.4% SC), carbendazim (12%) + mancozeb (63%WP), propiconazole (25% EC) and zineb (68%) + hexaconazole (4% WP); three non-systemic fungicides *viz.,* zineb (75% WP), mancozeb (75% WP) and copper oxychloride (50% WP); three botanicals *viz.,* garlic extract, mustard extract, neem extract and two bio-control agents that is *Trichoderma harzianum* and *Pseudomonas fluorescens* were evaluated as foliar spray against fruit drop in Kinnow mandarin. The nan-formulations were not found promising under *in vitro* studies, so were not included under field trails. The experiment was conducted at Fruit research farm, Department of fruit Science, Punjab Agricultural University, Ludhiana on Kinnow trees during 2021 and 2022 in randomized block design (RBD) with three replications per treatment. Five sprays of each treatment were given starting from mid-April, end July, mid-August, mid-September and at end of September. Water sprayed plants were kept as control. Along with this, sprays of Gibberellic acid (GA_3) @ 20 mg/l were also applied in mid-April, mid-August and mid-September. The number of fruits dropped in each treatment were counted starting from July till November at 10 days interval. Per cent fruit drop and per cent reduction in fruit drop were calculated using following formulas:

$$\text{Per cent fruit drop} = \frac{\text{Number of fruits dropped}}{\text{Number of total fruits harvested}} \times 100$$

$$\text{Reduction in fruit drop over control (\%)} = \frac{C-T}{C} \times 100$$

Where,

C= Fruit drop in control
T= Fruit drop in treatment

The data recorded in the laboratory experiments was statistically analysed using completely randomized design (CRD) and that of field experiments was analysed using the randomized block design (RBD) with computer programme CPCS1 and analysis of variance (ANOVA) was also calculated. In case of *in-vitro* evaluation of fungicides, ED_{50} and ED_{90} values were also determined by probit analysis. Data collected from each experiment was also analysed statistically by Duncan multiple range test (DMRT) using the software programme IBM SPSS 26.0.

RESULTS AND DISCUSSION

In vitro* efficacy of fungicides, botanicals, nano-formulations and bio-control agents against *Colletotrichum siamense

Evaluation of five systemic fungicides *viz.*, tebuconazole 50% + trifloxystrobin 25%WG, azoxystrobin 18.2% + difenoconazole 11.4% SC, carbendazim 12% + mancozeb 63%WP, propiconazole 25% EC and zineb 68% + hexaconazole 4% WP done against *C. siamense* at different concentrations (5, 10, 25, 50, 100 and 200 ppm) using poison food technique revealed that all systemic fungicides varied significantly at different concentrations in terms of mean per cent growth inhibition of *C. siamense*. It is evident from the results presented in Table 1 that, azoxystrobin 18.2% + difenoconazole 11.4% SC was found to be most effective in inhibiting 100% growth of the pathogen at 25 ppm concentration (Fig.2a) followed by propiconazole 25% EC (Fig.2b) and tebuconazole 50% + trifloxystrobin 25% WG both with 100% inhibition at 100 ppm. Zineb 68%+ hexaconazole 4% WP and carbendazim 12% + mancozeb 63% WP inhibited the growth of pathogen upto 91.66% and 84.25% at 100 ppm, respectively. ED_{50} and ED_{90} values determined using the probit analysis showed that azoxystrobin 18.2% + difenoconazole 11.4%SC and propiconazole 25 EC were found to be highly effective having ED_{50} value less than 5µl/ml and ED_{90} values less than 25µl/ml as calculated by probit analysis (Table 1).

