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Field evaluation of different fungicides for their effectiveness against cercospora leaf spot (*Cercospora sesame* Zimm.) of Sesame (*Sesamum indicum* L.)

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Abstract
Sesame (Sesamum indicum) is one of the well known oil crop produced and Ethiopia is one of the major producer country of the crop in the world. The Field experiment was conducted for two years (2015/2017 GC) at Delo-mena site of Sinana Agricultural Research Center (SARC) with the objective of identify effective fungicides for the management of Cercospora leaf spot of Sesame. The trial was arranged in RCB Design with three replication and the treatment fungicides were; Odeon 825 WDG, Mancozeb 80% WP, Natura 250 EW, Ridomil Gold MZ 68 WG, RexDuo, Tilt 250 EC and unsprayed control were included for treatment comparison. The highest Cercospora leafspot disease severity of 41.11% and the lowest (5.00%) were recorded from unsprayed control and Tilt 250 EC treated plots, respectively. Similarly, the highest AUDPC (1474.67%-days) and r (0.038292 units^{-1}) and the lowest AUDPC (165.67%-days) and r (-0.004976units^{-1}) were similarly calculated from unsprayed control and from Tilt 250 EC treated plots, respectively. Regarding yield and yield related traits; ANOVA has shown significant variations ($P \leq 0.05$) between treatments for the TKW and grain yield. The highest number of TKW (3.27 g) and grain yield (618.98 kg/ha) were recorded from a plot sprayed with Tilt 250 EC treated plot; while the lowest number of TKW (2.80 g) and grain yield (457.87 kg/ha) were recorded from unsprayed control plot. Simple linear regression of TKW and grain yield with Cercospora leaf spot severity and AUDPC have revealed a significant difference ($P \leq 0.05$) between treatments; the estimated slope of the regression line obtained for Cercospora leaf spot severity in relation to grain yield was -3.36 and for AUDPC was-0.093. The Correlation of grain yield with Cercospora leaf spot disease severity and AUDPC has depicted that Cercospora leaf spot disease severity and AUDPC has a significant negative correlation with grain yield (r= -0.4821, $P \leq 0.05$) and (r= -0.4834, $P \leq 0.05$), respectively. Therefore, based on the result of this study, a fungicide Tilt 250 EC is recommended for the management of Cercospora leaf spot disease on Sesame at both small scale and large scale production level.

Keywords: Faba bean, chocolate spot, disease severity index, AUDPC, disease progress curve

1. Introduction
Sesame (*Sesamum indicum*) is a vital oil crop produced in the tropical and subtropical parts of the World [7]. Ethiopia is one of the major producers of sesame in the World. In Ethiopia, during the 2010 cropping season, sesame was produced on an area of 384,682.79 ha of land with a total production of 3,277,409.22 quintals which increased by about 25.8% from that of 2009/10 production year [3]. The Area of land covered by the crop in the Oromia Region was about 70,238.66 ha with an approximate production of 544,242.35 quintals, whereas it was 132,522.80 quintals which were produced on an area of 18,855.25 ha in Bale zone in 2010/11 cropping season [3]. The crop is endowed with a diverse natural gifts, from which users can benefit. Seed from sesame is rich in oil (50-52%), protein (17-19%) and carbohydrates (16-18%) [5].
During the 2010 cropping season, national sesame productivity was 8.52 quintals per hectare [3]. This is far less than the Global average which is 22.5 quintals per hectare [10]. Diseases are reported to cause a considerable yield loss elsewhere in the World [4]. Powdery mildew and leaf spot are important fungal diseases that were reported to cause a yield loss of 45%-100% and 22-53%, respectively during severe epidemics. However, regardless of the economic importance of these diseases in the Bale zone; there is no effort made for its management. Still now, there are not any recommended fungicides are available against these severely damaging diseases.

This experiment is therefore initiated to evaluate some fungicides and recommend them for the end users which will take us one step forward in the management of this disease.

