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Controlling canker and stem-end rot of Kinnow (*Citrus deliciosa* Ten.)

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Abstract
Field trials were laid out at Agricultural Research Station (S.K. Rajasthan Agricultural University), Sriganganagar (Rajasthan) to test the bioefficacy of different dosage of (0.075, 0.1, 0.125, 0.15 and 0.2%) Copper hydroxide 46.1% DF (Kocide 3000) against canker and stem-end rot of Kinnow (*Citrus deliciosa* Ten.) during two consecutive years (2010-11 and 2011-12) in randomized block design. Foliar application of each dose of fungicide was applied twice during February-March and twice during July-August at 15 days intervals along with Streptocycline (0.01%) + Copper oxychloride (0.2%) which is recommended for citrus canker. Copper hydroxide when sprayed at higher concentration (0.2%), proved significantly superior over rest of the spray treatments in reducing canker intensity on leaves and incidence on leaves and fruits, which statistically at par with the dose of 0.15 per cent. The canker intensity on leaves at 0.20 & 0.15% concentration of Copper hydroxide was 13.03 and 15.84% respectively, as compared to intensity of 22.51% observed under recommended spray schedule. Similarly, Copper hydroxide @ 0.2 & 0.15% proved significantly superior against canker incidence on leaves (29.83 and 34.17%) as well as fruits (1.77 and 2.58%) over recommended spray which exhibited 44.67 and 8.55 per cent incidence on leaves and fruits, respectively. Sprays of Copper hydroxide at 0.2 and 0.15% 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 & 0.15%) was 3.87 & 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 Copper hydroxide.

Keywords: Kinnow, canker, stem-end rot, Copper hydroxide 46.1% DF (Kocide 3000)

Introduction
Citrus is one of the major fruit crop in India which primarily includes lime, lemon, orange, tangerine and mandarins. Citrus accounts for about nine per cent of the total fruit production in India (Chadha, 1995) [3]. In India, citrus is cultivated over an area of near about 10.7 lakh hectare with total annual production of 111.4 lakh tones and possesses third position in production with global share of 4.8 per cent (Sharma and Raj, 2018) [14]. Among citrus crops, mandarin orange covers largest area followed by sweet orange and acid lime (Kumar *et al*., 2010) [9]. Mandarins occupies 4.29 lac ha area and annual production is 47.54 lakh tones (Beniwal *et al*., 2018) [2]. Kinnow (*Citrus deliciosa* Ten.) is a hybrid variety of mandarin group of citrus which suffers from several diseases (Jameel *et al.,* 2014) [8]. Kinnow is mostly grown in Northern States of India, covering area of 45101 ha with production and productivity of 3.24 lac tonnes and 7.18 tonnes/ha (Singh and Thakur, 2006) [16]. In Rajasthan, it occupies significant place by covering 14,616 ha area with production of 1,82,000 tonnes and productivity of 12.45 tonnes/ha (Anonymous, 2018) [1]. Kinnow are attacked by a variety of microorganisms. Canker and pre-harvest stem end rot are most threatening diseases of Kinnow. Canker attacks all the aerial parts and adversely affects the quality as well as quantity of fruit yield resulting in severe economic loss. It is difficult to find any lime grove completely free from canker and infection can cause 50-60% yield reduction (Das, 2001) [4]. Major outbreaks of citrus canker occur when new shoots are emerging or when fruit are in the early stages of development. Frequent rainfall in warm weather, especially during storms, contributes to disease development.

Pre-harvest stem-end rot is of high economic importance as it decreases yield and quality of the fruits. The fruits may be contaminated in orchards right from the setting to harvesting stage leading to pre-mature fruit drop, and incipient pre-harvest infections causes subsequent post-harvest decaying during storage and transit under cordial conditions of temperature and moisture (Naqvi, 1993) [11].

Nearly 22 per cent losses of fruits of Nagpur mandarin occurred due to pre-harvest fruit dropping as a result of pre-harvest infection (Sharma *et al*., 2011) [15].

