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Research Article

Evaluation of some fungicides for Management of Sugar cane rust (*Puccinia melanocephela*) disease in Finchaa Sugar Estate, Horo -Guduru Wollega, Oromia Regional State, Ethiopia

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Abstract

Sugarcane (Saccharum officinarum L.) is an important industrial, monocotyledonous perennial cash crop. Sugarcane brown rust (Puccinia melanocephela Syd. & P. Syd) is one of the most devastating diseases. Sugar cane brown rust is new for Ethiopia and currently only fincha sugar Estate is affected. The current study was carried out to evaluate the efficiency of different fungicides (Opera, Tilt, Natura, Defender, Diprocon and Noble) with three times spray frequencies and their impact on yield and yield components under field conditions in Finchaa Sugar Estate, Ethiopia, during the main cropping season of 2016. For the management of sugarcane brown rust disease, seven treatments were arranged in randomized complete block design with three replications on sugarcane cultivated fields at Finchaa Sugar Estate. The statistical analysis showed that significant differences among treatments in sugarcane brown rust disease incidence, severity. Sugarcane brown rust incidence and severity were highest in the control plots compared to the fungicides sprayed plots. The highest severity value resulted in the lowest cane yield of sugarcane 26.26 t/ha in the control plots compared to a highest yield of 78.27 t/ha from sprayed plots with Opera fungicide and 64.9 t/ha from plots treated with Natura fungicide . Economic analysis revealed that the highest rate of return of 5751 birr was obtained from fungicide Opera and the highest net benefit 55559 birr again from Opera foliar spray treatment. The results of the present study revealed that the novel possibility of using foliar spray treatments which was found to be effective in decreasing sugarcane brown rust symptoms in sugarcane plants in Finchaa Sugar Estate and also increased yield. Further, the effective and feasible management options need to be developed on sugarcane brown rust disease in the country.

Introduction

Sugarcane (*Saccharum officinarum* L.) is an important cash crop of the globe, which belongs to the grass family, Poaceae [1]. Currently, the crop is cultivated over 120 countries with estimated total annual global sugar production of 1.7 billion tons in the year 2012 [2]. Sugarcane is responsible for ~70% raw table sugar production worldwide (Contreras et al., 2009). The sugar factories are also expected to contribute about 448 megawatt electric power through co-generation (Ethiopian Sugar Corporation [3].

In Ethiopia, sugarcane is the sole base material for sugar production and thus the sugar industries in Ethiopia depend on the fate of this crop. Sugarcane cultivation by smallholder subsistence farmers started centuries ago and preceded the commercial sector in Ethiopia [4]. A report by the Central Statistics Agency [5] of Ethiopia showed that 997,240 households grew sugarcane in about 22,388.48 hectares of

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land. In Ethiopia, sugarcane is grown in some parts even before the commencement of large-scale commercial plantations and establishment of a modern sugar factory at Wonji [6].

The sugar industry in Ethiopia has great contributions to the socio-economy of the country, given its agricultural and industrial investments, foreign exchange earnings, its high employment, and its linkages with major suppliers, support industries and customers (Khan *et al*., 2004). However, the current sugar production in Ethiopia covers only 60% of the annual demand for domestic consumption, while the deficit is imported from abroad.

In spite of this fact, the country has huge production potentials and opportunities, which include specifically identified irrigable suitable fertile areas of favorable weather conditions, cheap and productive labor force, high demand for sugar and other by-products and huge market outlets to the nearby countries. The country's annual production of sugar from the sugar estates is about 400,000 metric tons (ESC 2015/16) and Finchaa Sugar Factory has a total capacity of producing 850,000 quintals of sugar in one production year (242 days).

Despite the importance of sugarcane in the country, the yield of sugarcane is constrained by many environmental and management factors [7] and its production entails an integration of various factors such as weather, water, biotic, soil and economic factors. Diseases, weeds, and insect pests are among the major biotic constraints of sugarcane production [8].