2. Materials and Methods

2.1 Description of Experimental Site

This experiment was conducted for the last two years in 2015/16 and 2016/17 GC during the main cropping season of the Delomena area, Bale at Sinana Agricultural Research Center (SARC) sub-site. DeloMana is located at about 1314-1508 m.a.s.l and receives 986.2 mm mean annual rain fall and a mean annual temperature of 22.5 ºC (Daniel, 1977). The location represents the mid-land areas of the major Sesame producing area. The area is a hot spot environment for the development of Cercospora leaf spot (*Cercospora sesame* Zimm) of Sesame. Acccording to Ermias *et al., (2008)* the dominant soil of the area is Nitosol.

2.2 Treatments and Design

The experiment was arranged in three replications with Randomized Complete Block Design. Local Sesame cultivar was usedto evaluatethe effectiveness of different fungicides against Cercospora leaf spot (Table 2). A plot size was3m x 2.4 m with a total of 6 seeding rows with between row, plot and replication spacing of 0.4m, 2m and 2m, respectively was used. Disease infection gradient was created by spraying test fungicides at a rate of their normal pathological studies recommendation. Fungicides sprays were started immediately after about 10-15% disease development was observed on leaves and the sprays were continued at seven (7) days interval and sprayed three (3) times (Table 2). Cercospora leaf spot disease development was rated based on a scoring scale developed for the disease on a 0-6 scale [6] (Table 1).

Table 1: Disease score for Cercospora leaf spot disease of sesame

Scale	Disease Severity (%)	Resistance Category	Rating	Cercospora leaf spot characteristics
1	0-14	Immune (I)	No disease	No trace of infection
2	14.1-29	Highly Resistant (HR)	Hypersensitivity	Hypersensitive spot on lower leaves only
3	29.1-43	Resistant (R)	Trace infection	Small lesion on lower leaves only
4	43.1-57	Moderately Resistant (MR)	Slight infection	Small lesions on lower and upper leaves and stems
5	57.1-71	Moderately Susceptible (MS)	Moderate infection	Advanced lesions[1] on upper and lower leaves, with or without new infection stem and petiole
6	71.1-86	Susceptible (S)	Severe infection	Advanced lesionson upper and lower leaves, flower, buds, stems and petiole and slight infection of Capsule
7	86.1-100	Highly Susceptible (HS)	Very severe infection	All features of the above with severe infection of Capsule

[1] Advanced lesion is characterized by a dark to dark-brown spot with a whitish to the straw-colored or perforated center (Einkuomehin, *et al.,* 2002)

Untreated plot (Control) which has not received a fungicide spray was included as check for treatment comparison. A Seed rate of 4 kg/ha was used based on the recommendation and other agronomic management packages like fertilizer rate, weeding and other all agronomic packages are applied as per the recommendation.

Table 2: List of Fungicides and Treatment Arrangement of the Trail

Treatment No.	Test fungicide		Application rate	Application frequency
	Trade Name	Common Name		
1	Odeon 825 WDG	Chlorothalonil	2.5 kg/ha	3
2	Mancozeb 80% WP	Mancozeb	2.5 kg/ha	3
3	Natura 250 EW	Tebuconazole	0.65 l/ha	3
4	Ridomil Gold MZ 68 WG	Metalaxyl-M	2.5 kg/ha	3
5	RexDuo	Epoxiconazole + Thiophanate-methyl	0.5 l/ha	3
6	Tilt 250 EC	Propiconazole	0.5 l/ha	3
7	Untreated Control			

2.3 Data Management and Statistical Analysis

Logistic, [ln [(Y/1-Y)], (Vander Plank 1963) and Gompertz, -ln[-ln(Y)], [1] models were compared for estimation of disease parameters from each treatment. The goodness of the fit of the models was tested using the coefficient of determination (R^2) and the Logistic model was found to fit best for the current study. Therefore, Independent variables for field experiment data under different treatments were analyzed using the logistic model, ln[y/ (1-y)] with the SAS Procedure (SAS Institute, 1998). The slope of the regression line was used to estimate the disease progress rate in different treatments. Disease severity was recorded on 1 to 5 scale where, 1= 20% or less, 2= 20-40%, 3= 40-60%, 4= 60-80% and 5= more than 80% of the leaf area damaged by the disease and disease incidence will be recorded in percentage. The disease data recorded based on the scale mentioned above was converted to percentage severity index (PSI) according to [12]. AUDPC values were calculated for each plot using the following formula the standard formula [2] based on PSI calculated and ANOVA was performed for disease severity index [12], AUDPC [2], and rate of disease progress (r) accordingly. The association of disease parameters with yield and yield related parameters was assessed using correlation and regression analysis. Mean separation was made based on the LSD technique at a 5% probability level.