Similar results were discussed by Elshahawy

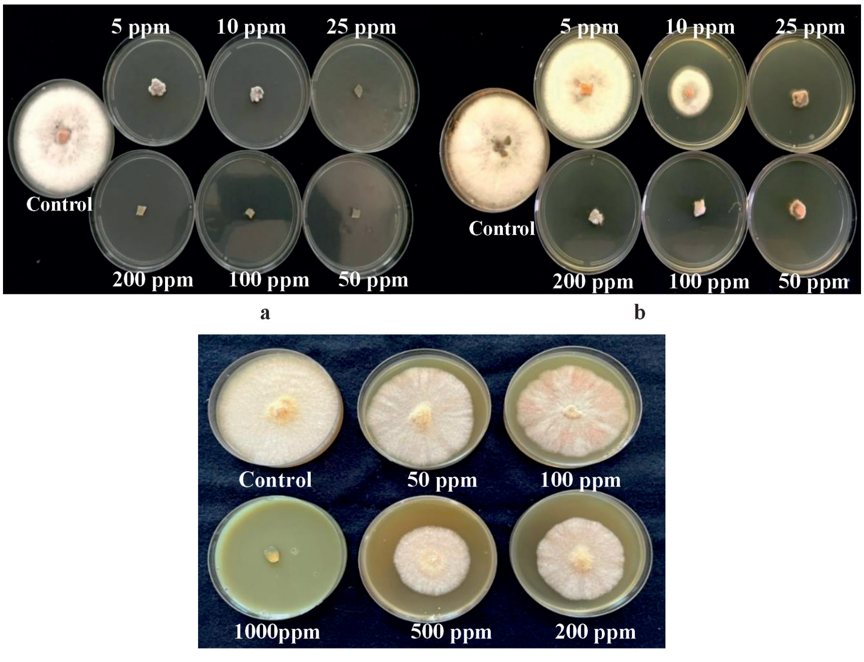

Fig. 2. ***In vitro*** **efficacy of (a) Azoxystrobin 18.2% + difenoconazole 11.4% SC (b) Propiconazole 25% EC (c) Copper oxychloride 50% WP against** ***Colletotrichum siamense***

and Darwesh (2023) where complete inhibition of colony growth of *C.gloeosporioides* was done by difenoconazole + azoxystrobin at 15 ppm concentration. Similarly, Malipatil *et al.* (2021) reported that difenconazole 25% EC, propiconazole 25% EC and tryfloxystrobin 25% + tebuconazole 50% completely inhibited the growth of *C. gloeosporioides* causing mango anthracnose. Mahesh *et al.* (2020) also reported that complete growth inhibition was shown by difenoconazole 25 EC at all concentrations *viz.,* 500, 1000 and 1500 ppm. Shivakumar *et al.* (2018) observed that propiconazole 25% EC was successful in completely (100%) inhibiting the growth of *C. gloeosporioides* causing mango anthracnose at all concentrations *viz.,* 0.025, 0.05, 0.1 and 0.15%. Similarly, Ranjitha *et al.* (2019) reported that propiconazole gave complete inhibition (100%) of *Colletotrichum* at all concentrations,

Table 1. ***In vitro*** **efficacy of systemic fungicides against** ***Colletotrichum siamense***

Fungicide	Per cent mycelial growth inhibition at different concentrations (ppm)*							
	5	10	25	50	100	200	ED$_{50}$	ED$_{90}$
Propiconazole 25% EC	73.89 (59.27)	78.33 (62.35)	88.33 (70.00)	92.22 (73.78)	100.00 (87.09)	100.00 (87.09)	1.94	23.98
Carbendazim 12% + mancozeb 63% WP	10.00 (18.42)	25.55 (30.35)	50.00 (44.98)	66.11 (54.37)	84.25 (66.60)	90.18 (71.71)	27.54	173.78
Azoxystrobin 18.2% +difenoconazole 11.4% SC	90.18 (71.72)	96.11 (78.61)	100.00 (87.09)	100.00 (87.09)	100.00 (87.09)	100.00 (87.09)	0.018	1.90
Zineb 68% + hexaconazole 4% WP	30.55 (33.54)	40.00 (39.21)	73.33 (58.88)	87.40 (69.20)	91.66 (73.19)	100.00 (87.09)	11.48	63.09
Tebuconazole 50% + trifloxystrobin 25% WG	23.88 (29.24)	60.55 (51.07)	81.66 (64.62)	89.44 (71.30)	100.00 (87.09)	100.00 (87.09)	9.12	42.65

*Mean of three replications

CD (p=0.05): Fungicides = 0.72; Concentrations =0.66; Fungicides × Concentrations = 1.63; Figures in parentheses represent growth inhibition in arc sine transformed value.