Fungicides are primary means of controlling plant diseases. Continuous use of selected agrochemicals led to the problem of resistance in citrus pathogens against these chemicals (Ladaniya, 2008) [10]. The resistance of fungal pathogens to antifungal compounds necessitates the screening of new fungicides against these two diseases of Kinnow *viz*., canker caused by *Xanthomonas axonopodis* pv. c*itri* (Vauterin *et al*., 1995) [18] and pre-harvest stem-end rot caused by *Colletotrichum gloeosporioides* (Penz.)*/Botryodiplodia theobromae* (Pat.). The present study was therefore undertaken with a view to evaluate new fungicide along with Streptocycline (0.01%) + Copper oxychloride (0.2%) against the canker and pre-harvest stem-end rot.

Materials and Methods

Field trials were undertaken for two consecutive crop seasons (2009-10 and 2010-11) to test the efficacy of Copper hydroxide 46.1% DF against canker and fruit rotting due to pre-harvest stem-end rot disease of Kinnow at Agricultural Research Station (S.K. Rajasthan Agricultural University), Sriganganagar (Rajasthan). The plants having uniform canopy were selected for the experiment. Five different doses of this fungicide (0.075%, 0.1%, 0.125%, 0.15% and 0.2%) were evaluated in comparison with recommended spray of Streptocycline @ 0.01% + Copper oxychloride 50% WP @ 0.2 per cent. Foliar applications were applied twice during the month of February-March and twice during the month of July-August at fifteen days intervals. The plants sprayed with only water served as control. The experiment framed in randomized block design with seven treatments including one set of control. Each treatment was replicated thrice considering single plant as one replication. All recommended agronomical practices were adopted for raising good plants.

The observations of canker were taken after 15 days of last spray during February-March and July-August, using 0-4 scale, where 0= free from infection, 1= traces to 10%, 2= 11-25%, 3= 26-50% and 4= >50% leaf area infected (Reddy, 1997) [13]. Per cent disease incidence was calculated on the basis of total leaves/fruits observed and Per cent intensity (PDI) was calculated as follows (Gaur and Sharma, 2010) [6].

$$PDI = \frac{\sum \text{All numerical ratings}}{\text{Total no. of leaves assessed x Maximum disease rating}} \times 100$$

For pre-harvest stem-end rot, the rotted fruits of each plant were recorded separately from first spray till final harvest. The per cent pre-harvest stem-end rot was calculated on the basis of total fruits/plant (Sharma *et al*., 2011) [15]. The fruits were harvested at maturity and individual plant fruit yield was recorded. Data were subjected to the analysis of variance (ANOVA) and the data in percentage were converted to angular transformation before using ANOVA.

Results and Discussion

Pooled data of two years (2009-10 and 2010-11) revealed significant reduction in canker intensity and incidence on leaves and fruits and fruits rotting due to stem end rot disease in all treatments as compared to control except lower dose (0.075%) of Copper hydroxide 46.1% DF where stem end rot incidence was at par with control. All the spray treatments rendered significant higher fruit yield as compared to control.

Copper hydroxide when sprayed at higher concentration (0.2%), proved significantly superior over rest of the treatments in reducing canker intensity on leaves and incidence on leaves and fruits but statistically at par with the dose of 0.15 per cent. The canker intensity on leaves at 0.20 & 0.15% concentration of Copper hydroxide was 13.03 and 15.84% respectively, as compared to intensity of 22.51% observed under recommended spray schedule. Similarly, Copper hydroxide @ 0.2 & 0.15% proved significantly superior against canker incidence on leaves (29.83 and 34.17%) as well as fruits (1.77 and 2.58%) over recommended spray which exhibited 44.67 and 8.55 per cent incidence on leaves and fruits respectively. The rest concentrations were either at par or were significantly inferior to recommended spray in reduction of canker incidence on leaves and fruits.

Sprays of Copper hydroxide at 0.2 and 0.15% concentration proved significantly superior to recommended treatment in reducing stem end rot incidence in fruits. The per cent fruit rot at these spray concentrations (0.2 & 0.15%) was 3.87 & 6.01 per cent, respectively as compared to 12.91 per cent under recommended spray schedule. Disease incidence at rest of the doses of Copper hydroxide was at par or significantly higher than recommended spray of Streptocyclene (0.01%) + Copper oxychloride (0.2%).