Surveys of sugarcane disease was carried out at different times in the Ethiopian Sugar Estates. A Survey in the sugarcane plantations of Ethiopia indicated that about 18 sugarcane diseases are recorded in the three sugar estates [8]. According to Agricultural Research Service (ARS), sugarcane smut, leaf blotches (*Xanthomonas albilineans*), and stem rot (*Phaecytostroma sacchri*) and brown rust (*Puccinia melanocephela*) were reported to be prevalent in some fields of the Finchaa Sugarcane Plantations. Among the biotic factors, brown rust shared the huge part. Brown rust was reported in Ethiopia for the first time in March 2007 to the sugarcane industry of Ethiopia [9].

Sugarcane rust in severe infections can cause leaf necrosis and premature death of even young leaves (Raid and Comstock 2006). The loss in stalk number as well as biomass causes a reduction in cane tonnage (Purdy *et al*., 1983; Raid and Comstock, 2006). Yield reduction due to sugarcane rust was not quantified in Ethiopia particularly at Finchaa sugar estate but some survey was conducted at Metehara and Kesem. In Ethiopian sugarcane plantations, the leaf area infected percentage that ranges from 5 - 8 % and 5 - 15 % has been recorded at Metahara Sugarcane Plantation and Kesem Sugar Project, respectively [10].

The current management practices across the worldwide are using resistant varieties, cultural practices, and chemical control methods. However, in Ethiopia there is no information about the control of sugarcane rust disease, since the disease is recently introduced to the country. A 'new' disease in fields of sugarcane variety DB377/60 was first reported in March 2007 in Ethiopian Sugarcane Research Services Station [9].

The above-mentioned sugarcane rust control methods have their own gaps, for example, rusts can be managed by planting resistant cultivars. However, due to the emergence of new races of the rust fungi, the resistance present in current cultivars can be broken. Therefore, this method needs the diversification of the varieties not to break their resistance. In Ethiopia, there are no chemicals evaluated to control sugarcane rust disease. Therefore, the current study was carried out to evaluate some fungicides for the management of sugarcane brown rust disease in Finchaa Sugar Estate, Ethiopia.

This study was carried out with the following objectives:

Objectives

General objective: To increase the yield of sugar cane through effective of fungicides for the management of sugar cane brown rust disease.

Specific objectives

- To evaluate the efficacy of fungicides for the management of sugarcane brown rut disease under natural rust disease infection.
- To know the frequency of fungicides application for the management of sugar cane brown rust disease.
- To assess the cost- benefit ratio of fungicides with yield and yield components of sugarcane.

Materials and methods

Description of the study area

Finchaa Sugar Estate is the third pioneer sugarcane plantation established in 1998. Finchaa Sugar Estate is located in the Finchaa River Valley of Ethiopia at a latitude of 8°31'N and longitude of 39°12'E, respectively with elevation ranging from 1350-1650 m. a. s. l. The zone has a bimodal rainfall distribution and is a typical sub-humid, high altitude agro-climatic zone. The area has a mean maximum temperature of 31 °C and a mean minimum temperature of 15 °C. The area has a mean annual total rainfall of 1300 mm (Figure 1).

Evaluation of fungicides for the management of sugar-cane brown rust disease

Experimental materials used

Sugarcane cultivar used: Sugarcane cultivar SP70/1284, a susceptible variety was used for the experimental study at Finchaa sugar Estate. This cultivar was selected based on its susceptibility as the author conducted the survey before the experiment was conducted at Finchaa sugar Estate.

