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Evaluation of Fungicides for Effective Management of Leaf and Fruit Spot (*Pseudocercospora angolensis*) Disease of Citrus under Field Conditions

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Abstract

Leaf and fruit spot (*Pseudocercospora angolensis*) disease of citrus attacks leaves, fruits, and young twigs of the plant. The disease can cause a yield loss of (50% to 100%) in areas with high rainfall and humidity during the active growth stages of the crop. Currently, citrus plantations in the south, south-west and north-west of Ethiopia are seriously affected by this disease. As a result, this study was proposed to study the effect of fungicides in controlling. And candidate fungicides were: Carbonchlor 50% SC only, Benline 50% WP only, Bellis 38% WG only, Carbonchlor 50% SC combined with Bellis 38% WG, Benline 50% WP combined with Carbonchlor 50% SC and Benline 50% WP combined with Matco 72% WP for effective management of citrus leaf and fruit spot (*Pseudocercospra angolensis*) disease. The study was carried out in 2021 cropping season. A Randomized Complete Block Design (RCBD) with three replications was the design applied. The result showed that the highest level of efficacy (90.46%) was produced by Bellis 38% WG fungicide followed by Carbonchlor 50% SC (86.50%), Bellis 38% WG + Carbonchlor 50% SC (82.00%), Carbonchlor 50% SC + Benline 50% WP (67.89%), Benline 50% WP (65.62%) and Matco 72% WP + Benline 50% WP (49.48%). Therefore, based on the outcome of the study application of Bellis 38% WG only followed by Carbonchlor 50% SC only, Carbonchlor 50% SC combined with Benline 50% WP, Bellis 38% WG combined with Carbonchlor 50% SC, Bellis 38% WG only, Benline 50% WP only and Matco 72% WP combined with Benline 50% WP were effective fungicides to be used for the control of leaf and fruit spot disease.

1. Introduction

In most of the Sub-Saharan African countries the supply of citrus fruits especially sweet orange is far below the demand mainly due to a significant yield loss caused by leaf and fruit spot *Pseudocercospora angolensis* disease. Due to its devastating nature and geographic distribution, this disease is considered as a quarantine pest for Europe. And this will critically affect the market linkage of the citrus industry and also the germ plasm exchange between countries. Moreover, this economically important disease can cause a potential threat to the rest of the world, especially to citrus growing areas of the tropical climate [1].

The most devastating effect of the disease on various citrus species is substantial premature abscission of leaves and fruits. And fruits may become blemish and remain on the tree. Infected fruits produce poor quality juice, or become very hard, juiceless and unattractive which are not suitable for market [2] [3] [4].

Leaf and fruit spot disease of citrus attacks leaves, fruits, and young twigs of the plant [3]. The disease can cause a yield loss of (50% to 100%) in areas with high rainfall and humidity during the active growth stages of the crop [1].

In Ethiopia, the disease was first reported in 1988 from the Southern part of the country [5]. Later, it spreads to South, Southwest, and Northwest parts of the country and cause heavy crop damage, often total crop loss [7].

Currently, citrus plantations in the south, south-west and north-west of Ethiopia are seriously affected by this disease. Consequently, the supply of citrus fruits in these areas has been insufficient for the last ten years. Several small-scale citrus growers have abandoned their trees due to severe infection of citrus by the disease and also the disease is becoming major limiting factor of the citrus industry in the country [3].

Therefore, the objective of this study was to evaluate the effect of fungicides in controlling leaf and fruit spot disease of citrus.

2. Materials and Methods

2.1. Study Area

The trial was carried out at Bikolo nursery in Mecha district, North-Western Ethiopia, where the disease was prevalent. The site was located 11°33'45" North latitude to 37°16'14" East longitude and at an altitude of 1850 m.a.s.l.

2.2. Treatments, Field Management and Experimental Design

The test contained seven treatments: Carbonchlor 50% SC, Benline 50% WP, Bellis 38% WG, Carbonchlor 50% SC combined with Bellis 38% WG, Benline 50% WP combined with Carbonchlor 50% SC, Benline 50% WP combined with

Matco 72% WP and un-sprayed check. The fungicides were applied based on the manufacturers' recommendation rate *i.e.*, 20 ml and 20 mg per 10 liters of water for liquid and solid formulations, respectively. In order to spray fungicides thoroughly, Knapsack sprayer was used for applying. And the timing of application was started at the onset of the disease and had been continued at fourteen days of interval until one week left for harvesting. And during application, to avoid drift problem the plots under application were protected with plastic sheet supported by four wooden poles.