Table 2. ***In vitro*** **efficacy of non-systemic fungicides against *Colletotrichum siamense***

Fungicide	Per cent mycelial growth inhibition at different concentrations (ppm)*						
	50	100	200	500	1000	ED_{50}	ED_{90}
Copper oxychloride 50% WP	10.74 (19.11)	13.88 (21.86)	33.89 (35.58)	65.74 (54.15)	100.00 (87.09)	218.7	676.0
Mancozeb 75% WP	25.92 (30.59)	29.25 (32.72)	37.29 (37.62)	42.77 (40.83)	67.18 (55.02)	489.7	23988.3
Zineb 75% WP	8.88 (17.33)	12.22 (20.45)	17.59 (24.78)	27.22 (31.43)	32.78 (34.91)	4365.1	281838

*Mean of three replications

CD (p=0.05): Fungicides = 0.42; Concentrations = 0.54; Fungicides × Concentrations = 0.95; Figures in parentheses represent growth inhibition in arc sine transformed values.

whereas tebuconazole + trifloxystrobin showed 94.86% and zineb + hexaconazole showed 85.06% mycelial growth inhibition at 0.1, 0.2 and 0.3% concentration.

Among non-systemic fungicides copper oxychloride 50% WP exhibited complete inhibition of mycelial growth at 1000 ppm concentration (Fig. 2c). It was followed by mancozeb 75% WP with 67.18 per cent growth inhibition at same concentration (Table 2).

ED_{50} value of copper oxychloride 50% WP and mancozeb 75% WP were less than 500 µl/ml. These results were similar to those of Shedge *et al.,* (2021) who reported that copper oxychloride showed 100% whereas zineb showed only 31.36% inhibition of mycelial growth of *C. gloeosporioides* at 0.025%, 0.05% and 0.1% concentration. Similarly, Asalkar *et al.* (2019) reported that copper oxychloride showed 97.11% followed by mancozeb with 95.77% mycelial growth inhibition of *C. gloeosporioides* at 500, 1000, 2000 and 2500 ppm, respectively. The results were also in compliance with Ranjitha *et al.* (2019) where mean growth inhibition of *C. gloeosporioides* was higher in case of copper oxychloride (84.10%) as compared to mancozeb (76.83%). Nuraini and Latiffah, (2019) also reported that mancozeb at 500 ppm exhibited 36.04% mycelial growth inhibition of *C. siamense* causing chilli anthracnose.

The results of *in vitro* efficacy of botanicals indicated significant variation among all three plant extract in terms of per cent growth inhibition of *C. siamense.* Maximum mycelial growth inhibition was showed by neem extract (47.96%) followed by mustard (30.00%) and garlic extract (22.78%) at 15% concentration (Table 3**).** These results were in accordance with Kolase *et al.* (2014) who reported that neem extract was significantly superior over other plant extracts against *C. gloeosporioides* at 2.5 and 5% concentration with mycelial growth inhibition of 35.21% whereas garlic extract was among the least effective with 11.57% inhibition. Similarly, Watve *et al.* (2009) reported that the maximum inhibition of *C. gloeosporioides* was achieved by neem extract (78.15%) followed by garlic extract

Table 3. ***In vitro*** **efficacy of botanicals against *Colletotrichum siamense***

	Percent mycelial growth inhibition at different concentrations (%) *		
Plant extract	**5**	**10**	**15**
Mustard	19.25 (26.01)	27.22 (31.43)	30.00 (33.19)
Neem	23.88 (29.22)	30.55 (33.54)	47.96 (38.01)
Garlic	8.51 (16.94)	18.88 (25.74)	22.78 (28.49)

*Mean of three replications

CD (p=0.05): Fungicides = 0.63; Concentrations = 0.63; Fungicides × Concentrations = 1.09; Figures in parentheses represent growth inhibition in arc sine transformed values.

Table 4. ***In vitro*** **efficacy of nano-particles against *Colletotrichum siamense***

	Per cent mycelial growth inhibition at different concentrations (ppm)*									
Nano-particles	100	200	300	400	500	600	700	800	900	1000
Silver	6.11 (14.29)	10.18 (18.59)	11.11 (19.46)	12.22 (20.45)	13.14 (21.24)	14.07 (22.02)	15.55 (23.21)	17.22 (24.50)	20.00 (26.55)	22.77 (28.49)
Copper	2.77 (9.55)	5.00 (12.90)	5.55 (13.61)	6.66 (14.94)	8.33 (16.76)	8.88 (17.33)	10.55 (18.94)	15.00 (22.77)	16.66 (24.08)	22.03 (27.98)

*Mean of three replications
CD (p=0.05): Fungicides = 0.29; Concentrations = 0.66; Fungicides × Concentrations = 0.93; Figures in parentheses represent growth inhibition in arc sine transformed values.