$$PSI = \frac{\text{Sum of Numerical Ratings X 100}}{\text{Number of Plants Scored X Maximum Score on Scale}} \quad \ldots\ldots 1$$

$$AUDPC = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i) \quad \ldots\ldots 2$$

Where, X_i= the PSI of disease at the i^{th} assessment
t_i= is the time of the i^{th} assessment in days from the first assessment date
n= total number of disease assessment

3. Result and Discussions

The combined Analysis of variance over years have shown that there were statistically significant variations across treatments for disease parameters such as Cercospora leaf spot disease severity (%), Area Under Disease Progress Curve (AUDPC) (%-days) and Disease Progress Rate (r) (units day^{-1}) (Table 3). In case yield and yield related parameters such as Percent stand, No. of Capsules per plant, Capsule length (mm), Plant height (cm), TKW (g), and Grain yield (kg/ha) (Table 4). A statistically significant difference ($P<0.05$) was observed for disease severity. The highest Cercospora leaf spot disease severity (41.11%) was recorded from a plot without fungicide treatment (untreated control), while the lowest disease severity of 5.00% was recorded from a plot sprayed with Tilt fungicide (Figure 1 and Table 3). This result is in agreement with some studies where both synthetic and botanical fungicides reduced Cercospora leaf spot disease severity on sesame [5]. Similarly, it was reported that the intensity of Cercospora leaf spot was significantly reduced by the effect of a fungicide treatment as compared to untreated crops [8].

Table 3: Effect of Fungicide application on cercospora leaf spot Severity (%), AUDPC (%-days) and Disease Progress Rate (r)

Treatment	Disease Severity (%)	AUDPC (%-days)	r (units-day^{-1})
Untreated Control	41.11	1474.67	0.038292
Odeon 825 WDG	7.89	281.17	-0.002486
Ridomil Gold MZ 68 WG	6.94	241.50	-0.003333
Rex Duo	6.89	236.83	-0.004414
Mancozeb 80% WP	6.78	235.67	-0.003407
Natura 250 EW	6.11	211.17	-0.003201
Tilt 250 EC	5.00	165.67	-0.004976
CV (%)	12	12.27	71.96
$LSD_{(p\leq 0.05)}$	2.42	87.39	0.003

Note: AUDPC-Area under disease progress curve; r-Disease progress rate

In the same way, statistically significant differences ($P<0.05$) were observed for AUDPC and disease progress rate (r). The highest AUDPC of 1474.67%-days and the lowest 165.67%-days) were calculated from a non-treated plot and a plot sprayed with Tilt fungicide, respectively (Table3). This result has agreed with [8] result in that the fungicide treatment has significantly reduced the disease progress curve. Similarly, the highest and the lowest Cercospora leaf spot disease progress rate (r) of 0.038292 units-day^{-1} and -0.004976 units-day^{-1}, respectively were calculated from a non-treated plot and a plot sprayed with Tilt fungicide, respectively.