A Randomized Complete Block Design (RCBD) with three replications was the design applied. Consequently, 21 sweet orange trees of Jaffa variety were chosen for the test as experimental unit.

2.3. Disease Assessment

Disease severity was estimated both on leaves and fruits of the tree. On leaves, it was estimated on eight randomly selected terminal shoots from the upper and lower halves of the canopy in four directions (North, South, East and West) of each selected tree [7]. And it was computed based on a zero-to-four scoring scale, where 0 = no symptoms, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75% and 4 = above 75% of leaf area infected [8] [9].

On fruits, disease severity was assessed on 5 to 40 randomly selected intact fruits in four directions of each tree [7]. And it was recorded using the following zero to four scoring scale, where 0 = healthy, 1 = less than 5%, 2 = 5% to 20%, 3 = 21% - 50% and 4 = above 50% of fruit surface affected [10].

For analysis, severity grades were converted into percentage severity index (PSI) and calculated using the formula suggested by [11]:

$$\text{PSI} = \frac{\text{Sum of all numerical ratings}}{\text{Total no. of observations} * \text{Maximum disease score}} * 100$$

From the severity data, AUDPC for each treatment was calculated as described by [12] as follow:

$$\text{AUDPC} = \sum_{i=1}^{n} \left[(x_i + x_{i-1})/2 \right] \left[t_i - t_{i-1} \right]$$

where, x_i = Present disease severity;

x_{i-1} = Previous disease severity;

$t_i - t_{i-1}$ = Time difference between two consecutive disease severities; and

n—is the total number of days disease severity was assessed.

2.4. Fungicide Efficacy

The efficacy of fungicides was calculated using [13] formula:

$$\text{EF}(\%) = \frac{X - Y}{X} * 100$$

where,

X—Disease severity in control plots;

Y—Disease severity in treated plots.

2.5. Data Analysis

All recorded data were analyzed by analysis of variance and tested for comparison of treatments at 0.01/0.05 level of probability using least significant difference (LSD). SAS separate analysis of variance, version 9.2 was the statistical package used for analysis [14].

3. Results

3.1. Fungicides Effect on the Severity of the Disease

Significant variations at ($P \leq 0.05$) were detected between Matco 72% WP + Benline 50% WP and Bellis 38% WG + Carbonchlor 50% SC, Carbonchlor 50% SC only and Bellis 38% WG. Whereas, there were no significant variation observed among Matco 72% WP + Benline 50% WP, Benline 50% WP only and Carbonchlor 50% SC + Benline 50% WP. Likewise, significant variation was not observed among Benline 50% WP only, Carbonchlor 50% SC + Benline 50% WP, Bellis 38% WG + Carbonchlor 50% SC, Carbonchlor 50% SC only and Bellis 38% WG (Table 1).

Furthermore, differences among treatments on the recorded mean disease severity of leaves over time were discerned. Consequently, minimum mean disease severity (PSI) of leaves (1.73%) was recorded in Bellis 38% WG treated trees. However, maximum severity (PSI) (18.15%) was observed in the control plots (Figure 1).

However, on fruits the highest disease severity (35.66%) was recorded in unsprayed trees. And it was zero in all fruits of trees treated with different fungicides (Table 2).

Table 1. Computed disease severity (PSI) of leaves.

	Disease severity (PSI)								
	Days after the first spray								
Treatments	14	28	42	56	70	84	98	112	126*
1) Control	1.69	2.4	4.33	8.39	18.05	31.85	37.84	40.67	18.15[a]
2) Matco 72% Wp + Benline 50% WP	0.0	0.0	2.06	3.18	8.49	16.66	20.17	22.78	9.17[b]
3) Benline 50% WP only	0.0	0.0	1.59	3.17	6.03	10.56	13.67	14.88	6.24[bc]
4) Carbonchlor 50% SC + Benline 50% WP	0.0	0.0	0.0	1.48	3.96	9.65	14.98	16.51	5.83[bc]
5) Bellis 38% WG + Carbonchlor 50% WP	0.0	0.0	0.0	0.0	2.06	4.9	8.62	10.45	3.27[c]
6) Carbonchlor 50% WP only	0.0	0.0	0.0	0.0	1.09	3.92	6.98	7.58	2.45[c]
7) Bellis 38% WG	0.0	0.0	0.0	0.0	0.0	1.66	5.78	6.46	1.73[c]

The day *126 after the first fungicides spray, is the mean of the three replications; means followed by the same letter are not significantly different by LSD ($P < 0.05$).