Fungicides used and spray frequency: Six fungicides, DEFENDER (azoxystrobin 20% + Cyproconazole 8%), NOBLE (Triadimefon), TILT (Propiconazole),OPERA (85g/pyraclos-

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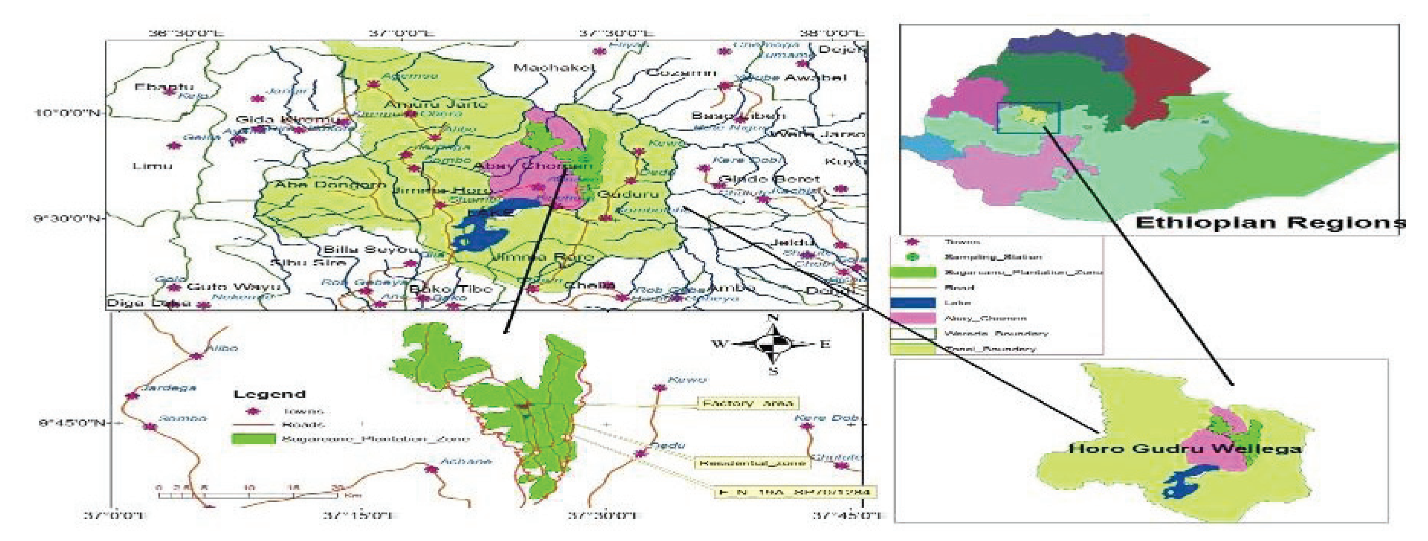

Figure 1: Map of Ethiopia showing sugarcane rust disease survey fields in Horo-Guduru Wollega zone of Oromia region (developed by Author).

trobin + 62.5g/lepoxiconazole), DIPROCON(Difeconazole and Propiconazole) and NATURA (Tebuconazole) were used against sugarcane rust disease (Table 1). All the fungicides were registered in Ethiopia but not for sugarcane, it is for other cereal crops. The fungicide, Tilt was used as a standard control check.

Experimental design, treatments and applications

The field experiment was conducted for the evaluation of fungicides for the maagement of sugarcane brown rust disesae in 2016 main cropping season at Finchaa sugar Estate sugarcane fields. A crop of five months old with natural brown rust infection which was at tillering growth stage was selected. Total of seven (7) treatments were evaluated (Table 2). Six fungicides were evaluated and unsprayed plots were used as control (Table 2). The fungicide, Tilt was used as a standard check. The experimental plots which had eight rows and each row had ten meters and the spacing between each row was 1.45mand the area of each plot was 116m². The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications of each treatment).All recommended agronomic practices were followed uniformly for all treatments. Weeding was performed twice, after six months.

Table 1: Trade, active ingredients of fungicides, its rate of application and time of application.

Serial no	Trade name	Active ingredients	Rate (L/ha)	Fungicide spray frequency	Time of application
1	Defender	Cyproconazole8% + Azoxystrobin20%	700ml/ha	3times	Disease onset
2	Noble	Triadimefon	0.8kg/ha	3 times	Disease onset
3	Opera	85g/pyraclostrobin + 62.5g/lepoxiconazole	700ml/ha	3 times	Disease onset
4	Natura	Tebuconazole	600ml/ha	3 times	Disease onset
5	Diprocon	Difeconazole and Propiconazole	300ml/ha	3 times	Disease onset
6	Tilt	Propiconazole	700ml/ha	3 times	Disease onset
7	Unsprayed	-	0ml/ha	3 times	Disease onset

Table 2: Sugarcane rust disease incidence on different fungicides management under field conditions.