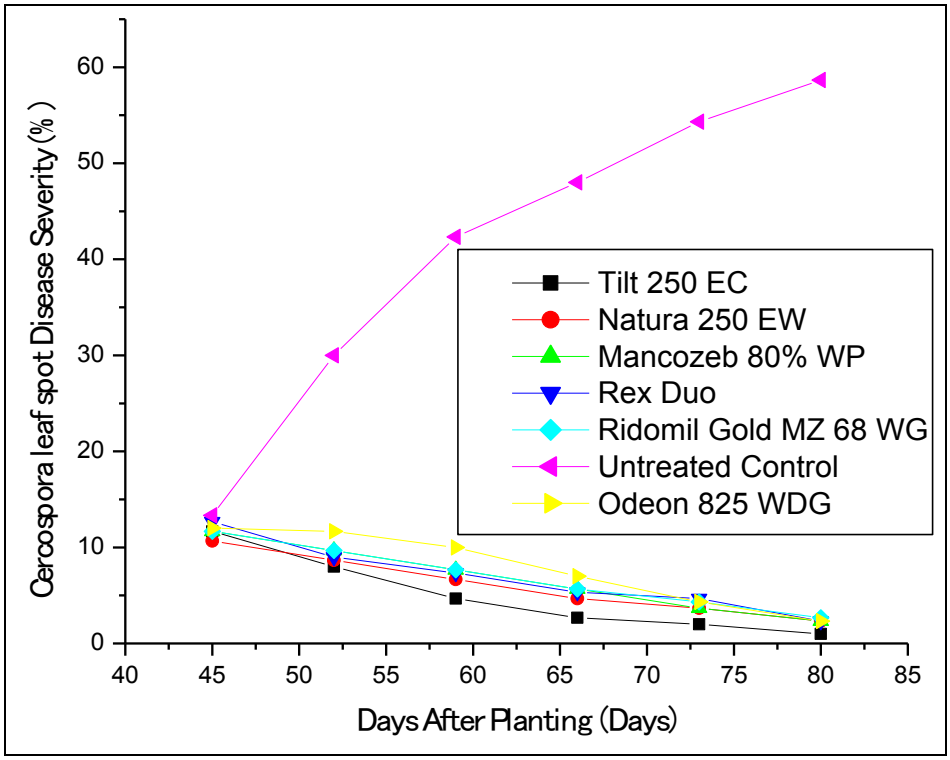

Fig 1: Cercospora leaf spot disease progress curve as affected by fungicide spray on Local landrace at Delo-mena, Bale

With regard to yield and yield related parameters, the maximum number of Capsules per plant (71.67) and the highest Capsule length (3.01 mm) were recorded from the plots sprayed with Tilt fungicide; while the smallest Capsule per plant (21.33) and Capsule length (2.30) were recorded from unsprayed plots (Table 4). Similarly, the highest plant height (144.89 cm) and the highest TKW (3.27 g) were recorded from a plot sprayed with Tilt fungicide; while the lowest plant height of 114.22 cm and the lowest TKW of 2.80 g were recorded from unsprayed plots (Table 4). Similarly it was reported by [11] that during their study they have found that the fungicides significantly influenced both yield and yield components positively. Likewise, the highest grain yield of 618.98 kg/ha was recorded from a plot treated with a fungicide Tilt; while the lowest grain yield of 457.87 kg/ha was recorded from a plot with no fungicide treatment (unsprayed control) (Table 4). All the tested fungicides have shown an overall efficacy over Cercospora leaf spot of Sesame in this trial. This result is supported by [5] when they found similar results from their study.

A simple linear regression model was employed to assess the relationship of cercospora leaf spot disease severity and AUDPC with TKW and Grain yield. Accordingly, the simple linear regression analysis result has revealed that there is a statistically justifiable significant difference ($P \leq 0.0001$) among treatments. The estimated slope of the regression line obtained for Cercospora leaf spot disease severity in its association with TKW was -0.009566. This estimate shows that for each unit increase in percent severity of Cercospora leaf spot disease, there was a sesame TKW loss of 0.009566 kg/ha (Figure 2A). F-statistics calculated have shown very high significance ($P \leq 0.0001$) of the over all probability of the equation. Similarly, the simple linear regression analysis between grain yield and Cercospora leaf spot disease severity has resulted in significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for Cercospora leaf spot disease severity was -3.36 which shows that for each unit increase in Cercospora leaf spot disease severity, there was a Sesame grain yield loss of 3.36 kg/ha (Figure 2B).