Table 2. Recorded disease severity of fruits.

	Disease severity (PSI)											
	Days after the first spray											
Treatments	14	28	42	56	70	84	98	112	126	140	156	170*
Carbonchlor 50% SC	0	0	0	0	0	0	0	0	0	0	0	0
Carbonchlor 50% SC + Benline 50% WP	0	0	0	0	0	0	0	0	0	0	0	0
Bellis 38% WG + Carbonchlor 50% SC	0	0	0	0	0	0	0	0	0	0	0	0
Bellis 38% WG only	0	0	0	0	0	0	0	0	0	0	0	0
Benline 50% WP only	0	0	0	0	0	0	0	0	0	0	0	0
Matco 72% WP + Benline 50% WP	0	0	0	0	0	0	0	0	0	0	0	0
Check (Control)	20	23.07	26.27	27.65	29.95	32.68	35.44	42.76	45.33	50.65	58.46	35.66

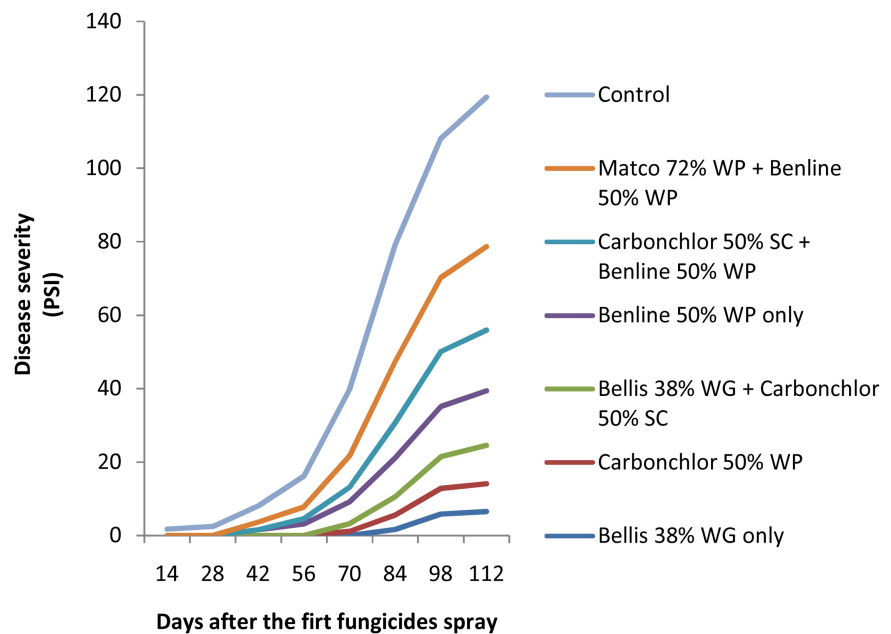*170 days after the first fungicides spray is the mean of the three replications.

Figure 1. Effect of fungicides on citrus leaf and fruit spot disease progress curve of leaves disease severity (PSI).

3.2. Calculated Area under the Disease Progress Curve (AUDPC)

Low rate of AUDPC (Area Under the Disease Progress Curve) was computed by Bellis 38% WG that was (149.38) followed by Carbonchlor 50% SC (220.92), Bellis 38% WG combined with Carbonchlor 50% SC (292.25), Benline 50% WP combined with Carbonchlor 50% SC (536.55), Benline 50% WP (594.44) and Matco 72% WP combined with Benline 50% WP (867.30). Whereas, it was (1736.56) by the unsprayed check (Figure 2).

3.3. Fungicide Efficacy (FE)

Based on the efficacy level of the fungicides, the highest level of efficacy (90.46%) was produced by Bellis 38% WG treated trees followed by Carbonchlor 50% SC (86.50%), Bellis 38% WG + Carbonchlor 50% SC (82.00%), Carbonchlor 50% SC + Benline 50% WP (67.89%), Benline 50% WP (65.62%) and Matco 72% WP + Benline 50% WP (49.48%) (Table 3).