Fungicides	Mean disease incidence (%) on different assessment dates at East bank section			
	Pre incidence (%)	14 days after application (%)	28 days after application (%)	42 days after application (%)
Noble	100	73.33b	46.67bc	40.00b
Natura	100	58.33bc	50.0b	15.00d
Tilt	100	63.33cd	50.0b	21.00e
Defender	100	80.0b	56.67b	43.33b
Diprocon	100	76.67bc	46.67bc	28.33c
Opera	100	53.33d	30.0c	3.33f
Untreated	100	100a	100a	100a
Mean	100	74.28	54.27	36.09
LSD(0.05)	0	14.29	17.51	4.32
CV%	0	10.99	18.42	6.84

LSD=Least significant difference at (P< 0.05), CV=Coefficient of variation, DAA= Days after Application, NS= Non significant, the mean values with the different letters in the columns are significant difference whereas the mean values with the same letters are non-significant

Data collection

Assessment of disease intensity: Disease incidences were recorded from the plants found in the experimental plots and disease severities were recorded from 10 pre- tagged plants in the middle 4 rows of each plot. The application of fungicides were at the interval of 14 days after first application .The fungicides were applied at the recommended rates indicated on the manuals which were given with fungicides from Lion chemical company, Addis Ababa, Ethiopia. The incidence and severity of the fields were calculated according to the methods/ formula, Bernier, *et al.* (1985) and Ding, *et al.* (1993).

Disease incidence; was calculated as the percentage of infected plants to the total number of plants counted per spot.

$$\text{Incidence} = \frac{\text{Total number of diseased plants}}{\text{Total number of plantsassessed}} \text{x} 100$$

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Disease severity; the severity was taken as the average of leaves per plant. Disease severity was recorded from older leaf to the younger leaf the highest mean severity was recorded on cultivar SP70/1284 with the value of 22.5%. Infections are usually most numerous towards the leaf tip, becoming less numerous toward the base.

$$\text{Disease severity}: \frac{\text{Area of plant tissue affected}}{\text{Total area of the plant}} \times 100$$

Growth parameters

The growth parameters such as stalk population, stalk height measurement, malleable cane count, and stalk diameter and stalk weight measurement were taken with the pre-determined interval except stalk weight measurement and stalk diameter which were measured at the end date of data collection.

Sugarcane stalk population

Stalks on the whole plots were counted at monthly interval until the maturity of the crop and the mean value of the stalks were calculated and converted to hectare.

Sugarcane stalk height measurement

Plant height is a main parameter of growth and yield. Although an internodes property (length, thickness and shape) is varietal characters, yet the rate of elongation and length of the internodes and hence plant height provides information about the general condition of the crop. Stalk height was measured from the first node to the top most developed node and then averaged taking ten representative stalks from each plot.

Stalk diameter

Stalk diameter is one of major components of growth parameter for sugarcane plant. Ten sugarcane stalks were sampled out from the middle four rows of the plot to measure the diameter of the stalks.

Juice quality

Ten millable stalks were sampled from each plot at age of twelve months from the middle four furrows for juice quality determination (pol percent, purity %, sucrose% and Brix (%).

Cost benefit analysis

The cost and benefit of each treatment was analyzed partially and marginal rate of return were computed by considering the variable cost available in the respective treatment. Yield and economic data were collected to compare the advantage of fungicides and its cost. Price of sugar (birr /ton) obtained from the local market and total sale from one hectare were computed. The price of the sugar at local market (birr/ton) at the local market was 30,000. Price of fungicides Noble (Triadimefon),Defender (Azoxystrobin20% + Cyproconazole 8% (700ml/ha), Tilt (Propiconazole 750ml),), Diprocon (Difenoconazole and Propiconazole 300ml/ha), Natura (Tebuconazole 600ml/ha) and Opera (85g/pyraclostrobin +62.5g/lepoxiconazole) were birr 300, 250, 400, 250, 300 birr/lt respectively for each type of fungicides was obtained.