Likewise, pair wise Pearson correlation analysis was employed to assess the degree of association between Cercospora leaf spot disease parameters and yield and yield related traits of Sesame. Cercospora leaf spot disease severity has a significant negative correlation with the number of Capsules per plant (r= -0.7112, $P<0.0001$) and grain yield (r= -0.4821, $P<0.05$). Similarly, Percent crop stand has a significant negative correlation with Cercospora leaf spot disease severity (r= -0.6365, $P \leq 0.001$) (Table 5).Likewise, significant negative correlation (r= -0.6381, $P \leq 0.001$; r= -0.7125 and -0.4347, $P \leq 0.0001$ and r= -0.68662, $P \leq 0.0001$) were found between AUDPC and Percent crop stand, number of Capsules per plant and Capsule length, respectively. Significant positive correlations were also found between disease parameters themselves and between yield and yield related parameters themselves as well (Table 5).

Table 4: Yield and yield components of sesameas influenced by the fungicide application against cercospora leaf spot

Treatment	% Stand	No. Capsule/plant	Capsule length (mm)	Plant height (cm)	TKW (gm)	Grain yield (kg/ha)
Unsprayed Control	75.00	21.33	2.30	114.22	2.80	457.87
Odeon 825 WDG	81.67	57.11	2.41	119.56	3.27	564.40
Ridomil Gold MZ 68 WG	86.67	59.56	2.35	133.89	2.87	555.37
Rex Duo	88.33	62.11	2.77	117.78	3.33	581.57
Mancozeb 80% WP	86.67	54.22	2.54	133.89	2.87	558.43
Natura 250 EW	88.33	66.56	2.79	142.78	3.13	590.51
Tilt 250 EC	90.00	71.67	3.01	144.89	3.27	618.98
CV (%)	6.53	26.35	7.73	12.75	6.84	15.40
$LSD_{(p \leq 0.05)}$	9.74	25.88	0.35	28.94	0.37	151.25

Note: TKW-Thousand Kernel Weight.

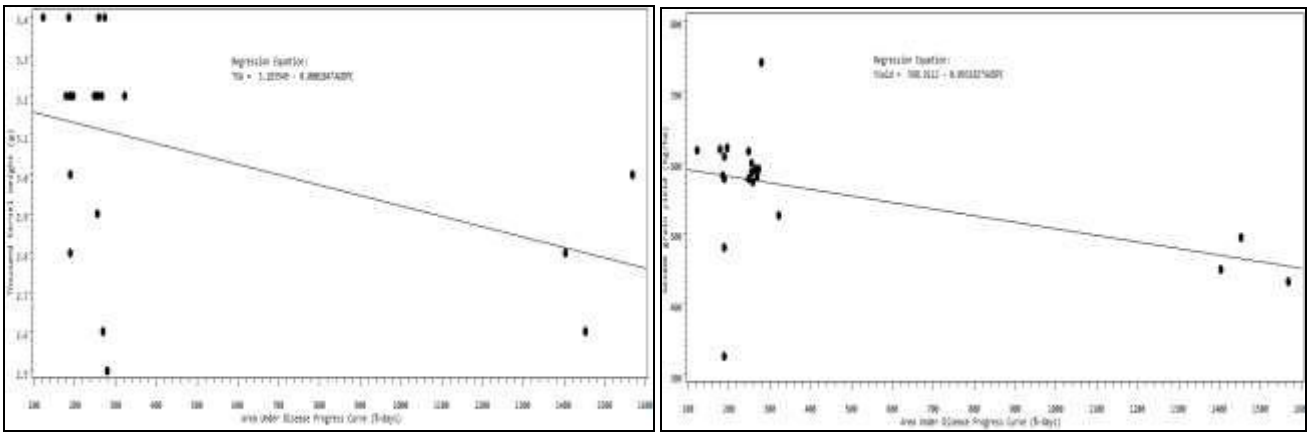

Fig 2: Estimated relationship between Sesame TKW and Cercospora leaf spot Disease (A), Sesame grain yield and Cercospora leaf spot Disease (B), TKW with Sercospora leaf spot AUDPC (C) and Sesame grain yield and AUDPC (D)

Table 5: Pair wise Pearson correlation coefficients among disease parameters, yield and yield Components of Sesame