4. Discussion

Significant variations in between fungicides treated plots and un-sprayed check regarding the recorded disease severity percentage of fruits (null) and (35.66%), respectively were observed. And the maximum Area under the Disease Progress
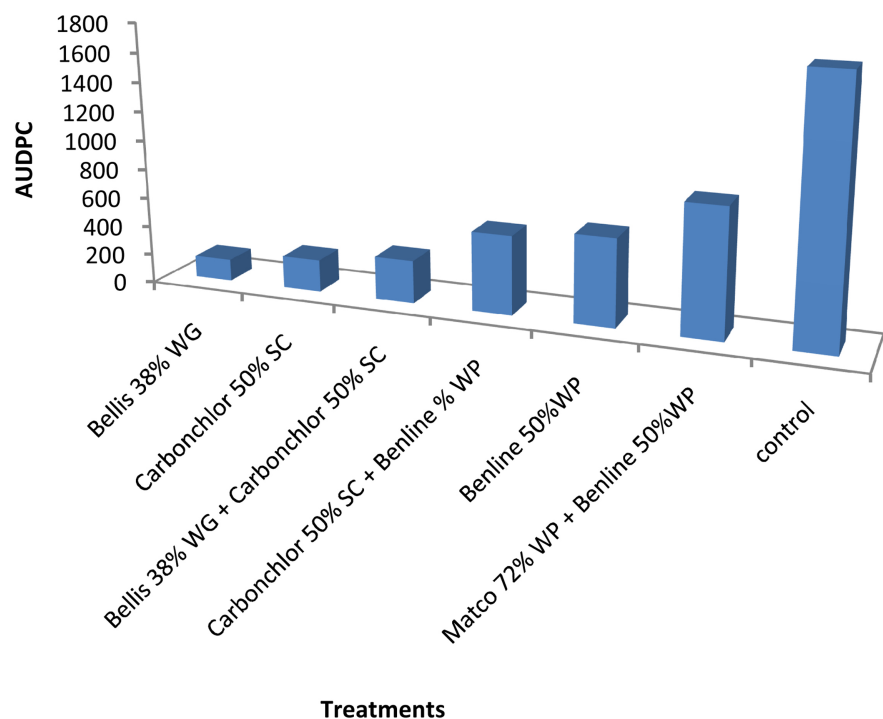

Figure 2. Area under the disease progress curve of each treatment.

Table 3. Efficacy of fungicides.

No	Treatments	Disease severity (PSI)	The level of efficacy
1	Bellis 38% WG only	1.73	90.46
2	Carbonchlor 50% SC only	2.45	86.50
3	Bellis 38% WG + Carbonchlor 50% SC	3.27	82.00
4	Carbonchlor 50% SC + Benline 50% WP	5.83	67.89
5	Benline 50% WP only	6.24	65.62
6	Matco 72% WP + Benline 50% WP	9.17	49.48
7	Control	18.15	-

Curve (AUDPC) rate (1736.56) was recorded in the unsprayed check. Moreover, significant difference was also observed between the candidate fungicides and the unsprayed check on their recorded mean disease severity of leaves over time. Consequently, the highest disease severity (PSI) (18.15%) was computed in the control plots. From these, it is possible to discuss that all candidate fungicides were showed effective result in controlling the disease as compared to the unsprayed check.

5. Conclusions

The study result revealed that the highest level of efficacy (90.46%) was produced by Bellis 38% WG treated trees followed by Carbonchlor 50% SC (86.50%), Bellis 38% WG + Carbonchlor 50% SC (82.00%), Carbonchlor 50% SC + Benline 50% WP (67.89%), Benline 50% WP (65.62%) and Matco 72% WP + Benline 50% WP (49.48%).

Therefore, based on the outcome of the study application of Bellis 38% WG only followed by Carbonchlor 50% SC only, Carbonchlor 50% SC combined with Benline 50% WP, Bellis 38% WG combined with Carbonchlor 50% SC, Bellis 38% WG only, Benline 50% WP only and Matco 72% WP combined with Benline 50% WP were effective fungicides to be used for the control of leaf and fruit spot disease.

Recommendation

It is further recommended that additional management strategies through host resistance, fungicides integrated with cultural and agronomic practices have to be implemented.

Acknowledgements

Conflicts of Interest

We have no conflict of interest to disclose.

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