The cost of labor for disease assessment and fungicides application was 40 birr per day. Based on the obtained data from the experimental site, cost benefit analysis was performed using partial budget analysis. Marginal analysis is concerned with the process of making choice between alternative factor-product combinations considering small changes. Marginal rate of return is a criterion which measures the effect of additional capital invested on net returns using new managements compared with the previous one(CIMMTY,1988).

$$\text{The formula is as follows}: \text{MRR} = \frac{\text{DIC}}{\text{DNI}}$$

Where, MRR is marginal rate of returns; DNI is difference in net income compared with control; DIC, is difference in input cost compared with control.

The following points were considered during cost benefit analysis using partial budget.

- Cost of all agronomic practices and treatments within site,
- Price of sugar per tones for each variety,
- Cost of fungicides and labor were taken based on the price in sugar Estate.
- Costs return and benefit were calculated per hectare basis.
- It was assumed that, the sugar Estate produce these varieties using fungicide managements when the varieties provide 100% marginal rate of returns.

Data analysis

Data on sugarcane rust disease incidence, prevalence, severity, AUDPC, disease progress rate, stalk height, millable cane, juice quality determinants (pol, cane degree Brix and purity)and cost-benefit were subjected to analysis of variance (ANOVA) to determine the treatment effect on dependable variables using SAS statistical software package (SAS, 2003). Least significant difference (LSD) was used for mean separation.

Results and discussion

Disease incidence and severity

Disease incidence: The ANOVA analysis indicated that fungicides application had significant variation in reducing sugarcane rust disease incidence on all dates of disease survey. The incidence data with no application of fungicides on sugarcane rust disease showed that there was no significant difference among the experimental plots. The incidence data was collected simply to know the infection level of sugarcane rust disease intensity before the management action was taken which helps to compare efficacy of the fungicides. During the

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application of fungicides, homogeneity of the experimental plots should be kept the similar to reduce the experimental error. The percentage incidence of sugarcane rust disease at this stage was about 100% in all plots that were used for the experimental study. This showed that in Finchaa Sugar Estate, the occurrence of sugarcane brown rust disease is high in percentage.

After application of fungicides there were significant different among the plots which were sprayed with different fungicides to evaluate the efficacy of fungicides. At the first application of fungicides the incidence of sugarcane brown rust disease was recorded 14 DAA (days after application) and the highest incidence was recorded on the untreated plots with the incidence of 100% and the least incidence was recorded on the plots that were treated with opera fungicide with the incidence of 53.33%. Plots that were treated with Natura were significantly different from the other plots and effectively manage sugarcane rust disease next to Opera fungicide. Plots, which received fungicide Diprocon, Tilt and Noble, were statistically similar to each other with the incidence of 76.67 Similarly, Raid (1992) investigated the use of fungicides for the management of brown rust on susceptible variety, CP72-1210 in US sugar industry; five different fungicides were tested for the control of rust in Mauritius. The best control was achieved with fungicides containing Fenpropimorph and Mancozeb. In Zimbabwe, trials included the use of Triazole fungicide and found to significantly reduce brown rust infections [11]. Trials in South Africa involved the use of Propiconazole (Triazole).

Sugarcane brown rust disease Severity

In the plots of the experiment after first time of fungicides application there were a significant difference among the plots where sugarcane brown rust disease severity occurred at P≤0.05.However, the highest sugarcane rust disease severity were recorded on the UN treated plot (fungicides UN treated plot) with sugarcane brown rust severity of about 17.00%. Followed by plot treated with Defender with sugarcane brown rust severity of 16.0% Table 3.