	Disease Severity	AUDPC	r	% Stand	No. Capsule/plant	Capsule length (mm)	Plant height (cm)	TKW	Grain yield
Disease Severity		0.9999***	0.9916***	-0.6365**	-0.7112***	-0.4316^{NS}	-0.3597^{NS}	-0.4297^{NS}	-0.4821*
AUDPC			0.9923***	-0.6381**	-0.7125***	-0.4347*	-0.3618^{NS}	-0.4283^{NS}	-0.4834*
r				-0.6508**	-0.7458***	-0.4221^{NS}	-0.3583^{NS}	-0.3970*	-0.5130*
% Stand					0.7261***	0.4820*	0.5549**	0.2021^{NS}	0.6271**
No. Capsule/plant						0.5263*	0.6672**	0.3176^{NS}	0.5033*
Capsule length (mm)							0.3294^{NS}	0.2551^{NS}	0.5620**
Plant height (cm)								0.0472^{NS}	0.1274^{NS}
TKW									0.0319^{NS}
Grain yield									

Note: AUDPC- Area Under Disease Progress Curve; r- Disease Progress Rate;% Stand- Percent plot Stand; TKW- Thousand Kernel Weight

Cost/Benefit Analysis

The result showed that Rex Duo sprayed plot provided the highest gross returns (ETB 30,870/ha) and the lowest gross return ETB 16,030/ha was computed from the untreated check. The plot sprayed with Rex Duo gave the maximum net return ETB 19,433.6/ha and also gave the highest benefit cost ratio (1.699). The Tilt 250 EC sprayed plots also provided the higher gross returns (ETB 21,665/ha) and gave the higher net return ETB 10,381.2/ha and also gave the higher benefit cost ratio (0.920). The highest (ETB 121.15) marginal rate of return was obtained from Rex Duo treated plots. In other words, for every ETB 1.00 investment in Rex Duo cost and spraying, there was a gain of ETB 1.2115. Therefore the most economic benefit for Cercospora leaf spot management was obtained from Rex Duo sprayed plots.

Table 6: Return and Benefit Cost Ratio of Treatment for the Control of Cercospora leaf spot on Sesame during 2015/16 and 2016/17 GC Season at Delo Mena

Treatments	Yield obtained (Qt/ha)	Sale price (ETB/Qt)	Total Variable Costs TVC (ETB/ha)	Gross Return (Price X Qt) GR	Net Return NR (GR-TVC)	% of benefit (NR/TVC)	MRR% (NR-NR of Control/TVC)
Unsprayed Control	4.58	3500	10451.6	16030	5,578.4	0.533	
Odeon 825 WDG	5.6	3500	11172	19600	8,428	0.754	25.5
Ridomil Gold MZ 68 WG	5.55	3500	11171	19425	8,254	0.739	23.95
Rex Duo	8.82	3500	11436.4	30870	19,433.6	1.699	121.15
Mancozeb 80% WP	5.58	3500	11171.6	19530	8,358.4	0.748	24.88
Natura 250 EW	5.9	3500	11378	20650	9,272	0.815	32.46
Tilt 250 EC	6.19	3500	11283.8	21665	10,381.2	0.920	43

3. Conclusion and Recommendation

Sesame (*Sesamum indicum* L.) is an important oil crop produced in the tropical and subtropical parts of the World. Likewise, Ethiopia is one of the major Sesame producer countries in the World. In Ethiopia, during the 2010/2011 cropping season, sesame was produced on an area of 384,682.79 ha of land with a total production of 3,277,409.22 quintals which increased by about 25.8% from that of 2009/10 production year [3].Currently, in the humid midland areas of Bale there is a wide expansion of Sesame production. And farmers of this area are producing the crop intensively due to its high market value. However, farmers are suffering from a huge productivity loss due to Cercospora leaf spot disease. This disease is challenging crop productivity putting its production highly under its potential. To tackle this problem, different fungicides supposed to control/reduce the diseases are evaluated in Delomena district of Bale zone. All of the evaluated fungicides have shown a promising efficacy as compared to the control plot against the disease. However, out of the tested fungicides Tilt has shown better controlling potential against the disease. Therefore, Tilt is recommended for use against Cercospora leaf spot.

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