Spray of different concentrations of Copper hydroxide and recommended spray schedule rendered significantly higher fruit yields compared to untreated control plants. However when compared with recommended spray schedule 0.2 per cent dose of Copper hydroxide proved superior and was at par with 0.15 per cent dose of Copper hydroxide. The yield at 0.2 & 0.15 per cent concentration of Copper hydroxide were 211.20 & 198.18 kg/tree as compared to 169.53 kg/tree yields obtained under recommended spray schedule. At rest of the doses of Copper hydroxide, the fruit yield was at par or significantly lower to recommended treatment (Table 1 and 2 and Fig. 1).

Findings of present investigation are in agreement with those of earlier workers who established the efficacy of copper hydroxide against the citrus canker (Stein *et al*., 2007, Narciso *et al.,* 2011, Ibrahim *et al.*, 2017, Galsurker *et al.,* 2018) [17, 12, 7, 5]. Similar to present findings, several workers (Sharma *et al.,* 2011 and Beniwal *et al*. 2018) [15, 2] has also been proved the efficacy of copper based fungicides in controlling pre-harvest stem-end rot of kinnow. The antimicrobial activity of copper hydroxide is because of its strong bonding affinity to amino acids and carboxyl groups, reacts with protein and acts as an enzyme inhibitor in target organisms. Copper kills spores by combining with sulphahydral groups of certain enzymes. Spores actively accumulate copper and thus germination of spores is inhibited, even at lower concentrations (Yang *et al.,* 2011) [19].

Table 1: Efficacy of different foliar sprays against canker disease of Kinnow (*Citrus deliciosa* Ten.)

S. No.	Treatments	Dose	Canker disease								
			Intensity on leaves (%)			Incidence on leaves (%)			Incidence on fruits (%)		
			2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
1	Foliar spray with Copper hydroxide 46.1% DF	0.075%	34.79 (36.15)	38.54 (38.36)	36.67 (37.26)	59.67 (50.58)	68.67 (56.00)	64.17 (53.29)	13.47 (21.20)	18.12 (25.01)	15.80 (23.10)
2	Foliar spray with Copper hydroxide 46.1% DF	0.1%	26.05 (30.68)	31.04 (33.85)	28.55 (32.27)	50.33 (45.17)	57.00 (49.00)	53.67 (47.08)	10.39 (18.80)	15.19 (22.82)	12.79 (20.81)
3	Foliar spray with Copper hydroxide 46.1% DF	0.125%	21.46 (27.58)	27.71 (31.73)	24.59 (29.66)	44.33 (41.73)	49.33 (44.63)	31.21 (43.18)	8.41 (16.83)	12.64 (20.70)	10.53 (18.77)
4	Foliar spray with Copper hydroxide 46.1% DF	0.15%	13.96 (21.90)	17.71 (24.78)	15.84 (23.34)	34.33 (35.90)	34.00 (35.49)	34.17 (35.70)	0.95 (5.60)	4.21 (11.80)	2.58 (8.70)
5	Foliar spray with Copper hydroxide 46.1% DF	0.2%	12.50 (20.70)	13.55 (21.56)	13.03 (21.13)	28.33 (32.17)	31.33 (34.00)	29.83 (33.08)	0.56 (4.24)	2.98 (9.78)	1.77 (7.01)
6	Foliar spray with Streptocycline + Copper oxychloride 50% WP	0.01% + 0.2%	20.42 (26.82)	24.59 (29.69)	22.51 (28.26)	43.67 (41.39)	45.67 (42.51)	44.67 (41.95)	6.75 (15.10)	10.34 (18.68)	8.55 (16.89)
7	Control	-	62.29 (52.14)	67.71 (55.44)	65.00 (53.79)	89.33 (71.03)	91.33 (73.50)	90.33 (72.27)	17.61 (24.77)	23.18 (28.78)	20.40 (26.77)
CD at 5% CV (%)			3.05 5.52	4.69 7.80	.02 5.24	4.28 5.27	5.46 6.42	3.22 3.86	3.64 13.36	4.96 14.19	2.30 7.39

Table 2: Effect of different foliar sprays on stem-end rot incidence and yield of Kinnow (*Citrus deliciosa* Ten.) fruits