Growth parameters Measurements (Stalk diameter, internodes length and stalk height)

The treatments showed a non-significant difference in stalk diameter (Table 4-6). However, the average, stalk diameter (2.51cm) of the treated plots were better than that of the untreated control plots with diameter of (2.06cm). The general reduction in plant size was observed in the sugarcane rust noted plots. However, the stalk diameter on these plots was not significantly different relative to the rust free plots. Reduction in plant size is among the symptoms of rust infection in sugarcane [12-15]. The stalk height showed a significant difference among the treatments (Table 6). Among the treated plots, plot receiving fungicide Opera had the highest stalk height, followed by plot receiving fungicide Tilt while the untreated control plot had the lowest stalk height Tables 7-9 [15-21].

Table 3: Effect of fungicides application on sugarcane rust disease severity.

Fungicides	Mean disease severity (%) at different assessment dates			
	Pre application	Post Application 1	Post Application 2	Post Application 3
Noble	20.29a	13.83ab	8.00bc	5.33c
Natura	19.0a	12.3abc	4.98d	0.703e
Tilt	21.68a	13.33bc	8.00c	3.45cd
Defender	21.15a	16.00a	11.33b	8.67b
Diprocon	18.17a	12.50bc	4.33d	1.31de
Opera	19.35a	9.33c	2.16d	0.00e
Untreated	18.00a	17.0a	16.5a	15.5a
Mean	19.66	13.44	7.65	4.75
LSD(0.05)	6.11	4.24	2.91	2.23
CV (%)	17.73	18.01	21.69	26.77

Values having the same letters along a column are not significantly different from each other at LSD (p<0.05), whereas Values having different letters along a column are significantly different from each other

Table 4: Effect of fungicides on stalk diameter, internodes length and stalk height in controlling sugarcane brown rust.

	Internode Length	Stalk diameter	Stalk height
Treatments			
Noble	15.00ab	24.16a	200.43bdc
Natura	16.00ab	23.67a	174.60d
Tilt	15.667ab	23.61a	302.26a
Defender	14.667b	23.06a	189.13dc
Diprocon	17.43a	24.69a	219.16b
Opera	21.33a	25.133a	322.78a
Control (untreated)	13.00bc	20.37a	206.21bc
Mean	15.71	24.24	230.65
LSD	1.66	3.156	28.511
CV (%)	6.05	7.43	7.058

Values having the same letters in the table are not significantly different from each other at LSD (p<0.05).The above data were taken at the different times on different age of sugarcane based on the interval before and after application of fungicides

Table 5: Effect of fungicide application on sugarcane stalk population.

Treatments	Population data count 1	Population data count 2	Population data count 3	Population data count 4
Noble	1074edc	974.67ab	928.33b	915.33bc
Natura	1024.00edc	915.67b	933.33b	933.00b
Tilt	1192.67abc	1005.00ab	900.00bc	902.67bc
Defender	939.67ed	919.33b	881.00c	896.00bc
Diprocon	1234.67ab	1100.00a	973.67ab	938.00b
Opera	1318.33a	1119.67a	1036.33a	1023.67a
Untreated	846.33e	887.33b	899.67c	800.67c
Mean	1089.95	984.95	921.7619	915.1905
LSD(0.05)	206.55	163.4	164.15	115
CV (%)	10.82	9.44	10.16944	7.175495

Values having different letters along a column are significantly different from each other at LSD (P<0.05) while the values that have the same letters along a column are not significantly difference from each other

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Table 6: The effect of fungicides on the sugarcane juice quality parameters (%Brix, Pol%, %purity and %Sucrose) in controlling sugarcane rust.