(58.89%). Mustard oil showed significant (40.00%) reduction in growth of *Colletotrichum* spp. at 1000 ppm concentration was also documented by Burgute *et al.* (2019).

Three nano-particles (NP's) *viz.,* copper, selenium and silver were tested at different concentrations (100-1000 ppm) using poison food technique and it was observed that these nano-particles were not much effective in inhibiting the mycelial growth of *C. siamense* at all the test concentrations. The percent growth inhibition at highest dose of 1000ppm was only 22.77% and 22.03% for silver and copper NP's, respectively (Table 4). The results were similar to those of Vera-Reyes *et al.* (2022), who reported that the effect of silver nano-particles was inconspicuous against *C. gloeosporioides*, but Chowdappa *et al.* (2014), reported that, chitosan-silver nano-particles at 10.00 µg/ml inhibited the spore germination of *C. gloeosporioides* by 78.00%. Similarly, Aguilar-Mendez *et al.* (2011) reported that silver nano-particles presented a dose-dependent fungistatic activity against *C. gloesporioides*.

Two bio-control agents *viz., Trichoderma harzianum* and *Pseudomonas fluorescens* were evaluated against *C. siamense* using dual culture technique. The data presented in Table 5 revealed that, maximum mycelial growth inhibition of the pathogen was achieved by *T. harzianum* (55.12%) whereas *P. fluorescens* showed only 22.85% mycelial growth of the pathogen as compared to control. The results were in compliance with Ramani *et al.* (2015) where highest mycelial growth inhibition of *C. gloeosporioides* was observed in *T. harzianum* (62.43%) whereas *P. fluorescens* showed only 42.53% inhibition. Similarly, Kaur *et al.* (2021) reported that *T. harzianum* performed superior than all tested BCAs against the *C. gloeosporioides* whereas *P. fluorescencs* was ineffective. Tasiwal *et al.* (2009) also reported similar results where growth inhibition of *C. gloeosporioides* causing anthracnose of papaya was higher in *T. Harzianum* (51.89%) as compared to *P. fluorescence* (42.87%). Similarly, Sutarman *et al.* (2021) reported that *T. harzianum* isolate Tc-Jjr-02 was able to inhibit the growth of *C. capcisi* by 65.0 ± 3.93%.

Field evaluation of different botanicals, bio-control agents and fungicides against fruit drop in Kinnow mandarin

The pooled analysis of two years data i.e 2021 and 2022 (Table 6) revealed that all the fungicides were found significantly effective in managing fruit drop in Kinnow mandarin as compared to untreated control.

Table 5. ***In vitro*** **screening of bio-control agents against *Colletotrichum siamense***

Bio-control agent	Pathogen growth (cm)	Antagonist growth (cm)	Inhibition zone (cm)	Control (cm)	Growth inhibition of the pathogen (%) *
Trichoderma harzianum	3.5	5	0.5	7.8	55.12 (47.91)
Pseudomonas fluorescens	5.40	3	0.30	7.0	22.85 (28.54)

*Mean of three replications
CD (p=0.05) = 0.0143; Figures in parentheses represent growth inhibition in arc sine transformed values.

Table 6. Field evaluation of different botanicals, bio-control agents and fungicides for managing fruit drop in Kinnow mandarin during 2021 and 2022