S. No.	Treatments	Dose	Stem-end rot incidence on fruits (%)			Fruit yield (kg/tree)		
			2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
1	Foliar spray with Copper hydroxide 46.1% DF	0.075%	23.25(28.70)	25.46(30.16)	24.36(29.43)	109.67	107.13	108.40
2	Foliar spray with Copper hydroxide 46.1% DF	0.1%	17.69(24.87)	20.38(26.73)	19.04(25.80)	135.27	129.07	132.17
3	Foliar spray with Copper hydroxide 46.1% DF	0.125%	14.61(22.47)	16.20(23.69)	15.41(23.08)	162.60	146.70	154.65
4	Foliar spray with Copper hydroxide 46.1% DF	0.15%	5.62(13.73)	6.40(14.49)	6.01(14.11)	216.07	180.30	198.18
5	Foliar spray with Copper hydroxide 46.1% DF	0.2%	3.86(11.30)	3.88(11.35)	3.87(11.33)	229.87	192.53	211.20
6	Foliar spray with Streptocycline + Copper oxychloride	0.01% + 0.2%	12.25(20.47)	13.56(21.38)	12.91(20.93)	181.13	157.93	169.53
7	Control	-	26.41(30.90)	31.75(34.24)	29.08(32.57)	82.93	66.07	74.50
CD at 5% CV (%)			3.61 9.27	5.9214.37	3.238.03	18.60 6.55	18.48 7.39	15.80 5.90

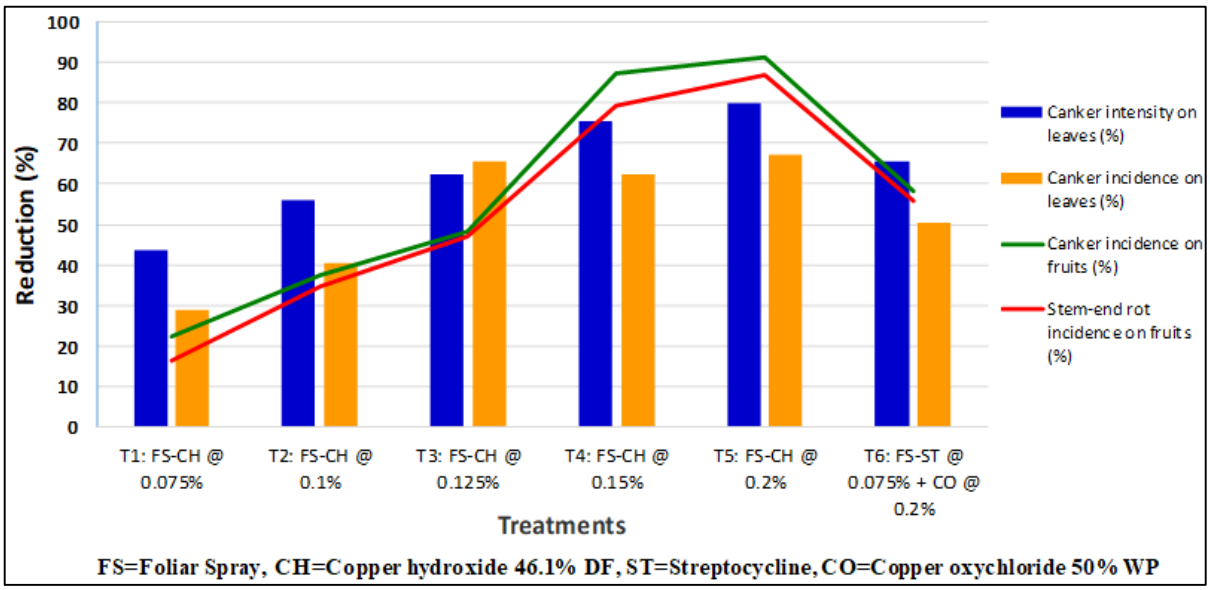

Fig 1: Per cent reduction in canker and pre-harvest stem-end rot of Kinnow under different treatments over control

Conclusion

On the basis of two year trials, it was concluded that the foliar sprays of Copper hydroxide 46.1% DF (Kocide 3000) at the concentration of 0.2% and 0.15% were significantly superior to rest of the treatments in controlling the both, citrus cancer and stem-end rot of Kinnow. However, statistically these two concentrations (0.2 & 0.15%) were at par with each other. Therefore, 0.15% of Copper hydroxide 46.1% DF (Kocide 3000) may be recommended for controlling the both cancer and stem-end rot of Kinnow.

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