Treatments	Brix %	Pol%	Purity%	Sucrose %	Sugar yield
Noble	16.29b	14.69b	90.17b	8.38c	9.64b
Natura	18.59ab	18.02a	**96.93a**	16.27b	10.8a
Tilt	15.89b	14.41b	90.68b	15.0b	10.21ab
Defender	13.86bc	11.45c	82.61c	9.81c	9.60b
Diprocon	19.29ab	18.05a	93.57ab	15.44b	10.01ab
Opera	20.09a	19.73a	98.21a	19.25a	11.01a
Control	12.48c	10.07c	80.68c	6.5c	3.35c
Mean	17.35	15.36	90.41	9.36	10.00
LSD %	1.6247	1.7677	2.7936	3.75	2.14479
CV%	5.30	6.69	1.85	6.53	7.858659

Values having different letters along a column are significantly different from each other at LSD (p<0.05) while the values that have the same letters along a column are not significantly difference from each other

Table 7: The effect fungicides on cane yield and sugar yield in controlling sugarcane rust disease.

Treatments	Cane yield per hectare ton per hectare	Sugar yield ton per hectare
Noble	30.28c	11.38c
Natura	64.9b	15.55b
Tilt	58.78bc	13.15bc
Defender	29.38c	9.81c
Diprocon	63.24b	14.45bc
Opera	78.27a	18.65a
Control	26.26c	7.45d
CV%	15.65	18
LSD (0.05)	2.65	1.75

Table 8: Cane yield loss due to Puccinia melanocephela for the respective treatments.

fungicides	Cane yield
Noble	47.99
Natura	13.38
Tilt	19.49
Defender	48.89
Diprocon	15.03
Opera	0
Untreated	52.01
CV%	25
LSD (0.05)	18.67

Summary and conclusions

Ethiopia has a suitable area of land for the production of sugarcane and planned to be one of the major producers of sugarcane. The low productivity of the crop in the country is attributed to susceptibility to biotic and a biotic stresses. The present study was carried out to evaluate the efficacy of some fungicides.

Seven treatments included untreated plots (Noble, Natura, Tilt, Defender Diprocon and Opera) with three spray frequencies were arranged in a Randomized complete block design with three replications. The statistical analysis showed that significant differences among treatments. On the final date of disease assessment, among the fungicides, fungicide Opera showed the lowest disease incidence, and severity with the values of (3.3%) and (0.0%) respectively. Whereas the highest disease incidence and severity were recorded on the untreated check plots with the values of (100%) and (22.5%) respectively. All of the fungicides showed significant variations in reducing disease severity. Likewise, effects of fungicides with three times spray frequencies showed significance difference on disease severity only at 14, 28 and42 DAA date of disease assessment. At 42 DAA of assessment date, the highest (43.33%) disease severity was recorded on unsprayed control plots. Effects of the six fungicides showed significant variation for cane yield per hectare and sugar yield per hectare on all fungicides and it was significant on millable cane weight only on specific fungicides.

The highest weight per plant i.e. 0.97kg on fungicide Opera and 0.8kg on fungicide Natura were recorded. The highest sugar yield was recorded on fungicide Opera that was sprayed with three times frequencies. The highest net benefit of 55,559 and 46,364 were obtained from the fungicide Opera and fungicide Natura, respectively that was sprayed with three frequencies and the least (Birr 0%) was obtained from the fungicide Defender with three times spray frequencies. On the other hand, the highest marginal rate of return (5751%) was obtained from fungicide Opera that was three times sprayed and the lower marginal rate of return (Birr 1113%) and (birr 0) was recorded on fungicide Tilt sprayed un untreated check plot respectively.

Recommendations

From this study, the fungicides Opera, Natura, and Diprocon with three times spray frequencies could be recommended for the management of sugarcane brown rust disease at Finchaa sugar Estate, Horo- guduru Wollega Zone Oromia Regional Estate, Ethiopia.

Sugarcane brown rust disease was reported in March 2007 to the country, its spreads at alarming rate in most of the major sugarcane growing areas of the country.

Thus further management/control of this disease should be aimed at reducing the crop losses and also check the spread of the disease to new areas. For the development of sound and successful management, information regarding on epidemiology of the disease in the country is a paramount. Thus any research towards this line could be highly appreciated/ recommended.

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