Treatments	Concentration (%)	Fruit drop (Number)*	Harvested yield (Fruit number / tree)*	Fruit drop (%)	Reduction in fruit drop over control (%)
Copper oxychloride50% WP	0.3	86.6 [i]	590.6 [g]	14.66 [i]	44.34 [f]
Mancozeb75% WP	0.2	90.3 [h]	605.3 [d]	14.91 [h]	41.96 [g]
Zineb75% WP	0.2	98.6 [g]	573.3 [j]	17.19 [g]	36.63 [h]
Propiconazole25% EC	0.1	63.3 [m]	612.6 [b]	10.33 [m]	59.12 [b]
Azoxystrobin 18.2% +difenoconazole 11.4% SC	0.1	56.3 [n]	624.3 [a]	9.01 [n]	63.81 [a]
Tebuconazole 50 % + trifloxystrobin 25% WG	0.1	69.6 [l]	609.3 [c]	11.42 [l]	55.26 [c]
Carbendazim 12% + mancozeb 63% WP	0.2	78.3 [j]	596.6 [f]	13.12 [j]	49.67 [e]
Zineb 68% + hexaconazole 4% WP	0.1	73.6 [k]	604.6 [e]	12.17 [k]	52.69 [d]
Neem extract	15	103.3 [f]	575.3 [i]	17.90 [f]	33.61 [i]
Garlic extract	15	124.6 [b]	564.3 [k]	22.08 [b]	19.92 [m]
Mustard extract	15	106.3 [d]	583.3 [h]	18.22 [e]	31.68 [k]
Pseudomonas fluorescens	1.5	118.3 [c]	549.6 [m]	21.52 [c]	23.97 [l]
Trichoderma harzianum	1.5	103.6 [e]	552.6 [l]	18.74 [d]	33.41 [j]
Control		155.6 [a]	506.3 [n]	30.73 [a]	-

*Mean of fifteen observations; The values followed by the same letter are not significantly different at $p = 0.05$ according to Duncan's multiple range test.

Fig. 3. Management of fruit drop in Kinnow mandarin with (a) Azoxystrobin 18.2% + difenoconazole 11.4% SC (b) Propiconazole 25% EC and (c) control

Maximum reduction in fruit drop i.e. 63.81% was exhibited by azoxystrobin 18.2% + difenoconazole 11.4% SC followed by propiconazole 25% EC with 59.12% fruit drop reduction, respectively during two consecutive years. (Fig.3). These results were in accordance with Kumar and Garg (2012) where difenoconazole controlled 81.8% fruit drop in Kinnow mandarin. Similarly, Sundravadana *et al.* (2007) reported that azoxystrobin was successful in controlling *C. gloeosporioides* causing mango anthracnose at 1, 2 and 4 ml/l concentration. Sayiprathap *et al.* (2018) observed that propiconazole was highly effective in controlling the mango anthracnose with 10.72 PDI over control.

Among non-systemic fungicides copper oxychloride 50% WP was most effective in reducing fruit drop upto 44.34% and zineb 75% WP was least effective with 36.63% reduction in fruit drop over control**.** These results were justified by the findings of Mohod *et al.* (2019) who reported that copper oxychloride showed significant reduction in pre-harvest fruit drop (50.52%) in Nagpur mandarin. Wathore *et al.* (2010) also reported that spraying of copper oxychloride (0.3%) reduced the intensity of blight upto 19.62%, caused by *C. gloeosporioides* in field conditions. Similarly, Vandana *et al.* (2021) also observed disease reduction of 54.35% and 45.65% by mancozeb and zineb in pomegranate anthracnose, respectively.

On the other hand, botanicals and bio-control agents were less effective as compared to fungicides in controlling the disease under field conditions. Among botanicals maximum reduction in fruit drop was recorded by neem extract i.e. 33.61% followed by 31.68% by mustard extract. This result was supported by the findings of Ingle *et al*. (2008) who reported that neem seed extract (5%) was significantly effective in reducing the fruit drop in Nagpur mandarin by 34.33 % over control. Similarly, Pwakem *et al.* (2020) observed that among different plant extracts, neem seed extract at 7.5% concentration had the maximum fungitoxic action that reduced the severity of mango anthracnose. *T. harzianum* showed 33.41% reduction in fruit drop over control and *P. fluorescens* was the least effective treatment with 23.97% fruit drop reduction under field conditions. These results were in accordance with Prabakar *et al.* (2008) who reported that *T. harzianum,* reduces the growth of *C. gleosporioides* by 42.00%. Similarly, Valenzuela *et al.* (2015) also reported that *T. harzianum* reduced radial growth of *C. gloeosporioides* by 53.00–56.00% under *in vitro* conditions.

Thus, from the present study, it is concluded that the different disease management strategies employed could be further incorporated in IDM programmes for the effective management of the fruit drop in Kinnow mandarin.

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